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Materials for the Green Transition

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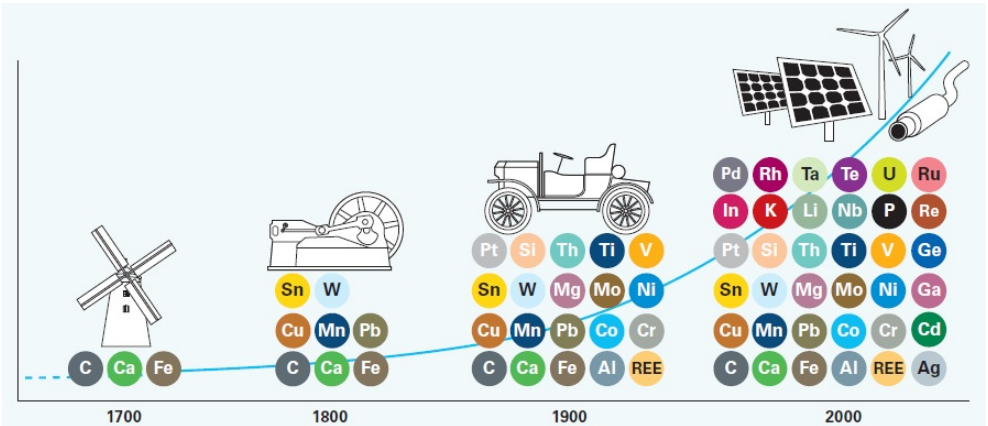
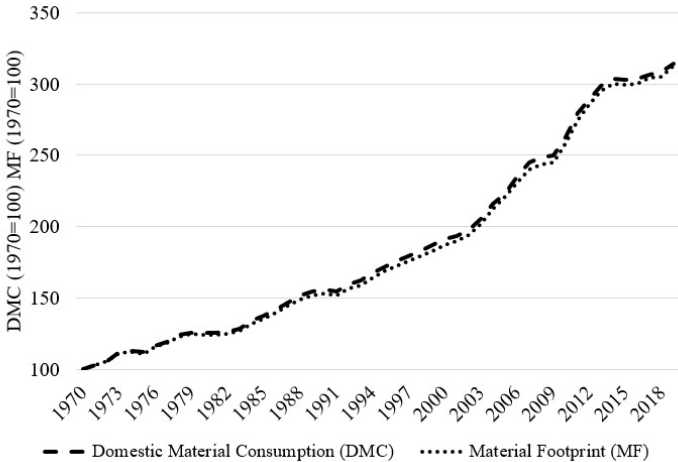
Materials

Modern Society and Decarbonized Future



Source: Zepf et al. (2014)

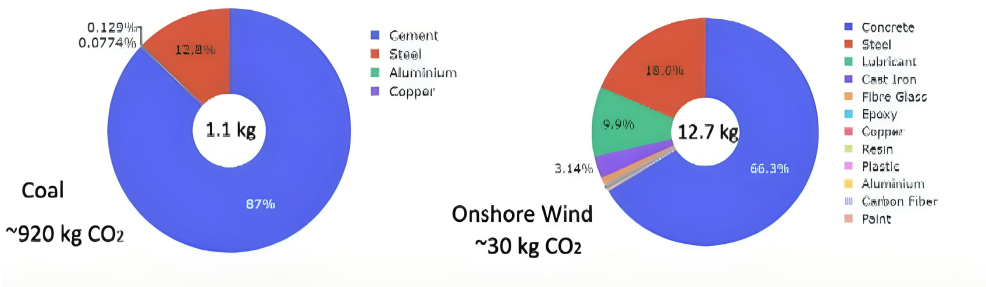
Material Consumption
From 1970 to 2019



Source: Global Material Flows Database (2022)

The Move from Energy to Materials

- To deliver 1 MWh of electricity, we need the following materials for power plants



Source: Barron et al. (2022)

- If the 20th century energy goal was about access to the oil and gas, the 21st century will be about the access to materials.

Why are materials important?

1. Economically vital
   - Tungsten for smartphones, gallium for many light-emitting diodes (LEDs), copper for electronics, and silicon metal for semiconductors
   - For example, 50 different metals in different quantities are needed to produce a standard smartphone (EC, 2018)
2. Low-carbon technologies
   - Solar panels, wind turbines, electric vehicles, batteries, carbon capture and storage
   - Rare earth element neodymium for wind turbine magnets
   - Copper used for EV production is about 4 times higher than a standard ICE.
   - The PV systems and wind power plants require 11-40 times more copper and 6-14 times more iron.

Global Demand for Materials is Expected to Grow

Source: OECD (2019)

- Under the sustainable development scenario, IEA (2022) projects that demand for lithium, cobalt, and nickel employed in clean technologies will increase by more than 60% by 2040.

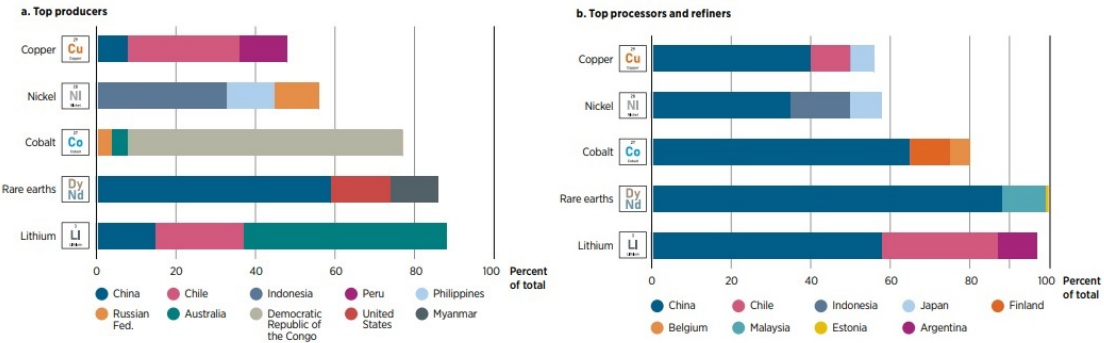
Growing Demand for CRMs

Actual (2021) and Projected (2050) Demand under IRENA's 1.5°C Scenario

Material		Demand in 2021 (Mt/year)	Demand in 2050 (Mt/year)	Source
29 Cu Copper 63.546	Copper	30 Mt/yr	50-70 Mt/yr	Elshkaki *et al.* (2016); ICGS (2021); INSG (2021)
28 Ni Nickel 58.693	Nickel	2.77 Mt/yr	5-8 Mt/yr	Elshkaki *et al.* (2017)
3 Li Lithium 6.94	Lithium	0.3 Mt/yr	2-4 Mt/yr	Moore and Bullard (2021)
60 Nd Neodymium 144.24	Neodymium	0.03 Mt/yr	0.2-0.5 Mt/yr	Barrera (2021); Joint Research Centre (2020, 2021); Deetman *et al.* (2021)

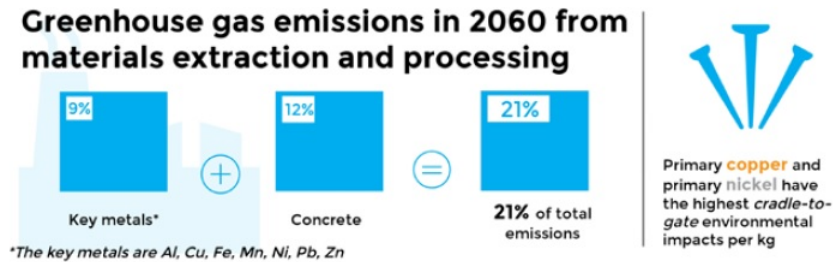
Source: IRENA (2022)

Risks to supplies of critical materials



Source: IRENA (2022)

Environmental Risks



Source: OECD (2019)

The Environmental Effect of Materials is Overlooked

Period	Carbon Intensity of Energy		Carbon Intensity of Material	
1990-1995	4: BRA, IDN, AUS, CHN	15: IRN, POL, MEX, ZAF, IND, SAU, ITA, TUR, KOR, CAN, GBR, JPN, DEU, RUS, USA	16: JPN, IND, ITA, ZAF, BRA, AUS, KOR, RUS, CAN, POL, MEX, IDN, SAU, GBR, IRN, TUR	3: USA, DEU, CHN
1995-2000	7: USA, CAN, MEX, TUR, AUS, IDN, BRA	12: ZAF, IRN, SAU, JPN, IND, ITA, POL, GBR, KOR, DEU, RUS, CHN	12: KOR, IND, JPN, IDN, IRN, RUS, BRA, TUR, SAU, GBR, AUS, CAN	7: ZAF, MEX, ITA, CHN, POL, DEU, USA
2000-2005	10: CHN, JPN, USA, ITA, IND, ZAF, IDN, MEX, GBR, AUS	9: CAN, BRA, POL, TUR, IRN, KOR, DEU, SAU, RUS	13: CHN, DEU, JPN, IND, KOR, ITA, AUS, ZAF, GBR, IRN, MEX, CAN, POL	6: TUR, BRA, IDN, SAU, RUS, USA
2005-2010	4: IDN, IND, KOR, ZAF	15: SAU, GBR, AUS, CAN, IRN, TUR, MEX, BRA, POL, DEU, JPN, RUS, ITA, USA, CHN	12: USA, ZAF, IND, IDN, GBR, RUS, KOR, IRN, AUS, JPN, ITA, MEX	7: BRA, SAU, POL, TUR, DEU, CAN, CHN
2010-2015	6: JPN, IND, BRA, IDN, SAU, RUS	13: MEX, ZAF, TUR, DEU, KOR, POL, ITA, AUS, CAN, IRN, GBR, USA, CHN	5: IND, IRN, ITA, BRA, SAU	14: JPN, ZAF, DEU, AUS, POL, KOR, TUR, MEX, CAN, IDN, GBR, RUS, USA, CHN
2015-2019	2: IDN, ZAF	17: TUR, SAU, CAN, MEX, ITA, POL, KOR, AUS, IRN, GBR, RUS, JPN, DEU, BRA, IND, USA, CHN	8: CHN, RUS, SAU, IDN, IRN, IND, ZAF, ITA	11: TUR, POL, KOR, CAN, MEX, JPN, AUS, BRA, DEU, GBR, USA
Whole	4: JPN, IDN, ZAF, MEX	15: IND, BRA, AUS, CAN, TUR, SAU, POL, IRN, ITA, KOR, GBR, DEU, RUS, CHN, USA	8: IND, JPN, IRN, ZAF, KOR, IDN, ITA, AUS	11: SAU, BRA, MEX, TUR, POL, CAN, GBR, RUS, USA, DEU, CHN

Source: Akdogan et al. (2022)