Industrial Energy Use

- 29% of global energy use
- 36% of global CO₂ emissions

U.S. Industrial Energy Use Composition
- 82% Manufacturing
- 9% Mining
- 5% Construction
- 4% Agriculture

Estimated U.S. Energy Consumption in 2017: 97.7 Quads

Credit: https://flowcharts.llnl.gov/
Challenges for Low-Carbon Uses in Industry

• Industry is heterogenous
• Majority of the energy required is for heat
• Heat is less fungible than electricity
  – Temperature
  – Quantity
  – Transmission limitations

Source: Adapted from S. J. Davis et al., *Science* 360, eaas9793 (2018). DOI: 10.1126/science.aas9793
Thermal Energy is the Key Demand for Industry

- Process heat is about 51% of U.S. industrial energy demand
- Heat integration is very common within industrial facilities but cross-facility heat integration and valorization could provide new opportunities
- Low-carbon sources that meet quality requirements and are economic is a key challenge

We are starting to identify geothermal (geo), small modular nuclear (SMR), and solar industrial process heat (SIPH) opportunities.

Identifying Opportunity Locations

County-level industrial heat demand 100°C – 400°C

Demands are distributed across the U.S.

Matching Resource with Demand (SIPH Example)

Use the NREL System Advisor Model (SAM) and other analysis tools, to model systems (e.g. solar IPH) and determine potentials

Fresno, CA example

Industries such as Fruit and Veg clustered together in good thermal potential areas and with nearby available land

Central Valley provides good resource and industry proximity


Example technologies for low-carbon heating by output temperature

- Heat pumps
- Solar thermal
- Deep geothermal
- Shallow geothermal
- Biomass
- Biogas
- Biomethane
- Hydrogen
- Syngas
- Electricity

Source: Oxford Energy Institute, BloombergNEF, EHPA
## Overview of process heating and ease of decarbonization in each sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>% of process heat demand</th>
<th>Major temperature</th>
<th>Major fuel</th>
<th>Efficiency gains</th>
<th>Fuel switching</th>
<th>New tech. or process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Big prizes (but hard to achieve)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron and steel</td>
<td>28%</td>
<td>High</td>
<td>Coal</td>
<td>Hard</td>
<td>Hard</td>
<td>Medium difficulty</td>
</tr>
<tr>
<td>Includes coke ovens and blast furnaces (241/31, 191)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-metallic minerals (cement). Also includes glass, ceramics, brick (23)</td>
<td>13%</td>
<td>High</td>
<td>Coal</td>
<td>Hard</td>
<td>Medium difficulty</td>
<td>Hard</td>
</tr>
<tr>
<td><strong>Medium prizes (middle size or difficulty)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>15%</td>
<td>High</td>
<td>Coal</td>
<td>Medium difficulty</td>
<td>Medium difficulty</td>
<td>Hard</td>
</tr>
<tr>
<td>Bulk chemicals, chemical products, pharma (20-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-ferrous metals (aluminum). Also includes non-ferrous metals (242/32)</td>
<td>6%</td>
<td>High</td>
<td>Electricity</td>
<td>Medium difficulty</td>
<td>Easier</td>
<td>Hard</td>
</tr>
<tr>
<td><strong>Smallest prizes (but easiest to achieve)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food and tobacco</td>
<td>5%</td>
<td>Low</td>
<td>Gas</td>
<td>Medium difficulty</td>
<td>Easier</td>
<td>Medium difficulty</td>
</tr>
<tr>
<td>Includes beverage, excludes agriculture (10-12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>5%</td>
<td>Low</td>
<td>Renewables (biomass/waste)</td>
<td>Medium difficulty</td>
<td>Easier</td>
<td>Easier</td>
</tr>
<tr>
<td>Includes printing, excludes forestry (17, 18)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BNEF
Thank you!

mark.ruth@nrel.gov

NREL/PR-6A50-73694