SELF SUFFICIENT NET ZERO CO_2 FACTORY: PV + H_2 + STORAGE + CHP

INTRODUCTION

Energy-intensive factories are among the largest CO_2 emitters. Despite the different energy needs and intensity, there is a big challenge behind making them a net zero activity. This white paper describes the design, setup, operational strategy, and simulation of an H_2 engine combined heat and power (CHP) system for a pharmaceutical industry using the COGMCI software. The factory and an H_2 electrolyzer plant are powered by a solar photovoltaic (PV) system. H_2 is used to fuel the engine CHP system. The pharmaceutical factory becomes self-sufficient with net-zero CO_2 thanks to the energy solution.

THE PHARMA FACTORY

The Pharma factory model uses the Energy Plus software (8760 hours analysis) and a pharma factory's data. The building is supposed to be located in Fortaleza-CE-Brazil and has ten thermal zones totaling 64,500 m^2: warehouse, manufacturing, technical floors, reception, offices, laboratories, kitchen, restaurant, etc – Figure 1.

All zones are air-conditioned, except the technical floors. Building materials are typical for Brazilian buildings.

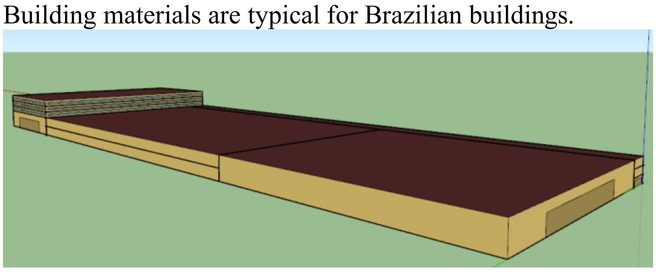


Figure 1 – The pharma factory building.

Design parameters, assumptions, and schedules for lights, activity, HVAC systems, people, internal loads, working hours, etc were defined. Energy Plus results were used as COGMCI software input.

SELF SUFFICIENT NET ZERO SOLUTION

The self-sufficient pharma factory uses a PV plant, an H_2 electrolyzer and storage plant and an engine CHP system. The PV is sized to meet the electricity needs and the H_2 electrolyzer. H_2 production meets the engine CHP operation.

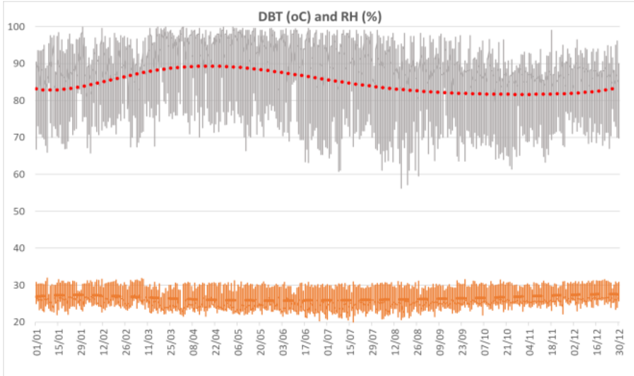
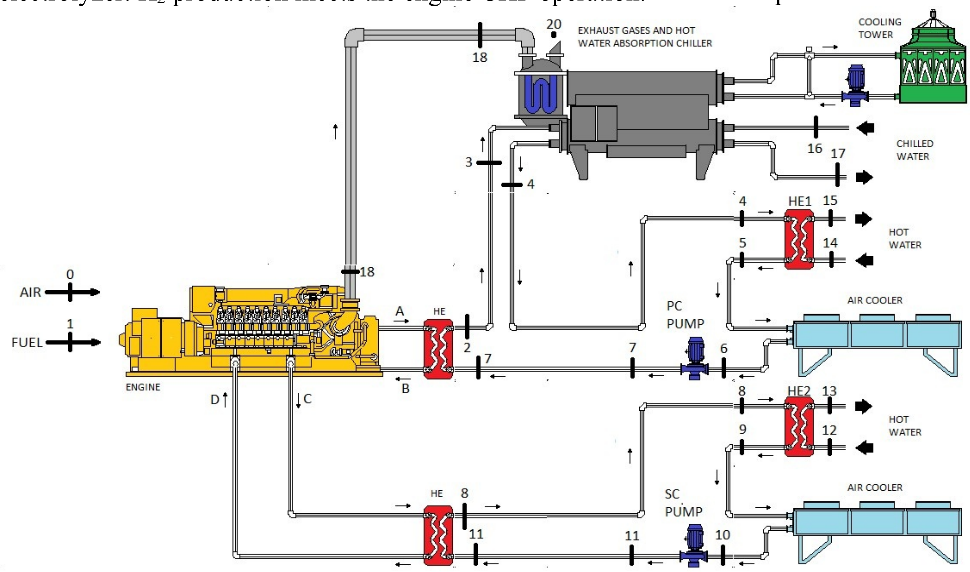


Figure 2 – Fortaleza weather data - 8760 hours.

The engine of the H_2 CHP system is 1800 kWe. Exhaust gases and jacket water energy are used on an absorption chiller (cooling load). Heat exchangers HE1 and HE2 recovers engine energy for sanitary use hot water production. The system and the thermodynamic properties are shown in figure 3.

A weather data file for site conditions (solar incidence, temperature, wind, etc) is used to assess PV production annually. In figure 4, the PV production is shown.

Figure 5 reveals electricity consumption and production. The electricity use (16,810,857 kWh/year) is indicated by blue lines. Engine CHP production is indicated by purple lines. A thorough analysis for a normal week is displayed in figure 6. The black line indicates the factory consumption. The pharma factory activity is reduced on Saturdays and Sundays, despite some production equipment and HVAC operates 24/7. Additionally, consumption is lower in the evening (no office activities) and in the early mornings (manufacturing takes place on a two-shift basis). Around hour 6, PV production starts, and it ends around hour 19 (orange lines). New consumption line is red and account for the avoided electricity in the electrical chillers when using the engine CHP system absorption chiller. Engine CHP power is blue, and it runs from 19 to 7. Engine CHP is always looking for 85% energy utilization factor (EUF). The system runs on a lower engine load when there are no thermal loads (cooling and sanitary hot water) - thermal dispatch. Green line is outside dry bulb temperature (DBT).



flow number	pressure (kPa)	temperature (oC)	mass flow (kg/s)	enthalpy (kJ/kg)
0	100.000	25.000	2.639	298.800
1	100.000	25.000	0.035	119,000
2	425.000	95.000	14.272	398.254
3	350.000	95.000	14.272	398.197
4	275.000	85.710	14.272	359.075
5	200.000	85.000	14.272	356.033
6	200.000	85.000	14.272	356.033
7	500.000	85.000	14.272	356.271
8	250.000	55.000	7.026	230.372
9	150.000	45.000	7.026	188.477
10	150.000	45.000	7.026	188.477
11	350.000	45.000	7.026	188.654
12	300.000	22.222	2.897	93.437
13	250.000	46.484	2.897	194.767
14	250.000	46.484	2.897	194.767
15	200.000	50.000	2.897	209.421
16	400.000	13.333	70.388	56.352
17	300.000	7.222	70.388	30.640
18	102.000	470.000	2.674	792.253
19	102.000	470.000	2.674	792.253
20	100.000	154.842	2.674	445.785

	ENERGY	
	(kW)	(%)
hot water SC	293.553	7.10
hot water PC	42.45264	1.03
chilled water	1809.816	43.76
steam	0	0.00
power	1,764	42.65
SUM	3909.822	94.53

Figure 3 – hydrogen engine CHP scheme and performance

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www.sisterm.com.br/en cogmci@sisterm.com.br

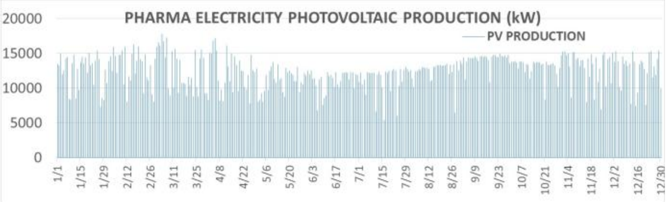

Figure 4 – photovoltaic production

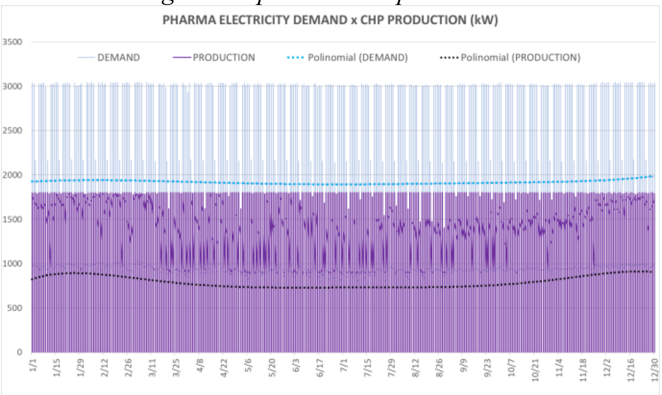

Figure 5 – electricity consumption and production

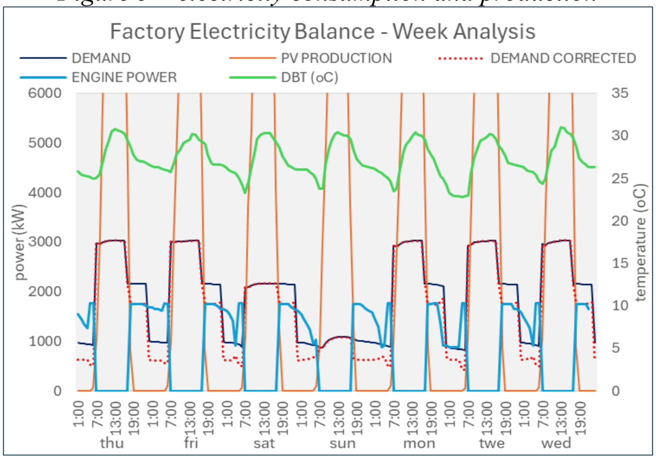

Figure 6 – electricity balance

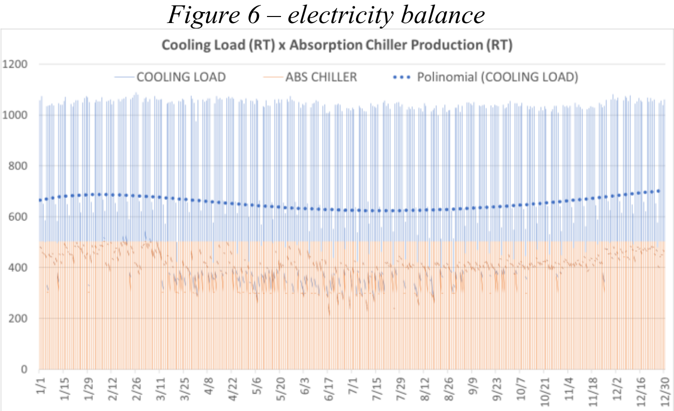

Figure 7 – cooling load and absorption chiller production

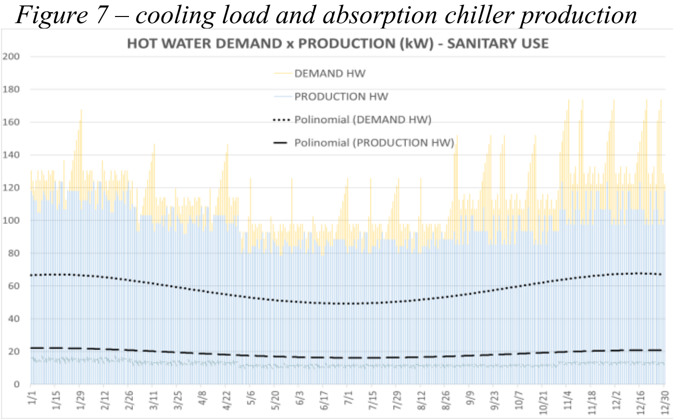

Figure 8 – sanitary hot water consumption and production

The cooling load and CHP absorption chiller production are shown in figure 7. The engine CHP accounts for 35% of the annual cooling load, the remaining 65% is handled by the electrical chillers. Sanitary use hot water consumption and engine CHP production are shown in figure 8, where the engine CHP provides 32% of the energy needs.

The engine load and EUF are shown in figure 9. The average for EUF is 85.5%. The average engine load is 81.6%.

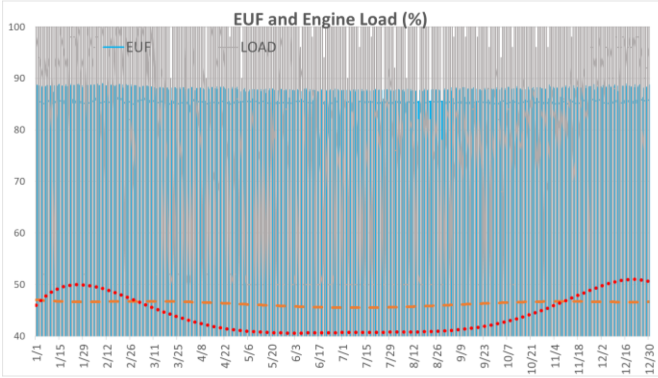

Figure 9 – engine load and EUF (energy utilization factor).

CONCLUSION

The equipment and systems for a self-sufficient net zero factory - PV + electrolysis + H_2 storage + H_2 engine CHP – were defined and sized using Energy Plus and the COGMCI software. Annual profiles (8760 hours) were used to simulate and predict the performance.

During sunny hours the factory energy consumption are met by the PV system. Excess PV electricity is used to produce H_2 in the electrolysis plant. Produced H_2 is stored and used by the engine CHP system to meet the factory energy consumption between hours 19 to 7 (13 hours per day). The proposed solution turns the factory 100% free CO_2 with reduced impact on the electrical grid.

This methodology can be used in data centers, commercial buildings and other factories. The solution can be implemented gradually as a strategic plan. A mixture of natural gas and H_2 can fuel the engine.

Better options should be assessed with consideration for strategic planning, electricity import and export regulations, renewables incentives, etc.

REFERENCES

[1] Espirito Santo, Performance evaluation of an electricity base load engine cogeneration system. Int J Energy Res 2010, 34 (9), 787-799.
[2] Espirito Santo, An energy and exergy analysis of a high-efficiency engine trigeneration system for a hospital: a case study methodology based on annual energy demand profiles. Energy and Buildings 2014, 76, 185-198.
[3] Espirito Santo, Energy and exergy efficiency of a building internal combustion engine trigeneration system under two different operational strategies. Energy and Buildings 2012, vol 53, 28-38.
[4] Espirito Santo, Gallo W.L.R., Utilizing primary energy savings and exergy destruction to compare centralized thermal plants and cogeneration/trigeneration systems. Energy 120 (2017) 785-795.
[5] COGMC Internal Combustion Engine CHP Software Evaluator – . https://www.sisterm.com.br/en/cogeneration.
[6] Energy Plus - https://energyplus.net.
[7] Net Zero CO_2 Industries – Pharma Factory Case.
[8] COGMCI Hydrogen CHP.
[9] COGMCI Toward a Zero CO_2 Economy.
[10] Net Zero CO_2 airport building terminal – H_2 Engine CHP.