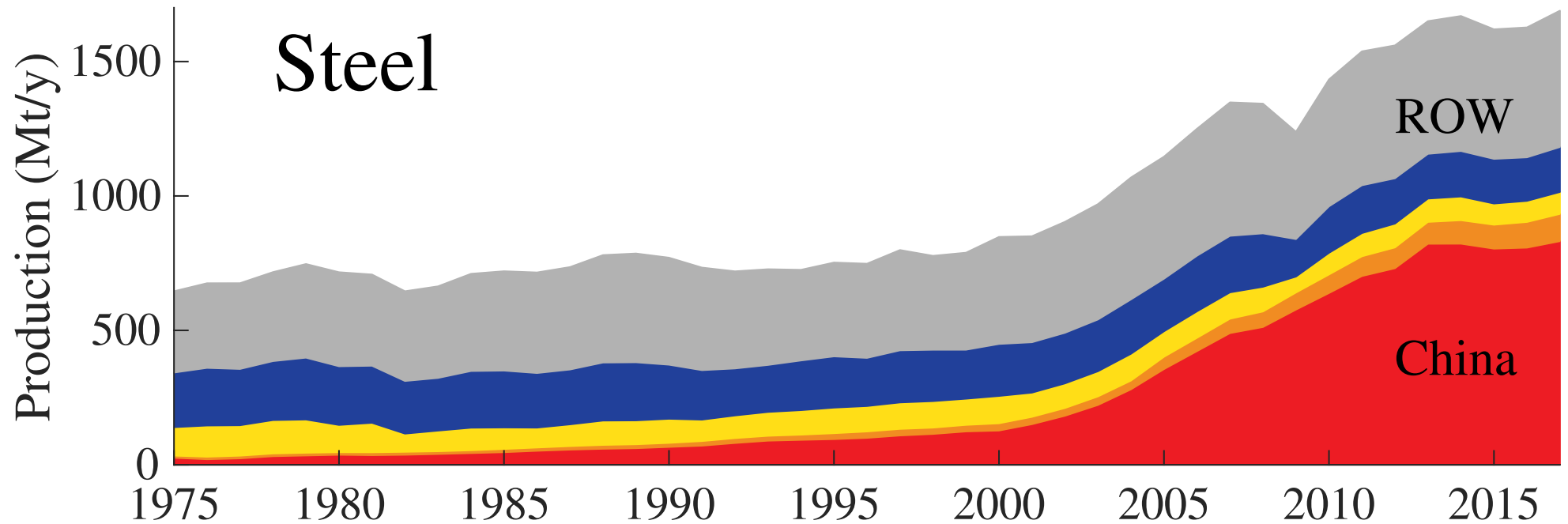


A photograph of a steel mill interior. In the foreground, a large, bright orange and yellow flame or molten metal stream is visible on the left. To the right, there are industrial structures with yellow safety railings and stairs. In the background, more industrial equipment and a large, dark, cylindrical structure are visible. The overall scene is industrial and high-temperature.

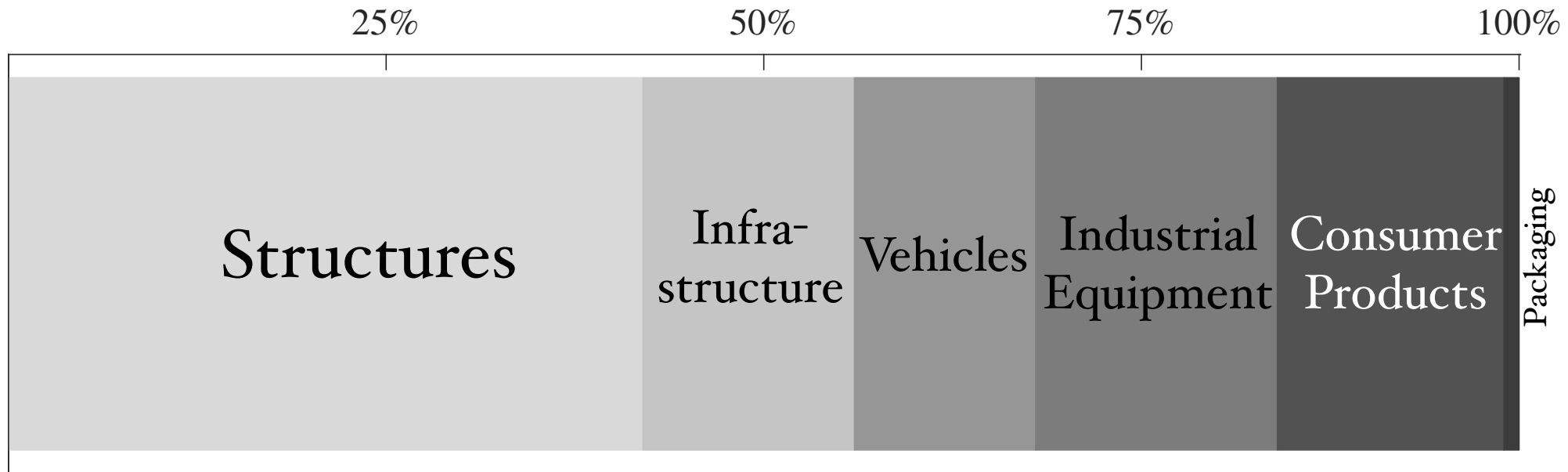
Steel Decarbonization in Context

Rebecca Walsh Dell
AGCI
November 2018

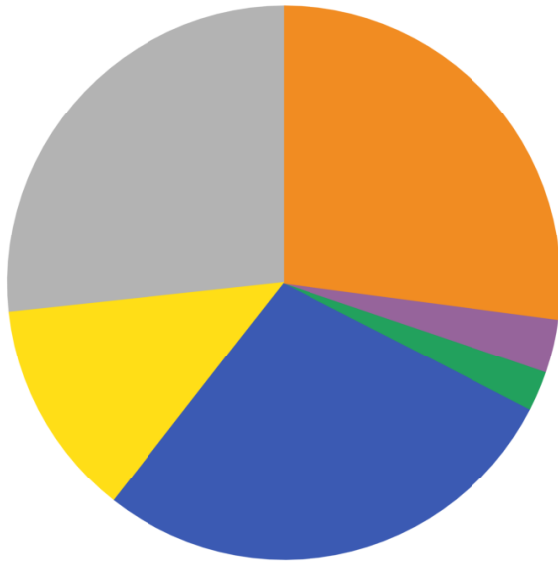
On average, every one of us has 220 kg of steel produced per year on our behalf.



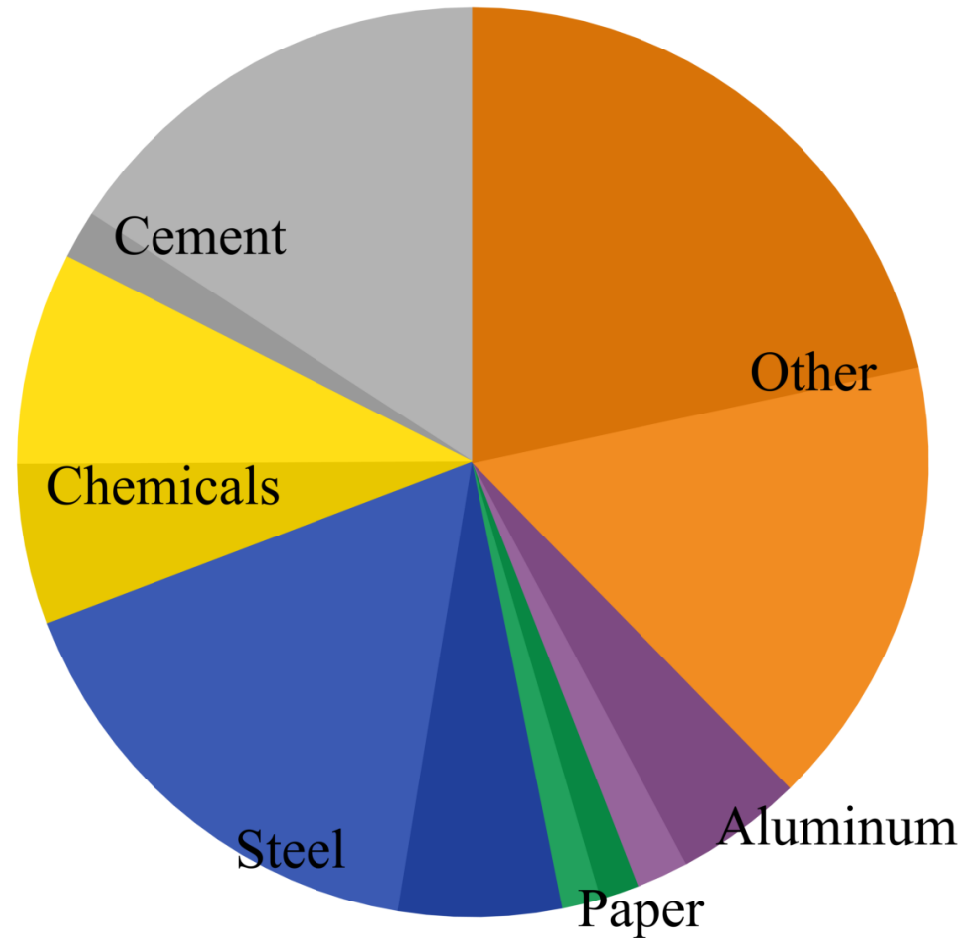
We use it for everything,
but mostly big things.



Steel has the highest emissions of any industrial sector.

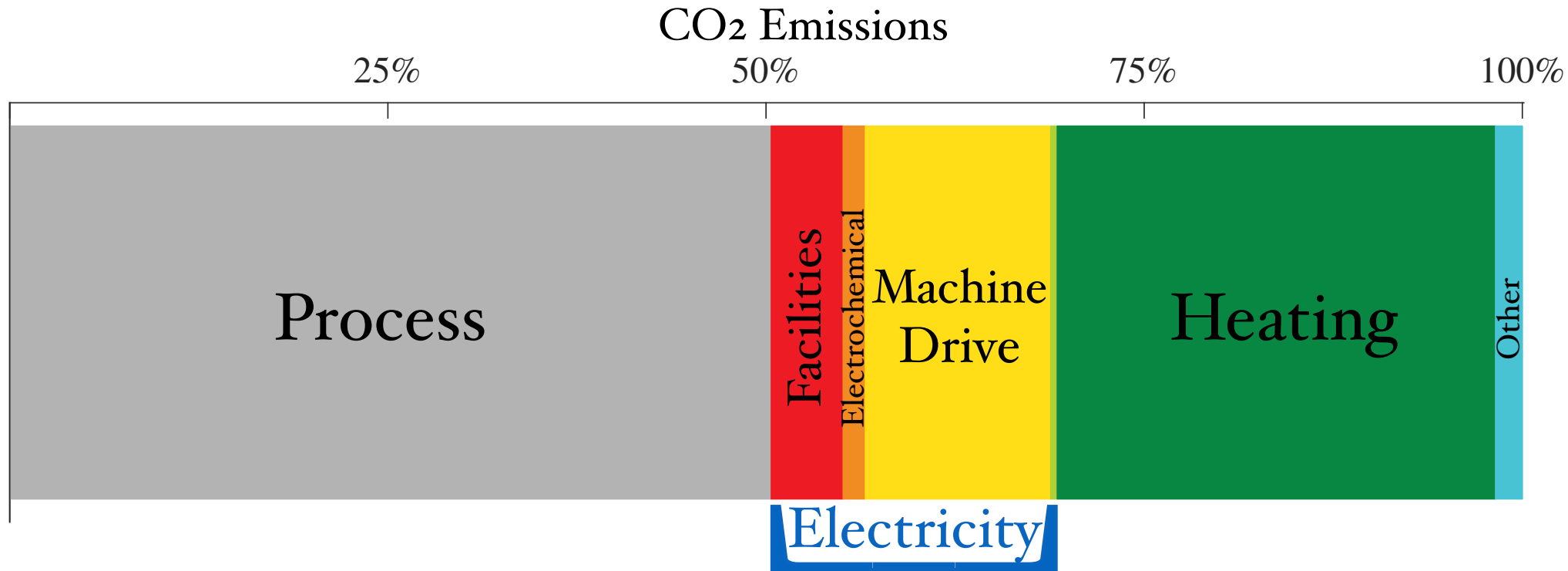


Total: 8.3 GtCO₂ (2014)
Direct Emissions Only



Total: 14.1 GtCO₂ (2014)
Including Power Emissions

Process emissions are about half of steel emissions.



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

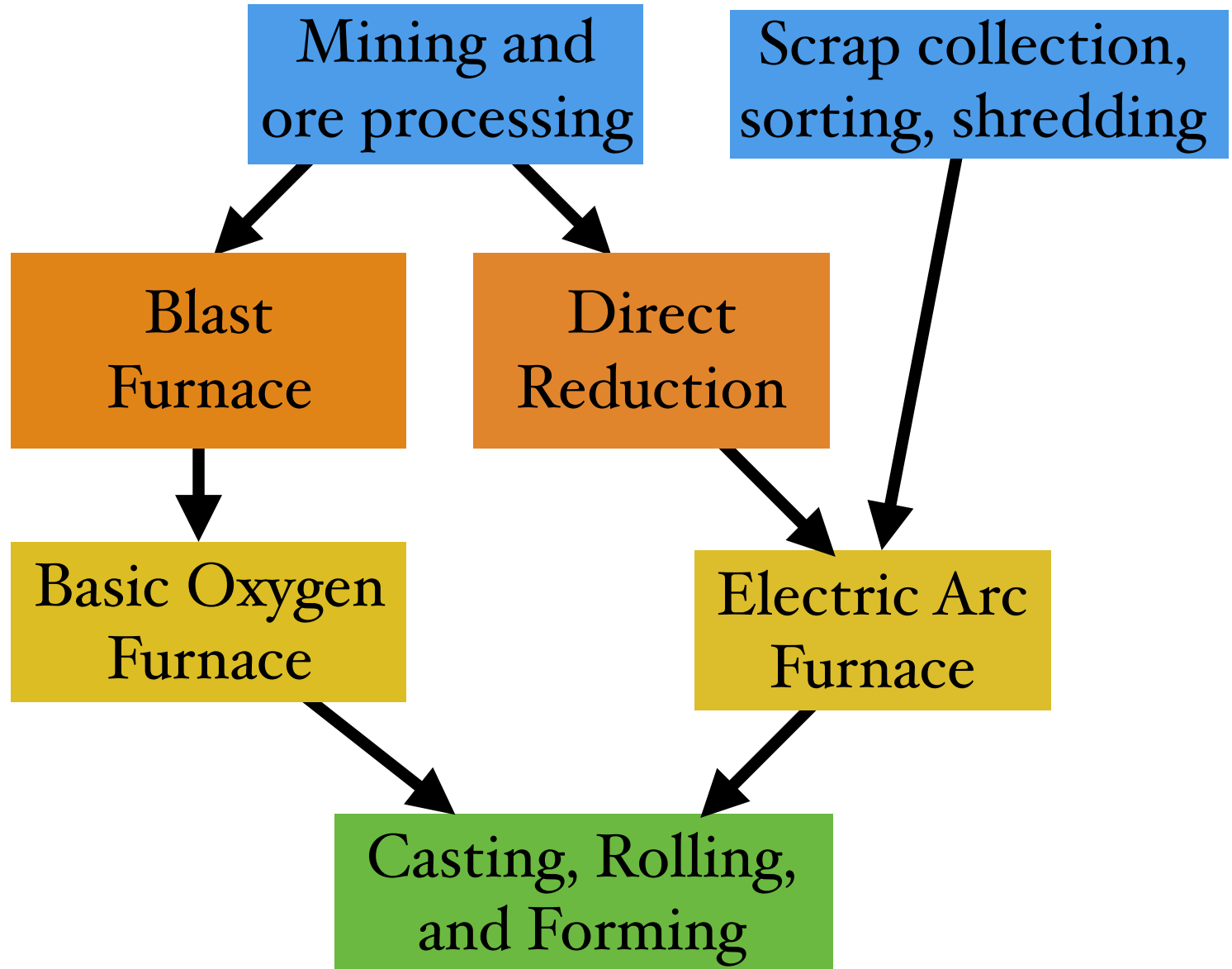
Direct
Reduction

Conversion
and Alloying

Basic Oxygen
Furnace

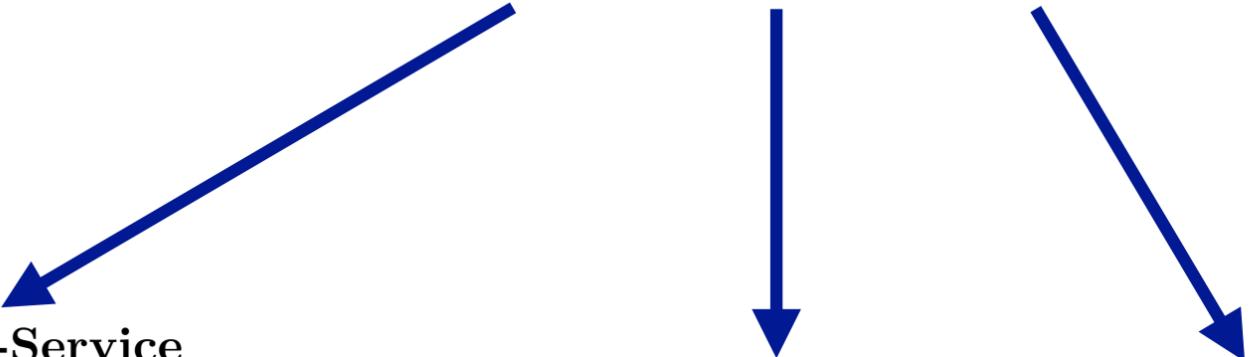
Electric Arc
Furnace

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.

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

Sources: BTS (2017, Tables 1-26 and 1-29), Gong (2018), Xi et al. (2016), Cao et al. (2017).

Buildings can be reused,
as well as their components.



Sources: skyscrapercentre.com, 300 Randolph St., and Allwood and Cullen (2015).

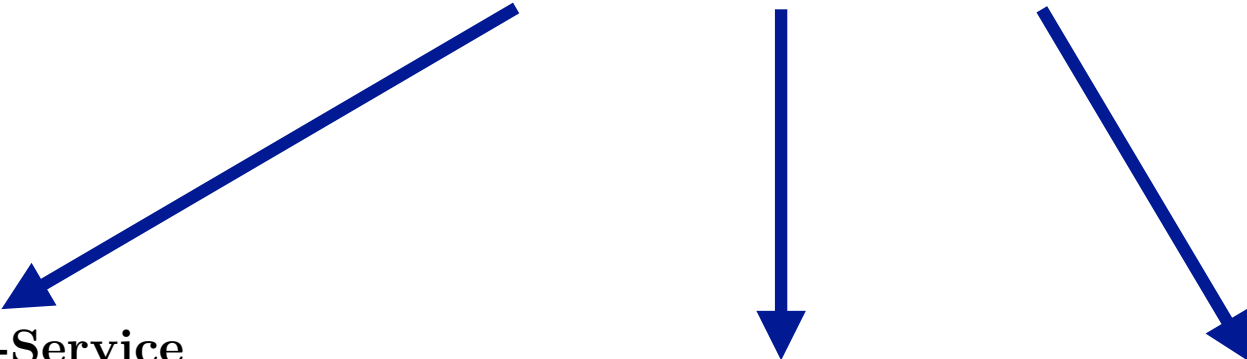
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Product-Service

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Emissions Intensity

- CCS
- Fuel switching
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- Energy efficiency
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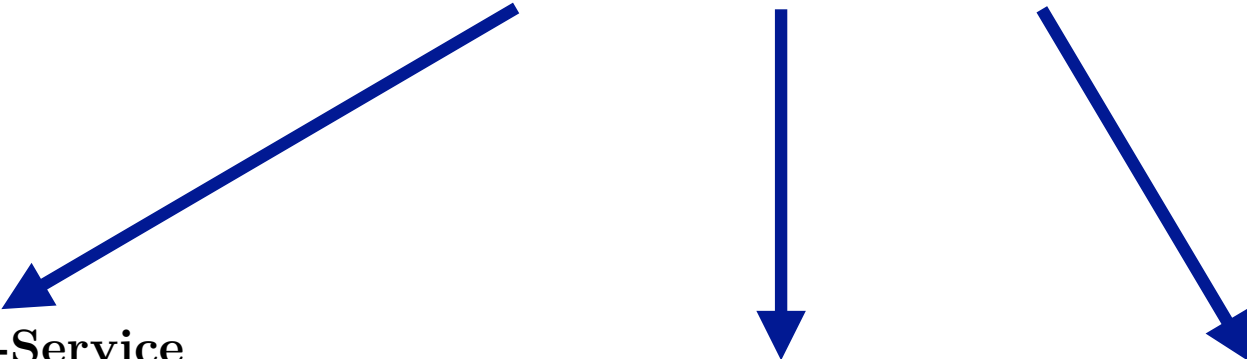
Modern timber products can substitute for steel in many contexts.



Source: Wood Innovation and Design Centre of Canada (2014).

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

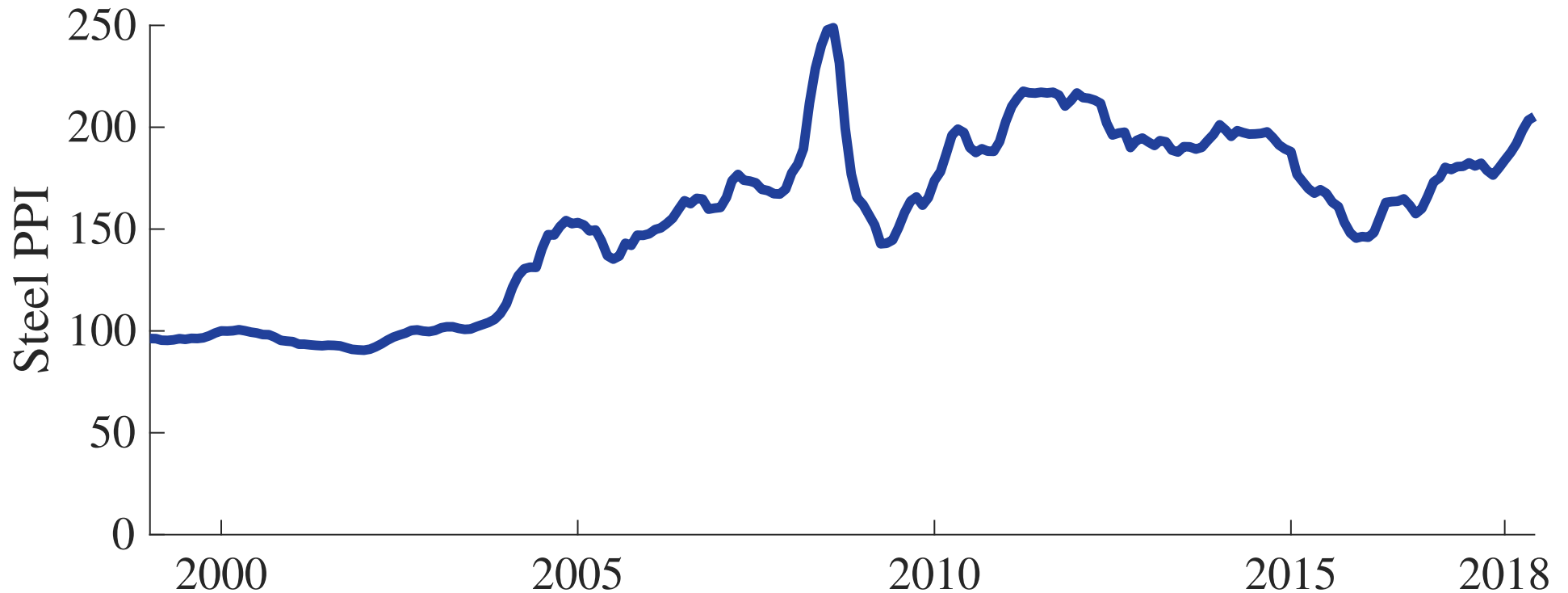
Materials Intensity

- Substituting low-C materials
- Light-weighting
- Process waste reduction
- Recycling

Emissions Intensity

- CCS
- Fuel switching
- Bio-energy
- Energy efficiency
- Innovative processes

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

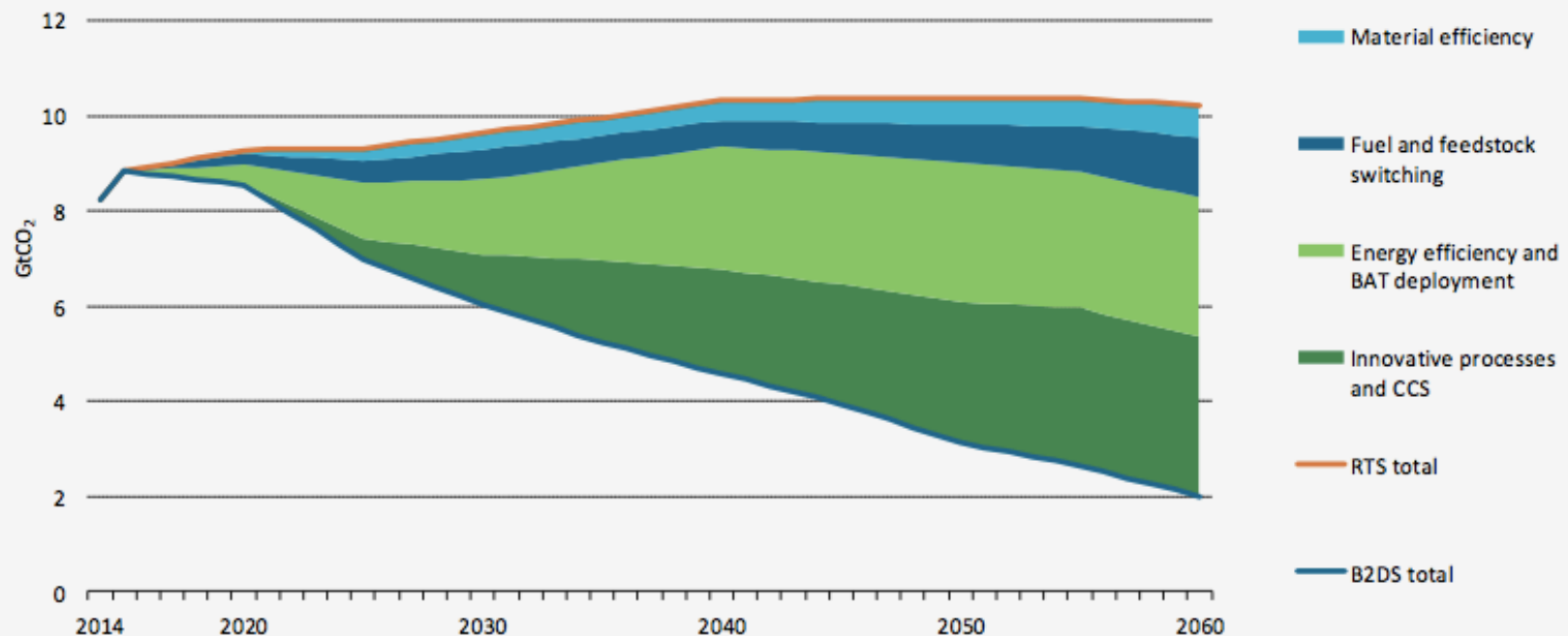
Themes of Technical Pathways

- (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.

Figure

4.4. Direct CO₂ emissions in industry by mitigation strategy in the B2DS compared with the RTS



Key point

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		
Material	(\$ per ton)	(per ton)	New Cost	% increase
Steel	\$ 600	3	\$ 900	50%
Cement	\$ 100	1	\$ 200	100%
Ethylene	\$ 1,000	2	\$ 1,100	20%

(b)		Material		
Product	Current Cost	Amount	New Cost	% increase
Car (steel)	\$ 30,000	1 ton	\$ 30,300	1%
Bridge (cement)	\$ 6.5 billion	100,000 ton	\$ 6.51 billion	1%
Soft drink (plastic)	\$ 2	10 gram	\$ 2.005	1%

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.

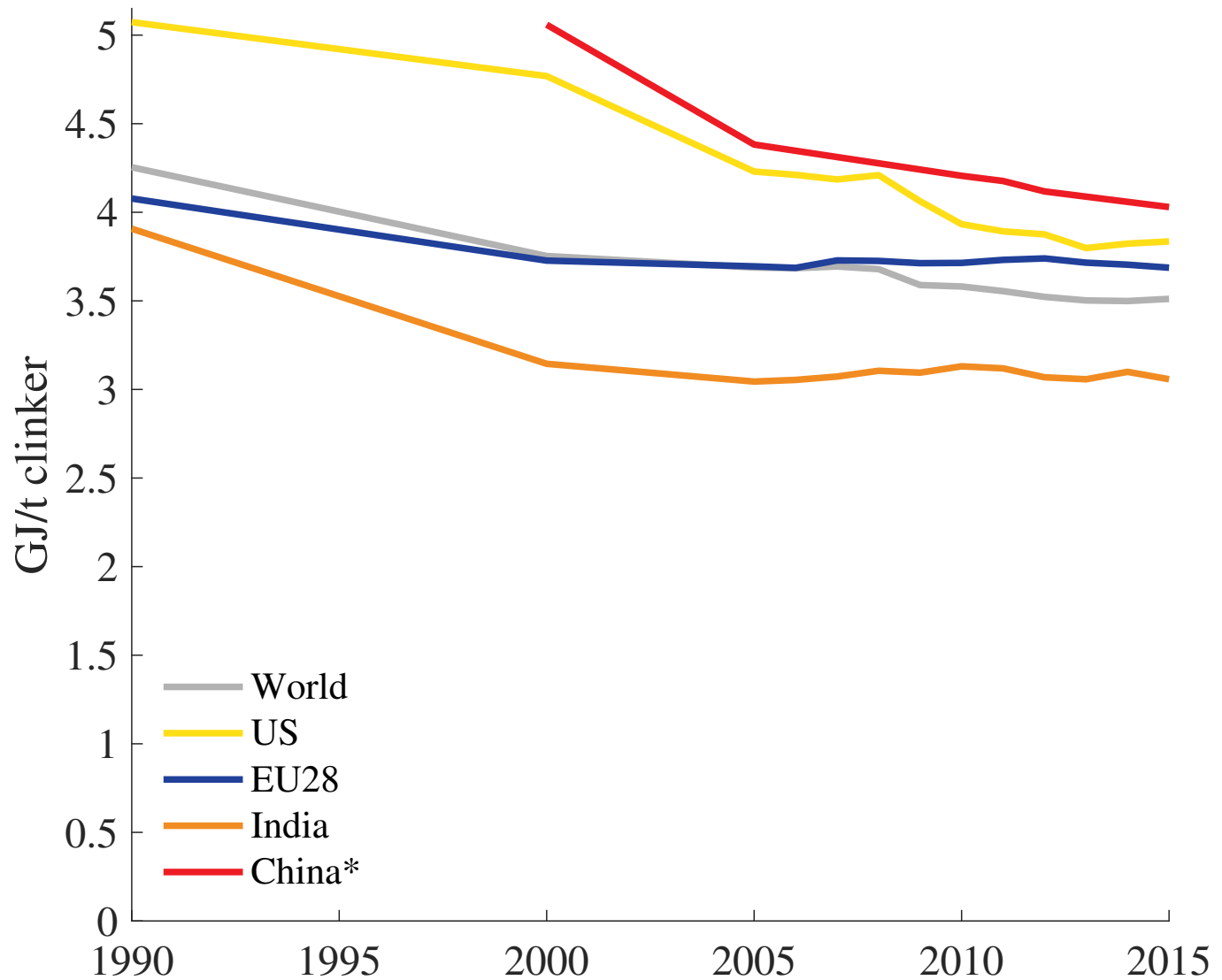
Create a public narrative: Communicate the connections between climate change and material use to both the general public and decision-makers.

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.

