How to electrify the industrial sector?

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Industrial sector amounts to 23% of global CO₂ emissions... and it’s hard to decarbonize.
Process energy breakdown by sector

Potential Reduction in Energy Use in Four U.S. Manufacturing Sub-Sectors

Current Consumption | State of the Art | R&D Opportunity
--- | --- | ---
Chlorine | 3,222 | 3,176 | 2,110
Petroleum | 2,456 | 2,756 | 1,645
Pulp and Paper | 1,235 | 1,963 | 1,498
Iron and Steel | 1,193 | 1,609 | 759

Note: Current energy consumption refers to the typical energy consumption of each manufacturing subsector as of 2010. State of the Art refers to energy consumption that could be achieved if the most energy-efficient technologies and practices existing today were widely adopted. R&D Opportunity refers to energy consumption that could be achieved if energy-saving technologies and practices currently under development are successfully deployed.

Use fossil fuels with CCS or renewable electricity?

“At zero-carbon electricity prices below ~$50/MWh, using zero-carbon electricity for heat or using hydrogen based on zero-carbon electricity becomes more economical than CCS”
Power-2-Heat
- Localized fast heating via ohmic heat, $H_2$ combustion

Power-2-Specialties
- Echem synthesis with high selectivity/efficiency, low waste, P and T
- Thermal catalytic processes

Power-2-Commodities
- Thermal/catalytic reduction
- Zero carbon fuels, chemicals and metals

Power-2-Hydrogen
- FCEV fueling, long term energy storage, feedstock
- SMR, coal gasification
Example: Power-2-Hydrogen

Hydrogen produced through electrolysis or thermal splitting of water to be used for transportation, fuels, steel and chemicals manufacturing, and heating.
Use of renewable electricity in industrial sector - benefits

- Increased industrial energy efficiency
  - 40-60% less energy losses
- Reduced fossil fuels consumption
  - less CO$_2$ emissions
- Effective use of renewable energy intermittent oversupply
- Reduced associated emissions due to cleaner processes
- Enable long-term energy storage
Current and possible ARPA-E programs

- **Power-2-Commodities**
  - *Conversion of renewable electricity to fuels (REFUEL)*
  - Steel production using hydrogen and other fuels
- **Power-2-Hydrogen**
  - *Use of AEMs for hydrogen production and in fuel cells (IONICS)*
- **Power-2-Heat**
  - Develop technology for cement production
  - Develop thermal storage for building heating
- **Power-2-Specialties**
  - Develop new electrochemical manufacturing processes
“After breakthroughs in the power, transport, and buildings sectors, industrial decarbonization is the next frontier”

D. Pinner, McKinsey report 2018

Any suggestions?

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