Electrifying U.S. Industry

A Technology- and Process-Based Approach to Decarbonization

January 27, 2021
Global Efficiency Intelligence (GEI) and David Gardiner and Associates (DGA) are pleased to announce the release today of their report to the Renewable Thermal Collaborative (RTC): *Electrifying U.S. Industry: A Technology-and Process-Based Approach to Decarbonization.*
Today’s Speakers

Blaine Collison
Executive Director
Renewable Thermal Collaborative

Steve Skarda
Global Energy
Sustainability Leader
Procter & Gamble

Ali Hasanbeigi, PhD
Founder & CEO
Global Efficiency Intelligence, LLC

Lynn A. Kirshbaum
Senior Associate
David Gardiner and Associates
Technical Assessment
U.S. Manufacturing Energy Use by End Uses (Trillion Btu)

Source: US DOE 2019 - manufacturing energy footprints
Industrial Heat Demand Profile

Figure a: Share of industrial heat demand by temperature in selected industries (Caludia et al., 2008)
Two-thirds of process heat is used in the U.S. industry is for applications below 300°C (572°F)

Figure b. Cumulative process heat demand by temperature in 2014 (McMillan, 2019)
Bottom-up Analysis Method

**Step 1**
- Detailed analysis of existing heating system

**Step 2**
- Selection of suitable electrification technology

**Step 3**
- Process integration assessment with new electrified heating technology

**Step 4**
- Calculation of changes in energy use and GHG emissions and cost implications

**Industry**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum casting</td>
<td>1</td>
</tr>
<tr>
<td>Ammonia</td>
<td>2</td>
</tr>
<tr>
<td>Methanol</td>
<td>3</td>
</tr>
<tr>
<td>Recycled plastic</td>
<td>4</td>
</tr>
<tr>
<td>Paper (from virgin pulp)</td>
<td>5</td>
</tr>
<tr>
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<td>6</td>
</tr>
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<td>Container Glass</td>
<td>7</td>
</tr>
<tr>
<td>Steel</td>
<td>8</td>
</tr>
<tr>
<td>Beer</td>
<td>9</td>
</tr>
<tr>
<td>Beet Sugar</td>
<td>10</td>
</tr>
<tr>
<td>Milk powder</td>
<td>11</td>
</tr>
<tr>
<td>Wet corn milling</td>
<td>12</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>13</td>
</tr>
</tbody>
</table>

Electrification of all industrial boilers
### Electrification of the Container Glass Industry in the U.S.

<table>
<thead>
<tr>
<th>Heating Equipment</th>
<th>Conventional System Process</th>
<th>All Electric Process</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electrical Demand (kWh/tonne)</td>
<td>Thermal Demand (kWh/tonne)</td>
</tr>
<tr>
<td>Electrically-powered mixer/crusher</td>
<td>161.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Gas-fired furnace</td>
<td>204.0</td>
<td>1150.0</td>
</tr>
<tr>
<td>Forehearth and forming equipment</td>
<td>26.0</td>
<td>105.0</td>
</tr>
<tr>
<td>Gas-fired Anealing lehr</td>
<td>25.0</td>
<td>210.0</td>
</tr>
<tr>
<td></td>
<td><strong>416.0</strong></td>
<td><strong>1465.0</strong></td>
</tr>
<tr>
<td></td>
<td><strong>1881</strong></td>
<td></td>
</tr>
</tbody>
</table>

Technical Assessment
Electrification of the Container Glass Industry in the U.S.

Change in total final energy use after electrification in U.S.

Note: This is the technical potential assuming 100% adoption rate.
Electrification of the Container Glass Industry in the U.S.

Emission factor for grid electricity in US (kgCO₂/MWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>414</td>
<td>207</td>
<td>103</td>
<td>0</td>
</tr>
</tbody>
</table>

Change in sector's net CO₂ emissions after electrification in U.S.

- 2019: 0
- 2030: -1000
- 2040: -2000
- 2050: -3000
Electrification of the **Container Glass Industry** in the U.S.

### Comparison of energy cost per tonne of product

<table>
<thead>
<tr>
<th>Year</th>
<th>Conventional Process</th>
<th>Electrified Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Energy cost per unit (2017 $/ton)

- **Natural gas cost (2017$/t product)**
  - 2019: 0.015
  - 2050: 0.020

- **Electricity cost (2017$/t product)**
  - 2019: 0.072
  - 2050: 0.073

### Average unit price of electricity for industry in U.S. (2017 US$/kWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>0.072</td>
<td>0.073</td>
</tr>
<tr>
<td>2050</td>
<td>0.073</td>
<td>0.073</td>
</tr>
</tbody>
</table>

**Average unit price of natural gas (NG) for industry in U.S. (2017 US$/kWh)**

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>0.015</td>
<td>0.020</td>
</tr>
<tr>
<td>2050</td>
<td>0.020</td>
<td>0.020</td>
</tr>
</tbody>
</table>
Industrial Conventional Boilers in the U.S.

Share of boilers energy use as a percent of total fuel consumption in the U.S. industry

Source: US DOE, 2017
Electrification of All Industrial Conventional Boilers in the U.S.

Estimated final energy use in conventional and electric steam boilers in the U.S. industrial sectors
Electrification of All Industrial Conventional Boilers in the U.S.

Change in total final energy use after electrification in U.S.

- Change in energy use (TJ/year)
  - 2019
  - 2030
  - 2040
  - 2050

- Change in energy use:
  - 2019: -250,000
  - 2030: -200,000
  - 2040: -150,000
  - 2050: -100,000

- Year:
  - 2019
  - 2030
  - 2040
  - 2050
Electrification of All Industrial Conventional Boilers in the U.S.

Change in net CO₂ emissions after electrification in U.S.
Electrification of All Industrial Conventional Boilers in the U.S.

Comparison of energy cost per tonne of steam

- Natural gas cost (2017$/t steam)
- Electricity cost (2017$/t steam)

Table: Energy cost per unit (2017$/t steam)

- 2019:
  - Conventional Process
  - Electrified Process
- 2050:
  - Conventional Process
  - Electrified Process
All Sectors’ Results for 2050

Change in sector's net CO₂ emissions after electrification in the U.S. in 2050 (kt CO₂/year)

-50,000 -45,000 -40,000 -35,000 -30,000 -25,000 -20,000 -15,000 -10,000 -5,000 0

- Aluminum casting
- Milk powder
- Beer
- Beet Sugar
- Container Glass
- Crude soybean oil
- Methanol
- Paper (from virgin pulp)
- Wet corn milling
- Recycled plastic
- Recycled paper
- Ammonia
- Steel (H2 DRI EAF)
<table>
<thead>
<tr>
<th>No.</th>
<th>Sectors</th>
<th>Change in total final energy use after electrification (TJ/Year)</th>
<th>Change in sector’s net CO\textsubscript{2} emissions after electrification in U.S. (kt CO\textsubscript{2}/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2019</td>
<td>2030</td>
</tr>
<tr>
<td>1</td>
<td>Aluminum casting</td>
<td>-2,314</td>
<td>-2,546</td>
</tr>
<tr>
<td>2</td>
<td>Paper (from virgin pulp)</td>
<td>-33,995</td>
<td>-32,295</td>
</tr>
<tr>
<td>3</td>
<td>Recycled paper</td>
<td>-75,121</td>
<td>-82,634</td>
</tr>
<tr>
<td>4</td>
<td>Container glass</td>
<td>-5,745</td>
<td>-6,320</td>
</tr>
<tr>
<td>6</td>
<td>Methanol</td>
<td>75,688</td>
<td>86,310</td>
</tr>
<tr>
<td>7</td>
<td>Recycled plastic</td>
<td>-257,955</td>
<td>-283,751</td>
</tr>
<tr>
<td>8</td>
<td>Steel (H\textsubscript{2} DRI EAF)</td>
<td>-123,599</td>
<td>-136,527</td>
</tr>
<tr>
<td>9</td>
<td>Beer</td>
<td>-20,591</td>
<td>-22,132</td>
</tr>
<tr>
<td>10</td>
<td>Beet sugar</td>
<td>-7,801</td>
<td>-8,385</td>
</tr>
<tr>
<td>11</td>
<td>Milk powder</td>
<td>-3,657</td>
<td>-4,023</td>
</tr>
<tr>
<td>12</td>
<td>Wet corn milling</td>
<td>-20,305</td>
<td>-21,825</td>
</tr>
<tr>
<td>13</td>
<td>Crude soybean oil</td>
<td>-31,732</td>
<td>-34,107</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>-529,824</td>
<td>-573,199</td>
</tr>
</tbody>
</table>
Barriers & Opportunities
Types of Barriers and Proposals to Overcome

- Technology
- Knowledge and Education
- Cost
- Financing
- Policy
- Electric Utility Connection and Reliability
Technology: Barriers

Needed Technology Not Commercially Available

- 39%: not a barrier
- 22%: a barrier, but not important
- 17%: a barrier, important
- 13%: a barrier, very important
- 9%: a barrier, the most important
Technology: Proposals

Technology RD&D

- 59%: would not help
- 23%: might be effective
- 9%: effective
- 9%: very effective
- 0%: the most effective
Knowledge and Education: Barriers

Insufficient Knowledge of Technologies Feasible for Processes

- not a barrier: 0%
- a barrier, but not important: 26%
- a barrier, important: 31%
- a barrier, very important: 26%
- a barrier, the most important: 17%
Knowledge and Education: Proposals

Research Needs: Very and Most Effective

- Case studies on specific electrification efforts: 30% most effective, 20% very effective
- Applicability and expansion of induction heating: 40% most effective, 10% very effective
- Process-level analysis and modeling: 50% most effective, 5% very effective
- Development of direct electrification process designs, equipment costs, demonstrations: 45% most effective, 3% very effective

Quantification of Benefits of Electrification: Very and Most Effective

- Air quality: 15% most effective, 10% very effective
- Health benefits: 10% most effective, 20% very effective
- Economic development: 50% most effective, 10% very effective
- Grid management: 40% most effective, 12% very effective
- Quality of industrial products: 55% most effective, 5% very effective
Cost: Barriers

High Upfront Costs

- Not a barrier: 44%
- A barrier, but not important: 26%
- A barrier, important: 26%
- A barrier, very important: 0%
- A barrier, the most important: 0%

Relative Fuel Costs Do Not Favor Electrification

- Not a barrier: 35%
- A barrier, but not important: 22%
- A barrier, important: 13%
- A barrier, very important: 0%
- A barrier, the most important: 0%
Cost: Proposals

Types of Incentives: Very and Most Effective

- **Tax incentives**: 70% (most effective), 40% (very effective)
- **Grants**: 60% (most effective), 30% (very effective)
- **Loan guarantees**: 10% (most effective), 5% (very effective)
Policy: Barriers

Policies Make Electrification Unattractive

- not a barrier: 5%
- a barrier, but not important: 18%
- a barrier, important: 32%
- a barrier, very important: 27%
- a barrier, the most important: 18%
Policy: Proposals
Action Plan
Key Actions

• Industrial sector
• Governments
• Utilities
• Suppliers of electrification technologies or equipment
Key Actions: Industrial Sector

• The industrial sector should initiate partnerships with academia, national labs, think tanks, and other stakeholders to develop or scale electrification technologies.

• Work with stakeholders to educate policymakers, utilities, and financial institutions about the benefits of electrification and what policy, regulatory, and financial support is required to electrify industrial processes.

• Provide training for employees and contractors about electrified technologies. Government and utilities should support such training programs.
Key Actions: Governments

• Provide incentives for electrification technology development and demonstration and use the capacity at the U.S. Department of Energy (DOE) national labs to advance electrification technologies for industry.

• Work with utilities to provide financial incentives in the form of tax credits or grants for pilot projects and demonstration of emerging electrification technologies in industry.

• Adopt a variety of policies and programs to support industrial electrification.

• Conduct techno-economic analysis for all electrification technologies applicable to each industrial subsector using capital cost, operation and maintenance cost, and energy cost.
Key Actions: Utilities

• **Evaluate the demand response (DR) potential** that increased electrification in the industrial sector can provide to utilities and its financial implications.

• **Provide information** about their electric rates, market structures, and grid upgrade implications of industrial electrification.

• **Adopt electricity rate designs** that encourage electrification.
Thank You.