Optimizing Combined Heat and Power in Michigan

Douglas Jester, Principal

5 Lakes Energy

Michigan Energy Office Project:
Optimize Adoption of CHP in Michigan

- Task 1 - Identify and evaluate CHP technologies and applications
- Task 2 - Use STEER Model to assess best options
- Task 3 - Identify and provide solutions to barriers
- Task 4 - Map supply chain and value chain
- Task 5 – Stakeholder involvement and education.

Optimize CHP in Michigan Project Team

5lakes energy
Clean Energy & Environmental Consultants

spart
Sustainable Partners, LLC
energy strategies

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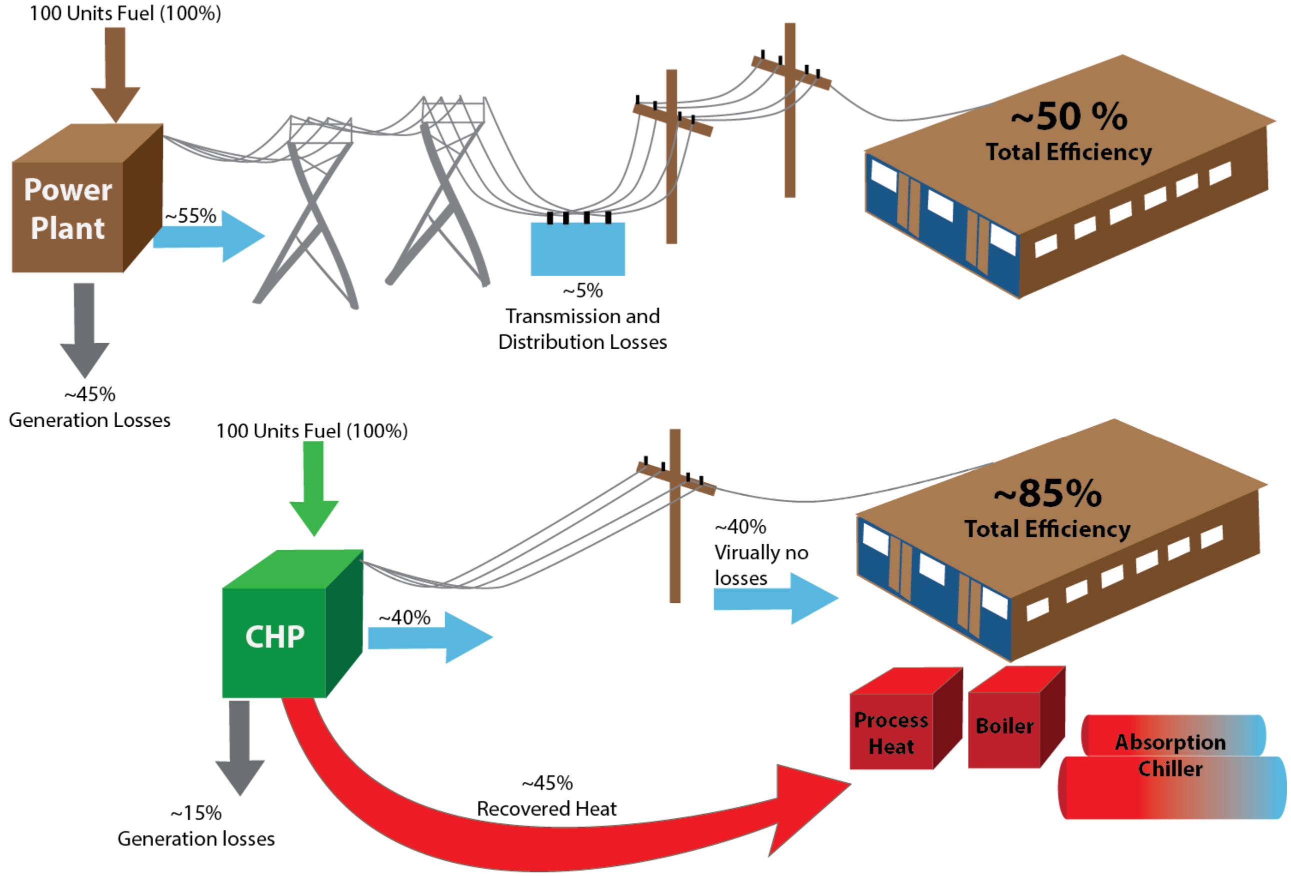
Technology Taxonomy

CHP Energy Technology



Technology Taxonomy Methodology

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

Michigan CHP Technical Potential

- Baseline data for Michigan technical potential sourced from "Combined Heat and Power (CHP) Technical Potential in the United States," US Department of Energy (DOE), revised March 2016
- Database is broken down by:
  - Commercial/industrial business type
  - Annual operating hours (7500 hours full-time vs. 4500 hours part-time)
  - Number of CHP sites and total Megawatt (MW) potential by project size range
    - 50-500 kilowatt (kW)
    - 500 kW – 1 MW
    - 1 MW – 5 MW
    - 5 MW – 20 MW
    - 20+ MW

Figure 1: Top Industrial Types with On-site CHP Technical Potential

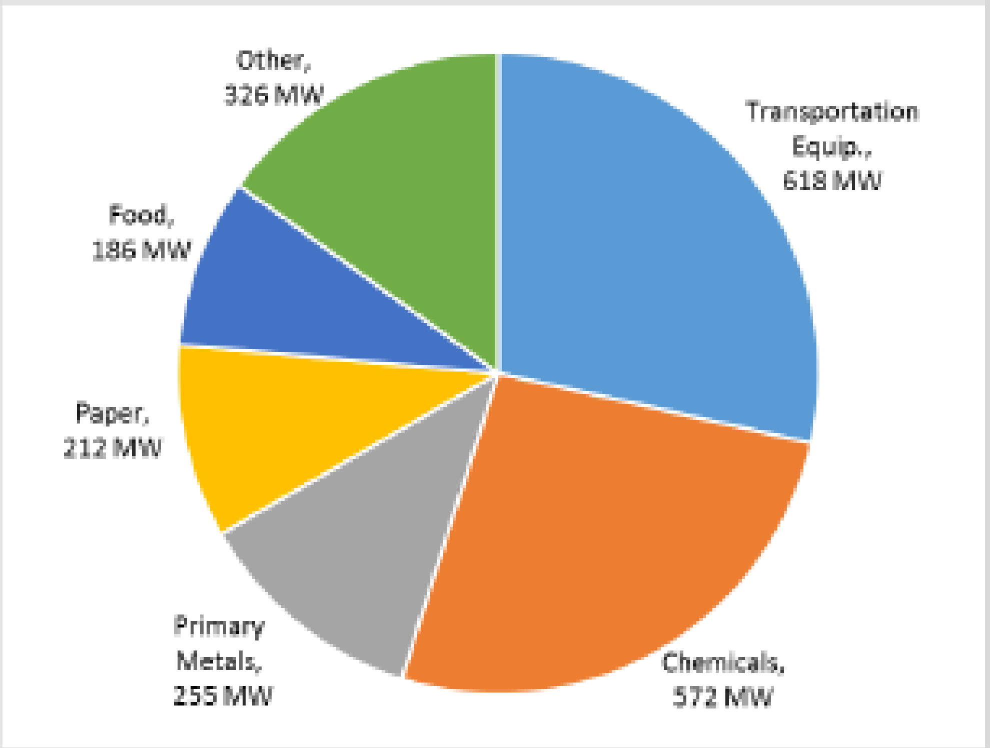
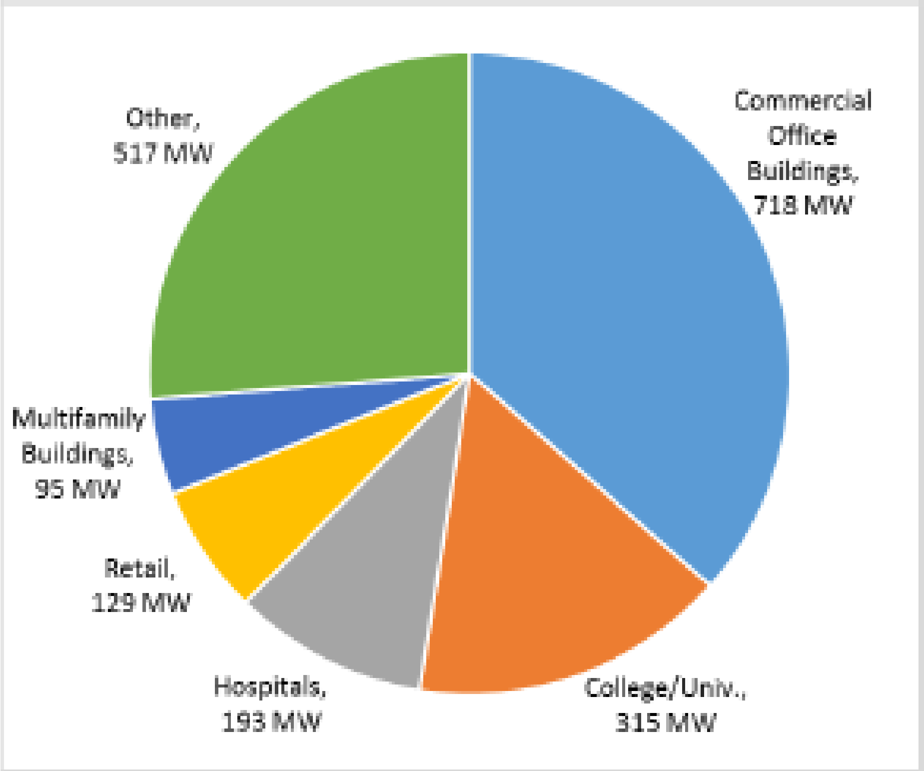


Figure 2: Top Commercial Business Types with On-site CHP Technical Potential



Industrial CHP Technical Potential

Table 2: All Industrial CHP Technical Potential (Including Topping Cycle CHP and WHP CHP)

		50-500 kW		0.5 - 1 MW		1 - 5 MW		5 - 20 MW		> 20 MW		Total	
SIC	Industrial Business Type	Sites	50-500 kW (MW)	Sites	0.5-1 MW (MW)	Sites	1-5 MW (MW)	Sites	5-20 MW (MW)	Sites	>20 MW (MW)	Total Sites	Total MW
12	Mining, Except Oil and Gas	0	0	0	0	0	0	0	0	0	0	0	0
13	Oil and Gas Extraction	10	2	0	0	1	2	1	6	0	0	12	10
20	Food	197	37	35	26	39	75	6	49	0	0	277	188
22	Textiles	19	4	4	3	0	0	0	0	0	0	23	6
24	Lumber and Wood	182	32	20	14	18	36	2	13	0	0	222	95
25	Furniture	7	0.7	0	0	0	0	0	0	0	0	7	1
26	Paper	64	17	12	10	23	52	2	16	3	118	104	212
27	Printing	36	4	2	1	0	0	0	0	0	0	38	6
28	Chemicals	150	27	42	30	67	154	24	234	3	132	286	576
29	Petroleum Refining	0	0	10	7	10	20	1	12	1	44	22	83
30	Rubber/Misc Plastics	300	49	21	15	11	19	1	5	0	0	333	88
32	Stone/Clay/Glass	2	0.2	0	0	2	7	5	42	1	25	10	74
33	Primary Metals	104	25	31	22	29	64	10	95	3	117	177	323
34	Fabricated Metals	147	17	2	1	0	0	0	0	0	0	149	18
35	Machinery/Computer Equip.	14	2	0	0	2	3	1	11	0	0	17	16
37	Transportation Equip.	300	59	111	77	91	178	22	178	5	127	529	618
38	Instruments	5	0.9	0	0	0	0	0	0	0	0	5	1
39	Misc. Manufacturing	6	0.5	0	0	0	0	0	0	0	0	6	0.5
49	Gas Processing	14	2	0	0	2	6	0	0	0	0	16	8
	Total	1,557	279	290	206	295	616	75	661	16	562	2,233	2,324

Commercial CHP Technical Potential

Table 3: All Commercial CHP Technical Potential (Including Topping Cycle CHP, WHP CHP and District Energy CHP)

		50-500 kW		0.5 - 1 MW		1 - 5 MW		5 - 20 MW		> 20 MW		Total	
SIC	Commercial Business Type	Sites	50-500 kW (MW)	Sites	0.5-1 MW (MW)	Sites	1-5 MW (MW)	Sites	5-20 MW (MW)	Sites	>20 MW (MW)	Total Sites	Total MW
43	Post Offices	24	2	0	0	0	0	0	0	0	0	24	2
52	Retail	602	90	43	25	8	14	0	0	0	0	653	129
4222	Refrigerated Warehouses	22	2	0	0	1	1	0	0	0	0	23	3
4581	Airports	7	2	2	1	2	4	0	0	0	0	11	7
4952	Waste Water Treatment Plants	24	3	0	0	1	2	0	0	0	0	25	5
4961	District Energy	0	0	0	0	0	0	0	0	2	696	2	696
5411	Food Stores	296	49	4	2	0	0	0	0	0	0	300	52
5812	Restaurants	701	62	2	1	3	4	0	0	0	0	706	67
6512	Commercial Office Buildings	2,393	120	1,047	419	299	179	0	0	0	0	3,739	718
6513	Multifamily Buildings	303	23	110	55	17	17	0	0	0	0	430	95
7011	Hotels	315	40	21	14	14	24	0	0	0	0	350	77
7211	Laundries	32	5	3	2	0	0	0	0	0	0	35	7
7374	Data Centers	52	8	10	7	8	13	0	0	0	0	70	28
7542	Car Washes	37	3	0	0	0	0	0	0	0	0	37	3
7832	Movie Theaters	4	0	0	0	0	0	0	0	0	0	4	0
7991	Health Clubs	76	7	3	2	0	0	0	0	0	0	79	9
7997	Golf/Country Clubs	243	28	0	0	0	0	0	0	0	0	243	28
8051	Nursing Homes	308	39	5	3	0	0	0	0	0	0	313	43
8062	Hospitals	79	20	29	19	59	127	4	27	0	0	171	193
8211	Schools	462	43	0	0	0	0	0	0	0	0	462	43
8221	College/Univ.	82	14	11	7	34	91	17	141	2	62	146	315
8412	Museums	26	3	0	0	1	2	0	0	0	0	27	5
9100	Government Buildings	193	26	15	10	16	30	1	5	0	0	225	71
9223	Prisons	8	2	8	6	36	50	0	0	0	0	52	57
9711	Military	5	1	2	1	3	7	0	0	0	0	10	9
	Total	**6,294**	**593**	**1,315**	**576**	**502**	**563**	**22**	**174**	**4**	**758**	**8,137**	**2,663**

CHP Technologies To Evaluate

- Microturbine
  - 30 kW to 1 MW
- Reciprocating Engine
  - 633kW to 9.341 MW
- Combustion Turbine
  - 3.5 MW to 45.607 MW
- Steam Turbine
  - 500 kW to 15 MW
- Fuel Cell
  - 0.7 kW to 1.5MW

Prime Mover Cost/Performance

Baseline data for prime mover cost and performance characteristics sourced from "Catalog of CHP Technologies," US Environmental Protection Agency (EPA) Combined Heat and Power Partnership, revised March 2015

This is just a "snapshot" of the full database

MT = Microturbine
RE = Reciprocating Engine
CT = Combustion Turbine
ST = Steam Turbine
FC = Fuel Cell

Prime Mover System (by TYPE)	MT1	MT3	MT5	MT6	RE2	RE3	RE4	RE5	CT1	CT4	CT5	ST1	ST2	ST3	FC1	FC4	FC5
Nominal/Nameplate Capacity (kW)	**30**	**200**	**333**	**1,000**	**633**	**1,121**	**3,326**	**9,341**	**3,510**	**21,730**	**45,607**	**500**	**3,000**	**15,000**	**0.7**	**400**	**1,400**
Net Power Generating Capacity (kW)	28	190	320	950	633	1,121	3,326	9,341	3,304	20,336	44,488	500	3,000	15,000	0.7	400	1,400
in MMBtu/hr	0.10	0.65	1.09	3.24	2.16	3.83	11.35	31.89	11.28	69.43	151.88	1.71	10.24	51.21	0.00	1.37	4.78
Electrical Heat Rate (Btu/kWh), HHV	15,535	12,824	12,198	12,824	9,896	9,264	8,454	8,207	14,247	10,265	9,488	54,418	69,350	46,676	9,666	9,948	8,028
Thermal Output (MMBtu/hr)	0.21	0.88	1.54	4.43	2.78	4.32	10.67	26.81	19.66	77.82	138.72	19.9	155.7	506.8	0.0034	1.8680	4.4240
in kW/hr	61.0	258.9	450.2	1,229.0	815	1,266	3,126	7,857	5,760	22,801	40,645	5,844	45,624	148,484	1.01	547.3	1,296.2
Net Thermal Rate (Btu/kWh)	6,211	6,983	6,170	6,963	4,400	4,442	4,445	4,619	6,810	5,481	5,590	4,541	4,540	4,442	9,666	9,948	8,028
Fuel Input (MMBtu/hr) HHV	0.434	2.431	3.894	12.155	6.26	10.38	28.12	76.66	47.1	208.7	422.1	27.2	208.3	700.1	0.0068	4.0	11.2
Total CHP Efficiency (%), HHV	70.0%	63.0%	67.5%	63.1%	78.9%	78.4%	78.3%	76.5%	65.7%	70.5%	68.8%	79.60%	79.68%	79.70%	86%	81%	82%
Electrical Efficiency (%), HHV	21.9%	26.6%	28.0%	26.6%	34.5%	36.8%	40.4%	41.6%	23.95%	33.24%	35.96%	6.27%	4.92%	7.31%	35.3%	34.3%	42.5%
Effective Electrical Efficiency, HHV (%)	54.9%	48.9%	55.3%	49.0%	78%	77%	77%	74%	50%	62%	61%	75.15%	75.18%	76.84%	96%	82%	84%
Power/Thermal Ratio	0.46	0.73	0.71	0.73	0.78	0.89	1.06	1.19	0.57	0.89	1.09	0.086	0.066	0.101	0.70	0.73	1.08
Generator Availability	98%	98%	98%	98%	95.99%	98.22%	98.22%	98.22%	94.73%	93.49%	93.49%	90.59%	90.59%	90.59%	95%	95%	95%
Total Installed Cost ($/kW Net Power Output)	$ 4,300	$ 3,150	$ 2,580	$ 2,500	$ 2,837	$ 2,366	$ 1,801	$ 1,433	$ 3,281	$ 1,518	$ 1,248	$ 1,136	$ 682	$ 666	$ 22,000	$ 7,000	$ 4,600
generating equipment only	$ 2,690	$ 2,120	$ 1,770	$ 1,710	$ 1,790	$ 1,475	$ 1,140	$ 925	$ 1,976	$ 954	$ 790	$ 668	$ 401	$ 392	$ 14,300	$ 4,550	$ 2,990
O&M, Variable, ($/kWh)	$ 0.020	$ 0.016	$ 0.009	$ 0.012	$ 0.0210	$ 0.0190	$ 0.0160	$ 0.0085	$ 0.0126	$ 0.0093	$ 0.0092	$ 0.010	$ 0.009	$ 0.006	$ 0.060	$ 0.036	$ 0.040

MI CHP Technical Potential by Prime Mover Type and Generating Capacity

SIC	Load Factor	Hours	A/C	Industrial Topping Business Type	50-500 kW Sites	50-500 kW MT	50-500 kW RE	50-500 kW FC	50-500 kW MW	50-500 kW Avg kW	500 kW - 1 MW Sites	500 kW - 1 MW MT	500 kW - 1 MW RE	500 kW - 1 MW MW	500 kW - 1 MW Avg kW	1-5 MW Sites	1-5 MW MT	1-5 MW RE	1-5 MW CT	1-5 MW MW	1-5 MW Avg kW
						49%	50%	1%				30%	70%					85%	15%		
20	High	7500	no	Food/Beverages	193	95	97	2	35	*181*	35	11	25	26	*743*	39	-	33	6	75	*1,923*
22	High	7500	no	Textiles	19	9	10	0	4	*211*	4	1	3	3	*750*	-	-	-	-	-	-
24	High	7500	no	Lumber/Wood	181	89	91	2	32	*177*	20	6	14	14	*700*	18	-	15	3	36	*2,000*
25	High	7500	no	Furniture	7	3	4	0	0.7	*100*	-	-	-	-	-	-	-	-	-	-	-
26	High	7500	no	Paper/Pulp	64	31	32	1	17	*266*	12	4	8	10	*833*	23	-	20	3	52	*2,261*
27	High	7500	no	Printing	36	18	18	0	4	*111*	2	1	1	1	*500*	-	-	-	-	-	-
28	High	7500	no	Chemicals	150	74	75	2	27	*180*	42	13	29	30	*714*	65	-	55	10	151	*2,323*
29	High	7500	no	Petroleum Refining	-	-	-	-	-	-	10	3	7	7	*700*	9	-	8	1	18	*2,000*
30	High	7500	no	Rubber/Misc/Plastics	300	147	150	3	49	*163*	21	6	15	15	*714*	11	-	9	2	19	*1,727*
32	High	7500	no	Stone/Clay/Glass	-	-	-	-	-	-	-	-	-	-	-	2	-	2	0	7	*3,500*
33	High	7500	no	Primary Metals	104	51	52	1	25	*240*	31	9	22	22	*710*	29	-	25	4	64	*2,207*
34	High	7500	no	Fabricated Metals	147	72	74	1	17	*116*	2	1	1	1	*500*	-	-	-	-	-	-
35	High	7500	no	Machinery/Comp. Equip.	14	7	7	0	2	*143*	-	-	-	-	-	2	-	2	0	3	*1,500*
37	High	7500	no	Transportation Equip.	300	147	150	3	59	*197*	111	33	78	77	*694*	91	-	77	14	178	*1,956*
38	High	7500	no	Instruments	5	2	3	0	0.9	*180*	-	-	-	-	-	-	-	-	-	-	-
39	High	7500	no	Misc. Manufacturing	6	3	3	0	0.5	*83*	-	-	-	-	-	-	-	-	-	-	-
49	High	7500	no	Gas Processing	14	7	7	0	2	*143*	-	-	-	-	-	2	-	2	0	6	*3,000*
				All Industrial Businesses	**1,540**	**755**	**770**	**15**	**275**	*179*	**290**	**87**	**203**	**206**	*710*	**291**	**-**	**247**	**44**	**609**	*2,093*

SIC	Load Factor	Hours	A/C	Industrial Topping Business Type	5-20 MW Sites	5-20 MW RE	5-20 MW CT	5-20 MW ST	5-20 MW MW	5-20 MW Avg kW	>20 MW Sites	>20 MW CT	>20 MW ST	>20 MW MW	>20 MW Avg kW	TOTALS Sites	TOTALS MT	TOTALS RE	TOTALS CT	TOTALS ST	TOTALS FC	TOTALS MW
						45%	45%	10%				75%	25%									
20	High	7500	no	Food/Beverages	6	3	3	1	49	*8,167*	-	-	-	-	-	273	105	157	9	1	2	185
22	High	7500	no	Textiles	-	-	-	-	-	-	-	-	-	-	-	23	11	12	-	-	0	7
24	High	7500	no	Lumber/Wood	2	1	1	0	13	*6,500*	-	-	-	-	-	221	95	121	4	0	2	95
25	High	7500	no	Furniture	-	-	-	-	-	-	-	-	-	-	-	7	3	4	-	-	0	0.7
26	High	7500	no	Paper/Pulp	2	1	1	0	16	*8,000*	3	2	1	118	*39,333*	104	35	61	7	1	1	213
27	High	7500	no	Printing	-	-	-	-	-	-	-	-	-	-	-	38	18	19	-	-	0	5
28	High	7500	no	Chemicals	24	11	11	2	234	*9,750*	3	2	1	132	*44,000*	284	86	170	23	3	2	574
29	High	7500	no	Petroleum Refining	-	-	-	-	-	-	1	1	0	44	*44,000*	20	3	15	2	0	-	69
30	High	7500	no	Rubber/Misc/Plastics	1	0	0	0	5	*5,000*	-	-	-	-	-	333	153	175	2	0	3	88
32	High	7500	no	Stone/Clay/Glass	2	1	1	0	10	*5,000*	-	-	-	-	-	4	-	3	1	0	-	17
33	High	7500	no	Primary Metals	2	1	1	0	27	*13,500*	3	2	1	117	*39,000*	169	60	99	8	1	1	255
34	High	7500	no	Fabricated Metals	-	-	-	-	-	-	-	-	-	-	-	149	73	75	-	-	1	18
35	High	7500	no	Machinery/Comp. Equip.	1	0	0	0	11	*11,000*	-	-	-	-	-	17	7	9	1	0	0	16
37	High	7500	no	Transportation Equip.	22	10	10	2	178	*8,091*	5	4	1	127	*25,400*	529	180	315	27	3	3	619
38	High	7500	no	Instruments	-	-	-	-	-	-	-	-	-	-	-	5	2	3	-	-	0	0.9
39	High	7500	no	Misc. Manufacturing	-	-	-	-	-	-	-	-	-	-	-	6	3	3	-	-	0	0.5
49	High	7500	no	Gas Processing	-	-	-	-	-	-	-	-	-	-	-	16	7	9	0	-	0	8
				All Industrial Businesses	**62**	**28**	**28**	**6**	**543**	*8,758*	**15**	**11**	**4**	**538**	*35,867*	**2,198**	**842**	**1,248**	**83**	**10**	**15**	**2,171**

MI Potential Cost/Performance Assumptions

- EPA prime mover cost/performance data for specific sized systems was extrapolated to average system sizes as determined through the Grant Team collaborative allocation of prime movers to total technical potential
- Tabulated data serves as a direct input to the STEER model

Prime Mover System (by TYPE)	RE1	RE2	RE3	RE4	RE5	RE6	RE7	RE8	RE9	RE10	RE11	RE12	RE13	RE14	RE15	RE16
Nominal/Nameplate Capacity (kW)	78	100	124	179	427	597	633	710	1,083	1,121	1,800	2,093	3,326	8,000	8,758	9,341
# of potential installations in Michigan	1,418	-	896	770	808	58	-	203	448	-	30	247	-	6	28	-
Net Power Generating Capacity (kW)	78	100	124	179	427	597	633	710	1,083	1,121	1,800	2,093	3,326	8,000	8,758	9,341
in MMBtu/hr	0.27	0.34	0.42	0.61	1.46	2.04	2.16	2.42	3.69	3.83	6.14	7.14	11.35	27.30	29.89	31.88
Electrical Heat Rate (Btu/kWh), HHV	12,875	12,637	12,186	11,566	10,498	10,498	9,890	9,749	9,272	9,272	8,749	8,530	8,446	8,222	8,222	8,202
Thermal Output (MMBtu/hr)	0.52	0.67	0.78	1.02	2.09	2.92	2.78	3.04	4.18	4.32	6.21	6.86	10.65	23.36	25.57	26.75
in kW/hr	151	196	227	300	611	854	815	891	1,224	1,267	1,818	2,009	3,120	6,843	7,492	7,837
Net Thermal Rate (Btu/kWh)	4,588	4,266	4,342	4,411	4,397	4,397	4,402	4,400	4,452	4,452	4,441	4,437	4,446	4,575	4,575	4,625
Fuel Input (MMBtu/hr) HHV	1.00	1.26	1.51	2.07	4.49	6.27	6.26	6.93	10.04	10.40	15.75	17.86	28.10	65.79	72.03	76.64
Total CHP Efficiency (%), HHV	78.0%	80.0%	79.5%	79.0%	79.0%	79.0%	78.9%	78.9%	78.4%	78.4%	78.4%	78.4%	78.3%	77.0%	77.0%	76.5%
Electrical Efficiency (%), HHV	26.5%	27.0%	28.0%	29.5%	32.5%	32.5%	34.5%	35.0%	36.8%	36.8%	39.0%	40.0%	40.4%	41.5%	41.5%	41.6%
Effective Electrical Efficiency, HHV (%)	74%	80%	79%	77%	78%	78%	78%	78%	77%	77%	77%	77%	77%	75%	75%	74%
Power/Thermal Ratio	0.51	0.51	0.54	0.60	0.70	0.70	0.78	0.80	0.88	0.88	0.99	1.04	1.07	1.17	1.17	1.19
Generator Availability	96.0%	97.9%	96.0%	96.0%	96.0%	96.0%	96.0%	96.0%	98.2%	98.2%	98.2%	98.2%	98.2%	98.2%	98.2%	98.2%
Total Installed Cost ($/kW Net Power Output)	$ 3,000	$ 2,900	$ 2,885	$ 2,875	$ 2,850	$ 2,840	$ 2,837	$ 2,700	2,370	$ 2,366	$ 2,250	$ 2,200	$ 1,801	$ 1,600	$ 1,500	$ 1,433
generating equipment only	$ 2,000	$ 1,900	$ 1,890	$ 1,875	$ 1,850	$ 1,800	$ 1,790	$ 1,700	1,480	$ 1,475	$ 1,350	$ 1,300	$ 1,140	$ 1,000	$ 950	$ 925
O&M, Variable, ($/kWh)	$ 0.025	$ 0.024	$ 0.024	$ 0.023	$ 0.022	$ 0.021	$ 0.021	$ 0.020	$ 0.019	$ 0.019	$ 0.018	$ 0.018	$ 0.016	$ 0.013	$ 0.012	$ 0.009

Refining MI CHP Technical Potential by Prime Mover Type and Generating Capacity

- Further break down DOE technical potential data from total number of CHP sites (per project size range) to number of CHP sites by prime mover type and generating capacity
- Required making assumptions about the future CHP market:
  - EPA cost/performance data for the various prime movers across the spectrum of available capacities
  - Project Team experience with public and private-sector CHP projects
  - Assumptions about the future of the market and pricing trends
- The relative proportion of prime movers in each CHP project size category can be easily refined by the Project Team moving forward to represent best available information

STEER Model

Introduction to STEER

- Open-access tool to find the least-cost implementation of the Clean Power Plan
- Conceived and managed by 5 Lakes Energy
- Initial development, called SCRAPS, funded by the Energy Foundation
- Additional development, STEER, funded by Advanced Energy Economy Institute
- Core model development by University of Michigan's Jeremiah Johnson and graduate students
- Data compilation and scenario analysis by 5 Lakes Energy, variously funded, for Michigan, Pennsylvania, Arkansas, Illinois, Virginia, North Carolina, Georgia, and Ohio
- STEER Michigan is delivered as an Excel spreadsheet and can be downloaded at no cost from: info.AEE.net/steer

How STEER works

Input Data
- Generator
  - Net Capacity, fuel, heat rate and VOM
- Net Load
  - 24 representative days
  - Weekday/weekend

Represent the Grid
- Create merit order of generators from dispatch costs
- Use merit order to match net load with generation to create hourly LMPs curves
- Calculate annual generation and emissions from LMP data

Incorporate Building Blocks for Mitigation
- STEER calculates the mitigation cost of each mitigation measure

Meet the Carbon Rules
- Optimization accounts for the interactive effects of the building blocks rather than a sequential selection of projects by block
- STEER minimizes the cost to mitigate from all blocks to create a unique mitigation strategy

Key Benefits of STEER

STEER was created specifically for state-level analysis of CPP

- Automatically finds least-cost plan given policies and forecasts
- Self-contained Excel file that can be readily modified
- High resolution of input data and results, matching utility and regulator decision structure
- Generator level data
- Renewable resources (site-specific hourly resolution)
- Energy efficiency (>200 measures from three sectors)
- Addresses both system-wide emissions and cost impacts
- Reflects interactive effects of mitigation options
- For example: coal unit heat rate improvements affect carbon mitigation potential of coal to gas switching
- Allows evaluation of a full range of generation and demand management technologies.

Reliability/Resource Adequacy in CPP Implementation

Reliable power and resource adequacy are addressed in STEER.

- STEER Michigan models hourly demand as modified by energy efficiency, demand response, conservation voltage reduction, and net of non-dispatchable generation. It deploys dispatchable generators in merit order to satisfy net hourly load and calculates resulting locational marginal price, generation costs, and emissions.
- Under business as usual without the Clean Power Plan but with the announced plant retirements, STEER would recommend constructing (or purchasing equivalent capacity credits) 4800 MW of new capacity by 2030 to replace announced retiring capacity and meet load growth.

Natural Gas Generation in STEER

Existing STEER Michigan considers natural gas generation in four ways:

- Existing natural gas plants
- Advanced Combustion Turbines built and operated for capacity unless displaced by other generation
- Additions of new natural gas combined cycle plants
- Additions of new natural-gas-fueled industrial cogeneration. This project adds the full cogeneration taxonomy to STEER.

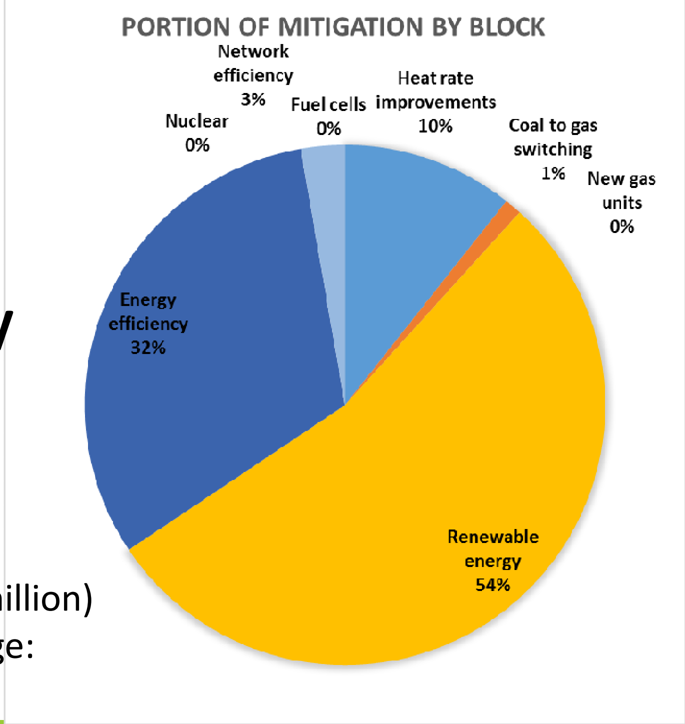
STEER Model Outcomes

- While the model allows for customization, there are some clear outcomes based on likely scenarios for Michigan’s energy system.
- Results presented are based on CPP carbon limits for 2030.

Network Efficiency in CPP Implementation

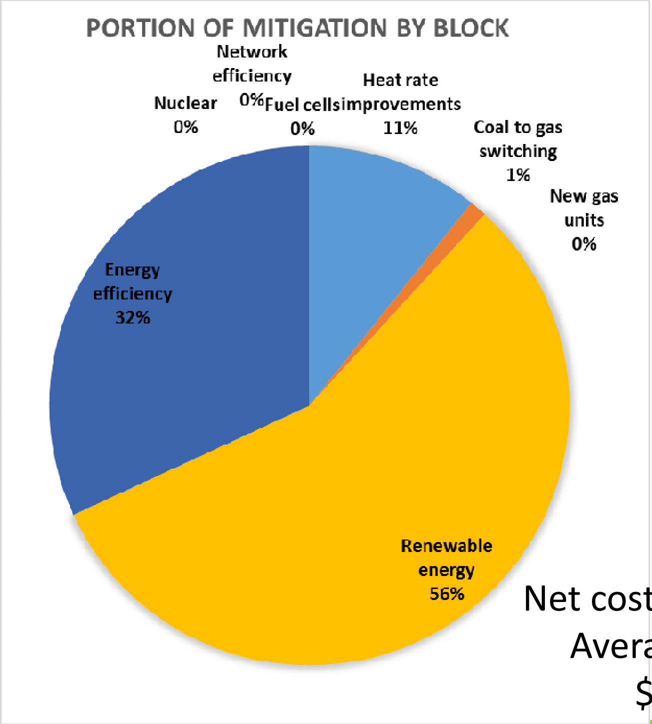
Network Efficiency technologies include Dynamic Volt-VAR control and Conservation Voltage Reduction

With Network Efficiency



Net cost of CPP: ($96 million)
Average Rate Change: ($0.0009/kWh)

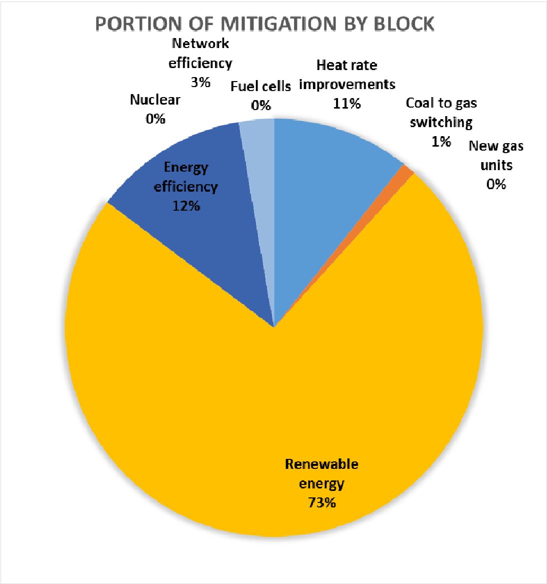
Without Network Efficiency



Net cost of CPP: $14 million
Average Rate Change: $0.0001/kWh

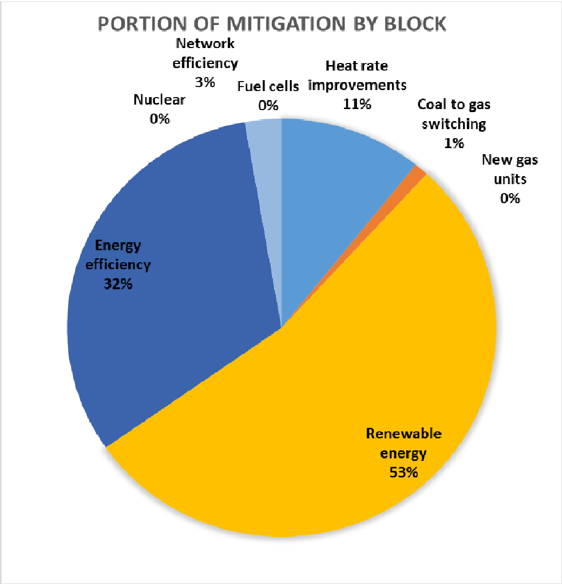
Utility Efficiency Programs in CPP Implementation

GDS Constrained Potential



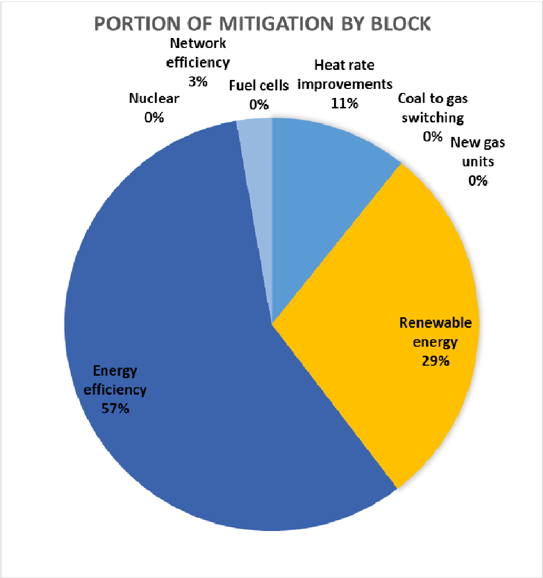
Utility Cost of EE: $132 million
Net cost of CPP: $673 million
Average Rate Change:
$0.0059/kWh
Load reduction: 4.2%

GDS Achievable Potential



Utility Cost of EE: $366 million
Net cost of CPP: ($96 million)
Average Rate Change:
($0.0009/kWh)
Load reduction: 11%

GDS Economic Potential

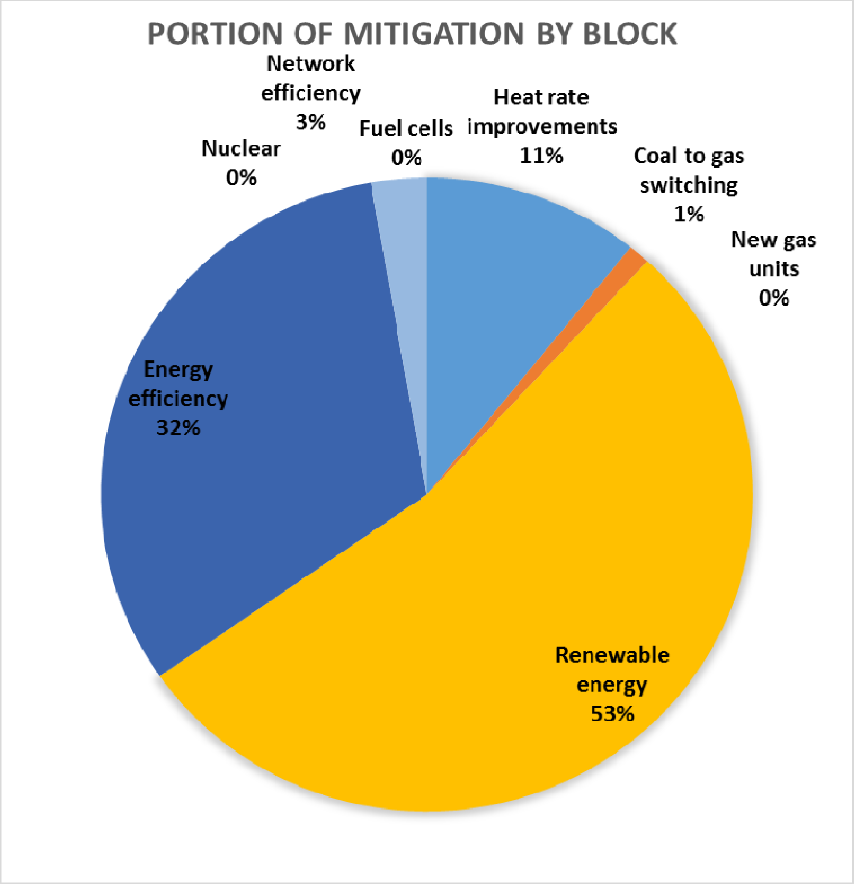


Utility Cost of EE: $596 million
Net cost of CPP: ($811 million)
Average Rate Change:
($0.0085/kWh)
Load reduction: 20%

Generation Tradeoffs

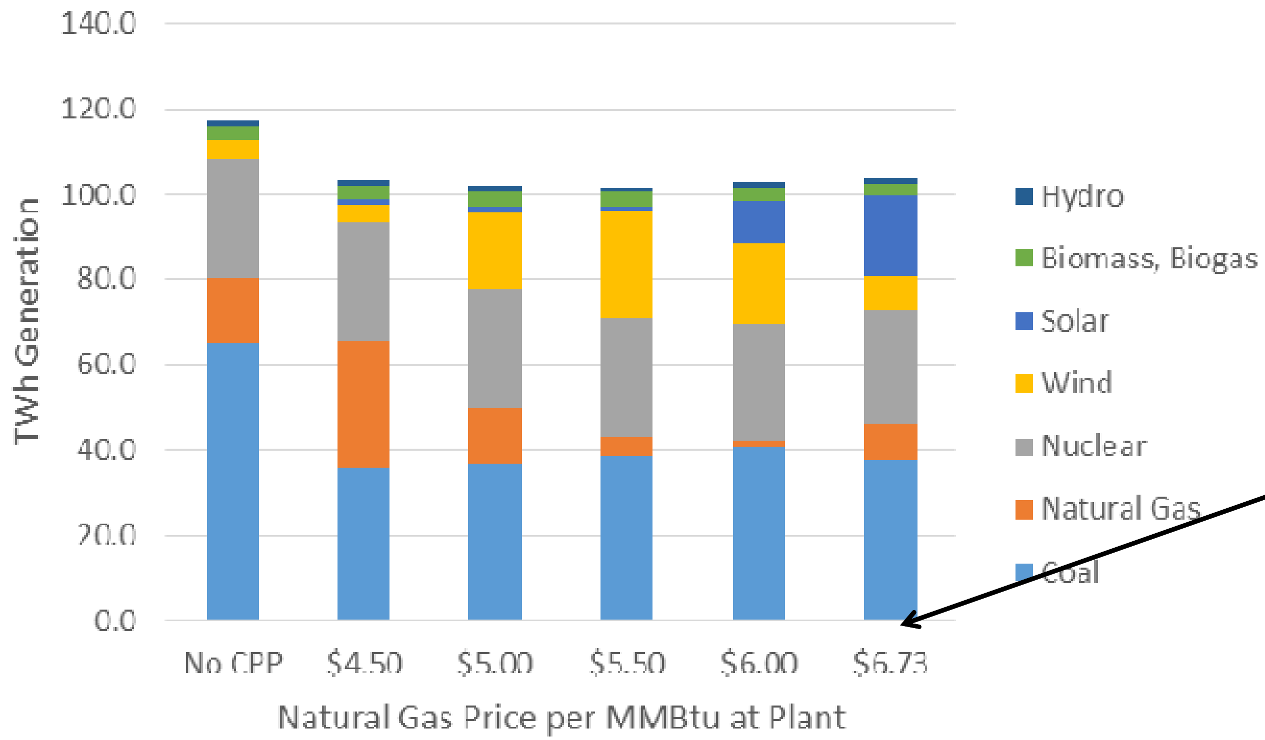
Network Efficiency and End-Use Energy Efficiency are always recommended as part of the least-cost CPP implementation, because they are cost-effective even without CPP.

- If we assume GDS achievable energy efficiency potential, 2% network efficiency, and 1% net metering cap, these account for about 35% of Michigan's carbon mitigation under the CPP rule.
- Changes in generation must accomplish the remaining 65% of carbon mitigation.



Least-cost Generation Mix

Generation requirements in 2030 are significantly avoided due to energy efficiency programs.

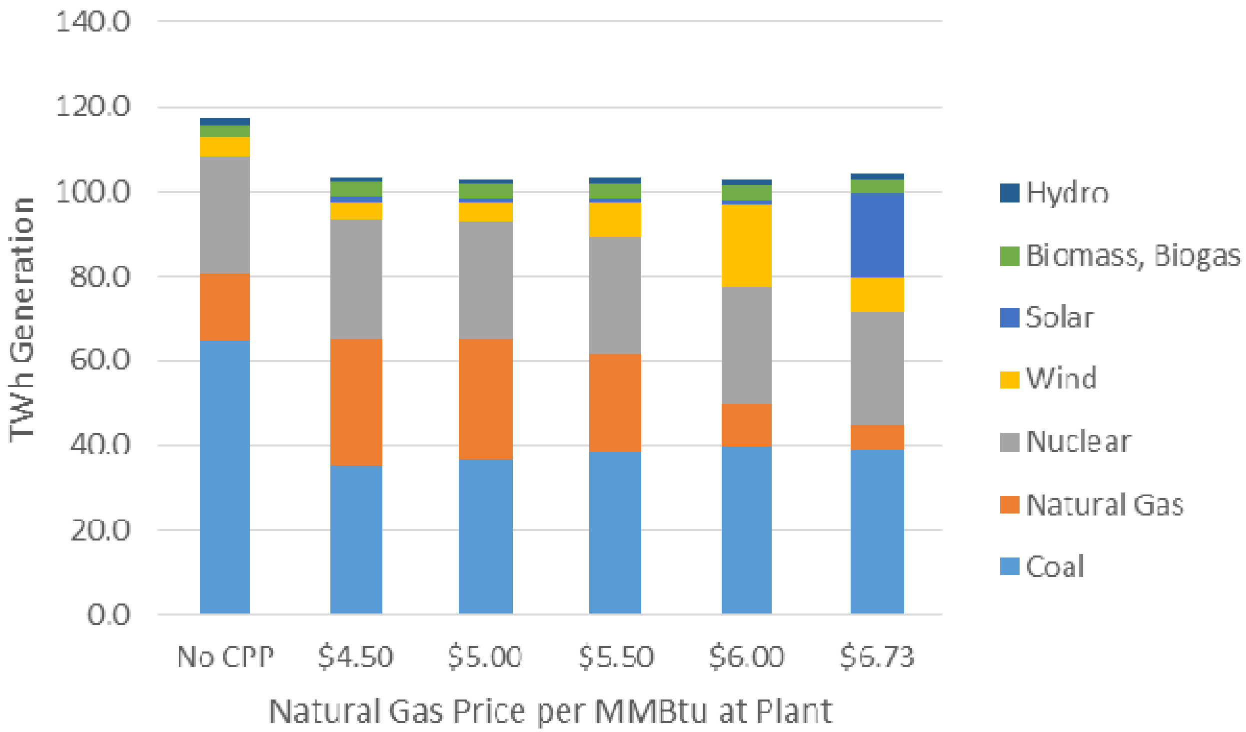


Without Co-generation

Generation strategy is a bet on the future price of natural gas

Least-cost Generation Mix

With co-generation, natural gas generation is cost-effective at substantially higher natural gas prices than without cogeneration.



With Co-generation

Barriers to CHP

Methodology

- Surveyed Market Participants
  - Developers / Equipment Reps / Sites
- TAP Knowledge
  - Screening Analysis Results
- Regulator Discussions
  - MPSC / DEQ
- General Barriers

Education

- 53 MW has been removed over the past 10 years (Luckily, 45 MW was due to plant closings)
  - Detroit Area hospitals have largely removed CHP
  - Bad experiences are difficult to overcome
- Solutions?
  - Promote Technical Assistance
  - Workshops
  - Increasing Awareness

Utility Rates

- Industrial Rates (Spark Spread)
  - Relatively low electric prices make CHP economic viability relatively challenging
  - Industrial customers require very short payback (usually >1 year and not more than 2 years)
- Equilibrium with Natural Gas Prices
  - Decreased value in CHP when power prices start following gas prices (currently 20% generation comes from NG)

Utility Rates

- Standby Rates
  - High standby rate / increase payback
  - Confusing
  - Do not acknowledge possible benefits that CHP installations bring to the grid
- PURPA Avoided Cost Rates
  - Low avoided costs lead to under sizing of CHP systems to prevent export to the grid

Utility Adoption

- Utilities Don’t Plan for New CHP
  - Uncomfortable with planning resources they don’t control
- Utilities Don’t Want New CHP
  - Earn profits on investment in plants
  - Customer-owned CHP reduces utility profits

Addressing Barriers

Regulatory Action

- Standby Rate
- Avoided Cost Rates
- Integrated Resource Planning

CHP Effects on Facility Average Hourly Electricity Using NYSERDA Data from ConEd Territory

Facility	121	133	166	185	203	211	227	236	252	312	166	181	185	203	211	227	252	312	345
Year	2014	2014	2014	2014	2014	2014	2014	2014	2014	2014	2015	2015	2015	2015	2015	2015	2015	2015	2015
CP1	-6705	-547	-290	-63	-238	2	-98	-234	-109	-31	-450	-128	-137	-245	-62	-48	-39	-35	-1
CP4	-6801	-554	-360	-137	-226	-69	-113	-235	-115	-32	-339	-240	-139	-246	-133	-99	-30	-35	-9
CP12	-5731	-452	-368	-139	-235	-125	-95	-216	-91	-35	-345	-250	-103	-241	-162	-106	-39	-37	-43
Energy	-5837	-493	-327	-89	-232	-124	-97	-149	-95	-28	-323	-232	-97	-241	-175	-108	-39	-28	-41
Peak Energy	-6142	-512	-347	-103	-231	-129	-100	-163	-94	-33	-337	-265	-104	-240	-177	-109	-40	-32	-41
Off-peak Energy	-5742	-487	-320	-85	-232	-122	-96	-144	-95	-27	-318	-222	-95	-241	-174	-107	-39	-26	-41
Winter Peak Energy	-5830	-497	-331	-110	-233	-149	-96	-156	-89	-35	-325	-258	-92	-238	-185	-109	-43	-33	-45
Summer Peak Energy	-6790	-541	-379	-88	-226	-88	-107	-178	-106	-29	-359	-278	-128	-244	-163	-110	-34	-29	-32
Demand	-3235	-209	-111	-36	-52	0	-3	-25	-110	-2	-121	-160	-82	-99	1	-6	-27	1	-1
Monthly Peak Demand	-4573	-404	-255	-65	-54	-57	-11	-48	-86	-31	-238	-202	-54	-86	-66	-35	-29	-16	-12
CPP Energy	-6787	-551	-358	-160	-221	-149	-105	-211	-116	-33	-395	-262	-113	-225	-128	-105	-36	-33	-23

Empirical Rate Design

Assume cost drivers (e.g. 4CP, 12CP) are valid but not usable as billing determinants

Assume a set of usable billing determinants (e.g., demand, energy, etc.)

Assignment of costs to individual customers with least error can be found by regressing each cost driver (dependent variable) against the set of billing determinants

Billing determinant coefficient * average value of billing determinant/average cost driver = % of cost driver to allocate to billing determinant

5 Lakes Energy Recommendations to MPSC Standby Rates Working Group

Based on analysis of data about ConEd's CHP customers, rate design for standby and supplemental power for Michigan CHP customers should be based only on billing determinants as follows:

- Off-peak Energy (energy costs only)
- Winter Peak Energy (energy and transmission)
- Summer Peak Energy (energy, transmission, and capacity)
- and, perhaps, Critical Peak Period Energy

No distinction between standby and supplemental power appears warranted when demand isn't used as a billing determinant.

5 Lakes Energy Recommendations to MPSC PURPA Avoided Costs Working Group

Cogeneration and renewable generation facilities to be compensated based on costs of capacity and energy from what the utility would build next – usually combined cycle natural gas plant.

Credit for avoided transmission and distribution costs

“Bankable” contract terms.

Integrated Resource Planning

Under MCL 460.6s(4)(a), a utility seeking a Certificate of Necessity for a new power plant, transmission project, or major power purchase contract must show that they have established the need for that capacity through an approved Integrated Resource Plan. This is a relatively new requirement and has not been completed by a Michigan utility.

Pending legislation would require periodic Integrated Resource Plans by each utility.

Integrated Resource Planning

- IRP must include a description of existing and potential DG resources.
  - A description of the distributed generation technology, primary fuel and fuel alternatives, capacity, and expected capacity factor.
  - Costs of developing, acquiring, or purchasing energy from distributed generation resources.
  - A discussion of the commercial viability, availability, or developmental status of distributed generation technologies.

Integrated Resource Planning

- Unanswered questions:
  - Where does CHP Fit?
    - Supply Side / Demand Side?
    - Utility Owned / Behind the Meter?
    - Load Forecasting?

Stakeholder Engagement
Mapping Supply and Value Chains

Stakeholder Engagement

Methodology

- Announced the study at 2016 CHP in Michigan Conference in partnership with Oakland University
- Seek input from NEP Stakeholders – June 2016
- Conference for CHP at Hospitals – August 2016
- Education and outreach through Economic Development regions to potential end-users and A & E firms
- Seek input from NEP Stakeholder – January 2017
- Partner with Oakland University on 2017 CHP in Michigan Conference

Supply Chain & Value Chain

Methodology

- What is required to implement CHP?
- What is or can be made in Michigan?
- Create a Strawman of Supply Chain/Value Chain
- Populate database with contacts
- Conduct surveys
- Conduct targeted interviews
- Revise assumptions and gather information to address gaps

Supply Chain

Fuel contractors/suppliers

Prime Movers Manufacturers & Distributors

- Gas Turbine
- Steam Turbine
- Reciprocating engine
- Fuel cell
- TBD based on Task 1/ Task 2

Major Component Manufacturers & Distributors

- Controls equipment and programming
- Electrical generator
- Interconnection equipment
- Heat recovery unit
- Absorption chiller
- Radiator
- Pumps & water treatment for cooling loop

Gas conditioning system (for biogas/ landfill gas applications)

Value Chain

Project Design & Development

- Academic, incubator, accelerator
- Feasibility analysis firms
- Project developers
- Architectural/engineering firms
- Permitting/Regulatory agencies
- Utilities (electric/gas), ESCOs
- Legal firms
- Tax advisory firms

Project Investment/Financing

- Banks (debt lenders)
- Venture capital (equity) providers
- Tax equity partners
- Governmental agencies (grants)
- Property Assessed Clean Energy (PACE) financing

Construction, Installation, and Operations

- EPC contractor
- Electrical contractor
- Mechanical contractor

Operations & maintenance providers

Logistics

Testing

Recycling/remanufacturing