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1944 - 2019 75 YEARS OF INNOVATION

Zinc recovery from hard to recycle industry by-products

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Overview

- Background
- Existing recovery technologies
- Future recovery technologies
- Conclusions

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Sustainable Development Goals

- The Global “Material Footprint” increased by 70% between 2000 and 2017.
- Global consumption of materials increased from 87 billion tons in 2015 to 92.1 billion tons in 2017, in line with economic development.
- The global population is predicted to reach 9.5 billion people by 2050.
- We need 1.75 Earths to sustain our current population .
- If this trend continues, 3 Earths will be needed by 2050 [1].

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Linear Economy

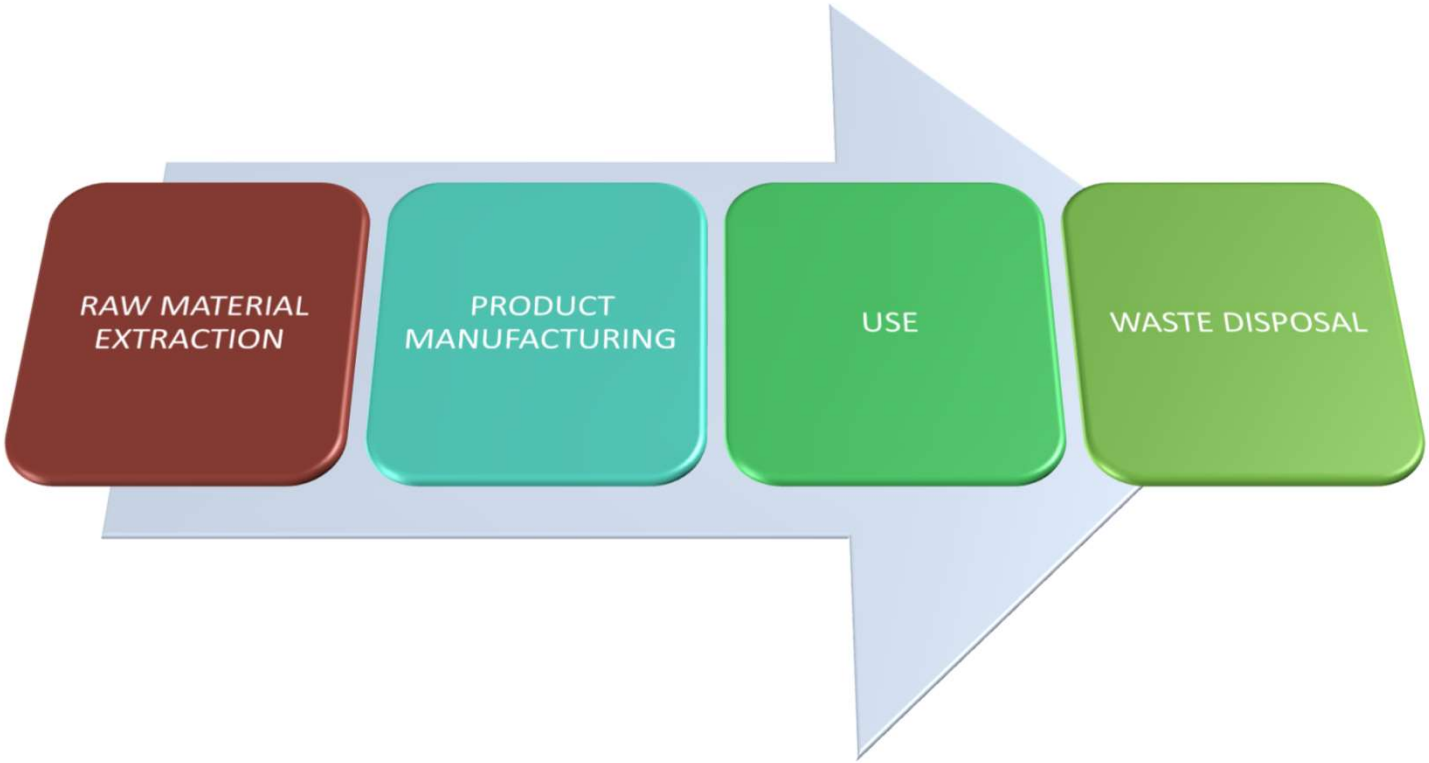

Figure 1: Schematic of a linear economy [2].

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Circular Economy

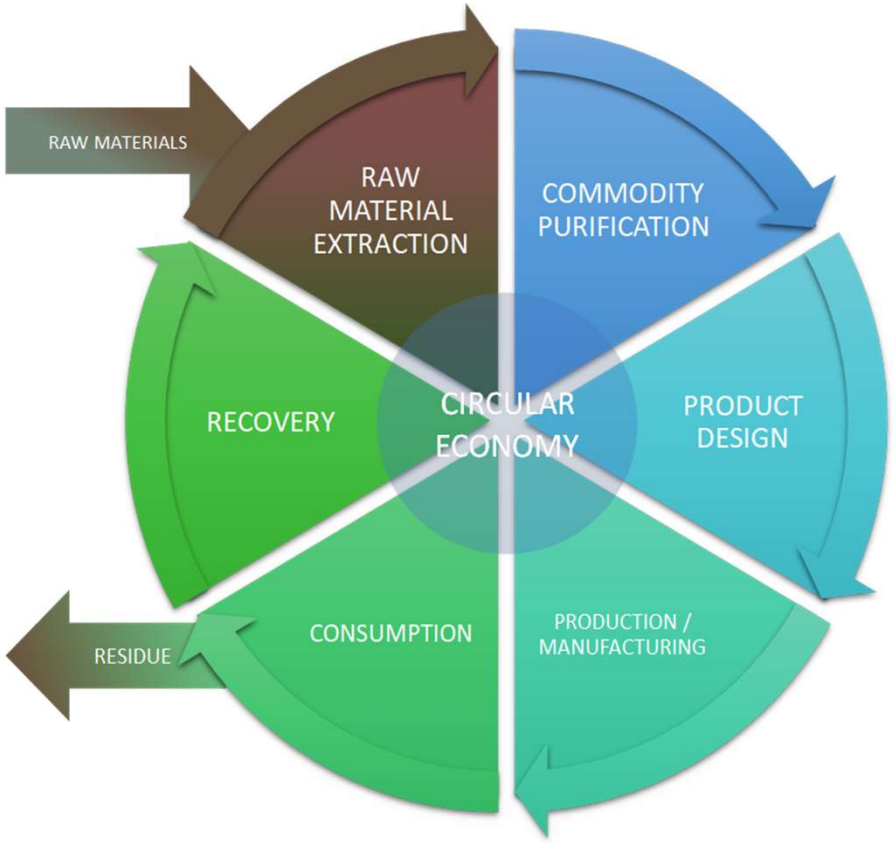

Figure 2: Schematic of a circular economy [2].

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Industrial Symbiosis

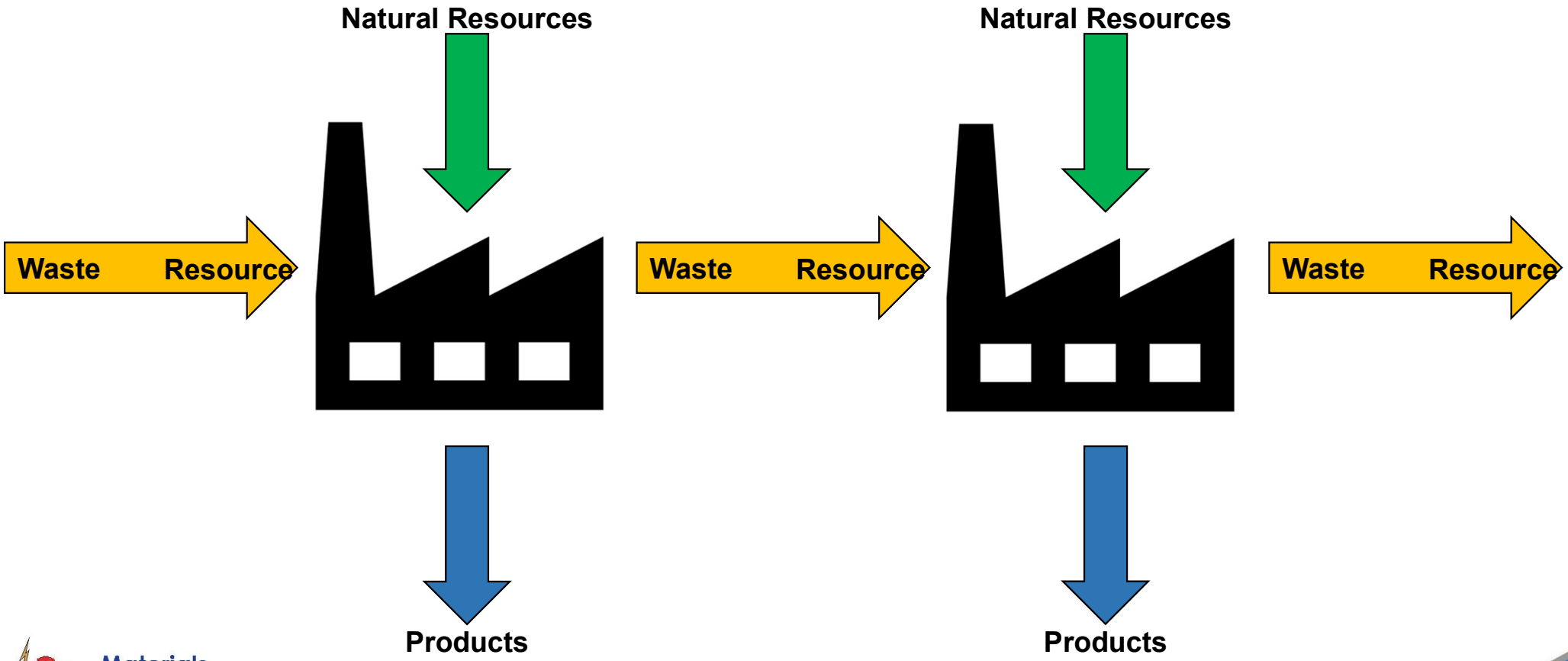

Figure 3: Schematic of a linear economy [3, 4].

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Iron and steelmaking

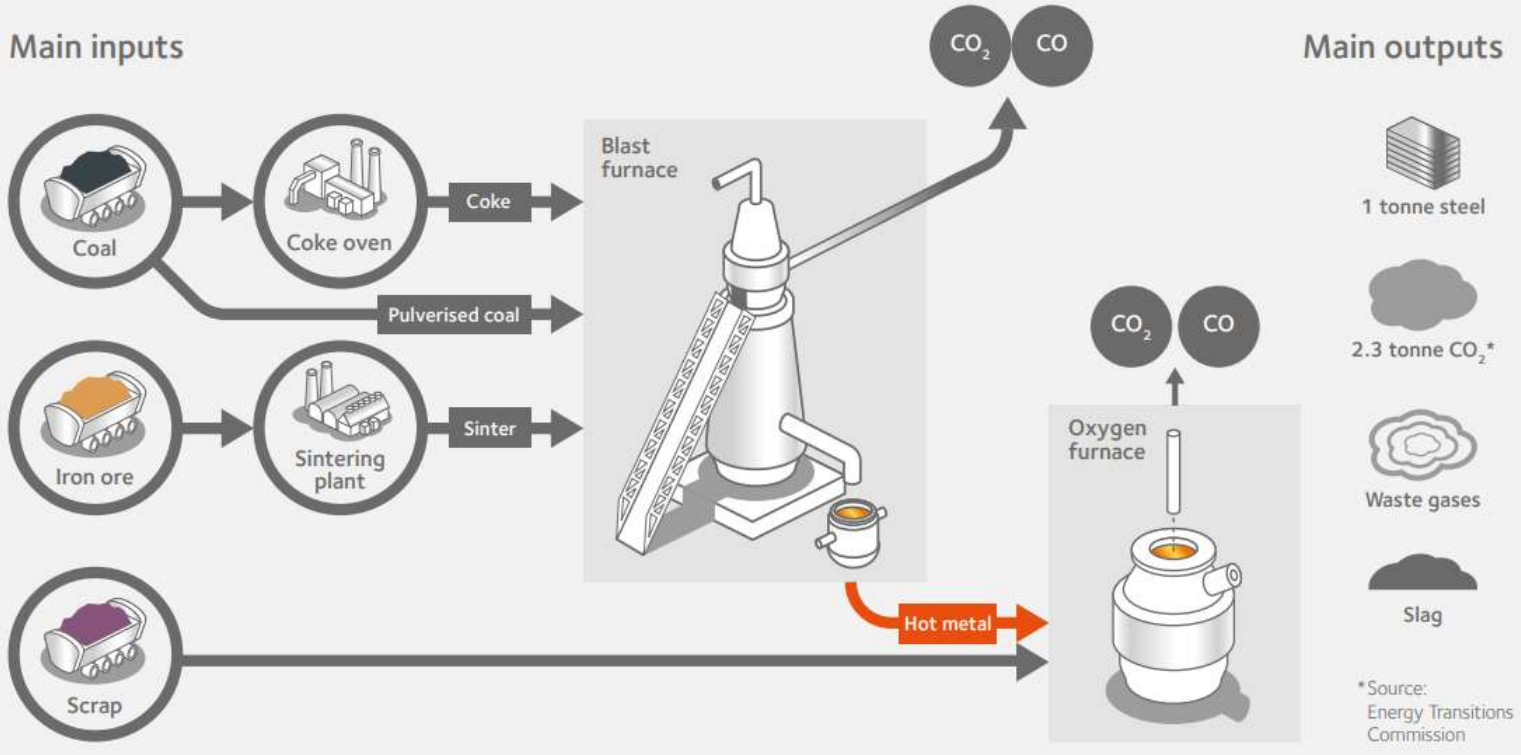

Figure 4: Process Flow Diagram of iron and steelmaking [5].

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Steelmaking

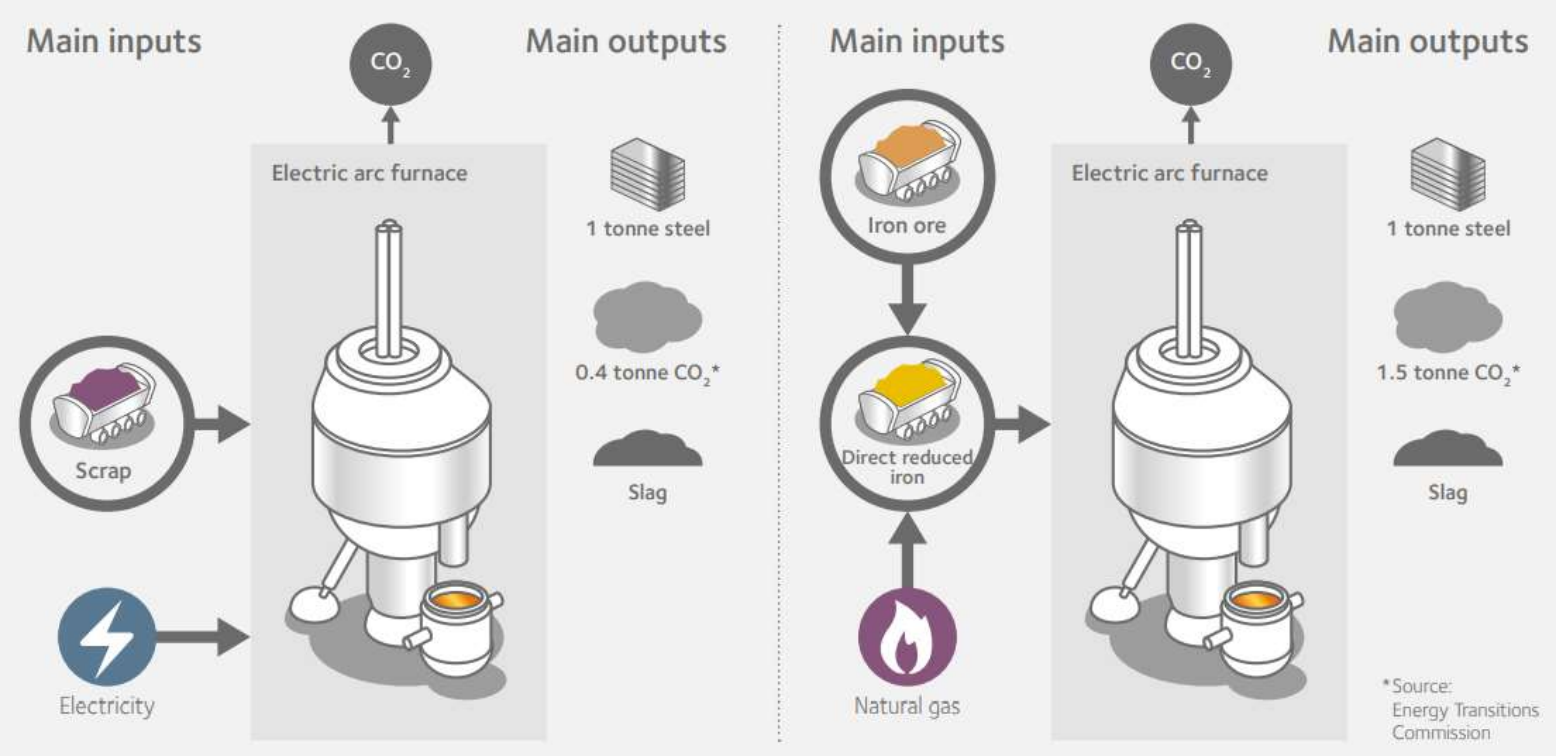

Figure 5: Process Flow Diagram of Electric Arc Furnace steelmaking [5].

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Global steel demand

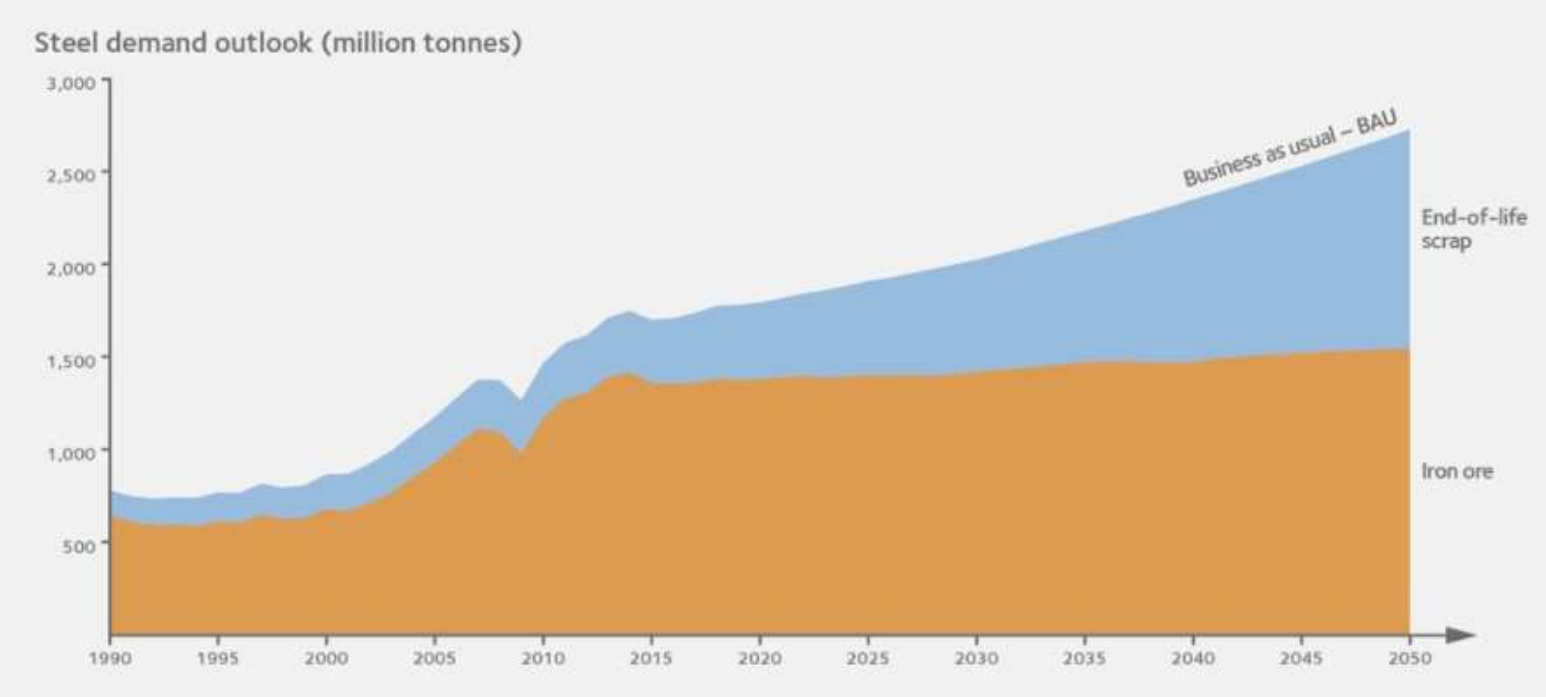

Figure 6: Global steel demand outlook [6].

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Iron and steelmaking slags

Source	Processing	Application
Blast Furnace	Slow cooling (air cooled), crushing, sieving	Concrete and road aggregate
	Rapid cooling (water cooled), gridding	Cement, concrete addition
Basic Oxygen Furnace	Slow cooling, crushing, sieving	Concrete and road aggregate
Electric Arc Furnace	Slow cooling, crushing, sieving	Cement addition and concrete
	Slow cooling, moistened, crushing, sieving	Concrete and road aggregate
Ladle Furnace	Slow cooling, moistened, crushing, sieving	pH stabiliser, roads, cement

Table 1: Source, processing, and applications of iron and steelmaking slags [7].

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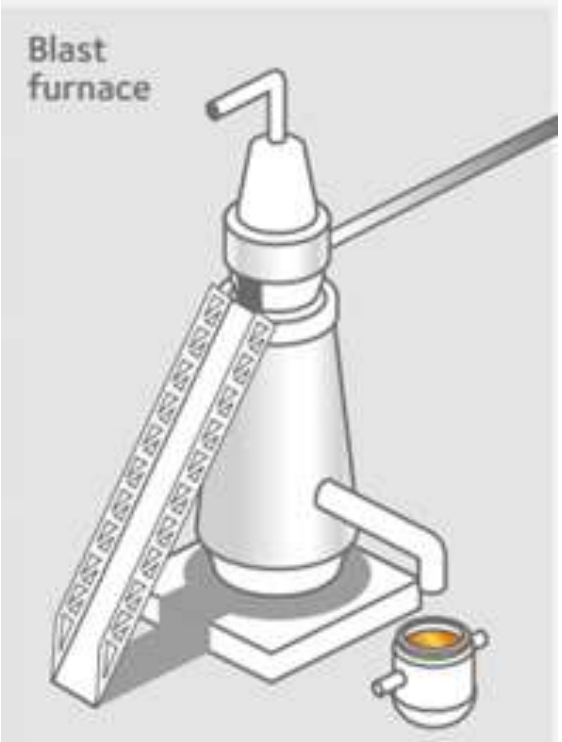
Iron and steelmaking sludges

- Zinc and iron-rich
- Zinc cannot be recycled in the blast furnace
  - Build up
  - Poor processing conditions
- Stock piled
- Legacy and arising material
- Poor recycling infrastructure
- Under-developed market for zinc recycling
- Recycling based on proven technology and an integrated market structure do exist at the industrial scale outside the UK.



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Recovery Technologies

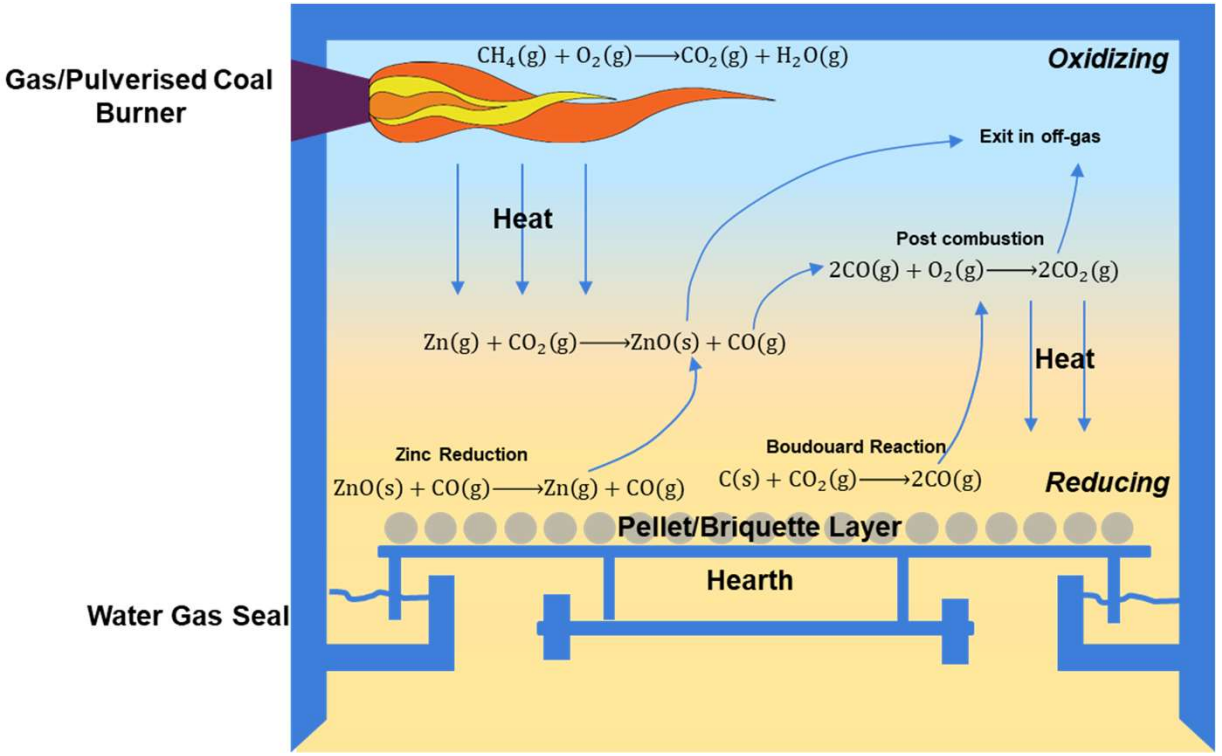

Figure 7: Cross-section of a Rotary Hearth Furnace [8].

Pyrometallurgical techniques

- Rotary Hearth Furnace
- Electric Arc Furnace
- Waelz Kiln
- Shaft Furnace
- Microwave technology

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Recovery Technologies – Hydrometallurgical Techniques

Method	Comments
Mineral acid leaching	High zinc leaching efficiency but low selectivity of zinc over iron. Franklinite ($ZnFe^{3+}_2O_4$) can be dissolved.
Organic acid leaching	Lower zinc leaching efficiency and higher selectivity when compared to mineral acid leaching. More environmentally than mineral acid leaching. Franklinite ($ZnFe^{3+}_2O_4$) can't be dissolved.
Alkali leaching	Very selective removal of zinc over iron. High reagent consumption. Thermal pre-treatment required to dissolve Franklinite.
Ammoniacal leaching	Very selective removal of zinc over iron. Low reagent cost. Thermal pre-treatment required to dissolve Franklinite.

Table 2: Summarised analysis of the hydrometallurgical processes available for the recovery of zinc from Basic Oxygen Furnace Sludge [9]

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Recovery Technologies – Mirco Cavitation Duct

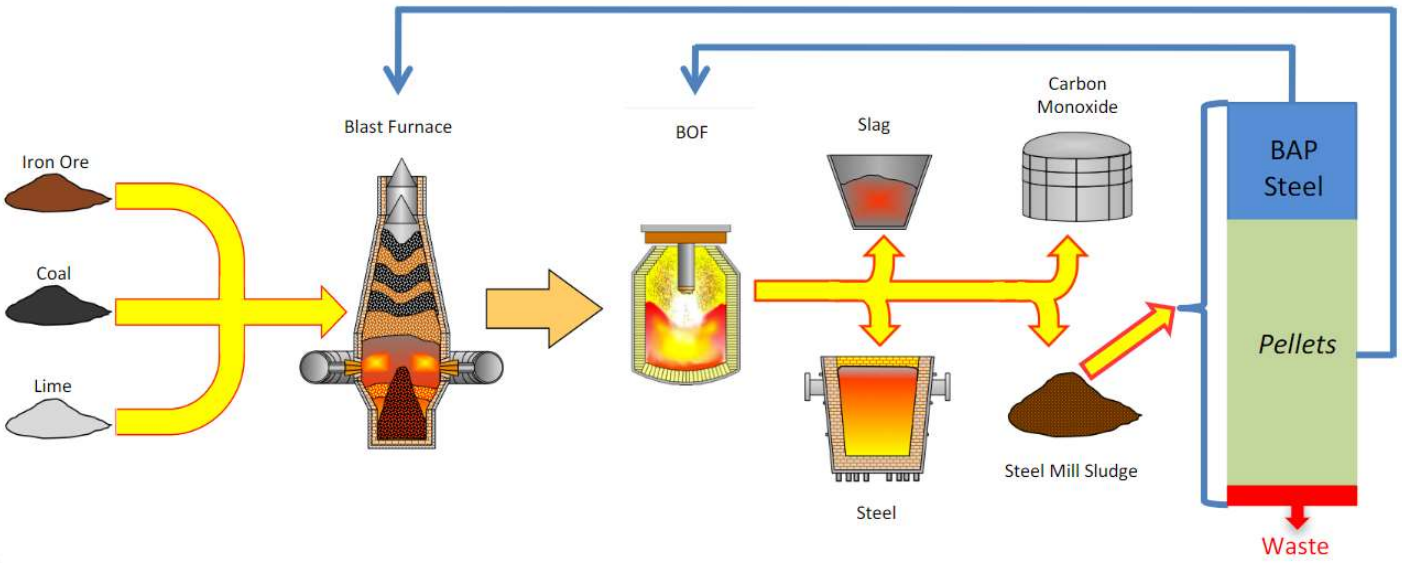

Figure 8: Circular economy closed loop of the Micro Cavitation Duct process [10].

- Recovery of both course and thin sludge from Basic Oxygen Furnaces (BOFs)
  - Disaggregation and cleaning of the sludge
  - Isolation of the steel
  - Segregation of the contaminants.
  - >90% purity
  - Pelletising without a binder.
- Recovery of 70% of the course sludge
  - Disaggregation and pH neutralisation
  - Filtration to remove contaminants
  - Pelletising without a binder.
- The remaining 30% is processed using the thin sludge process.
- Closed loop process.

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Recovery Technologies – Oxidative Ionothermal Synthesis

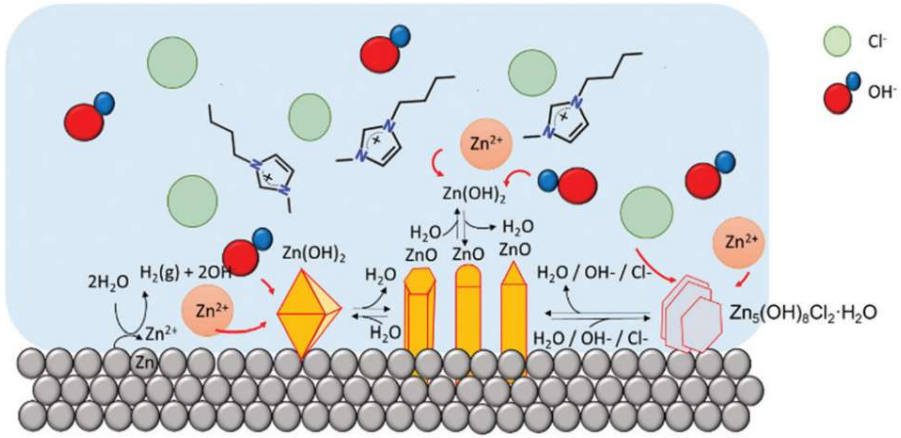

Figure 9: Cartoon of Zn-based micro/nano particles in [C4C1im]Cl at high water content [11].

- Direct oxidation of metallic zinc from zinc oxide
  - Not limited to zinc-based materials.
- OIS uses ionic liquids and water mixtures,
  - The water content, temperature, and exposure time of different species are adjusted to produce nano and micro materials.
- Ionic liquids have low melting points and very low volatility salts and their chemical and physical properties can be altered.
- Environmentally friendly alternative to industrial organic solvents.
- OIS can be utilised to produce “materials-by-design” that have been developed to meet a specific industrial requirement.

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Conclusions

- Industrial symbiosis is an underpinning system of a Circular Economy.
- The steel industry produces a range of slag by-products that are recycled.
- Some sludge by-products are harder to recycle due to their high zinc content.
- Pyrometallurgical processes exist to treat this sludge.
- Hydrometallurgical processes exist and are under development.
- Zinc removal will support iron and steel manufacturing and the zinc supply chain.

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Thank You

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