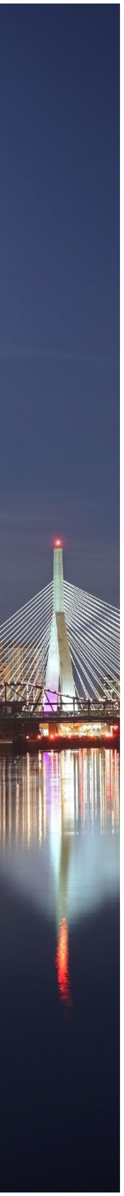

LEADING THE WAY
CampusEnergy2022
Feb. 15-18 | Westin Boston Seaport District Hotel | Boston, Mass.
INTERNATIONAL
DISTRICT ENERGY
ASSOCIATION



CHP Operation Where Resiliency, Carbon, and Cost Intersect

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Massachusetts Institute of Technology

icetec

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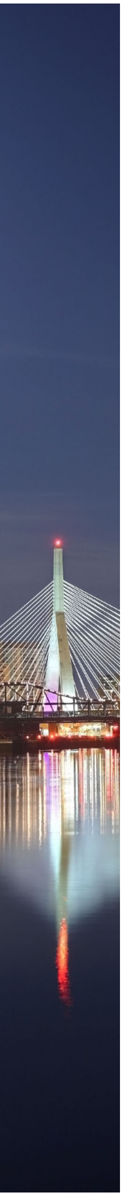
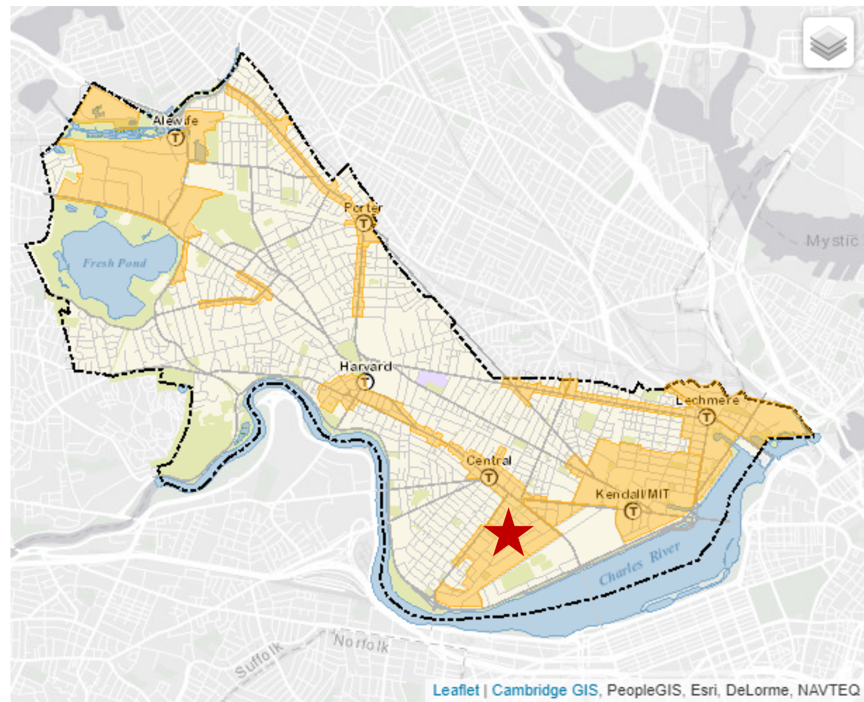


About MIT

- Located in **Cambridge, MA**
- Student population **11,000+** (undergraduate and graduate)
- **12,000+** faculty and staff
- Spans **168 acres**
- **190 buildings** and **13 million** gross square feet of building space
- **5** schools + **1** college



Source: Cambridge CDD Locator Map

SEEN

190 buildings
7.3M GSF academics & research
3.5M GSF residential
2.2M GSF service

1.8 million gross square feet
of new construction since 2011

U.S. GREEN BUILDING COUNCIL USGBC

24+ LEED-certified projects
with all new construction and major renovation projects required to earn LEED Gold

UNSEEN

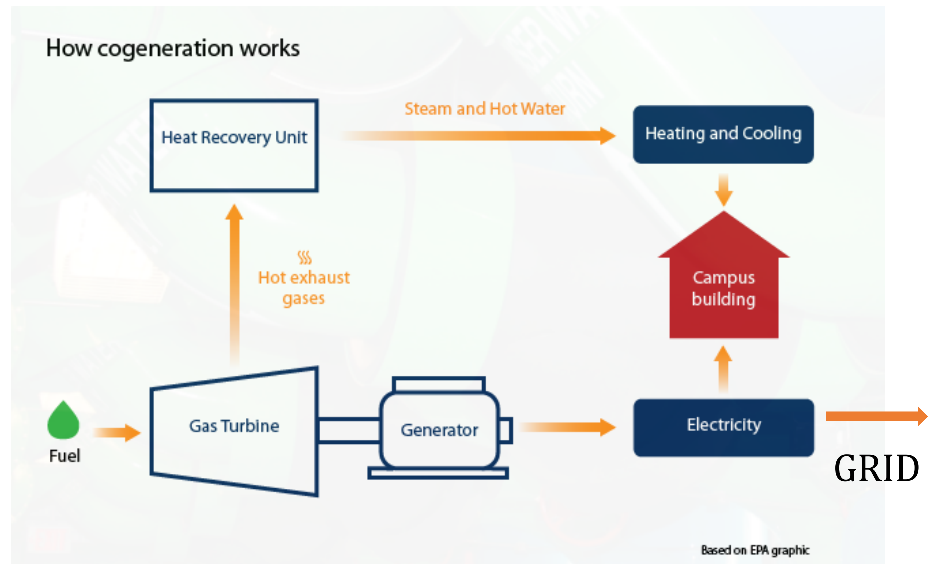
16.5 miles
of district energy infrastructure

21% less GHG emissions
since 2014

300+ energy efficiency projects
Significant cost and emissions benefits since 2010

MIT’s District Energy System

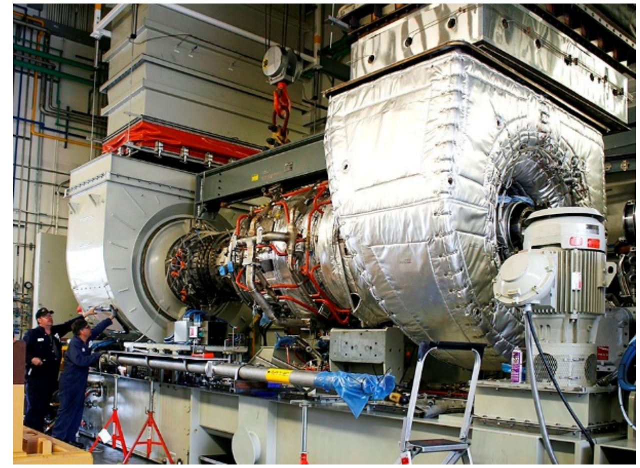
- Central Utilities Plant (CUP) serves campus electrical, heating, and cooling needs
  - Peak electrical ~38MW
  - Peak steam load ~365 kpph
  - Peak chilled water load ~26,000 tons
- Ability to export to grid when excess power produced (rarely)

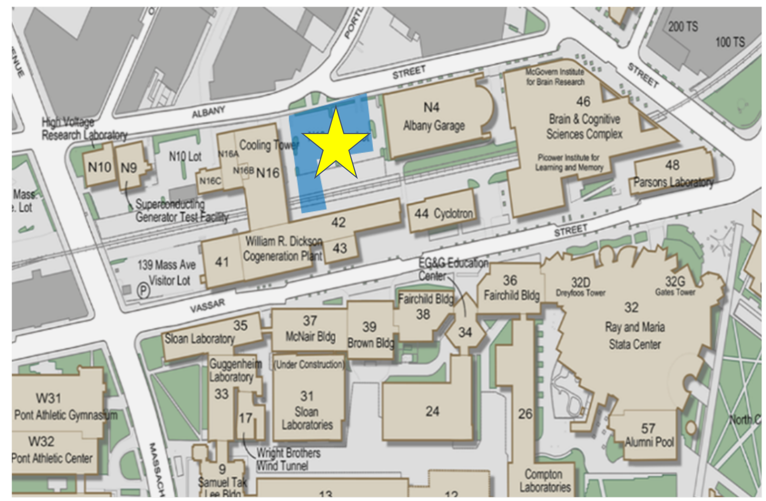


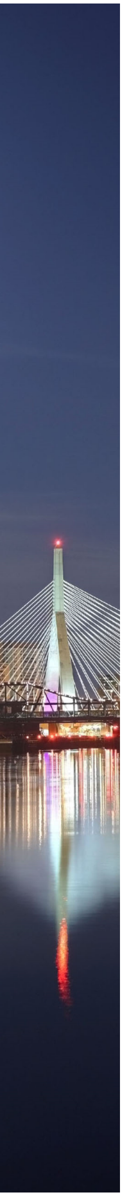
Source: EPA

MIT CUP Expansion

- Construction commenced in 2017;
  new plant fully operational Dec. 2021
- Replace 20+ year turbine + add second turbine:
  - Two 22-MW combustion turbines
  - Two HRSG boilers
- Additional upgrades included:
  - New condensing economizer
  - New emergency engine
  - Chilled water plant upgrades
  - Fuel transition
  - Boiler modernization

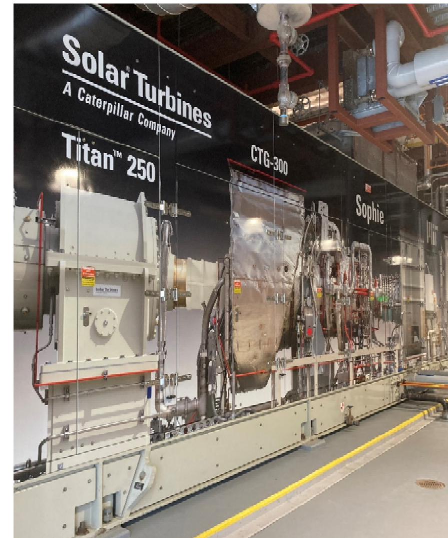


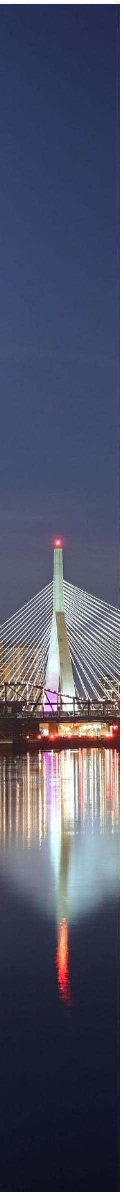




MIT’s “Bridge to Future”

- Upgrades provide increased capacity and resiliency, utilizing clean energy solution
- Operation is now carbon/resiliency driven
- **<u>Benefits</u>**
  - Reduce regulated pollutant & GHG emissions
    - 68,000 metric tons CO_2 emissions avoided since 1995
    - 25% reduction in pollutant emissions (2014 baseline)
  - Ability to export clean power to grid
  - Eliminate operation on oil except for testing emergencies
  - Flexible system to incorporate emerging technologies

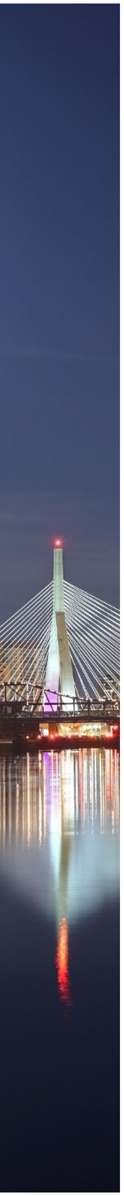




Objectives

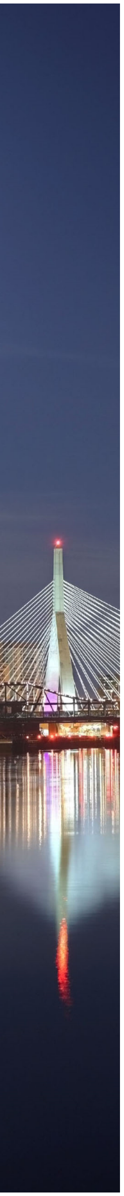
<u>Identify</u>

- How long will the CUP outperform the local grid’s annual GHG metrics?
- How can the CUP provide a benefit to the local grid?
- With rising utility costs, can we see both the utility savings and GHG savings?
- How is resiliency impacted if we prioritize utility costs and GHG reductions?



Operating Principles and Dispatch Priorities

Retired 20MW	Upgraded 40MW
Resiliency	Carbon Reduction
Efficiency	Resiliency
Market Economics	Efficiency
	Market Economics



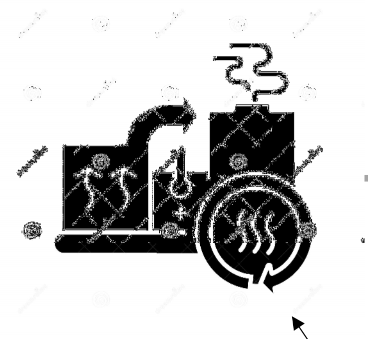
High-Level Dispatch Goals

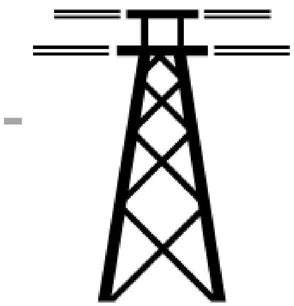
- Optimize thermal load requirements for efficiency
- Coordinate chiller plant dispatch with cogeneration operation
- Carbon optimization for the thermal and power loads
- Market participation primarily ahead of the meter
- Carbon for load to serve the campus is valued at the cogeneration carbon rate at the time
- Utility power for the campus is valued at the grid average rate at the time
- Carbon for market dispatch and export or injection is valued at the difference between cogeneration carbon rate and the marginal carbon rate at the time

Serving Campus / Exporting to Grid

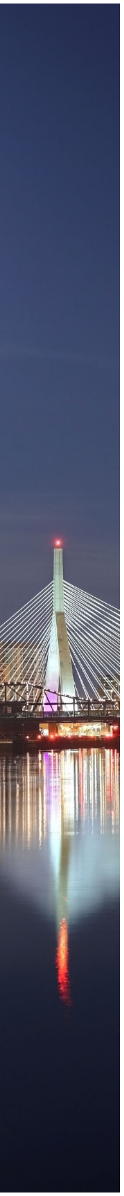
Carbon accounting for serving campus load accounted for

Carbon implications for exporting MWh to grid during high grid carbon under discussion





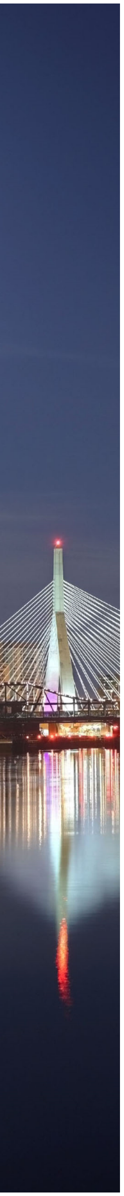
*Common scenario for microgrids designed for resiliency, sized for peak power loads – ability to inject in shoulder/winter months



Real Operational Scenarios

- **Study 1:** One GT online at full load, 20MW with duct burners
- **Study 2:** Two GTs online at 10MW per unit with duct burners
- **Study 3:** Two GTs online at 20MW per unit with duct burners and exporting power

	Study 1	Study 2	Study 3
Carbon	**	*	***
Resiliency	*	**	***
Cost Benefits	**	*	***



Calculating Grid Carbon Intensity

ISO New England Operating Parameters:

- Evaluates demand on grid every 5 minutes
- Matches grid demand by choosing lowest cost resources available to operate
- Resources are placed into supply stacks that are called upon to operate when needed
- Stack that is "next in line" to be called upon is referred to as the ***marginal resource***
- Marginal resource sets price of electricity for every 5-minute interval

Average Grid Emission Rate

$$\frac{Annual\ Grid\ Emissions}{Total\ MWH\ Consumed\ (Grid)}$$

*Adoption of renewables does not directly displace fossil fuel burning resources, particularly in periods of higher demand.

Time-Weighted Average Marginal Grid Emission Rate

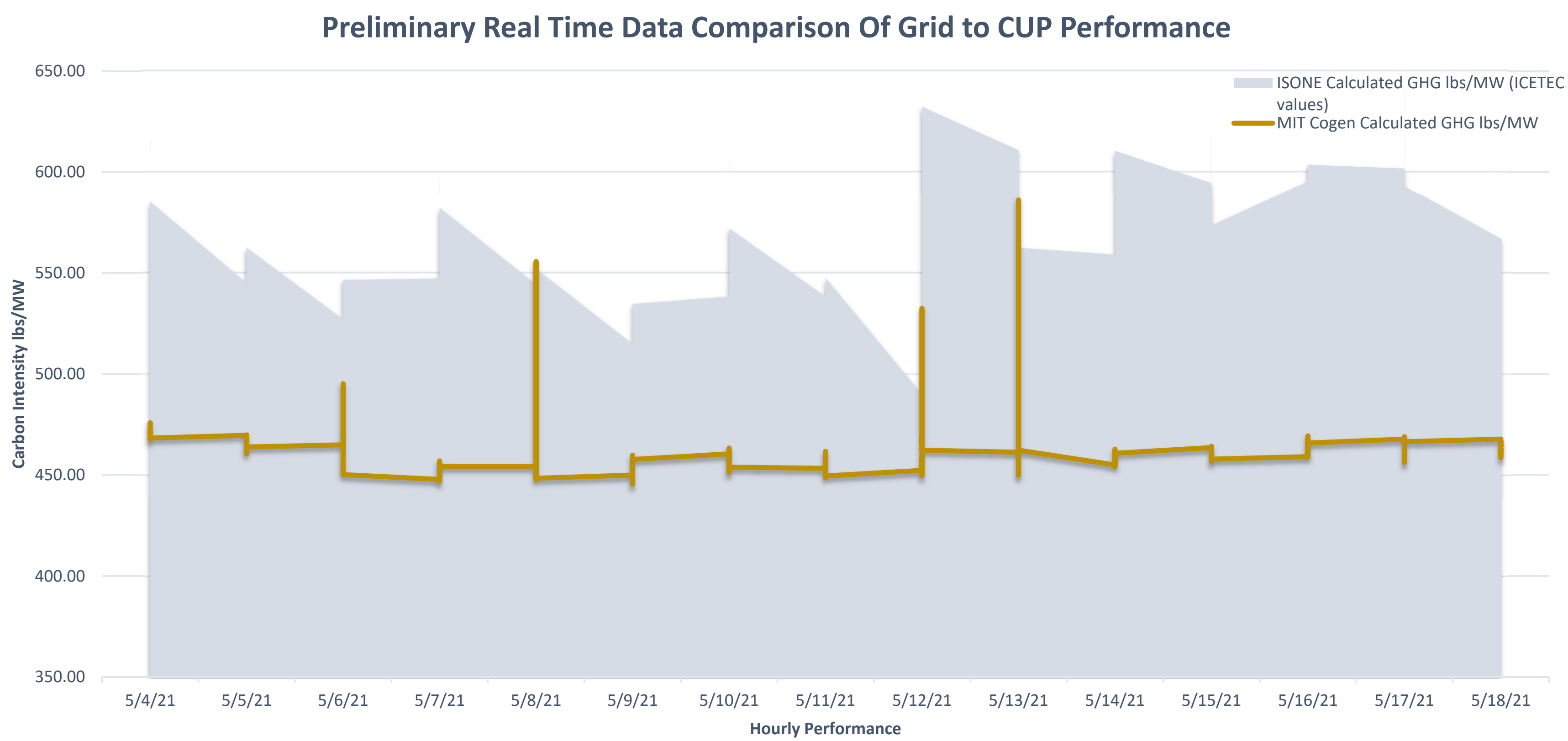
Annual average emission rates from marginal units over a certain time period when load is assumed to be split evenly amongst all operating units (i.e., % of hour marginal).

Load-Weighted Average Marginal Grid Emission Rate

Annual average emissions rates from marginal units on calendar year basis. Method weighs marginal emission rate by ***share of load*** served by that marginal resource.

As the grid approaches decarbonization, the methodology for evaluating the grid's carbon intensity will evolve to consider the grid's carbon health during marginal periods of operation (historically more carbon-intensive).

Initial Operating Data – GHG Performance



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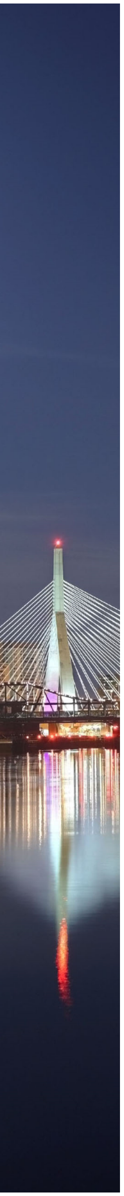
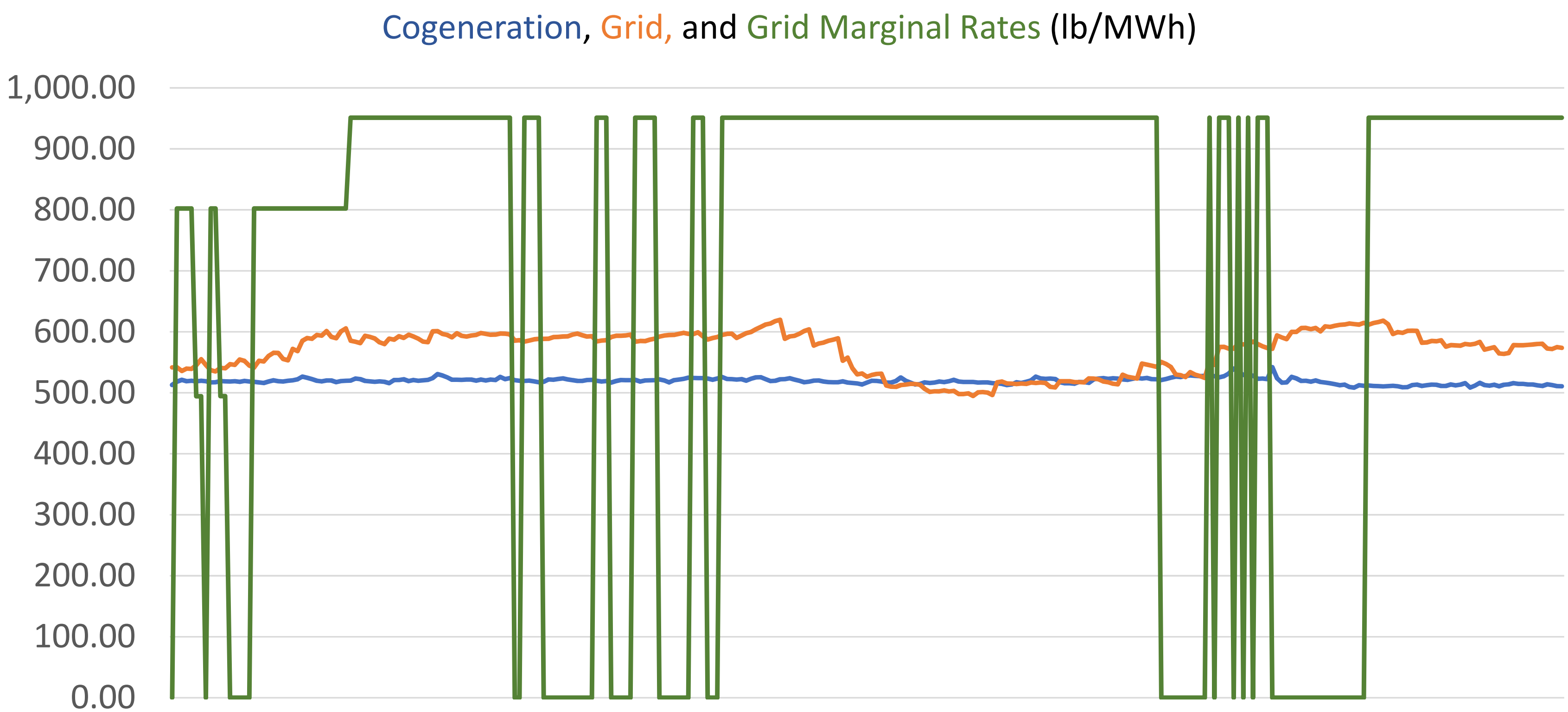
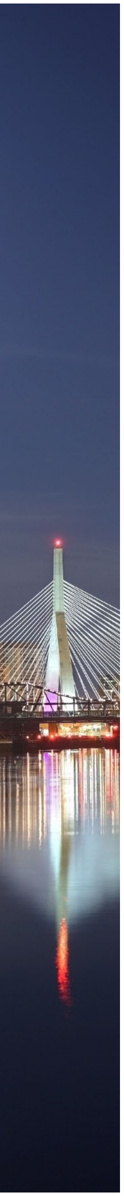
Exporting Operation - GHG Evaluation





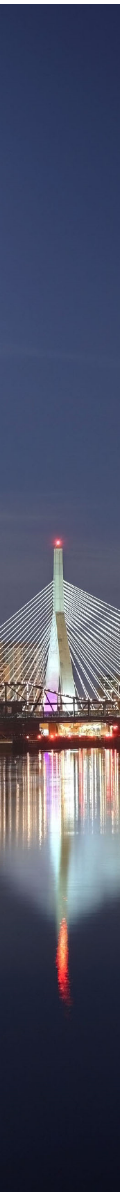
12/14/21 – 12/15/21 Real Time Trends

Exporting Operation - GHG Evaluation



Timestamp	HR	Total_Generation	Cogen_co2_lbs	Generated for site	Carbon for Site Load	Utility_Export MW	Carbon for Expoer	Export Net Carbon	Cogen Carbon w/Export
2021-12-14 17:00:00	17	24.00	12,441.91	24.00	12,441.91	0.00	0.00	0.00	12,441.91
2021-12-14 18:00:00	18	24.01	12,496.53	24.01	12,496.53	0.00	0.00	0.00	12,496.53
2021-12-14 19:00:00	19	24.53	12,835.06	24.53	12,434.45	0.00	400.61	400.61	12,835.06
2021-12-14 20:00:00	20	24.72	12,871.74	24.18	12,275.41	0.54	596.33	-491.88	11,783.53
2021-12-14 21:00:00	21	24.70	12,950.90	23.94	12,216.72	0.76	734.18	-597.55	11,619.18
2021-12-14 22:00:00	22	24.70	12,931.74	23.64	11,997.54	1.06	934.19	-764.71	11,232.84
2021-12-14 23:00:00	23	24.97	13,429.36	23.65	11,939.11	1.32	1,490.25	-1,244.54	10,694.57
2021-12-15 00:00:00	0	35.08	20,777.65	27.39	11,690.11	7.69	9,087.54	-7,636.07	4,054.04
2021-12-15 01:00:00	1	40.20	20,790.26	27.88	11,634.03	12.32	9,156.24	-7,688.18	3,945.85
2021-12-15 02:00:00	2	40.20	20,800.19	27.77	11,492.91	12.43	9,307.28	-7,811.09	3,681.82
2021-12-15 03:00:00	3	40.20	21,050.33	27.58	11,550.01	12.62	9,500.32	-7,760.74	3,789.27
2021-12-15 04:00:00	4	40.20	21,043.41	27.53	11,528.86	12.67	9,514.55	-7,775.04	3,753.82
2021-12-15 05:00:00	5	31.30	13,378.62	23.52	11,284.34	7.78	2,094.28	-1,721.12	9,563.23
2021-12-15 06:00:00	6	21.93	11,428.90	21.93	11,428.90	0.00	0.00	0.00	11,428.90
2021-12-15 07:00:00	7	21.69	11,725.74	21.69	11,725.74	0.00	0.00	0.00	11,725.74
2021-12-15 08:00:00	8	21.69	11,049.89	21.69	11,049.89	0.00	0.00	0.00	11,049.89
2021-12-15 09:00:00	9	22.14	11,468.89	22.14	11,468.89	0.00	0.00	0.00	11,468.89
2021-12-15 10:00:00	10	22.84	11,754.09	22.84	11,754.09	0.00	0.00	0.00	11,754.09
2021-12-15 11:00:00	11	23.36	12,051.62	23.36	12,051.62	0.00	0.00	0.00	12,051.62
2021-12-15 12:00:00	12	23.58	12,042.34	23.58	12,042.34	0.00	0.00	0.00	12,042.34
2021-12-15 13:00:00	13	23.42	11,944.92	23.42	11,944.92	0.00	0.00	0.00	11,944.92
2021-12-15 14:00:00	14	23.66	11,957.23	23.66	11,957.23	0.00	0.00	0.00	11,957.23
2021-12-15 15:00:00	15	23.59	12,028.42	23.59	12,028.42	0.00	0.00	0.00	12,028.42
2021-12-15 16:00:00	16	23.49	12,015.26	23.49	12,015.26	0.00	0.00	0.00	12,015.26
Totals		**650.20**	**337,265.02**	**581.01**	**284,449.25**	**69.19**	**52,815.77**	**-43,090.29**	**241,358.96**

12/14/21 – 12/15/21 Dispatch Example



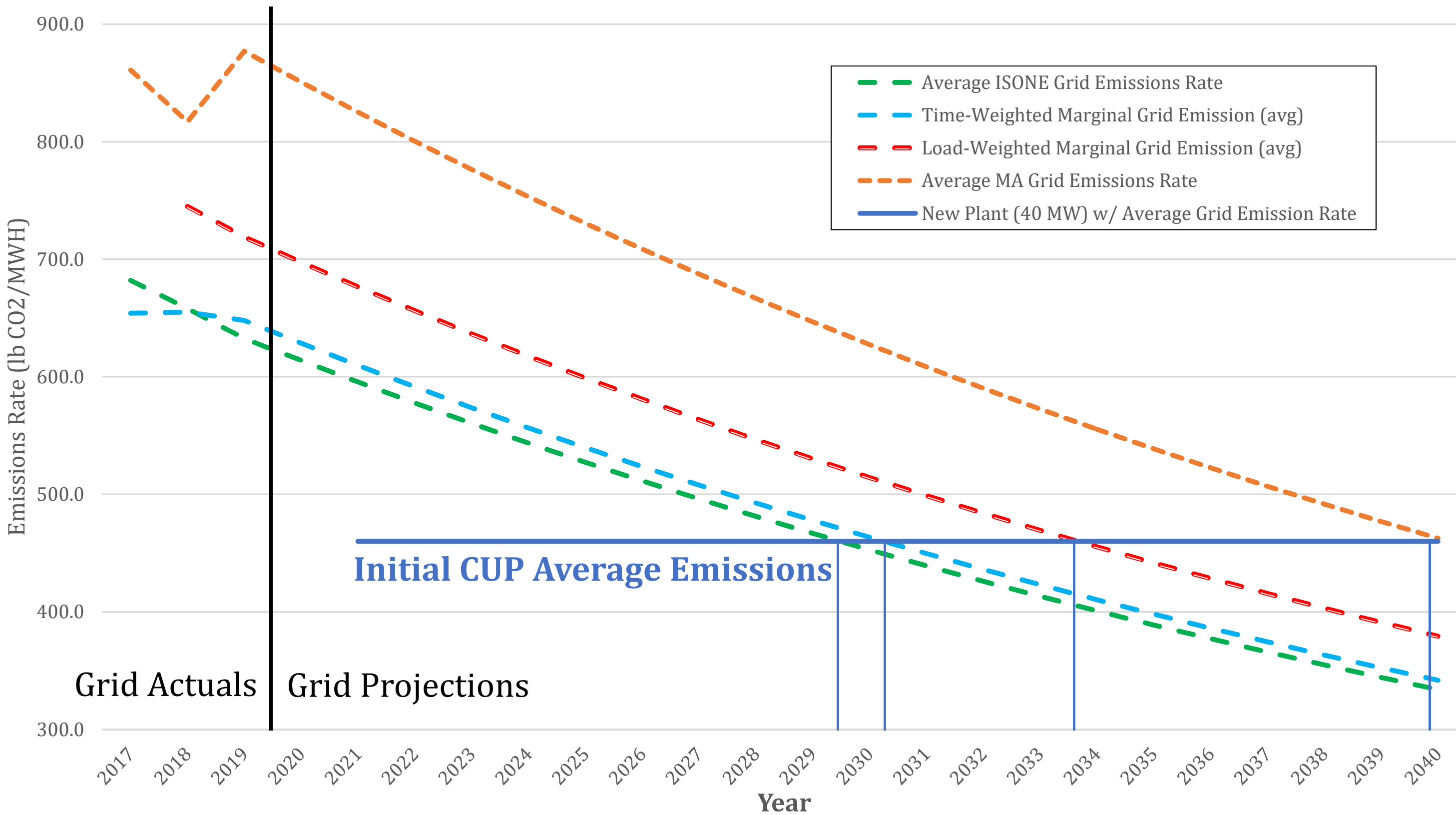
Exporting Operation - GHG Evaluation

Total Generation	mW	650.20
Total Carbon For Generation	Lbs	337,265.02
Generated for Site	mW	581.01
Cogeneration Carbon For Site	Lbs	284,449.25
Export Power	mW	69.19
Cogeneration Carbon For Export	Lbs	52,815.77
Net Export Cargon	Lbs	-43,090.29
Site Plus Export Carbon	Lbs	241,358.96

Net Export Carbon is equal to Cogeneration Carbon for Export minus Export Power times marginal rate

12/14/21 – 12/15/21 Dispatch Example

ISO NE Grid Emissions Projections



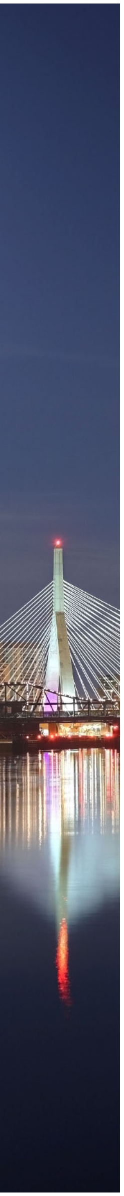
TODAY
CUP ~457 lbs CO2/MWH
Grid ~600 lbs CO2/MWH

Avg ISONE Grid
Grid ↔ CUP ~2030

Time-Weighted Methodology
Grid ↔ CUP ~2030+

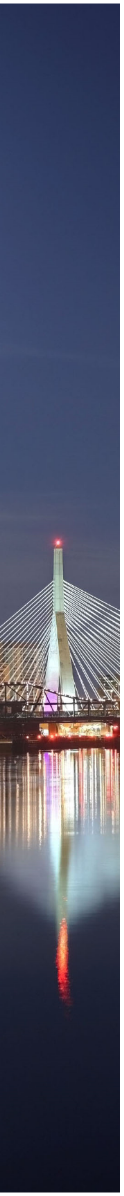
Load-Weighted Methodology
Grid ↔ CUP ~2034+

Avg MA Grid
Grid ↔ CUP ~2040+



Looking to the Future: Additional Considerations

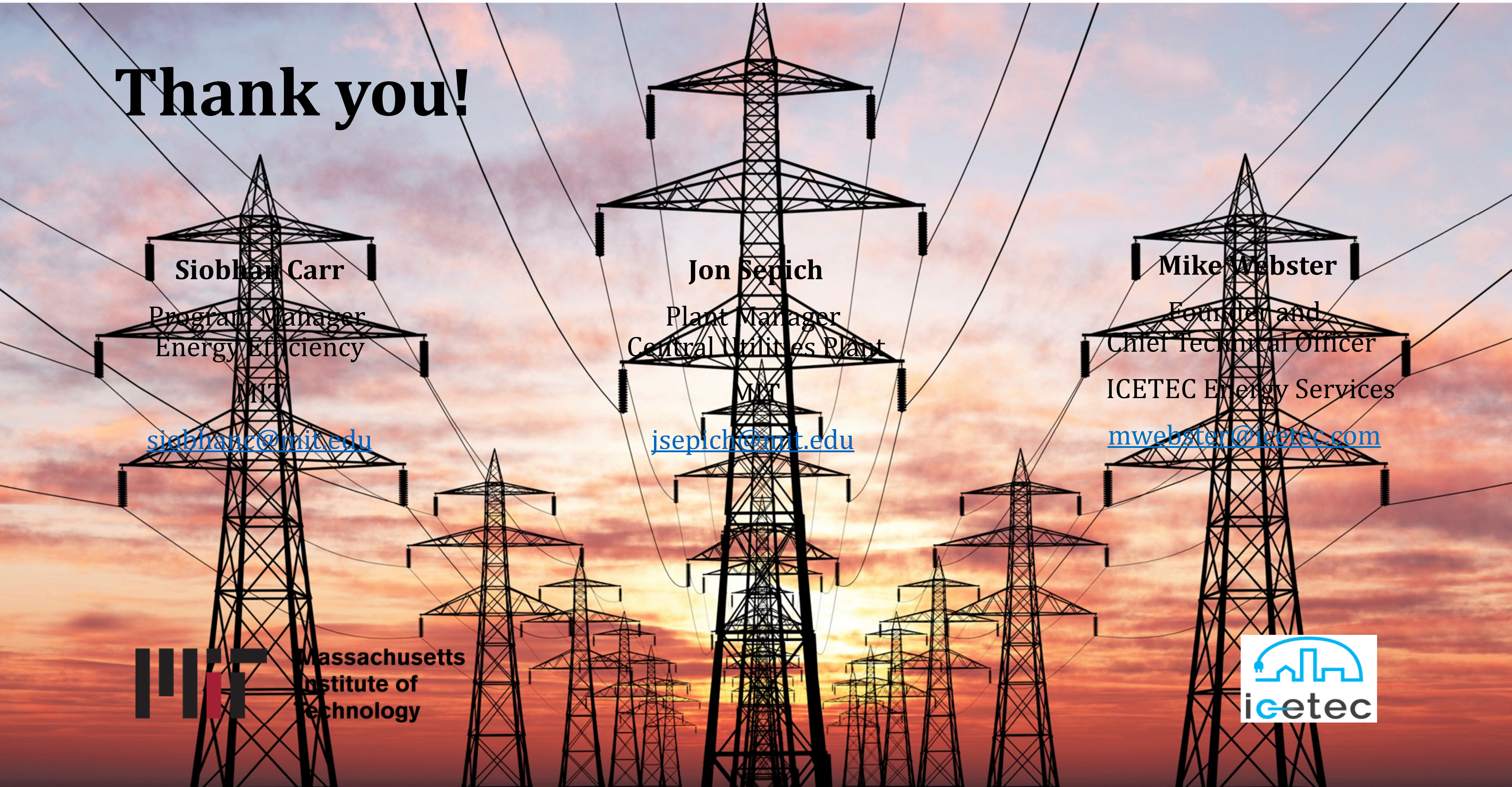
- How will climate change events affect the plant’s resiliency/contingency for the campus?
- How do the conversations regarding electrification affect the plant's operation?
- How can we begin to think about incorporating MIT-based gateway technologies (MIT Research – Micro Turbine, Magnetic Fusion Reactors…)?



High-Level Conclusions

- Based on current understanding and assuming a 3% reduction per year, we anticipate that the CUP will outperform the grid's average emissions for the next 7-8 years. However, there are a lot of factors, and we will have to monitor the situation yearly.
- During peak demand times, the CUP can help offset the marginal unit, which is typically more GHG-intensive.
- Currently, the market costs and GHG values are aligned.
- If done appropriately, we can optimize costs and GHG without compromising resiliency for the campus.

Questions?



Thank you!

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