Executive Summary

Waste Heat Recovery Opportunities in Selected US Industries
Aluminium

**Historical and Forecasted Industry Energy Intensity**

The amount of energy used for each kg of Primary Aluminium has consistently decreased over the past 30 years, and is expected to continue decreasing. It is forecast to reach 11 kWh/kg by 2020. Note that Secondary Aluminium uses less than 20% of this figure.

The consistent improvement in the energy intensity for the production of Aluminium, and particularly with regards to the Hall-Heroult cell, has made the significant impact seen above. In the 1900s, one kilo of Aluminium processed required nearly 50kWh along from start to finish (excl. transport). In 2020, it is forecasted that only 11kWh will be required. Moreover, the increased use of recycled aluminium (Secondary Aluminium) from around 500,000 tons in 1980 to 2.9 million tons in 2009, further reduces the overall energy intensity of the industry. Secondary Aluminium requires less than 20% of the energy of Primary Aluminium per unit weight. The following page shows the two different processes.
Aluminium

Total Energy Used and Wasted Heat in the Value Chain

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>N/A</td>
<td>2.67</td>
</tr>
<tr>
<td>Refining</td>
<td>37</td>
<td>4.32</td>
</tr>
<tr>
<td>Anode Production</td>
<td>438</td>
<td>5.46</td>
</tr>
<tr>
<td>Smelting</td>
<td>13</td>
<td>2.67</td>
</tr>
<tr>
<td>Primary Melting/Casting</td>
<td>27</td>
<td>16.2</td>
</tr>
<tr>
<td>Secondary Casting</td>
<td>52</td>
<td>2.67</td>
</tr>
<tr>
<td>Scrap Aluminium</td>
<td>2.67</td>
<td>4.32</td>
</tr>
<tr>
<td>Primary Melting/Casting</td>
<td>21</td>
<td>15.65</td>
</tr>
<tr>
<td>Secondary Casting</td>
<td>27</td>
<td>2.67</td>
</tr>
<tr>
<td>Rolling</td>
<td>52</td>
<td>2.67</td>
</tr>
<tr>
<td>Extrusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaping</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Energy Used (10^12 Btu per year, 2008)
Heat Wasted (10^12 Btu per year, 2008)
Aluminium

Overall Waste Heat Schematic

- **Flue Gases**
  - High Temp >500°C (920°F): 11.7
  - Medium Temp 200°C-500°C (400°F-920°F): 18.4
  - Low Temp <200°C (400°F): 0.4

- **Steam/Vapour**
  - Currently Recovered (of Total potential): 2.8

- **Other**
  - Currently Recovered (of Total potential): 5.1

N.B: Units are in BTU x10^12

Currently Recovered (of Total potential)

100%

100%

100%
The US has the world’s largest refining capacity, representing around 25% of global needs. The oil refining sector grew 2% per year until the mid 1970s when the oil crisis hit global demand, and therefore production. Following the oil crisis, the average year on year growth in refining returned to positive growth with a 1.4% per annum increase. Across the 1990s, the growth in the refining sector grew slowly in terms of oil production, but significantly increased spending on equipment, plant design and engineering services (including software mapping of plant processes). Now that oil consumption in the US is declining due to a higher oil price and more efficient cars, a strong focus on energy efficiency is emerging.

Oil Refining

Historical and Forecast Industry Energy Intensity

The amount of energy used for each kg of crude oil used has consistently decreased over the past 30 years, and is expected to continue decreasing. It should reach 1 kWh/kg in 2020. (An average of 13 million barrels refined per day was used)
**Oil Refining**

- **Total Energy Used and Waste Heat in the Value Chain**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Distillation</td>
<td>240</td>
<td>55</td>
</tr>
<tr>
<td>Vacuum Distillation</td>
<td>204</td>
<td>42</td>
</tr>
<tr>
<td>Naptha hydrotreating</td>
<td>253</td>
<td>115</td>
</tr>
<tr>
<td>Coking</td>
<td>640</td>
<td>101</td>
</tr>
<tr>
<td>Hydrocracking</td>
<td>101</td>
<td>55</td>
</tr>
<tr>
<td>Mid-distillate hydrotreating</td>
<td>140</td>
<td>42</td>
</tr>
<tr>
<td>FCC</td>
<td>190</td>
<td>77</td>
</tr>
<tr>
<td>Catalytic Reforming</td>
<td>101</td>
<td>55</td>
</tr>
</tbody>
</table>

8 processes chosen = ~68% of the total energy consumption
The energy intensity in the US steel industry has dramatically decreased since the '80s. Recent data published by the American Iron & Steel Institute reveal that energy intensity across the industry has decreased and reached 30% of previous levels in the last 20 years. The forecast is for a further, sustained fall.

Both the US Department of Energy and the American Iron & Steel Institute indicate that the energy intensity in the production of steel has declined at the fastest pace of any US industry since the 1980s. The fuel combination of the energy sources employed in the US steelmaking industry in 2008 was the following: 45% gas, 31% coke and coal, 19% electricity and 4% other sources including renewables.
Steel Manufacturing

**Total Energy Used and Waste Heat in the Value Chain**

<table>
<thead>
<tr>
<th>Process</th>
<th>Coke Oven</th>
<th>Sinter Plant</th>
<th>Blast Furnace</th>
<th>BOF</th>
<th>EAF</th>
<th>Casting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Used</strong></td>
<td>130</td>
<td>52</td>
<td>353</td>
<td>221</td>
<td>90</td>
<td>170</td>
</tr>
<tr>
<td><strong>Waste Heat</strong></td>
<td>52</td>
<td>28</td>
<td>16.5</td>
<td>5.1</td>
<td>2.1</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: Nippon Steel Corporation
Pulp & paper is the third largest industrial consumer of energy behind petroleum and chemicals. An energy reduction of 20% was achieved between 1980 and 2008 and a further reduction of 5% are expected by 2020. A variety of factors are responsible for this decrease in energy needed, the main ones include an increase in waste paper recycling, requiring significantly less energy, a declining share of the high energy intensive mechanical pulping processes and the implementation of a variety of energy saving measures, including waste heat recovery. Despite a reduction in required energy per production unit, the total amount of energy consumed in the industry has remained relatively stable over the past three decades as production output significantly increased.

From about 5.1 kWh/kg in 1980, the amount of energy used for each ton of paper has consistently decreased over the past 30 years, and is expected to continue decreasing. It should reach a forecasted 3.8 kWh/kg in 2020.
Pulp & Paper

Total Energy Used and Waste Heat in the Value Chain

The figures stating the energy input and waste heat by process are based on estimations from secondary sources such as the US Department of Energy and opinions of industry experts.
Legislation & Competitive Landscape

Legislation – Overview and Key Implications

- **American Recovery and Reinvestment Act** – to encourage economic growth, grants for ‘shovel-ready’ projects
- **Industrial Technological Program** – to improve industrial energy efficiency, includes no-cost energy assessments
- **Investment Tax Credit** – federal corporate tax credit for commercial, industrial and corporate sectors, equalling to 30% of the investment cost
- **Production Tax Credit** – a per-kW-hour tax credit for electricity generated by renewable sources and sold to a third party
- **Renewable Energy Grants** – federal grant program, equalling to 30% of the property cost
- **Renewable Portfolio Standard** – aimed at increasing renewable energy generation, requiring utilities to supply a specified amount of electricity generated by renewable sources

Key Implications:

1. **Legislation acts both as a driver and a restraint.**
   Although there is increasing support from the government to help realise the potential waste heat recovery represents, the US energy regulation requires further modifications to accommodate the required change as well as a speedier response to market conditions. Also, regarding applicable legislation or incentives, there is no common agreement on whether to regard waste heat recovery as green energy or not.

2. **The availability of funding plays an important role in realising market potential.**
   The lack of capital and available third party financing also hamper market development. In addition, the current investment hurdle rate (between 25 to 45%) needs to fall further before the market can develop further.

3. **The focus is not yet on industrial process heating recovery.**
   Due to better regulatory and financial support, as well as lower investment cost and better return, product and service providers tend to concentrate on the more rewarding waste heat recovery projects. At the moment the majority of recovered heat comes from CHP plants that recycle waste energy rather than waste heat from industrial processes turned into electricity or steam. Also, waste heat recovery is just one of the many ways of improving energy efficiency and lowering costs and simpler efficiency improvement alternatives can provide quicker results at lower costs.
Legislation & Competitive Landscape

Market Overview and Project Steps

- In the US, waste heat recovery, together with cogeneration, are commonly referred to as the two main parts of Recycled Energy and according to a DOE study, one-third of the potentially recyclable power could come from waste energy recovery, while two-thirds from CHP plants.
- Process related efficiency improvements differ from the traditional performance contracting type of solutions commonly used in public and commercial buildings for facility related efficiency gains. This is due to difficulties in acquiring funds for the project and in calculating the achievable savings potential.

- The project is usually divided into two main parts, Engineering+ Procurement and Construction.
- Answering no to the following questions usually means the use of external help is required:
  - Does the owner of the company have all the capabilities to come up with the concept and carry out the work?
  - Is the owner of the company able to get all permitting done, including environmental, water and air permits?
  - Is the owner of the company able to sell the generated electricity back to the grid?
- The various players in the market can provide either or all missing skills and capabilities.
### Legislation & Competitive Landscape

#### Types of Players and Their Roles

<table>
<thead>
<tr>
<th>Types of Players</th>
<th>Key Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial Plants</strong></td>
<td>Many industrial companies have great expertise in engineering and process related issues and would normally take care of waste heat recovery projects themselves.</td>
</tr>
</tbody>
</table>
| **EPC / Engineering Companies** | Local or national players with local presence.  
Mainly interested in the design and build phases and in 50MW+ projects.  
E.g.: Fluor Daniel, Jacobs, Turbo Steam, etc. |
| **‘Do-it-all’ types of Companies** | Cover all aspects of the project from funding, to the technical piece, to selling the power.  
Usually work on below 50M projects.  
E.g.: Recycled Energy Development, ElectraTherm, Synergy, etc. |
| **Small Start-up Companies** | Growing presence.  
Offering pioneering proprietary products, focusing on low hanging fruit, such as biomass plants. |
| **Unregulated arms of utility companies** | Initially created as a result of PURPA law  
Cater for bigger projects (50MW+). |
| **Equipment Suppliers** | Not in direct competition with service providers as they are regarded simply as subcontractors/ suppliers of the required equipment.  
E.g.: Nooter Eriksen, Babcock & Wilcox, Dresser Round, Clayton Industries, etc. |
| **Consultancies** | Providing energy assessments and feasibility studies.  
E.g.: Productive Energy, Steam Engineering, VGA EC, NE EES, Go Sustainable Energy, etc |
| **Carbon Credit Trading Companies** | Specialist providers, dealing with the purchase and sale of RECs (Renewables Energy Certificate) and carbon credits. |

### Key Messages:

1. **Complex market**
   In terms of key industry participants and their major roles, the market is regarded as very complex, with many overlaps. For ease of understanding, the industry prefers to look at it from a financial point of view, i.e. where the financing for a given project originates from.

2. **Confusion in the industry**
   Many players find it difficult to identify their competitors. As waste heat recovery equipment, in most cases, is process specific and tailored to the specific requirements of a plant or a given process, often market participants do not feel they are in direct competition with each other. This is further complicated given the fact that the market is not well established from a supplier perspective.
Frost & Sullivan is a global growth consulting company with more than 40 years experience. We specialise in these 8 industries:

- Energy & Power Systems
- Automotive & Transportation
- Chemicals, Materials & Food
- Healthcare
- Industrial Automation & Electronics
- Aerospace & Defense
- Environment & Building Technologies
- Information & Communication Technologies
"The Growth Partnership Company"

A global growth consulting company that **partners with clients** to support the development of innovative growth strategies

A local presence and global expertise: 31 offices worldwide – 2,000+ employees