CHP Technology Roadmapping and Modeling

DRAFT findings and recommendations from

Michigan Energy Office CHP Roadmap Project

Modeling to inform Roadmap

- In second year of Michigan Energy Office CHP Roadmap project
- 5 Lakes Energy's project partners include:
  - Sustainable Partners LLC
  - NextEnergy
  - Energy Resources Center of University of Illinois at Chicago
- Using modeling to inform development of roadmap for optimized CHP deployment in Michigan
- Technology taxonomy and modeling results may have implications for IRP guidance by MPSC to utilities

CHP Technology Roadmap

- A technology roadmap is a plan that matches short-term and long-term market goals, such as the widespread deployment of cost-effective CHP systems in Michigan, with specific technology solutions to help meet those goals.

State Tool for Electricity Emissions Reduction (STEER) Model

- In order to give state lawmakers, regulators, and stakeholders the ability to evaluate competing energy resources (such as in an IRP process), 5 Lakes Energy, working with researchers at the University of Michigan, previously developed the STEER model with funding from the Energy Foundation and Advanced Energy Economy Institute.
- The principal purpose of the STEER model is to facilitate stakeholder access to data and integrated resource planning analysis.

State Tool for Electricity Emissions Reduction (STEER) Model

- The STEER model automatically calculates the least-cost compliance and implementation strategies, along with cost to users, given certain policy options and forecasts of electricity demand, fuel prices, and technology costs and performance.
- All data, inputs, and formulae are visible to and changeable by the user.
- The Michigan version of the STEER model is available for download online.

State Tool for Electricity Emissions Reduction (STEER) Model

- STEER can dynamically model Michigan's electricity system on an hourly basis by dispatching resource options based on lowest marginal cost, and has the advantage of representing a range of supply-side and demand-side resource options at the level of individual units.
- This provides a rigorous capability to screen and quantify CHP potential in Michigan.

EIA Data

- STEER is populated with U.S. Energy Information Administration (EIA) data of Michigan's existing portfolio of power plants and various modules of fossil-fueled and renewable generating units that can be deployed as needed to meet hourly energy and capacity requirements out to the year 2030.
- Modifications were made to include an expanded, more detailed suite of CHP prime mover technologies, system sizes, and operating characteristics.

U.S. EPA's "Catalog of CHP Technologies"

- STEER modifications required the establishment of criteria to evaluate prime mover technologies for the suite of CHP options.
- According to the U.S. EPA's "Catalog of CHP Technologies" published in March 2015, 97% of CHP projects installed in the U.S. and 99% of total installed CHP capacity are comprised of reciprocating engines, combustion turbines, microturbines, steam turbines and fuel cells.

http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf

Prime Mover Technologies

The project team limited its focus to these five technologies:

- Reciprocating engines
- Combustion turbines
- Microturbines
- Steam turbines
- Fuel cells

Goals

Project partners identified and evaluated CHP technologies and applications as a prelude to modifying the STEER model in order to achieve the following goals:

- Quantify Michigan CHP technical potential by prime mover type;
- Quantify industry average cost and performance data for each prime mover type;
- Extrapolate these data to Michigan prime mover technical potential.

Technical Potential

- The U.S. DOE's report "Combined Heat and Power (CHP) Technical Potential in the United States" published in March 2016, defines technical potential as "an estimation of market size constrained only by technological limits – the ability of CHP technologies to fit customer energy needs without regard to economic or market factors."

http://energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf

Upper Boundary

- Technical potential provides a valid upper boundary of CHP deployment in Michigan, with actual deployment levels being lower due to a number of factors that can be represented as inputs to the STEER model that act to constrain deployment below technical potential.

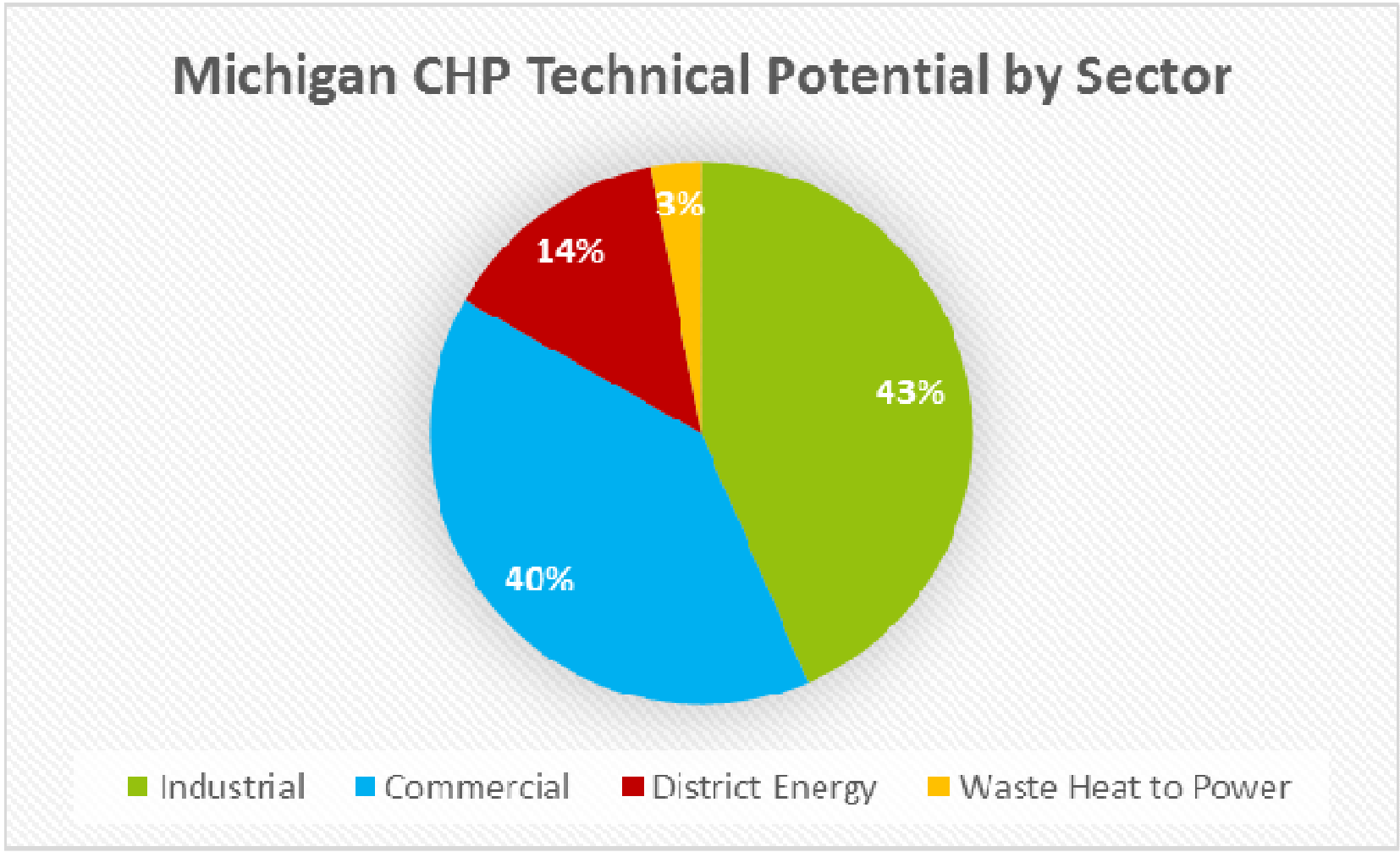
http://energy.gov/sites/prod/files/2016/04/f30/CHP%20Technical%20Potential%20Study%203-31-2016%20Final.pdf

Michigan's Technical Potential

- According to the DOE report, Michigan has nearly 5 GW of CHP technical potential across more than 10,000 sites, as depicted in Figure 3.
- There are 2.2 GW of industrial on-site CHP potential primarily in the transportation equipment, chemicals, primary metals, paper, and food sectors.
- Another 2.0 GW of commercial CHP technical potential exists primarily at commercial office buildings, colleges and universities, hospitals, retail locations, and multifamily housing sectors.

Michigan's Technical Potential

- Michigan also has 700 MW of CHP potential deployment at 2 district energy sites and 150 MW of waste heat to power (WHP) potential identified at 36 sites primarily in the oil and gas extraction, refining, stone/clay/glass, and primary metals sectors.


Michigan CHP Technical Potential by Sector
3%
14%
43%
40%
Industrial
Commercial
District Energy
Waste Heat to Power

Technical Potential - capacity

- Beyond commercial and industrial business types, the DOE database also quantifies the technical CHP potential in Michigan, by number of sites and capacity potential, according to annual operating hours (7,500 hours/full-time versus 4,500 hours/part-time) and project size classification (50 to 500 kW, 500 kW to 1 MW, 1 MW to 5 MW, 5 MW to 20 MW, and 20+ MW).

Differentiating Prime Mover Types

- For STEER customization, the DOE's CHP technical potential data for Michigan needed to be broken down one level further, from the total number of CHP sites and capacity (per project size range), to differentiate among the five prime mover types. To complete this task, the project team relied on:
  - CHP cost and performance data from the EPA catalog for the prime movers across the spectrum of available capacities;
  - Project members' collective experience with public and private-sector CHP projects;
  - Various assumptions about the future of the market and pricing trends.

Prime Mover Technologies by System Capacity

Capacity	Fuel Cell	Microturbine	Reciprocating Engine	Combustion Turbine	Steam Turbine
50 kW – 500 KW	X	X	X		
500 kW – 1 MW		X	X		
1 MW – 5 MW		X	X	X	
5 MW – 20 MW			X	X	X
> 20 MW				X	X

EPA Technology and System Size Combinations

In their “Catalog of CHP Technologies”, the EPA compiled cost and performance data for twenty-four CHP technology and size combinations as indicated here:

Prime Mover Technology	System Sizes (kW)	EPA Catalog Reference
Fuel Cell	0.7, 1.5, 300, 400, 1400	Table 6-3
Microturbine	30, 65, 200, 250, 333, 1000	Table 5-2
Reciprocating Engine	100, 633, 1121, 3326, 9341	Table 2-2
Combustion Turbine	3510, 7520, 10680, 21730, 45607	Table 3-5
Steam Turbine	500, 3000, 15000	Table 4-2

Cost and Performance Data

- Project partners extrapolated, via simple regression modeling, the cost and performance data for the EPA's 24 technology/size combinations to include 33 additional technology/size combinations, which reflect average system sizes determined by allocating prime movers to Michigan technical potential.
- The following table lists all 57 resource options that are now available in the STEER model's CHP suite. The extrapolated data in combination with the EPA provided data provide the basis for technical analysis of CHP in the STEER model.

STEER Model CHP Suite

Prime Mover Technology	System Sizes (kW)
Fuel Cell	0.7, 1.5, 78, 124, 179, 300, 400, 1400
Microturbine	30, 65, 78, 124, 179, 200, 250, 333, 427, 597, 710, 1000, 1083
Reciprocating Engine	78, 100, 124, 179, 427, 597, 633, 710, 1083, 1121, 1800, 2093, 3326, 8000, 8758, 9341
Combustion Turbine	2093, 3510, 5000, 7520, 8000, 8758, 10680, 21730, 31000, 35867, 45607
Steam Turbine	500, 3000, 8000, 8758, 9091, 15000, 25000, 31000, 35867

Modeling CHP Costs

- Since STEER is a model of the electrical system and CHP provides heat-related benefits to the site host, we assumed that CHP systems will be sized to meet host thermal requirements.
- We used the incremental capital and fuel costs associated with adding electricity production as the costs of CHP generation of electricity.
- The required capital and fuel costs for production of heat presumably would occur anyway, so they are appropriately excluded from the analysis of optimum CHP deployment.

Modeling CHP with STEER

- This modified version of STEER containing these 57 CHP options can now identify which CHP configurations are economically viable across a wide variety of scenarios, narrowing the scope of Michigan's technical potential to only include those projects that should be implemented based on financial expectations and Michigan's overall electricity generation portfolio.

Results

- Using the EIA Reference Case for fuel prices and allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment B**. In this scenario, steam turbines of any size, combustion turbines larger than 20 MW capacity, and reciprocating engines larger than 3 MW capacity are profitable. Michigan technical potential for these CHP technologies totals 1.014 GW.

Name	Technical Potential	Variable O&M ($/MWh)	Fuel ($/MMBtu)	Electric Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor If Built	Capital Recovery Rev Req ($/MWh)	Marginal LMP ($/MWh) If Built	Value of Capacity ($/MWh) If Built	Unmet Rev Req ($/MWh) If Built	Cost to Mitigate ($/t)	Carbon Mitigated (t/yr)	Rank	Built?
Cogen_ST_8758	54.300	8.00	5.48	4.45	32.38	69.8%	8.72	51.35	18.31	-28.56	-70.01	135382	1	1
Cogen_ST_8000	56.000	8.00	5.48	4.45	32.38	70.1%	8.67	51.24	18.22	-28.41	-68.85	141858	2	1
Cogen_ST_3000	0.000	9.00	5.48	4.54	33.90	69.3%	8.82	51.46	18.42	-27.16	-68.34	7242	3	1
Cogen_ST_9091	100.000	8.00	5.48	4.45	32.38	70.4%	8.63	51.04	18.13	-28.16	-67.24	258420	4	1
Cogen_ST_15000	0.000	6.00	5.48	4.44	30.34	72.7%	8.27	50.54	17.56	-29.49	-67.07	42016	5	1
Cogen_ST_31000	0.000	6.00	5.48	4.44	30.31	73.0%	8.22	50.34	17.49	-29.29	-65.94	88121	6	1
Cogen_ST_25000	0.000	6.00	5.48	4.44	30.31	73.5%	8.18	50.34	17.38	-29.23	-65.79	71513	7	1
Cogen_ST_35867	134.500	6.00	5.48	4.44	30.31	74.3%	8.08	49.92	17.18	-28.72	-63.38	396757	8	1
Cogen_ST_500	0.000	10.00	5.48	4.54	34.87	69.3%	14.83	51.46	18.42	-20.18	-50.75	1208	9	1
Cogen_CT_45607	0.000	9.20	5.48	5.59	39.86	63.3%	19.21	53.13	20.17	-14.23	-43.91	79969	10	1
Cogen_RE_9341	0.000	8.50	5.48	4.63	33.85	75.3%	18.92	51.41	16.97	-15.61	-39.51	24339	11	1
Cogen_CT_35867	377.273	9.30	5.48	5.55	39.69	66.6%	20.10	52.19	19.17	-11.57	-35.59	715771	12	1
Cogen_CT_31000	0.000	9.30	5.48	5.55	39.69	68.1%	19.76	52.19	18.76	-11.49	-35.35	56190	13	1
Cogen_CT_21730	0.000	9.30	5.48	5.49	39.36	68.1%	20.46	52.17	18.74	-11.09	-33.77	39879	14	1
Cogen_RE_8758	244.350	12.00	5.48	4.57	37.07	73.8%	19.82	51.46	17.31	-11.88	-30.04	624721	15	0
Cogen_RE_8000	48.000	12.50	5.48	4.57	37.57	71.9%	20.81	52.02	17.77	-11.42	-29.93	115268	16	0
Cogen_RE_3326	0.000	16.00	5.48	4.45	40.36	66.4%	23.89	53.15	19.23	-8.12	-20.76	7573	17	0
Cogen_RE_2093	517.650	17.50	5.48	4.44	41.81	62.5%	32.00	53.15	20.42	0.24	0.61	1111311	18	0
Cogen_CT_10680	0.000	12.00	5.48	5.90	44.36	43.7%	43.21	57.88	29.20	0.49	1.55	12058	19	0
Cogen_RE_1800	54.000	18.00	5.48	4.44	42.34	58.2%	34.98	54.67	21.96	0.68	1.72	108446	20	0
Cogen_CT_7520	0.000	12.30	5.48	5.68	43.44	50.1%	38.74	56.08	25.47	0.64	1.96	10064	21	0
Cogen_CT_8758	228.467	12.20	5.48	5.79	43.93	48.3%	39.80	56.13	26.42	1.18	3.70	309089	22	0
Cogen_CT_8000	59.840	12.30	5.48	5.79	44.03	46.7%	41.54	56.89	27.34	1.34	4.17	78771	23	0
Cogen_RE_1121	0.000	19.00	5.48	4.45	43.40	52.1%	40.57	56.08	24.49	3.40	8.56	2036	24	0
Cogen_RE_1083	485.450	19.00	5.48	4.45	43.40	55.6%	38.10	54.85	22.96	3.69	9.35	932244	25	0
Cogen_RE_710	144.200	20.00	5.48	4.40	44.11	45.9%	57.01	57.08	27.82	16.22	40.20	233914	51	0
Cogen_MT_333	0.000	9.00	5.48	6.17	42.82	57.6%	47.29	54.85	22.17	13.09	44.59	474	52	0
Cogen_RE_633	0.000	21.00	5.48	4.40	45.12	43.7%	61.19	58.06	29.20	19.05	47.16	980	53	0
Cogen_RE_597	34.400	21.00	5.48	4.40	45.10	44.0%	60.93	57.91	29.01	19.11	47.25	53646	54	0
Cogen_CT_5000	0.000	12.40	5.48	6.36	47.25	39.3%	58.72	59.16	32.48	14.33	49.58	4655	55	0
Cogen_RE_427	345.150	22.00	5.48	4.40	46.10	42.3%	64.26	58.06	30.23	22.07	54.60	516484	56	0
Cogen_RE_179	137.550	23.00	5.48	4.41	47.17	40.7%	67.14	58.76	31.39	24.16	59.94	197587	57	0
Cogen_RE_124	110.800	23.50	5.48	4.34	47.30	39.0%	70.37	59.18	32.78	25.70	63.15	153875	58	0
Cogen_RE_100	0.000	24.00	5.48	4.27	47.38	39.1%	79.52	59.67	32.70	34.54	84.02	141	59	0
Cogen_MT_250	0.000	11.00	5.48	6.42	46.16	42.2%	67.19	58.76	30.30	24.29	84.95	253	60	0
Cogen_MT_427	176.558	11.00	5.48	6.68	47.61	37.3%	72.88	59.67	34.25	26.58	98.47	155700	61	0

Cogen_MT_65	0.000	13.00	5.48	5.99	45.85	44.6%	73.09	58.06	28.61	32.28	103.81	74	63	0
Cogen_MT_710	58.710	11.00	5.48	6.84	48.49	35.5%	76.28	60.84	36.02	27.92	107.49	47373	64	0
Cogen_CT_3510	0.000	12.60	5.48	6.81	49.94	31.2%	83.95	62.05	40.91	30.93	118.70	2355	65	0
Cogen_MT_1000	0.000	12.00	5.48	6.98	50.23	28.5%	92.10	63.55	44.84	33.95	133.60	602	66	0
Cogen_MT_1083	24.273	12.00	5.48	7.00	50.38	28.3%	92.56	63.66	45.17	34.10	135.10	15172	67	0
Cogen_RE_78	110.250	25.00	5.48	4.59	50.14	28.6%	112.14	63.14	44.71	54.43	138.11	108733	68	0
Cogen_MT_78	179.550	15.00	5.48	6.18	48.88	34.2%	95.46	60.92	37.36	46.05	154.38	160400	69	0
Cogen_CT_2093	85.412	13.00	5.48	7.17	52.32	23.7%	116.57	65.51	53.78	49.59	206.54	42659	70	0
Cogen_MT_124	131.575	15.00	5.48	6.48	50.54	26.7%	122.13	63.90	47.80	60.97	215.95	86952	71	0
Cogen_MT_179	128.059	15.00	5.48	6.73	51.87	25.1%	129.95	65.23	50.86	65.73	247.02	74965	72	0
Cogen_MT_200	0.000	16.00	5.48	6.99	54.32	23.6%	138.18	66.23	54.08	72.19	287.47	99	73	0
Cogen_MT_30	0.000	20.00	5.48	6.21	54.05	23.6%	175.34	66.23	54.08	109.08	367.73	17	74	0
Cogen_FC_300	0.000	45.00	5.48	4.08	67.38	10.2%	981.52	72.51	125.29	851.11	2152.57	106	75	0
Cogen_FC_179	2.751	50.00	5.48	4.27	73.38	4.1%	2775.48	74.88	313.22	2460.76	6395.20	378	76	0
Cogen_FC_124	27.700	50.00	5.48	4.27	73.38	4.1%	3016.74	74.88	313.22	2702.02	7022.20	3807	77	0
Cogen_FC_78	15.750	50.00	5.48	4.27	73.38	4.1%	3177.58	74.88	313.22	2862.86	7440.21	2165	78	0
Cogen_FC_1400	0.000	40.00	5.48	8.03	83.99	0.0%	4602.61	0.00	1277.19	3409.42	340941.96	0	79	0
Cogen_FC_400	0.000	36.00	5.48	9.95	90.51	0.0%	7003.98	0.00	1277.19	5817.30	581730.08	0	80	0
Cogen_FC_0.7	0.000	60.00	5.48	3.54	79.41	0.0%	22012.50	0.00	1277.19	20814.72	2081471.51	0	81	0
Cogen_FC_1.5	0.000	55.00	5.48	4.74	80.96	0.0%	23013.07	0.00	1277.19	21816.84	2181683.55	0	82	0

- Using the EIA Reference Case for fuel prices without allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment C**. In this scenario, the same CHP technologies as in the scenario with renewables are profitable, but in order to meet Clean Power Plan carbon emissions limits, STEER is also choosing combustion turbines down to 3 MW capacity and reciprocating engines down to 1 MW capacity. Michigan technical potential for these additional CHP technologies totals 1.345 GW, for a total selected capacity of 2.36 GW.

Name	Technical Potential	Variable O&M ($/MWh)	Fuel ($/MMBtu)	Electric Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor If Built	Capital Recovery Rev Req ($/MWh)	Marginal LMP ($/MWh) If Built	Value of Capacity ($/MWh) If Built	Unmet Rev Req ($/MWh) If Built	Cost to Mitigate ($/t)	Carbon Mitigated (t/yr)	Rank	Built?
Cogen_ST_8758	54.300	8.00	5.48	4.45	32.38	69.8%	8.72	51.35	18.31	-28.56	-70.01	135382	1	1
Cogen_ST_8000	56.000	8.00	5.48	4.45	32.38	70.1%	8.67	51.24	18.22	-28.41	-68.85	141858	2	1
Cogen_ST_3000	0.000	9.00	5.48	4.54	33.90	69.3%	8.82	51.46	18.42	-27.16	-68.34	7242	3	1
Cogen_ST_9091	100.000	8.00	5.48	4.45	32.38	70.4%	8.63	51.04	18.13	-28.16	-67.24	258420	4	1
Cogen_ST_15000	0.000	6.00	5.48	4.44	30.34	72.7%	8.27	50.54	17.56	-29.49	-67.07	42016	5	1
Cogen_ST_31000	0.000	6.00	5.48	4.44	30.31	73.0%	8.22	50.34	17.49	-29.29	-65.94	88121	6	1
Cogen_ST_25000	0.000	6.00	5.48	4.44	30.31	73.5%	8.18	50.34	17.38	-29.23	-65.79	71513	7	1
Cogen_ST_35867	134.500	6.00	5.48	4.44	30.31	74.3%	8.08	49.92	17.18	-28.72	-63.38	396757	8	1
Cogen_ST_500	0.000	10.00	5.48	4.54	34.87	69.3%	14.83	51.46	18.42	-20.18	-50.75	1208	9	1
Cogen_CT_45607	0.000	9.20	5.48	5.59	39.86	63.3%	19.21	53.13	20.17	-14.23	-43.91	79969	10	1
Cogen_RE_9341	0.000	8.50	5.48	4.63	33.85	75.3%	18.92	51.41	16.97	-15.61	-39.51	24339	11	1
Cogen_CT_35867	377.273	9.30	5.48	5.55	39.69	66.6%	20.10	52.19	19.17	-11.57	-35.59	715771	12	1
Cogen_CT_31000	0.000	9.30	5.48	5.55	39.69	68.1%	19.76	52.19	18.76	-11.49	-35.35	56190	13	1
Cogen_CT_21730	0.000	9.30	5.48	5.49	39.36	68.1%	20.46	52.17	18.74	-11.09	-33.77	39879	14	1
Cogen_RE_8758	244.350	12.00	5.48	4.57	37.07	73.8%	19.82	51.46	17.31	-11.88	-30.04	624721	15	1
Cogen_RE_8000	48.000	12.50	5.48	4.57	37.57	71.9%	20.81	52.02	17.77	-11.42	-29.93	115268	16	1
Cogen_RE_3326	0.000	16.00	5.48	4.45	40.36	66.4%	23.89	53.15	19.23	-8.12	-20.76	7573	17	1
Cogen_RE_2093	517.650	17.50	5.48	4.44	41.81	62.5%	32.00	53.15	20.42	0.24	0.61	1111311	18	1
Cogen_CT_10680	0.000	12.00	5.48	5.90	44.36	43.7%	43.21	57.88	29.20	0.49	1.55	12058	19	1
Cogen_RE_1800	54.000	18.00	5.48	4.44	42.34	58.2%	34.98	54.67	21.96	0.68	1.72	108446	20	1
Cogen_CT_7520	0.000	12.30	5.48	5.68	43.44	50.1%	38.74	56.08	25.47	0.64	1.96	10064	21	1
Cogen_CT_8758	228.467	12.20	5.48	5.79	43.93	48.3%	39.80	56.13	26.42	1.18	3.70	309089	22	1
Cogen_CT_8000	59.840	12.30	5.48	5.79	44.03	46.7%	41.54	56.89	27.34	1.34	4.17	78771	23	1
Cogen_RE_1121	0.000	19.00	5.48	4.45	43.40	52.1%	40.57	56.08	24.49	3.40	8.56	2036	24	1
Cogen_RE_1083	485.450	19.00	5.48	4.45	43.40	55.6%	38.10	54.85	22.96	3.69	9.35	932244	25	1
Cogen_RE_710	144.200	20.00	5.48	4.40	44.11	45.9%	57.01	57.08	27.82	16.22	40.20	233914	51	0
Cogen_MT_333	0.000	9.00	5.48	6.17	42.82	57.6%	47.29	54.85	22.17	13.09	44.59	474	52	0
Cogen_RE_633	0.000	21.00	5.48	4.40	45.12	43.7%	61.19	58.06	29.20	19.05	47.16	980	53	0
Cogen_RE_597	34.400	21.00	5.48	4.40	45.10	44.0%	60.93	57.91	29.01	19.11	47.25	53646	54	0
Cogen_CT_5000	0.000	12.40	5.48	6.36	47.25	39.3%	58.72	59.16	32.48	14.33	49.58	4655	55	0
Cogen_RE_427	345.150	22.00	5.48	4.40	46.10	42.3%	64.26	58.06	30.23	22.07	54.60	516484	56	0
Cogen_RE_179	137.550	23.00	5.48	4.41	47.17	40.7%	67.14	58.76	31.39	24.16	59.94	197587	57	0
Cogen_RE_124	110.800	23.50	5.48	4.34	47.30	39.0%	70.37	59.18	32.78	25.70	63.15	153875	58	0
Cogen_RE_100	0.000	24.00	5.48	4.27	47.38	39.1%	79.52	59.67	32.70	34.54	84.02	141	59	0
Cogen_MT_250	0.000	11.00	5.48	6.42	46.16	42.2%	67.19	58.76	30.30	24.29	84.95	253	60	0
Cogen_MT_427	176.558	11.00	5.48	6.68	47.61	37.3%	72.88	59.67	34.25	26.58	98.47	155700	61	0
Cogen_MT_597	8.170	11.00	5.48	6.76	48.05	36.1%	75.13	60.67	35.39	27.13	102.52	6834	62	0
Cogen_MT_65	0.000	13.00	5.48	5.99	45.85	44.6%	73.09	58.06	28.61	32.28	103.81	74	63	0
Cogen_MT_710	58.710	11.00	5.48	6.84	48.49	35.5%	76.28	60.84	36.02	27.92	107.49	47373	64	0

- Using the EIA High Resource Case for fuel prices and allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment D**. Although natural gas prices are lower in this scenario, CHP is generally competing with combined cycle natural gas in the dispatch order, so that the same technologies are profitable as in the Reference Case: steam turbines of any size, combustion turbines larger than 20 MW capacity, and reciprocating engines larger than 3 MW capacity. As in the Reference case, these have Michigan technical potential totaling 1.014 GW.

Name	Technical Potential	Variable O&M ($/MWh)	Fuel ($/MMBtu)	Electric Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor If Built	Capital Recovery Rev Req ($/MWh)	Marginal LMP ($/MWh) If Built	Value of Capacity ($/MWh) If Built	Unmet Rev Req ($/MWh) If Built	Cost to Mitigate ($/t)	Carbon Mitigated (t/yr)	Rank	Built?
Cogen_ST_31000	31.000	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.12	127983	1	1
Cogen_ST_35867	134.500	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.12	555279	2	1
Cogen_ST_25000	25.000	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.11	103223	3	1
Cogen_ST_15000	15.000	6.00	3.89	4.44	23.28	90.6%	6.64	37.18	14.10	-21.36	-41.08	61896	4	1
Cogen_ST_3000	3.000	9.00	3.89	4.54	26.67	83.0%	7.37	38.20	15.39	-19.54	-39.83	10701	5	1
Cogen_ST_8758	54.300	8.00	3.89	4.45	25.31	89.8%	6.77	37.29	14.23	-19.44	-37.58	220865	6	1
Cogen_ST_8000	56.000	8.00	3.89	4.45	25.31	89.8%	6.77	37.27	14.22	-19.41	-37.50	228125	7	1
Cogen_ST_9091	100.000	8.00	3.89	4.45	25.31	90.1%	6.75	37.23	14.18	-19.35	-37.30	409307	8	1
Cogen_ST_500	0.500	10.00	3.89	4.54	27.65	71.0%	14.48	40.14	17.99	-15.99	-37.25	1335	9	1
Cogen_CT_45607	44.488	9.20	3.89	5.59	30.96	64.0%	19.00	41.51	19.96	-11.50	-30.45	94172	10	1
Cogen_CT_35867	377.273	9.30	3.89	5.55	30.87	66.9%	20.01	40.91	19.08	-9.11	-24.25	831539	11	1
Cogen_CT_31000	28.985	9.30	3.89	5.55	30.87	68.2%	19.75	40.90	18.74	-9.02	-24.01	65025	12	1
Cogen_CT_21730	20.336	9.30	3.89	5.49	30.64	70.0%	19.90	40.61	18.23	-8.30	-22.01	47058	13	1
Cogen_RE_9341	9.341	8.50	3.89	4.63	26.49	90.1%	15.80	38.18	14.17	-10.06	-20.70	35848	14	1
Cogen_RE_8758	244.350	12.00	3.89	4.57	29.80	75.6%	19.34	40.23	16.89	-7.99	-18.68	692206	15	1
Cogen_RE_8000	48.000	12.50	3.89	4.57	30.30	73.9%	20.24	40.54	17.29	-7.29	-16.96	133499	16	1
Cogen_RE_3326	3.326	16.00	3.89	4.45	33.29	66.6%	23.82	41.65	19.17	-3.71	-8.31	8656	17	0
Cogen_CT_7520	7.038	12.30	3.89	5.68	34.41	64.3%	30.23	41.65	19.88	3.11	8.33	14801	18	0
Cogen_CT_8758	228.467	12.20	3.89	5.79	34.72	63.6%	30.27	41.65	20.09	3.25	8.84	467386	19	0
Cogen_CT_10680	9.950	12.00	3.89	5.90	34.97	54.6%	34.62	42.86	23.39	3.34	10.26	15471	20	0
Cogen_RE_2093	517.650	17.50	3.89	4.44	34.76	60.2%	33.22	41.89	21.20	4.88	11.15	1196212	21	0
Cogen_CT_8000	59.840	12.30	3.89	5.79	34.82	54.9%	35.38	42.81	23.28	4.10	12.36	95393	22	0
Cogen_RE_1800	54.000	18.00	3.89	4.44	35.28	56.0%	36.33	42.89	22.81	5.90	14.36	108745	23	0
Cogen_RE_1083	485.450	19.00	3.89	4.45	36.32	52.6%	40.26	43.03	24.26	9.29	22.65	917817	49	0
Cogen_RE_1121	1.121	19.00	3.89	4.45	36.32	49.1%	43.10	43.88	26.02	9.52	23.20	1978	50	0
Cogen_MT_333	0.320	9.00	3.89	6.17	33.00	66.5%	40.99	41.65	19.21	13.13	38.04	643	51	0
Cogen_CT_5000	4.675	12.40	3.89	6.36	37.14	43.7%	52.79	44.47	29.20	16.26	54.25	5368	52	0
Cogen_RE_710	144.200	20.00	3.89	4.40	37.12	44.9%	58.26	44.32	28.43	22.62	54.69	234659	53	0
Cogen_RE_633	0.633	21.00	3.89	4.40	38.12	43.0%	62.19	44.67	29.68	25.96	62.47	992	54	0
Cogen_RE_597	34.400	21.00	3.89	4.40	38.11	43.2%	62.08	44.60	29.56	26.03	62.68	54071	55	0
Cogen_MT_250	0.240	11.00	3.89	6.42	35.96	55.4%	51.16	43.03	23.07	21.02	71.21	344	56	0
Cogen_RE_427	345.150	22.00	3.89	4.40	39.11	39.9%	68.10	44.87	32.03	30.30	72.55	503513	57	0
Cogen_RE_179	137.550	23.00	3.89	4.41	40.16	35.8%	76.36	45.62	35.70	35.20	83.09	182593	58	0
Cogen_MT_427	176.558	11.00	3.89	6.68	36.99	47.4%	57.35	43.93	26.95	23.46	83.76	205310	59	0
Cogen_RE_124	110.800	23.50	3.89	4.34	40.39	33.4%	82.10	46.04	38.25	38.21	88.68	139635	60	0
Cogen_MT_597	8.170	11.00	3.89	6.76	37.30	45.3%	59.92	44.47	28.22	24.53	88.83	8943	61	0
Cogen_MT_710	58.710	11.00	3.89	6.84	37.62	44.9%	60.20	44.47	28.42	24.92	91.81	62726	62	0
Cogen_CT_3519	3.304	12.60	3.89	6.81	39.10	41.9%	63.04	44.87	31.15	27.01	97.71	3289	63	0

- Using the EIA High Resource Case for fuel prices without allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment E**. In this scenario, the same CHP technologies are profitable as in the preceding scenario, but in order to meet Clean Power Plan carbon emissions limits, STEER is also choosing combustion turbines down to 8 MW, for an additional technical potential of 228 MW and a total technical potential of 1.242 GW.

Name	Technical Potential	Variable O&M ($/MWh)	Fuel ($/MMBtu)	Electric Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor If Built	Capital Recovery Rev Req ($/MWh)	Marginal LMP ($/MWh) If Built	Value of Capacity ($/MWh) If Built	Unmet Rev Req ($/MWh) If Built	Cost to Mitigate ($/t)	Carbon Mitigated (t/yr)	Rank	Built?
Cogen_ST_31000	0.000	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.12	127983	1	1
Cogen_ST_35867	134.500	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.12	555279	2	1
Cogen_ST_25000	0.000	6.00	3.89	4.44	23.26	90.6%	6.63	37.18	14.10	-21.39	-41.11	103223	3	1
Cogen_ST_15000	0.000	6.00	3.89	4.44	23.28	90.6%	6.64	37.18	14.10	-21.36	-41.08	61896	4	1
Cogen_ST_3000	0.000	9.00	3.89	4.54	26.67	83.0%	7.37	38.20	15.39	-19.54	-39.83	10701	5	1
Cogen_ST_8758	54.300	8.00	3.89	4.45	25.31	89.8%	6.77	37.29	14.23	-19.44	-37.58	220865	6	1
Cogen_ST_8000	56.000	8.00	3.89	4.45	25.31	89.8%	6.77	37.27	14.22	-19.41	-37.50	228125	7	1
Cogen_ST_9091	100.000	8.00	3.89	4.45	25.31	90.1%	6.75	37.23	14.18	-19.35	-37.30	409307	8	1
Cogen_ST_500	0.000	10.00	3.89	4.54	27.65	71.0%	14.48	40.14	17.99	-15.99	-37.25	1335	9	1
Cogen_CT_45607	0.000	9.20	3.89	5.59	30.96	64.0%	19.00	41.51	19.96	-11.50	-30.45	94172	10	1
Cogen_CT_35867	377.273	9.30	3.89	5.55	30.87	66.9%	20.01	40.91	19.08	-9.11	-24.25	831539	11	1
Cogen_CT_31000	0.000	9.30	3.89	5.55	30.87	68.2%	19.75	40.90	18.74	-9.02	-24.01	65025	12	1
Cogen_CT_21730	0.000	9.30	3.89	5.49	30.64	70.0%	19.90	40.61	18.23	-8.30	-22.01	47058	13	1
Cogen_RE_9341	0.000	8.50	3.89	4.63	26.49	90.1%	15.80	38.18	14.17	-10.06	-20.70	35848	14	1
Cogen_RE_8758	244.350	12.00	3.89	4.57	29.80	75.6%	19.34	40.23	16.89	-7.99	-18.68	692206	15	1
Cogen_RE_8000	48.000	12.50	3.89	4.57	30.30	73.9%	20.24	40.54	17.29	-7.29	-16.96	133499	16	1
Cogen_RE_3326	0.000	16.00	3.89	4.45	33.29	66.6%	23.82	41.65	19.17	-3.71	-8.31	8656	17	1
Cogen_CT_7520	0.000	12.30	3.89	5.68	34.41	64.3%	30.23	41.65	19.88	3.11	8.33	14801	18	1
Cogen_CT_8758	228.467	12.20	3.89	5.79	34.72	63.6%	30.27	41.65	20.09	3.25	8.84	467386	19	1
Cogen_CT_10680	0.000	12.00	3.89	5.90	34.97	54.6%	34.62	42.86	23.39	3.34	10.26	15471	20	0
Cogen_RE_2093	517.650	17.50	3.89	4.44	34.76	60.2%	33.22	41.89	21.20	4.88	11.15	1196212	21	0
Cogen_CT_8000	59.840	12.30	3.89	5.79	34.82	54.9%	35.38	42.81	23.28	4.10	12.36	95393	22	0
Cogen_RE_1800	54.000	18.00	3.89	4.44	35.28	56.0%	36.33	42.89	22.81	5.90	14.36	108745	23	0
Cogen_RE_1083	485.450	19.00	3.89	4.45	36.32	52.6%	40.26	43.03	24.26	9.29	22.65	917817	49	0
Cogen_RE_1121	0.000	19.00	3.89	4.45	36.32	49.1%	43.10	43.88	26.02	9.52	23.20	1978	50	0
Cogen_MT_333	0.000	9.00	3.89	6.17	33.00	66.5%	40.99	41.65	19.21	13.13	38.04	643	51	0
Cogen_CT_5000	0.000	12.40	3.89	6.36	37.14	43.7%	52.79	44.47	29.20	16.26	54.25	5368	52	0
Cogen_RE_710	144.200	20.00	3.89	4.40	37.12	44.9%	58.26	44.32	28.43	22.62	54.69	234659	53	0
Cogen_RE_633	0.000	21.00	3.89	4.40	38.12	43.0%	62.19	44.67	29.68	25.96	62.47	992	54	0
Cogen_RE_597	34.400	21.00	3.89	4.40	38.11	43.2%	62.08	44.60	29.56	26.03	62.68	54071	55	0
Cogen_MT_250	0.000	11.00	3.89	6.42	35.96	55.4%	51.16	43.03	23.07	21.02	71.21	344	56	0
Cogen_RE_427	345.150	22.00	3.89	4.40	39.11	39.9%	68.10	44.87	32.03	30.30	72.55	503513	57	0
Cogen_RE_179	137.550	23.00	3.89	4.41	40.16	35.8%	76.36	45.62	35.70	35.20	83.09	182593	58	0
Cogen_MT_427	176.558	11.00	3.89	6.68	36.99	47.4%	57.35	43.93	26.95	23.46	83.76	205310	59	0
Cogen_RE_124	110.800	23.50	3.89	4.34	40.39	33.4%	82.10	46.04	38.25	38.21	88.68	139635	60	0
Cogen_MT_597	8.170	11.00	3.89	6.76	37.30	45.3%	59.92	44.47	28.22	24.53	88.83	8943	61	0
Cogen_MT_710	58.710	11.00	3.89	6.84	37.62	44.9%	60.20	44.47	28.42	24.92	91.81	62726	62	0

- Using the EIA Low Resource Case for fuel prices and allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment F**. With the higher natural gas prices used in this scenario, the relative fuel efficiency of CHP generation as compared to combined cycle and electricity-only combustion turbines causes a wider range of CHP technologies to be profitable, including steam turbines of any size, combustion turbines 8 MW capacity and larger, and reciprocating engines 1 MW capacity and larger. Michigan technical potential for these technologies totals 2.36 GW.

Name	Technical Potential	Variable O&M ($/MWh)	Fuel ($/MMBtu)	Electric Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor If Built	Capital Recovery Rev Req ($/MWh)	Marginal LMP ($/MWh) If Built	Value of Capacity ($/MWh) If Built	Unmet Rev Req ($/MWh) If Built	Cost to Mitigate ($/t)	Carbon Mitigated (t/yr)	Rank	Built?
Cogen_ST_8758	54.300	8.00	8.5	4.45	45.82	67.7%	8.98	72.45	18.87	-36.52	-94.56	124309	1	1
Cogen_ST_8000	56.000	8.00	8.5	4.45	45.82	68.0%	8.94	72.29	18.77	-36.31	-94.07	128834	2	1
Cogen_ST_3000	0.000	9.00	8.5	4.54	47.62	67.3%	9.10	72.65	18.99	-34.92	-91.70	6732	3	1
Cogen_ST_15000	0.000	6.00	8.5	4.44	43.75	70.2%	8.57	71.53	18.20	-37.40	-90.66	38048	4	1
Cogen_ST_31000	0.000	6.00	8.5	4.44	43.71	70.3%	8.54	71.41	18.17	-37.32	-89.71	79414	5	1
Cogen_ST_25000	0.000	6.00	8.5	4.44	43.71	70.5%	8.52	71.41	18.11	-37.28	-89.62	64238	6	1
Cogen_ST_9091	100.000	8.00	8.5	4.45	45.82	68.8%	8.84	71.85	18.57	-35.76	-88.86	242411	7	1
Cogen_ST_35867	134.500	6.00	8.5	4.44	43.71	71.3%	8.42	70.84	17.91	-36.62	-85.85	358348	8	1
Cogen_ST_500	0.000	10.00	8.5	4.54	48.58	67.3%	15.29	72.65	18.99	-27.78	-72.88	1123	9	1
Cogen_CT_45607	0.000	9.20	8.5	5.59	56.76	52.4%	23.22	78.58	24.39	-22.99	-70.24	66803	10	1
Cogen_RE_9341	0.000	8.50	8.5	4.63	47.81	72.9%	19.52	72.65	17.51	-22.83	-60.70	22443	11	1
Cogen_CT_35867	377.273	9.30	8.5	5.55	56.44	54.0%	24.79	77.30	23.64	-19.71	-60.02	586311	12	1
Cogen_CT_31000	0.000	9.30	8.5	5.55	56.44	55.8%	24.11	77.17	22.88	-19.50	-59.42	46504	13	1
Cogen_CT_21730	0.000	9.30	8.5	5.49	55.93	56.2%	24.83	77.13	22.74	-19.12	-57.65	33183	14	1
Cogen_RE_8000	48.000	12.50	8.5	4.57	51.38	67.8%	22.05	74.14	18.84	-19.54	-51.33	108500	15	1
Cogen_RE_8758	244.350	12.00	8.5	4.57	50.88	71.5%	20.46	72.83	17.87	-19.35	-51.04	579973	16	1
Cogen_RE_3326	0.000	16.00	8.5	4.45	53.79	67.6%	23.49	74.35	18.91	-15.97	-41.12	7644	17	0
Cogen_CT_10680	0.000	12.00	8.5	5.90	62.19	34.4%	54.92	89.37	37.11	-9.37	-30.07	9345	18	0
Cogen_CT_7520	0.000	12.30	8.5	5.68	60.61	38.8%	50.02	86.20	32.89	-8.45	-25.95	7799	19	0
Cogen_CT_8000	59.840	12.30	8.5	5.79	61.51	34.8%	55.76	88.75	36.70	-8.17	-25.66	58099	20	0
Cogen_CT_8758	228.467	12.20	8.5	5.79	61.41	36.7%	52.42	86.20	34.79	-7.16	-22.40	234739	21	0
Cogen_RE_1800	54.000	18.00	8.5	4.44	55.75	59.3%	34.31	76.74	21.55	-8.22	-20.96	109946	22	0
Cogen_RE_2093	517.650	17.50	8.5	4.44	55.21	64.1%	31.21	74.52	19.92	-8.01	-20.59	1131297	23	0
Cogen_RE_1121	0.000	19.00	8.5	4.45	56.84	46.9%	45.09	82.40	27.22	-7.68	-19.30	1834	24	0
Cogen_RE_1083	485.450	19.00	8.5	4.45	56.84	50.8%	41.68	78.71	25.12	-5.31	-13.47	852748	25	0
Cogen_RE_710	144.200	20.00	8.5	4.40	57.40	45.3%	57.77	82.40	28.19	4.58	11.41	229533	26	0
Cogen_RE_633	0.000	21.00	8.5	4.40	58.42	44.8%	59.69	82.97	28.49	6.65	16.55	999	27	0
Cogen_RE_597	34.400	21.00	8.5	4.40	58.38	44.9%	59.80	82.92	28.47	6.79	16.88	54353	28	0
Cogen_RE_427	345.150	22.00	8.5	4.40	59.38	42.8%	63.50	83.11	29.87	9.90	24.62	519882	29	0
Cogen_CT_5000	0.000	12.40	8.5	6.36	66.45	33.7%	68.52	89.92	37.90	7.16	25.14	3929	30	0
Cogen_RE_124	110.800	23.50	8.5	4.34	60.41	41.4%	66.16	84.78	30.82	10.97	27.10	162768	31	0
Cogen_RE_179	137.550	23.00	8.5	4.41	60.49	40.1%	68.05	85.14	31.81	11.58	28.92	193748	32	0
Cogen_MT_333	0.000	9.00	8.5	6.17	61.45	36.4%	74.80	88.75	35.06	12.44	42.01	302	33	0
Cogen_RE_100	0.000	24.00	8.5	4.27	60.26	42.5%	73.12	84.78	30.06	18.54	45.31	152	34	0
Cogen_MT_250	0.000	11.00	8.5	6.42	65.53	34.9%	81.25	89.92	36.64	20.23	71.90	206	60	0
Cogen_RE_78	110.250	25.00	8.5	4.59	64.00	34.6%	92.57	89.37	36.91	30.29	77.98	129822	61	0
Cogen_MT_427	176.558	11.00	8.5	6.68	67.79	29.6%	91.84	92.94	43.15	23.54	89.06	120967	62	0
Cogen_MT_597	8.170	11.00	8.5	6.76	68.47	28.7%	94.38	94.67	44.46	23.73	91.54	5330	63	0

- Using the EIA Low Resource Case for fuel prices without allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment G**. As is generally true, the same set of CHP technologies is profitable in this scenario as in the previous scenario that uses the same fuel prices but also allows renewables. Without renewables available in this scenario and the carbon emissions constraint of the Clean Power Plan, STEER also chooses reciprocating engines down to 700 kW capacity, which adds 144 MW technical potential for a total of 2.5 GW.

Name	Capacity	VOM ($/MWh)	Fuel ($/MMBtu)	Heat Rate (MMBtu/MWh)	Dispatch Cost	Capacity Factor	Rev Req ($/MWh)	Marginal LMP ($/MWh)	Value of Capacity ($/MWh)	Unmet Rev Req ($/MWh)	Cost to Mitigate ($/t)	Carbon Mitigated (t)	Rank Corrected	Built?
Cogen_ST_8758	54.300	8.00	8.5	4.45	45.82	67.7%	8.98	72.45	18.87	-36.52	-94.56	124309	1	1
Cogen_ST_8000	56.000	8.00	8.5	4.45	45.82	68.0%	8.94	72.29	18.77	-36.31	-94.07	128834	2	1
Cogen_ST_3000	3.000	9.00	8.5	4.54	47.62	67.3%	9.10	72.65	18.99	-34.92	-91.70	6732	3	1
Cogen_ST_15000	15.000	6.00	8.5	4.44	43.75	70.2%	8.57	71.53	18.20	-37.40	-90.66	38048	4	1
Cogen_ST_31000	31.000	6.00	8.5	4.44	43.71	70.3%	8.54	71.41	18.17	-37.32	-89.71	79414	5	1
Cogen_ST_25000	25.000	6.00	8.5	4.44	43.71	70.5%	8.52	71.41	18.11	-37.28	-89.62	64238	6	1
Cogen_ST_9091	100.000	8.00	8.5	4.45	45.82	68.8%	8.84	71.85	18.57	-35.76	-88.86	242411	7	1
Cogen_ST_35867	134.500	6.00	8.5	4.44	43.71	71.3%	8.42	70.84	17.91	-36.62	-85.85	358348	8	1
Cogen_ST_500	0.500	10.00	8.5	4.54	48.58	67.3%	15.29	72.65	18.99	-27.78	-72.88	1123	9	1
Cogen_CT_45607	44.488	9.20	8.5	5.59	56.76	52.4%	23.22	78.58	24.39	-22.99	-70.24	66803	10	1
Cogen_RE_9341	9.341	8.50	8.5	4.63	47.81	72.9%	19.52	72.65	17.51	-22.83	-60.70	22443	11	1
Cogen_CT_35867	377.273	9.30	8.5	5.55	56.44	54.0%	24.79	77.30	23.64	-19.71	-60.02	586311	12	1
Cogen_CT_31000	28.985	9.30	8.5	5.55	56.44	55.8%	24.11	77.17	22.88	-19.50	-59.42	46504	13	1
Cogen_CT_21730	20.336	9.30	8.5	5.49	55.93	56.2%	24.83	77.13	22.74	-19.12	-57.65	33183	14	1
Cogen_RE_8000	48.000	12.50	8.5	4.57	51.38	67.8%	22.05	74.14	18.84	-19.54	-51.33	108500	15	1
Cogen_RE_8758	244.350	12.00	8.5	4.57	50.88	71.5%	20.46	72.83	17.87	-19.35	-51.04	579973	16	1
Cogen_RE_3326	3.326	16.00	8.5	4.45	53.79	67.6%	23.49	74.35	18.91	-15.97	-41.12	7644	17	1
Cogen_CT_10680	9.950	12.00	8.5	5.90	62.19	34.4%	54.92	89.37	37.11	-9.37	-30.07	9345	18	1
Cogen_CT_7520	7.038	12.30	8.5	5.68	60.61	38.8%	50.02	86.20	32.89	-8.45	-25.95	7799	19	1
Cogen_CT_8000	59.840	12.30	8.5	5.79	61.51	34.8%	55.76	88.75	36.70	-8.17	-25.66	58099	20	1
Cogen_CT_8758	228.467	12.20	8.5	5.79	61.41	36.7%	52.42	86.20	34.79	-7.16	-22.40	234739	21	1
Cogen_RE_1800	54.000	18.00	8.5	4.44	55.75	59.3%	34.31	76.74	21.55	-8.22	-20.96	109946	22	1
Cogen_RE_2093	517.650	17.50	8.5	4.44	55.21	64.1%	31.21	74.52	19.92	-8.01	-20.59	1131297	23	1
Cogen_RE_1121	1.121	19.00	8.5	4.45	56.84	46.9%	45.09	82.40	27.22	-7.68	-19.30	1834	24	1
Cogen_RE_1083	485.450	19.00	8.5	4.45	56.84	50.8%	41.68	78.71	25.12	-5.31	-13.47	852748	25	1
Cogen_RE_710	144.200	20.00	8.5	4.40	57.40	45.3%	57.77	82.40	28.19	4.58	11.41	229533	26	1
Cogen_RE_633	0.633	21.00	8.5	4.40	58.42	44.8%	59.69	82.97	28.49	6.65	16.55	999	27	0
Cogen_RE_597	34.400	21.00	8.5	4.40	58.38	44.9%	59.80	82.92	28.47	6.79	16.88	54353	28	0
Cogen_RE_427	345.150	22.00	8.5	4.40	59.38	42.8%	63.50	83.11	29.87	9.90	24.62	519882	29	0
Cogen_CT_5000	4.675	12.40	8.5	6.36	66.45	33.7%	68.52	89.92	37.90	7.16	25.14	3929	30	0
Cogen_RE_124	110.800	23.50	8.5	4.34	60.41	41.4%	66.16	84.78	30.82	10.97	27.10	162768	31	0
Cogen_RE_179	137.550	23.00	8.5	4.41	60.49	40.1%	68.05	85.14	31.81	11.58	28.92	193748	32	0
Cogen_MT_333	0.320	9.00	8.5	6.17	61.45	36.4%	74.80	88.75	35.06	12.44	42.01	302	33	0
Cogen_RE_100	0.100	24.00	8.5	4.27	60.26	42.5%	73.12	84.78	30.06	18.54	45.31	152	34	0
Cogen_MT_250	0.240	11.00	8.5	6.42	65.53	34.9%	81.25	89.92	36.64	20.23	71.90	206	60	0
Cogen_RE_78	110.250	25.00	8.5	4.59	64.00	34.6%	92.57	89.37	36.91	30.29	77.98	129822	61	0
Cogen_MT_427	176.558	11.00	8.5	6.68	67.79	29.6%	91.84	92.94	43.15	23.54	89.06	120967	62	0
Cogen_MT_597	8.170	11.00	8.5	6.76	68.47	28.7%	94.38	94.67	44.46	23.73	91.54	5330	63	0

Results

- Across a fairly broad range of scenarios, neither microturbines nor fuel cells appear economically viable for broad application in Michigan.
- Steam turbines, combustion turbines, and reciprocating engines above some threshold size appear profitable in each scenario with the minimum size threshold being lower under higher natural gas pricing and when renewables aren’t available.

Results

- The CHP technologies that appear viable based on STEER modeling results based solely on their value to the power system have potential in specific economic sectors.
- The following table summarizes the number of sites in each sector for which there appear to be viable technologies, where a range reflects the results in the various scenarios described above.

Sector	Steam Turbine	Combustion Turbine	Reciprocating Engine
Food/Beverages	1	3	3-36
Lumber/Wood	-	1	1-16
Paper/Pulp	1	2-3	1-21
Chemicals	3	2-13	11-66
Petroleum Refining	-	-	0-8
Rubber/Plastics	-	-	0-9
Stone/Clay/Glass	-	1	1-3
Primary Metals	1	2-3	1-26
Machinery/Comp Equip	-	-	0-2
Transportation Equip	3	4-14	10-87
Gas Processing	-	-	0-2
Refrigerated Warehouses	-	-	1
Wastewater Treatment	-	-	1
Commercial Office Buildings	-	-	0-284
Multifamily Housing	-	-	0-16
Hotels	-	-	0-15
Data Centers	-	-	0-8
Hospitals	-	0-3	1-57
Colleges/Universities	8	1-6	5-37
Prisons	-	-	0-34
Military Facilities	-	-	0-3
Airports	-	-	0-2
Museums	-	-	0-1

Recommendations Regarding IRP Assumptions and Scenarios

- Cogeneration resources must be included in the Integrated Resource Plan, both as a forecast offset to load and demand and as a potential resource.
- Resource screening should at least include steam turbines, combustion turbines, and reciprocating engines in CHP applications.
- DOE Technical Potential and EPA Catalog of CHP Technologies are valid references and should be the default information for IRP.
- CHP economic potential is concentrated in a few sectors. IRP analysis should include specific outreach to customers in these sectors, likely as a formal solicitation of interest offering both PURPA contracts and utility-ownership models.

An Important Additional Observation

- The analysis above ignored a critical potential value of CHP as an element of a microgrid for a critical facility. Consideration of this value would broaden the applicability of CHP for hospitals, extended care facilities, water and sewer systems, public safety facilities, and government buildings as refuges.
- Utilities should consider supporting applications of CHP at critical facilities as a resilience strategy for the communities they serve.
- The Commission could establish means to identify and authorize cost recovery for such a strategy.

Questions?

- Jamie Scripps, jscripps@5lakesenergy.com
- Douglas Jester, djester@5lakesenergy.com