The Economics of Combined Heat & Power Systems in Massachusetts

Prepared by:

Energy Tariff Experts

for the

Associated Industries of Massachusetts (AIM) Foundation

and the

Massachusetts CHP Coalition

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Introduction

This study was done to provide up-to-date and accurate information on the costs to install and operate Combined Heat and Power (CHP) systems in Massachusetts. That information was used to estimate the time to simple payback from the operation of those CHP systems and gather insights regarding organizational decision making to proceed with CHP investments including the critical role that state incentives have played in shortening those estimated payback times. Time to payback, as referred to in this report, represents the time in years to achieve a positive value for cumulative cash flows from a CHP project given the selected input variables.

The study was prepared by Energy Tariff Experts (ETE)[1] for the Associated Industries of Massachusetts (AIM) Foundation.[2] The Foundation was assisted in contracting for the study with support from a diverse group of CHP system owners in Massachusetts that calls itself the Massachusetts CHP Coalition.[3]

The study presents data and related analysis of capital and operating costs of Thirty-six (36) CHP systems located in Massachusetts of various sizes and technologies. It included a survey of the owners and operators of CHP systems that are either operating or in advanced stages of construction and collected data regarding the capital costs for construction of these systems as well as operation and maintenance (O&M) expenses.

This data was then used to populate a pro-forma model created by ETE to determine estimated time to payback for turbine and reciprocating engine systems of various sizes, located in different electric and gas utility service areas in Massachusetts.

Principle Findings of the Study

The study by ETE resulted in the following principal findings.

1. In the case of typical CHP systems in Massachusetts, capital costs are approximately $5,000/kW for reciprocating engines and $6,500/kW for turbines.

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1 Energy Tariff Experts, Inc. (ETE) is a Boston-based consulting firm that provides analysis of utility costs for retail consumers of electricity. ETE's capabilities include provision of energy cost studies for existing or planned infrastructure, expert witness support, tariff optimization, regulatory research, and provision of utility rate datasets. ETE has worked on CHP projects throughout the US including several in MA and provides services as an Independent Verifier (IV) for the generation of AECs in the MA APS for several CHP facilities.

2 The AIM Foundation is a section 501(C)(3) tax-exempt organization authorized under the Internal Revenue Code by Associated Industries of Massachusetts (AIM) to develop in-depth, non- partisan analysis of public policy issues.

3 The member companies of the CHP Coalition include the Associated Industries of Massachusetts, Encore, Erving Industries, Green Harbor Energy, Medical Area Total Energy Plant (MATEP), NextGrid Markets, Renew Energy Partners, Twin Rivers Technologies and Vicinity Energy.

2. Average operating costs for CHP systems range from $178/kW-year for reciprocating engines and $147/kW-year for turbines.

3. Discussions with CHP owners revealed that, to approve an investment in a CHP system, most companies require their investment be paid back through savings (compared to alternative feasible technologies) in 5 years or less.

4. Alternative Energy Credits (AECs) produced pursuant to the Alternative Portfolio Standard (APS) are a crucial revenue stream to accomplish projects at or below the 5-year payback threshold. Depending on their market value, these credits can reduce payback times by 1 to 2 years.

5. Few projects are approved with paybacks longer than 5 years. Those that are approved typically involve other site-specific considerations such as mission critical needs for resilient and continuously reliable power supply (for example, hospitals). Nevertheless, their economic acceptability still depends heavily on the revenue from the monetizing of APS credits.

Context for the Study

The MA Department of Energy Resources (DOER) is currently conducting a review of the Alternative Energy Portfolio Standard (APS).[4] This review includes a study of the costs and benefits of the program to ratepayers, an examination of the effectiveness of the program in meeting the energy and environmental goals of the Commonwealth, and an evaluation of whether the Minimum Standard or its rate of increase should be adjusted.

As part of this process, DOER commissioned a report from Daymark Energy Advisors. LLC (hereafter, Daymark) to provide an assessment of the APS program and recommendations for future changes. The Daymark report was made available by DOER to APS stakeholders who were invited to comment on it by December 4th, of 2020. The Daymark report included several claims regarding CHP systems including:

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[4] The APS regulatory program was established by legislation pursuant to The Green Communities Act of 2008, Chapter 251 of the Acts of 2014 and Chapter 188 of the Acts of 2016. The most recent version of the APS regulations was finalized in 2019.

- *"CHP systems are currently economic without the support of the APS…….and do not require the support of the APS in order to achieve net benefits over a 5-year period."*[5]
- *"CHP is economic without the support of the APS for the three sizes studied. This is evidenced by the fact that all three cases modeled achieve a positive NPV in less than 5 years of operation and the payback period for CHP units is approximately 1 year."*[6]
- CHP installed capital costs range from $2,028 to $3,266/kW and operations and maintenance expenses range from $8 to $20/kW-yr.[7]

Many CHP owners and operators, developers, and other CHP industry participants in MA were concerned that the claims in the Daymark report regarding CHP costs and economics were inaccurate. This study was prepared to provide DOER with information regarding CHP costs and economics that reflect the actual experiences of owners and operators of CHP systems located in Massachusetts.

Survey to Collect CHP Data

ETE devised a CHP facility questionnaire and worked with the CHP Coalition to send it to CHP facility operators, engineering firms, CHP developers, and equipment suppliers to assemble a dataset of installed and under construction projects in MA. The questionnaire gathered data on topics such as:

- Type of organization (whether for-profit or not-for-profit);
- Generating capacity of the CHP system in kW;
- Type of CHP technology (turbine vs reciprocating engine) and manufacturer
- Commissioning date for the CHP system;
- Electric and/or gas utility providing fuel and/or power;
- Capital costs to install the system (inclusive of equipment, engineering, project management, and interconnection);
- O&M costs of the system (inclusive of long-term service agreements, consumables, replacement parts): and
- Other CHP-driven costs beyond the owner's "business-as-usual" costs.

ETE checked the responses for sufficient completeness so that only high-quality data was used in the study. When survey responses were ambiguous or facilities had significant complexity, ETE conducted follow-up conference calls to ensure that key operational details and financial

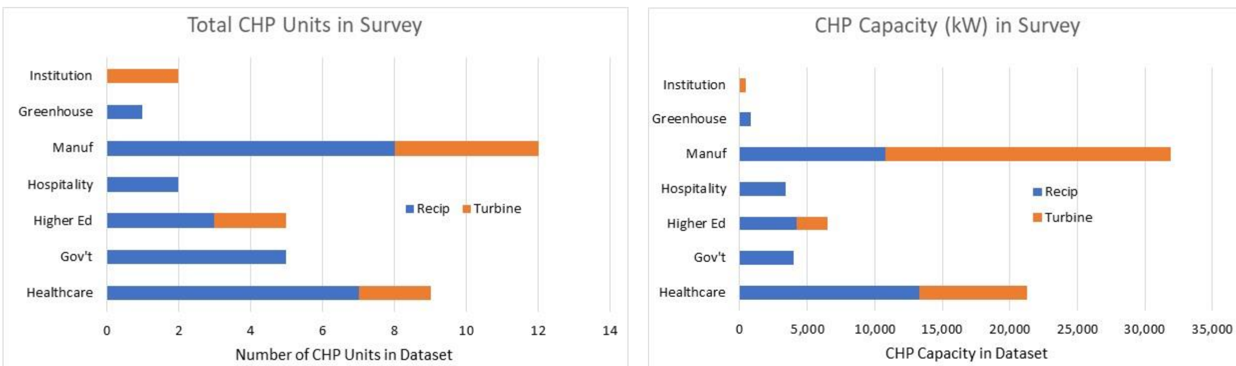
[5] Daymark Energy Advisors, ALTERNATIVE ENERGY PORTFOLIO STANDARD REVIEW, Prepared for Massachusetts Department of Energy Resources, 10/30/2021, p. 6
[6] Ibid, p. 18
[7] Ibid, p. 44

performance metrics were fully understood. For facilities constructed prior to 2021, ETE used a composite of energy related PPI indices to trend capital costs to 2021 dollars.[8]

Summary of Sites in the Dataset

ETE assembled a dataset that included thirty-six (36) CHP systems installed in MA within the last eight years. *Figure 1* below provides an overview of the number of CHP units and nameplate electric capacity in kW in the dataset by industry.

Figure 1: CHP Units and Capacity Included in the Dataset



As *Figure 1* indicates, the healthcare, higher education, and manufacturing sectors comprise the majority of the dataset. Twenty-two (22) sites in the dataset are in the National Grid electric service area while thirteen (13) are served by Eversource and one by Until.

Capital Costs of MA CHP systems

ETE received complete capital cost responses for thirty-four (34) systems in the survey. Figure 2 shows the system capital costs by CHP nameplate kW and technology type.

[8] ETE used the following weightings of PPI indices to trend capital costs to the present: Power Distribution (25%); Electric Turbine Generator Manufacturing (50%); Electric Power & Specialty Transformer Manufacturing (15%); and Engineering Services (10%)

Figure 2: Capital Costs of CHP Systems in the Dataset

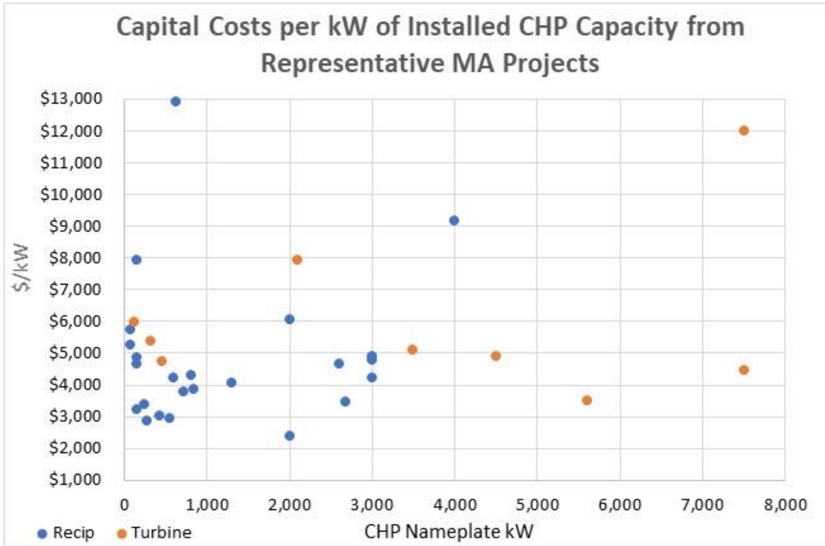


Table 1 below provides a summary of average system capital costs by size and technology type.

Table 1: Average Capital Costs ($/kW) of CHP Systems Constructed in MA by Size and Technology

Size Category	Reciprocating Engine ($/kW)	Turbine ($/kW)
Small (< 500 kW)	$4,550	$9,230
Medium (500 – 3,000 kW)	$4,791	
Large (> 3,000 kW)	$5,757	$5,985

Annual O&M Costs for MA CHP systems

ETE obtained high quality data for O&M expense from twenty (20) CHP facilities. ETE normalized the data provided to units of $/kW-year as some CHP systems provided O&M data in terms of $/kWh of electric generation while others provided data based on $/run hour. *Figure 3* shows the O&M costs for CHP systems in the dataset.

Figure 3: Operating Costs of CHP Systems in the Dataset

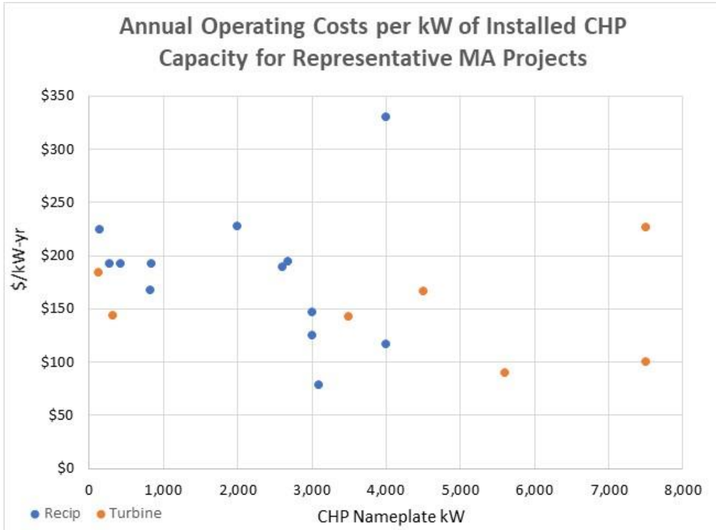


Table 2 below provides a summary of annual operating costs for CHP systems in the dataset.

Table 2: Summary of Annual O&M Costs ($/kW-yr) for CHP Systems in the Dataset

Operating Costs ($/kW) - All Systems				
	Min	Average	Max	Sample Size
Small	$144	$188	$225	5
Medium	$167	$194	$228	5
Large	$79	$152	$330	10

Table 2 includes data for both reciprocating engines and turbines. Turbine systems tend to have lower O&M costs than reciprocating engines.

Pro-forma Model Description

ETE created a pro-forma model to estimate the Net Present Value (NPV) and Years to Simple Payback for CHP systems with estimated sizes of 100 kW, 2,000 kW, and 5,000 kW.[9, 10] The model calculates useful thermal and electric generation from CHP systems and natural gas consumption from the CHP systems. The natural gas consumed by CHP systems is compared with the natural gas that would otherwise be consumed by a standard boiler in the absence of CHP. The savings attributable to CHP are based on the avoided electric cost minus the

9 Turbines were omitted from the 2,000 kW scenario due to a lack of data for turbines of this size.

10 Cumulative cashflows are calculated by summing the initial cash outlay for the system with subsequent annual cash flows. Annual cash flow is calculated by taking the Net Income from the pro-forma statement and adding back depreciation and subtracting debt principal payments (if applicable). The pro-forma net income model considers energy savings and AEC revenues as income and expenses include Operations & Maintenance, debt interest (if applicable), and income taxes (if applicable).

incremental cost of natural gas for CHP systems relative to the natural gas cost for a standard boiler in the no CHP scenario.

This gross savings value represents top line revenue which may also include revenues from the sales of AECs based on scenario selections. The top line revenues are then adjusted for O&M costs, depreciation, debt costs (if applicable), and income taxes (if applicable) to determine net income, cash flow, and cumulative project cash flows.

Model Inputs and Assumptions

The model has built-in assumptions for power-to-heat ratios by CHP technology type. It uses capital and O&M costs from CHP systems' survey data.[11] Natural gas and electric costs are determined using May 2021 effective utility rates for National Grid and Eversource.[12] The model assumes that CHP users would have competitive electric supply charges at a discount of 10% to Basic Service costs.

Other variables that users can directly enter into the model include CHP unit operating hours (% of time operating) and efficiency, number of trips per year, escalation rates for utility and O&M charges, debt interest and NPV hurdle rates, utility incentives, for profit vs non-profit entity, ITC eligibility, and AEC eligibility and AEC prices. A screenshot of the inputs and variables in the model is included in Appendix A.

The model purposefully makes several aggressive assumptions including the following:

- CHP system is undersized relative to onsite loads and all thermal and electric generation is fully utilized.
- Unit operating time is in the 90% range.
- System efficiency is approximately 78%.
- The number of months with unit trips (creating foregone demand savings) are 7 for turbines and 9 for reciprocating engines.

ETE utilized these assumptions in order to present an optimistic case for CHP economic performance utilizing the capital and O&M costs collected in its survey. These optimistic assumptions were also used to try to replicate the results of the Daymark report. An optimistic case on CHP operations was used to avoid criticism that the study was designed to make a case for APS credits based on the need to make up for poor operating characteristics. See Appendix A for an illustration of the model inputs and assumptions in spreadsheet format.

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[11] The pro-formal model assumes Power to Heat ratios of 0.5 for turbines (2 MMBTU heat for 1 MMBTU power) and 1 for reciprocating engines

[12] Modeled natural gas rates include National Grid G-53 and G-54 and Eversource G-52 and G-53 depending on CHP system size. Modeled electric rates include National Grid G-3 (WCMA) and Eversource B-7 and B-3 (NEMA) depending on system size. All rates used in the model are those posted on tariff sheets effective as of May 2021. Basic Service rates used to estimated supply costs are from June 2020 through May 2021.

Results from the Model Regarding Paybacks for CHP systems

The model results over a range of variables are shown in *Table 3*. Scenarios are shown in groupings of three where the utilities, entity types, and trip scenarios are held constant and the Years to Simple Payback are calculated over a range of AEC price scenarios. As the data illustrates, CHP systems generally have a time to Simple Payback of seven years or greater without AECs and that AEC revenues provide a material improvement in project paybacks.

Table 3: Summary of Time to Simple Payback Under Different Scenarios

	Summary of Time to Simple Payback for CHPs Under Various Scenarios											
Model Variable	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**
Electric Utility:	Eversource			Eversource			National Grid			National Grid		
Gas Utility:	National Grid			National Grid			Eversource			Eversource		
Entity Type	For Profit			Non-Profit			For Profit			Non-Profit		
No. Trips/yr - Recip Engine	9			9			9			9		
No. Trips/yr - Turbine	7			7			7			7		
AEC Value:	None	$10	$20	None	$10	$20	None	$10	$20	None	$10	$20
Time to Simple Payback by CHP Technology & Size												
100 kW Recip	7	6	5	8	6	5	6	5.8	5.2	7	5.8	5.2
2,000 kW Recip	7	6	5	8	6	5	6	5.6	5.1	6	5.7	5.15
5,000 kW Recip	8	7	6	9	7	6	7	6	5	7	6	5
100 kW Turbine	10	8	7	>10	9	8	9	8	7	10	8	7
5,000 kW Turbine	8	7	6	8	7	6	7	6	5	7	6	6

Comparison of the Model Results to the Daymark Results

As the table in the previous section demonstrates, Time to Simple Payback for CHP systems across a range of sizes and technologies is approximately five years for CHP systems that can earn AECs at an AEC price of $20/AEC. This is a significantly longer payback term than the payback term of approximately one year claimed in the Daymark report. We now try to account for the discrepancies between estimates from the ETE Model of Existing CHP Systems and the results found in the Daymark report.

The Daymark report provided estimated capital cost and O&M cost data for reciprocating engine systems of 100 kW, 633 kW, and 3,326 kW. *Table 4* and provide a comparison of the values asserted by Daymark and those collected from MA CHP industry participants with reciprocating engines in CHP Coalition dataset.[13]

13 Daymark Energy Advisors, ALTERNATIVE ENERGY PORTFOLIO STANDARD REVIEW, Prepared for Massachusetts Department of Energy Resources, 10/30/2021, Table 17, p. 44

Table 4: Comparison of Capital Costs for Reciprocating Engines ($/kW)

System Size	Daymark	MA CHP Dataset
Small	$3,266	$4,550
Medium	$3,194	$4,791
Large	$2,028	$5,757

Table 5: Comparison of Operating Costs for Reciprocating Engines ($/kW-yr)

System Size	Daymark	MA CHP Dataset
Small	$20	$203
Medium	$20	$194
Large	$20	$159

CHP Development Timelines

Complex CHP systems are approved by management at host sites at least two years before they enter operation. Procurement of required equipment, engineering, and construction efforts can range from one to three years depending on site complexity, resiliency needs, and interconnection issues. Optimistic times to simple payback are approximately five years if CHP facilities are able to earn AECs. Without AECs, payback periods are longer by two years or greater. Most entities, whether for profit or non-profit will not approve an energy capital project that demonstrates a payback of greater than five years.

Given the long project lead times and capital-intensive nature of CHP projects, it is important for policies to be stable over the period of time that a CHP project requires in order to meet its expected financial metrics. CHP operators in MA are faced with a dramatically different APS landscape in 2021 compared with just a few years ago when many projects were approved in reliance upon a regulatory framework that has now shifted. This policy instability can undermine faith in MA incentive programs and has presented financial challenges for CHP systems that have recently come online or are in advanced stages of development.

Conclusions

- The dataset for capital and O&M costs assembled by ETE with assistance from CHP Coalition is more representative of the experiences of CHP industry participants in Massachusetts than the estimates used by Daymark in their report.
- Typical CHP capital costs are approximately $5,000/kW for reciprocating engines and $6,500/kW for turbines.

- Average operating costs for CHP systems range from $178/kW-yr. for reciprocating engines and $147/kW-yr. for turbines.
- Discussions with CHP owners and operators reveal that most organizations require a base case payback of 5 years or less to approve an investment in CHP.
    - AECs are a crucial revenue stream to bring projects to the 5-year threshold as they can accelerate payback by 1-2 years depending on their value.
    - Few projects are approved with longer paybacks. Those that are typically involve other site-specific considerations such as resiliency.
- CHP systems in Massachusetts are able to achieve the time to simple payback of five years when eligible to earn AEC revenues at AEC prices of $20/MWh. This more accurately reflects actual CHP business conditions in Massachusetts compared with the Time to Simple Payback of approximately one year claimed by Daymark.
- CHP systems involve long lead times and require long term policy stability to achieve the required financial metrics for project approval from management at host sites.

Appendix A:

Pro-forma Model Inputs and Variables

Assumed boiler Eff:	80%	CHP Type	Recip	Entity Type:	For Profit	AEC Eligible:	TRUE
Assumed CHP efficiency:	78%	No. of Trips/yr	9	Eff Tax Rate:	29%	AEC Price ($/AEC):	$15
% Uptime:	95%	Electric Utility	National Grid	Amount Financed:	$0	Utility Incentive ($/kW):	$750
Capex ($/kW):	$4,791	Gas Utility	National Grid	Loan Term (yrs)	6	Discount Rate:	6%
Opex ($/kW-yr):	$194	Nameplate (kW):	2,000	Debt Interest Rate:	6%	NPV (10 yrs)	$4,253,000
Total Capex:	$9,582,042	YoY Electric Cost Trend:	3.0%	O&M Escalator:	3.00%	IRR	18%
Capex net of Utility Incentive:	$8,082,042	YoY Nat Gas Cost Trend:	3.0%	Depreciation Sch:	5-year	Yrs to Simple Payback:	5
Total Annual Opex:	$388,599	Supply Discount to Basic Service	10%				