Steel Decarbonization in Context

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November 2018
On average, every one of us has 220 kg of steel produced per year on our behalf.

We use it for everything, but mostly big things.

Steel has the highest emissions of any industrial sector.

Total: 8.3 GtCO$_2$ (2014)
Direct Emissions Only

Total: 14.1 GtCO$_2$ (2014)
Including Power Emissions

Process emissions are about half of steel emissions.

\[
\text{Fe}_3\text{O}_4 + 2 \text{ C} + \text{heat} \rightarrow 3 \text{ Fe} + 2 \text{ CO}_2
\]

Steel has a few production pathways, and they all have the same steps.

Extraction and Preparation

Mining and ore processing

Scrap collection, sorting, shredding

Reduction

Blast Furnace

Direct Reduction

Conversion and Alloying

Basic Oxygen Furnace

Electric Arc Furnace

Casting, Rolling, and Forming
Emissions reductions come in three basic categories.

\[
GHG = S \times \frac{P}{S} \times \frac{M}{P} \times \frac{GHG}{M}
\]

- **Product-Service Intensity**
  - Precision application
  - Increased product lifetimes
  - Reuse
  - Increased utilization

- **Materials Intensity**
  - Substituting low-C materials
  - Light-weighting
  - Process waste reduction
  - Recycling

- **Emissions Intensity**
  - CCS
  - Fuel switching
  - Bio-energy
  - Energy efficiency
  - Innovative processes
Opportunities abound to increase product lifetimes.

<table>
<thead>
<tr>
<th>Durable Goods</th>
<th>Typical Lifetime in China</th>
<th>Typical Lifetime in US/OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>6-7 years</td>
<td>12 years</td>
</tr>
<tr>
<td>Taxis</td>
<td>600,000 km</td>
<td>750,000+ km</td>
</tr>
<tr>
<td>Residential Buildings</td>
<td>33 years</td>
<td>75-80 years</td>
</tr>
<tr>
<td>Civil Engineering Works</td>
<td>30 years</td>
<td>60 years</td>
</tr>
</tbody>
</table>

Buildings can be reused, as well as their components.

Sources: skyscrapercentre.com, 300 Randolph St., and Allwood and Cullen (2015).
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Modern timber products can substitute for steel in many contexts.

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Economic conditions make the steel sector particularly resistant to change.

Headwinds include:

- Large-scale production
- Geographic concentration
- Trade exposure
- Long-lived capital
- Over-capacity
- Weak balance sheets

Appendix
Themes of Technical Pathways

(1) **Technology Readiness**: Key technologies for industrial decarbonization are at a wide range of states of technology readiness.

(2) **Importance of Demand-Side Options**: In the context of a rising population and rising incomes, it will not be possible to meet the Paris goals without reducing demand for new commodity materials.

(3) **Timing**: Which options are available changes over time. This leaves industry with almost no extra time.

(4) **Insufficiency of Energy Efficiency**: Most industrial decarbonization work so far has focused on energy efficiency, but high-emitting industries are generally already quite efficient.

(5) **Limits to Electrification**: Fuel switching to electricity is an important but limited tool for industrial decarbonization.

(6) **Interaction with Other Sectors**: Industrial facilities and supply chains are densely embedded in larger systems, but not enough analysis has been done on understanding the interactions of these systems and how they might create barriers and opportunities for decarbonization.
Deep decarbonization will require innovative technologies.

While energy efficiency and fuel switching dominate carbon mitigation impact in the near term, low-carbon innovative processes become crucial in the long term to meet the B2DS.

Commodity materials are a small part of the price of finished goods.

(a) Current Cost tCO2 New Cost % increase
<table>
<thead>
<tr>
<th>Material</th>
<th>($ per ton)</th>
<th>(per ton)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>$ 600</td>
<td>3</td>
<td>$ 900</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Cement</td>
<td>$ 100</td>
<td>1</td>
<td>$ 200</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Ethylene</td>
<td>$ 1,000</td>
<td>2</td>
<td>$ 1,100</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

(b) Material Current Cost Amount New Cost % increase
<table>
<thead>
<tr>
<th>Product</th>
<th>Current Cost</th>
<th>Amount</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Car (steel)</td>
<td>$ 30,000</td>
<td>1 ton</td>
<td>$ 30,300</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Bridge (cement)</td>
<td>$ 6.5 billion</td>
<td>100,000 ton</td>
<td>$ 6.51 billion</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Soft drink (plastic)</td>
<td>$ 2</td>
<td>10 gram</td>
<td>$ 2.005</td>
<td>1%</td>
<td></td>
</tr>
</tbody>
</table>
A broad industrial decarbonization strategy should have several characteristics.

**Focus on the emissions**: Work on basic commodity processing, and on steel, cement, and chemicals in particular.

**Match approaches to timescales**: Pursue in parallel both near-term performance improvements and long-term system changes with investments calibrated by timescale.

**Reinforce efforts from multiple policy directions**: No one policy will address the multiple barriers to industry decarbonization, so we need to consider carbon pricing, procurement, trade, tax, R\&D, and other types of policies simultaneously.

**Activate key stakeholders**: Identify partners in commodity processing firms and also their most powerful customers. Build a network of experts and advocates.

**Create a public narrative**: Communicate the connections between climate change and material use to both the general public and decision-makers.
Industrial emissions are large and rapidly growing.

We have good, affordable options for reducing them.

Philanthropy can catalyze industrial decarbonization.
Energy performance in the cement industry has converged over time.

Process emissions can be more than half of overall emissions.

**Steel**: $\text{Fe}_3\text{O}_4 + 2\text{C} + \text{heat} \rightarrow 3\text{Fe} + 2\text{CO}_2$

**Cement**: $\text{CaCO}_3 + \text{heat} \rightarrow \text{CaO} + \text{CO}_2$