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Scrap Supply Chains and Residual Impacts: Benchmarking Price Implications Today and Into the Future

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NREL at-a-Glance

2,926

Workforce, including

219 postdoctoral researchers

60 graduate students

81 undergraduate students

World-class

facilities, renowned technology experts

More than **900**

Partnerships

with industry, academia, and government

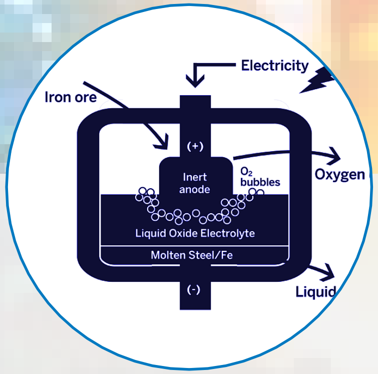
Campus

operates as a living laboratory

Iron & Steel Decarb R&D Frontiers

H2 Reduction

Using H2 instead of fossil fuels to reduce iron oxide (ore) to metallic iron for steelmaking

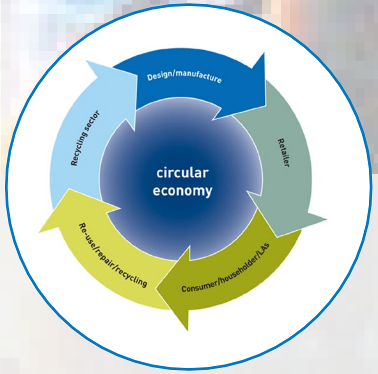


Electrolytic Reduction

Developing efficient, cost-effective electrolytic reduction processes and inert anodes

Bio-Based Feedstocks

Biochar for iron ore reduction, thermal input, and EAF injection



Circularity

Increasing impurity tolerances, material efficiency, operational/process circularity

Grid Integration

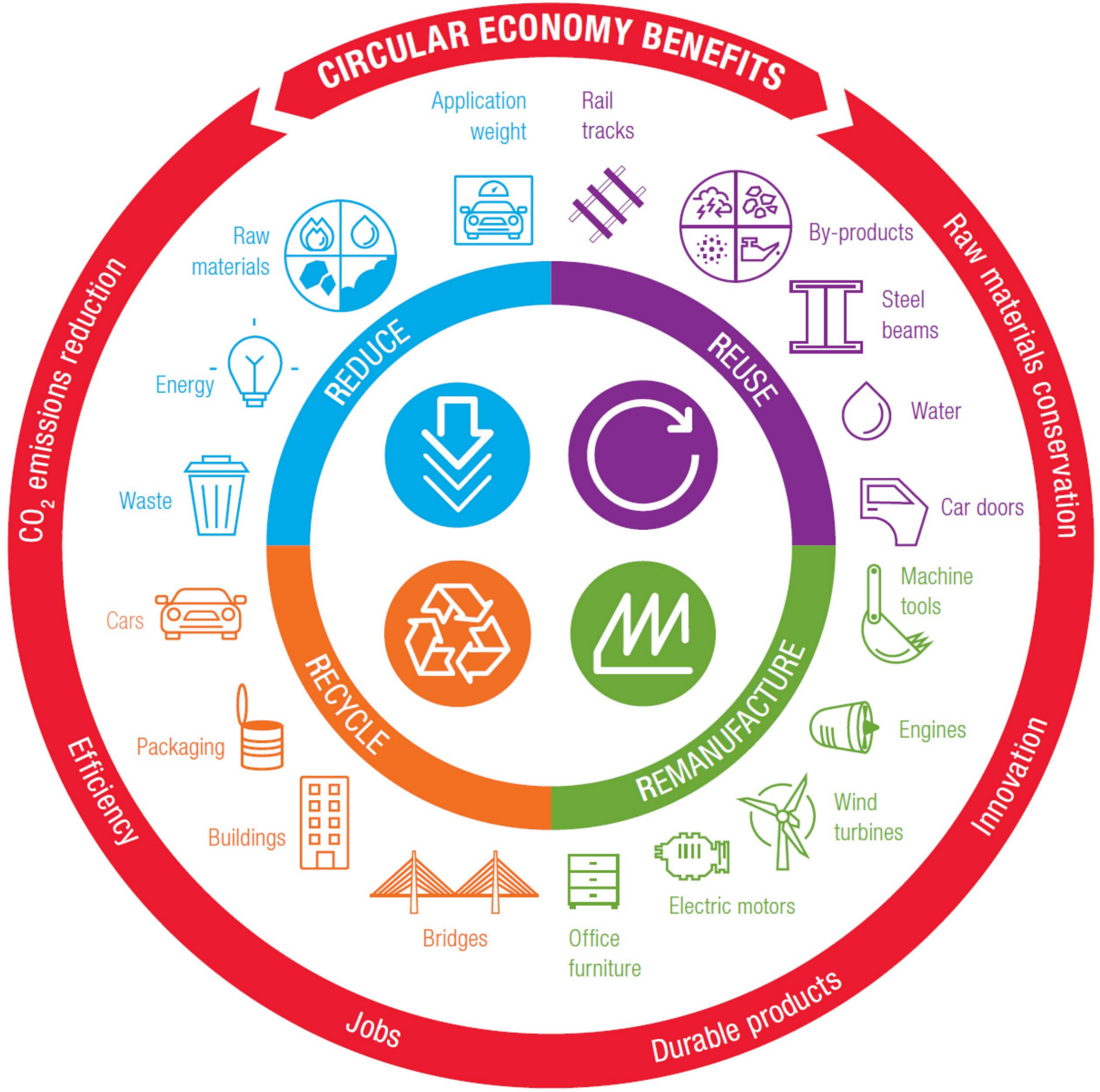
Integrating H2 electrolysis and EAF steelmaking into a dynamic grid, flexibilizing operations

Reduce
material and energy efficiency

Reuse
repurposing products

Remanufacture
restoring durable products

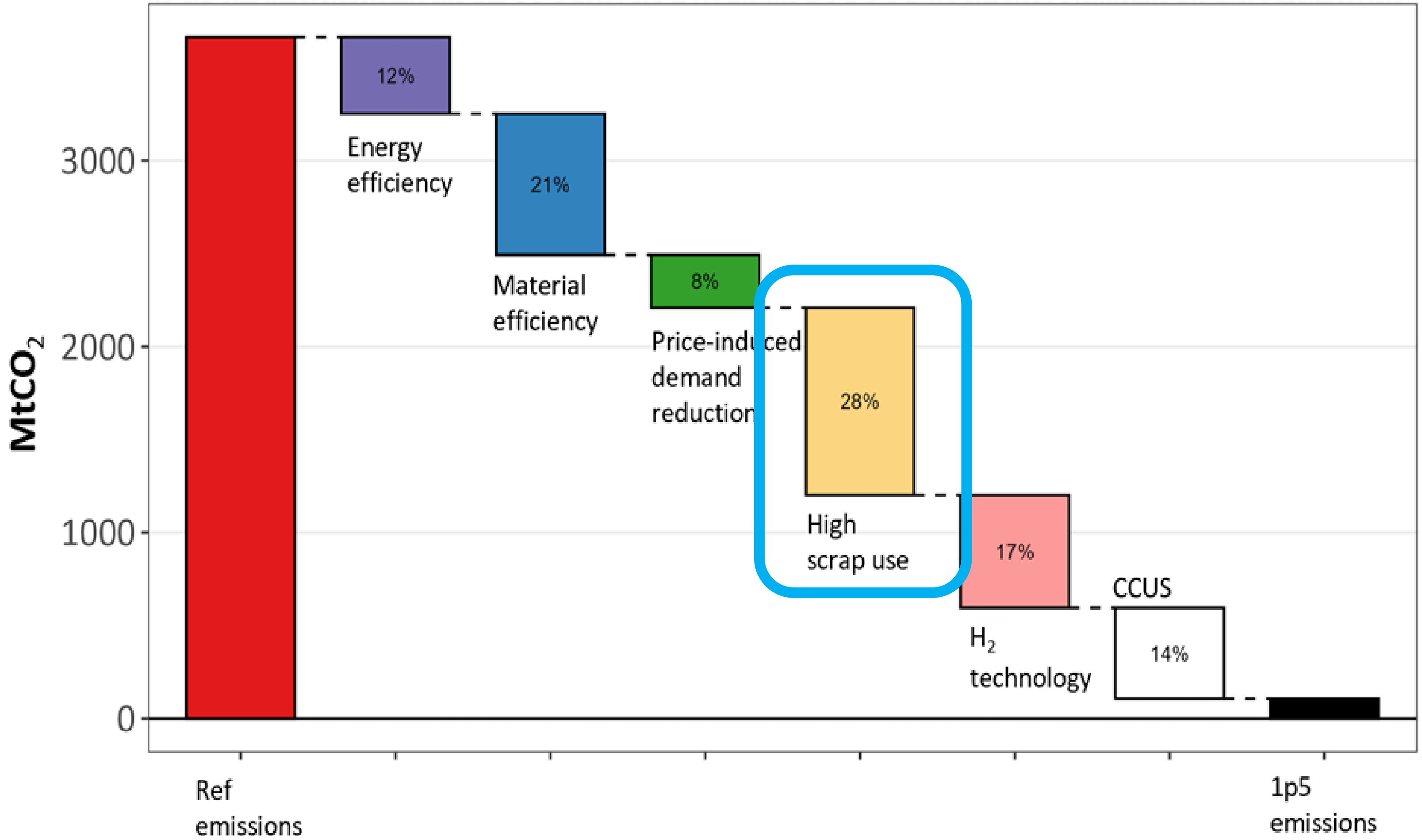
Recycle
Scrap melting



Maximizing Scrap Recycling by Designing Cu Tolerant Steel Compositions

- **Overview:** This project will identify an economically viable process window for increasing steel product copper (Cu) tolerances to enable (1) blending high-Cu scraps that have a sustainable domestic supply chain and (2) manufacturing of a wide range of fully-recycled EAF steels.
- **Implementation Budget and Timeframe:** 3-year, $2.8 million award from DOE Advanced Manufacturing Office
- **Objectives:** Increase Cu tolerance to >0.15 wt.%, enabling 100% scrap heats – this could realize 80% energy savings for very soft steels. For other grades (tube, plate, bar, rod) the target will be to increase Cu tolerance by 0.1 wt.% over the currently employed limits (some of which are up to 0.25 wt.%)
- **Impacts:** Project target is to increase Cu tolerance to >0.15 wt. %, enabling 100% scrap heats – this could realize 10-50% energy savings depending on product line.
- **Key partners:** Steel companies, academic institutions

Mitigation for 1.5°C Steel by 2050

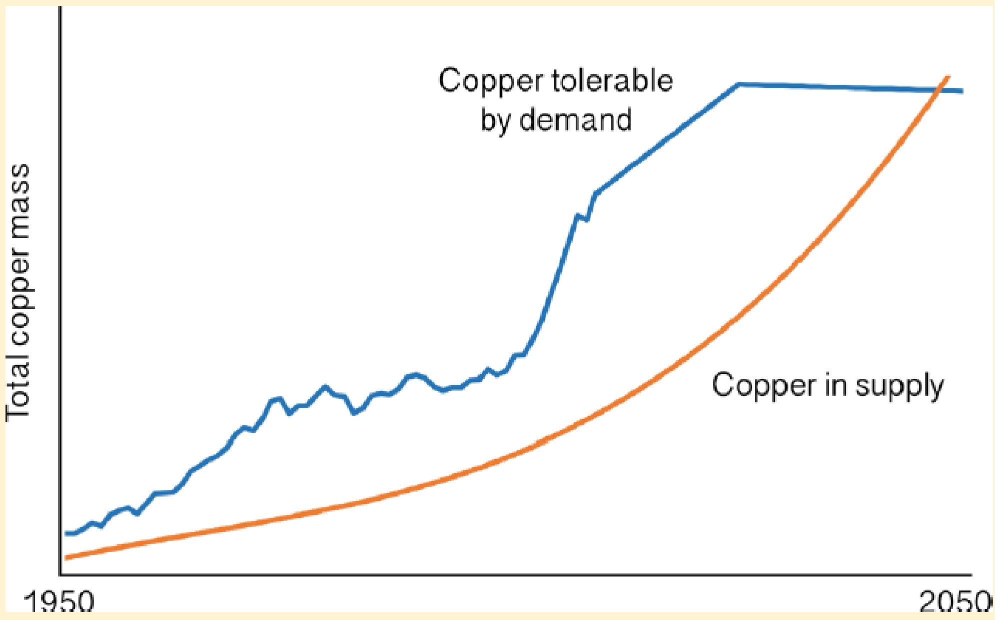


Source: Yu et al. 2021

Scrap can eliminate up to 90% of the total energy consumed in integrated steelmaking by reducing the quantity of virgin iron required

The Copper Challenge

- High-value steels require purity grades that limits usability of scrap stocks
- Copper quantities in the scrap supply chain is increasing



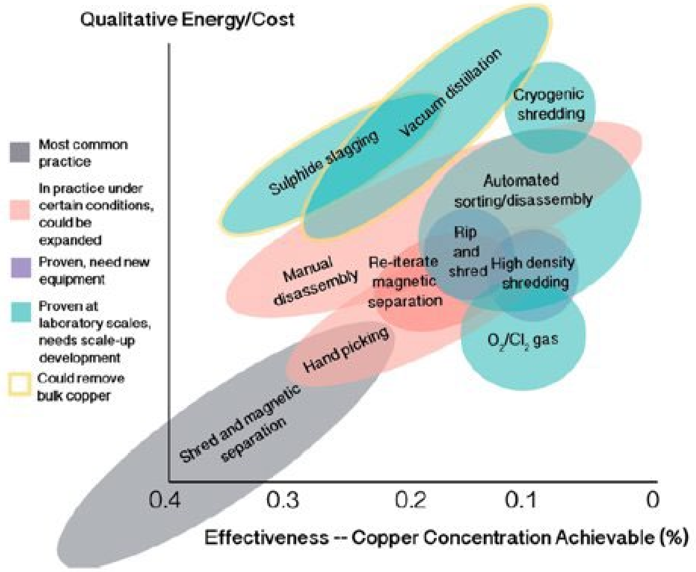
Source: Daehn et al. 2017

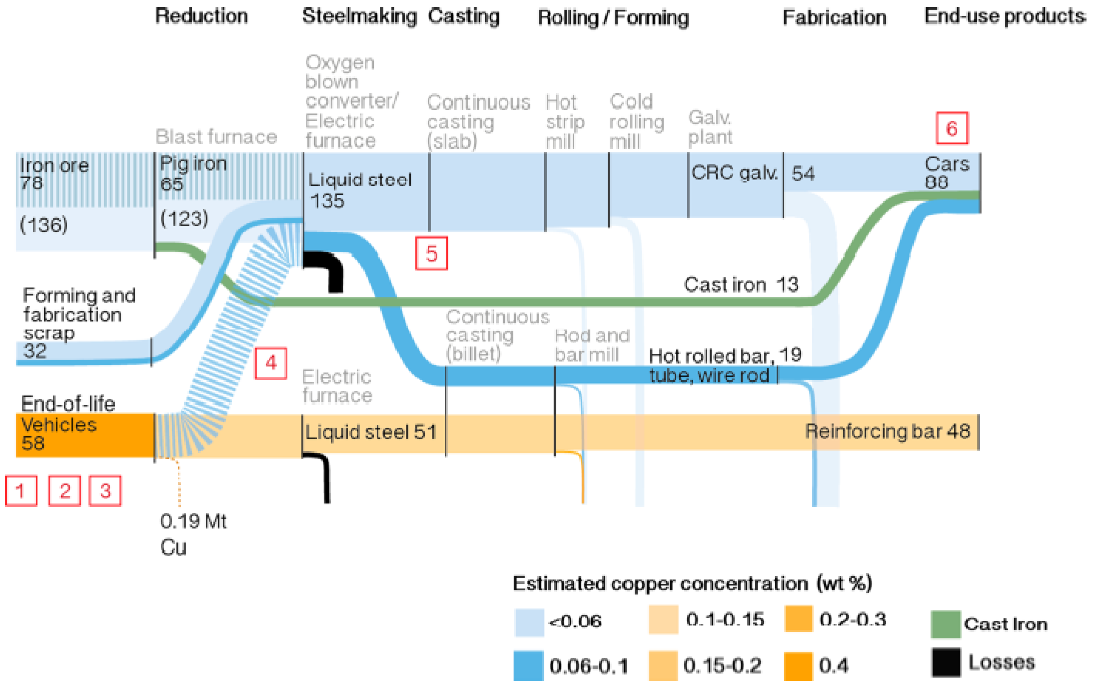
Cu content in weight percent (wt. %)						
Representative Steel Products	Cu content limit for steel products	Scrap Cu content	Pig Iron Cu content	% Scrap	% Pig Iron	Energy use for pig iron manufacture required for dilution, GJ[d] (100 ton heat)
Interstitial Free (IF)[a]	0.03	0.23[c]	0.01[c]	12.5	87.5	1225.0
Commercial[b]	0.10			41.7	58.3	816.2
Scrap	0.23			100	0.00	0.00
Rebar, Other	>0.23			100	0.00	0.00

[a]Automotive bodies, [b]Bar, Plate, Rod, [c]see Table 2, [d]14 GJ per ton

Electric Vehicles in the Steel Supply Chain

- Electric and hybrid vehicles contain up to twice the copper content of an average vehicle
- Average lifetime of a light-duty vehicle in the U.S. is 11.8 yrs
- Only about 7 – 8% of recovered car steel is returned to new automotives
- Current best-in-class copper separation routes are costly





Source: Daehn et al. 2017

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New Light-Duty Electric Vehicle U.S. Sales Projections

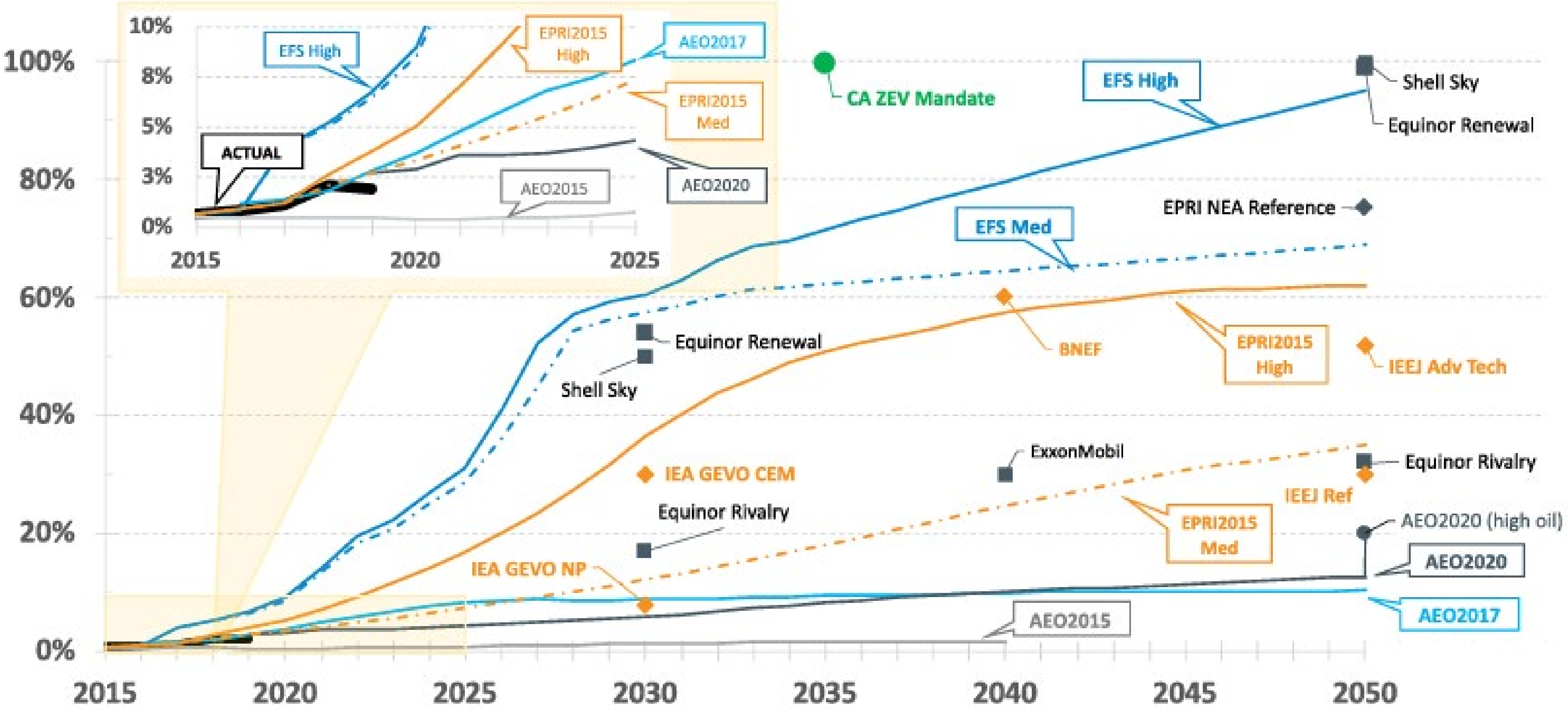
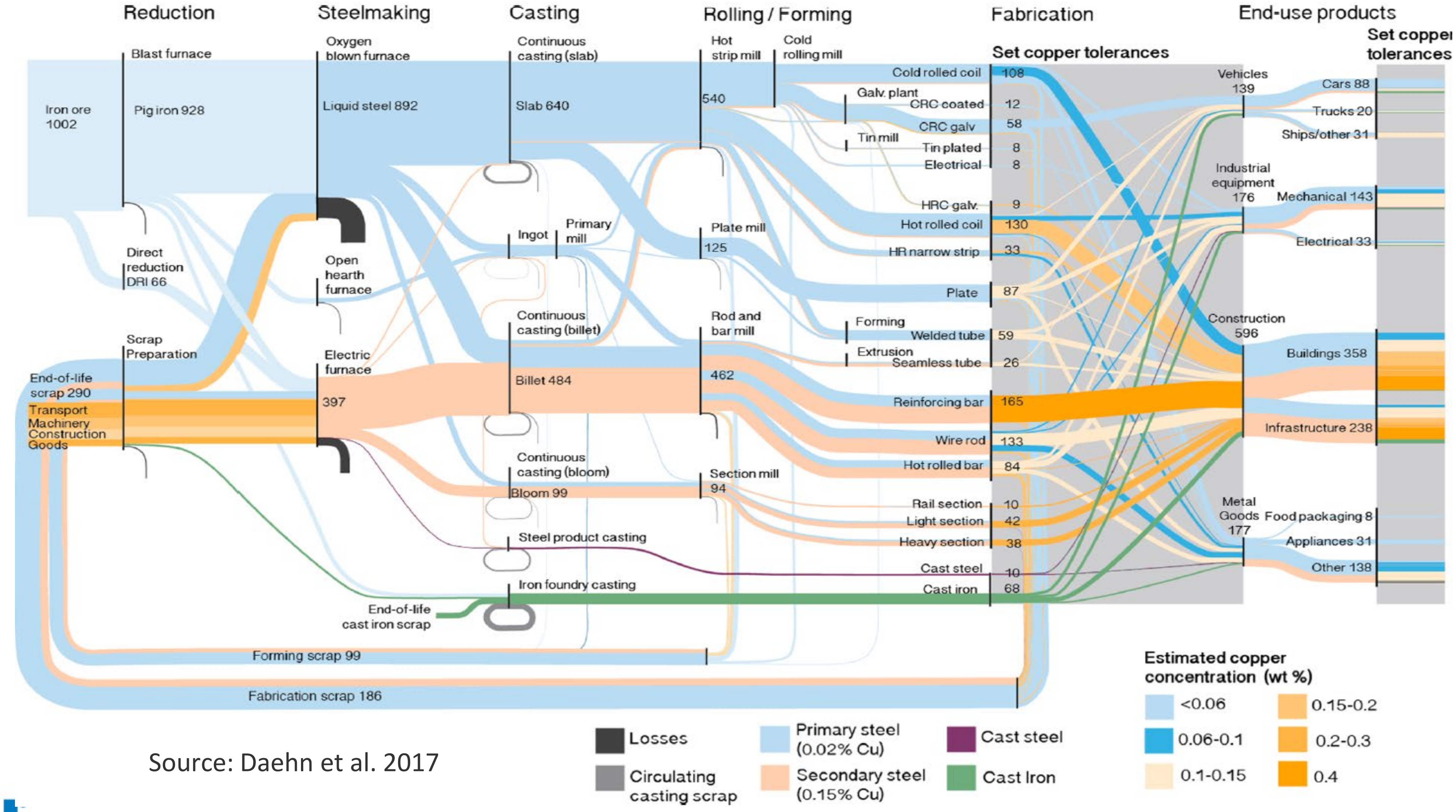


Figure 1. Electric LDV (BEV and PHEV) new sales projections from numerous international sources. Unless otherwise noted, data refer to new U.S. sales. AEO2015 = EIA Annual Energy Outlook 2015, Reference Scenario. AEO2017 = EIA Annual Energy Outlook 2017, Reference Scenario. AEO2020 = EIA Annual Energy Outlook 2020, Reference Scenario. AEO2020HO = EIA Annual Energy Outlook 2020, High Oil Scenario. EFS Med = National Renewable Energy Laboratory (NREL) Electrification Futures Study, Medium Scenario. EFS High = NREL Electrification Futures Study, High Scenario. EPRI Med = EPRI Plug-in Electric Vehicle Projections: Scenarios and Impacts, Medium Scenario. EPRI High = EPRI Plug-in Electric Vehicle Projections: Scenarios and Impacts, High Scenario. EPRI NEA = EPRI National Electrification Assessment, Reference Scenario. GEVO NP = IEA Global EV Outlook 2019, New Policies Scenario. GEVO CEM = IEA Global EV Outlook 2019, Clean Energy Ministerial 30@30 Campaign Scenario. BNEF = BloombergNEF EV Outlook 2020. Equinor Riv = Equinor 2019 Energy Perspectives, Rivalry Scenario. Equinor Ren = Equinor 2019 Energy Perspectives, Renewal Scenario. Shell Sky = Shell Sky Scenario. ExxonMobil = 2019 ExxonMobil Outlook for Energy. IEEJ Ref = The Institute of Energy Economics, Japan. 2019 Outlook, Reference Scenario (global sales). IEEJ Adv = The Institute of Energy Economics, Japan. 2019 Outlook, Advanced Technologies Scenario (global sales). CA ZEV Mandate = California zero-emission vehicle (ZEV) Executive Order N-79-20 (September 2020).

Source: Muratori et al. 2021

Copper in the Steel Supply Chain



Source: Daehn et al. 2017

Heuristics for Copper Content to Scrap Price Ratio

- "An increase of 1 point of Cu (0.01wt%) saves approximately $1.00/ton at low Cu levels."
  — Yalamanchili et al. 1999

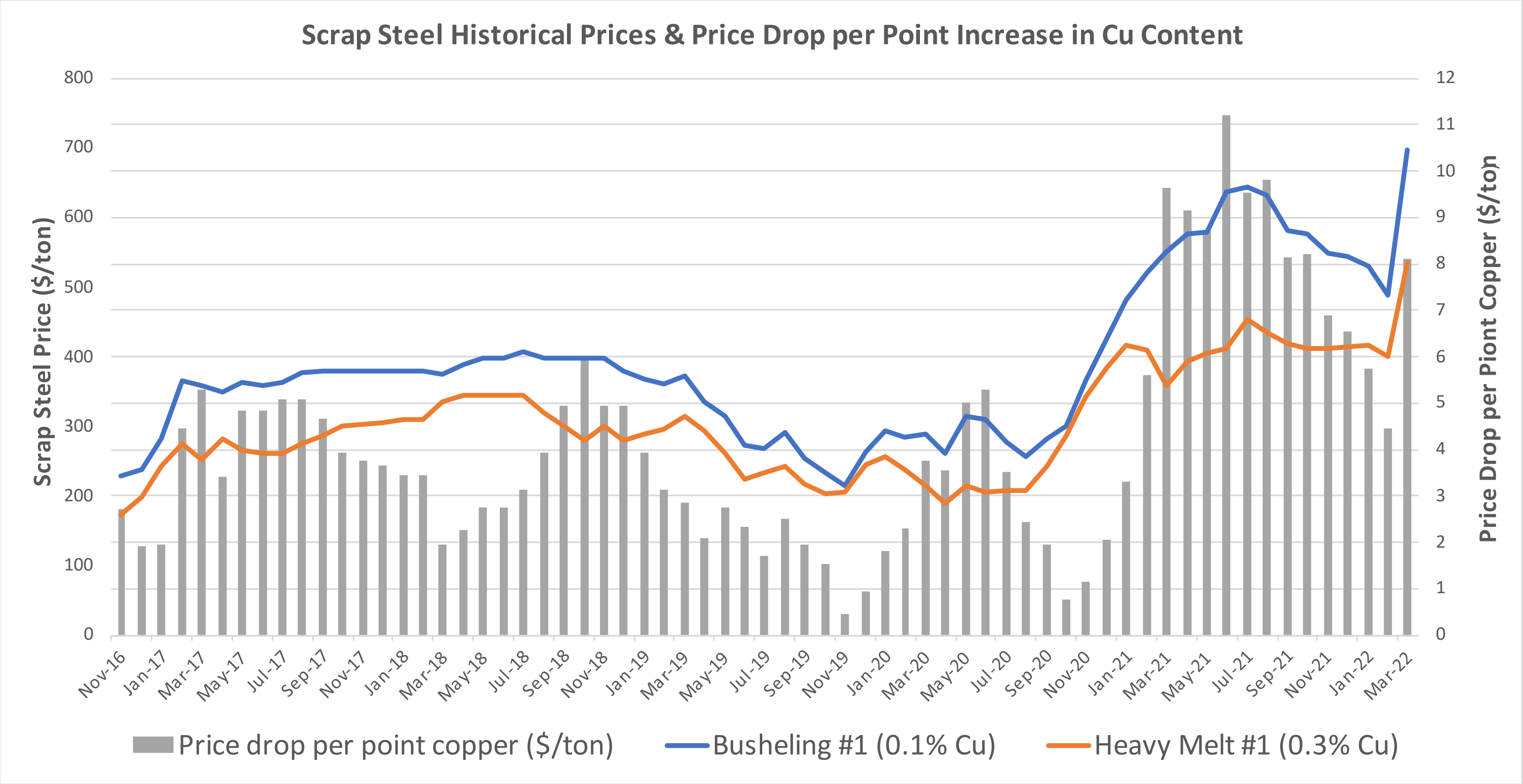
- "Pre-pandemic, we were using a ratio of 5 points copper to $15 decrease per ton (3x)"
  — Anonymous

Copper Content to Scrap Price Ratio

An increase of one point of Cu (0.01 wt%) would save between $2.18/ton and $8.06/ton on average based on scrap steel prices between 2016 and 2021.

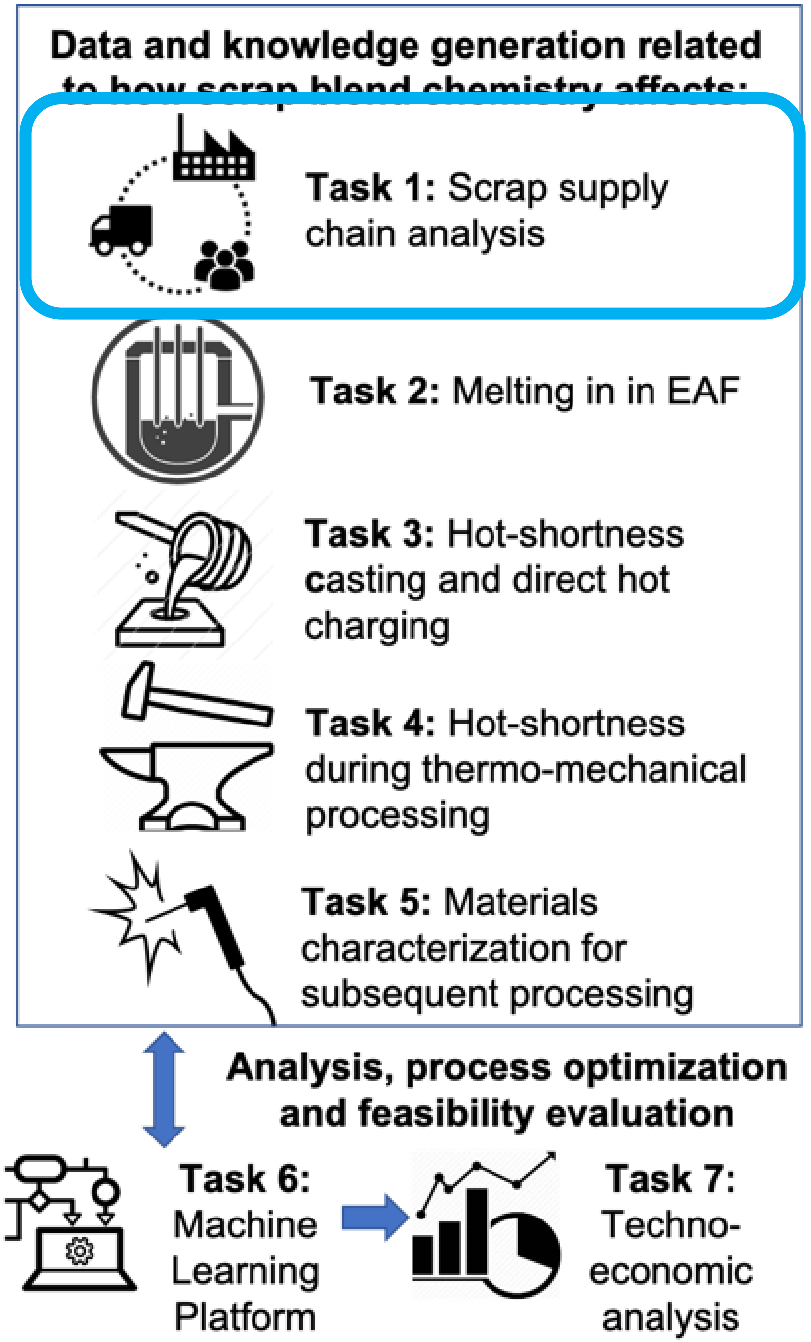
Year	Average Price Drop per Point Copper ($/ton)
2017	4.25
2018	3.70
2019	2.18
2020	2.80
2021	8.06
2022**	6.01

** Includes estimated values between January and March 2022.



Database Development

- Identify and map the scrap chemistries from the US supply chain
- Understand the future of US scrap supply chain and steel manufacturing competitiveness
- Estimate scrap that will be generated in the US and demand of steel by key end-use steel products. Evaluate how much of the proposed steel can be absorbed by the US market and how much will need to be exported



Acknowledgements

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  - National Renewable Energy Lab

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