



Metals, technologies & innovations

Prof. Eric PIRARD

Renewable Times

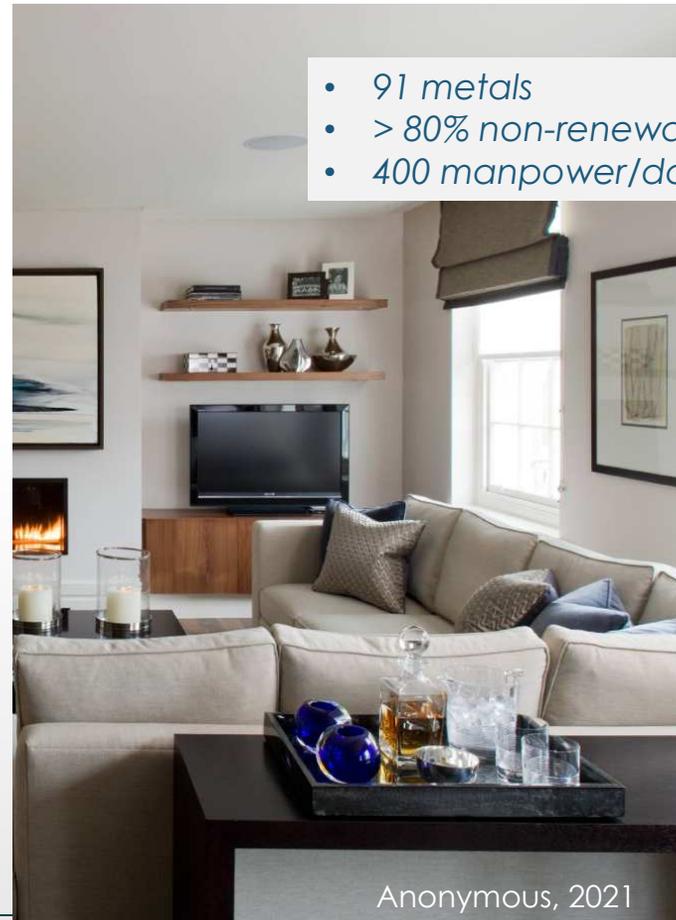
Renewable times

- 7 metals
- Renewable energies
- 3-4 manpower/day



J. Van Eyck, 1434

- 91 metals
- > 80% non-renewable energies
- 400 manpower/day



Anonymous, 2021

« Ceci n'est pas de l'argent »

Maillechort
75% Cu 20% Zn 5 % Ni

German Silver
75%Cu 25% Ni



Nordic Gold
89% Cu 5% Al 5% Zn 1% Sn

This is not iron

SS304

18 % Cr
8 % Ni



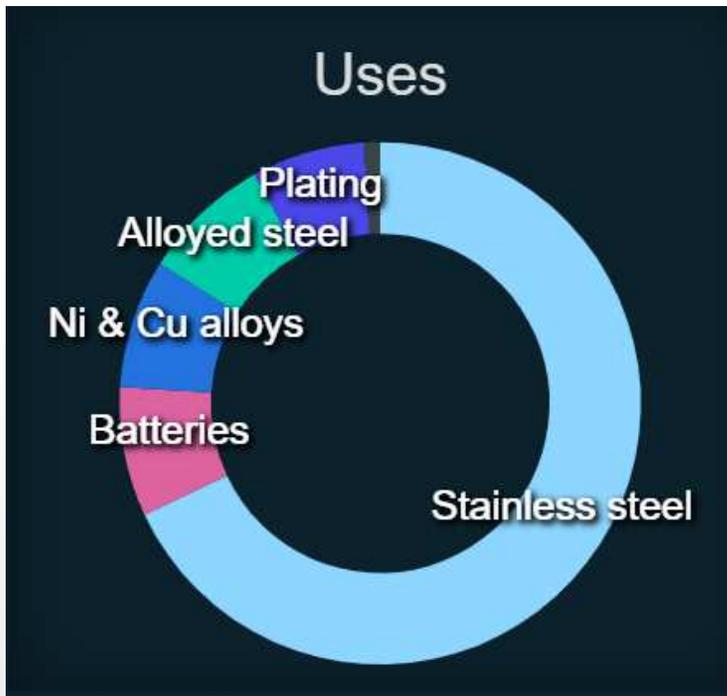
SS316

16 % Cr
10 % Ni
2 % Mo



Raw Materials Information System

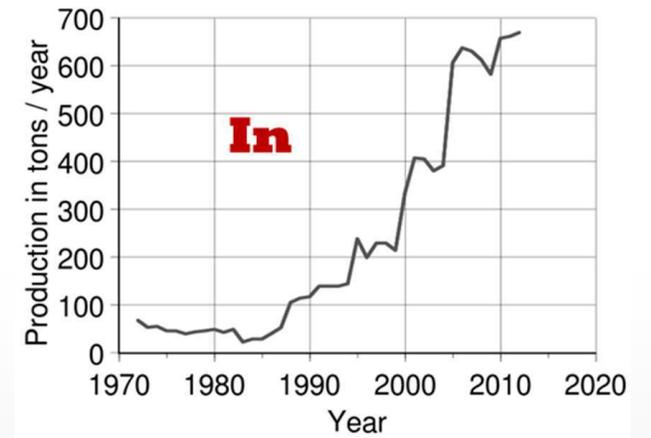
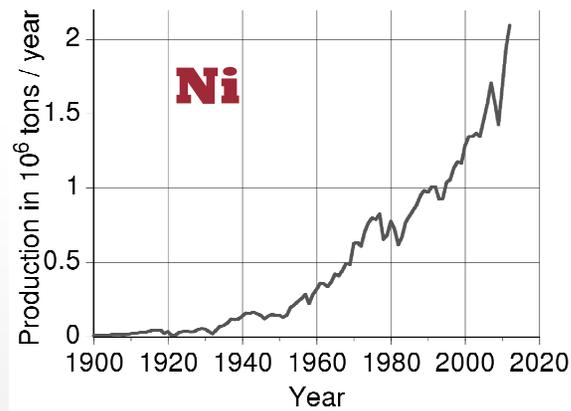
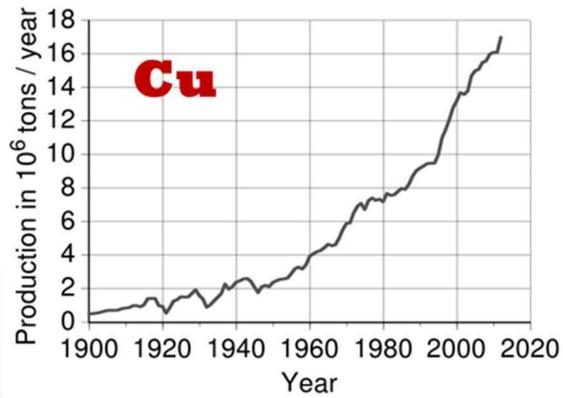
- <https://rmis.jrc.ec.europa.eu/>



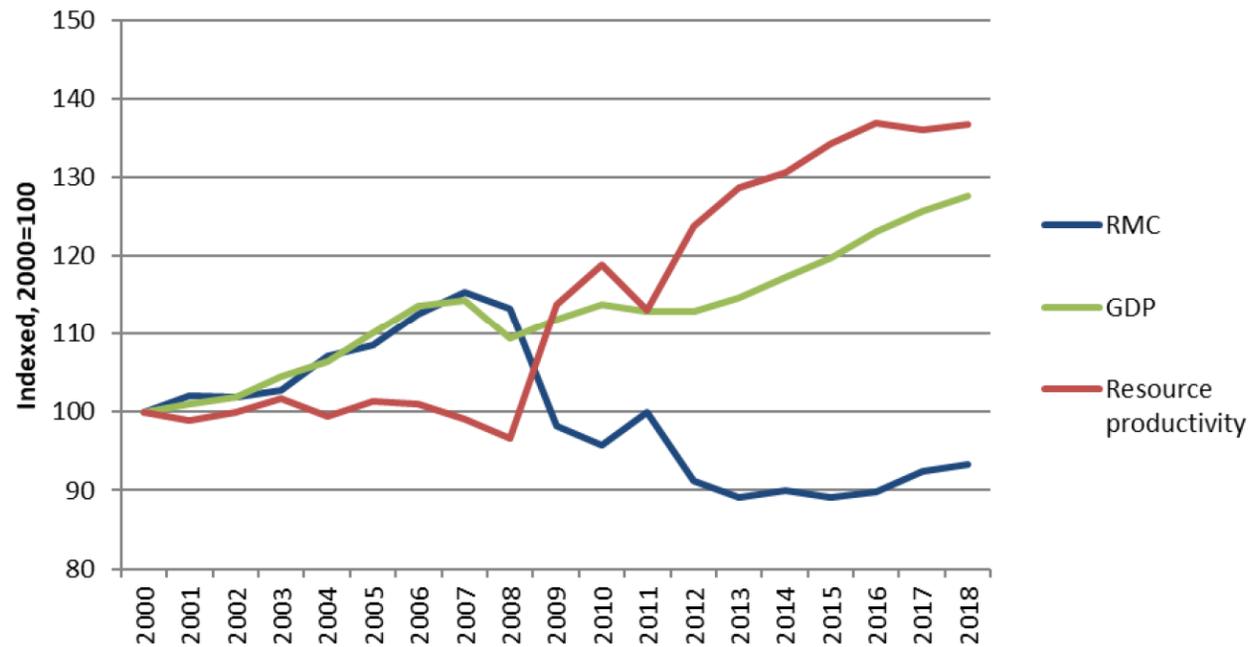
Nickel Dashboard

Green Growth

Green Growth



Green Growth



<http://www.materialflows.net/decoupling-material-use-and-economic-performance/>

eurostat

Handbook for estimating raw material equivalents

of imports and exports and RME-based indicators on the country level – based on Eurostat's EU RME model

November 2020

RMC

Raw Materials Consumption

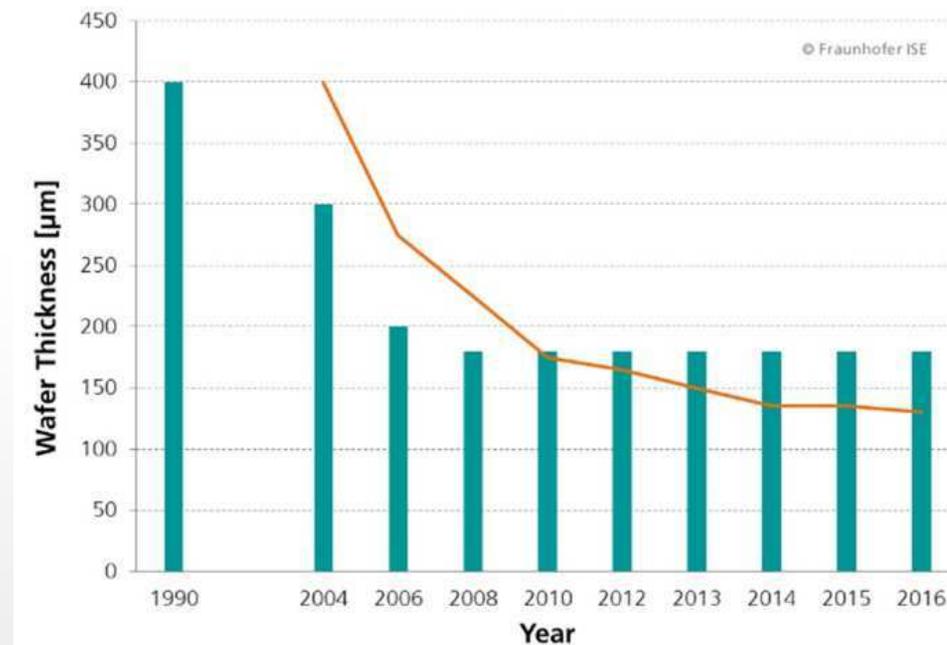
vs.

IMP-RME

Raw Material Equivalents of Imports

Green Growth

- Decrease of Si-wafer thickness in solar panels



The thickness of polysilicon wafers used in solar panels shows a downward trend from 300µm (2004) down to 160 µm (2016) (Fraunhofer ISE)

Green Growth



*Mini means 600kg
in 1960*

*Mini SE means 1440 kg
in 2021*

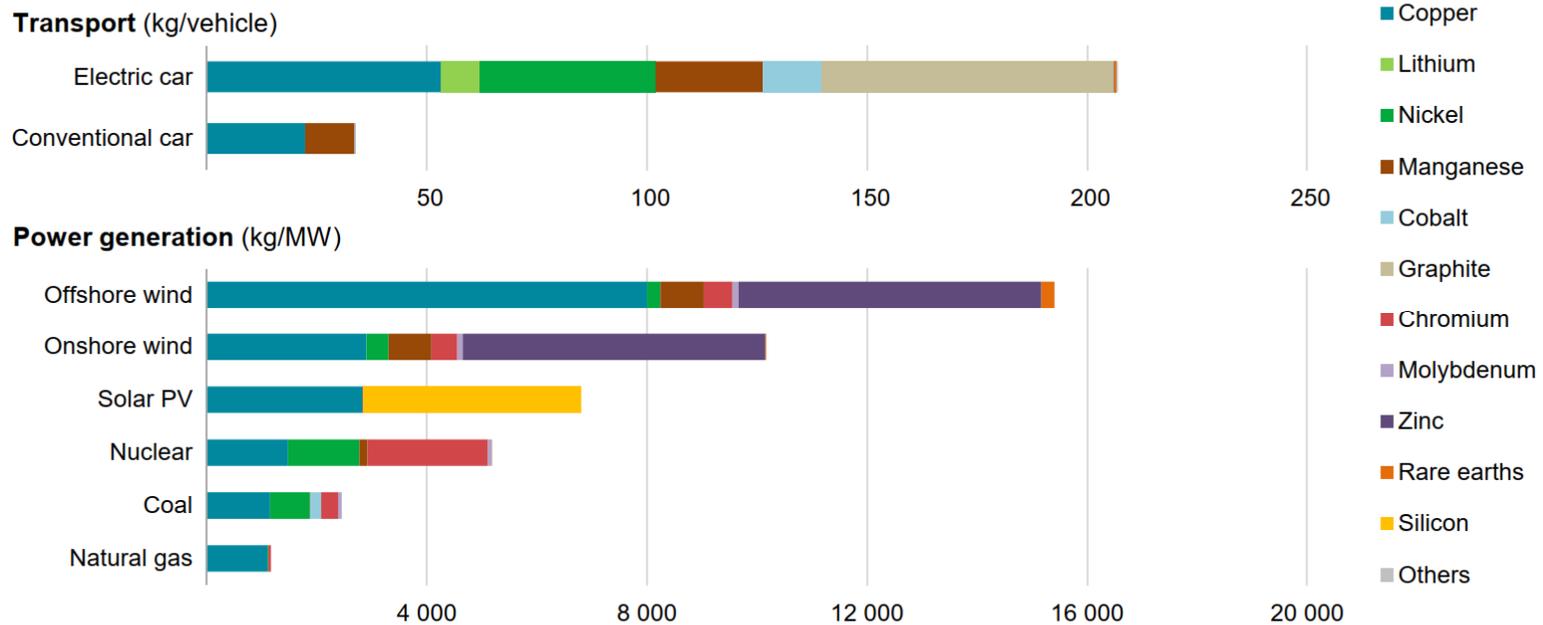
Green Growth

- IEA (2021)

The Role of Critical Minerals in Clean Energy Transitions



Minerals used in selected clean energy technologies



Going Circular

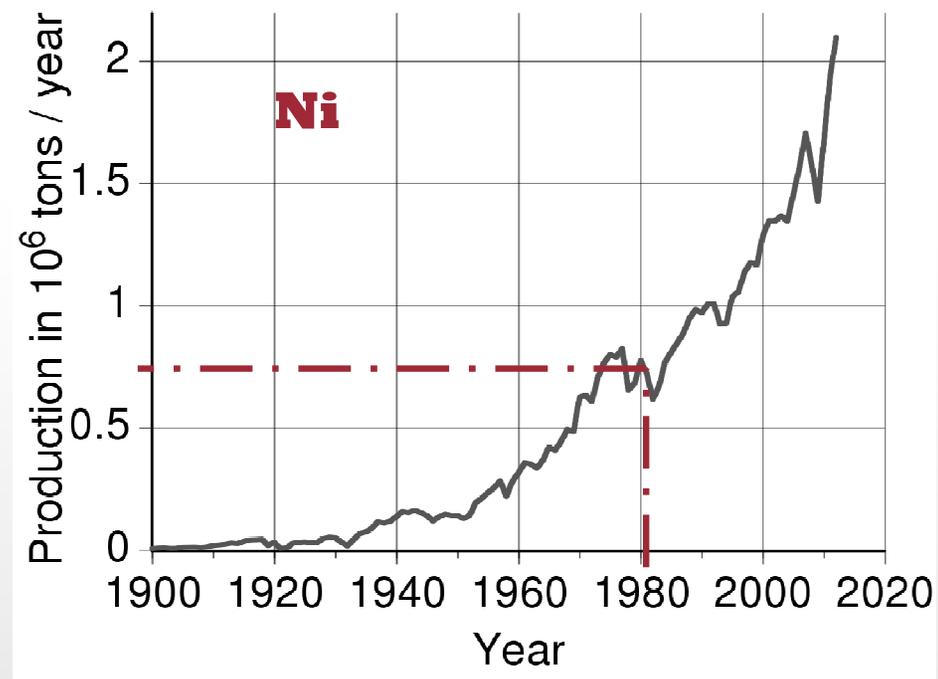
Going Circular

- Four challenges
 - Feed – Design - Slow Down - Close



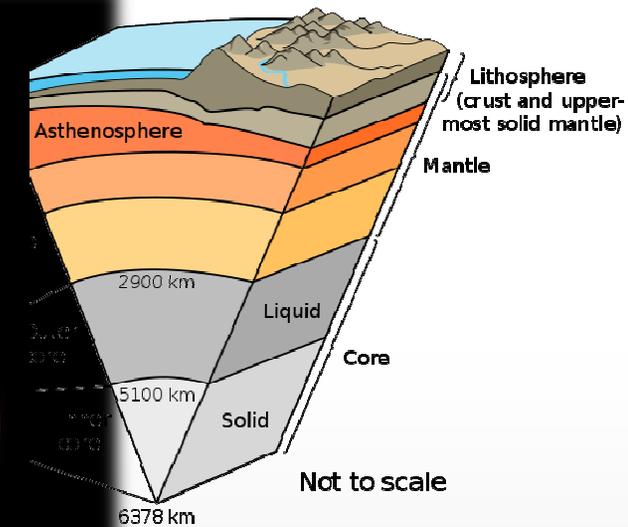
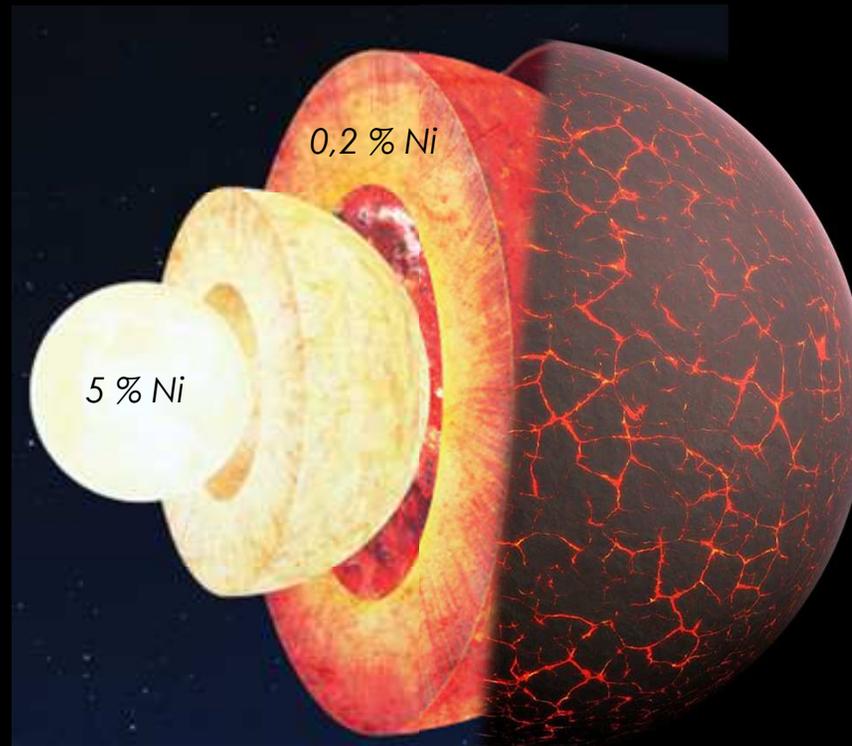
Feed the Loop

- Recycling alone will not suffice
 - 40 years old Ni represents 30% of current needs



Feed the Loop

- Responsible sourcing



USGS 'Inside the Earth' Wikimedia Commons

Feed the Loop

- Responsible sourcing – Choice n°1
 - **LATERITE** - Oceanic crust exposed to tropical alteration
 - Complex hydrated Ni-silicates $(\text{Mg,Fe,Ni})_3\text{Si}_2\text{O}_5(\text{OH})_4$



New Caledonia

Feed the Loop

- Responsible sourcing – Choice n°2
 - **MASSIVE SULPHIDES** – Segregated from magmatic rocks
 - Iron-Copper-Nickel Sulphides (Fe,Ni)₉S₈



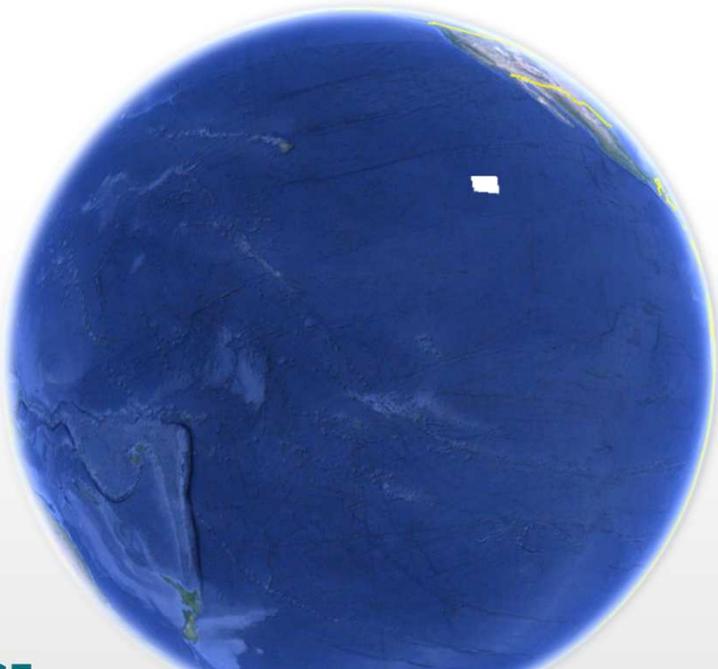
1,5 % Ni



Lake Lefroy (Aus) © Burtynsky

Feed the Loop

- Responsible sourcing – Choice n°3
 - **POLYMETALLIC NODULES** – Ocean floor alteration
 - Manganese-Nickel-Iron (Oxy)Hydroxides

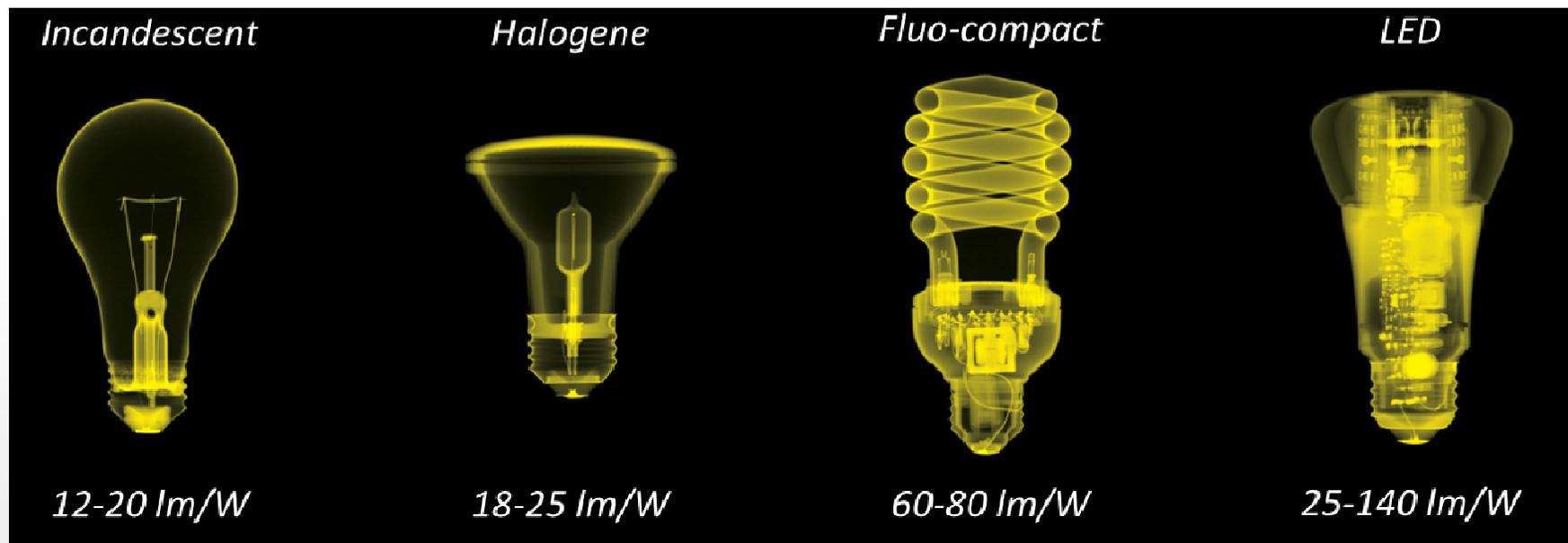


1,5 % Ni

Design the Loop

Therefore, instead of worrying about reaching “peak” production or “exhausting” a resource, we should instead be more **concerned about what we do with the resource after it has been extracted.**

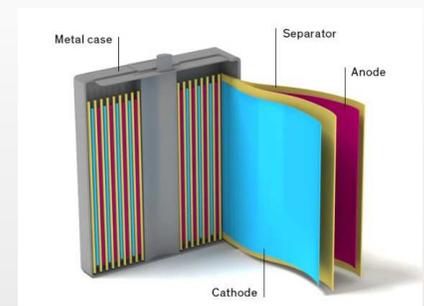
Meinert et al., 2016, Mineral Resources: Reserves, Peak Production and the Future



Not just the lifecycle analysis of the use phase...

Design the Loop

- Functionality cannot come at the expense of recyclability



Slow Down the Loop

- Ban single use
 - End of the « BIC Generation »



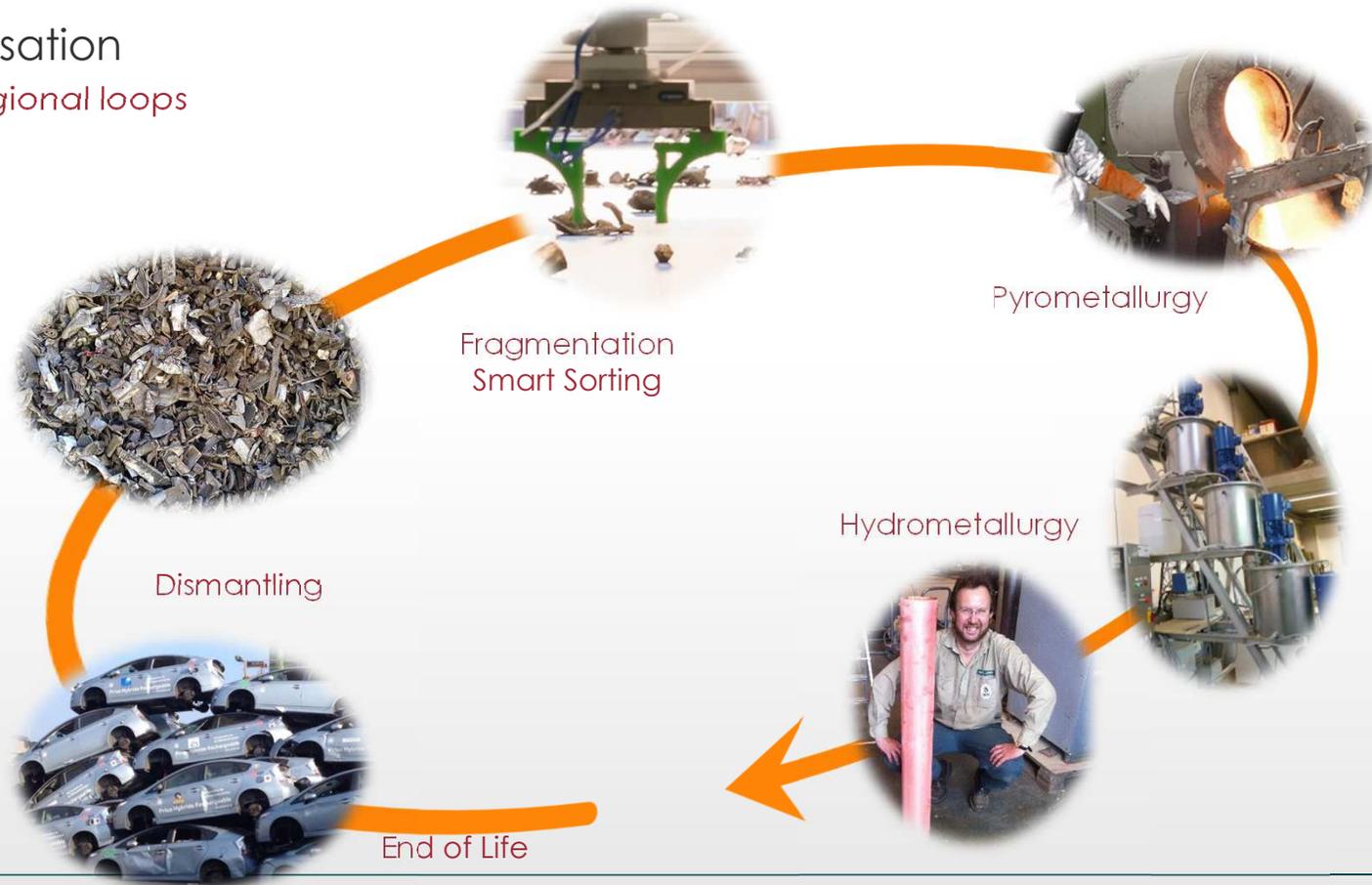
Slow Down the Loop

- Extend lifetime of all goods
 - « Right to Repair »
 - Encourage long guarantees



Close the Loop

- Reindustrialisation
 - Closing regional loops



Close the Loop

- Sort – sort – sort!
 - Multisensor Robotics and Deep-Learning



SS304

18 % Cr
8 % Ni



SS316

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10 % Ni
2 % Mo



MultiPick Prototype

Reverse Metallurgy in Wallonia

The End

Anthropy or Entropy ?



Keep in mind!

A 95% recovery rate generates 50% of losses after only 14 cycles