Case Study Report

The staggering economics of RNG CHP Microgrid for HOSPITALS with The Inflation Reduction Act benefits

CogenS™

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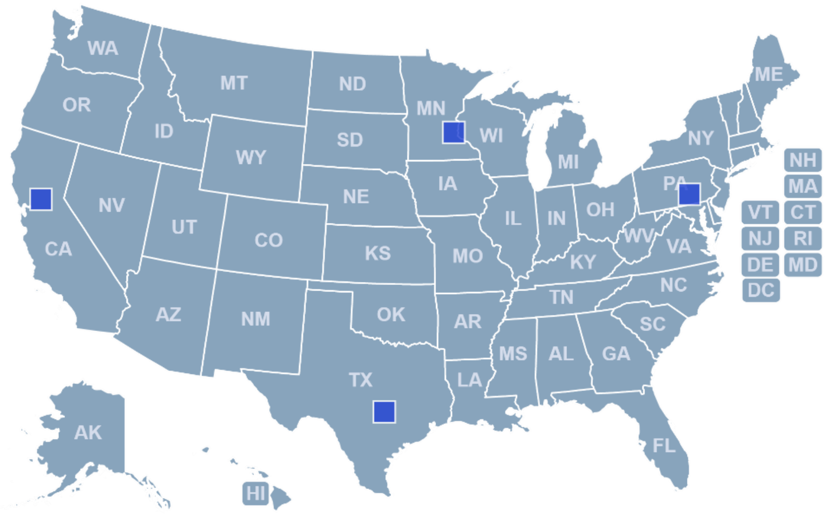
BACKGROUND

CHP for Hospitals Hypothetical Project Locations



"Hospitals and healthcare systems are at the front line of responding to natural disasters, reducing mortality rates, and assisting with public health crises. Combined heat and power (CHP) systems can ensure that these facilities, along with the patient health and critical life support systems they house, operate nonstop, even during grid outages."

(Source: US DOE CHP Fact sheets)

In this case study we examine the feasibility of a 20-year Renewable Natural Gas (RNG) fueled CHP Microgrid (CHP + Solar), for a typical 241,351 sq.ft, 5 Floors Hospital (as described by the US DOE Reference Buildings) in 4 different states across the US; California, Texas, Pennsylvania, and Minnesota.

These states were selected based on maximum feasibility potential for CHP systems according to the CHP project profile installation database and state regulations, energy prices, emissions and other factors (checkout our article on this subject).

The proposed solution will also include a new Absorption chiller to maximize the CHP feasibility potential and extend full load operation during the summer season.

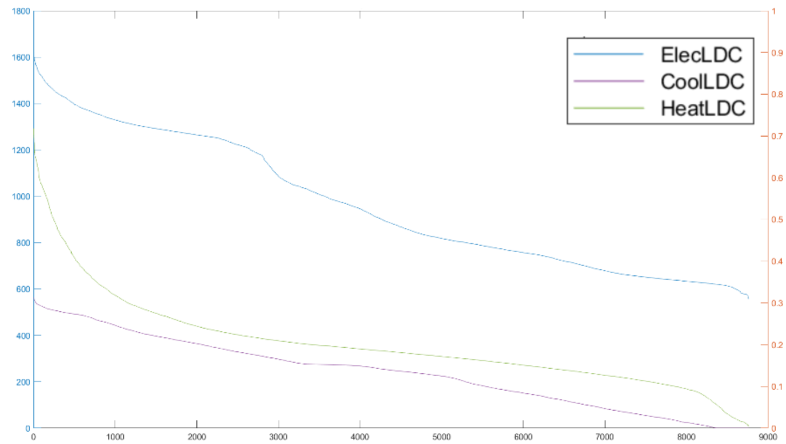
With the Inflation Reduction Act recently signed into law by President Biden; projects involving these technologies will receive 30% Tax Credit Incentives if placed in operation before the end of 2024.

WHAT MAKES CHP HYPER FEASIBLE FOR HOSPITALS

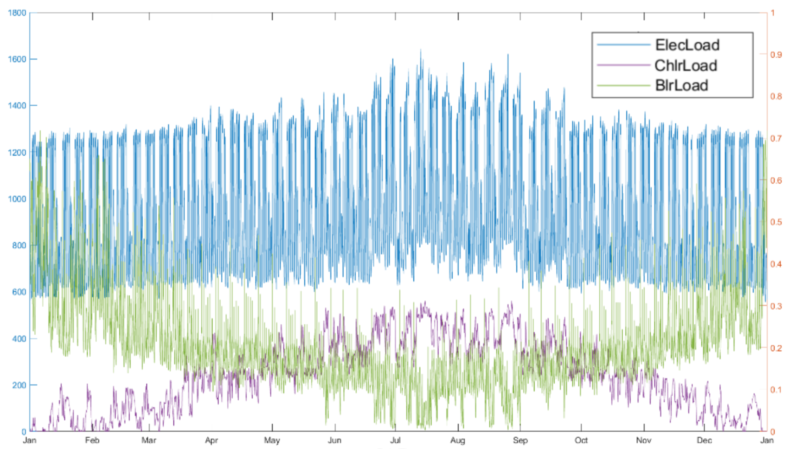
"Hospitals require continuous power for their operations and have significant thermal demands for heating, hot water, steam for sterilization, cooling, dehumidification, and laundry services.
These coincident thermal and electric loads make CHP a good fit to provide year-round critical power and thermal energy."
(Source: [US DOE CHP Fact sheets](#))

With that said, this feasibility study only examines the Thermal Demand from Space Heating and Cooling as depicted in the Typical Profiles and Duration Curves on the right. This means that the potential for CHP feasibility could be even higher than the results from this study.

Typical Hospital Load Profiles

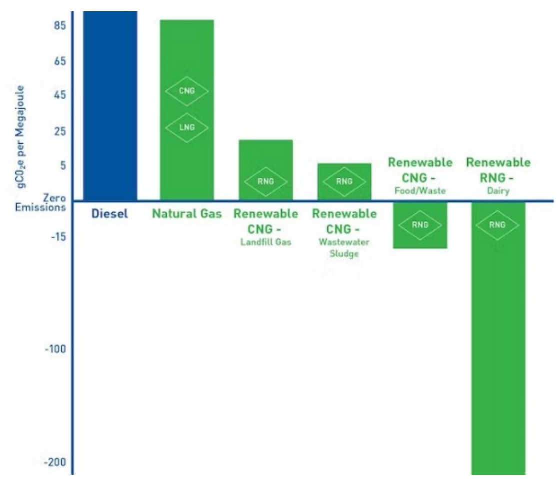


Typical Hospital Load Duration Curves



WHY EXAMINE RNG AND NOT NATURAL GAS AS FUEL FOR CHP

Source: RNG.CleanEnergyFuels.com



"RNG projects capture and recover methane produced at a landfill or anaerobic digestion (AD) facility. Methane has a global warming potential more than 25 times greater than CO2 and a relatively short (12-year) atmospheric life, so reducing these emissions can achieve near-term beneficial impacts in mitigating global climate change."

(Source: EPA.gov)

RNG can be purchased in the form of:

1. Carbon Reduction Credits or Certificates for scope 1 emissions (i.e. onsite direct emitting stationary energy generation equipment) separate from actual natural gas purchases (unbundled). Examples of organizations providing RNG certificates are:
   a. Green-e®.
   b. M-RETS.
2. Utility bundled Natural Gas and RNG Tariffs such as:
   a. SoCalGas in California.
   b. VGS in Vermont.
   c. A number of Pennsylvania Gas utilities.

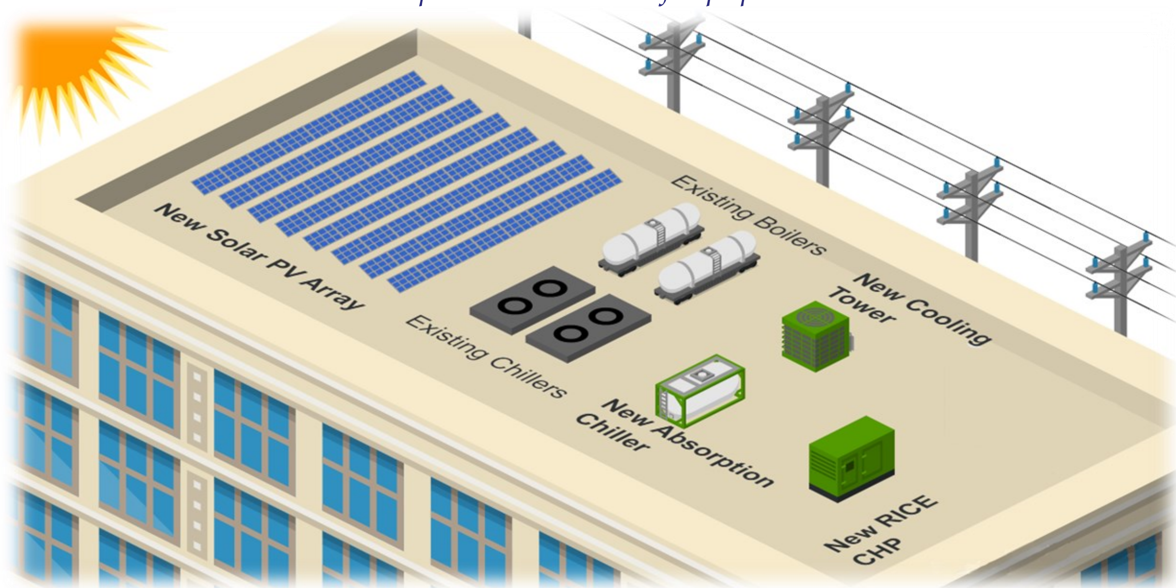
Investing in RNG Certificates and tariffs supports the development of more RNG projects, and in turn decarbonizes the gas pipeline infrastructure, increases and diversifies domestic energy production, and benefits the local economy.

EXISTING AND CHP MICROGRID SYSTEM ASSUMPTIONS

To begin assessing the feasibility of the CHP - PV system, we would need to make a series of simplified assumptions related to the building space, shape, equipment, utility providers, outages, and the Hospital owner's financial considerations.

These assumptions are generalized for all locations, under the categorization listed in the Appendix section of this study, to help ease the feasibility process. However, only a few location-related critical assumptions are made, at the end of the assumptions, that can have a significant impact on the project feasibility.

Hospital Assumed Roof Equipment



COGENS MODELING RESULTS

There are far too many factors to consider when properly evaluating CHP systems feasibility; Cooling, Heating and Power systems efficiency, part-load performance, multi-unit operation, ambient temperature performance effects, optimization, dispatch control, degradation, complex utility tariffs for with and without the CHP Microgrid, financial modeling … just to name a few.

CogenS™ modeling process is highly sophisticated and detailed in that sense, making it a perfect techno-economic modeling tool for CHP projects requiring such complex capabilities for investment grade feasibility studies.

In this case study, we used CogenS™ to run an investment grade model for the Hospital system described above for each of the target states aforementioned; California, Texas, Pennsylvania, and Minnesota.

The resulting environmental and economic benefits of the model proved more than feasible when it comes to any organization measure of success:

1. A staggering 23% Internal Rate of Return.
2. A remarkable 4 years discounted payback period.
3. An outstanding 48% CO_2e emission reduction (equivalent to 1698 Tonnes/year).

Note: These numbers are the average results of all 4 states studied.

A more in-depth modeling results from CogenS™ can be further investigated in the Appendix section of the Study.

CONCLUSION

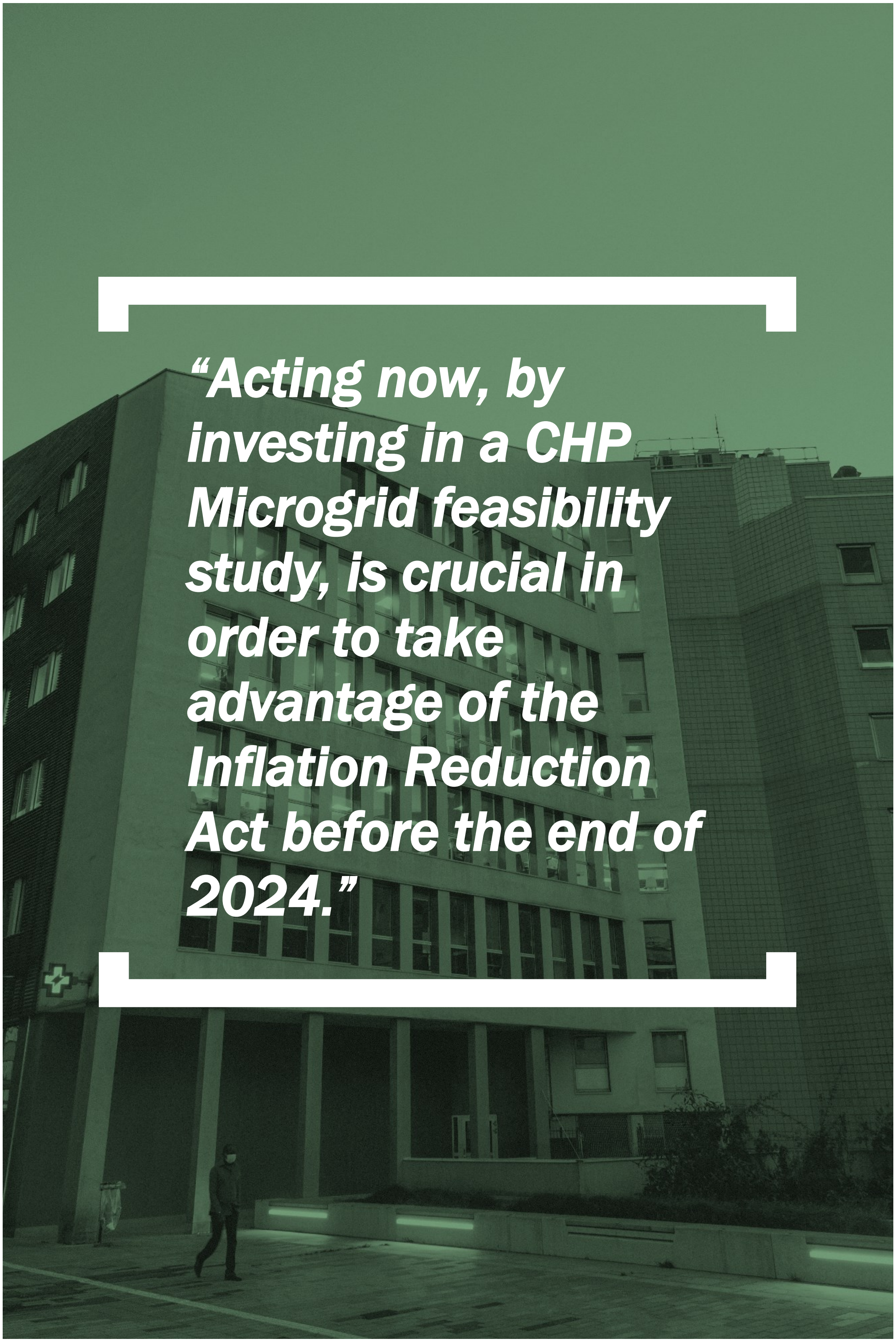
Hospitals around the US should be seriously considering CHP systems for their scope 1 emissions reduction, power resiliency enhancement, and energy efficiency improvement plans for the next 20 years:

1. *CO2e emissions can be reduced by up to 50%, 2219 Tonnes/year, by investing in RNG certificates or tariffs from the local providers.*
2. *Energy bill savings can reach upwards of 35%, or $450,000 annually.*
3. *The project can pay for itself in as little as 3 years.*

Up to **$450,000 Saved**

Up to **2,200 Tonnes Saved**

As soon as **3 Years Pay Back**


"Acting now, by investing in a CHP Microgrid feasibility study, is crucial in order to take advantage of the Inflation Reduction Act before the end of 2024."

APPENDIX

CASE STUDY ASSUMPTIONS

Space Assumptions:

1. The roof space was calculated as the total Hospital area of 241,351 sq.ft, divided by 5 floors, equating to 48,270 sq.ft. of roof space.
2. Only half of the roof area is available for a roof mounted Solar PV array, equating to 24,135 sq.ft.
3. Space is available for CHP system installation, and Hot/Chilled water piping modifications.

Microgrid sizing Assumptions:

1. A 21 Watt/sq.ft. Solar PV Array production rate, which equates to approximately 500 kW DC of roof-mounted Solar PV with 12% losses.
2. The CHP system is sized for baseload operation at 450 kW.
3. The absorption chiller is sized at 100 tons to serve 50% of the cooling load, with the electric chillers, throughout the year.

Grid Assumptions:

1. Grid outages occur according to the below schedule:
   - 25-Oct at 08:00 AM for 2 hours
   - 27-Nov at 14:00 PM for 10 hours
2. A Critical Electric Load factor of 0.5 during outages.
3. A 51 $/Tonne cost of Carbon Dioxide equivalent emissions (CO_2e).
4. A 150 $/Tonne cost of reduction in CO_2e using Renewable Natural Gas (RNG).

Equipment Efficiency Assumptions:

1. Existing Electric Chiller system for space cooling rated at 12 EER efficiency.
2. Existing Hot Water Gas Boilers for space heating rated at 80% efficiency.
3. New Reciprocating Engine CHP unit rated at 40.6% Electric Efficiency, and 45.2% Thermal Efficiency.
4. New Water-Cooled Single-Stage Absorption Chiller rated at 0.7 COP.
5. 96% PV-Inverter efficiency.

Fuel and Emissions Assumptions:

1. A 117 lb/MMBtu CO_2e Factor for Natural Gas (NG) fueled Boilers.
2. A 20 lb/MMBtu CO_2e Factor for RNG fueled CHP.
3. A zero CO_2e Factor for Solar Production.

Financial Assumptions:

1. Study period: 20 years.
2. Capital and Operating expenses:

	CHP	PV	Absorption Chiller
Installed Capital Cost	1700 $/kW$_e$	1720 $/kW$_{DC}$	6,000 $/ton
O&M Cost	0.017 $/kWh	18.55 $/kW$_{DC}$/year	0.006 $/ton-hr

3. Loan:

Amount	Interest Rate	Term
$1,000,000	6%	20 years

4. Depreciation and Incentives:

	CHP	PV	Absorption Chiller
Depreciation	5 years - MACRS	5 years - MACRS	5 years - MACRS
Tax Credit Incentive	30% of installed cost	30% of installed cost	30% of installed cost

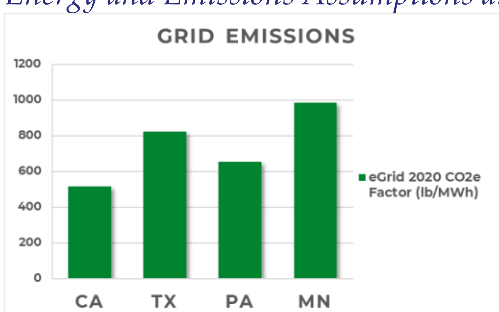
5. Effective Tax Rate: 22%
6. Nominal Discounting Rate: 6%.
7. Inflation Rates:

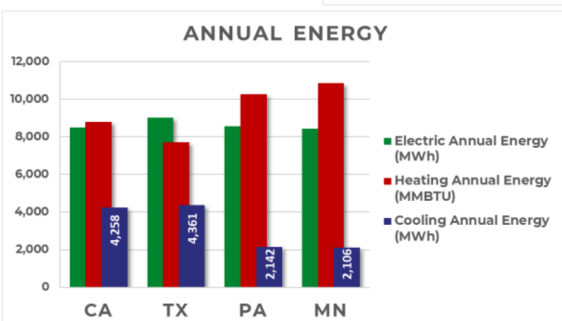
	Electric charges	NG charges	O&M charges
Annual Inflation rate	1.5%	1.5%	2%

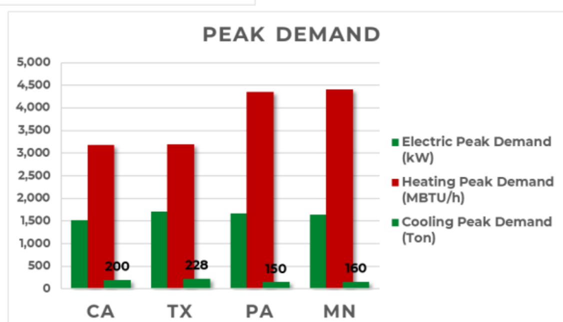
Location specific assumptions:

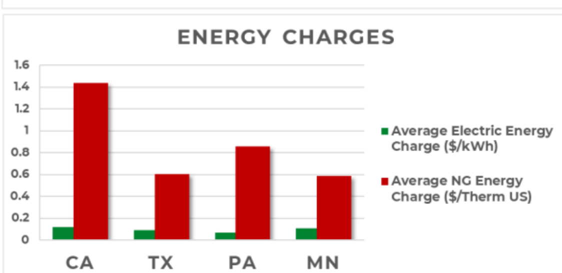
	CA	TX	PA	MN
Grid Emissions				
eGrid 2020 CO_2e Factor (lb/MWh)	515.5	822.04	655.4	986.63
Energy charges				
TOU Energy and Demand Electric Charges	yes	yes	no	no
Seasonal Energy and Demand NG Charges	yes	no	no	yes
Average Electric Energy Charge ($/kWh)	0.11735	0.0892	0.0686	0.11
Average Electric Demand Charge ($/kW)	21.03	11.0971	10.575	4.75
Average NG Energy Charge ($/Therm US)	1.436	0.6032	0.86	0.5892
Average NG Demand Charge ($/Daily Max Therm US)	0	0	0	1.5272
Electric Load				
Peak Demand (kW)	1,519	1,704	1,672	1,643
Annual Energy (MWh)	8,498	9,011	8,567	8,425
Heating Load				
Peak Demand (MMBTU/h)	3.186	3.193	4.353	4.410
Annual Energy (MMBTU)	8,779	7,719	10,270	10,861
Cooling Load				
Peak Demand (Ton)	200	227.5	150	160
Annual Energy (MWh)	4,258	4,361	2,142	2,106

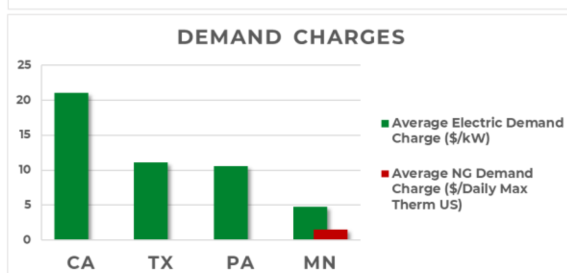
Location Energy and Emissions Assumptions at a Glance







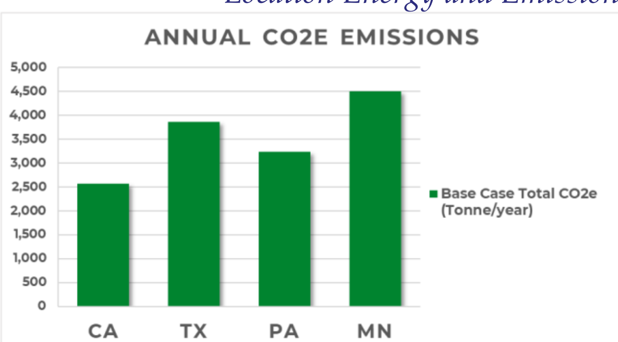


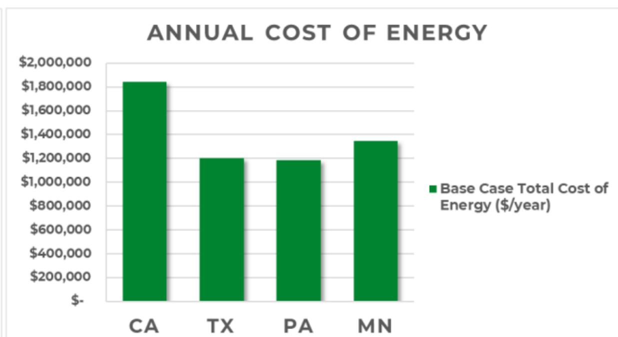


BASE CASE MODELING RESULTS USING COGENS

	CA	TX	PA	MN
Annual Energy Consumption				
Electric Peak Demand (kW)	1,519	1,704	1,672	1,643
Electric Annual Energy (MWh/year)	8,498	9,011	8,567	8,425
Heating Peak Demand (MBTU/h)	3,186	3,193	4,353	4,410
Heating Annual Energy (MMBTU/year)	8,779	7,719	10,270	10,861
Boiler system consumption (Therms US/year)	109,480	96,509	13,070	138,250
Chiller system consumption (MWh/year)	602	862	517	497
Annual CO2e Emissions				
Base Case Heating CO2e (Tonne/year)	581	512	694	734
Base Case Grid CO2e (Tonne/year)	1,984	3,354	2,543	3,764
Base Case Total CO2e (Tonne/year)	2,567	3,869	3,239	4,500
Annual Energy Cost				
Base Case Cost of CO2e ($/year)	$ 130,921	$ 197,304	$ 165,185	$ 229,533
Base Case Cost of Electricity ($/year)	$ 1,553,600	$ 943,455	$ 866,639	$ 1,008,000
Base Case Cost of Gas ($/year)	$ 156,148	$ 58,653	$ 152,951	$ 105,809
Base Case Cost of Outages ($/year)	$ 2,224	$ 2,398	$ 2,223	$ 2,177
Base Case Total Cost of Energy ($/year)	$ 1,842,800	$ 1,201,800	$ 1,187,000	$ 1,345,500

Location Energy and Emissions Base Case Results at a Glance

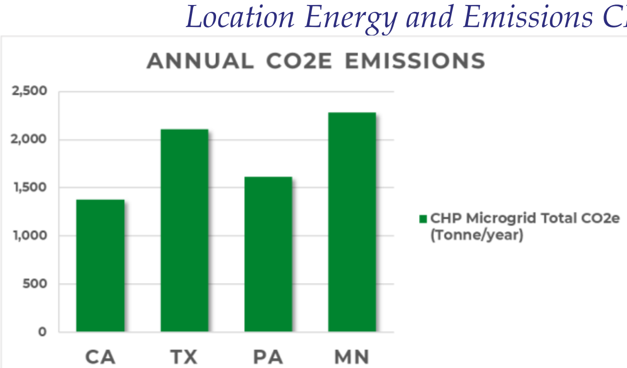


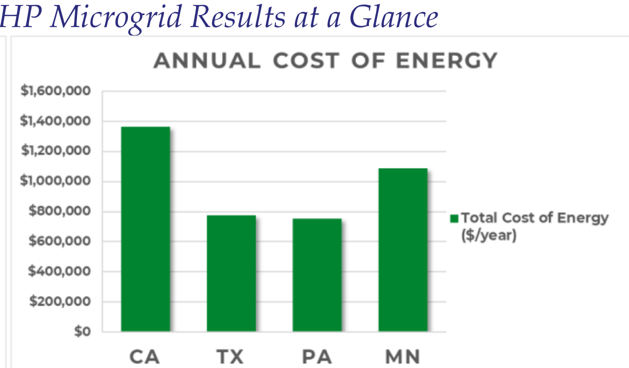


CHP MICROGRID SYSTEMS MODELING RESULTS USING COGENS™

	CA	TX	PA	MN
Annual Peak Demand				
New Electric Peak Demand (kW)	1,520	1,636	1,606	1,610
New Grid supplied Peak Demand (kW)	1,057	1,116	1,233	1,245
New Heating Peak Demand (MBTU/h)	3,970	3,955	4,353	4,410
Annual Energy Consumption				
New Total Electric Energy (MWh/year)	8,470	8,804	8,396	8,456
New Heating Annual Energy (MMBTU/year)	17,946	17,692	15,307	15,731
Boiler system Consumption (Therms US/year)	40,861	43,913	15,131	22,034
Existing Chiller system consumption (MWh/year)	474	549	258	249
New Cooling Tower Consumption (MWh/year)	102	109	92	285
CHP consumption (Therms US/year)	326,830	317,860	329,700	332,200
CHP Electric Production (MWh/year)	3,897	3,717	3,584	3,587
CHP Heat Production (MMBTU/year)	14,739	14,383	14,028	14,025
CHP Waste Heat (MMBTU/year)	0	0	0	0
Solar PV Electricity Production (MWh/year)	882	821	645	704
Excess Electricity sent to Grid (MWh/year)	-0.50	-0.07	-0.20	-0.62
Consumed Electricity from Grid (MWh/year)	3,688	4,262	4,164	4,163
Gas consumed from Grid (Therms US/year)	367,690	361,780	344,830	354,240
Annual CO2e Emissions				
CHP Microgrid Heating CO2e (Tonne/year)	217	233	80	119
CHP Microgrid Grid CO2e (Tonne/year)	862	1,589	1,238	1,862
CHP Microgrid Total CO2e (Tonne/year)	1,376	2,111	1,617	2,281
CHP Microgrid RNG CO2e reduced (Tonne/year)	1,434	1,398	1,450	1,400
Annual Energy Cost				
Cost of CO2e ($/year)	$ 70,152	$ 107,644	$ 82,484	$ 116,000
Cost of Electricity ($/year)	$ 819,821	$ 462,560	$ 373,370	$ 520,000
Cost of Gas ($/year)	$ 475,101	$ 207,048	$ 296,512	$ 243,000
Cost of RNG Credit ($/year)	$ 215,100	$ 209,700	$ 217,500	$ 210,000
Total Cost of Energy ($/year)	$ 1,365,100	$ 777,252	$ 752,366	$ 1,089,000

Location Energy and Emissions CHP Microgrid Results at a Glance

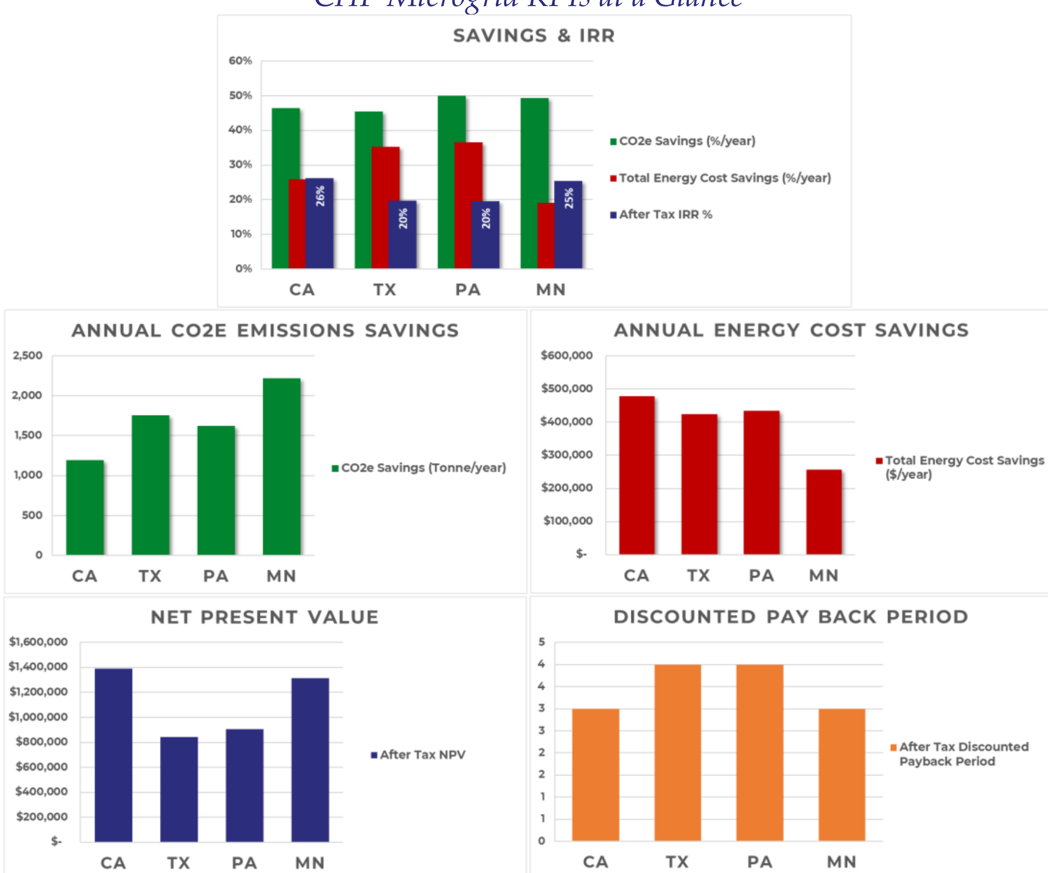




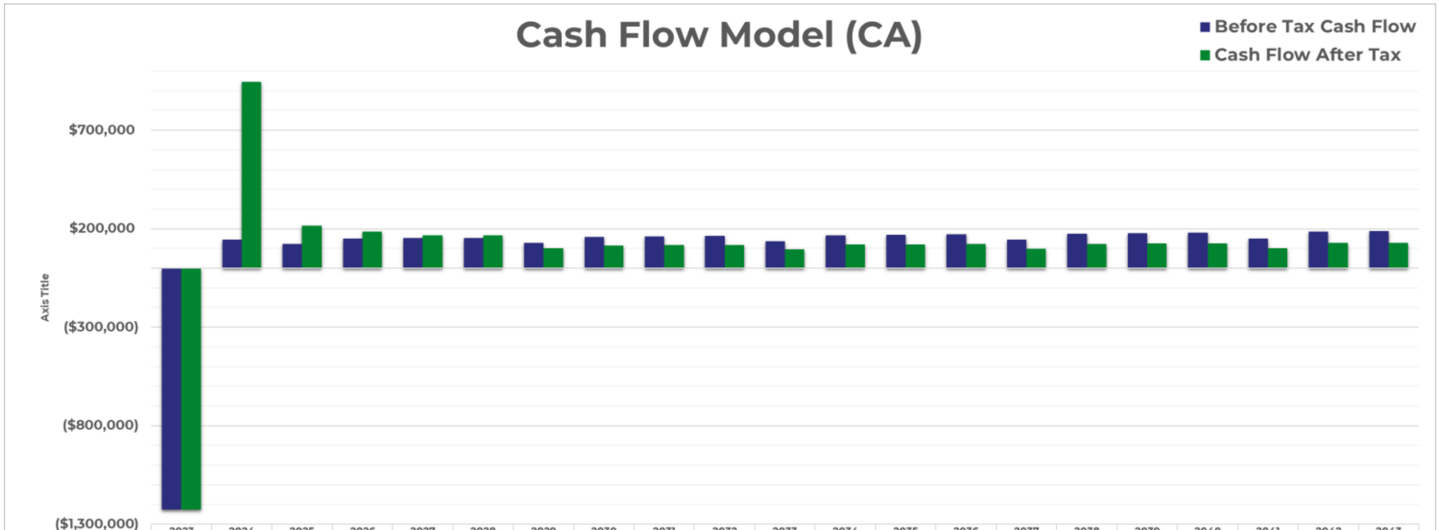
RNG CHP & Solar Microgrid for Hospital Technoeconomic Key Project Performance Indicators

RNG CHP MICROGRID FOR HOSPITAL PROJECT KPIS				
CO_2e Savings (Tonne/year)	**1,192**	**1,758**	**1,622**	**2,219**
CO_2e Savings (%/year)	**46%**	**45%**	**50%**	**49%**
Total Energy Cost Savings ($ /year)	**$ 477,700**	**$ 424,548**	**$ 434,634**	**$ 256,500**
Total Energy Cost Savings (%/year)	**26%**	**35%**	**37%**	**19%**
Before Tax NPV	$ 911,270	$ 210,210	$ 357,290	$ 792,970
Before Tax IRR %	11%	6%	7%	10%
Before Tax Simple Payback Period	9	13	12	9
Before Tax Discounted Payback Period	11	17	15	12
Before Tax Benefit to Cost Ratio	1.1	1.0	1.0	1.1
Before Tax Equivalent Annual Revenue	$ 66,588	$ 15,360	$ 26,108	$ 57,943
After Tax NPV	**$ 1,390,500**	**$ 843,730**	**$ 907,250**	**$ 1,315,300**
After Tax IRR %	**26%**	**20%**	**20%**	**25%**
After Tax Simple Payback Period	**3**	**3**	**4**	**3**
After Tax Discounted Payback Period	3	4	4	3
After Tax Benefit to Cost Ratio	1.2	1.1	1.1	1.2
After Tax Equivalent Annual Revenue	$ 101,610	$ 61,652	$ 66,294	$ 96,114

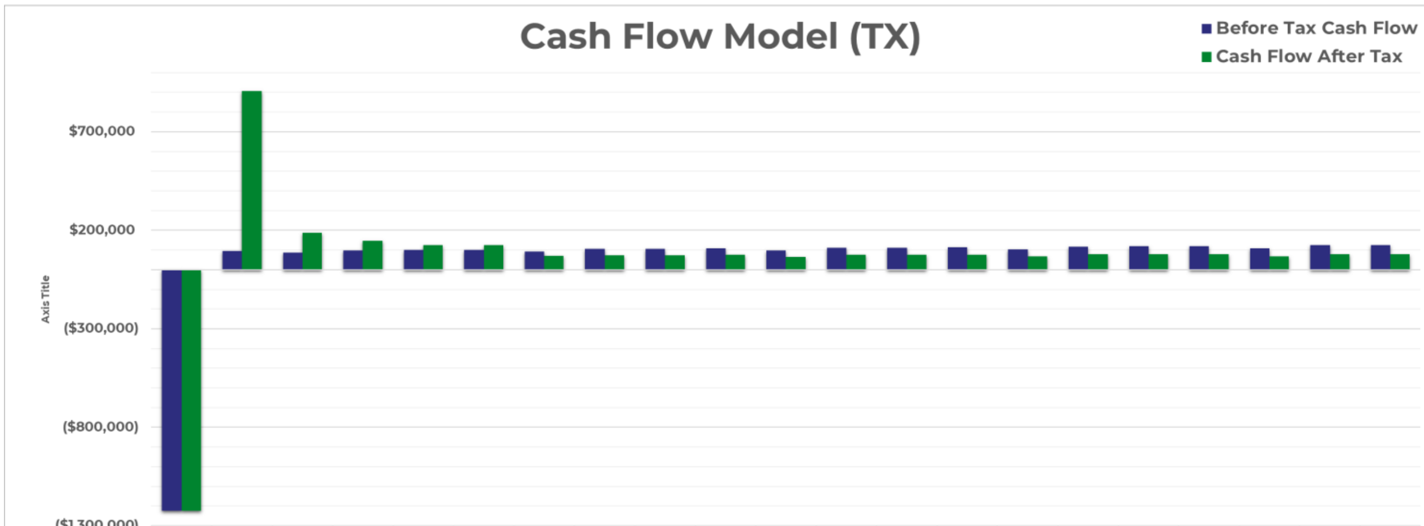
CHP Microgrid KPIs at a Glance



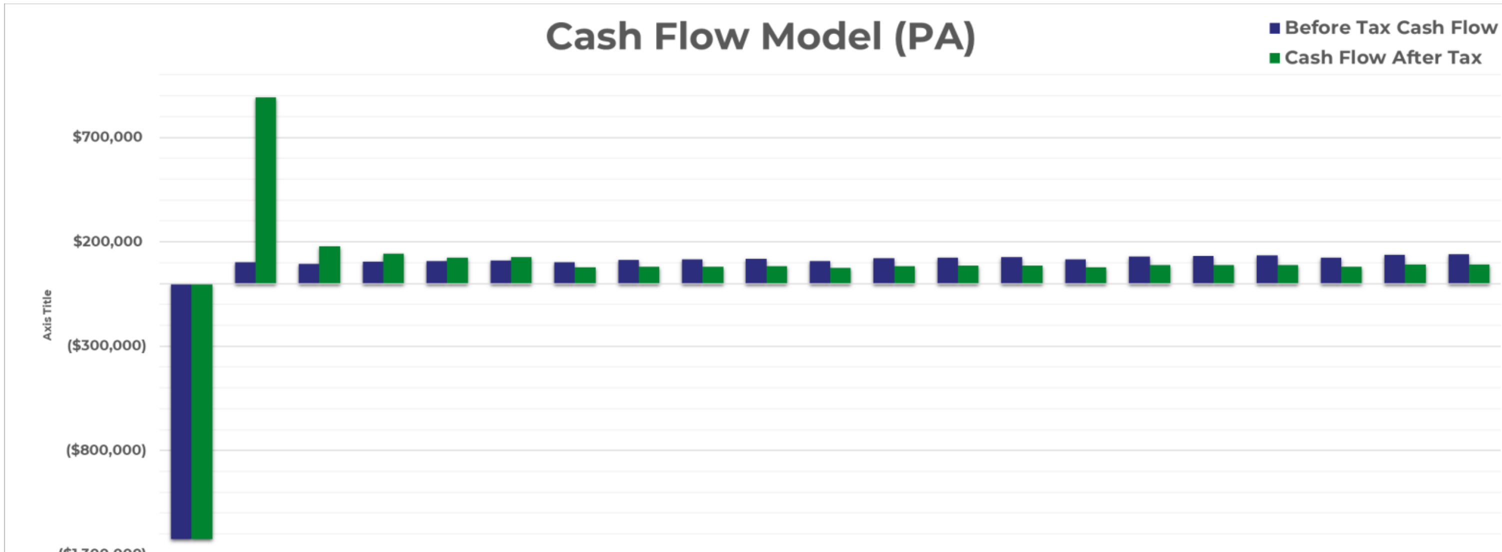
RNG CHP & Solar Microgrid for Hospital Cash Flows Before and After Tax



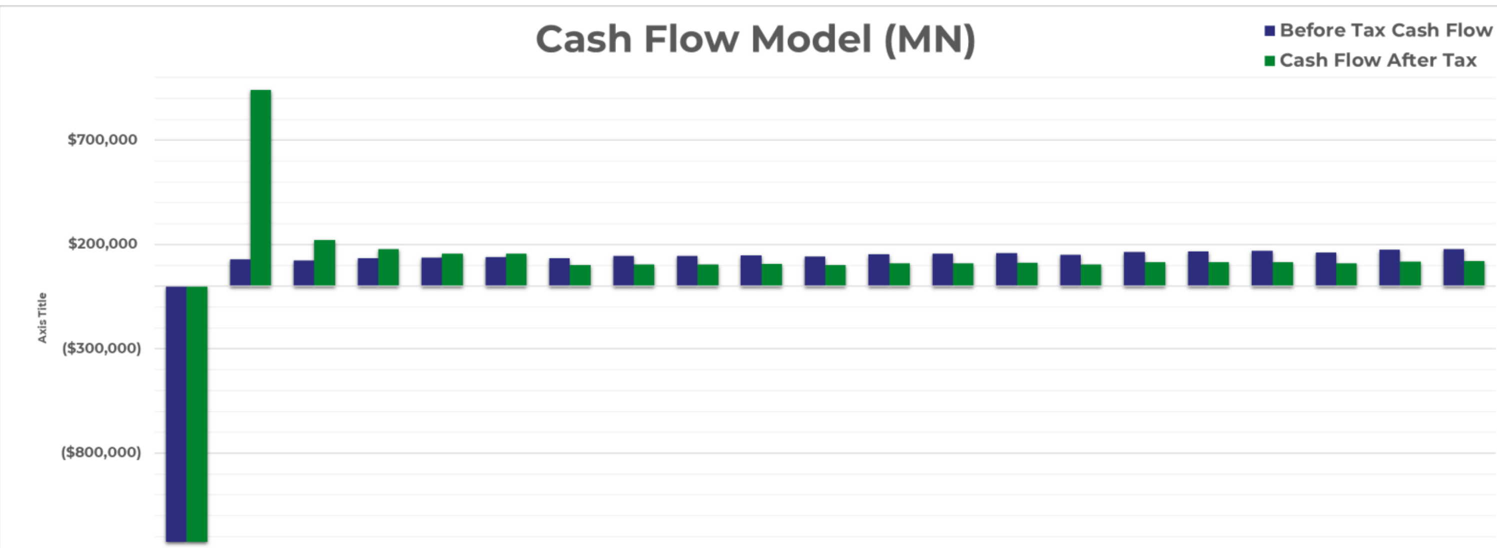
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Before Tax Cash Flow	($1,225,	$145,060	$122,370	$149,390	$151,570	$153,750	$129,560	$158,140	$160,340	$162,540	$136,750	$166,970	$169,190	$171,410	$143,910	$175,860	$178,080	$180,310	$151,000	$184,770	$186,990
Cash Flow After Tax	($1,225,	$945,990	$216,380	$186,170	$164,990	$166,270	$99,810	$114,860	$116,070	$117,250	$96,564	$119,530	$120,610	$121,660	$99,496	$123,650	$124,570	$125,450	$101,670	$127,050	$127,760



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Before Tax Cash Flow	($1,225,	$94,903	$85,362	$98,087	$99,683	$101,280	$91,046	$104,480	$106,070	$107,670	$96,696	$110,870	$112,460	$114,050	$102,280	$117,230	$118,810	$120,390	$107,760	$123,530	$125,090
Cash Flow After Tax	($1,225,	$906,870	$187,510	$146,150	$124,520	$125,340	$69,768	$73,008	$73,746	$74,453	$65,319	$75,766	$76,367	$76,929	$67,022	$77,918	$78,341	$78,712	$67,949	$79,283	$79,477

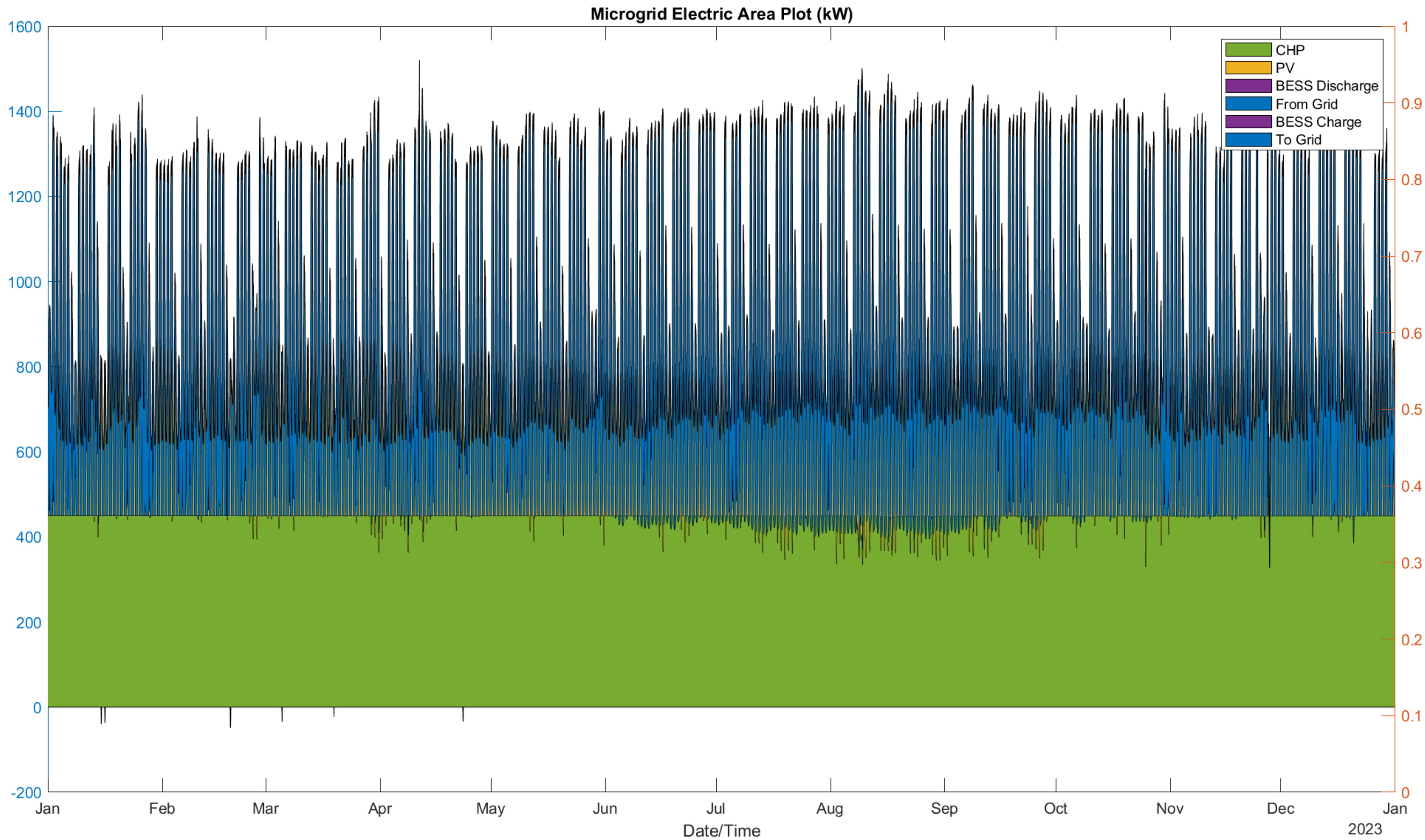


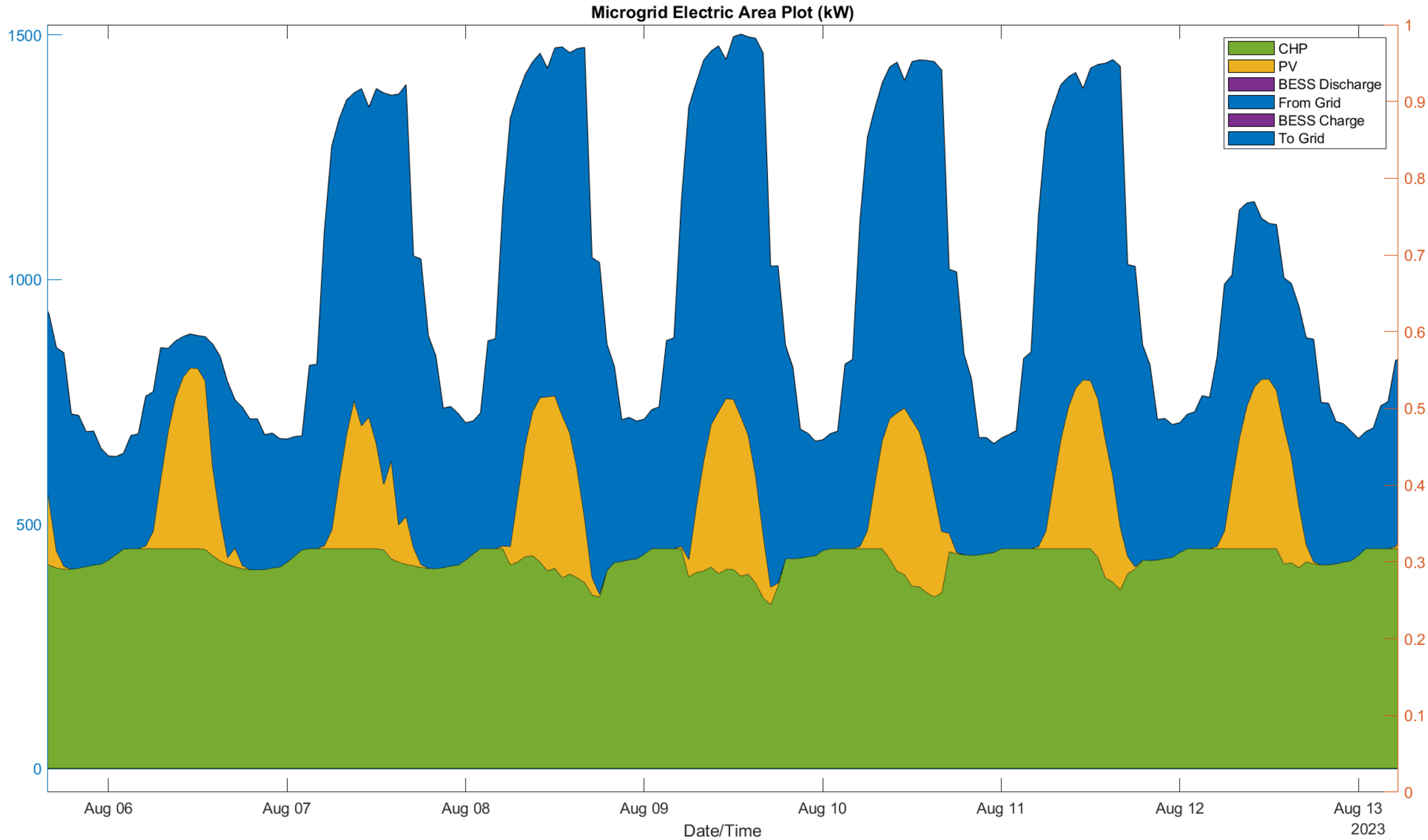
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Before Tax Cash Flow	($1,225,	$102,240	$93,873	$106,110	$108,050	$110,010	$101,050	$113,950	$115,930	$117,930	$108,340	$121,940	$123,960	$125,990	$115,720	$130,060	$132,110	$134,160	$123,170	$138,290	$140,360
Cash Flow After Tax	($1,225,	$892,960	$179,570	$143,650	$124,870	$125,970	$76,795	$80,396	$81,435	$82,450	$74,398	$84,402	$85,334	$86,234	$77,505	$87,926	$88,712	$89,455	$79,971	$90,795	$91,387

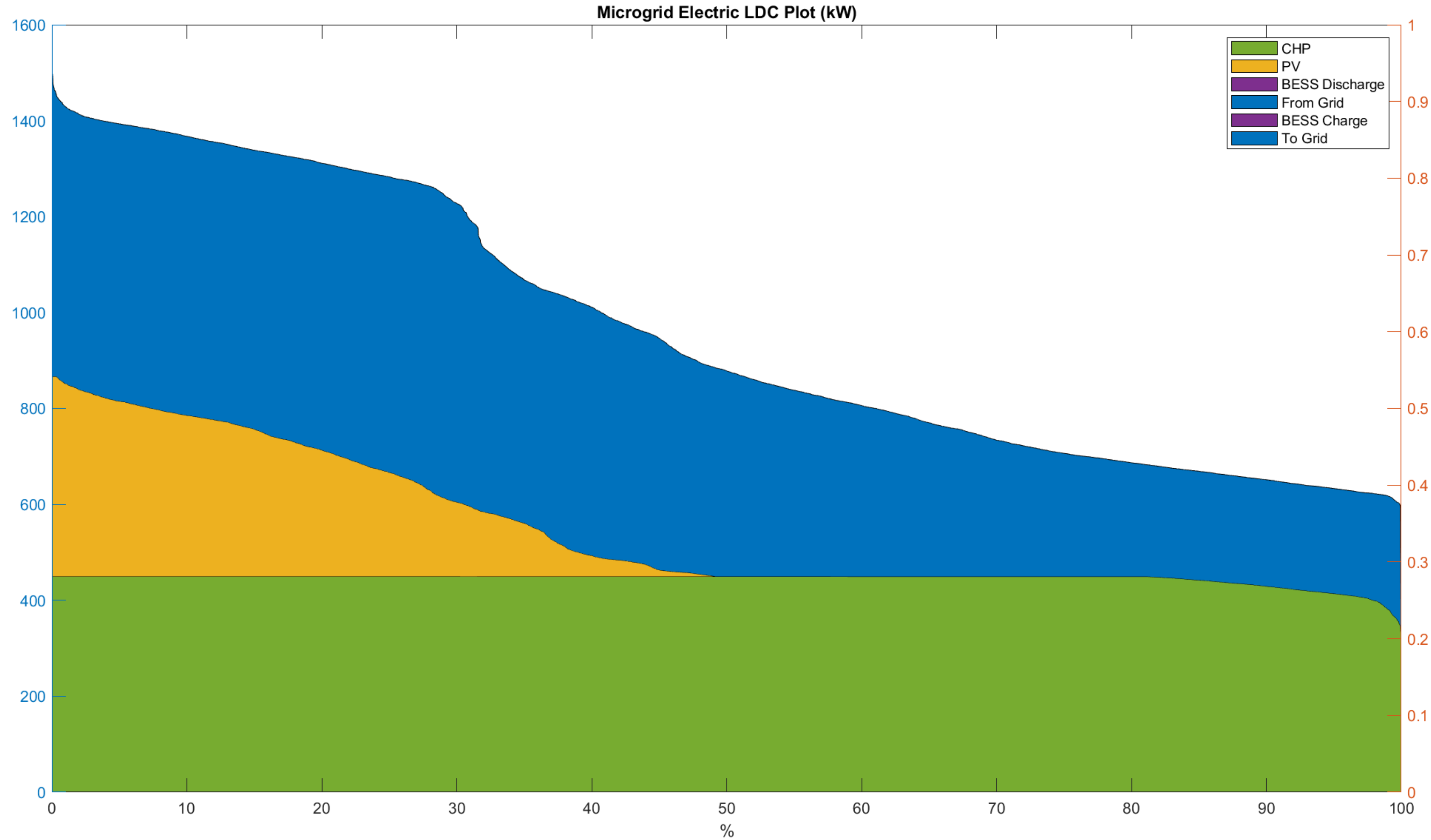


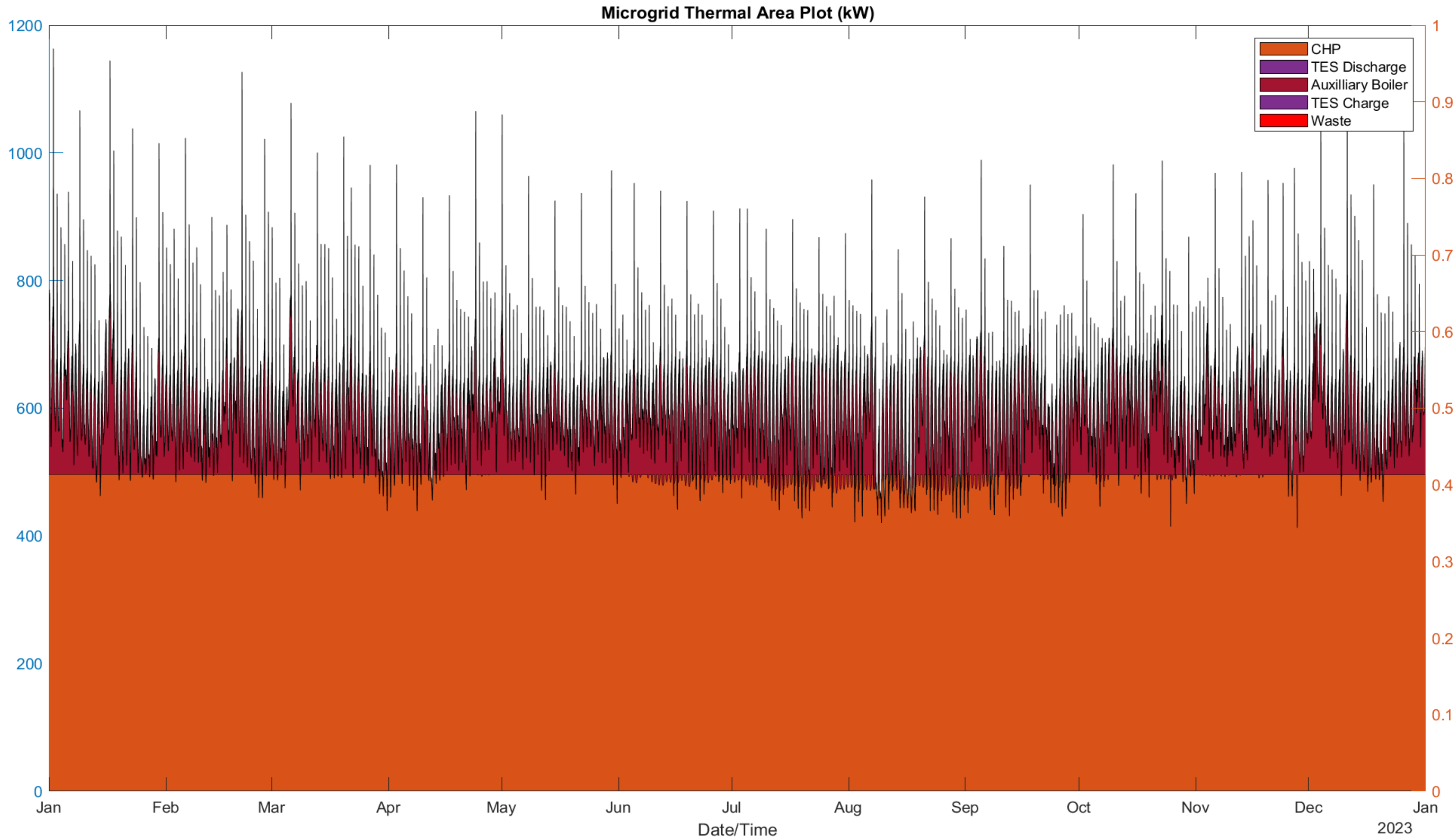
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Before Tax Cash Flow	($1,225,	$129,920	$124,210	$134,570	$136,920	$139,290	$133,160	$144,070	$146,480	$148,910	$142,320	$153,810	$156,280	$158,770	$151,700	$163,790	$166,330	$168,870	$161,270	$174,000	$176,590
Cash Flow After Tax	($1,225,	$940,730	$222,680	$177,530	$155,630	$157,050	$102,870	$103,890	$105,260	$106,620	$100,910	$109,260	$110,550	$111,810	$105,570	$114,240	$115,400	$116,530	$109,690	$118,650	$119,640

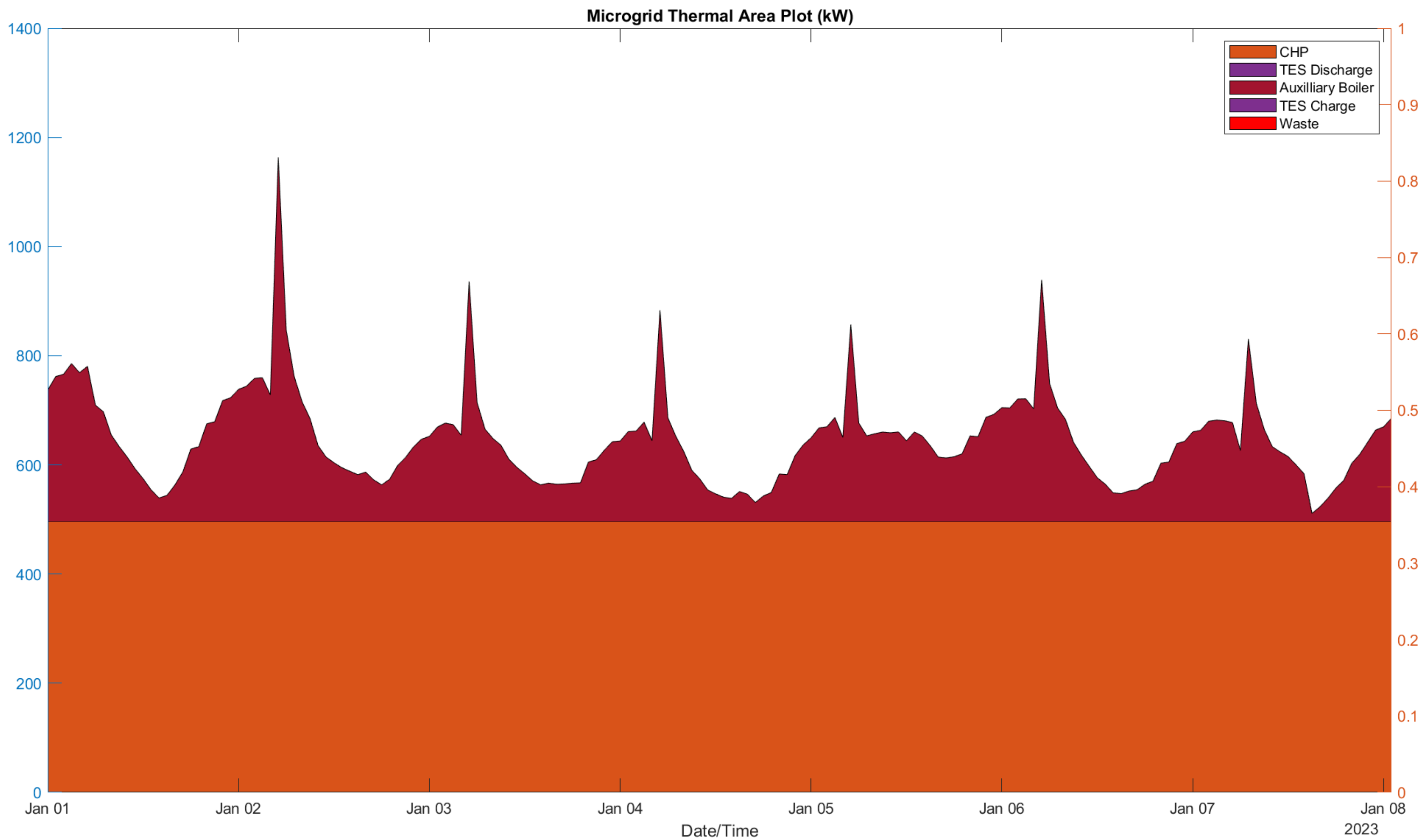
CogenS RNG CHP & Solar Microgrid Energy Plot Samples for California Hospital

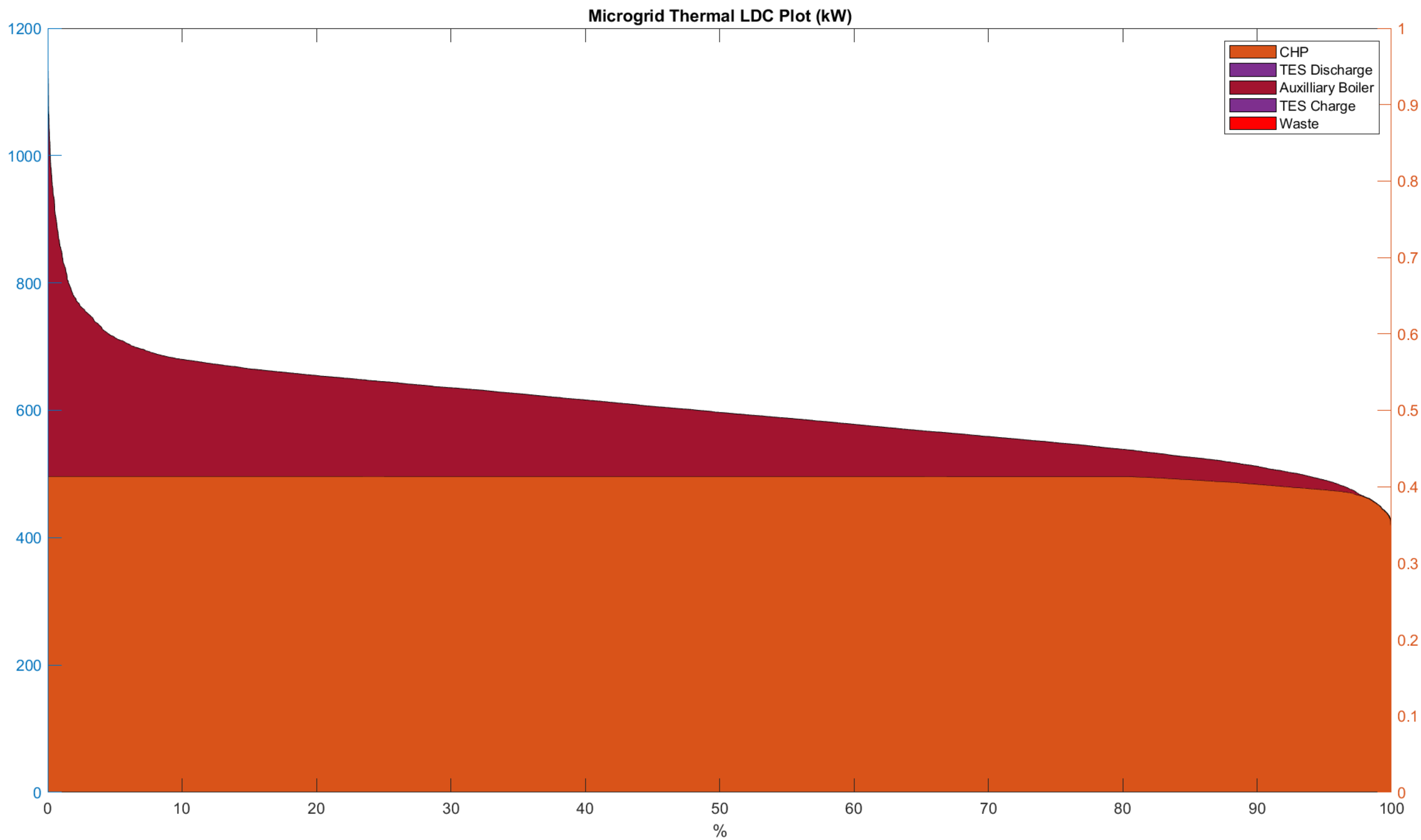



Microgrid Electric Area Plot (kW)
CHP
PV
BESS Discharge
From Grid
BESS Charge
To Grid
1500
1000
500
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Aug 06
Aug 07
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
2023
Date/Time


Microgrid Electric LDC Plot (kW)
CHP
PV
BESS Discharge
From Grid
BESS Charge
To Grid
1600
1400
1200
1000
800
600
400
200
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
%


Microgrid Thermal Area Plot (kW)
CHP
TES Discharge
Auxilliary Boiler
TES Charge
Waste
0
200
400
600
800
1000
1200
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2023
Date/Time


Microgrid Thermal Area Plot (kW)
CHP
TES Discharge
Auxilliary Boiler
TES Charge
Waste
0
200
400
600
800
1000
1200
1400
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Jan 01
Jan 02
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 08
2023
Date/Time


Microgrid Thermal LDC Plot (kW)
CHP
TES Discharge
Auxilliary Boiler
TES Charge
Waste
1200
1000
800
600
400
200
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
%