Iowa
Environmental
Council

MichaelsEnergy

Industrial & Agricultural Electrification Study

Assessing the opportunity for electrification of industrial and agricultural end-uses to facilitate economic development in Iowa where natural gas supplies are constrained.

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CONTENTS

1 INTRODUCTION

The Iowa Economic Development Authority contracted with Michaels Energy and the Iowa Environmental Council ("the Research Team") to research the opportunity for electrification of industrial and agricultural end uses. Some facilities may lack sufficient natural gas service or firm capacity on existing natural gas supply pipelines, limiting facility and production expansion. This limitation in natural gas supply is a barrier to economic development. The Research Team partnered with local utilities and local economic development agencies to help identify customers with this specific growth limitation.

Cost-effective electric technologies could be leveraged to free up pipeline capacity and enable growth. The Research Team researched and documented the extent of the problem created by natural gas supply constraints in Iowa, investigated the applicable end use conversion opportunities for electrification pertaining to Iowa's industrial and agricultural mix, and conducted in-the-field audits of facilities to quantify the cost savings and process improvement potential associated with incorporating electric technologies into industrial and agricultural processes.

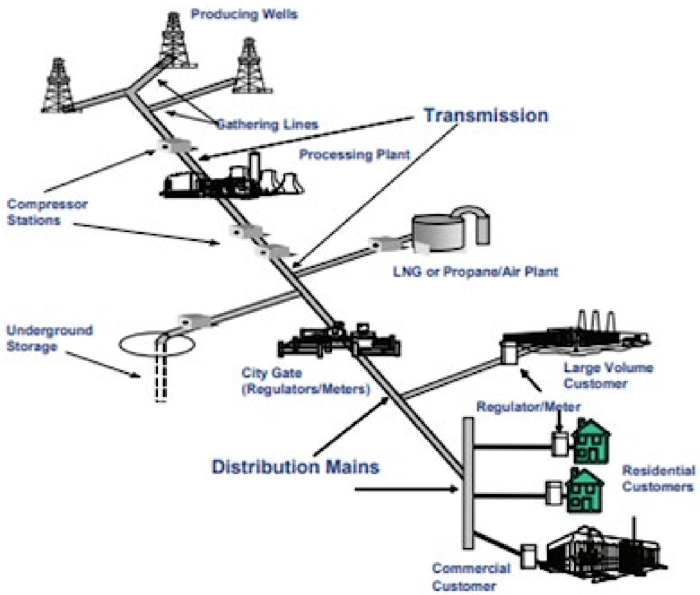
Electrification of industrial processes offers unique benefits outside the conventional residential and commercial markets, such as reduced equipment size, improved process speeds, and reduced point source emissions.

2 CUSTOMER-LEVEL GAS PIPELINE CONSTRAINTS

2.1 NATURAL GAS CONSTRAINTS BACKGROUND

Natural gas utilities in Iowa purchase natural gas from producers and processing plants and then have it transported over interstate pipelines to city gates at which natural gas utilities' distribution systems are interconnected with the interstate pipeline. The natural gas utilities then deliver the natural gas over the distribution system to individual customers. Figure 1 below illustrates the natural gas system supply chain.

Figure 1. Natural Gas System Supply Chain



Source: https://www.epa.gov/sites/production/files/2016-06/documents/ngstar_accomplishments_2007.pdf

Constraints on the pipeline system can occur on the interstate pipeline system, on the branch lines, or behind the city gates. First, constraints may occur because of limitations in the total firm transportation that can be provided over the interstate pipeline as it is currently constructed. This means that the firm capacity – the amount of natural gas that can be delivered to customers without interruption – is fully contracted for. Some of this firm capacity is contracted for by individual large customers while most of the firm capacity is contracted for by natural gas utilities (rate-regulated or municipals). There is generally still capacity on the pipeline for interruptible customers who are willing to be interrupted on those occasions when firm customers take their maximum limits. These interruptible customers can take gas at a lower cost and historically have not been interrupted except on very rare occasions.

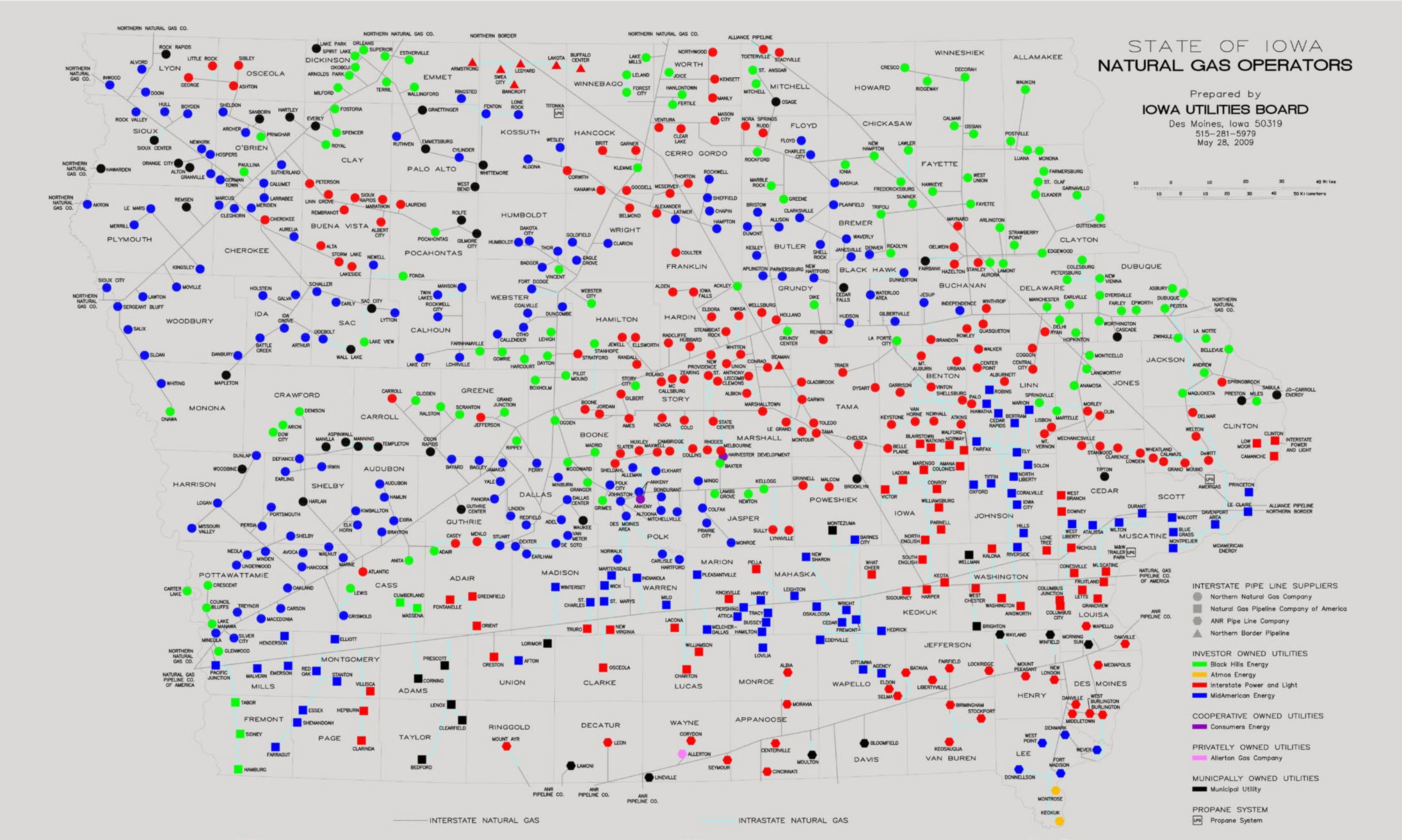
Another factor that influences customers' or communities' access to natural gas is the distance from the interstate pipeline. The further from the interstate pipeline the customer is located, the smaller the pipeline and capacity available, and the more likely there will be a constraint. Again, capacity constraints usually involve those customers wanting firm capacity. Interruptible customers can usually still get natural gas.

Constraints can also occur where the distribution line from the interstate pipeline to a municipality is so small that even if capacity is expanded on the interstate line, there is no additional capacity to the municipality located on the small line.

Constraints on a natural gas line can limit an area's ability to attract new businesses or to expand existing businesses. Historically, constraints are addressed only when there are enough customers willing to pay for the expansion.

The natural gas infrastructure in Iowa is shown below in Figure 2.

Figure 2. Natural Gas Pipelines, City Gates, and Operators in Iowa



Source, click to see larger map: https://iub.iowa.gov/sites/default/files/documents/2018/08/map_gas_operators_2009.pdf

REGULATION OF PIPELINES

Natural gas service to Iowa customers originates in other parts of the United States where producers have wells. The main sources of natural gas for Iowa are from the Rocky Mountains and the Gulf Coast region.

INTERSTATE PIPELINES

The natural gas is transported from the producers by interstate pipeline companies[1]. These companies are regulated by the Federal Energy Regulatory Commission (FERC) and are only allowed to transport the gas. They do not own the gas they deliver over their transmission pipelines. The Iowa Utilities Board (IUB) has no jurisdiction over the interstate pipeline companies.

When the constraint is lack of capacity on the interstate pipeline, then FERC authorizes construction of facilities and regulates the rates and services offered. FERC allows some expansions under a blanket certificate. Under a blanket certificate issued pursuant to section 7(c) of the Natural Gas Act, a natural gas company may undertake a restricted array of routine activities without the need to obtain a case-specific certificate for each individual project. Projects for non-mainline facilities up to $12.5 million may proceed without prior notice to FERC. For construction on interstate pipelines costing between $12.5 million and $35.2 million, the interstate pipeline must file a notice with FERC and potentially affected landowners with advance notice and

1 Northern Natural Gas Company, Natural Gas Pipeline Company of America, ANR Pipeline Company, and Northern Border Pipeline

a description of a planned project[2]. A Public Notice of the planned project will be issued by the Commission (published in the Commission's eLibrary). The Public Notice is also published in the Federal Register. Within 60 days of publication of the Public Notice on the Commission's Website, any person may participate by intervening or by commenting/protesting a planned project. Once the 60-day period to protest expires, if no protest has been filed, the project may proceed. However, if a protest is filed by the public or by Commission staff, interested persons have 30 days to resolve the issues raised in the protest. If the issues are not resolved, and the protest is not withdrawn or dismissed, the planned project will not be authorized under the company's blanket certificate but will instead be treated as if the proposed project were presented in an application for project-specific certificate authorization. From 1996 through 2020, only 6 pipeline expansion projects in Iowa required project-specific certificates, with the last one occurring in 2007.

For construction over $35.2 million, the interstate pipeline must file for FERC authorization for a project-specific certificate which can take 9-14 months. In all pipeline expansions, whether by blanket certificate or project-specific certificate, the costs of the expansion are paid for by the customers obtaining the benefit of the expansion.

DISTRIBUTION LINES

Natural gas utilities[3] in Iowa buy gas from the producers and then have it transported over the interstate pipelines to city gates at which natural gas utilities' distribution systems are interconnected with the interstate pipeline. There are also municipal utilities that operate natural gas distribution systems that provide gas to customers. The IUB regulates the rates of the natural gas utilities but does not regulate the rates of municipal natural gas utilities. However, the IUB does have some regulatory authority over municipal utilities' service to customers.

The IUB approves all pipeline laterals whether owned by a natural gas utility or a municipal utility. Pipeline laterals connect individual cities to the large interstate or transmission pipeline. The lateral typically connects from the interstate pipeline to the city's distribution network at the city gate. These laterals can span from under a mile to over ten miles and frequently are the sole source of natural gas for a smaller town. Larger cities in Iowa typically have multiple laterals connecting to one or even several interstate lines. Many laterals were constructed in the early 1960s, with some subsequent construction in the 1980s and later.

The utilities that own and operate these laterals are required to maintain individual pipeline permits for each lateral with the IUB.[4] These permits must be renewed every 25 years.

2.2 GAS CONSTRAINT RESEARCH FINDINGS

The project team identified natural gas constraints in Iowa using two primary methods: tabletop research and outreach to utilities and economic development agencies.

TABLETOP RESEARCH

The Iowa Environmental Council (IEC) performed online research of available resources to identify natural gas constraints. This included publicly examining available reports filed with the IUB, FERC, and the Energy Information Agency (EIA). In addition, we reviewed websites maintained by the interstate pipelines serving Iowa to identify natural gas constraints.

The information obtained through the tabletop research is presented below including maps of identified gas constraint areas. The natural gas utilities (interstate pipeline, distribution utilities, and municipal utilities) are identified including the city gates.

2 Dollar thresholds are the values for 2020.

3 Black Hills Energy, Interstate Power and Light, Liberty Utilities, and MidAmerican Energy

4 See Iowa Code Chapter 479, which sets out requirements for permit applications and renewals, and Iowa Utilities Board rule chapter 199 IAC 10, which implements chapter 479.

The research team reviewed the pipeline permit renewal applications and associated documents filed with the IUB and available electronically through the IUB's Electronic Filing System (EFS).[5] This includes approximately ten years of pipeline permit renewals from the inception of the EFS. Because pipeline permits must be renewed every 25 years, the ten-year window of available permit renewal documents allowed for a review of approximately one-third of all pipeline permit renewals. Permit renewal applications and documents prior to the implementation of the IUB EFS should be available in the paper archives at the IUB, but were not reviewed.

The research team reviewed nearly 200 pipeline or P-dockets available on the EFS. Of these, about 100 dockets were pipeline permit renewals. Because some pipeline laterals connect multiple cities, 133 cities are included in the research. Many of the P-dockets not for pipeline permit renewals are inspection report filings or other filings that do not concern gas constraint issues. However, some P-dockets include proposals for new or upgraded pipelines, which are discussed in more detail below.

In the permit renewal filing, utilities are required to provide the MCF/day (one MCF is one thousand cubic feet of gas) that the pipeline is capable of delivering to the city gate. We compiled the MCF/day that each pipeline lateral delivers to each city. Again, in many instances, this lateral is the only pipeline delivering gas to the city and the MCF/day listed for this pipeline would be the total MCF/day delivered to that city.

A breakdown of the MCF/day information from the P-dockets for 133 cities is shown in Figures 3 through 7. These cities are served by a single lateral either directly to the city or to several cities along the single lateral. We have included a full table of dockets, cities, MCF/day, and miles of pipeline in the lateral in Appendix A.

Figure 3. Natural Gas Capacity for Cities Based on P-Dockets

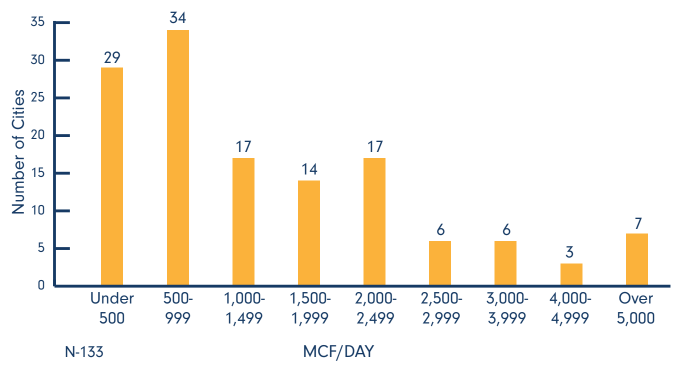


Figure 4. Natural Gas Capacity for Cities

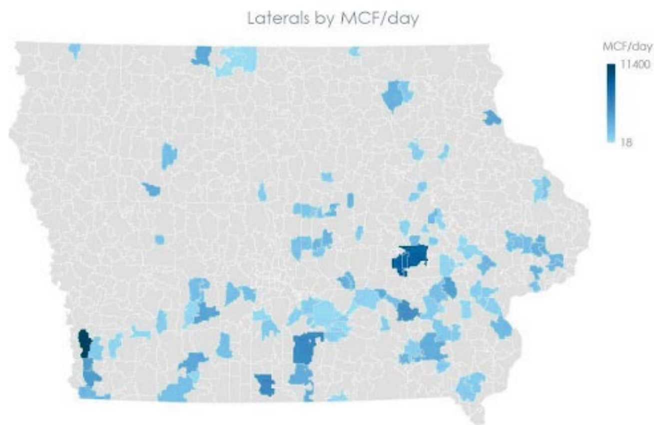
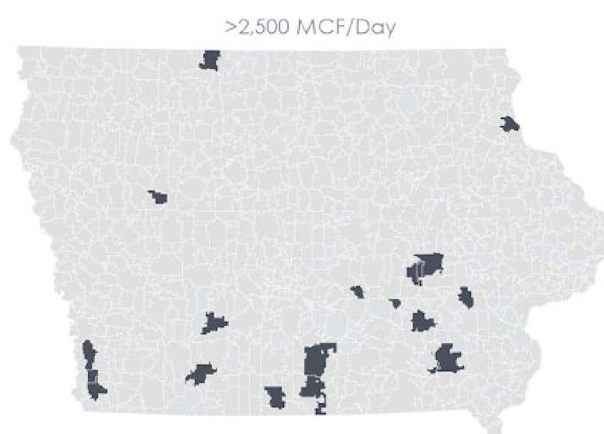


Figure 5. Natural Gas Capacity for Cities (>2,500 MCF/Day)



5 Iowa Utilities Board, Natural Gas Pipeline Permits, at https://iub.iowa.gov/regulated-industries/natural-gas-pipeline-permits.

Figure 6. Natural Gas Capacity for Cities (1,000 – 2,500 MCF/Day)

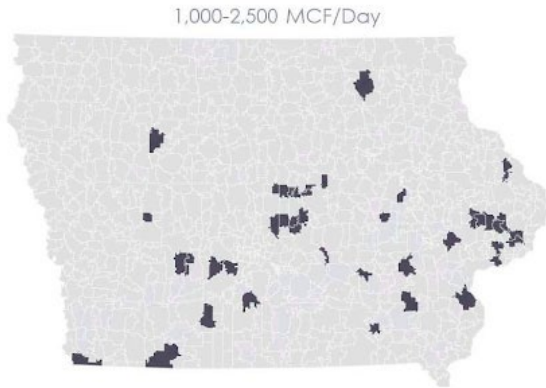
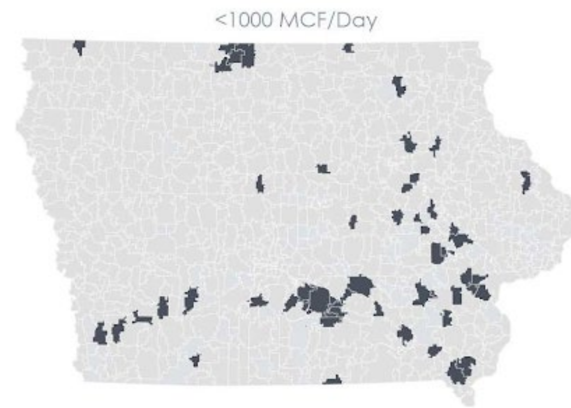


Figure 7. Natural Gas Capacity for Cities (<1,000 MCF/Day)



To put this information in context, Michaels reviewed the natural gas usage of Alliant customers receiving energy efficiency audits to estimate the MCF/day requirements for different types of commercial, institutional, and industrial facilities (Table 1).

Table 1. Typical Winter Daily Usage by Facility Type and Square Footage (MCF/day)

Facility	5,000 SF	10,000 SF	50,000 SF	100,000 SF
K-12 school	–	274	1,873	2,439
Grocery/convenience	–	274	2,020	5,967
Hospital	–	–	2,753	6,172
Clinic/healthcare	499	998	–	–
Large office	–	–	654	2,347
Small office	296	351	–	–
Large retail	–	–	1,134	1,926
Small retail	272	545	–	–
Lodging/hotel	–	–	1,169	2,568
Public assembly	–	342	3,586	–
Restaurant	572	1,144	–	–
Warehouse	–	185	923	–
Industrial	–	1,092	2,044	10,408

Source: Analysis of natural gas usage of Alliant customers receiving audits

For example, a 5,000 square foot restaurant would require 572 MCF/day while a 5,000 square small office would require 296 MCF/day. A 50,000 square foot K-12 school would require 1,873 MCF/day. A 50,000 square foot warehouse requires 923 MCF/day, while a 50,000 square industrial facility would require 2,044 MCF/day.

For most of the pipeline laterals and cities reviewed, the MCF/day is not sufficient to meet the needs of many types of new commercial, institutional, or industrial facilities. Some portion, likely a significant portion, of the current MCF/day delivered to the city is being used by existing customers. While utilities are not required to identify this amount in the permit renewal application, limited information from other filings suggests less than half, even less than one quarter, of the MCF/day listed is likely to be available to new customers. For example, a city that receives 1,500 MCF/day may only have 375 MCF/day available for new users. As a result, construction of such a new facility in many of these cities - if powered with gas - would require a pipeline upgrade to deliver sufficient gas supply.

EXAMPLES OF SPECIFIC CONSTRAINTS & PIPELINE UPGRADES IN IUB DOCKETS

As discussed previously, not all of the P-dockets reviewed were renewals of pipeline permits. Some P-dockets include proposals for new pipelines or upgrades of existing pipelines. Below are summarized examples of gas constraints from several of these dockets. In some cases, a business that wanted to use natural gas in an area that had no gas service prompted construction of a new pipeline. In other cases, existing pipeline infrastructure was insufficient to meet growing demand from new and existing businesses. The dockets described below provide examples of how limited gas supply is a recurring issue across the state.

Pomeroy/New Cooperative Inc. (P-0895)

The city of Pomeroy (pop. 613) did not have natural gas service when New Cooperative Inc. proposed building a grain pelletizing plant that would use natural gas in its operations. The pelletizing plant is a $15M investment with 15 new jobs. MidAmerican Energy proposed two options to build a pipeline. One option would meet only New Cooperative's requirements of 735 MCF/day. The second option would supply 1,584 MCF/day, enough to meet New Cooperative's requirements and allow residents of Pomeroy to use natural gas for home heating at a future point, after a distribution network is added to the city. The IUB ultimately approved the second option. The 9.9 mile pipeline was completed in 2016, but to date MidAmerican does not provide natural gas to the residents of Pomeroy.

Manning Municipal Utilities (P-0901)

Manning Municipal Utilities (MMU) proposed to build a 24-mile pipeline that would serve as a new lateral to a different interstate pipeline because its existing lateral - and existing interstate line - were constrained. MMU had several large customers that were expanding and increasing demand, including a grain drying business, and several customers seeking to go from interruptible to firm service. MMU could not meet the increased demand from these customers using its existing lateral from the Northern Natural Gas "Denison" branch, which provided 1,356 MCF/day. A separate Northern Natural Gas branch, the "Carroll" branch, provided enough capacity if MMU built the new 24 mile lateral, at 4,600 MCF/day.

Mount Ayr Rebuild (P-0570)

Interstate Power & Light renewed the permit for the 10.9-mile lateral to Mount Ayr in 2015, indicating that the lateral could deliver 2,326 MCF/day to Mount Ayr. Mount Ayr appears to be the only city in Ringgold County with natural gas service.[6] In 2017, IPL proposed to upgrade and slightly shorten the line to a 10.3-mile lateral to Mount Ayr in Ringgold County. IPL indicated that several factors supported the rebuild, including increasing the MCF/day to 9,024. IPL stated that the existing lateral (providing 2,326 MCF/day) only had about 750 MCF/day or 32% of unused capacity and that additional capacity would be needed to support growing use of gas in the area.

DDS Rentals LLC (P-0887)

DDS Rentals and Excel Engineering required natural gas to supply a testing facility located in Ringgold County. Because the county has almost no gas pipeline infrastructure, DDS Rentals proposed building a 7.2-mile pipeline to connect to pipeline infrastructure in Taylor County and deliver gas to its testing facility. The pipeline supplies 2,000 MCF/day.

Muscatine Rebuild (P-0507)

A large industrial company's plan to increase natural gas usage prompted IPL to propose reconstructing 3.3 miles of pipeline serving Muscatine. The existing pipeline only had 19.2% of available capacity to support expanding or new load. After the industrial customer expanded, the available capacity would shrink to 7.7%. IPL proposed a rebuild to go from 31,200 MCF/day to 64,112 MCF/day, which would have over 50% available capacity.

Clinton Area Upgrades (P-0893, P-0512)

In 2015, IPL proposed building a new 12.3-mile lateral to the city of Clinton because of the existing supply would not support additional gas use in the area and the existing lateral was aging and facing reduced capacity from pending safety regulations. IPL specifically stated that "the amount of excess capacity for additional natural gas load in the Clinton area is very limited."[7] IPL indicated that the lack of gas

6 Note that DDR Rentals near Diagonal in Ringgold County built its own pipeline for its facility, described in a separate example.

7 Iowa Utilities Board Docket No. P-0893, Direct Testimony of John S. Boston (March 25, 2016) at 5.

capacity was a concern for both existing businesses looking to expand and new businesses looking to locate in the area and that "lack of adequate excess natural gas capacity was the primary factor in at least two companies ultimately choosing locations other than the Clinton area."[8] The IUB approved IPL's application for the new pipeline, which has now been constructed and can deliver 160,800 MCF/day. While the new pipeline is likely to relieve these constraints, this docket demonstrates the extent to which gas constraints have affected decisions to locate or expand by new and existing businesses.

Northern Natural Gas Ventura North extension (M-0233, FERC Docket No. CP19-35-000)

Northern Natural Gas Company (Northern) submitted a filing requesting authorization to: (1) construct and operate a 1.94-mile, 36-inch diameter pipeline extension with appurtenances; and (2) abandon a valve setting and short segments of pipeline, all located in Worth County, Iowa, and Freeborn County, Minnesota. The total estimated cost of the proposed facilities is approximately $12.6 million.

GAS AVAILABILITY BY CITY

IEC reviewed a list of natural gas suppliers by city from the Iowa Utilities Board and compared it to a full list of incorporated cities and respective 2019 population estimates from the State Data Center. Approximately 320 incorporated cities in Iowa have no gas provider, or about one-third of incorporated cities. The total population associated with these communities is proportionately small, well below one-third of the population of Iowans living in incorporated cities. Still, a new facility requiring gas service would be faced with pipeline construction costs to locate in one of these small communities without gas service, a factor that is likely to encourage a facility owner to locate in communities with an existing supply of gas that can meet its requirements.

2.3 OUTREACH TO UTILITIES AND ECONOMIC DEVELOPMENT AGENCIES

IEC, with assistance from our project partners, Alliant Energy (Alliant) and Iowa Rural Power (the education arm of the Iowa Association of Electric Cooperatives), reached out to the Rural Electric Cooperatives (RECs), the municipalities, the Iowa Association of Municipal Utilities (IAMU), and economic development groups.

ONLINE SURVEY

IEC created an online survey with a set of standard questions targeted for each of three stakeholder groups. The stakeholder groups were the RECs, Economic Development groups, and the Municipal Utilities. The survey included the following questions:

1. *Is the availability of natural gas a typical concern for many new businesses that explore locating facilities in your area?*
2. *In the past five or ten years, were businesses unable to locate new facilities in your area in part because of insufficient supply of natural gas?*
3. *Did businesses require construction of new or upgraded natural gas pipelines to provide sufficient natural gas supply for their facility?*
4. *If businesses required new infrastructure, were there any obstacles to this infrastructure development, such as timing or cost? If yes, briefly describe the obstacle.*

8 Id. at 7.

5. *Have existing businesses in your area been interested in expanding facilities and increasing use of natural gas in the past five or ten years?*

6. *Has supply of sufficient natural gas been an obstacle for existing businesses considering expansion?*
   If yes, rate the obstacle from 1 to 5 with 1 being minimal and 5 being a complete obstacle.

Responses were received from 25 economic development groups and 20 RECs and municipal utilities. The survey found that 58% of the respondents were aware of natural gas constraints in their area. Of those respondents, 65% responded that they were aware of businesses that did not locate in their area or were unable to expand because of natural gas constraints, thereby preventing economic development. Based on the survey results, IEC conducted targeted interviews with relevant respondents.

Figure 8. Awareness of Natural Gas Constraints

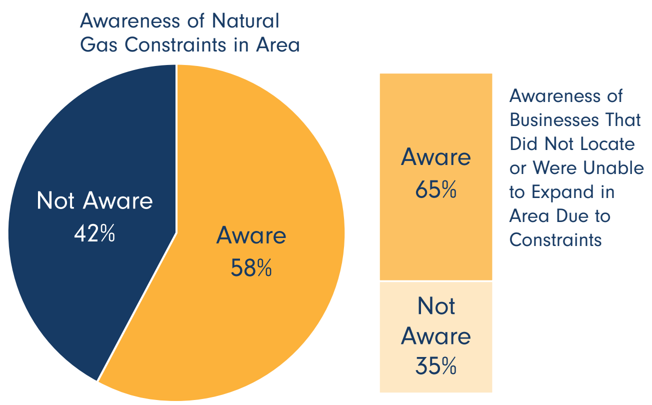
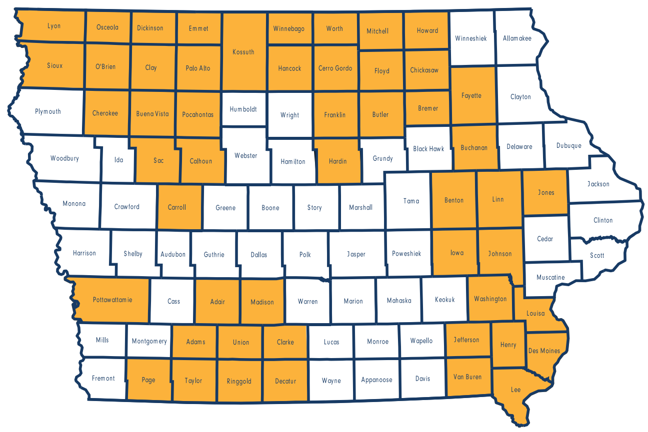


Figure 9. Iowa Counties with Identified Natural Gas Constraints



SPECIFIC EXAMPLES OF CONSTRAINTS

Interviews with RECs, municipal utilities, and economic development groups provided the project team with specific examples of natural gas constraints. Examples are described below.

Lyon County

The survey results indicated that the compressor at Paulina has limited capacity. This may be a limiting factor to economic development in Lyon County. The survey listed the example of the possible loss of Elanco moving to Fort Dodge because of a gas supply constraint to Rock Rapids.

Kossuth, Winnebago, Worth, Mitchell, Floyd, Cerro Gordo, Franklin, and Hancock Counties

The survey indicated several examples of constraints including those where cost was the issue.

- Survey respondents identified a pipeline project from Ventura to Mitchell County through the Manly terminal. The proposed pipeline is 45 miles in length, and the feasibility study has been completed, but the project has stalled. It is unclear why the project has stalled.
- The survey indicated that Greenfield Nitrogen proposed a fertilizer plant at Garner, Iowa in Hancock County. Although the project was announced in 2018, it has yet to come to fruition.
- The survey indicated that Mitchell County failed to land a $100 million prospect a couple of years ago due to natural gas constraints.
- The survey discussed a pipeline project from Lake Mills to the Diamond Joe Casino at Northwood. Although Black Hills declined to construct the project based on the cost of the pipeline, the pipeline was constructed after the Winnebago supervisors paid the entire cost to build the pipeline.

Des Moines, Henry, Lee, Louisa Counties

The survey respondents indicated examples of constraints including those where the constraints may impede economic development.

- The respondents discussed Iowa Fertilizer as being both limited on production and expansion plans. However, since natural gas is the feedstock, this constraint is also impacting further economic development in the area.
- The respondents also discussed a prospective project with the current gas constraint potentially limiting the economic development of a $600 million project.

Calhoun County

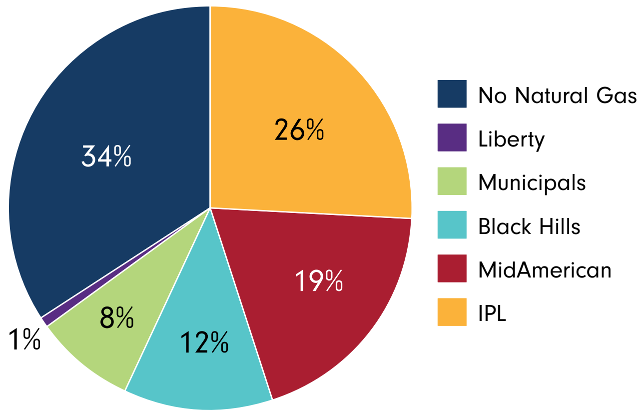
The survey indicated a couple of examples of constraints including those where the constraints impeded economic development.

- The survey indicated that a potential Poet ethanol plant could not get natural gas in Calhoun County, so Poet located the plant in Gowrie in Webster County instead.
- The survey also discussed an entity that would like to have natural gas in Pomeroy, but Pomeroy does not have natural gas so the entity uses LP.

2.4 COMBINATION OF THE TABLE TOP RESEARCH AND ONLINE SURVEY

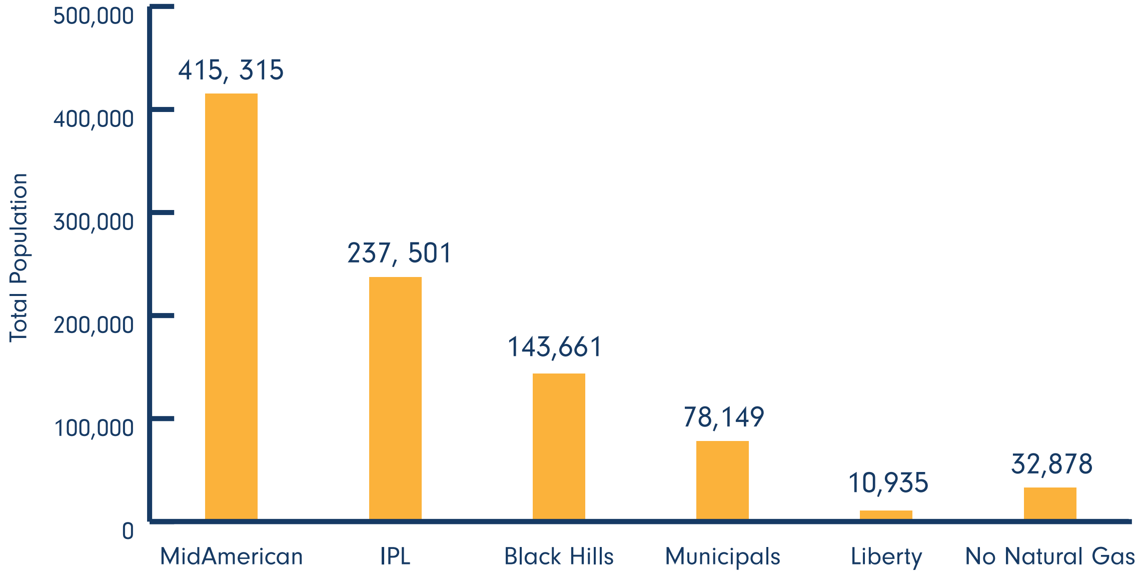
When the table-top research is combined with the online survey, the identified gas constraint areas cover 444 communities. See the attached Appendix A and Appendix B. Of the 444 communities, the covered constraint areas break down as follows by natural gas utility.

Figure 10. Number of Communities with Natural Gas Constraints by Natural Gas Utility



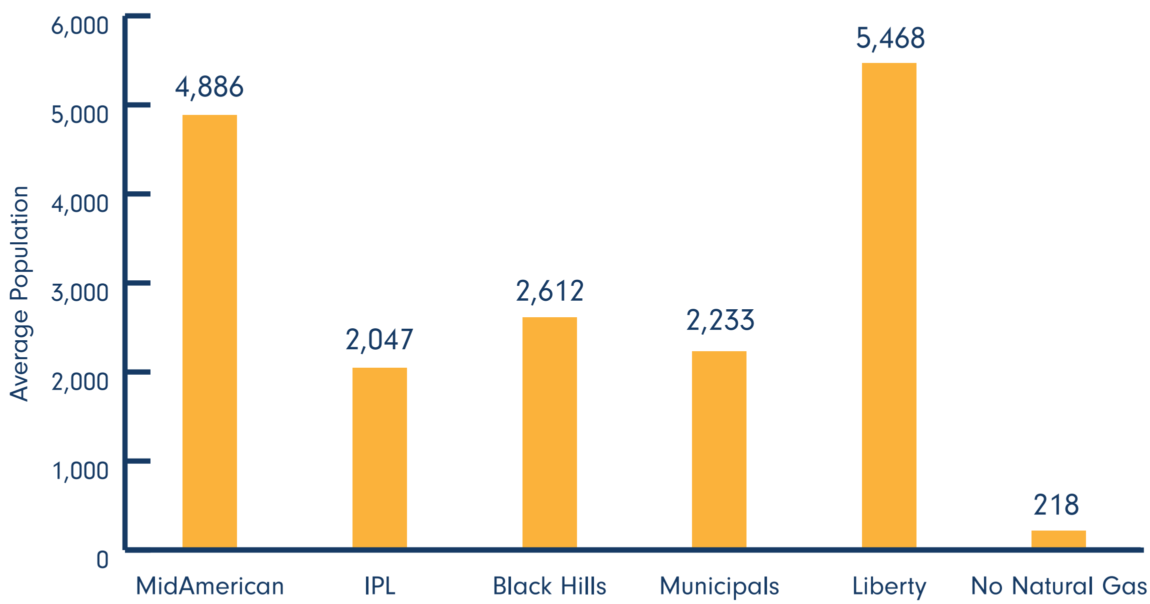
Our research also evaluated the population of the areas with and without natural gas in constrained areas. The research found that larger population centers have better access to natural gas. Although one-third of the identified constrained communities have no natural gas service, those communities represent only 4% of the population of the cities we identified as constrained. Ninety six percent of the population in the identified constraint communities currently have natural gas service.

Figure 11. Total Population of Natural Gas Constrained Communities by Natural Gas Utility



When those same identified constrained communities are evaluated by the average population, the areas with natural gas service have average community populations almost 10 times greater than the areas without natural gas service. In the identified constraint areas, 151 communities, with populations ranging from 14 to 1,501 do not have natural gas service.

Figure 12. Average Population of Natural Gas Constrained Communities by Natural Gas Utility



3 ELECTRIC TECHNOLOGIES

The Research Team compiled an exhaustive list of electric technologies that could potentially be used in industrial and agricultural applications. This list includes technologies that have been in use for decades as well as newer technologies that have limited commercial availability. Table 2 provides a summary of these technologies, as well as the applications and segments in which they would likely be used, their benefits and challenges, and their commercial availability.

The 'application/examples' and 'likely Iowa segments' were determined either from how these technologies were used in the field or while learning about the technology and its applications.

For the commercial status, 'Commercial' indicates this technology is operating in the field.. 'Infancy/Commercial' indicates that we have not encountered this technology in the field, but it appears to be available. 'Infancy' indicates an emerging technology not yet commercially available.

Table 2. Summary of Electric Technologies

Technology	Description	Applications/ Examples	Benefits	Challenges	Commercial Status	Likely Iowa Segments
Hybrid boiler	Boiler with a heat pump to boost the efficiency.	Heating, process heat	Flexibility on energy source, ability to take advantage of price and availability, resilience, minimizing price volatility impact	Somewhat more expensive, support needed for two systems	Commercial	Many. Any with hot water heating source.
Electric boiler	Boiler with straight electric resistance heaters	100–150°C process heat, food, chemicals, plastics	Low CO2 when powered by renewable energy, less expensive/ lower capital cost	Low efficiency with thermally produced electricity, higher energy costs on energy basis than natural gas	Commercial	Many. Any with hot water heating source.
Electric boiler (w/thermal storage)	Electric boiler with a medium to change electrical energy as heat.	Smaller hot water applications with temperatures below 180° F	Uses off peak demand to heat a thermal storage unit (ceramics for example). Helps to offset On-peak demand	Needs time-of-day rate structure.	Commercial	Many. Any with hot water heating source.
Heat pump, 90–160°C	Using heat pumps to achieve hotter temperatures than typical for a heat pump	Sterilization, melting, reacting, processing	Efficient, convenient, avoid boiler house costs, fast response, safe, durable, low maintenance, cooling and heating options. Experience limited, higher-temperature units emerging	Requires close proximity to heat source/ load for highest efficiency, high electric supply needs, complexity	Infancy/ Commercial	Many. Any with hot water heating source.

Technology	Description	Applications/ Examples	Benefits	Challenges	Commercial Status	Likely Iowa Segments
Direct arc melting	Electrical probes deliver a resistance arc through metal to melt it.	Steel and metal transformation of ores	High melt rates and pouring temperatures, excellent control of melt chemistry	High electric demands	Commercial	Metals
Resistance heating	Using resistance heater	Primary metals, plastics, chemicals processing	Backup heat for heat pumps below 40°C	High electric demands	Commercial	Metals. Larger process.
Electric steam generators	Same as electric boiler but with more pressure.	100–150°C process heat	Convenience, compactness, low capital costs, efficiency, fast response, durability, safety, low downtime, dry steam	Displacement of legacy steam systems, possible need to increase electricity capacity, feed water and steam system O&M still required	Commercial	Many. Any with process or heating steam.
Heat pumps < 90°C	Reversible refrigeration system	Drying/ evaporation	Fast response, safety, durability, low maintenance, combined cooling/heating/ dehumidification	Most efficient close to heat source, < 7°C heat quality varies, higher-capacity units need high power	Commercial	Many. HVAC or Process drying
Microwave, radio-frequency	Using microwaves to dry out processes	Drying/ evaporation, sterilization, melting, reacting, processing	Reduced drying times/ higher throughput, energy efficiency, uniform heating, targeted heating, compactness, increased reaction yields	Materials must be compatible, requires electrical capacity upgrades, payback can be longer	Infancy/ Commercial	Food processing
Ohmic drying	Uses the passage of alternating electrical current through food products (typically). Creating internal heat as the result of electrical resistance.	Drying/ evaporation, sterilization, melting, reacting, processing, boost heating (glass), plasma cutting, heat treating	Efficiency, low energy use, emissions-free operation, low cost, small size, controllability	Effectiveness depends on resistance of target material, scarcity, scaling challenges, situation-specific design	Infancy/ Commercial	Food processing

Technology	Description	Applications/ Examples	Benefits	Challenges	Commercial Status	Likely Iowa Segments
Infrared drying	Heating directly using the infrared wavelength.	Drying/ evaporation, melting, reacting, processing, process line heating, mold forming	Reduced operating costs, improved product quality, fast response, durability, low maintenance, safety, low initial cost	High-capacity units may require upgraded electric and network capacity	Commercial	Metal Manufacturing Misc Manufacturing
Pulsed electric field	Used in potato related products	Sterilization, melting, reacting, processing	Faster drying times, ability to be used in combination with osmotic drying, energy savings, increased rate of minerals uptake	Newer. Not well vetted	Infancy/ Commercial	Food Manufacturing
Ultrasound	High frequency sound	Sterilization, enhanced drying	Effective mixing, increased mass transfer, reduced temperature, increased production rate, reduced degradation	Newer. Not well vetted	Infancy/ Commercial	Food Manufacturing
Pulsed light	Using UV-C light to sanitize products in short bursts of light.	Sterilization	Suitability for a range of disinfection applications	Non-penetrating, effects of shadows may limit application	Infancy/ Commercial	Food Manufacturing. Medical Manufacturing
Ultraviolet	UV light to kill biologicals	Sterilization, surface curing	Uniformity for in-package heating	Non-penetrating, effects of shadows may limit application	Commercial	Food Manufacturing. Medical Manufacturing
Friction heating	Exactly like it sounds	Melting, reacting, processing	High efficiency, fast heating, ability to be used for products with no conductivity	Mechanical with rotating equipment so will have maintenance needs, max 50°C	Commercial	Misc Manufacturing
Induction heating	Using a high frequency AC to heat a metal directly	Melting, reacting, processing, melting of primary metals	Reduced costs, increased throughput, presets that aid quality, safety, fast response	Capital and energy costs, electric capacity, maintenance	Commercial	Misc Manufacturing

Technology	Description	Applications/ Examples	Benefits	Challenges	Commercial Status	Likely Iowa Segments
Indirect electric resistance heating	Electric resistance heater with a medium in between	Aluminum Melting	Furnaces that use direct immersion electric resistance heaters (Thermal efficiency around 99%) with low melt loss. ITM melts aluminum via conduction and convection	High first cost, high electric demand.	Infancy/ Commercial	Metals
Extrusion porosification	Heating with a Screw and heater barrels (like you would plastic).	Melting, reacting, processing	Low energy consumption, efficiency, low space requirements, low cost and maintenance, controllability	Inefficient in large spaces, large-unit power consumption may increase network, installation costs	Infancy/ Commercial	Misc Manufacturing
Electroslag, Vacuum, Plasma	Melting and welding metals together	Drying/ concentration	Enhanced powders mixing	Newer. Not well vetted	Infancy	Metals
Hydrogen DRI	Removing the oxygen from Iron oxides to form iron at slightly lower temperatures	Primary metal melting	Lower energy input to produce metals	Expensive to change existing process. Few customers (but typically huge customers)	Infancy	Metals
Electric Grain Dryer	Smaller electric resistance heating with grain bins (typically farmer ones).	New technologies for air flows are making all electric options more favorable.	With new flows better drying capabilities are available.	The airflow technology is fuel source independent. Meaning the increase in flow efficiency would work with NG or Propane.	Commercial	Ag. Grain

After compiling the list of electric technologies, the Michaels team reviewed the list to determine their likely applicability in the industrial and agricultural sectors as well as their applicability in Iowa. The applicability is an assumption based on number and types of customers deal with while traveling in Iowa. For example, technologies that deal with grain drying, corn drying, or metal manufacturing are typically 'Very Applicable'. Where there is no indication of applicability there are very few customers and very few if any applicable with those customers (for example there are not many agriculture applications with melting).

Table 3. Applicability of Electric Technologies

Technology	Industrial Applicability	Agricultural Applicability	Iowa Applicability
Hybrid boiler	●	⦿	⦿
Electric boiler	●	⦿	⦿
Electric boiler (w/thermal storage)	●	●	●
Heat pump, 90–160°C	●	○	⦿
Direct arc melting	●	○	⦿
Resistance heating	●	●	⦿
Electric steam generators	●	○	⦿
Heat pumps < 90°C	⦿	⦿	⦿
Microwave, radiofrequency	⦿	●	⦿
Ohmic drying	⦿	●	⦿
Infrared drying	●	●	⦿
Pulsed electric field	⦿	⦿	⦿
Ultrasound	⦿	○	○
Pulsed light	⦿	○	○
Ultraviolet	●	○	⦿
Friction heating	●	⦿	⦿
Induction heating	●	○	⦿
Indirect electric resistance heating	⦿	●	⦿
Extrusion porosification	⦿	○	●
Electroslag, Vacuum, Plasma	●	○	⦿
Hydrogen DRI	⦿	○	○
Electric Grain Dryer	○	●	●

● Very Applicable ⦿ Somewhat Applicable ○ Limited applicability

Finally, we created a list of the most common industrial segments in Iowa and identified which electric technologies might be most commonly used in each of the top segments. We developed the list based on the count of firms in the Infogroup database with industrial NAICS codes. There were around 6,500 individual entries. We used zip codes for these entries to concentrate on opportunities in less populated areas (below 5,000), which assumes that natural gas restrictions are more likely to happen in these areas. We then combined common entries, which resulted in around 850 individual entries. Only the entries with ten or more potential customers were considered. Shown next are the industrial top 20.

Table 4. Top Iowa Industrial Segments and Common Electric Technologies

Primary NAICS Description	Estimated Rural Iowa Customers	Common Technology
All other miscellaneous manufacturing	351	Electric boiler
Machine shops	282	IR Curing
Sign manufacturing	266	IR Curing
Other animal food manufacturing	161	Ohmic drying
Farm machinery & equipment manufacturing	150	IR Curing
Ready-mix concrete manufacturing	144	Heat pump, 90–160°C
Animal slaughtering (except poultry)	102	Electric steam generators
Other motor vehicle parts manufacturing	101	IR Curing
Breweries	92	Heat pumps < 90°C
All other misc fabricated metal product mfg	92	Infrared drying
Wineries	91	Heat pumps < 90°C
Fabricated structural metal manufacturing	89	Hydrogen DRI
Other concrete product manufacturing	83	Resistance heating
All other miscellaneous food manufacturing	79	Ohmic drying
Nitrogenous fertilizer manufacturing	78	Electric boiler
Other fabricated wire product manufacturing	76	Indirect electric resistance heating
Fertilizer (mixing only) manufacturing	74	Electric steam generators
Sheet metal work manufacturing	66	Electric boiler
Motor vehicle electrical & electronic equip mfg	55	IR Curing
Other motor vehicle parts manufacturing	54	IR Curing

4 SUMMARY OF ELECTRIFICATION AUDITS

4.1 AUDIT BACKGROUND

As part of this research, Michaels Energy conducted audits of select industrial and agricultural facilities to understand the applicable end-use conversion opportunities for electrification and to quantify the cost savings and process improvement potential associated with incorporating electric technologies into industrial processes.

The audit consisted of an engineer from Michaels Energy visiting the facility to document potential electrification opportunities. Based on the information collected on-site, we calculated the potential energy and cost impacts that would result from implementing these technologies. Following the audit, the Research Team presented the facility with a summary of the findings from the audit. The Team then followed up with each site three to nine months after the audit.

We customized the information collected for each audit based on the type of facility.

The information collected during the audit included:

- Specifications of the natural gas-using equipment that could potentially be converted to electric technologies
- The facility's energy usage data and electric rate structure
- Facility and equipment scheduling
- Seasonality of natural gas usage
- Use of heat recovery from any natural-gas process loads

4.2 SUMMARY OF AUDITED FACILITIES

The Research Team conducted audits at seven Iowa facilities. They included four industrial facilities and three agriculture facilities, as shown in Table 5.

Table 5. Summary of Audited Facilities

Site Number	Facility Type	Square Footage
1	Milk production	100,000 – 250,000
2	Manufacturing	Over 1,000,000
3	Grain/corn drying	N/A
4	Manufacturing	Over 1,000,000
5	Greenhouses/nurseries	100,000 – 250,000
6	Breweries/wineries	Under 50,000
7	Animal processing	250,000 – 500,000

SUMMARY OF IDENTIFIED ELECTRIFICATION OPPORTUNITIES

In the course of the audits, the Research Team identified many opportunities to replace natural gas equipment with electric solutions. Table 6 lists these opportunities by facility with their simple payback period. In some cases, the costs of the equipment are greater than the calculated fuel cost savings, resulting in a negative net present value[1][9]. More detailed descriptions of each opportunity are provided in the site-specific audit reports found in Appendix C.

9 To calculate the simple payback period, the Research Team did not use a discount rate accounting for the time value of money.

Table 6. Economic Summary of Identified Electrification Opportunities

Site Number	Segment	Identified Electrification Opportunities	Simple Payback (Years)
1	Milk Production	Supplement Ground-Source Heat Pumps	7.7
		Reduce Hot Water Use for Sanitation	6.1
		Install Heat Recovery Chiller	18.2
		Heat Pump Clothes Dryer	N/A
		High Temperature Heat Pump	N/A
		Electric Radiant Heating	N/A
2	Manufacturing	Replace RTUs with Air-Source Heat Pumps	N/A
		Install Electric Resistance Paint Oven with Back up	N/A
		Air-Source Heat Pump and Heat Recovery*	N/A
		Replace RTUs with Geothermal Heat Pumps	4.2
		Install High-Temperature Heat Pump	136.1
3	Grain/Corn Drying	Aeration Probes and Controls	32.3
		Bin Aeration Circulator Tubes and Controller	49.2
		Install Heat Pump Low Temperature Heating	22.3
4	Manufacturing	Electric Backup and Infrared Preheat	N/A
		Infrared Pre-Heating	0.8
		Compressed Air Heat Recovery	1.7
		Heat Pump Water Heater with Pre-heat	15.9
5	Greenhouses/ Nurseries	Electric Hot Water	N/A
		Vertical Destratification Fans	3.2
		Heat Recovery Chiller*	10.0
		Peak Hot Water Storage	30.6
		Supplemental Solar Hot Water	22.8

Site Number	Segment	Identified Electrification Opportunities	Simple Payback (Years)
6	Breweries/ Wineries	Electric Kettle in Winter	N/A
		Electrical Kettle	N/A
		Hot Water Heat Pump	71.3
		Heat Pump (Heat Recovery Chiller)*	64.8
7	Animal Processing	Install Electric Boiler (25% of Capacity)	N/A
		Install Electric Superheater	0.8
		Install Mechanical Recompressor	2.4
		High Temperature Heat Pump	4.1
		Continuous Rendering	23.5

The costs used to calculate the payback period are the estimated full costs of the equipment and do not include any utility incentives or tax credits. The fuel costs used in this section are an average of 2022 Iowa commercial and industrial fuel costs from the US Energy Information Administration (EIA).[10] The annual energy cost savings presented in the customer audits (included in Appendix C) are based on the actual fuel expenditures for each facility at the time of the audit and will vary by site based on fuel costs, rate structure, and utility.[11] Additionally, many of the identified opportunities have simple payback periods much longer than the expected useful life of the equipment, which typically ranges from 15 to 25 years for industrial equipment, suggesting that these opportunities are unlikely to be implemented given the described scenario.

4.3 SENSITIVITY ANALYSES

The cost-effectiveness of electrification can change with the cost of the fuels and the availability of incentives from utilities and other parties. The Research Team conducted sensitivity analyses to illustrate the impact of different assumptions on the estimated payback period of electrification opportunities.

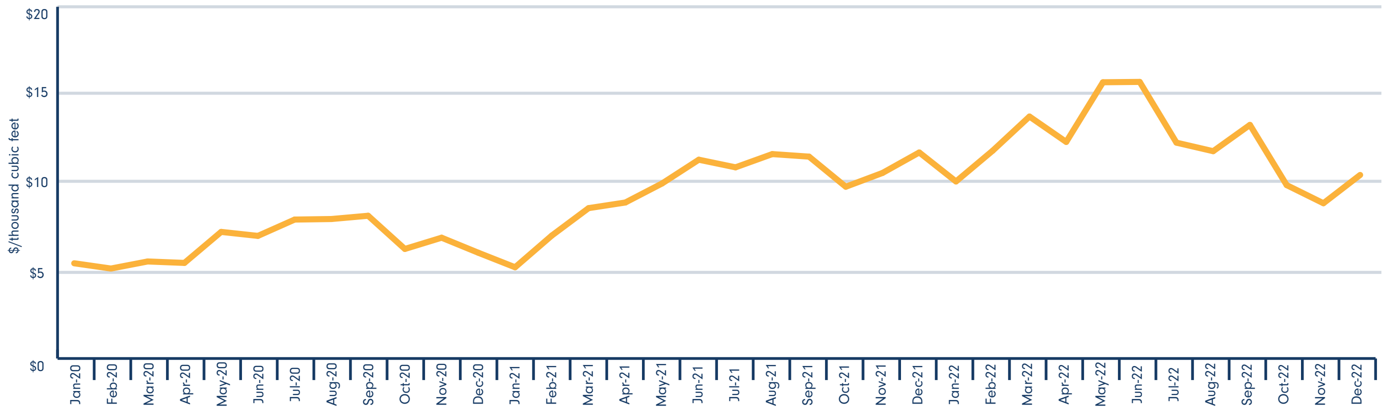
PRICE OF NATURAL GAS

The cost of natural gas has increased recently and appears likely to continue to increase over the short term. Figure 13 shows the average price of natural gas sold to Iowa commercial customers from 2020 to 2022. While the actual cost of natural gas at each facility will vary by rate and utility, this chart is intended to show the increase in cost in recent years. The Research Team assumes that the cost of natural gas will outpace the increase in the cost of electricity due to the many different sources of electricity.

10 https://www.eia.gov/dnav/ng/hist/n3020ia3m.htm

11 Some audited sites were on energy-only electric rates and did not include demand changes in their utility bills. Some sites also were on gas transport rates instead of commercial rates.

Figure 13. Price of Natural Gas Sold to Iowa Commercial Customers



Source: IEA https://www.eia.gov/dnav/ng/hist/n3020ia3m.htm

Table 7 shows the change in simple payback of the measures listed for different natural gas prices, with the cost of electricity held constant. Although the prices of both electricity and natural gas have increased recently, the cost of natural gas is expected to increase faster than the cost of electricity in the near term. The table shows the different payback periods estimated given a price of $1.09 per therm, a decrease of 25%, an increase of 25%, and an increase of 50%.[12]

As expected, the cost effectiveness of electrification can improve considerably as the cost of natural gas increases. For some of the studied electrification measures, such as heat pumps, a 50% increase in the cost of natural gas cuts the expected payback period by almost half.

Table 7. Payback Period in Years for Electrification Opportunities at Select Natural Gas Prices

Site Number	Facility Type	Recommended Measure	$0.82/ Therm (-25%)	$1.09/ Therm	$0.1.36/ Therm (+25%)	$0.1.63/ Therm (+50%)
1	Milk Production	Supplement ground-source heat pumps	10.9	7.7	5.9	4.8
		Reduce hot water use for sanitation	11.2	6.1	4.2	3.2
		Install heat recovery chiller	31.9	18.2	12.7	9.8
		Heat pump clothes dryer	Negative	>50	>50	48.4
		High temperature heat pump	Negative	Negative	Negative	Negative
		Electric radiant heating	Negative	Negative	Negative	Negative

12 In these scenarios, the cost of electricity was held constant at $0.09 per kWh.

Site Number	Facility Type	Recommended Measure	$0.82/ Therm (-25%)	$1.09/ Therm	$0.1.36/ Therm (+25%)	$0.1.63/ Therm (+50%)
2	**Manufacturing**	Replace RTUs with air-source heat pumps	Negative	>50	>50	44.2
		Install electric resistance paint oven with back up	Negative	Negative	Negative	Negative
		Air-source heat pump and heat recovery*	Negative	Negative	Negative	Negative
		Replace rtus with geothermal heat pumps	6.4	4.2	3.1	2.5
		Install high-temperature heat pump	Negative	>50	>50	44.7
3	**Grain/Corn Drying**	Aeration probes and controls	32.3	32.3	32.3	32.3
		Bin aeration circulator tubes and controller	49.4	49.2	49.1	48.9
		Install heat pump low temperature heating	38.6	22.3	15.6	12.1
4	**Manufacturing**	Electric backup and infrared preheat	Negative	Negative	Negative	Negative
		Infrared pre-heating	1.2	0.8	0.6	0.4
		Compressed air heat recovery	2.3	1.7	1.3	1.1
		Heat pump water heater with pre-heat	Negative	15.9	7.6	5.0
5	**Greenhouses/ Nurseries**	Electric hot water	Negative	>50	>50	>50
		Vertical destratification fans	4.4	3.2	2.6	2.1
		Heat recovery chiller*	14.1	10.0	7.8	6.4
		Peak hot water storage	41.8	30.6	24.2	20.0
		Supplemental solar hot water	32.3	22.8	17.6	14.3
6	**Breweries/ Wineries**	Electric kettle in winter	Negative	>50	43.2	28.6
		Electrical kettle	Negative	>50	34.0	21.7
		Hot water heat pump	Negative	>50	29.7	18.7
		Heat pump (heat recovery chiller)*	>50	>50	>50	43.7

Site Number	Facility Type	Recommended Measure	$0.82/ Therm (-25%)	$1.09/ Therm	$0.1.36/ Therm (+25%)	$0.1.63/ Therm (+50%)
7	**Animal Processing**	Install electric boiler (25% of capacity)	Negative	Negative	Negative	Negative
		Install electric superheater	1.1	0.8	0.6	0.5
		Install mechanical recompressor	3.5	2.4	1.9	1.5
		High temperature heat pump	>50	4.1	2.1	1.4
		Continuous rendering	31.3	23.5	18.8	15.7

*Project costs are based on incremental costs

INCENTIVE LEVELS

The Research Team also explored the effect of different incentive levels on payback periods. Utilities often offer customers incentives for energy efficient equipment to defray the incremental cost of moving from an inefficient solution to an efficient solution. For industrial and agricultural customers, these incentives are often custom and are based on the incremental cost of the efficient equipment. The availability and level of incentives vary by utility and equipment type. Note that Iowa's existing energy efficiency policy does not address replacing fossil fuel-using equipment with electric equipment and utilities may provide incentives for equipment that address fuel switching applications.[13]

In addition to utility incentives, the passage of recent federal legislation, including the Inflation Reduction Act (IRA), Infrastructure Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA), may result in further funding for electrification opportunities in Iowa, through tax credits, grants, direct incentives, or loans.

Due to the high level of uncertainty around potential incentive levels, the Research Team conducted a sensitivity analysis to understand the effect of different incentive levels on payback periods. Table 8 shows the payback period for electrification opportunities given different incentive levels.[14] For every 10% decrease in project cost (due to an increased incentive), there is a corresponding 10% decrease in the payback period.

13 https://www.aceee.org/sites/default/files/pdfs/state_fuel-switching_policies_and_rules_7-21-22.pdf

14 Note that the payback periods listed in table 9 are based on a weighted average fuel price point instead of site-specific fuel prices to compare values across sites.

Table 8. Payback Period in Years for Electrification Opportunities with Select Incentive Levels

Site Number	Facility Type	Recommended Measure	No Incentive	Incentive Equal to 10% of Project Cost	Incentive Equal to 20% of Project Cost	Incentive Equal to 30% of Project Cost
1	**Milk Production**	Supplement ground-source heat pumps	7.7	6.9	6.1	5.4
		Reduce hot water use for sanitation	6.1	5.5	4.9	4.2
		Install heat recovery chiller	18.2	16.4	14.6	12.7
		Heat pump clothes dryer	>50	>50	>50	>50
		High temperature heat pump	Negative	Negative	Negative	Negative
		Electric radiant heating	Negative	Negative	Negative	Negative
2	**Manufacturing**	Replace rtus with air-source heat pumps	>50	>50	>50	>50
		Install electric resistance paint oven with back up	Negative	Negative	Negative	Negative
		Air-source heat pump and heat recovery	Negative	Negative	Negative	Negative
		Replace rtus with geothermal heat pumps	4.2	3.7	3.3	2.9
		Install high-temperature heat pump	>50	>50	>50	>50
3	**Grain/Corn Drying**	Aeration probes and controls	32.3	29.1	25.8	22.6
		Bin aeration circulator tubes and controller	49.2	44.3	39.4	34.5
		Install heat pump low temperature heating	22.3	20.0	17.8	15.6
4	**Manufacturing**	Electric backup and infrared preheat	Negative	Negative	Negative	Negative
		Infrared pre-heating	0.8	0.7	0.6	0.5
		Compressed air heat recovery	1.7	1.5	1.3	1.2
		Heat pump water heater with pre-heat	15.9	14.3	12.7	11.1

Site Number	Facility Type	Recommended Measure	No Incentive	Incentive Equal to 10% of Project Cost	Incentive Equal to 20% of Project Cost	Incentive Equal to 30% of Project Cost
5	Greenhouses/ Nurseries	Electric hot water	>50	>50	>50	>50
		Vertical destratification fans	3.2	2.9	2.6	2.3
		Heat recovery chiller	10.0	9.0	8.0	7.0
		Peak hot water storage	30.6	27.6	24.5	21.4
		Supplemental solar hot water	22.8	20.5	18.2	15.9
6	Breweries/ Wineries	Electric kettle in winter	>50	>50	>50	>50
		Electrical kettle	>50	>50	>50	>50
		Hot water heat pump	>50	>50	>50	>50
		Heat pump (heat recovery chiller)	>50	>50	>50	>50
7	Animal Processing	Install electric boiler (25% of capacity)	Negative	Negative	Negative	Negative
		Install electric superheater	0.8	0.7	0.6	0.5
		Install mechanical recompressor	2.4	2.2	1.9	1.7
		High temperature heat pump	4.1	3.7	3.3	2.9
		Continuous rendering	23.5	21.1	18.8	16.4

4.4 FOLLOW-UP SURVEY RESULTS

For each audited facility, the Research Team made recommendations of electric alternatives for either replacement or temporary alternatives during natural gas curtailment. After three to nine months, each of the participants was surveyed to determine if they had implemented or are considering operational alternatives identified as a part of the electrification study. Additionally, since the Inflation Reduction Act (IRA) was signed into law in 2022, the Research Team surveyed participants to assess awareness of the IRA and if the IRA information is helpful in their decision making regarding future implementation of the alternatives.

Collectively, 29 measures were identified as alternatives along with the associated costs and projected payback time. At the time of the survey, none of the 29 measures have been implemented, although 3 measures are currently being considered for implementation.

Figure 14 illustrates the reasons respondents identified for not implementing the identified electrification measures. As shown earlier, most identified opportunities have payback periods of 20 years or more. As expected, survey respondents cited this long payback period as the primary reason for not implementing the measures.

As shown in Figure 15, most respondents would further explore electrification measures if rebates and incentives were available to help with the cost of the equipment. Only one of the seven audited sites stated that they were aware of IRA incentives (Figure 16). This is not surprising, given that opportunities for industrial incentives are still being developed and have not been announced with the level of detail as residential incentives and tax credits.

Figure 14. Reasons For Not Implementing Identified Electrification Measures (n=6)

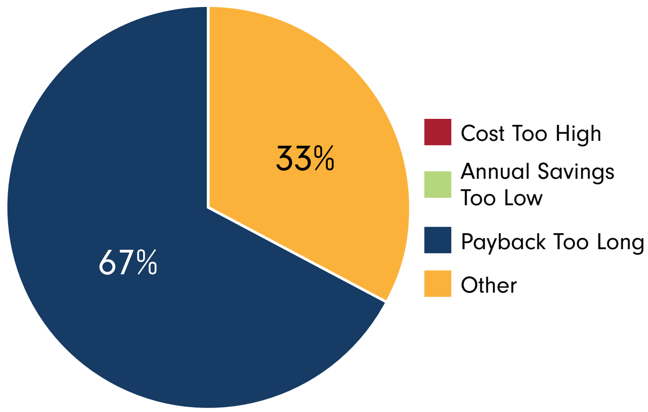


Figure 15. Likelihood of Exploring Electrification Measures If Rebates and Incentives Are Available (n=6),

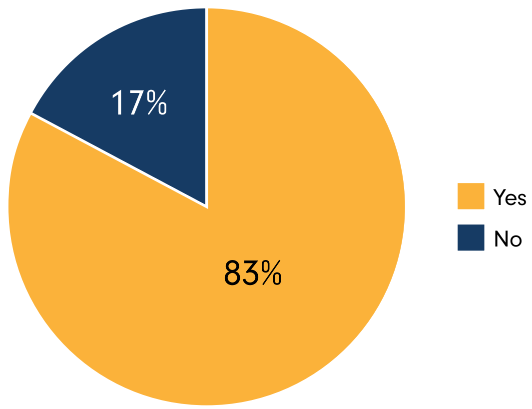
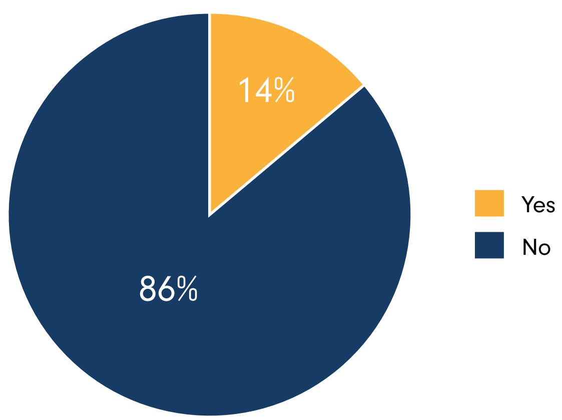


Figure 16. Awareness of IRA Incentives (n=7)



Most respondents found the IRA incentives as only somewhat helpful or not at all helpful. This is likely due to the current lack of public information about industrial and agricultural incentives through the legislation. It is likely that the perceived helpfulness of the incentives increases over time as general awareness grows.

Figure 18 shows that more than half of respondents are either unlikely or very unlikely to implement the electrification project if internal costs and payback criteria are not met.

Figure 17. Perceived Helpfulness of IRA Incentives (n=7)

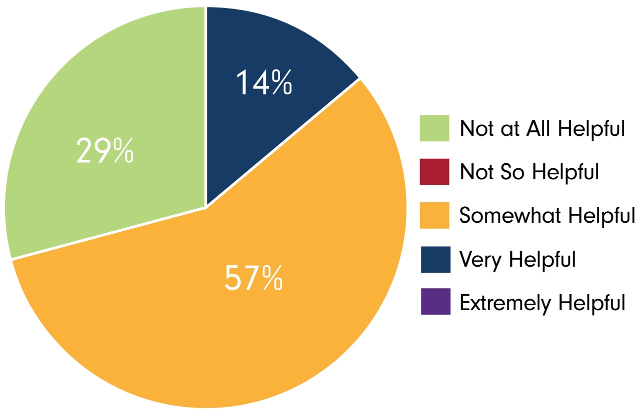
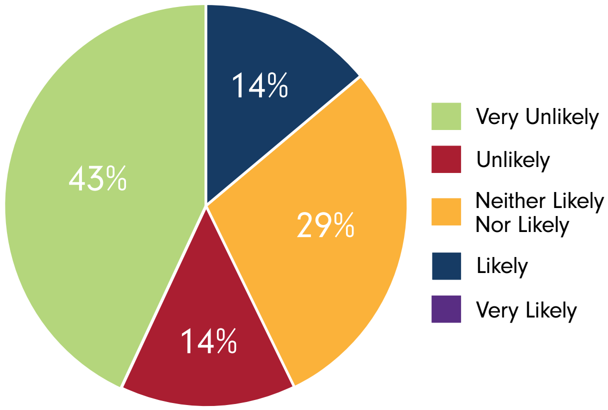


Figure 18. Likelihood of Implementation If Costs and Payback Criteria Are Not Met (n=7)



5 CONCLUSIONS

THIS SECTION SUMMARIZES THE CONCLUSIONS OF THIS STUDY BASED ON THE RESULTS PRESENTED IN THE REPORT.

- The Research Team found that natural gas constraints exist in Iowa, particularly in less populated areas of the state. To increase economic development in constrained areas or areas without natural gas access, alternatives to natural gas expansion, such as electrification of industrial and agricultural facilities, should be explored.

- Our research found that given current fuel prices, the payback for electrification in industrial and agricultural applications in Iowa is too long for most customers. Of the 32 identified measures, only 21 had positive payback periods and, of those, only five had simple paybacks of less than ten years using the site-specific fuel costs at the time of the audit. This length of time is too long for most businesses.

- The cost-effectiveness of electrification can improve considerably as the cost of natural gas increases. For some of the studied electrification measures, such as heat pumps, a 50% increase in the cost of natural gas cuts the expected payback period by almost half.

- To increase the financial attractiveness of electrification, most businesses will need incentives. These may come from utilities or from other sources, such as the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA). However, awareness of such incentives or funding is low.

- There are many electric technologies currently available to meet the needs of industrial and agricultural facilities and more in development.

- While payback period was a key barrier to implementing electrification measures, other barriers existed as well. These included electric rate structures and, for existing facilities, the need to undergo a major facility retrofit to replace existing gas-powered equipment. Because of this, it will likely be easier and less costly for new facilities to implement electric solutions than existing facilities.

APPENDIX A | NATURAL GAS VOLUME

Table 9. Reviewed Natural Gas Pipeline Dockets

Docket Number	Docket type/summary	City/Location	ZIP	MCF/day
P-0709	MidAm permit renewal - PENDING	Afton	50830	1,440
P-0565	IPL permit renewal	Ainsworth	52201	312
P-0787	IPL permit renewal	Albion	50005	2,207
P-0813	IPL permit renewal	Armstrong	50514	2,990
P-0711	MidAm permit renewal	Attica	50044	240
P-0796	BHE permit renewal	Aurora	50607	648
P-0814	IPL permit renewal	Bancroft	50517	44
P-0646	Permit renewal - Montezuma Natural Gas Dept	Barnes City	50027	3,000
P-0785	IPL permit renewal	Batavia	52533	718
P-0777	BHE permit renewal	Baxter	50028	1,150
P-0784	IPL permit renewal	Beaman	50609	2,224
P-0643	Pipeline renewal - Bedford Municipal Utilities	Bedford	50833	1,512
P-0819	IPL permit renewal	Blairstown	52209	1,751
P-0529	MidAm permit renewal	Blue Grass	52726	1,422
P-0811	IPL permit renewal	Brandon	52210	840
P-0611	Brighton Municipal Gas System permit renewal	Brighton	52540	1,033
P-0828	IPL permit renewal	Buffalo Center	50424	100
P-0576	MidAm permit renewal	Bussey	50044	722
P-0826	IPL permit renewal	Calamus	52729	2,476
P-0803	IPL permit renewal	Casey	50048	1,600
P-0473	IPL permit renewal	Chariton	50049	5,280
P-0613	IPL permit renewal	Cincinnati	52549	220
P-0824	IPL permit renewal	Clarence	52216	1,565
P-0645	Clearfield Municipal Gas permit renewal	Clearfield	50840	336
P-0827	IPL permit renewal	Clemons	50051	1,061
P-0821	IPL permit renewal	Collins	50055	1,320
P-0517	IPL permit renewal	Conesville	52739	708
P-0730	MidAm permit renewal	Coralville	52241	406
P-0457	IPL permit renewal	Corydon	50060	2,760
P-0665	BHE permit renewal	Cumberland	50843	770
P-0768	MidAm permit renewal	De Soto	50069	1,595
P-0561	MidAm permit renewal	Donnellson	52625	775
P-0768	MidAm permit renewal	Earlham	50072	1,595
P-0785	IPL permit renewal	Eldon	52554	2,224
P-0618	MidAm permit renewal	Eldridge	52748	2,100
P-0476	MidAm permit renewal	Elliott	51532	396
P-0692	MidAm permit renewal	Ely	52227	271
P-0273	MidAm permit renewal	Emerson	51533	430
P-0805	Fairbank Municipal Utilities permit renewal	Fairbank	50629	642
P-0801	IPL permit renewal	Fairfield	52556	2,714
P-0804	BHE permit renewal	Fonda	50540	1,560

Docket Number	Docket type/summary	City/Location	ZIP	MCF/day
P-0549	IPL permit renewal	Fontanelle	50846	340
P-0491	MidAm permit renewal	Fremont	52561	700
P-0800	BHE permit renewal.	Garnavillo	52049	3,350
P-0826	IPL permit renewal	Grand Mound	52751	2,476
P-0622	IPL permit renewal	Grandview	52752	281
P-0029	IPL permit renewal	Greenfield	50849	3,360
P-0509	BHE permit renewal	Hamburg	51640	2,000
P-0576	MidAm permit renewal	Hamilton	50116	722
P-0710	MidAm permit renewal	Harvey	50119	252
P-0647	MidAm permit renewal	Hills	52235	406
P-0569	IPL permit renewal	Kalona	52247	3,744
P-0460	IPL permit renewal	Keota	52248	840
P-0794	IPL permit renewal	Keystone	52249	544
	BHE permit renewal	La Motte	52054	1,200
P-0773	IPL permit renewal	Ladora	52251	8,800
P-0797	BHE permit renewal	Lake View	51450	2,760
P-0828	IPL permit renewal	Lakota	50451	100
P-0791	BHE permit renewal	Lawler	52154	960
P-0820	IPL permit renewal	Ledyard	50556	18
P-0578	MidAm permit renewal	Leighton	50143	85
P-0644	Lenox Municipal Natural Gas Utility permit renewal	Lenox	50851	3,048
P-0458	IPL permit renewal	Leon	50144	5,040
P-0558	IPL permit renewal	Letts	52754	660
P-0801	IPL permit renewal	Libertyville	52567	2,714
P-0787	IPL permit renewal	Liscomb	50148	2,207
P-0810	IPL permit renewal	Little Rock	51243	792
P-0517	IPL permit renewal	Lone Tree	52755	720
P-0618	MidAm permit renewal	Long Grove	52756	2,100
P-0576	MidAm permit renewal	Lovilia	50150	722
P-0616	IPL permit renewal	Low Moor	52757	1,050
P-0824	IPL permit renewal	Lowden	52255	1,565
P-0798	BHE permit renewal	Lynnville	50153	2,308
P-0272	MidAm permit renewal	Malvern	51551	936
P-0773	IPL permit renewal	Marengo	52301	8,800
P-0714	MidAm permit renewal	Martensdale	50160	397
P-0821	IPL permit renewal	Maxwell	50161	1,320
P-0789	IPL permit renewal	Mccallsburg	50154	1,296
P-0786	IPL permit renewal	Melbourne	50162	2,179
P-0475	MidAm permit renewal	Melcher-Dallas	50062	707
P-0803	IPL permit renewal	Menlo	50164	1,600
P-0509	BHE permit renewal	Glenwood	51534	11,400
P-0474	MidAm permit renewal	Milo	50166	687
P-0646	Permit renewal - Montezuma Natural Gas Dept	Montezuma	50171	3,000

Docket Number	Docket type/summary	City/Location	ZIP	MCF/day
P-0809	Pre-EFS paper documents added to EFS	Montour	50173	900
P-0782	IPL permit renewal	Mount Auburn	52313	620
P-0333	Pre-EFS paper documents added to EFS	New Hampton	50659	2,340
P-0548	MidAm permit renewal	New Sharon	50207	510
P-0506	IPL permit renewal	New Virginia	50210	1,020
P-0794	IPL permit renewal	Newhall	52315	544
P-0517	IPL permit renewal	Nichols	52766	900
P-0819	IPL permit renewal	Norway	52318	943
P-0730	MidAm permit renewal	Oxford	52322	406
P-0794	IPL permit renewal	Palo	52324	402
P-0618	MidAm permit renewal	Park View	52748	2,100
P-0711	MidAm permit renewal	Pershing	50138	240
P-0511	MidAm permit renewal	Pleasantville	50225	762
P-0786	IPL permit renewal	Rhodes	50234	2,179
P-0794	IPL permit renewal	Shellsburg	52332	1,726
P-0509	BHE permit renewal	Sidney	51652	4,100
P-0461	IPL permit renewal	Sigourney	52591	4,800
P-0663	MidAm permit renewal	Solon	52333	406
P-0827	IPL permit renewal	St. Anthony	50239	1,061
P-0577	MidAm permit renewal	St. Charles	50240	260
P-0714	MidAm permit renewal	St. Marys	50241	397
P-0815	IPL permit renewal	Stacyville	50476	500
P-0799	BHE permit renewal	Stanhope	50246	840
P-0818	IPL permit renewal	Steamboat Rock	50672	780
P-0716	IPL petition for permit amendment, later withdrawn. IPL had proposed to reconstruct and extend the existing pipeline from 7.4 miles to 11.1 miles and from 787 mcf/day to 8,414 mcf/day. Filings indicate current info for Stockport. Info for Keosauqua and Birmingham unclear - later incomplete filings unclear whether they supersede earlier filings	Stockport	52651	787
P-0798	IPL permit renewal	Sully	50251	2,507
P-0813	IPL permit renewal	Swea City	50590	3,912
P-0509	BHE permit renewal	Tabor	51653	4,100
P-0822	Manning Municipal Utilities permit renewal	Templeton	51463	1,356
P-0730	MidAm permit renewal	Tiffin	52340	406
P-0815	IPL permit renewal	Toeterville	50481	700
P-0576	MidAm permit renewal	Tracy	50256	722
P-0768	MidAm permit renewal	Van Meter	50261	1,595
P-0773	IPL permit renewal	Victor	52347	8,800
P-0554	MidAm permit renewal	Walcott	52773	2,350
P-0819	IPL permit renewal	Walford	52351	1,070
P-0487	IPL permit renewal	Wapello	52653	1,950
P-0579	Wayland Municipal Utilities permit renewal	Wayland	52654	905
P-0566	Wellman Municipal Gas System permit renewal	Wellman	52356	1,500

Docket Number	Docket type/summary	City/Location	ZIP	MCF/day
P-0517	IPL permit renewal	West Branch	52358	2,000
P-0517	IPL permit renewal	West Branch	52358	10,800
P-0513	IPL permit renewal	West Chester	52359	351
P-0772	MidAm permit renewal	West Point	52656	960
P-0462	IPL permit renewal	What Cheer	50268	1,488
P-0824	IPL permit renewal	Wheatland	52777	1,565
P-0817	IPL permit renewal	Williamson	50272	240
P-0789	IPL permit renewal	Zearing	50278	1,296
P-0778	BHE permit renewal	Zwingle	52079	500

APPENDIX B | DETAILED AUDIT RESULTS

Table 10. Natural Gas Contrained Communities by County

City	County	Gas Provider	Population
Nodaway	Adams	None	103
Corning	Adams	Corning Municipal	1,433
Prescott	Adams	Prescott Municipal Utilities	237
Belle Plaine	Benton	IPL	2,440
Blairstown	Benton	IPL	659
Garrison	Benton	IPL	360
Keystone	Benton	IPL	612
Mount Auburn	Benton	IPL	144
Newhall	Benton	IPL	858
Norway	Benton	IPL	528
Urbana	Benton	IPL	1,494
Van Horne	Benton	IPL	656
Vinton	Benton	IPL	5,075
Walford	Benton	IPL	1,445
Atkins	Benton	MidAmerican	1,970
Shellsburg	Benton	MidAmerican	4,820
Luzerne	Benton	None	93
Readlyn	Bremer	BHE	846
Sumner	Bremer	BHE	1,962
Denver	Bremer	MidAmerican	1,856
Janesville	Bremer	MidAmerican	986
Plainfield	Bremer	MidAmerican	414
Tripoli	Bremer	MidAmerican	965
Frederika	Bremer	None	203
Waverly	Bremer	Waukee Municipal Gas	24,089
Aurora	Buchanan	BHE	161
Lamont	Buchanan	BHE	457
Brandon	Buchanan	IPL	320

City	County	Gas Provider	Population
Hazleton	Buchanan	IPL	833
Quasqueton	Buchanan	IPL	564
Rowley	Buchanan	IPL	270
Stanley	Buchanan	IPL	120
Winthrop	Buchanan	IPL	849
Independence	Buchanan	MidAmerican	6,124
Jesup	Buchanan	MidAmerican	2,703
Fairbank	Buchanan	Fairbank Municipal	1,133
Truesdale	Buena Vista	BHE	1,360
Albert City	Buena Vista	IPL	665
Alta	Buena Vista	IPL	1,903
Lakeside	Buena Vista	IPL	689
Linn Grove	Buena Vista	IPL	146
Marathon	Buena Vista	IPL	227
Rembrandt	Buena Vista	IPL	194
Sioux Rapids	Buena Vista	IPL	744
Storm Lake	Buena Vista	IPL	10,322
Newell	Buena Vista	MidAmerican	852
Greene	Butler	BHE	1,063
Shell Rock	Butler	IPL	972
Allison	Butler	MidAmerican	973
Aplington	Butler	MidAmerican	1,050
Bristow	Butler	MidAmerican	149
Clarksville	Butler	MidAmerican	1,346
Dumont	Butler	MidAmerican	602
New Hartford	Butler	MidAmerican	488
Parkersburg	Butler	MidAmerican	1,928
Aredale	Butler	None	69
Farnhamville	Calhoun	BHE	344
Lake City	Calhoun	MidAmerican	1,642
Lohrville	Calhoun	MidAmerican	345
Manson	Calhoun	MidAmerican	1,566
Rockwell City	Calhoun	MidAmerican	2,082
Jolley	Calhoun	None	37
Knierim	Calhoun	None	58
Pomeroy	Calhoun	None	613
Rinard	Calhoun	None	50
Somers	Calhoun	None	106
Yetter	Calhoun	None	32
Glidden	Carroll	BHE	1,106
Ralston	Carroll	BHE	73
Carroll	Carroll	IPL	9,833
Breda	Carroll	MidAmerican	110
Dedham	Carroll	MidAmerican	256

City	County	Gas Provider	Population
Arcadia	Carroll	None	520
Halbur	Carroll	None	256
Lanesboro	Carroll	None	109
Lidderdale	Carroll	None	171
Willey	Carroll	None	98
Coon Rapids	Carroll	Coon Rapids Municipal	1,232
Manning	Carroll	Manning Municipal	1,422
Templeton	Carroll	Manning Municipal	334
Clear Lake	Cerro Gordo	IPL	7,550
Mason City	Cerro Gordo	IPL	26,931
Meservey	Cerro Gordo	IPL	238
Thornton	Cerro Gordo	IPL	402
Ventura	Cerro Gordo	IPL	713
Rockwell	Cerro Gordo	MidAmerican	990
Dougherty	Cerro Gordo	None	57
Plymouth	Cerro Gordo	None	362
Rock Falls	Cerro Gordo	None	143
Swaledale	Cerro Gordo	None	158
Cherokee	Cherokee	IPL	4,869
Aurelia	Cherokee	MidAmerican	958
Cleghorn	Cherokee	MidAmerican	216
Larrabee	Cherokee	MidAmerican	131
Marcus	Cherokee	MidAmerican	1,054
Meriden	Cherokee	MidAmerican	148
Quimby	Cherokee	None	292
Washta	Cherokee	None	223
Fredericksburg	Chickasaw	BHE	923
Ionia	Chickasaw	BHE	275
Lawler	Chickasaw	BHE	419
New Hampton	Chickasaw	BHE	3,406
Nashua	Chickasaw	MidAmerican	1,589
Alta Vista	Chickasaw	None	252
Bassett	Chickasaw	None	63
North Washington	Chickasaw	None	138
Osceola	Clarke	IPL	5,242
Murray	Clarke	None	702
Woodburn	Clarke	None	194
Fostoria	Clay	BHE	223
Royal	Clay	BHE	409
Spencer	Clay	BHE	10,952
Peterson	Clay	IPL	309
Dickens	Clay	None	171
Gillett Grove	Clay	None	47
Greenville	Clay	None	68

City	County	Gas Provider	Population
Rossie	Clay	None	68
Webb	Clay	None	128
Everly	Clay	City of Everly	550
Leon	Decatur	IPL	1,823
Davis City	Decatur	None	184
Decatur City	Decatur	None	184
Garden Grove	Decatur	None	197
Grand River	Decatur	None	215
Le Roy	Decatur	None	14
Pleasanton	Decatur	None	44
Van Wert	Decatur	None	204
Weldon	Decatur	None	115
Lamoni	Decatur	Lamoni Municipal	2,249
Burlington	Des Moines	IPL	24,713
Danville	Des Moines	IPL	899
Mediapolis	Des Moines	IPL	1,517
Middletown	Des Moines	IPL	335
West Burlington	Des Moines	IPL	2,890
Arnolds Park	Dickinson	BHE	1,313
Milford	Dickinson	BHE	2,997
Okoboji	Dickinson	BHE	792
Orleans	Dickinson	BHE	587
Spirit Lake	Dickinson	BHE	5,155
Superior	Dickinson	BHE	119
Terril	Dickinson	BHE	336
Wahpeton	Dickinson	BHE	345
West Okoboji	Dickinson	BHE	291
Lake Park	Dickinson	Lake Park Municipal	1,123
Estherville	Emmet	BHE	5,666
Wallingford	Emmet	BHE	173
Dolliver	Emmet	None	59
Gruver	Emmet	None	83
Ringsted	Emmet	None	370
Armstrong	Emmett	IPL	840
Arlington	Fayette	BHE	399
Fayette	Fayette	BHE	1,441
Hawkeye	Fayette	BHE	408
West Union	Fayette	BHE	2,305
Maynard	Fayette	IPL	488
Oelwein	Fayette	IPL	5,900
Clermont	Fayette	None	583
Elgin	Fayette	None	634
Randalia	Fayette	None	56
St. Lucas	Fayette	None	136

City	County	Gas Provider	Population
Wadena	Fayette	None	240
Waucoma	Fayette	None	245
Westgate	Fayette	None	198
Marble Rock	Floyd	BHE	287
Rockford	Floyd	BHE	822
Nora Springs	Floyd	IPL	1,354
Rudd	Floyd	IPL	346
Charles City	Floyd	MidAmerican	7,307
Floyd	Floyd	MidAmerican	315
Colwell	Floyd	None	70
Alexander	Franklin	IPL	161
Coulter	Franklin	IPL	263
Hampton	Franklin	MidAmerican	4,205
Latimer	Franklin	MidAmerican	470
Sheffield	Franklin	MidAmerican	1,106
Geneva	Franklin	None	153
Hansell	Franklin	None	90
Popejoy	Franklin	None	75
Klemme	Hancock	BHE	463
Britt	Hancock	IPL	1,955
Corwith	Hancock	IPL	254
Garner	Hancock	IPL	3,033
Goodell	Hancock	IPL	128
Kanawha	Hancock	IPL	595
Crystal Lake	Hancock	None	232
Woden	Hancock	None	206
Ackley	Hardin	BHE	1,498
Alden	Hardin	IPL	738
Eldora	Hardin	IPL	2,612
Hubbard	Hardin	IPL	801
Iowa Falls	Hardin	IPL	5,059
New Providence	Hardin	IPL	223
Owasa	Hardin	IPL	42
Radcliffe	Hardin	IPL	524
Steamboat Rock	Hardin	IPL	302
Union	Hardin	IPL	381
Whitten	Hardin	IPL	145
Buckeye	Hardin	None	108
Mount Pleasant	Henry	IPL	8,668
New London	Henry	IPL	1,839
Coppock	Henry	None	48
Hillsboro	Henry	None	177
Olds	Henry	None	223
Rome	Henry	None	116

City	County	Gas Provider	Population
Salem	Henry	None	384
Westwood	Henry	None	110
Wayland	Henry	Wayland Municipal Gas System	943
Winfield	Henry	Winfield Municipal Gas	1,088
Cresco	Howard	BHE	3,739
Chester	Howard	None	120
Elma	Howard	None	527
Lime Springs	Howard	None	474
Protivin	Howard	None	270
Ladora	Iowa	IPL	274
Marengo	Iowa	IPL	2,466
North English	Iowa	IPL	1,007
Parnell	Iowa	IPL	264
Victor	Iowa	IPL	868
Williamsburg	Iowa	IPL	3,164
Millersburg	Iowa	None	142
Batavia	Jefferson	IPL	549
Fairfield	Jefferson	IPL	10,425
Libertyville	Jefferson	IPL	341
Lockridge	Jefferson	IPL	290
Pleasant Plain	Jefferson	None	98
Lone Tree	Johnson	IPL	1,381
Coralville	Johnson	MidAmerican	22,290
Hills	Johnson	MidAmerican	804
Iowa City	Johnson	MidAmerican	75,130
North Liberty	Johnson	MidAmerican	19,501
Oxford	Johnson	MidAmerican	792
Solon	Johnson	MidAmerican	2,690
Tiffin	Johnson	MidAmerican	4,157
Shueyville	Johnson	None	655
Swisher	Johnson	None	953
Anamosa	Jones	BHE	5,537
Martelle	Jones	BHE	250
Monticello	Jones	BHE	3,880
Morley	Jones	IPL	113
Olin	Jones	IPL	687
Onslow	Jones	None	193
Oxford Junction	Jones	None	483
Wyoming	Jones	None	515
Bancroft	Kossuth	IPL	696
Lakota	Kossuth	IPL	279
Ledyard	Kossuth	IPL	120
Swea City	Kossuth	IPL	507
Algona	Kossuth	MidAmerican	5,397

City	County	Gas Provider	Population
Fenton	Kossuth	MidAmerican	233
Lone Rock	Kossuth	MidAmerican	139
Wesley	Kossuth	MidAmerican	365
Burt	Kossuth	None	498
LuVerne	Kossuth	None	93
Titonka	Kossuth	Titonka Municipal Utilities	443
Whittemore	Kossuth	Whittemore Municipal Utilities	476
Keokuk	Lee	Liberty Utilities	10,157
Montrose	Lee	Liberty Utilities	778
Donnellson	Lee	MidAmerican	854
Fort Madison	Lee	MidAmerican	10,321
Franklin	Lee	None	132
Houghton	Lee	None	136
St. Paul	Lee	None	124
West Point	Lee	none	930
Springville	Linn	BHE	1,137
Alburnett	Linn	IPL	699
Center Point	Linn	IPL	2,555
Central City	Linn	IPL	1,296
Coggon	Linn	IPL	667
Lisbon	Linn	IPL	2,247
Mount Vernon	Linn	IPL	4,466
Palo	Linn	IPL	1,066
Walker	Linn	IPL	789
Cedar Rapids	Linn	MidAmerican	133,562
Ely	Linn	MidAmerican	2,343
Fairfax	Linn	MidAmerican	2,856
Hiawatha	Linn	MidAmerican	7,420
Marion	Linn	MidAmerican	40,359
Robins	Linn	MidAmerican	3,537
Bertram	Linn	None	290
Prairieburg	Linn	None	188
Columbus City	Louisa	IPL	372
Columbus Junction	Louisa	IPL	1,837
Letts	Louisa	IPL	373
Wapello	Louisa	IPL	1,999
Cotter	Louisa	None	46
Fredonia	Louisa	None	235
Grandview	Louisa	None	215
Oakville	Louisa	None	169
Morning Sun	Louisa	Morning Sun Municipal	796
George	Lyon	IPL	1,042
Little Rock	Lyon	IPL	433
Alvord	Lyon	MidAmerican	201

City	County	Gas Provider	Population
Doon	Lyon	MidAmerican	601
Inwood	Lyon	MidAmerican	849
Larchwood	Lyon	None	891
Lester	Lyon	None	302
Rock Rapids	Lyon	Rock Rapids Municipal Utility	2,522
Earlham	Madison	MidAmerican	1,410
St. Charles	Madison	MidAmerican	619
Winterset	Madison	MidAmerican	5,383
Bevington	Madison	None	69
East Peru	Madison	None	131
Macksburg	Madison	None	118
Patterson	Madison	None	161
Truro	Madison	None	77
Mitchell	Mitchell	BHE	130
St. Ansgar	Mitchell	BHE	1,120
Stacyville	Mitchell	IPL	463
Carpenter	Mitchell	None	106
McIntire	Mitchell	None	125
Orchard	Mitchell	None	71
Riceville	Mitchell	None	764
Osage	Mitchell	Osage Municipal Gas Utility	3,555
Paullina	O'Brien	BHE	977
Primghar	O'Brien	BHE	856
Archer	O'Brien	MidAmerican	124
Calumet	O'Brien	MidAmerican	157
Sheldon	O'Brien	MidAmerican	1,275
Sutherland	O'Brien	MidAmerican	596
Hartley	O'Brien	Hartley Municipal	1,574
Sanborn	O'Brien	Sanborn Municipal Gas Utility	1,381
Ashton	Osceola	IPL	420
Sibley	Osceola	IPL	2,574
Harris	Osceola	None	157
Melvin	Osceola	None	198
Ocheyedan	Osceola	None	459
Clarinda	Page	IPL	5,366
Hepburn	Page	IPL	17
Essex	Page	MidAmerican	739
Blanchard	Page	None	36
Braddyville	Page	None	152
Coin	Page	None	174
College Springs	Page	None	203
Northboro	Page	None	56
Shambaugh	Page	None	179
Shenandoah	Page	None	178

City	County	Gas Provider	Population
Yorktown	Page	None	86
Cylinder	Palo Alto	MidAmerican	82
Ruthven	Palo Alto	MidAmerican	682
Ayrshire	Palo Alto	None	134
Curlew	Palo Alto	None	55
Mallard	Palo Alto	None	258
Rodman	Palo Alto	None	41
Emmetsburg	Palo Alto	Emmetsburg Municipal	3,684
Graettinger	Palo Alto	Graettinger Municipal	795
West Bend	Palo Alto	West Bend Municipal Gas	748
Fonda	Pocahontas	BHE	575
Pocahontas	Pocahontas	BHE	1,634
Laurens	Pocahontas	IPL	1,120
Havelock	Pocahontas	None	124
Palmer	Pocahontas	None	149
Plover	Pocahontas	None	69
Varina	Pocahontas	None	65
Rolfe	Pocahontas	Rolfe Municipal Gas	532
Carter Lake	Pottawattamie	BHE	3,785
Council Bluffs	Pottawattamie	BHE	62,166
Crescent	Pottawattamie	BHE	616
Underwood	Pottawattamie	IPL	491
Treynor	Pottawattamie	MidAmerican	965
Avoca	Pottawattamie	MidAmerican	1,521
Carson	Pottawattamie	MidAmerican	809
Hancock	Pottawattamie	MidAmerican	196
Macedonia	Pottawattamie	MidAmerican	243
Minden	Pottawattamie	MidAmerican	598
Neola	Pottawattamie	MidAmerican	891
Walnut	Pottawattamie	MidAmerican	769
McClelland	Pottawattamie	None	155
Oakland	Pottawattamie	None	1,501
Mount Ayr	Ringgold	IPL	1,619
Beaconsfield	Ringgold	None	14
Benton	Ringgold	None	41
Delphos	Ringgold	None	24
Diagonal	Ringgold	None	317
Ellston	Ringgold	None	39
Kellerton	Ringgold	None	297
Maloy	Ringgold	None	28
Redding	Ringgold	None	78
Tingley	Ringgold	None	173
Lake View	Sac	BHE	1,084
Early	Sac	MidAmerican	515

City	County	Gas Provider	Population
Lytton	Sac	MidAmerican	289
Odebolt	Sac	MidAmerican	943
Schaller	Sac	MidAmerican	723
Auburn	Sac	None	305
Nemaha	Sac	None	81
Sac City	Sac	Sac City Municipal Gas	2,068
Wall Lake	Sac	Wall Lake Municipal	769
Boyden	Sioux	MidAmerican	679
Granville	Sioux	MidAmerican	304
Hospers	Sioux	MidAmerican	696
Hull	Sioux	MidAmerican	2,299
Rock Valley	Sioux	MidAmerican	3,854
Chatsworth	Sioux	None	81
Ireton	Sioux	None	599
Matlock	Sioux	None	87
Maurice	Sioux	None	271
Alton	Sioux	Alton Municipal	1,248
Hawarden	Sioux	Hawarden Municipal	2,444
Orange City	Sioux	Orange City Municipal	6,182
Sioux Center	Sioux	Sioux Center Municipal Utilities	7,605
Blockton	Taylor	None	185
Conway	Taylor	None	40
Gravity	Taylor	None	181
New Market	Taylor	None	401
Sharpsburg	Taylor	None	85
Bedford	Taylor	Bedford Municipal Gas	1,384
Clearfield	Taylor	Clearfield Municipal	343
Lenox	Taylor	Lenox Municipal	1,389
Creston	Union	IPL	7,713
Afton	Union	MidAmerican	815
Arispe	Union	None	97
Cromwell	Union	None	108
Shannon City	Union	None	69
Thayer	Union	None	55
Lorimor	Union	Lorimor Municipal	343
Birmingham	Van Buren	IPL	421
Keosauqua	Van Buren	IPL	908
Stockport	Van Buren	IPL	276
Bonaparte	Van Buren	None	403
Cantril	Van Buren	None	207
Farmington	Van Buren	None	622
Milton	Van Buren	None	398
Brighton	Washington	Brighton Municipal	640
Ainsworth	Washington	IPL	579

City	County	Gas Provider	Population
Kalona	Washington	IPL	2,537
Washington	Washington	IPL	7,230
West Chester	Washington	IPL	147
Riverside	Washington	MidAmerican	1,022
Crawfordsville	Washington	None	265
Wellman	Washington	Wellman Municipal Gas System	1,395
Forest City	Winnebago	BHE	4,025
Lake Mills	Winnebago	BHE	1,984
Buffalo Center	Winnebago	IPL	855
Leland	Winnebago	None	271
Rake	Winnebago	None	209
Scarville	Winnebago	None	67
Thompson	Winnebago	None	469
Fertile	Worth	BHE	360
Hanlontown	Worth	BHE	220
Joice	Worth	BHE	210
Kensett	Worth	IPL	256
Manly	Worth	IPL	1,278
Northwood	Worth	IPL	1,955
Grafton	Worth	None	244

Table 11. Communities with Natural Gas Constraints by Natural Gas Provider

City	County	Gas provider	Population
Readlyn	Bremer	BHE	846
Sumner	Bremer	BHE	1,962
Aurora	Buchanan	BHE	161
Lamont	Buchanan	BHE	457
Truesdale	Buena Vista	BHE	1,360
Greene	Butler	BHE	1,063
Farnhamville	Calhoun	BHE	344
Glidden	Carroll	BHE	1,106
Ralston	Carroll	BHE	73
Fredericksburg	Chickasaw	BHE	923
Ionia	Chickasaw	BHE	275
Lawler	Chickasaw	BHE	419
New Hampton	Chickasaw	BHE	3,406
Fostoria	Clay	BHE	223
Royal	Clay	BHE	409
Spencer	Clay	BHE	10,952
Arnolds Park	Dickinson	BHE	1,313
Milford	Dickinson	BHE	2,997
Okoboji	Dickinson	BHE	792
Orleans	Dickinson	BHE	587

City	County	Gas provider	Population
Spirit Lake	Dickinson	BHE	5,155
Superior	Dickinson	BHE	119
Terril	Dickinson	BHE	336
Wahpeton	Dickinson	BHE	345
West Okoboji	Dickinson	BHE	291
Estherville	Emmet	BHE	5,666
Wallingford	Emmet	BHE	173
Arlington	Fayette	BHE	399
Fayette	Fayette	BHE	1,441
Hawkeye	Fayette	BHE	408
West Union	Fayette	BHE	2,305
Marble Rock	Floyd	BHE	287
Rockford	Floyd	BHE	822
Klemme	Hancock	BHE	463
Ackley	Hardin	BHE	1,498
Cresco	Howard	BHE	3,739
Anamosa	Jones	BHE	5,537
Martelle	Jones	BHE	250
Monticello	Jones	BHE	3,880
Springville	Linn	BHE	1,137
Mitchell	Mitchell	BHE	130
St. Ansgar	Mitchell	BHE	1,120
Paullina	O'Brien	BHE	977
Primghar	O'Brien	BHE	856
Fonda	Pocahontas	BHE	575
Pocahontas	Pocahontas	BHE	1,634
Carter Lake	Pottawattamie	BHE	3,785
Council Bluffs	Pottawattamie	BHE	62,166
Crescent	Pottawattamie	BHE	616
Lake View	Sac	BHE	1,084
Forest City	Winnebago	BHE	4,025
Lake Mills	Winnebago	BHE	1,984
Fertile	Worth	BHE	360
Hanlontown	Worth	BHE	220
Joice	Worth	BHE	210
Belle Plaine	Benton	IPL	2,440
Blairstown	Benton	IPL	659
Garrison	Benton	IPL	360
Keystone	Benton	IPL	612
Mount Auburn	Benton	IPL	144
Newhall	Benton	IPL	858
Norway	Benton	IPL	528
Urbana	Benton	IPL	1,494

City	County	Gas provider	Population
Van Horne	Benton	IPL	656
Vinton	Benton	IPL	5,075
Walford	Benton	IPL	1,445
Brandon	Buchanan	IPL	320
Hazleton	Buchanan	IPL	833
Quasqueton	Buchanan	IPL	564
Rowley	Buchanan	IPL	270
Stanley	Buchanan	IPL	120
Winthrop	Buchanan	IPL	849
Albert City	Buena Vista	IPL	665
Alta	Buena Vista	IPL	1,903
Lakeside	Buena Vista	IPL	689
Linn Grove	Buena Vista	IPL	146
Marathon	Buena Vista	IPL	227
Rembrandt	Buena Vista	IPL	194
Sioux Rapids	Buena Vista	IPL	744
Storm Lake	Buena Vista	IPL	10,322
Shell Rock	Butler	IPL	972
Carroll	Carroll	IPL	9,833
Clear Lake	Cerro Gordo	IPL	7,550
Mason City	Cerro Gordo	IPL	26,931
Meservey	Cerro Gordo	IPL	238
Thornton	Cerro Gordo	IPL	402
Ventura	Cerro Gordo	IPL	713
Cherokee	Cherokee	IPL	4,869
Osceola	Clarke	IPL	5,242
Peterson	Clay	IPL	309
Leon	Decatur	IPL	1,823
Burlington	Des Moines	IPL	24,713
Danville	Des Moines	IPL	899
Mediapolis	Des Moines	IPL	1,517
Middletown	Des Moines	IPL	335
West Burlington	Des Moines	IPL	2,890
Armstrong	Emmett	IPL	840
Maynard	Fayette	IPL	488
Oelwein	Fayette	IPL	5,900
Nora Springs	Floyd	IPL	1,354
Rudd	Floyd	IPL	346
Alexander	Franklin	IPL	161
Coulter	Franklin	IPL	263
Britt	Hancock	IPL	1,955
Corwith	Hancock	IPL	254
Garner	Hancock	IPL	3,033

City	County	Gas provider	Population
Goodell	Hancock	IPL	128
Kanawha	Hancock	IPL	595
Alden	Hardin	IPL	738
Eldora	Hardin	IPL	2,612
Hubbard	Hardin	IPL	801
Iowa Falls	Hardin	IPL	5,059
New Providence	Hardin	IPL	223
Owasa	Hardin	IPL	42
Radcliffe	Hardin	IPL	524
Steamboat Rock	Hardin	IPL	302
Union	Hardin	IPL	381
Whitten	Hardin	IPL	145
Mount Pleasant	Henry	IPL	8,668
New London	Henry	IPL	1,839
Ladora	Iowa	IPL	274
Marengo	Iowa	IPL	2,466
North English	Iowa	IPL	1,007
Parnell	Iowa	IPL	264
Victor	Iowa	IPL	868
Williamsburg	Iowa	IPL	3,164
Batavia	Jefferson	IPL	549
Fairfield	Jefferson	IPL	10,425
Libertyville	Jefferson	IPL	341
Lockridge	Jefferson	IPL	290
Lone Tree	Johnson	IPL	1,381
Morley	Jones	IPL	113
Olin	Jones	IPL	687
Bancroft	Kossuth	IPL	696
Lakota	Kossuth	IPL	279
Ledyard	Kossuth	IPL	120
Swea City	Kossuth	IPL	507
Alburnett	Linn	IPL	699
Center Point	Linn	IPL	2,555
Central City	Linn	IPL	1,296
Coggon	Linn	IPL	667
Lisbon	Linn	IPL	2,247
Mount Vernon	Linn	IPL	4,466
Palo	Linn	IPL	1,066
Walker	Linn	IPL	789
Columbus City	Louisa	IPL	372
Columbus Junction	Louisa	IPL	1,837
Letts	Louisa	IPL	373
Wapello	Louisa	IPL	1,999

City	County	Gas provider	Population
George	Lyon	IPL	1,042
Little Rock	Lyon	IPL	433
Stacyville	Mitchell	IPL	463
Ashton	Osceola	IPL	420
Sibley	Osceola	IPL	2,574
Clarinda	Page	IPL	5,366
Hepburn	Page	IPL	17
Laurens	Pocahontas	IPL	1,120
Underwood	Pottawattamie	IPL	491
Mount Ayr	Ringgold	IPL	1,619
Creston	Union	IPL	7,713
Birmingham	Van Buren	IPL	421
Keosauqua	Van Buren	IPL	908
Stockport	Van Buren	IPL	276
Ainsworth	Washington	IPL	579
Kalona	Washington	IPL	2,537
Washington	Washington	IPL	7,230
West Chester	Washington	IPL	147
Buffalo Center	Winnebago	IPL	855
Kensett	Worth	IPL	256
Manly	Worth	IPL	1,278
Northwood	Worth	IPL	1,955
Atkins	Benton	MidAmerican	1,970
Shellsburg	Benton	MidAmerican	4,820
Denver	Bremer	MidAmerican	1,856
Janesville	Bremer	MidAmerican	986
Plainfield	Bremer	MidAmerican	414
Tripoli	Bremer	MidAmerican	965
Independence	Buchanan	MidAmerican	6,124
Jesup	Buchanan	MidAmerican	2,703
Newell	Buena Vista	MidAmerican	852
Allison	Butler	MidAmerican	973
Aplington	Butler	MidAmerican	1,050
Bristow	Butler	MidAmerican	149
Clarksville	Butler	MidAmerican	1,346
Dumont	Butler	MidAmerican	602
New Hartford	Butler	MidAmerican	488
Parkersburg	Butler	MidAmerican	1,928
Lake City	Calhoun	MidAmerican	1,642
Lohrville	Calhoun	MidAmerican	345
Manson	Calhoun	MidAmerican	1,566
Rockwell City	Calhoun	MidAmerican	2,082
Breda	Carroll	MidAmerican	110

City	County	Gas provider	Population
Dedham	Carroll	MidAmerican	256
Rockwell	Cerro Gordo	MidAmerican	990
Aurelia	Cherokee	MidAmerican	958
Cleghorn	Cherokee	MidAmerican	216
Larrabee	Cherokee	MidAmerican	131
Marcus	Cherokee	MidAmerican	1,054
Meriden	Cherokee	MidAmerican	148
Nashua	Chickasaw	MidAmerican	1,589
Charles City	Floyd	MidAmerican	7,307
Floyd	Floyd	MidAmerican	315
Hampton	Franklin	MidAmerican	4,205
Latimer	Franklin	MidAmerican	470
Sheffield	Franklin	MidAmerican	1,106
Coralville	Johnson	MidAmerican	22,290
Hills	Johnson	MidAmerican	804
Iowa City	Johnson	MidAmerican	75,130
North Liberty	Johnson	MidAmerican	19,501
Oxford	Johnson	MidAmerican	792
Solon	Johnson	MidAmerican	2,690
Tiffin	Johnson	MidAmerican	4,157
Algona	Kossuth	MidAmerican	5,397
Fenton	Kossuth	MidAmerican	233
Lone Rock	Kossuth	MidAmerican	139
Wesley	Kossuth	MidAmerican	365
Donnellson	Lee	MidAmerican	854
Fort Madison	Lee	MidAmerican	10,321
Cedar Rapids	Linn	MidAmerican	133,562
Ely	Linn	MidAmerican	2,343
Fairfax	Linn	MidAmerican	2,856
Hiawatha	Linn	MidAmerican	7,420
Marion	Linn	MidAmerican	40,359
Robins	Linn	MidAmerican	3,537
Alvord	Lyon	MidAmerican	201
Doon	Lyon	MidAmerican	601
Inwood	Lyon	MidAmerican	849
Earlham	Madison	MidAmerican	1,410
St. Charles	Madison	MidAmerican	619
Winterset	Madison	MidAmerican	5,383
Archer	O'Brien	MidAmerican	124
Calumet	O'Brien	MidAmerican	157
Sheldon	O'Brien	MidAmerican	1,275
Sutherland	O'Brien	MidAmerican	596
Essex	Page	MidAmerican	739

City	County	Gas provider	Population
Cylinder	Palo Alto	MidAmerican	82
Ruthven	Palo Alto	MidAmerican	682
Treynor	Pottawattamie	MidAmerican	965
Avoca	Pottawattamie	MidAmerican	1,521
Carson	Pottawattamie	MidAmerican	809
Hancock	Pottawattamie	MidAmerican	196
Macedonia	Pottawattamie	MidAmerican	243
Minden	Pottawattamie	MidAmerican	598
Neola	Pottawattamie	MidAmerican	891
Walnut	Pottawattamie	MidAmerican	769
Early	Sac	MidAmerican	515
Lytton	Sac	MidAmerican	289
Odebolt	Sac	MidAmerican	943
Schaller	Sac	MidAmerican	723
Boyden	Sioux	MidAmerican	679
Granville	Sioux	MidAmerican	304
Hospers	Sioux	MidAmerican	696
Hull	Sioux	MidAmerican	2,299
Rock Valley	Sioux	MidAmerican	3,854
Afton	Union	MidAmerican	815
Riverside	Washington	MidAmerican	1,022
Alton	Sioux	Muni (Alton Municipal)	1,248
Bedford	Taylor	Muni (Bedford Municipal Gas)	1,384
Brighton	Washington	Muni (Brighton Municipal)	640
Everly	Clay	Muni (City of Everly)	550
Clearfield	Taylor	Muni (Clearfield Municipal)	343
Coon Rapids	Carroll	Muni (Coon Rapids Municipal)	1,232
Corning	Adams	Muni (Corning Municipal)	1,433
Emmetsburg	Palo Alto	Muni (Emmetsburg Municipal)	3,684
Fairbank	Buchanan	Muni (Fairbank Municipal)	1,133
Graettinger	Palo Alto	Muni (Graettinger Municipal)	795
Hartley	O'Brien	Muni (Hartley Municipal)	1,574
Hawarden	Sioux	Muni (Hawarden Municipal)	2,444
Lake Park	Dickinson	Muni (Lake Park Municipal)	1,123
Lamoni	Decatur	Muni (Lamoni Municipal)	2,249
Lenox	Taylor	Muni (Lenox Municipal)	1,389
Keokuk	Lee	Muni (Liberty Utilities)	10,157
Montrose	Lee	Muni (Liberty Utilities)	778
Lorimor	Union	Muni (Lorimor Municipal)	343
Manning	Carroll	Muni (Manning Municipal)	1,422
Templeton	Carroll	Muni (Manning Municipal)	334
Morning Sun	Louisa	Muni (Morning Sun Municipal)	796
Orange City	Sioux	Muni (Orange City Municipal)	6,182
Osage	Mitchell	Muni (Osage Municipal Gas Utility)	3,555

City	County	Gas provider	Population
Prescott	Adams	Muni (Prescott Municipal Utilities)	237
Rock Rapids	Lyon	Muni (Rock Rapids Municipal Utility)	2,522
Rolfe	Pocahontas	Muni (Rolfe Municipal Gas)	532
Sac City	Sac	Muni (Sac City Municipal Gas)	2,068
Sanborn	O'Brien	Muni (Sanborn Municipal Gas Utility)	1,381
Sioux Center	Sioux	Muni (Sioux Center Municipal Utilities)	7,605
Titonka	Kossuth	Muni (Titonka Municipal Utilities)	443
Wall Lake	Sac	Muni (Wall Lake Municipal)	769
Waverly	Bremer	Muni (Waukee Municipal Gas)	24,089
Wayland	Henry	Muni (Wayland Municipal Gas System)	943
Wellman	Washington	Muni (Wellman Municipal Gas System)	1,395
West Bend	Palo Alto	Muni (West Bend Municipal Gas)	748
Whittemore	Kossuth	Muni (Whittemore Municipal Utilities)	476
Winfield	Henry	Muni (Winfield Municipal Gas)	1,088
Nodaway	Adams	None	103
Luzerne	Benton	None	93
Frederika	Bremer	None	203
Aredale	Butler	None	69
Jolley	Calhoun	None	37
Knierim	Calhoun	None	58
Pomeroy	Calhoun	None	613
Rinard	Calhoun	None	50
Somers	Calhoun	None	106
Yetter	Calhoun	None	32
Arcadia	Carroll	None	520
Halbur	Carroll	None	256
Lanesboro	Carroll	None	109
Lidderdale	Carroll	None	171
Willey	Carroll	None	98
Dougherty	Cerro Gordo	None	57
Plymouth	Cerro Gordo	None	362
Rock Falls	Cerro Gordo	None	143
Swaledale	Cerro Gordo	None	158
Quimby	Cherokee	None	292
Washta	Cherokee	None	223
Alta Vista	Chickasaw	None	252
Bassett	Chickasaw	None	63
North Washington	Chickasaw	None	138
Murray	Clarke	None	702
Woodburn	Clarke	None	194
Dickens	Clay	None	171
Gillett Grove	Clay	None	47
Greenville	Clay	None	68

City	County	Gas provider	Population
Rossie	Clay	None	68
Webb	Clay	None	128
Davis City	Decatur	None	184
Decatur City	Decatur	None	184
Garden Grove	Decatur	None	197
Grand River	Decatur	None	215
Le Roy	Decatur	None	14
Pleasanton	Decatur	None	44
Van Wert	Decatur	None	204
Weldon	Decatur	None	115
Dolliver	Emmet	None	59
Gruver	Emmet	None	83
Ringsted	Emmet	None	370
Clermont	Fayette	None	583
Elgin	Fayette	None	634
Randalia	Fayette	None	56
St. Lucas	Fayette	None	136
Wadena	Fayette	None	240
Waucoma	Fayette	None	245
Westgate	Fayette	None	198
Colwell	Floyd	None	70
Geneva	Franklin	None	153
Hansell	Franklin	None	90
Popejoy	Franklin	None	75
Crystal Lake	Hancock	None	232
Woden	Hancock	None	206
Buckeye	Hardin	None	108
Coppock	Henry	None	48
Hillsboro	Henry	None	177
Olds	Henry	None	223
Rome	Henry	None	116
Salem	Henry	None	384
Westwood	Henry	None	110
Chester	Howard	None	120
Elma	Howard	None	527
Lime Springs	Howard	None	474
Protivin	Howard	None	270
Millersburg	Iowa	None	142
Pleasant Plain	Jefferson	None	98
Shueyville	Johnson	None	655
Swisher	Johnson	None	953
Onslow	Jones	None	193
Oxford Junction	Jones	None	483

City	County	Gas provider	Population
Wyoming	Jones	None	515
Burt	Kossuth	None	498
LuVerne	Kossuth	None	93
Franklin	Lee	None	132
Houghton	Lee	None	136
St. Paul	Lee	None	124
West Point	Lee	None	930
Bertram	Linn	None	290
Prairieburg	Linn	None	188
Cotter	Louisa	None	46
Fredonia	Louisa	None	235
Grandview	Louisa	None	215
Oakville	Louisa	None	169
Larchwood	Lyon	None	891
Lester	Lyon	None	302
Bevington	Madison	None	69
East Peru	Madison	None	131
Macksburg	Madison	None	118
Patterson	Madison	None	161
Truro	Madison	None	77
Carpenter	Mitchell	None	106
McIntire	Mitchell	None	125
Orchard	Mitchell	None	71
Riceville	Mitchell	None	764
Harris	Osceola	None	157
Melvin	Osceola	None	198
Ocheyedan	Osceola	None	459
Blanchard	Page	None	36
Braddyville	Page	None	152
Coin	Page	None	174
College Springs	Page	None	203
Northboro	Page	None	56
Shambaugh	Page	None	179
Shenandoah	Page	None	178
Yorktown	Page	None	86
Ayrshire	Palo Alto	None	134
Curlew	Palo Alto	None	55
Mallard	Palo Alto	None	258
Rodman	Palo Alto	None	41
Havelock	Pocahontas	None	124
Palmer	Pocahontas	None	149
Plover	Pocahontas	None	69
Varina	Pocahontas	None	65

City	County	Gas provider	Population
McClelland	Pottawattamie	None	155
Oakland	Pottawattamie	None	1,501
Beaconsfield	Ringgold	None	14
Benton	Ringgold	None	41
Delphos	Ringgold	None	24
Diagonal	Ringgold	None	317
Ellston	Ringgold	None	39
Kellerton	Ringgold	None	297
Maloy	Ringgold	None	28
Redding	Ringgold	None	78
Tingley	Ringgold	None	173
Auburn	Sac	None	305
Nemaha	Sac	None	81
Chatsworth	Sioux	None	81
Ireton	Sioux	None	599
Matlock	Sioux	None	87
Maurice	Sioux	None	271
Blockton	Taylor	None	185
Conway	Taylor	None	40
Gravity	Taylor	None	181
New Market	Taylor	None	401
Sharpsburg	Taylor	None	85
Arispe	Union	None	97
Cromwell	Union	None	108
Shannon City	Union	None	69
Thayer	Union	None	55
Bonaparte	Van Buren	None	403
Cantril	Van Buren	None	207
Farmington	Van Buren	None	622
Milton	Van Buren	None	398
Crawfordsville	Washington	None	265
Leland	Winnebago	None	271
Rake	Winnebago	None	209
Scarville	Winnebago	None	67
Thompson	Winnebago	None	469
Grafton	Worth	None	244

APPENDIX C | DETAILED AUDIT RESULTS

This section provides the detailed results for the seven electrification audits conducted as part of this study. The Research Team provided participants with a copy of these results, including information about utility billing history, rates, and site-specific details. In this report, any identifying and site-specific information has been removed to preserve the confidentiality of the facilities.

Note that, unlike the results presented earlier the report which are based on average fuel costs for comparison, the annual energy cost savings presented in the audits are based on the actual fuel expenditures for each facility at the time of the audit and will vary by site based on fuel costs, rate structure, and utility.[15] In some cases, the costs of the equipment are greater than the calculated fuel cost savings, resulting in a negative net present value.[16]

SITE 1: MILK PRODUCTION

Michaels Energy completed an electrification study of a milk production facility with square footage between 100,000 and 250,000 SF.

Table 12 presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary alternatives during natural gas curtailment.

Costs for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measures will be relatively more expensive than other measures.

Table 12. Electrification Financial Savings Summary

Energy Saving Strategy	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Annual Non-Energy Savings ($)	Approx. Payback (Years)
Obtain Specifications for Implementation:					
Supplement ground-source heat pumps	$70,000	TBD	$6,500	$ -	10.8
Reduce hot water use for sanitation	$14,000	TBD	$1,000	$ -	14.0
Install heat recovery chiller	$150,000	TBD	$4,000	$ -	37.5
Total for all measures above recommended for implementation or study:	**$234,000**	**$ -**	**$11,500**	**$ -**	**20.3**
Additional Measures:					
Negative payback - heat pump clothes dryer	$1,500	TBD	$ (20)	$ -	(75.0)
Negative payback - high temperature heat pump	$200,000	TBD	$ (24,500)	$ -	(8.2)
Negative payback - electric radiant heating	$19,000	TBD	$ (8,780)	$ -	(2.2)

* Further study required, † Incremental cost used, TBD = to be determined

Negative Payback is shown given prices at the time of the site visit.

15 Some audited sites were on energy-only electric rates and did not include demand changes in their utility bills. Some sites also were on gas transport rates instead of commercial rates.

16 To calculate the simple payback period, the Research Team did not use a discount rate accounting for the time value of money.

Table 13. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:				
Supplement ground-source heat pumps	(19,440)	0	10,000	50
Reduce hot water use for sanitation	(21,410)	0	3,900	10
Install heat recovery chiller	(65,250)	0	13,000	30
Total for all measures above recommended for implementation or study:	**(106,100)**	**0**	**26,900**	**90**
Additional Opportunities:				
Negative payback - heat pump clothes dryer	(560)	0	50	0
Negative payback - high temperature heat pump	(355,130)	0	15,000	(150)
Negative payback - electric radiant heating	(126,020)	0	5,400	(60)

5.1.1 ELECTRIFICATION OPPORTUNITIES

HVAC OPTIONS

EXISTING OPERATION

Many dairies use well water to pre-cool the milk before the chiller. This water is typically around 55°F exiting the ground and 70°F exiting the pre-cooling (changes per location). The milk enters around 100°F and, after the pre-cooler, is around 55°F. The milk is then sent through a chiller to reduce the temperature to about 37°F for storage.

The system uses a heat exchanger to recover heat being rejected out of the chiller system. This recovered heat is used to heat the 55°F well water to around 130°F in a 500-gallon storage tank. About 500 gallons is used per wash.

The facility is heated with small unit heaters. A large sand reclamation area uses propane radiant heaters instead of conventional convection heaters.

SUPPLEMENT GROUND-SOURCE HEAT PUMPS

Using the well water after the pre-cooler (assumed to be around 70°F +/-) for a water-to-air heat pump would increase the heating COP of a heat pump versus a typical geothermal heat pump taking in ground water at around 50°F (+/-).

The water that may otherwise have been rejected back to the ground at around 70°F would be rejected at a lower temperature since the heat pump is absorbing this extra heat. Any large-scale change to the geothermal well field should be investigated. Geothermal well fields are typically balanced to provide heating and cooling given certain loads, flows, and temperatures. If these parameters are changed significantly, it may cause the ground water temperatures to slowly rise or lower over time.

Many dairies use well water for cooling. The cost for this measure assumes that a water-to-air heat pump would be necessary, but that ground water (well water) is already readily available. If well water is not already available, this may add significant cost to the project.

ELECTRIC RADIANT HEATING

The sand reclamation area uses propane radiant heaters. For areas with large doors, which can allow a large amount of outside air into the building, radiant heating is recommended. Radiant heaters can heat objects without heating the air and using hot air to heat the space.

The results of this measure show the impact of replacing a natural gas infrared heater with an electric infrared heater. At the current cost of utilities for this location, installing an electric infrared heater does not have a positive payback.

Individual savings for replacing forced air heating with radiant depends on each building, and the ability to retain hot air. Savings for "good" applications can lower heating loads by as much as 10-15%.

MILK COOLING OPTIONS

CHILLER ALTERNATIVES

Many dairies use well water to pre-cool the milk before the chiller. This water is typically around 50°F exiting the ground and 70°F exiting the pre-cooling (changes per location). The milk is then sent through a chiller to reduce the temperature to about 37°F for storage.

INSTALL HEAT RECOVERY CHILLER

Many larger dairies use heat recovery chillers to boost hot water to a more useable temperature. This works similar to a typical chiller where the heat from the refrigerant is rejected to a water. In most conventional chillers, the condenser water absorbs this heat and rejects it to the atmosphere. In a heat recovery chiller, the chiller is designed to not only to reject that heat but boost the temperature to a higher temperature than usual. These units can typically produce hot water around 130°F, which can be used for HVAC (if the HVAC coils are designed for lower temperature). Alternatively, this hot water could, as in the case of this location, be used to heat sanitation water. This would require storage as sanitation is not a constant process. If the recovered heat load is high enough, it could be used for both applications.

Cooling comes at a slight penalty versus a conventional chiller, but the heating benefits far outweigh any cooling penalty when heating loads are substantial.

This location already has a heat recovery system to heat water to 130°F. This measure is recommended for new applications or facilities that do not currently utilize them.

If there is no call for heating, the chiller would reject the heat to the outside (like a typical chiller would do).

HIGH TEMPERATURE HEAT RECOVERY CHILLER

Like the heat recovery chiller mentioned above, a high-temperature heat recovery chiller would have all the benefits of the heat recovery chiller, but no supplemental heating would be necessary. These temperatures can reach up to 170-180°F.

These heat-pumps are not as common and therefore are more expensive. Due to the lack of market penetration, these high temperature units may be more difficult to find local repair options. The benefit is only one piece of equipment would be necessary to both chill the milk and heat the water, and would not require an additional booster heater to increase temperatures from 130°F to 170°F.

WASH REDUCTION

This facility does not use pressure washing for cleaning, but in some milking parlors pressure washers are used to clean parlor stalls. A similar facility, not this location, used a pressure washer with a flowrate of 4 GPM, using 130°F, or hotter, hot water. There were (2) 90-minute wash cycles per day, and hot water was used for both cycles.

REDUCE HOT WATER USE FOR SANITATION

Using a foam wash system can reduce the amount of hot water usage. The foam will be applied using cold water only and rinsed off using hot water at the end of the wash cycle. This will still require an estimated 30 minutes of operation for both pressure washers but would reduce the amount of hot water needed. This is not an electrification measure itself but would reduce the heat load for hot water, which may make more conventional electric hot water, or a hot water heat pump, a more viable option.

A hot water heat pump works just like any other heat pump, absorbing heat from one area (the air) and moving it to another area (the tank). This will result in the heat pump putting out colder air, since it absorbed heat from the air.

This measure uses a hot water heat pump to show a fully electric alternative. The hot water heat pump is assumed to have a COP of around 2.4 at a setpoint of 130°F. The baseline used natural gas units with an efficiency of 90-95%, typical for newer natural gas units.

CLOTHES DRYER

This facility uses a large, commercial size, natural gas clothes dryer to dry employee clothes. The dryer runs multiple loads per day.

HEAT PUMP CLOTHES DRYER

Heat pump clothes dryers can dry the same amount of clothes. The heat pump works just like any other heat pump, absorbing heat from one area (the air) and moving it to another area (the clothes tub). In this case, the heat is being absorbed from the room and rejected to the clothes dryer. This means that this will reject cold air to the area surrounding the clothes dryer.

At the current cost of natural gas and electricity at this location, there is no actual dollar savings for this measure.

5.1.2 SUMMARY OF RECOMMENDATIONS

All options are shown regardless of payback. The measures presented are not all recommended at this location. Some measures were shown for typical applications at similar facilities. Incremental cost for air-source was used to show a baseline cooling (NG heating) conversion to air-source heat pump and the cost of a heat exchanger was added.

Table 14. Energy Savings for Options

Energy Saving Strategy	Electrical Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:				
Supplement ground-source heat pumps	(19,440)	0	10,000	50
Reduce hot water use for sanitation	(21,410)	0	3,900	10
Install heat recovery chiller	(65,250)	0	13,000	30
Total for all measures above recommended for implementation or study:	**(106,100)**	**0**	**26,900**	**90**
Additional Opportunities:				
Negative payback - heat pump clothes dryer	(560)	0	50	0
Negative payback - high temperature heat pump	(355,130)	0	15,000	(150)
Negative payback - electric radiant heating	(126,020)	0	5,400	(60)

The following table summarizes the emissions associated with the identified improvement strategies based on the emission factors of the electric and natural gas utilities. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 15. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)
Obtain Specifications for Implementation:				
Supplement ground-source heat pumps	94,000	(110)	(50)	50
Reduce hot water use for sanitation	16,000	(120)	(60)	10
Install heat recovery chiller	64,000	(360)	(180)	30
Total for all measures above recommended for implementation or study:	**174,000**	**(590)**	**(290)**	**90**
Additional Opportunities:				
Negative payback - heat pump clothes dryer	(220)	0	0	0
Negative payback - high temperature heat pump	(306,150)	(1,960)	(980)	(150)
Negative payback - electric radiant heating	(109,820)	(690)	(350)	(60)

SITE 2: MANUFACTURING

Michaels Energy completed an electrification study of a manufacturing facility with an area of over 1,000,000 SF. The purpose of the study was to investigate equipment and operations relying on natural gas with the goal of supplying electric alternatives during curtailment and for potential replacement.

Table 16 presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary alternatives during natural gas curtailment.

Costs for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measures will be relatively more expensive than other measures.

Table 16. Electrification Financial Savings Summary

Energy Saving Strategy	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Annual Non-Energy Savings ($)	Approx. Payback (Years)
Obtain Specifications for Implementation:					
Replace rtus with air-source heat pumps	$130,000	TBD	$ (3,420)	$ -	(38.0)
Install electric resistance paint oven with back up	$100,000	TBD	$ (6,960)	$ -	(14.4)
Air-source heat pump and heat recovery †	$20,000	TBD	$ (2,700)	$ -	(7.4)
Replace rtus with geothermal heat pumps	$10,000,000	TBD	$130,000	$ -	76.9
Install high temperature heat pump	$250,000	TBD	$300	$ -	833.3
Total for all measures above recommended for implementation or study:	**$10,500,000**	**$ -**	**$117,220**	**$ -**	**89.6**

† Incremental cost used

Table 17. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:				
Replace RTUs with air-source heat pumps	(57,700)	(20)	5,000	0
Install electric resistance paint oven with back up	(152,940)	(50)	4,500	(60)
Air-source heat pump and heat recovery	(73,840)	0	4,900	(10)
Replace rtus with geothermal heat pumps	(10,453,870)	(2,420)	3,080,000	12,000
Install high temperature heat pump	(62,730)	(10)	6,900	10
Total for all measures above recommended for implementation or study:	**(10,801,080)**	**(2,500)**	**3,101,300**	**11,940**

5.2.1 ELECTRIFICATION OPPORTUNITIES

HVAC OPTIONS

EXISTING OPERATION

The facility is in the process of replacing the larger steam system, and the connected make up air units, used for heating the facility, with natural gas make up air units. There is currently no cooling for these make up air units. The facility has around (100) 50,000-CFM units, many with two-level burners. These units can run with 100% outdoor air. In the warmer part of the year, above 50°F degrees, these units run near 100% flow and modulate the outdoor air dampers (0-100%) to control room temperatures. In the winter operations these units run about half speed (around 20% of full flow) and the outdoor air dampers modulate to maintain a mixed air temperature around 55°F degrees. The steam is off in the summer and in the winter the steam valve will module to control the discharge temperature of the unit based on space temperature.

REPLACE RTUs WITH AIR-SOURCE HEAT PUMPS

Many mainstream heat pump manufactures have a maximum capacity of around 20-tons cooling and 220 MBH heating. This is smaller than the units being replaced at this facility, so replacements at this facility would not be cost effective since it would take many more units and increase the number of connections, thermostats, dampers, fans, etc.

The savings and cost shown is a 20-ton convention unit being replaced with a 20-ton air-source heat pump. The air-source heat pump would require a back up heating source which can be either natural gas, propane, or electric.

On this rate even switching from electric cooling and natural gas heating to air-source heat pumps does not show savings until the natural gas increases substantially. This project does not make financial sense given the current cost of natural gas and electrical.

REPLACE RTUs WITH GEOTHERMAL HEAT PUMPS

The existing steam system, used for the make-up air units, is piped throughout the building. Additionally large amounts of ground water are required to be used at this location. It appears this facility is moving to conventional natural gas heating units. The energy and demand were considered for heating only to maintain apples-to-apples comparison.

The existing ground-water system supplemented with hot water boilers and cooling towers might be able to be used to heat and cool large areas of the plant. These units can supply heating and cooling for RTUs. If the RTUs use 20% outside air, similar to conventional units, geothermal systems can be sized to supply the plant. At larger amounts of outside air it is recommended to couple geothermal with heat recovery. Recovering heating or cooling from the exhaust can lower the energy required for the make-up air.

The amount and temperature of the ground water would need to be verified. For this measure it is assumed to be a ground water source (no wells). This would allow for a less balanced system. Geothermal systems with wells need to be balanced for the seasons more accurately, if a building is more heating or cooling dominant more wells would be required to help prevent drift in the average temperatures of the well field and costs can increase substantially.

This particular site is unique in that they are required to pump out ground water regardless and therefore a ground water source is readily available at no additional cost. Installing a geothermal system of this size is not common. The estimated cost for this system is less precise than typical measures due to the size of the buildings and amount of equipment

OTHER HVAC

OPERATION WITH HEATING AND COOLING

In this facility the cooling benefit of installing air-source heat pumps would include a substantial demand on a rate with an existing substantial demand charge. This increase in demand does not make this measure cost effective.

There was no mention of the cooling benefit on employee retention so it assumed that cooling the production floor is not as desirable at it may be at other places. Typically, existing units would include direct exchange (Dx) cooling with compressors and natural gas heating.

Coupling heat pumps with heat recovery does increase the capacity of the heat pumps, allowing more air. Heat recovery would also help to decrease the size of a conventional electric-cooling, Natural gas-heating (or propane) unit.

AIR-SOURCE HEAT PUMP AND HEAT RECOVERY

A large manufacturing facility wishing to cool the floor as well as heat and bring in outside air may want to investigate air source heat pumps (ASHP) with heat recovery. At present it appears that conventional manufacturers have units of around 20-tons. Coupling the air-source heat pump with heat recovery will increase the average temperature the ASHP sees and increase the efficiency of the ASHP during the low temperatures. The demand on the heat recovery will also increase the efficiency of the ASHP at higher outside air temperatures as well by reducing the temperature entering the heat pump.

Air source heat pumps can operate down to 17°F, but around this temperature and below the heat pump has around the same efficiency as an electric resistance heater. These units require a back-up heating source of either electric resistance or fuel. Using the conventional electric resistance will cause high demand in winter months.

For this measure baseline cooling was added and is based on a conventional direct exchange (dx) cooling unit and natural gas heating. The size of the baseline unit is 20-ton make up air unit at around 4000 CFM of supply air using around 100% outside air. The proposed unit includes an air-to-air heat exchanger to help temper the incoming air for the ASHP.

To match the total air flow for this facility the number of units required would not make sense. This is not being suggested at this facility but is being shown for smaller facilities with less outside air requirements.

PAINT CURING OPTIONS

EXISTING OPERATION

The existing paint line is wet-on-wet. This system allows for paint to be cured relatively quickly and at around 200-250°F. There are two different paint lines at this facility. Each paint tine uses a boiler to heat the water for washing and rinsing the part before they are painted. The curing ovens have two 43,000 BTU heaters burners for two different zones. One is kept at 200-210°F and the other at around 230°F although both are designed to produce 250°F during warm up.

INSTALL ELECTRIC RESISTANCE PAINT OVEN WITH BACK UP

Installing electric back-up would be a tried technology that would be relatively easy install. The electric heating elements are like a toaster. The natural gas would remain in place and be used as a back-up in winter. With the current electrical rate, it is assuming the natural gas burner would operate during the summer. This would allow the demand to be changed as an interruptible load which is at a lower rate given the rate structure.

In some instances, electric heating may lead to less blemishes due to the lower amount of outside air (combustion air), versus natural gas or propane. It is unclear if it would make a difference in blemishes at this location.

This is not cost effective given the current cost of natural gas and electric rate used by this customer. This is true (not cost effective) using the natural gas during the summer months with a higher electric rate and electric for the rest of the year (nine months).

INSTALL HIGH TEMPERATURE HEAT PUMP

Another option for the paint curing line to heat it with high temperature heat pump (HTHP). There are HTHPs available that can reach this temperature as an output. Typical water-source heat pumps are available up to 160°F.

High temperature heat pumps are available that can reach temperatures of around 220–260°F. These are more cost effective when the cooling side of the water source heat pump is available for process cooling all year. This application is only available with a waste heat source that can be cooled. For a more optimal efficiency of around 240-260°F ,a waste heat stream of around 120-180°F would be ideal. For this example, it is assumed that the rinse water discharge can be used as a heat rejection stream. The rinse water for the coolest leg is around 120-130°F. Discharge rates were not measured.

If discharge rates are adequate, an evaporator (heat exchanger) is used to absorbed the rinse water heat, lowering the temperature of the discharge, and the heat is rejected via a condenser to the paint booth to maintain the 240°F.

There was no other known waste heat stream in the area of the paint booth. If waste stream with required cooling can be found (a separate chiller is being used) the payback for this application can be substantially lower.

5.2.2 SUMMARY OF RECOMMENDATIONS

All options are shown regardless of payback. The shown measures are not all recommended at this location. Some measures were shown for typically applications at similar facilities. Incremental cost for air-source was used to show a baseline cooling (NG heating) going to ASHP and the cost of a heat exchanger was added.

Table 18: Energy Savings for Options

Energy Saving Strategy	Electrical Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:				
Replace RTUs with air source heat pumps	(57,700)	(20)	5,000	0
Install electric resistance paint oven with back up	(152,940)	(50)	4,500	(60)
Air-source heat pump and heat recovery	(73,840)	0	4,900	(10)
Replace rtus with geothermal heat pumps	(10,453,870)	(2,420)	3,080,000	12,000
Install high temperature heat pump	(62,730)	(10)	6,900	10
Total for all measures above recommended for implementation or study:	**(10,801,080)**	**(2,500)**	**3,101,300**	**11,940**

The following table summarizes the emissions associated with the identified improvement strategies based on the emission factors of the site's electric and natural gas utilities. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 19. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)	SO2 (lbs)	NOx (lbs)
Obtain Specifications for Implementation:						
Replace RTUs with air-source heat pumps	(2,840)	0	0	0	(20)	(560)
Install electric resistance paint oven with back up	(109,630)	0	0	(60)	(60)	(1,480)
Air-source heat pump and heat recovery	(20,750)	0	0	(10)	(30)	(720)
Replace rtus with geothermal heat pumps	24,960,000	(40)	500	12,000	(3,860)	(101,490)
Install high temperature heat pump	(5,770)	(350)	(170)	10	0	0

SITE 3: GRAIN/CORN DRYING

Michaels Energy completed an electrification study of a grain drying facility. The purpose of the study was to investigate equipment and operations relying on natural gas with the goal of supplying electric alternatives during curtailment and for potential replacement.

This report presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary alternatives during curtailment.

Costs for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measures will be relatively more expensive than other measures.

Table 20. Electrification Financial Savings Summary

Electrification Options:	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Approx. Payback (Years)	Net Present Value
Obtain Specifications for Implementation:					
Competitive electric rates	$0	TBD	($6,050)	-	$0.00
Aeration probes and controls	$35,000	TBD	$1,600	22	$16,000.00
Bin aeration circulator tubes and controller	$45,000	TBD	$1,300	35	$19,500.00
Install heat pump low temperature heating	$200,000	TBD	$5,100	39	$76,500.00

Negative Payback is shown given prices at the time of the site visit.

Table 21 is the impact of the same information as Table 20 (above) at $1.20 and $0.80 per gallon of propane.

Table 21. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas Savings (Therms/yr)
Obtain Specifications for Implementation:		
Competitive electric rates	(422,270)	14,000
Aeration probes and controls	12,000	0
Bin aeration circulator tubes and controller	10,000	10
Install heat pump low temperature heating	(69,110)	14,000

5.3.1 ELECTRIFICATION OPPORTUNITIES

Our investigation of the facility yielded the following opportunities for improvement. Throughout this section, we identify the opportunity, benefits to the facility, and the estimated cost and savings per measure.

INSTALL BIN AERATION CIRCULATOR TUBES AND CONTROLLER

EXISTING OPERATION

A new grain dryer was moved from a nearby location to its current location. The dryer can dry 4,000 bushels per hour (corn) from 20% moisture to 15% moisture. The product is stored in large grain bins. These bins have circulation fans to move air through the bins and prevent temperature and moisture from building up. Due to the large mass of the bins, air flow through the bins is difficult; therefore, reducing the build-up of moisture is also difficult. This is why the grain is dried to near 15% moisture (for corn).

AUGMENT SYSTEM WITH NATURAL AIR CIRCULATOR TUBES

One idea is to install an air-circulation system that uses natural air circulator tubes. These systems are commercially available and are more efficient compared to traditional systems that require large quantities of horsepower. This system would put larger air tubes through the middle of the bins that force air through them to dry the product naturally.

This is being suggested as a potential curtailment solution at this location. For smaller farmers this can be used instead of drying, if the moisture of the grain (corn) is below 25%.

If asked to curtail and not use the existing natural gas dryer, the corn being delivered during that time would be directed to this storage bin to be dried using outside air instead of the grain dryer. If not asked to curtail during harvest season this would be used as regular/typical storage. During typical harvest season the outside air has a lower relative humidity, and it is assumed that any curtailment would take place during periods of extreme cold temperatures.

This system requires an air plenum temperature of 100°F to maintain the correct grain moisture. To maintain this temperature, it is assumed there will be some natural gas usage, but it appears minimal compared to the instant demand for the dryer. This would make it a beneficial technology during curtailment times.

INSTALL AIR-SOURCE HEAT PUMP DRYER

EXISTING OPERATION

A new grain dryer was moved from a nearby location to this location. This dryer can dry 4,000 bushels per hour from 20% moisture to 15% moisture.

INSTALL AIR-SOURCE HEAT PUMP DRYER

Installing an air source heat pump to dry grain is not currently commercially available. It is starting to be used for batch dryers of fruit and grains. The savings shown are using COPs of 2-3 which are likely generous as this is done in more favorable weather conditions and not conditions typical of Iowa winters.

While this solution is possible for COOP customers, the high-flow bulk requirements of COOP customers make this option experimental and expensive. At extreme cold temperatures these units can have poor performance and electric resistance back up may be necessary to maintain nominal flows. Electric input makes this option more readily available and scalable. Savings versus conventional electric heating are also greater.

5.3.2 INSTALL MOISTURE PROBES

EXISTING OPERATION

Typical aeration fans are expected to run around 500-1,000 hours per year to help maintain temperature and moisture levels. These bins have a combined fan horsepower of 45 hp.

INSTALL MOISTURE CONTROL PROBES TO CONTROL FANS

Aeration fan controls can save energy by automatically modulating fans based on weather and the heat of the grain. A previous project for grain storage (of similar size and fan hp) resulted in the fans reducing run times by around 70%. Potential savings assume annual hours runtime would be reduced to around 320 hours with the controls.

This measure is being shown as more of an energy savings measure than an electrification measure, but probes may allow for grain to be stored at higher moisture content. This may have additional cost impacts as over drying the corn may reduce the selling weight of the corn.

An estimated cost of $50,000 was used for this technology (sensor cables and controls), for a 50,000-bushel bin with existing fans and perforated floor.

This measure has no electrification application but is being added as a potential energy efficiency measure.

5.3.3 OTHER ALTERNATIVES

COMPETITIVE ELECTRIC RATES

EXISTING

Smaller farmers typically have a mixture of natural gas, electric, and propane dryers. Propane is typically not desired due to the unfavorable result of the grain. Electric heating is one of the more accessible ways of drying grain, and can typically be used as a backup on grain dryers if necessary.

PROPOSED ELECTRIC RATE

This is not currently an option for larger utilities in Iowa. If adopted by utilities in Iowa it would involve installing a utility-controlled meter on a separate rate. It would lower your electric rate during harvest season but this would be shut off by the utility when needed for large demands so a backup source, or temporary storage of wet corn is necessary. The meter would be turned on for drying from late September to late November. All other times the meter would be shut off.

This would require utilities and state regulators to agree on rate plans among other things. It is not available at this time and is being included as a potential alternative. The cost in dollars per kWh is much lower than the normal commercial rate, but it is hoped that the timing of harvest season, typically during lower cooling loads, would allow for a lower monthly rate.

It may also be necessary to make this meter controllable by the utility. In cases of large electric peaks (hot/humid fall day) the utility would be able to shut off this meter. It is unclear if this control would be feasible due to the financial impact on the individual farmer.

Existing electrical infrastructure in some areas may not be able to handle multiple large grain drying loads and would need to be vetted by each installation.

5.3.4 SUMMARY OF RECOMMENDATIONS

Table 22. Cost and Payback Summary

Electrification Options	Cost ($)	Annual Energy Savings ($)	Approx. Payback (Years)
Obtain Specifications for Implementation:			
Competitive electric rates	$0	($6,050)	-
Aeration probes and controls	$35,000	$1,600	22
Bin aeration circulator tubes and controller	$45,000	$1,300	35
Install heat pump low temperature heating	$200,000	$5,100	39

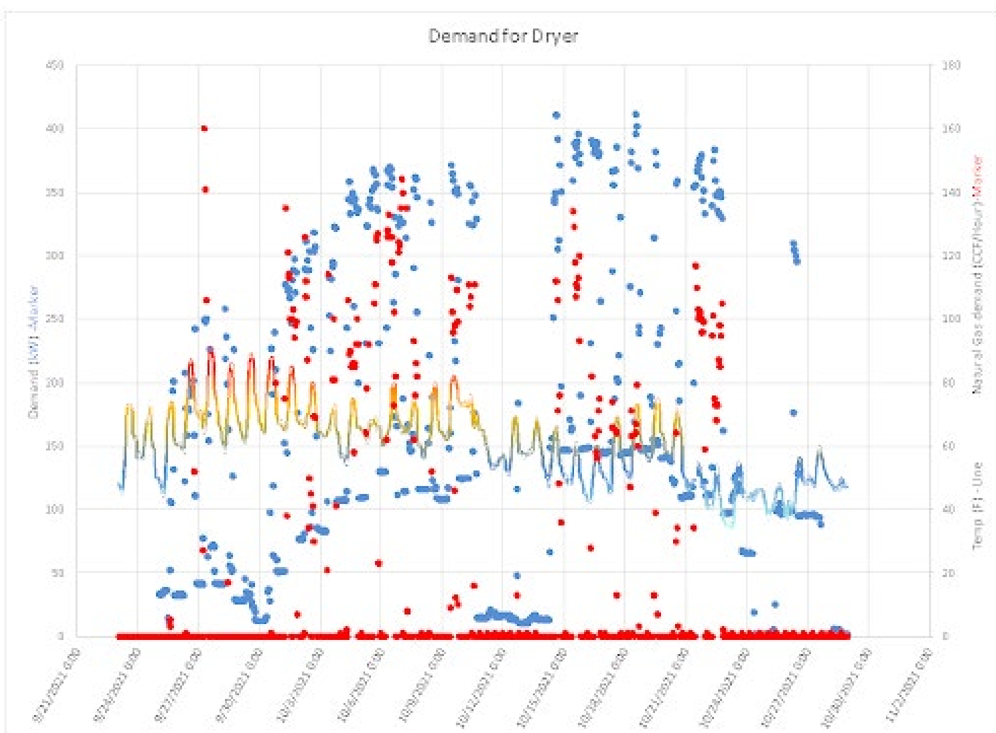
EMISSION DETAILS

The following table summarizes the emissions associated with the identified improvement strategies using average emission factors for the state of Iowa. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 23. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)
Obtain Specifications for Implementation:				
Competitive electric rates	(202,266)	(32)	22	(202,544)
Aeration probes and controls	10,266	1	0	10,338
Bin aeration circulator tubes and controller	8,669	1	0	8,730
Install heat pump low temperature heating	99,862	(1)	26	101,704

Figure 19. Electric, Natural Gas and Temperature Data



For figure 19, the temperature is the line, the red circle marker is the natural gas usage in hundred cubic feet per hour (CCF/hour), and the existing kW demand is the blue circle marker.

SITE 4: MANUFACTURING

Michael Energy completed an electrification study of a manufacturing facility with an area of over 1,000,000 SF. The purpose of the study was to investigate equipment and operations relying on natural gas with the goal of supplying electric alternatives during curtailment and for potential replacement.

Table 24 presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary alternatives during natural gas curtailment.

Costs for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measures will be relatively more expensive than other measures.

Table 24. Electrification Financial Savings Summary

Electrification Options	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Approx. Payback (Years)	Net Present Value
Obtain Specifications for Implementation:					
Electric backup and infrared preheat	$750,000	TBD	($312,150)	(2)	($4,682,250.00)
Infrared pre-heating	$49,000	TBD	$44,000	1	$660,000.00
Compressed air heat recovery	$25,000	TBD	$11,000	2	$110,000.00
Heat pump water heater with pre-heat	$60,000	TBD	$3,000	20	$30,000.00

Table 25. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms/yr)
Obtain Specifications for Implementation:		
Electric backup and infrared preheat	(8,960,150)	450,000
Infrared pre-heating	(322,770)	85,000
Compressed air heat recovery	(15,790)	15,000
Heat pump water heater with pre-heat	(138,860)	15,000

5.4.1 ELECTRIFICATION OPPORTUNITIES

INFRARED PREHEATING

EXISTING OPERATION

The current powder coat curing oven operates at high temperatures to melt and cure the powder topcoat finish. The oven uses forced air convection to fully heat the painted part and cure the finish. The finished products must go through a full cool down before they can be transferred to the assembly area.

INSTALL INFRARED PREHEATING BEFORE THE CURING OVEN

Consider installing an infrared preheating section to the curing oven. The infrared heating section would initiate the powder coating melting process before the part enters the convection section of the oven. The entire part is not heated to the final oven temperature as is the case with the current convection oven. Infrared radiation heats up only what it "sees" or radiates heat towards the object surface, thus enabling oven temperatures to be lowered and improving heating effectiveness by only putting the heat where it is needed. The final curing can often take place at a lower oven temperature, which could result in lower equipment energy requirements. In the case where the part to be painted has substantial mass, the infrared process may speed the entire operation as the powder melting would occur before the entire part is fully heated. Faster finishing speeds would also improve the efficiency of the coating process. Infrared heaters may also be used in the preheating stages before powder coating is applied.

The suggested infrared curing oven section would have to be designed and controlled for the parts being finished and for the type of finishing material. How a properly designed infrared preheat oven would perform in this application is very difficult to predict and needs to be studied further with the assistance of an expert in finishing oven design. Published case studies suggest such a modification would have a positive effect on the process efficiency and system performance. Depending on the needs of the process, infrared heating elements may be electric or natural gas fired.

Infrared heaters work best with uniform products since the heaters can be better conformed to the parts. Hidden surfaces are not heated well with infrared heating.

REPLACE OVEN WITH INFRARED PREHEATING AND ELECTRIC OVEN

EXISTING OPERATION

The present powder coat curing oven operates at high temperatures to melt and cure the powder topcoat finish. The oven uses forced air convection to fully heat the painted part and cure the finish. The finished products must go through a full cool down before they can be transferred to the assembly area.

INSTALL ELECTRIC BACK UP HEATING AND ELECTRIC PREHEATING

Installing electric backup heating for the curing oven and installing electric infrared preheating would allow for the system to be maintained in times of curtailment. The exhaust heat from the infrared curing would be used for burner air in the paint line to reduce the exhaust air amount.

If electrical heaters are installed as a back-up, it is recommended to run this mainly in times of curtailment or during winter off-peak hours when the kW/kWh rates are more cost effective compared to natural gas.

Leaving natural gas in place would allow this load to be an interruptible load, which can be charged at a lower rate by the utility. This was considered with the saving shown.

REPLACE WATER HEATER WITH HEAT PUMP

EXISTING OPERATION

The existing water heater is a gas fired tube heater. This is used to bring the water temperature up to around 120-140°F for the wash of the metal parts.

INSTALL HEAT PUMP WATER HEATER

Replacing the water heater with a heat exchanger supplied by a heat pump should be investigated. This technology is improving in cost and efficiency but does not appear to be cost effective at this time versus straight natural gas. As natural gas costs and efficiencies increase, this maybe be a better fit for this location. The measure assumes the heat pump would heat the water to 130°F. This type of application can typically payback when coupled with a constant source of cooling that is nearby. The cooling energy produced can be used for minor cooling loads. However, there are no known cooling loads for this location, aside from maybe office areas in the summer or worker comfort. The level and amount of cooling potential is small, and the potential cooling load would need to be in proximity.

Savings are based on 100 GPM being heated to around 130°F. While these heat pumps can produce higher temperatures it does not appear to be a common application for it. At present temperatures over 160°F are achievable but are not in common use in industrial application in the United States.

5.4.2 OTHER ALTERNATIVES

COMPRESSED AIR HEAT RECOVERY

EXISTING OPERATION

The main compressed air plant includes (four) 100-HP compressors controlled by a sequencer. Typically, one or two compressors operate at full capacity, and a single compressor uses load/unload controls to maintain the system set point. There are several other stand-alone and booster compressors throughout the plant that use load/unload capacity controls. This type of compressor control typically uses roughly 30% of full load power while unloaded, resulting in inefficiencies.

PROPOSED OPERATION

Air compressors are 35% efficient at making air and around 90% efficient at making heat. Heat recovery can be as large as 50-90% of the heat produced if designed well.

To move the heat to the right locations, a small fan will be required and is shown in the measure as negative kWh. The heating this measure would be replacing is direct fired make up air, or radiant heat. Therefore, a baseline heating efficiency of 90% was used to determine the savings.

5.4.3 SUMMARY OF RECOMMENDATIONS

Options are shown for natural gas interrupts and for larger scale electrification (replacement of the existing system or large-scale changes).

Table 26: Energy Savings for Options

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms/yr)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:			
Electric backup and infrared preheat	(8,960,150)	450,000	(2,536,393)
Infrared pre-heating	(322,770)	85,000	700,902
Compressed air heat recovery	(15,790)	15,000	159,156
Heat pump water heater with pre-heat	(138,860)	15,000	53,131

PROCESS DESCRIPTION

One larger paint booth is used to apply the powder coat and the parts are sent into an oven to cure powder at temperatures of around 400°F.

Parts and assemblies entering the paint line are first washed with a detergent, then rinsed and pre-heated via a natural gas-fired furnace section. There is a secondary wash station with two rinse stages following. The washing and rinse stages each use 15- to 40-horsepower motors for pumping. The parts are heated in a natural gas-fired furnace before they are sent through the powder-coating booth. After powder coating, the parts are cured in an oven and eventually unloaded in the "hot room".

A burn off oven is used for removing paint and other contaminates from parts hangers that are used on the paint line conveyor system. The hanger and parts need to maintain electrical contact for the powder coating process to work effectively. This equipment utilizes a natural gas-fired burner and operates roughly 50% of the shift time.

EMISSION DETAILS

The following table summarizes the emissions associated with the identified improvement strategies based on the average emission factors for the state of Iowa. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 27. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)	SO2 (lbs)	NOx (lbs)
Obtain Specifications for Implementation:						
Electric backup and infrared preheat	(2,555,151)	(614)	757	(2,536,393)	(465)	(86,715)
Infrared pre-heating	689,141	5	161	700,902	45	(3,082)
Compressed air heat recovery	156,834	4	29	159,156	12	(144)
Heat pump water heater with pre-heat	51,547	(6)	27	53,131	0	(1,339)

SITE 5: GREENHOUSE

Michaels Energy completed an electrification study of a greenhouse facility with area between 100,000 and 250,000 SF. The purpose of the study was to investigate equipment and operations relying on natural gas with the goal of supplying electric alternatives during curtailment and for potential replacement.

This report presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary supply during a natural gas curtailment.

Costs for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measures will be relatively more expensive than other measures.

Table 28. Financial Savings Summary

Electrification Options	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Approx. Payback (Years)	Net Present Value
Obtain Specifications for Implementation:					
Electric hot water	$200,000	TBD	($470)	(426)	($7,050.00)
Vertical destratification fans	$150,000	TBD	$22,000	7	$330,000.00
Heat recovery chiller	$200,000	TBD	$11,000	18	$165,000.00
Peak hot water storage	$53,000	TBD	$800	66	$12,000.00
Supplimental solar hot water	$1,300,000	TBD	$18,000	72	$270,000.00

Table 29. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms/yr)
Obtain Specifications for Implementation:		
Electric hot water	(22,190)	2,200
Vertical destratification fans	(15,890)	44,000
Heat recovery chiller	(32,490)	21,000
Peak hot water storage	(1,300)	1,700
Supplimental solar hot water	(114,760)	62,000

5.5.1 ELECTRIFICATION OPPORTUNITIES

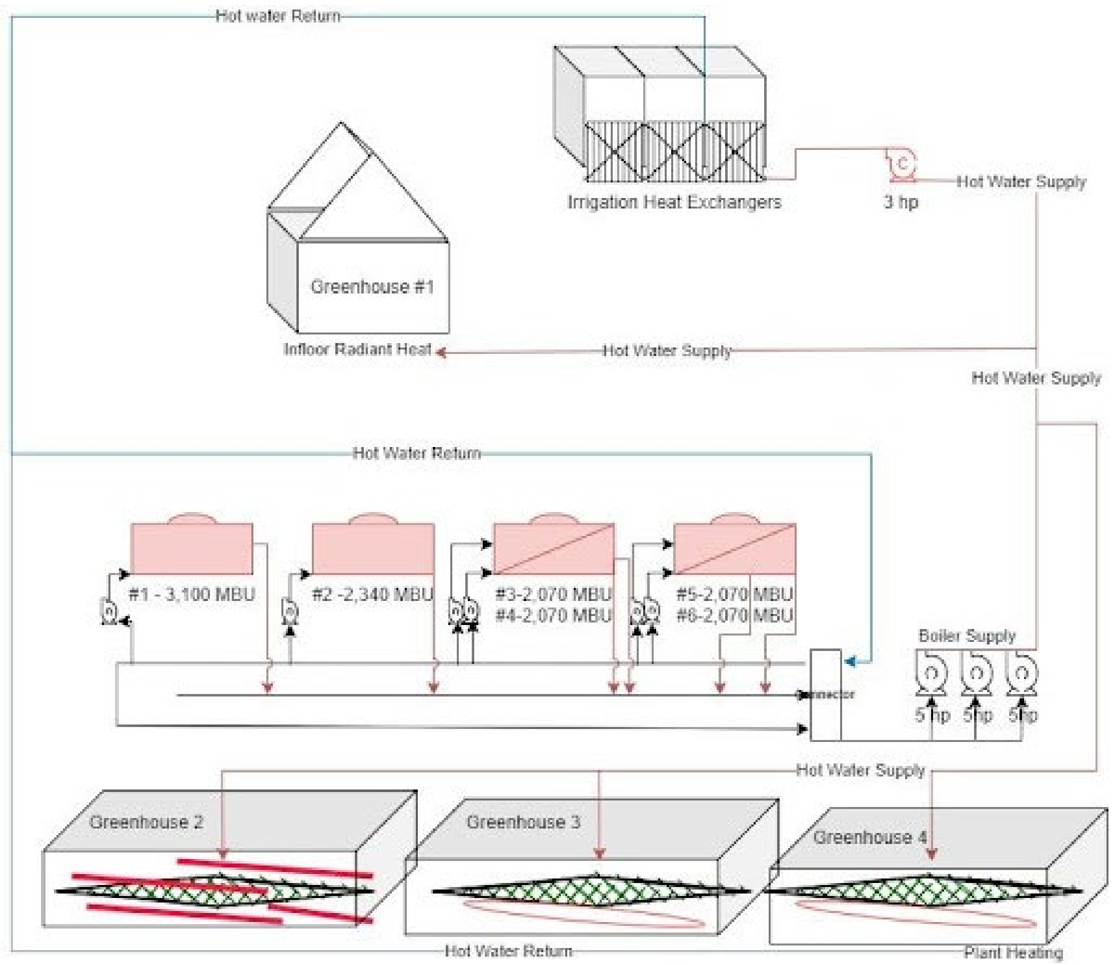
INSTALL LARGE HOT WATER TANK

EXISTING SET UP

The boiler system heats hot water for a common supply loop. This loop is used for heating the city water irrigation heat exchanger, the radiant heating for greenhouse #1 and plant in greenhouses #2, #3, and #4. A diagram of the system is shown in Figure 20 below. The greenhouses gain a solar heat load easily and during many sunny days little boiler load is needed to maintain temperatures of the space. The greenhouses easily loose this heat when the solar load is no longer available. This causes a huge swing in boiler loads during a short period.

The boilers appear to be maintaining relatively low hot water temperature causing short runtimes and instant needs. The largest boiler for example cycled on for at least two, five-minute periods to supply a temperature of around 135°Fz.

Figure 20. Current Boiler System Set-up

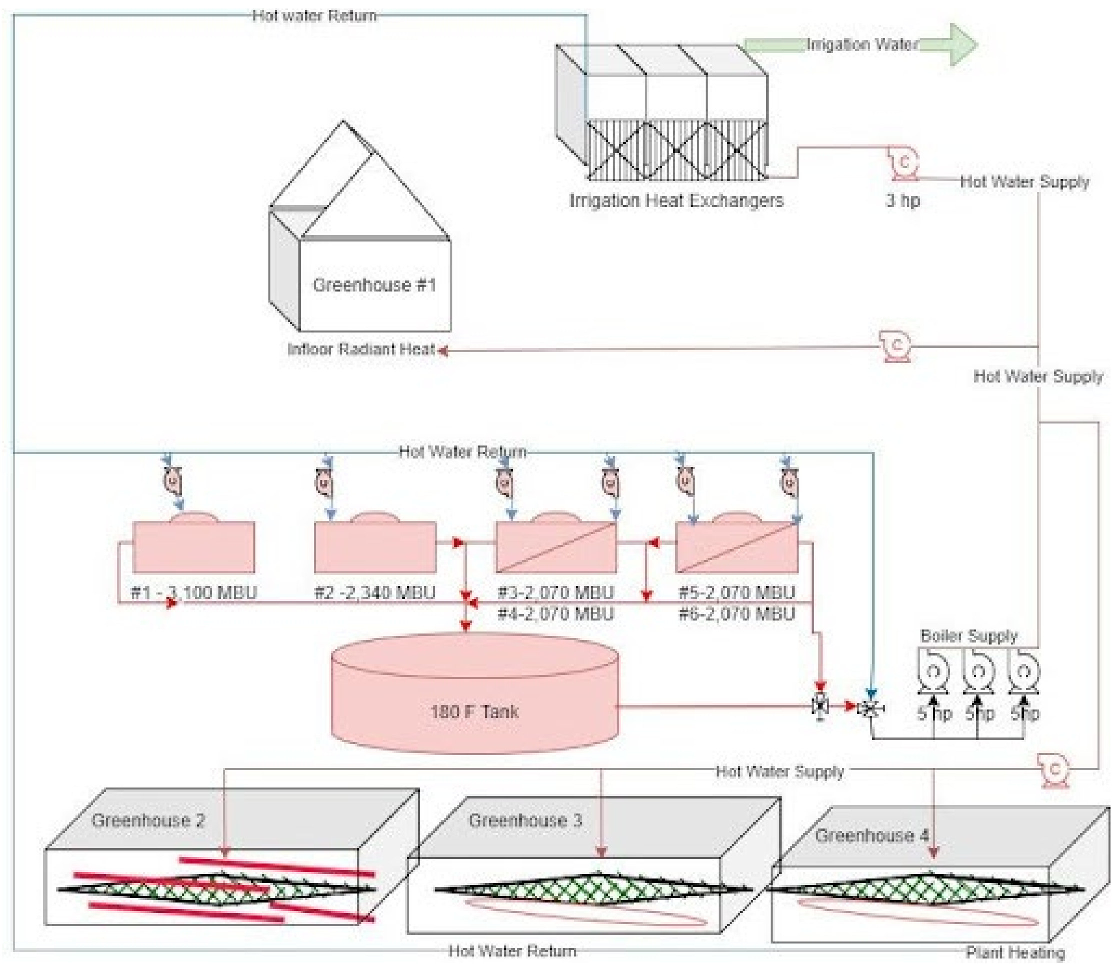


INSTALL HOT WATER SURGE TANK

Consider installing a larger hot water storage tank. This tank would act as a buffer during short surge periods. It can be kept at higher temperatures of around 180°F (insulated to help maintain 180°F) and bleed into the supply to maintain the temperatures of the supply system. The calculation assumes that this tank would use electric heaters to help maintain the hot water temperature.

Figure 21 shows (two) three-way valves to direct the water as needed. This would allow hot water to flow directly from the boilers, directly from the hot water tank or both based on demand. It is assumed a dead-band for the tank fill would be included so the boiler would not short cycle every time the water level goes down.

Figure 21. Proposed Boiler System Set up



INSTALL VERTICAL CIRCULATION FANS TO REDIRECT CEILING AIR

EXISTING SET UP

The greenhouse ambient air is heated with unit heaters that are adjacent to outside air dampers on the wall. This allows the unit to recirculate the room air or mix outside and room air.

The greenhouses are not mechanically cooled, instead outside air is used and drawn through the greenhouses. In greenhouse #1 it is drawn all the way across the space. In greenhouses #2, #3, and #4 the air is drawn in from the outside and exhausted in the middle of the greenhouse, which allows for more control of the different zones than compared to greenhouse #1.

INSTALL FANS TO DESTRATIFY AIR

Stratified air (air layered with the heat trapped in the ceiling) exists in each greenhouse. A typical solution to destratify air is installing a larger fan that can evenly distribute the air. In a greenhouse this is not as easy. There are two options sometimes installed in greenhouses. One is a small fan set vertically with clear plastic duct to direct the air down towards the ground. This would prevent the heat trapped in the ceiling from escaping as easy. The other is a more compact fan, typically pear-shaped, that forces the air straight down.

The savings from either is expected to be the same. Less heat would be trapped by the ceiling and the evening out of temperatures would allow less of the heat to be lost to the outside.

OFF PEAK ELECTRIC BOILER

EXISTING OPERATION

There are five hot water boilers in this system shown in Figure 20. At peak loads it is assumed that most, if not all, of the boilers are needed. This causes large natural gas loads on the line and maximizes the capacity the customer can draw.

PROPOSED OPERATION

Using an electric boiler or large heat pump to heat the hot water would reduce the natural gas demand. This type of application is not typically recommended for payback with the current rate structure.

If used to help reduce the stress on natural gas capacities, it should only be run during off-peak hours to reduce the peak demand. This boiler would cause a peak demand so this boiler should only be run after the lights are turned off to reduce the peak demand to your bill. In the winter this may be difficult as the largest natural gas demand at present appears to be after 7 am (7 am is typically on-peak start time during the week). If the boiler is needed during the on peak time it will significantly increase the billed demand.

With the current cost of gas and electricity. This measure does not show a favorable payback, even running only on off-peak time only. Currently your cost of gas is around 3 times the cost of electricity. For this measure to payback the cost of natural gas therms would be need to be closer to 10-11 times that of electrical kWh.

HEAT RECOVERY CHILLER

EXISTING OPERATION

Irrigation for plants is produced by using the boilers in a heat exchanger to heat the city water before watering the plants. The city water temperature can fluctuate between 40-55°F.

Dehumification is a problem occasionally and the easiest method of removing it is to introduce dry outside air. The baseline for this measure is a chiller dehumidification system. The baseline would use 100,000 kWh or more depending on the size. The size used for this application was 50 tons which was assumed to match the load for heating the city water used for irrigation.

PROPOSED OPERATION

Using a heat pump to add heat to the irrigation water would be able to raise the temperature, but for it to payback it would need to absorb heat from an external source. Controlling the humidity in the greenhouse could provide a heat source. The heat pump would function as a dehumification device. It is assumed that this would have extended run times. The calculation assumes a run time of around half the time, and lower lows at lower outside air temperatures. The dehumidification would work similar to a home dehumidifier with a fan to blow the humid air over cold coils and collect the moisture to a drain.

The cost and complexity of such an application is unknown and the impact on the overall natural gas usage is small compared to the heating load. It is also assumed to have a minimal peak heating load impact.

SUPPLEMENTAL SOLAR HOT WATER

EXISTING SYSTEM

The boiler system heats hot water for a common supply loop. This loop is used for heating the city water irrigation heat exchanger, the radiant heating for greenhouse #1 and plants in greenhouses #2, #3, and #4. A diagram of the system is shown in Figure 20. The greenhouses gain a solar heat load easily and during many sunny days little boiler load is needed to maintain temperatures of the space. The greenhouses easily loose this heat when the solar load is no longer available. This causes a huge swing in boiler loads during a short period.

PROPOSED SYSTEM

Install solar collector panels to collect 160°F water when available. We suggest installing a storage tank similar to the hot water tank describe earlier. This would have the dual purpose of providing the surge volume and allow for a constant flow of the solar hot water when enough solar energy is available. Solar collectors are more effective at lower temperatures which is why they are generally used for domestic hot water. This can be used to supplement lower temperature needs or applications.

5.5.2 OTHER ALTERNATIVES

INSTALL CLEAR PLASTIC HVAC DUCT SOCK

EXISTING OPERATION

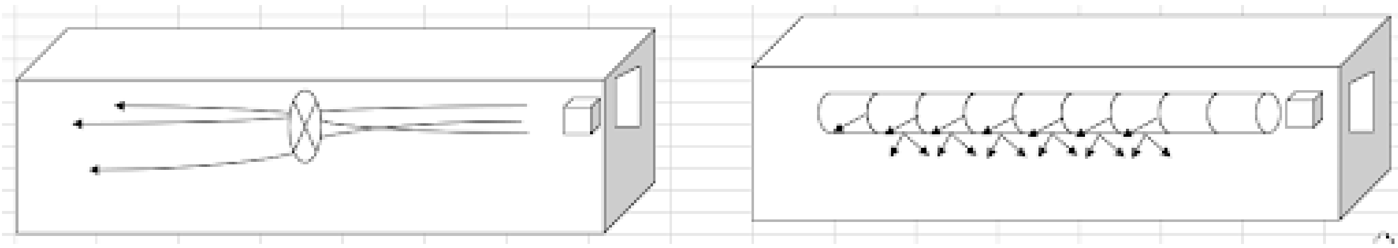
Unit heaters hanging on the east side and west side of the green houses provide space heating. These units heat a mixture of space air and outside air. The air is moved down the length of the greenhouses using smaller horsepower fans.

INSTALL CLEAR PLASTIC HVAC DUCT SOCK

Consider installing a clear plastic duct sock for the unit heaters. This would help force the air from the unit heater down the length of the building and perforations on the underside of the duct would force the air down instead of the more vertical current set up.

The savings for this cannot be estimated with any accuracy. Typically these types of ducts are tied to air handlers themselves. They can be inflated with a small fans to transfer air from the unit heater and direct throughout the greenhouse more efficiently. The diagram below shows a possible scenario for air movement improvement.

Figure 22. Potential Air Movement Scenario.



5.5.3 SUMMARY OF RECOMMENDATIONS

It is hoped that the large peak natural gas demand can be alleviated a little with a large water tank. The frequency of the natural gas usage in MMBTU is shown below. Depending on how large a surge tank purchased and the fill rate of the boilers it is hoped that this tank can reduce the peak demand around 3-4 MMBTU if not more. In conjunction with other measures this can reduce peak demand significantly.

Table 30. Frequency of Natural Gas Demand

MMBtu	Hours per Year
19	2
18	3
17	10
16	35
15	54
14	81
13	80
12	94
11	116
10	188
9	289
8	434
7	606
6	644
5	679
4	677
3	753
2	4,052
1	0

Table 31. Energy and Emission Savings Summary

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms/yr)	Propane Savings (Gal/yr)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:				
Electric hot water	(22,190)	2,200	0	3
Vertical destratification fans	(15,890)	44,000	0	247
Heat recovery chiller	(32,490)	21,000	0	107
Peak hot water storage	(1,300)	1,700	0	9
Supplimental solar hot water	(114,760)	62,000	0	308

EMISSION DETAILS

The following table summarizes the emissions associated with the identified improvement strategies. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 32. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)	SO2 (lbs)	NOx (lbs)
Obtain Specifications for Implementation:						
Electric hot water	6,000	(1)	4	3	(0)	(214)
Vertical destratification fans	486,076	16	85	247	38	(128)
Heat recovery chiller	210,683	5	40	107	16	(303)
Peak hot water storage	18,193	1	3	9	1	(12)
Supplimental solar hot water	605,903	14	119	308	45	(1,077)

SITE 6: BREWERY

Michaels Energy completed an energy audit of the steam system of a brewery with a total area of under 50,000 SF. The purpose of the audit was to investigate equipment and operations with the goal of identifying electrification opportunities for larger natural gas load. This would help to promote alternatives to natural gas equipment in areas with no, or significantly restrained, natural gas.

This report presents recommendations for improvement, benefits of implementing the recommendations, and the cost of not doing anything.

Recommended measures are represented in the first group of the table below. The next steps for these measures as indicated, include requesting specifications and pricing for implementing these measures.

Table 33. Financial Savings Summary

Electrification Options:	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Approx. Payback (Years)	Net Present Value
Obtain Specifications for Implementation:					
Electric kettle in winter	$150,000	TBD	($1,870)	N/A	($28,050.00)
Electrical kettle	$150,000	TBD	($4,870)	N/A	($73,050.00)
Hot water heat pump	$65,000	TBD	$5,200	13	$78,000.00
Future Options:	**($) Measure Cost**	**Potential Rebate ($)**	**Annual Non-energy ($) Savings**		
Electrification Options:					
Heat pump (heat recovery chiller) *	$350,000	TBD	$5,300	66	$53,000.00

* Further study required

5.6.1 ELECTRIFICATION OPPORTUNITIES

Our investigation of the facility yielded the following opportunities for electrification. Throughout this section, we identify the opportunity, benefits to the facility and the estimated cost and savings per measure. Measures may not make sense at this facility, at this time, but some measure may make sense at similar facilities in natural gas restrained areas.

ELECTRIC RESISTANCE KETTLE

EXISTING SET UP

A natural gas boiler is being used to produce 15 PSI steam for the boil kettle. This temperature allows the large amount of fluid in the kettle to maintain 160°F +/- for extended periods of time. It also boils this same amount of fluid for around an hour. The process is done a few times a week but is not a constant process.

ELECTRIC KETTLE TO REPLACE STEAM KETTLE

Kettles can also be electric with electric resistance coils used to boil the liquid or hold temperature. Estimated capacity for the electrical demand is around 150-180 kW to match the existing capacity. This demand would be a substantial increase over the existing demand. Due to the lower run hours and high demand needed this measure would make more financial sense on the Utility energy-only rate. However, the energy-only rate for this Utility does not produce a positive payback.

Replacing the steam jacketed kettle with an electric kettle does not have a positive energy cost savings based on the current price of natural gas and electricity. However, savings do not consider maintenance and labor savings associated with steam boilers. Electric kettles typically have less maintenance involved than steam kettles.

ELECTRIC KETTLE IN WINTER

EXISTING SET UP

The process described above operates throughout the year.

INSTALL ELECTRIC KETTLE FOR WINTER USE

Installing an electric kettle described above and operating it during the winter would help natural gas restrained areas. Natural gas is most restrained in extreme cold weather. During the winter the Utility rate is typically lower. In the summer the natural gas rates might be slightly lower and availability should increase. This measure would also make slightly more sense from a cost savings standpoint. Given the current rates and structure this measure is not cost effective at this time, at this location.

Purchasing a kettle to sit idle is not financially sound but if future process throughput or expansion is expected, and more than one kettle is required, it may be worth the investment. This would also allow for expansion or back up.

HOT WATER HEAT PUMP

EXISTING SET UP

The process utilizes a substantial amount of hot water for the process. This hot water is around 160-180°F to maintain process fluids at certain temperatures. A conventional 199 MBH natural gas fired unit is needed to maintain large batches of beer at around 160-180°F, and for process cleaning.

INSTALL HOT WATER HEAT PUMP

High temperature hot water air-source heat pumps can supply temperatures of around 180°F. Typical hot water heat pumps are designed for 130°F maximum temperatures. Heat pumps with temperatures of around 180°F are more specialized, which make the cost for these slightly more expensive, and may make maintenance on them more expensive. However, at ideal conditions these high temperatures water heaters can have COPs of 3 or larger. Air source heat pumps have lower capacities at low outside air temperatures and may not be able to operate effectively at temperatures around 17°F or lower (depending on the make/model it may be lower).

Since there is a steam boiler here with excess capacity it is assumed that a steam-to-hot water heat exchanger could be installed as a backup, incase outside air temperatures cause the heat pump to lose capacity and fail to keep up with routine process operations.

Cost was based on the cost of a domestic (130°F) water heater of the same size. It is expected that this unit will cost at least 15-20% more due to higher temperatures needed and the lower amount of these units currently being sold which resulted in a cost of $65,000.

5.6.2 OTHER ALTERNATIVES

HEAT RECOVERY CHILLER

EXISTING OPERATION

The process uses both a chiller and hot water heater to maintain and hold the process at certain temperatures throughout the process cycle. The chiller is an air-cooled glycol chiller with supply temperatures estimated to be around 30°F. The hot water heater is a 199 MBH unit maintaining around 160-180°F for the process and cleaning. The usage and run times of these units depend on what product is being made.

PROPOSED OPERATION

The process has needs for both heating and cooling in the summer as well as the winter. Typically, when these types of loads are needed at the same time a heat recovery chiller can be an ideal application. However, at this facility it appears as if the need is for one or the other and the timing for it is a little more sporadic than typical food/beverage manufacturer applications that may run constantly.

This is not being recommended at this location at this time, but in breweries with more consistent needs for both hot water and cold water this can be an ideal application. The unit operates much like a typical heat pump but instead of rejecting heat to the outside it rejects it to heat up water needed for heating or process. This can have substantial savings since the efficiencies of the unit are only slightly worse than a chiller, but the benefits are all the heat gained (no longer needed to be supplied by the hot water heater). A few years ago, these units produced hot water temperatures of around 140°F, but temperatures for these units have climbed to 160-180°F in the last couple years.

5.6.3 SUMMARY OF RECOMMENDATIONS

Given the current cost of the different utilities involved there are no projects shown that are a quick fit and have quick paybacks. However, none of the measures mentioned include rebates or other incentives, which may reduce potential payback periods. It is assumed that the cost of natural gas will increase, per unit, faster than the cost of electrical power given the multiple sources for electrical energy. However, there is no guarantee of this, especially in the short term.

The impact of carbon dioxide on the environment has driven many utilities to strive to reduce the impact of CO_2. Natural gas emissions are likely to stay the same while electrical emissions are improving over the last few years and are likely to continue to improve. There is no clear, calculable, way to show this as part of a life-cycle analysis given all the variables but if carbon dioxide continues to be a major hurdle to overcome it is likely that the cost of those utilized with lots of CO_2 will increase faster than those without.

Table 34. Energy and Emission Savings Summary

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms/yr)	Emission Savings (tons CO2e)
Obtain Specifications for Implementation:			
Electric kettle in winter	(59,390)	6,500	23,698
Electrical kettle	(89,640)	9,200	28,734
Hot water heat pump	(46,480)	4,700	14,089
Future Options	**Annual HVAC Electrical Usage (kWh)**	**Natural Gas (Therms/yr)**	**Emission Savings (tons CO2e)**
Additional Opportunities:			
Heat pump (heat recovery chiller) *	2,000	4,800	57,006

* Further study required

EMISSION DETAILS

The following table summarizes the emissions associated with the identified improvement strategies based on local emission factors. Greenhouse gas emissions are represented by three gases (CO_2, N_2O, CH_4) and a combined equivalent to carbon dioxide (CO_2e). The unit of measurement for CO_2e is tons, which is equivalent to 2,000 pounds.

Table 35. Emissions Savings Summary

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)	SO2 (lbs)	NOx (lbs)
Obtain Specifications for Implementation:						
Electric kettle in winter	23,007	(3)	12	23,698	0	(573)
Electrical kettle	27,789	(4)	17	28,734	(0)	(865)
Hot water heat pump	13,610	(2)	9	14,089	(0)	(448)
Future Options	**CO2 (lbs)**	**N2O (lbs)**	**CH4 (lbs)**	**CO2e (tons)**	**SO2 (lbs)**	**NOx (lbs)**
Additional Opportunities:						
Heat pump (heat recovery chiller) *	56,220	2	9	57,006	5	22

* Further study required

SITE 7: ANIMAL PROCESSING

Michaels Energy completed an electrification study of an animal processing facility with an area of 250,000 to 500,000 SF. The purpose of the study was to investigate equipment and operations relying on natural gas with the goal of supplying electric alternatives during curtailment and for potential replacement.

This report presents potential measures for electrification. Electrification being defined as electric alternatives to natural gas. These options are being given as alternatives for either replacement or temporary alternative to a natural gas curtailment.

Cost for these measures cannot be accurately determined due to the size and quantity needed. The cost should be meant as scale to show that some measure will be relatively more expensive than other measures.

Table 36. Financial Savings Summary

Electrification Options	Cost ($)	Potential Rebate ($)	Annual Energy Savings ($)	Approx. Payback (Years)
Obtain Specifications for Implementation:				
Install electric boiler (25% of capacity)	$1,000,000	TBD	($800,630)	N/A
Install electric superheater	$300,000	TBD	$230,000	1
Install mechanical recompressor	$1,000,000	TBD	$240,000	4
High temperature heat pump	$1,500,000	TBD	$89,000	17
Continuous rendering	$50,000,000	TBD	$1,290,000	39

Table 37. Energy Usage Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms)
Obtain Specifications for Implementation:		
Install electric boiler (25% of capacity)	(25,936,090)	1,400,000
Install electric superheater	(1,028,970)	450,000
Install mechanical recompressor	(859,640)	450,000
High temperature heat pump	(11,465,650)	1,290,000
Continuous rendering	89,000	1,950,000

5.7.1 ELECTRIFICATION OPPORTUNITIES

Our investigation of the facility yielded the following electrification opportunities. Throughout this section, we identify the opportunity, benefits to the facility, and the estimated cost and savings per measure. Some of these measures are assumed to work at the facility although a more in-depth engineering study was not completed to cover all the contingencies.

ELECTRIC HEATING ALTERNATIVE

EXISTING OPERATION

The boiler system is currently set up to produce steam pressure at a flow of around 68,000 lb/hr at 100-120 PSI. The main load on this plant is the rendering facility, which uses around 75% of the total load at around 90 PSI, on average. The boiler feed water temperature was around 210°F during the onsite and was assumed typical.

ELECTRIC BACK UP STEAM

Install a boiler to produce enough steam to shut off one steam boiler. This electric boiler would be able to augment the existing boiler. It would only be run during curtailment or when economically feasible.

For new applications this may be done with a hybrid boiler. Hybrid boilers use a heat pump system to increase the feed water temperature to the boiler. This facility, as with may others, returns much of the condensate or does heat recovery from condensate to increase the input temperature of the feed water before it reaches the boiler. The input temperature observed was around 200°F. The outlet temperatures of high temperature heat pumps are, on typically a maximum of 200°F. Higher temperature heat pumps are available for new boiler systems, but this type of system does not appear to be economically feasible at this location.

One thing not addressed in this study was the capacity and infrastructure of implementing this measure. It is unknown if replacing a transformer would be involved to be able to maintain the 2,500-3,000 kW needed to implement this type of measure. At this time there is no electric heating rates from your electrical provider that would help alleviate the large demand this measure would incur.

WASTE STEAM SUPERHEATER

EXISTING OPERATION

The steam enters the steam jacket at around 90 PSIG to maintain internal temperatures around 250-275°F. The outlets of the 11 different cookers are combined and used in a hot water heat exchanger to produce 140-180°F hot water for other processes in the plant. This outlet is assumed to be a steady 220-250°F with a low-pressure equivalent of around 5-15 PSI.

INSTALL ELECTRIC WASTE HEAT SUPERHEATER

The cooker's waste stream is drained into a common flash tank, or impingement tank. Depending on the flow rate of the steam remaining, the low-pressure flash steam from the impingement tank could be super-heated to the temperatures needed to maintain one or two other cookers. This measure assumes a superheater could use the waste stream of around eight cookers to supply enough steam for one cooker.

This would not be a solution for all the batch cookers. It is assumed that the low-pressure steam from a few would be able to supplement the steam to one or two cookers. This superheater is only an electric heater used to boost the energy of the steam. It may be able to be used throughout the year, but it would be more advantageous to use it during off-peak times due to the more favorable rates.

WASTE HEAT MECHANICAL RECOMPRESSION

EXISTING OPERATION

The steam enters the steam jacket at around 90 PSIG to maintain internal temperatures around 250-275°F. The outlets of the 11 different cookers are combined and used in a hot water heat exchanger to produce 140-180°F hot water for other processes in the plant.

INSTALL MECHANICAL RE-COMPRESSORS

Any gas, including steam, can be compressed. Whether it's worth it to recompress it depends on the pressures that need to be achieved. The waste steam from the rendering plant is assumed to be around 15 PSIG and it is assumed that this would need to be boosted back up to around 90 PSIG, which is more than 3.5 times the pressure.

This measure would require more engineering. Typically, these re-compressors are less than two times the original pressure for steam, so it is unknown if recompression would be able to obtain the temperature pressures required for the current cookers.

This would not be a solution for all the batch cookers. It is assumed that the low-pressure steam from a few would be able to supplement the steam to one or two cookers. Using your current rate, it is assumed that this potential solution would only be used during the winter and likely during off-peak (or curtailment) times.

REPLACE BATCH COOKERS WITH CONTINUOUS COOKERS

EXISTING OPERATION

The current process uses 11 batch cooker units. In a batch cooker system, a horizontal, steam-jacketed cylinder with a mechanical agitator is used to render animal byproducts into usable byproducts for resale or disposal. The plant has 11 of these units at various cook times and temperatures based on what is being processed.

REPLACE BATCH COOKERS WITH CONTINUOUS COOKERS

The continuous rendering system involves continuous cooking with raw material fed into one end of the cooker. The cooked material is then discharged from the other end. With a continuous cooker it may be possible to achieve higher capacity while being more energy efficient. The savings are estimated on steam savings of around 40% based on two different studies found.

This study does not consider the potential resale or economic factors tied to producing a certain byproduct. It is assumed that continuous rendering would be able to produce the same byproducts at the same quantity as the current system. The cost for replacing the current system with a continuous cooker of this size is difficult to price. It is expected to cost millions. A ballpark estimate cost was used to help define the simple payback.

INDUSTRIAL HEAT PUMP

EXISTING OPERATION

The steam enters the steam jacket at around 90 PSIG to maintain internal temperatures around 250 -275°F. The outlets of the 11 different cookers are combined and used in a hot water heat exchanger to produce 140-180°F hot water for other processes in the plant.

INSTALL HIGH TEMPERATURE INDUSTRIAL HEAT PUMP

This technology is not wildly use at this time. The cost for these are unknown and typically designed for project specific accounts. European and Japanese companies are starting to make heat pump that produce outlet temperatures of around 270-320°F. These units are not main stream at this time and are designed for specific applications. This unit would need a waste stream of around 140-160°F to make these temperatures. The heating COP would be closer to 2-2.5. For this measure a 13,000 MBH producing unit was used. Some companies claim to produce units that will be able to supply this entire plant.

These units can sometimes produce refrigeration level water as a byproduct. This was not included with the measure only using the hot water stream as a heat sink.

5.7.2 OTHER ALTERNATIVES

These options do not have enough information to determine if they have substantial savings, or if they would be a fit for this location.

REDESIGN PLANT FOR LOW TEMPERATURE RENDERING

EXISTING OPERATION

This facility has high temperature batch cookers that use around seven million therms worth of energy per year. These cookers run in batches of around 100 minutes on average.

REDESIGN FOR LOW TEMPERATURE RENDERING USING ELECTRIC

One alternative option is to redesign the plant for low-temperature rendering. Some studies show this as a potential energy saving measure, but not enough information is available to determine if this application would work in typical meat production plants in the Midwest. One study shows 30% electrical savings and 25% natural gas savings for continuous low-temperature rendering. However only one manufacturer is showing these types of savings.

This is a high-cost option for replacing the existing system. It would be easier to implement in a new plant. The initial cost of implementing such a system to encompass the entire flow of a typical slaughterhouse would be in the millions of dollars. A ballpark estimate cost was used to help define the simple payback.

This study does not consider the potential resale or economic factors tied to producing a certain byproduct. It is assumed that low temperature rendering would be able to produce the same byproducts at the same quality as the current system; however, this assumption was not verified.

LIQUEFACTION

EXISTING OPERATION

Rendering all animal byproducts into usable product.

CHANGE SYSTEM TO LIQUEFACTION

This method of processing raw materials employs a combination of physics and chemistry to reduce whole carcasses (if required) to a soup-like consistency. The hydrolysis units are engineered to facilitate very alkaline conditions (pH above 12), high pressures (higher than three atmospheres), and mixing by a pumping circulation system. In principle, the concept includes the ability to inactivate animal tissues that may contain infective agents such as bovine spongiform encephalopathy (BSE). However, the capital cost per ton processed is very high (partly due to low/batch throughputs) and any subsequent disposal cost of the liquid soup would also be considerable due to the polluting load.

This study does not include the potential impacts of not selling the rendered animal byproduct. The assumption is that rendering is a necessary way of disposing of animal byproducts and therefore disposing of the animal byproduct this way, instead of paying for the removal, is net zero savings. This assumption was not verified.

BIOMAL/CO-INCINERATION

EXISTING OPERATION

Rendering all animal byproducts into usable product.

CHANGE SYSTEM TO INCINERATION

This option would involve combusting or incinerating the animal byproduct, while recovering the energy. In this case the intended source of the heat would be the steam system itself. With less material to render, the steam system would not need to be as large. The Biomal system would crush the raw material and inject this material into a fluidized bed boiler where it is co-combusted together with a base fuel such as wood chips or municipal waste.

The amount of energy savings would depend on the cost savings of using material versus selling the byproduct. This can be used in curtailment; instead of reducing the amount of rendering product, the product itself would be used to provide steam for the plant. It may be possible to provide steam for the plant and some of the rendering plant as well. Upfront costs are substantial and additional products to help facilitate burning would be an incurred cost.

This study does not include the potential impacts of using the byproducts as a fuel instead of selling it. The assumption is that rendering is a necessary way of disposing of animal byproducts and therefore using it instead of paying for the removal is a net gain. This assumption was not verified.

5.7.3 SUMMARY OF RECOMMENDATIONS

Options are shown for natural gas interrupts and for larger scale electrification (replacement of the existing system or large-scale changes).

The study does not consider the potential resale or economic factors tied to producing a certain byproduct. It is assumed that continuous rendering would be able to produce the same byproducts at the same quality as the current system.

Table 38. Summary of Recommended Electrification Strategies

Energy Saving Strategy	Electrical Savings (kWh)	Natural Gas (Therms)
Obtain Specifications for Implementation:		
Install electric boiler (25% of capacity)	(25,936,090)	1,400,000
Install electric superheater	(1,028,970)	450,000
Install mechanical recompressor	(859,640)	450,000
High temperature heat pump	(11,465,650)	1,290,000
Continuous rendering	89,000	1,950,000

EMISSION DETAILS

The following table summarizes the emissions associated with the identified improvement strategies based on the average emission factors for the state of Iowa. Greenhouse gas emissions are represented by three gases (CO2, N2O, CH4) and a combined equivalent to carbon dioxide (CO2e). The unit of measurement for CO2e is tons, which is equivalent to 2,000 pounds.

Table 39. Emission Results of Estimated Strategies

Energy Saving Strategy	CO2 (lbs)	N2O (lbs)	CH4 (lbs)	CO2e (tons)
Obtain Specifications for Implementation:				
Install electric boiler (25% of capacity)	(6,289,747)	(1,739)	2,381	(6,219,750)
Install electric superheater	4,229,973	84	860	4,296,318
Install mechanical recompressor	4,374,835	99	863	4,442,196
High temperature heat pump	4,840,540	(508)	2,356	4,979,634
Continuous rendering	22,220,587	765	3,787	22,535,369

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