Sisterm Engineering Renewables THERMAL SYSTEMS

COGMCI GETTING THE MOST FROM A CHP DESIGN & ANALYSIS

SELF-SUFFICIENT NET-ZERO CO_2 PLASTIC FOOD-PACKAGING FACTORY: PV + HYDROGEN + STORAGE + CHP

INTRODUCTION

Energy-intensive factories are among the largest contributors to global CO_2 emissions. Although their energy demands vary widely, achieving true net-zero CO_2 operations while minimizing impacts on the surrounding energy infrastructure remains a significant challenge. This white paper presents the design, configuration, operational strategy, and performance simulation of a hydrogen-fueled combined heat and power (CHP) system for a plastic food-packaging facility. The analysis integrates EnergyPlus and COGMCI software to evaluate system behavior and optimize overall energy performance. A solar photovoltaic (PV) system supplies electricity to both the factory and the hydrogen electrolyzer plant, enabling on-site hydrogen production. Through this integrated approach, the facility becomes fully energy-self-sufficient and achieves net-zero CO_2 emissions.

THE PLASTIC FOOD PACK FACTORY

The factory model was developed in EnergyPlus using 8,760-hour simulation calibrated with facility data (figure 1). The Miami, Florida building (figure 2) includes 17 thermal zones totaling 68,200 m²—warehouse, manufacturing, technical floors, offices, labs, kitchen, and restaurant. Most of the zones are air-conditioned, and construction materials match the local climate. Design parameters and schedules for lighting, occupancy, HVAC, internal loads, and operations were defined. EnergyPlus outputs are used as input to COGMCI for system design and performance evaluation.

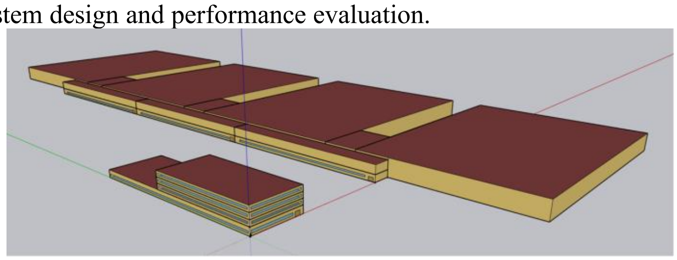


Figure 1 – The plastic food-packaging factory building.

SELF SUFFICIENT NET ZERO SOLUTION

The PV system powers daytime factory loads and the hydrogen electrolyzers. Stored hydrogen fuels two 1,560-kWe CHP engines at night, supplying electricity, chilled water, steam, and hot water. Exhaust heat produces steam. Jacket-water heat drives the chiller, and heat exchangers HE1 and HE2 provide sanitary hot water. Unused steam is used for jacket water reheat before the absorption chiller. Figure 3 shows the system and thermodynamic properties.

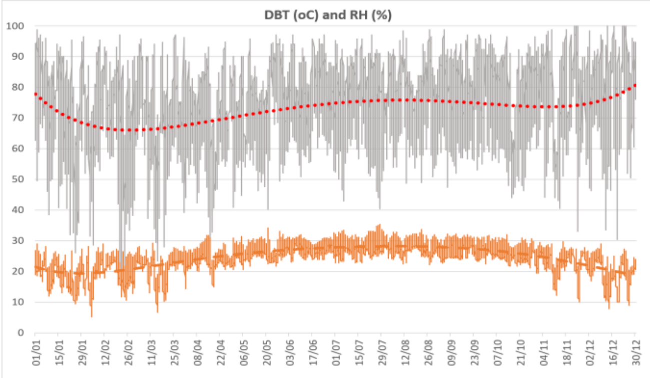


Figure 2 – Miami weather data - 8760 hours.

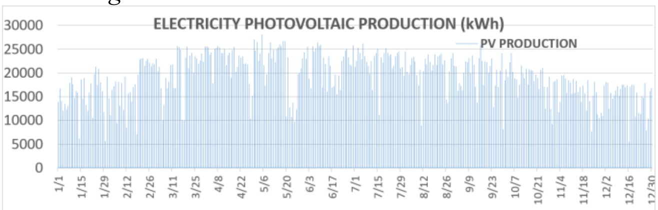
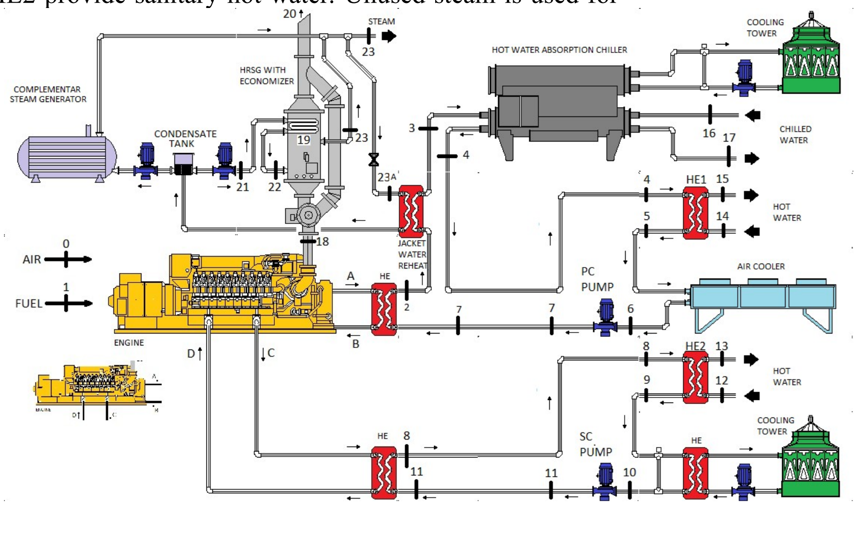


Figure 4 – photovoltaic production 8760 hours

A site-specific weather file determines annual PV output (Fig. 4). Figure 5 presents the facility's electricity consumption and CHP on-site generation. Electricity use is shown in blue, while CHP engine production appears in orange. A detailed analysis for a typical summer week is provided in Figure 6. The blue line represents the factory's baseline electricity demand, which decreases on Saturdays and Sundays even though production equipment and HVAC systems operate continuously. Demand also drops in the evenings due to the absence of office activity and in the early morning hours, despite manufacturing running on a three-shift schedule. PV generation begins around hour 6 and continues until approximately hour 19 (orange line). The red dashed line represents the adjusted electricity demand after accounting for the avoided chiller load when the absorption chiller is driven by the CHP system. CHP electrical output is shown in purple and operates from 19:00 to 07:00, with one or both engines dispatched as required. The green line indicates the outside dry-bulb temperature (DBT).



flow number	pressure (kPa)	temperature (oC)	mass flow (kg/s)	enthalpy (kJ/kg)
0	100.0	25.0	2.4	298.8
1	100.0	25.0	0.030	119,000.0
2	462.5	99.0	19.0	415.1
3	375.0	99.0	19.0	415.1
4	287.5	89.7	19.0	376.1
5	200.0	89.0	19.0	372.8
6	200.0	89.0	19.0	372.8
7	550.0	89.0	19.0	373.1
8	275.0	50.0	3.5	209.5
9	150.0	40.0	3.5	167.6
10	150.0	40.0	3.5	167.6
11	400.0	40.0	3.5	167.8
12	300.0	22.2	1.3	93.3
13	250.0	49.0	1.3	205.3
14	250.0	30.0	0.7	125.9
15	200.0	50.0	0.7	209.4
16	400.0	13.3	25.0	56.4
17	300.0	7.2	25.0	30.6
18	102.0	420.0	2.4	735.6
19	101.0	171.1	2.4	463.1
20	100.0	129.9	2.4	419.3
21	823.2	70.0	0.3	293.6
22	721.9	149.5	0.3	630.3
23	721.9	166.2	0.3	2,763.3

	ENERGY	
	(kW)	(%)
hot water SC	145.0742	4.00
hot water PC	59.97382	1.65
chilled water	643.7256	17.74
steam	740.8962	20.42
power	1,529	42.14
SUM	3118.47	85.96

Figure 3 – hydrogen engine CHP scheme and performance

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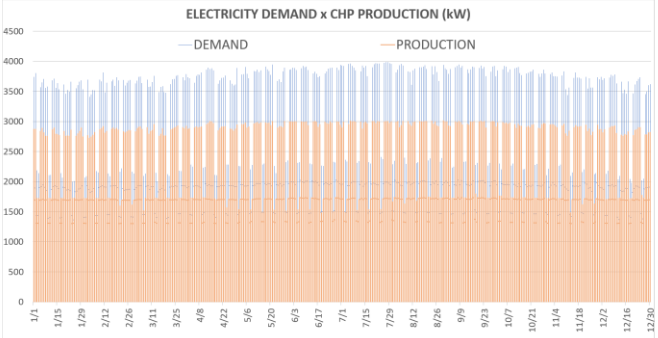

Fig. 5 – electricity demand and production - 8760 hours

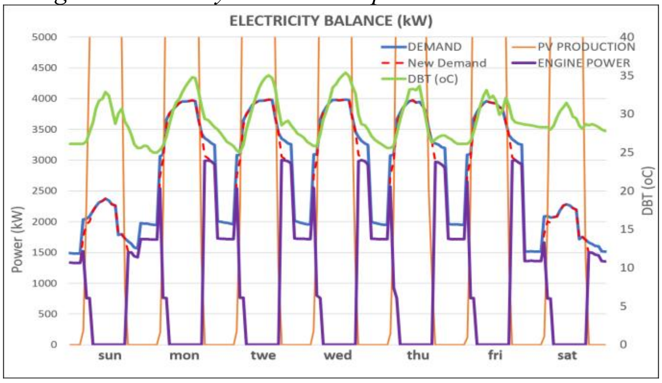

Figure 6 – electricity balance

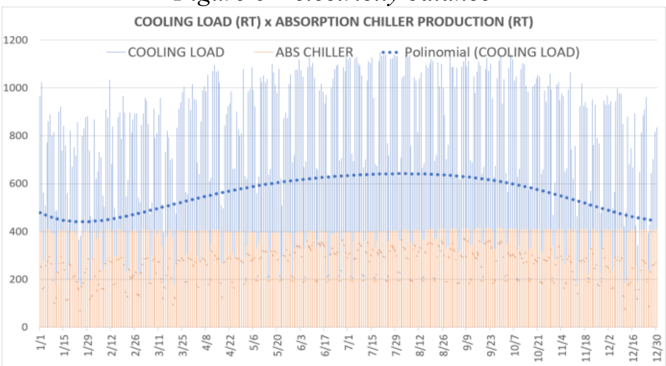

Fig. 7 – cooling load and absorption chiller - 8760 hours

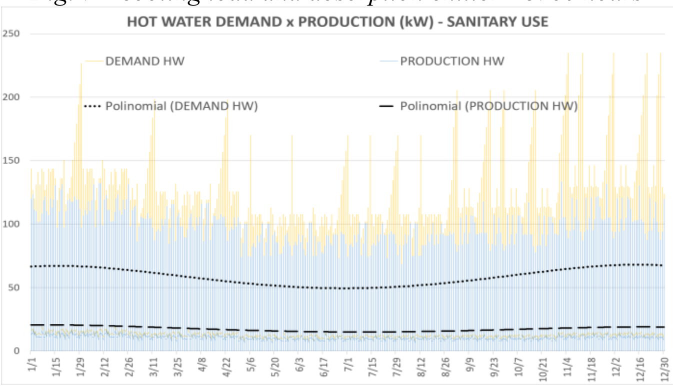

Figure 8 – hot water demand and production - 8760 hours

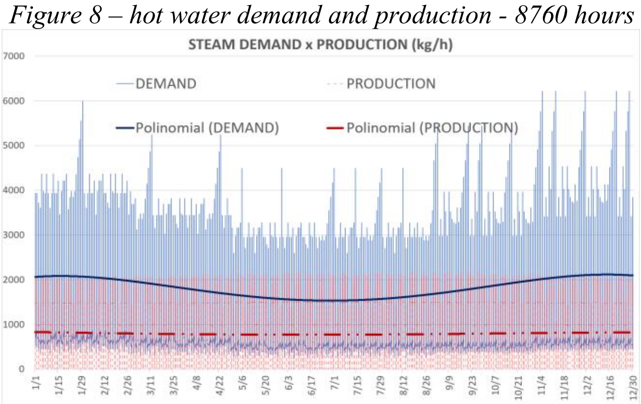

Figure 9 – steam demand and production - 8760 hours

Figure 7 shows cooling demand and CHP absorption-chiller output: CHP supplies 26% of annual cooling, electric chillers 74%. Figure 8 shows sanitary hot-water demand, with CHP providing 30% of needs. Figure 9 shows steam demand, 43% met by the H_2 CHP.

Figure 10 shows engine load and EUF: average EUF 75%, average load 73%. Red line indicates engine count: one engine for 1,563 h/yr, two engines for 3,182 h/yr.

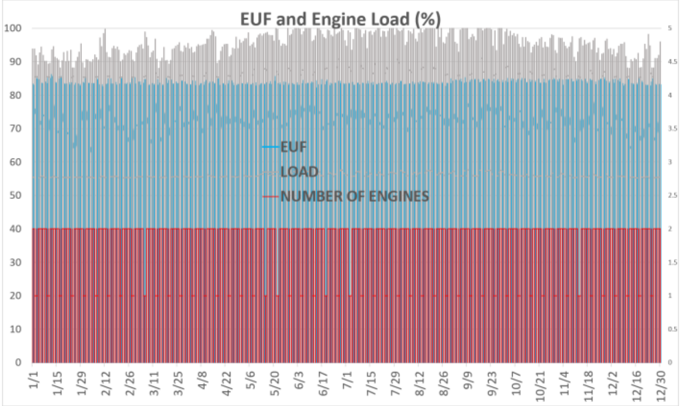

Figure 10 – engine load, EUF and number of engines.

CONCLUSION

The equipment and systems required for a self-sufficient, net-zero-CO_2 factory—PV generation, electrolysis, hydrogen storage, and H_2-fueled CHP—were defined and sized using EnergyPlus and COGMCI. Full 8,760-hour annual profiles were used to simulate, optimize, and predict system performance.

During sunny hours, factory electricity demand is supplied by the PV system. Surplus PV power feeds the electrolysis plant to produce hydrogen, which is stored and later used by the CHP engines to meet factory energy needs between 19:00 and 07:00 (13 hours per day). This integrated configuration enables the facility to operate with zero direct CO_2 emissions while reducing its impact on the electrical grid.

The methodology is applicable to data centers, commercial buildings, and other manufacturing processes, with flexibility to develop alternative strategies and operational schedules. Hybrid fueling—using a mixture of natural gas and hydrogen—is also feasible. Optimal solutions should be evaluated considering strategic planning, electricity import/export regulations, renewable-energy incentives, and site-specific constraints.

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