Energy Benchmarking Analysis

A study to identify energy benchmarks for Minnesota's manufacturers

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Minnesota Technical Assistance Program
MnTAP

Project Goals & Objectives

The overall goal of the project is to help Minnesota utilities meet the 1.5% annual energy savings goal by assisting Minnesota business and industry to identify opportunities to become more energy efficient.

To achieve the overall goal, MnTAP conducted industrial market sector analyses to identify sector-specific energy efficiency opportunities for eight investor-owned utilities. This benchmarking project built upon the industrial market analysis and included analyzing energy use and facility metric data (facility area, employment data, and sales) to develop energy use benchmarks. The benchmarks are intended to be used to compare facility energy use with that of sub-sector peers.

Utility Companies Represented

Alliant Energy
CenterPoint Energy
Great Plains Gas
Minnesota Energy Resources Corp.
Ottertail Power
Xcel Energy

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About MnTAP

The Minnesota Technical Assistance Program (MnTAP) is an outreach and assistance program at the University of Minnesota that helps Minnesota businesses develop and implement industry-tailored solutions that prevent pollution at the source, maximize efficient use of resources, and reduce energy use and cost to improve public health and the environment.

Established in 1984, MnTAP is funded primarily by the Minnesota Pollution Control Agency's Prevention and Assistance Division and is located at the University of Minnesota in the School of Public Health, Division of Environmental Health Sciences. The University's mission, carried out on multiple campuses and throughout the state, is threefold: research and discovery, teaching and learning, and outreach and public service.

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Introduction

Energy benchmarks provide a means for comparing a facility's annual energy use to that of similar facilities. An energy benchmark consists of a ratio of annual energy use to a metric of comparison that is common to each facility. For example, a common energy benchmark for commercial buildings is energy use per square foot. Benchmarks are most reliable and useful when the metric used for comparison is a good indicator of anticipated annual energy use. Preferable benchmarks for manufacturing facilities would be energy use per unit of production; however, they are difficult to formulate due to wide variations in manufacturing processes and products. As a result, benchmarks for manufacturing facilities and processes are not generally available at this time.

The Minnesota Technical Assistance Program (MnTAP) believes that energy benchmarks can provide manufacturing facilities with necessary energy use information and persuade them to implement energy efficiency opportunities as a means to remain competitive among their peers. Therefore, MnTAP proposed to use customer and energy data collected as part of the Industrial Conservation Market Analysis study to develop manufacturing facility energy benchmarks. The resulting benchmarks provide a starting point to quickly quantify and compare the relative efficiency of industrial facilities to sub-sector peers.

A previous energy benchmarking effort performed by MnTAP for Minnesota fuel ethanol facilities found annual production to be a useful metric for energy benchmarking: energy per gallon of ethanol produced annually. Annual production was a reliable indicator of an ethanol facility's annual energy use because, in general, as annual production varied from facility to facility, annual energy use varied proportionally.

However, annual production data was not readily available for most manufacturing facilities, and it was not available for this benchmarking study. Therefore, MnTAP proposed using facility area (ft^2), annual sales, and employment instead of annual production, as it was believed that these metrics could provide a similar indication of energy use if benchmarks were created for a narrow enough range of similar operations. To ensure the reliability and usefulness of these benchmarks, MnTAP used statistical analysis to determine if a correlation could be drawn between energy use and the chosen metrics.

During the course of the project, several factors led to uncertainty and unreliability in the benchmarks. As a result, MnTAP was unable to identify a single metric that provided a universally reliable standard for comparison among manufacturing facilities. However, MnTAP found that some metrics were statistically reliable for certain manufacturing sub-sectors and might be useful in determining how efficient a facility is, as compared to its peers. This report describes the methodology, results, limitations, and conclusions of the benchmarking study.

Methodology and limitations

Sub-sector selection

This benchmarking study is a part of a larger energy conservation study that MnTAP conducted for eight utilities in the State of Minnesota. As part of the larger project, MnTAP analyzed energy use data for manufacturing facilities within the eight utility service territories. All facilities were grouped into manufacturing sectors and then sub-sectors based on the similarity of their manufacturing processes. The overall goal of the project was to recommend the top three sub-sectors in each sector for each utility, in terms of energy consumption and conservation opportunities available. Additionally, MnTAP would develop benchmarks for the top three sub-sectors. After starting the benchmark study, MnTAP realized that recommending more than three sub-sectors would yield better results for the utilities.

Utilities included in study

Only data from six of the eight utility companies was included for the benchmarking report. The sole Greater Minnesota Gas manufacturing customer was not included in the analysis because it was in a sub-sector that was not evaluated for any other utility. Minnesota Power customers were not included because the benchmarking effort was largely complete before MnTAP had received the utility's customer data.

Number of sub-sectors included

Rather than identifying the top three sub-sectors to be included in this benchmarking study, MnTAP included all the sub-sectors that were recommended in the larger report as having significant conservation potential. This decision was made when it became apparent that some sub-sectors previously identified as being in the "top three" had unreliable benchmarks that would not provide utilities with a useful tool for comparison. By including all the sub-sectors in the benchmarking study, MnTAP expanded the number of facilities that can be compared using the benchmark metrics that were developed and are expected to be reliable. Tables 1 and 2 list the sub-sectors that were benchmarked for electricity and gas energy, respectively.

Table 1: Electricity sub-sectors for which benchmarks were performed.

Sector	Sub-Sector	# of Facilities Benchmarked
Chemical Manufacturing	Compressed Gas	4
	Ethanol Production	4
	Pharmaceutical Manufacturing	9
	Resin Production	15
	Shingle Manufacturing	1
Fabricated Metals	Computer Components/Hardware	10
	Machine Tool and Die/Metal Shops	97
	Medium Duty Industrial Equipment	49
	Metal Can Manufacturing	4
	Plating, Polishing, & Finishing	17
	Sheetmetal Products	82
Food Processing	Canned Fruits, Vegetables and Specialties	8
	Commercial Baking	25
	Dairy, Cheese, Butter, & Whey	9
	Dried Food	6
	Frozen Food	13
	Margarine	1
	Meat Processing	21
	Pet/Animal Food Manufacturing	20
	Poultry Processing	6
	Rendering	1
	Snack Food Production	12
	Soybean Processing	3
	Sunflower Seed & Wild Rice Processing	3
Pulp & Paper	Board Converting, Non-Heat Set	32
	Multi-Wall Converting, with Heat-Set	5
	Pulp & Paper Mills	3
Primary Metals	Aluminum Operations	10
	Heat Treat Operations	5
	Iron Operations	7
Printing	Heat Set Printers	10
	Newspapers	68
	Non-Heat Set Printers	251
Wood Products	Reconstituted Wood Products	1
	Primary Sawmills	2

Table 2: ***Gas sub-sectors for which benchmarks were performed.***

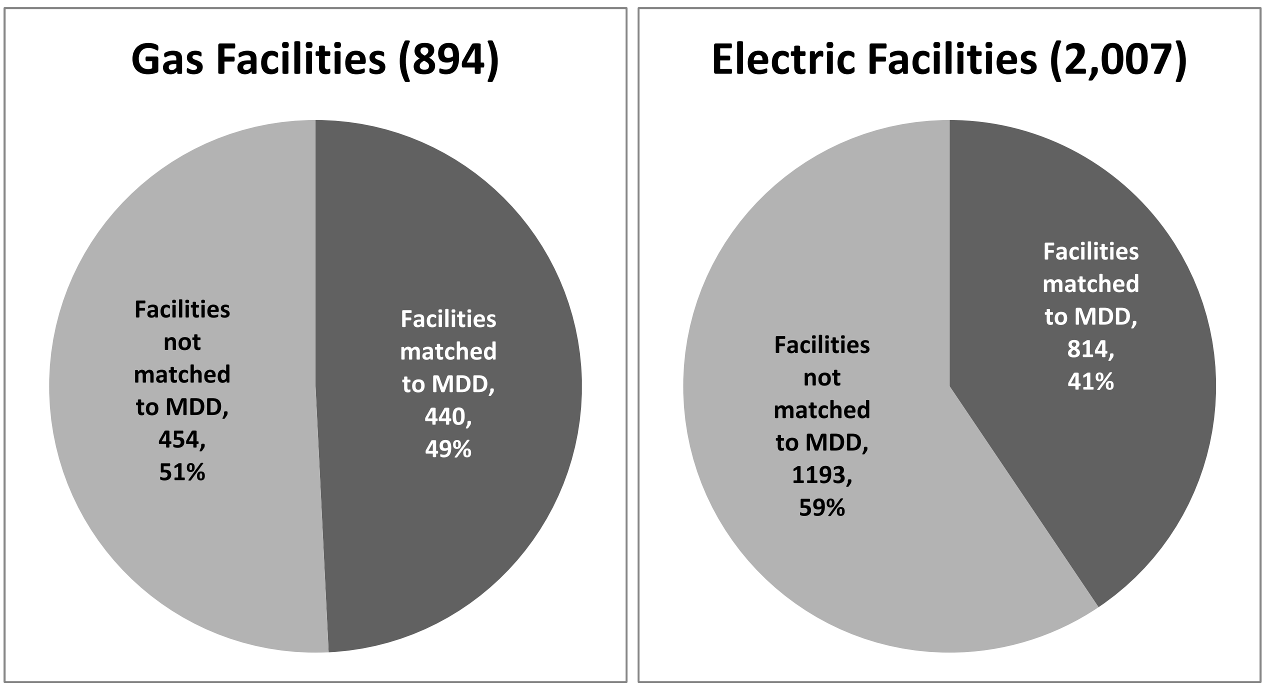
Sector	Sub-Sector	# of Facilities Benchmarked
Chemical Manufacturing	Compressed Gas	3
	Ethanol Production	11
	Explosives	1
	Pharmaceutical Manufacturing	17
	Resin Production	4
	Shingle Manufacturing	1
Industrial Drying	Grain Elevators	11
Fabricated Metals	Computer Components/Hardware	1
	Machine Tool and Die/Metal Shops	59
	Medium Duty Industrial Equipment	14
	Metal Can Manufacturing	3
	Metal Tube Manufacturing	3
	Plating, Polishing, & Finishing	17
	Sheetmetal	21
	Sheetmetal Products	11
Food Processing	Canned Fruits, Vegetables and Specialties	12
	Commercial Baking	9
	Dairy, Cheese, Butter, & Whey	3
	Dried Dairy Products	8
	Dried Food	2
	Margarine	1
	Meat Processing	15
	Poultry Processing	9
	Rendering	3
	Soybean Processing	3
Pulp & Paper	Board Converting, Non-Heat Set	9
	Multi-Wall Converting, with Heat-Set	5
	Pulp & Paper Mills	5
Primary Metals	Aluminum Operations	16
	Heat Treat Operations	6
	Iron Operations	7
Printing	Heat Set Printers	28
	Newspapers	29
	Non-Heat Set Printers	93

Data collection and benchmark calculation

To identify the metrics for comparison (area, employees, and sales), MnTAP attempted to match the customer names (if provided), service addresses, SIC codes, and NAICS codes that the utilities provided to business profiles in the Million Dollar Directory (MDD). Most utilities provided customer name information with the exceptions of Xcel Energy and Great Plains Gas, who withheld this information due to concerns with confidentiality. Despite some success in matching utilities' customer data to MDD entries, some facilities remained unidentified, while others whose identity was known did not appear in the MDD. Facilities that were not able to be matched to the MDD were removed from the benchmarking study as there was no metric data available for them.

Figure 1 shows the relative success rates for identifying electric and gas customers in the MDD. It is important to note that the overall group of electric customers was larger than the group of gas customers. Figure 1 also indicates that matching customer data to MDD entries was more successful for gas customers; this may be due to Xcel Energy having a higher proportion of electric customers whose identity could not be determined. Because many facilities could not be identified in the MDD, the number of facilities for which benchmarks could be derived, dropped significantly.

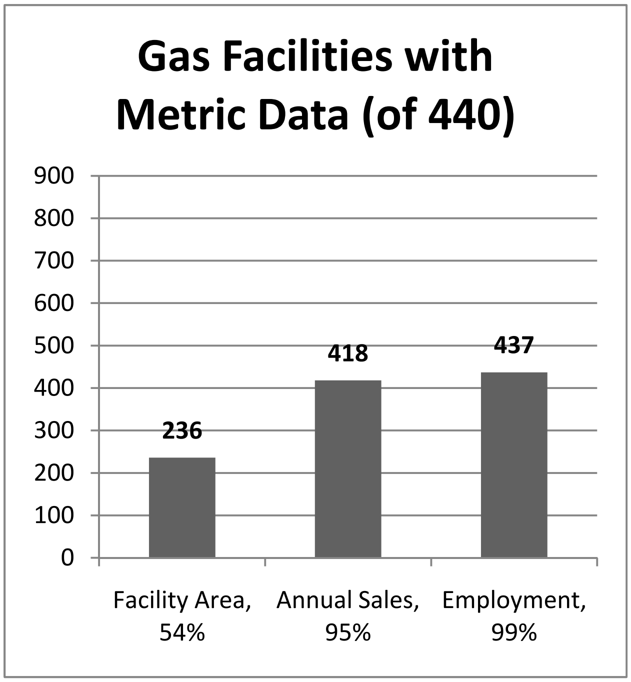
Figure 1: ***Comparison of facilities that that were matched to entries in the MDD to those that were not matched to entries in the MDD.***

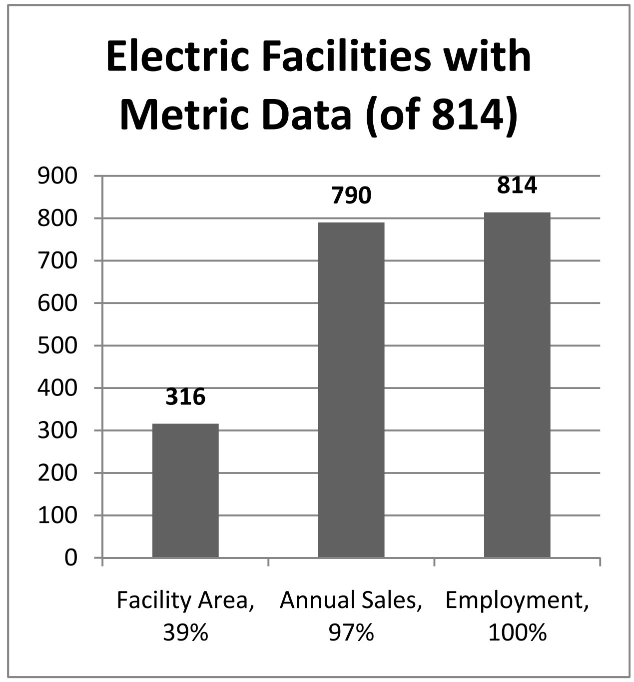


For facilities that did appear in the MDD, facility area (ft^2), annual sales, and employment data were used to calculate energy benchmarks by dividing annual energy use (either kWh of electric energy or therms of gas energy) by each metric. However, some of the facility area, annual sales, or employment data was incomplete for a number of facilities listed in the MDD. The incompleteness of the MDD data further reduced the number of benchmarks that could be calculated.

Figure 2 shows the relative completeness of metric data obtained from the MDD for both electric and gas facilities in the benchmarking study. Almost all facilities had sales metrics, but only about half had a facility square footage provided by the MDD. Again, it should be noted that the number of electric customers is significantly larger than the number of gas customers.

Figure 2: *Completeness of MDD metric data.*





Removing outliers

The underlying assumption of benchmarks is that energy use will increase approximately linearly with a proportional increase in any one of the comparison metrics (facility area, annual sales, and employment data).

After the initial benchmarks were calculated, some of the benchmark ranges for many sub-sectors were larger than expected, which indicated that some facilities within a sub-sector may have used several thousand times more energy per metric than others. These phenomena could be explained by a number of possibilities:

- There *are* actually facilities within the same sub-sector that are up to several thousand times more efficient than others.
- The metric used to calculate the benchmark is a poor indicator facility energy use.
- Incorrect matches have been made between unnamed facilities and entries in the MDD, which attributed incorrect metrics to energy use.
- The metric data is inaccurate for some facilities.
- The sub-sectors include facilities with significant variations in manufacturing processes with varying degrees of energy intensity; despite efforts to group facilities that have similar operations requiring similar amounts of energy, facilities with unique operations or uses of energy likely exist within sub-sectors.

It is unclear how the MDD obtains facility area, sales, and employment data. Poor incoming data quality can influence benchmark values and create statistical outliers. Following a review of the initial benchmarks, MnTAP standardized them to identify outliers that were likely to be generated due to data quality issues.

To standardize the benchmark values, a log transformation was performed on all benchmark data to make sure that the benchmarks within a sub-sector were normally distributed. The standardized values were calculated, and any benchmark that fell outside of the range of ±2 standard deviations from the average was removed from the analysis. Removing outliers in this way reduced the frequency of questionable benchmark data appearing within the analysis. Removing outliers also reduced suspicious data points that negatively influence the expected relationship between energy use and the metric.

Benchmark reliability

To determine if the benchmarks are reliable and a good measure of expected energy use, MnTAP compared and contrasted the rough linear relationship between energy use and the metrics for all sub-sectors. Benchmarks are expected to be reliable if they meet the following criteria:

Metric-to-energy use correlation coefficients are at or above 0.7 to ensure reasonable linearity between energy use and the metric. The range of values for a correlation coefficient is from -1 to 1, with 0 indicating no linearity between variables. -1 indicates a perfectly negative linearity between variables and 1 indicates a perfectly positive linearity between variables. Requiring the correlation value to be at least 0.7 is significant because it would suggest that approximately 50% of the variation in energy use can be explained by the benchmark metric, while the remaining 50% can be explained by unknown, lurking variables or inherent variability. Those unknown variables could include the expected differences in energy efficiency between sub-sector peers.

A sub-sector population size of at least five facilities was considered large enough to be representative of facilities throughout the state. Requiring a specific sub-sector population size helps ensure that a variety of facilities would represent each sub-sector. Setting the requirement at five facilities allowed small sub-sectors to remain in the benchmark study.

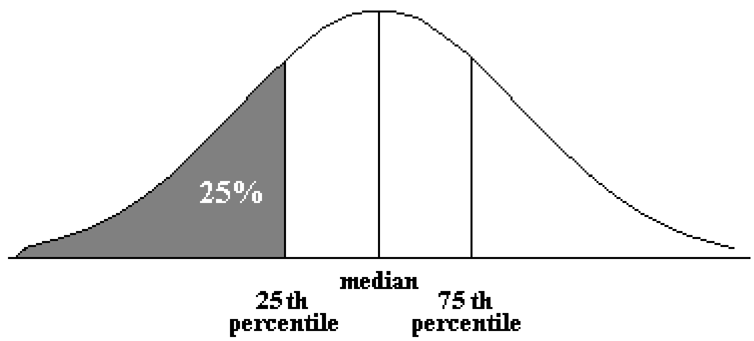
The ratio of the maximum and minimum values of facility benchmarks within the mid-range of the sub-sector should be less than 10. MnTAP imposed this criterion in an effort to eliminate benchmarks for sub-sectors that include facilities with wide variations in manufacturing processes. It seemed reasonable that average performing facilities may exhibit an energy intensity that 10 times more for one facility than another. For sub-sectors that were eliminated due to the wide variations in processes, perhaps they should be further subdivided before benchmarking results would prove accurate.

Once the reliability of the sub-sector benchmarks was determined, MnTAP then ranked the benchmarks by their expected reliability.

Results and Limitations

Figure 3 approximates the distribution of expected facility benchmark results. We expect most facilities to have energy benchmarks in the mid-range. We divided the distribution into quartiles as a tool to provide guidance on the likelihood of energy conservation opportunities depending on where on the distribution a specific facility might fall. Q1, shown highlighted, represents the smallest values within a population. Facilities that use the least amount of energy-per-metric will fall into Q1, as they are more efficient than other facilities

Figure 3: ***Example of a normal distribution with quartiles indicated. The first quartile (Q1) is highlighted.***



- Benchmark values that fall within the range of the lowest-value quartile (Q1) suggest that the facility is of above average efficiency, and can be expected to be more efficient than at least 75% of their sub-sector peers. **Additional conservation opportunities probably exist, but they are probably less numerous, more expensive, and harder to accomplish**. Low-hanging fruit opportunities are likely to have already been implemented. On the other hand, these facilities may be more motivated and more capable to accomplish further conservation, or have historically faced fewer barriers to implement conservation opportunities.
- Benchmark values that fall within the range of the second quartile (Q2) suggest that the facility is slightly above average efficiency, and can be expected to be more efficient than at least 50% of their sub-sector peers. **Additional conservation opportunities are more likely to exist than for Q1 facilities, but may be more difficult to identify or implement than for Q3 or Q4 facilities.** These facilities are likely doing well with implementing low-hanging fruit conservation opportunities, but may face barriers to implementing capital-intensive conservation projects.
- Benchmark values that fall within the range of the third quartile (Q3) suggest that the facility is slightly below average efficiency, and can be expected to be more efficient than at least 25% of their sub-sector peers. **Additional conservation opportunities are likely to exist and may be easier to identify or implement.** These facilities are slightly behind their more-efficient peers. It may be that they are knowledgeable of conservation, but that resources have not been devoted to implementing many conservation opportunities.
- Benchmark values that fall within the range of the highest-value quartile (Q4) suggest that the facility is well below average efficiency, and can be expected to be among the least efficient 25% of their sub-sector peers. **Additional conservation opportunities are very likely to exist and may be among the easiest to identify or implement**. It is likely that these facilities have little knowledge of conservation and the many opportunities that are available to them. Low-hanging fruit opportunities are very likely to exist, as well as more capital intensive conservation opportunities. Q4 facilities may face significant barriers to implementing conservation, including a lack of internal employees with the skill or time to devote to exploring conservation

opportunities, the inability to fund such improvements, or a rigid manufacturing schedule that limits the ability to have planned downtime.

Sub-sectors with reliable benchmarks are shown in Tables 3-6 in each benchmark category. The energy use per metric is given for each quartile, as explained above. Unreliable sub-sector benchmarks and quartile ranges were omitted from the report due to uncertainty in the quality of data, small sub-sector population sizes, a lack of linearity between energy and the benchmark metric, and/or unexpected anomalies in benchmark ranges.

The absolute magnitude of the benchmarks seen in Tables 3-6 below also provide a sense of the energy intensity of a sub-sector. Benchmarks in Table 3, for example, suggest that manufacturing ethanol is substantially more electricity intensive per square foot than the other industries and that dried food is of above average intensity. The amount of spread in the benchmarks is also significant. Many sub-sectors have a Q4 benchmark that is about two times larger than the Q1 benchmark, while dried food has almost a five-fold difference. This suggests that either this sub-sector has more variation in the operations, the metric is less reliable, or that this sub-sector has greater variation in the use of energy efficient technologies and procedures – some of these facilities may have very large opportunities.

kWh/ft^2 – Electric Energy per Facility Area Benchmarks

Of the 35 electric energy sub-sectors benchmarked, 10 are expected to have reliable kWh/ft^2 benchmarks. These sub-sectors and their benchmark quartile ranges can be seen in Table **3**.

Table 3: ***Sub-sector kWh/ft^2 benchmark quartile ranges.***

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 1,070	1,070 - 1,422	1,422 - 1,889	> 1,889
Fabricated Metals	Machine Tool and Die/Metal Shops	< 14	14 - 22	22 - 34	> 34
	Plating, Polishing, Finishing	< 21	21 - 31	31 - 47	> 47
	Sheetmetal Products	< 8	8 - 16	16 - 32	> 32
Food Processing	Commercial Baking	< 18	18 - 33	33 - 59	> 59
	Dried Food	< 38	38 - 86	86 - 192	> 192
	Snack Chip Production	< 27	27 - 44	44 - 72	> 72
	Sunflower Seed & Wild Rice Processing	< 43	43 - 73	73 - 125	> 125
Pulp & Paper	Board Converting Non-Heat Set	< 24	24 - 37	37 - 58	> 58
Printing	Non-Heat Set Printers	< 8	8 - 15	15 - 27	> 27

kWh/employee – Electric Energy per Employee Benchmarks

Of the 35 electric energy sub-sectors benchmarked, 16 are expected to have reliable kWh/employee benchmarks. These sub-sectors and their benchmark quartile ranges can be seen in Table **4**.

Table 4: ***Sub-sector kWh/employee benchmark quartile ranges.***

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 612,896	612,896 - 803,404	803,404 - 1,053,129	> 1,053,129
	Resin Production	< 6,097	6,097 - 10,256	10,256 - 17,253	> 17,253
Fabricated Metals	Machine Tool and Die/Metal Shops	< 6,090	6,090 - 11,242	11,242 - 20,752	> 20,752
	Medium Duty Industrial Equipment	< 2,940	2,940 - 5,577	5,577 - 10,577	> 10,577
	Plating, Polishing, Finishing	< 16,390	16,390 - 25,656	25,656 - 40,160	> 40,160
	Sheetmetal Products	< 5,765	5,765 - 11,345	11,345 - 22,326	> 22,326
Food Processing	Commercial Baking	< 6,502	6,502 - 10,926	10,926 - 18,362	> 18,362
	Dried Food	< 27,431	27,431 - 46,649	46,649 - 79,331	> 79,331
	Meat Processing	< 23,037	23,037 - 33,052	33,052 - 47,422	> 47,422
	Pet Food Manufacturing	< 10,357	10,357 - 21,310	21,310 - 43,846	> 43,846
	Poultry Processing	< 22,934	22,934 - 42,222	42,222 - 77,732	> 77,732
	Snack Chip Production	< 6,010	6,010 - 11,768	11,768 - 23,043	> 23,043
Pulp & Paper	Board Converting Non-Heat Set	< 8,168	8,168 - 16,197	16,197 - 32,117	> 32,117
Primary Metals	Aluminum Operations	< 20,734	20,734 - 32,105	32,105 - 49,713	> 49,713
Printing	Heat Set Printers	< 6,635	6,635 - 10,085	10,085 - 15,329	> 15,329
	Non-Heat Set Printers	< 4,566	4,566 - 8,103	8,103 - 14,378	> 14,378

therm/ft² – Thermal Energy per Facility Area Benchmarks

Of the 34 thermal energy sub-sectors benchmarked, 5 are expected to have reliable therm/ft^2 benchmarks. These sub-sectors and their benchmark quartile ranges can be seen in Table 5.

Table 5: ***Sub-sector thm/ft^2 benchmark quartile ranges.***

Sector	Sub-sector	Q1	Q2	Q3	Q4
Fabricated Metals	Machine Tool and Die/Metal Shops	< 0.15	0.15 - 0.27	0.27 - 0.47	> 0.47
	Plating, Polishing, Finishing	< 1.17	1.17 - 2.53	2.53 - 5.47	> 5.47
Food Processing	Dairy, Cheese, Butter, Whey	< 98.71	98.71 - 119.31	119.31 - 144.22	> 144.22
Primary Metals	Aluminum Operations	< 4.80	4.80 - 7.17	7.17 - 10.71	> 10.71
Printing	Non-Heat Set Printers	< 0.27	0.27 - 0.37	0.37 - 0.51	> 0.51

therm/employee – Thermal Energy per Employee Benchmarks

Of the 34 thermal energy sub-sectors benchmarked, 8 are expected to have reliable therm/employee benchmarks. These sub-sectors and their benchmark quartile ranges can be seen in Table 6.

Table 6: ***Sub-sector therm/employee benchmark quartile ranges.***

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 241,686	241,686 - 302,801	302,801 - 379,369	> 379,369
Fabricated Metals	Medium Duty Industrial Equipment	< 174	174 - 337	337 - 653	> 653
Food Processing	Commercial Baking	< 494	494 - 666	666 - 899	> 899
	Dairy, Cheese, Butter, Whey	< 24,825	24,825 - 27,798	27,798 - 31,127	> 31,127
Pulp & Paper	Board Converting Non-Heat Set	< 337	337 - 554	554 - 912	> 912
	Multi-Wall Converting with Heat Set	< 1,160	1,160 - 1,769	1,769 - 2,700	> 2,700
Primary Metals	Aluminum Operations	< 2,615	2,615 - 3,445	3,445 - 4,537	> 4,537
Printing	Heat Set Printers	< 454	454 - 982	982 - 2,121	> 2,121

It is important to note that MnTAP determined that sales figures make an unacceptable metric for determining the benchmarks. Annual sales values are expected to continually rise due to inflation and such increases in sales figures would shift all benchmarks lower, indicating that facilities are artificially becoming more energy efficient over time. Energy per sales benchmarks would only be reliable and useful within a very short time following the generation of the benchmarks. Because of this, energy per sales benchmarks are not provided.

How to use the results

While MnTAP anticipates that the reported benchmarks are accurate and will be helpful in predicting the relative efficiency of facilities throughout the State of Minnesota, there have been no formal efforts to test the validity of the results. MnTAP therefore recommends some caution be used in applying benchmark comparisons, and requests feedback from both state and utility partners to assess the reliability and usefulness of these benchmarks.

Facilities within a sub-sector that has a reliable benchmark (as shown in Tables 3-6) can estimate their relative efficiency as compared to their sub-sector peers. To do so, annual facility energy (kWh or therms) should be divided by the appropriate metric (ft^2 or employment). Annual facility energy can be determined by adding together consumption data shown on monthly utility bills. Facility area should include all conditioned floor space. Employment numbers should include all employees rather than employee shift totals. The result should be compared with the quartile ranges in the appropriate table (3, 4, 5, or 6) to determine the facility's quartile placement. Finally, the quartile placement can be used to assess the likelihood that potential conservation opportunities exist.

While determining where a facility's energy benchmark fits into the quartiles, it is important to consider what is known about the facility's operations to determine if the quartile placement makes sense. Factors to consider might include if there are significant differences with sub-sector peers in relation to the types of operations performed, types of products made, utilization of floor space, and/or utilization of employees. Undoubtedly, energy use, plant area, and employee numbers can change over time; therefore, it is suggested that facilities, at regular intervals over time, determine their benchmark and which quartile range it falls in. Examining if a facility appears wasteful or efficient, is new or old, has knowledgeable staff, or has recently implemented energy efficiency improvements can help determine if the facility's benchmark is an accurate reflection of the facility. Overall, the benchmark can help confirm and quantify how a facility's energy conservation compares to peers, but the benchmark should not be used as the sole indicator.

If the quartile placement seems reasonable, consider its implication to the availability of conservation opportunities and to the facility's position to remain competitive with its peers. Benchmarks can be used to estimate what magnitude of energy savings would be required to improve a facility's quartile placement. For example, a 10,000 square-foot machine shop that uses 240,000 kWh annually would have a benchmark of 24 kWh/ft^2, placing it in the below average energy efficiency (Q3) group. In order to be considered above average (moving from Q3 to Q2), the shop would need to achieve an energy savings of *at least* 2 kWh/ft^2, or 20,000 kWh for the 10,000 square-foot facility, approximately 8.33% of their current usage.

Limitations

Many of the sub-sector benchmarks were deemed unreliable because they did not meet the criteria described in the "Benchmark reliability" section of the report. Although efforts were made to select and report the benchmarks with the highest anticipated reliability, there remain uncertainties that require anyone using the benchmarks to exhibit discretion when attempting to apply them to a facility. The most significant limitations are included in this section.

Benchmark metric uncertainty

- Reported facility areas can vary considerably within a sub-sector. For example, if one facility acts as a manufacturing center and company headquarters, it will likely have a larger reported facility area than a peer facility that has manufacturing space and limited office space. Other facilities might have warehouse space, and still others may have multiple types of operations such as a metal casting facility that also has significant machining operations. If the metric provided was as precise as to indicate production area, it is expected that such a metric would provide a more reliable relationship with facility energy.
- Some MDD entries indicate that facility area, sales, and/or employment figures have been reported as estimated, we know nothing about the method or quality of those estimates. Estimated data can skew calculated benchmarks either higher or lower when the metrics have been estimated at lower than actual or higher than actual.
- Employment values may differ significantly from facility to facility depending on the level of automation that is utilized in the facility.

Unidentified customer energy use data

- When analyzing the energy use data provided by each utility, it became apparent that some facilities had multiple meters that were reported by the utility as separate entities. To more accurately report facility energy use, MnTAP attempted combine the meter data if it appeared that multiple meters belonged to a single facility. However, energy use data was not always provided with a facility name, which makes it possible that some meters may have been combined incorrectly or not at all, thus generating invalid benchmark values. If one or more meters were mistakenly left out for a facility, the benchmark would be lower than actual, suggesting that the facility is more efficient than it actually is. If more meters were combined to represent a facility than the facility might actually have, the benchmark value would be higher than actual, suggesting that the facility is less efficient than it is.
- When the utility companies provided the energy use data without facility names, MnTAP attempted to match the facilities to MDD entries using industry code, address, and zip code information. It is possible that these matches were made incorrectly, thus generating completely meaningless benchmark values.

Incomplete facility metric data

- Some facilities, even in situations when the facility name was known, did not appear in the MDD. Typically, smaller facilities were absent from the MDD; therefore, facility metric data was unavailable for these facilities. This has the potential to skew the benchmark data to only include and represent larger facilities.
- For MDD entries that did exist, many did not include complete facility area and sales data. This greatly reduced the number of facilities that could be benchmarked, generating more sub-sectors with substandard population sizes.

Conclusions

Energy benchmarking can provide a powerful tool for comparing the relative efficiency of facilities within a given manufacturing sub-sector. While annual production may be the most obvious choice for a benchmarking metric, it is expected that surrogate metrics may be as useful or nearly as useful, as long as the relationships between energy use and the metrics are reasonably studied and understood.

Despite limitations and uncertainties, MnTAP has analyzed the relationships between energy use and facility metrics (facility size and employment data) and developed a preliminary set of energy benchmarks that are expected to be reliable and useful in predicting the relative efficiency of facilities within a sub-sector. Understanding that many uncertainties were present throughout the benchmarking analysis, MnTAP welcomes the use and application of the reported benchmarking results to determine estimated facility efficiency as compared to peer facilities.

Appendix A: How to Use Energy Benchmarks

How to Use Energy Benchmarks

What is an energy benchmark?

Energy benchmarks provide a means for comparing a facility's annual energy use to that of similar facilities. An energy benchmark consists of a ratio of annual energy use to a metric of comparison that is common to each facility. For example, a common energy benchmark for commercial building is energy use per square foot. Benchmarks are most reliable and useful when the metric used for comparison is a good indicator of anticipated annual energy use.

Does the benchmark fit?

To help determine if a benchmark is an accurate reflection of the facility in relation to its sub-sector peers, consider a number of factors:

- Types of operations performed
- Types of products made
- Utilization of floor space
- Utilization of employees

Additionally, consider if the benchmark reflects what is known about the facility:

- Is it wasteful or efficient?
- Is it new or old?
- Does it have knowledgeable staff?
- Has it recently implemented energy efficiency improvements?

Overall, the benchmark can help confirm and quantify how a facility's energy efficiency compares to peers, but the benchmark should not be used as the sole indicator.

Calculate your energy benchmark

Facilities within a sub-sector that has a reliable benchmark (as shown on Page 2) can estimate their relative efficiency as compared to their sub-sector peers by following these steps:

1. Determine your annual electric or thermal energy use (kWh or therms), facility area (sq. ft.), and employment data.

Annual facility energy can be determined by adding together consumption data shown on monthly utility bills. Facility area should include all conditioned floor space. Employment numbers should include all employees rather than employee shift totals.

2. Divide your annual energy use by facility area or employment data.

Example: A heat set printer that occupies a 10,000 sq. ft. facility and employs 150 people uses 1.2 million kWh and 72,000 therms annually. NOTE: Reliable benchmarks only exist for kWh/employee and therms/employee for this sub-sector.

$$\text{kWh/employee} = \frac{1{,}200{,}000}{150} = 8{,}000 \qquad \text{therms/employee} = \frac{72{,}000}{150} = 480$$

3. Compare your facility data with peer facilities.

The following benchmarks were developed for heat set printers. Therefore, the facility data above indicates that this example facility is in the top 50% of heat set printers and is more efficient than at least 50% of its peers.

	Most efficient 25% (Q1)	More efficient 25% (Q2)	Less efficient 25% (Q3)	Least efficient 25% (Q4)
kWh/employee	< 6,635	6,635 - 10,085	10,085 - 15,329	> 15,329
therms/employee	< 454	454 - 982	982 - 2,121	> 2,121

4. Evaluate what opportunities may exist for your facility.

Compare your facility benchmark with your sub-sector peers to determine what opportunities may still exist. A brief description of each quartile as well as likely types of conservation opportunities is shown in the table below.

Quartile Ranking	Facility Description	Opportunities
Most efficient 25% (Q1)	Above average efficiency and expected to be more efficient than at least 75% of their sub-sector peers.	Conservation opportunities that are likely to exist will tend to require more capital, staff time, and potentially shut-down times for implementation. Low-hanging fruit opportunities are likely to have been implemented.
More efficient 25% (Q2)	Slightly above average in terms of efficiency and expected to be more efficient than at least 50% of their sub-sector peers.	These facilities have few low-hanging fruit conservation opportunities remaining, but are more likey to have significant capital-intensive conservation projects remaining.
Less efficient 25% (Q3)	Slightly below average efficiency and expected to be more efficient than at least 25% of their sub-sector peers.	Substantial conservation opportunities are likely to exist and can range from low-hanging fruit opportunities to capital-intensive projects. A lack of knowledge about resources or opportunities may exist in these facilities.
Least efficient 25% (Q4)	Well below average efficiency and expected to be among the least efficient 25% of their sub-sector peers.	Conservation opportunities are very likely to exist and may be among the easiest to identify or implement. Facilities should start with low-hanging fruit opportunties and take advantage of opportunities to learn about energy conservation strategies.

University of Minnesota

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Sub-sector kWh/ft^2 benchmark quartile ranges.

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 1,070	1,070 - 1,422	1,422 - 1,889	> 1,889
Fabricated Metals	Machine Tool and Die/Metal Shops	< 14	14 - 22	22 - 34	> 34
	Plating, Polishing, Finishing	< 21	21 - 31	31 - 47	> 47
	Sheetmetal Products	< 8	8 - 16	16 - 32	> 32
Food Processing	Commercial Baking	< 18	18 - 33	33 - 59	> 59
	Dried Food	< 38	38 - 86	86 - 192	> 192
	Snack Chip Production	< 27	27 - 44	44 - 72	> 72
	Sunflower Seed & Wild Rice Processing	< 43	43 - 73	73 - 125	> 125
Pulp & Paper	Board Converting Non-Heat Set	< 24	24 - 37	37 - 58	> 58
Printing	Non-Heat Set Printers	< 8	8 - 15	15 - 27	> 27

Sub-sector kWh/employee benchmark quartile ranges.

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 612,896	612,896 - 803,404	803,404 - 1,053,129	> 1,053,129
	Resin Production	< 6,097	6,097 - 10,256	10,256 - 17,253	> 17,253
Fabricated Metals	Machine Tool and Die/Metal Shops	< 6,090	6,090 - 11,242	11,242 - 20,752	> 20,752
	Medium Duty Industrial Equipment	< 2,940	2,940 - 5,577	5,577 - 10,577	> 10,577
	Plating, Polishing, Finishing	< 16,390	16,390 - 25,656	25,656 - 40,160	> 40,160
	Sheetmetal Products	< 5,765	5,765 - 11,345	11,345 - 22,326	> 22,326
Food Processing	Commercial Baking	< 6,502	6,502 - 10,926	10,926 - 18,362	> 18,362
	Dried Food	< 27,431	27,431 - 46,649	46,649 - 79,331	> 79,331
	Meat Processing	< 23,037	23,037 - 33,052	33,052 - 47,422	> 47,422
	Pet Food Manufacturing	< 10,357	10,357 - 21,310	21,310 - 43,846	> 43,846
	Poultry Processing	< 22,934	22,934 - 42,222	42,222 - 77,732	> 77,732
	Snack Chip Production	< 6,010	6,010 - 11,768	11,768 - 23,043	> 23,043
Pulp & Paper	Board Converting Non-Heat Set	< 8,168	8,168 - 16,197	16,197 - 32,117	> 32,117
Primary Metals	Aluminum Operations	< 20,734	20,734 - 32,105	32,105 - 49,713	> 49,713
Printing	Heat Set Printers	< 6,635	6,635 - 10,085	10,085 - 15,329	> 15,329
	Non-Heat Set Printers	< 4,566	4,566 - 8,103	8,103 - 14,378	> 14,378

Sub-sector therms/ft^2 benchmark quartile ranges.

Sector	Sub-sector	Q1	Q2	Q3	Q4
Fabricated Metals	Machine Tool and Die/Metal Shops	< 0.15	0.15 - 0.27	0.27 - 0.47	> 0.47
	Plating, Polishing, Finishing	< 1.17	1.17 - 2.53	2.53 - 5.47	> 5.47
Food Processing	Dairy, Cheese, Butter, Whey	< 98.71	98.71 - 119.31	119.31 - 144.22	> 144.22
Primary Metals	Aluminum Operations	< 4.80	4.80 - 7.17	7.17 - 10.71	> 10.71
Printing	Non-Heat Set Printers	< 0.27	0.27 - 0.37	0.37 - 0.51	> 0.51

Sub-sector therms/employee benchmark quartile ranges.

Sector	Sub-sector	Q1	Q2	Q3	Q4
Chemical Manufacturing	Ethanol Production	< 241,686	241,686 - 302,801	302,801 - 379,369	> 379,369
Fabricated Metals	Medium Duty Industrial Equipment	< 174	174 - 337	337 - 653	> 653
Food Processing	Commercial Baking	< 494	494 - 666	666 - 899	> 899
	Dairy, Cheese, Butter, Whey	< 24,825	24,825 - 27,798	27,798 - 31,127	> 31,127
Pulp & Paper	Board Converting Non-Heat Set	< 337	337 - 554	554 - 912	> 912
	Multi-Wall Converting with Heat Set	< 1,160	1,160 - 1,769	1,769 - 2,700	> 2,700
Primary Metals	Aluminum Operations	< 2,615	2,615 - 3,445	3,445 - 4,537	> 4,537
Printing	Heat Set Printers	< 454	454 - 982	982 - 2,121	> 2,121