NTNU

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The influence of stock dynamics on new technology penetration

Technology stocks in the global Aluminium cycle

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Outline

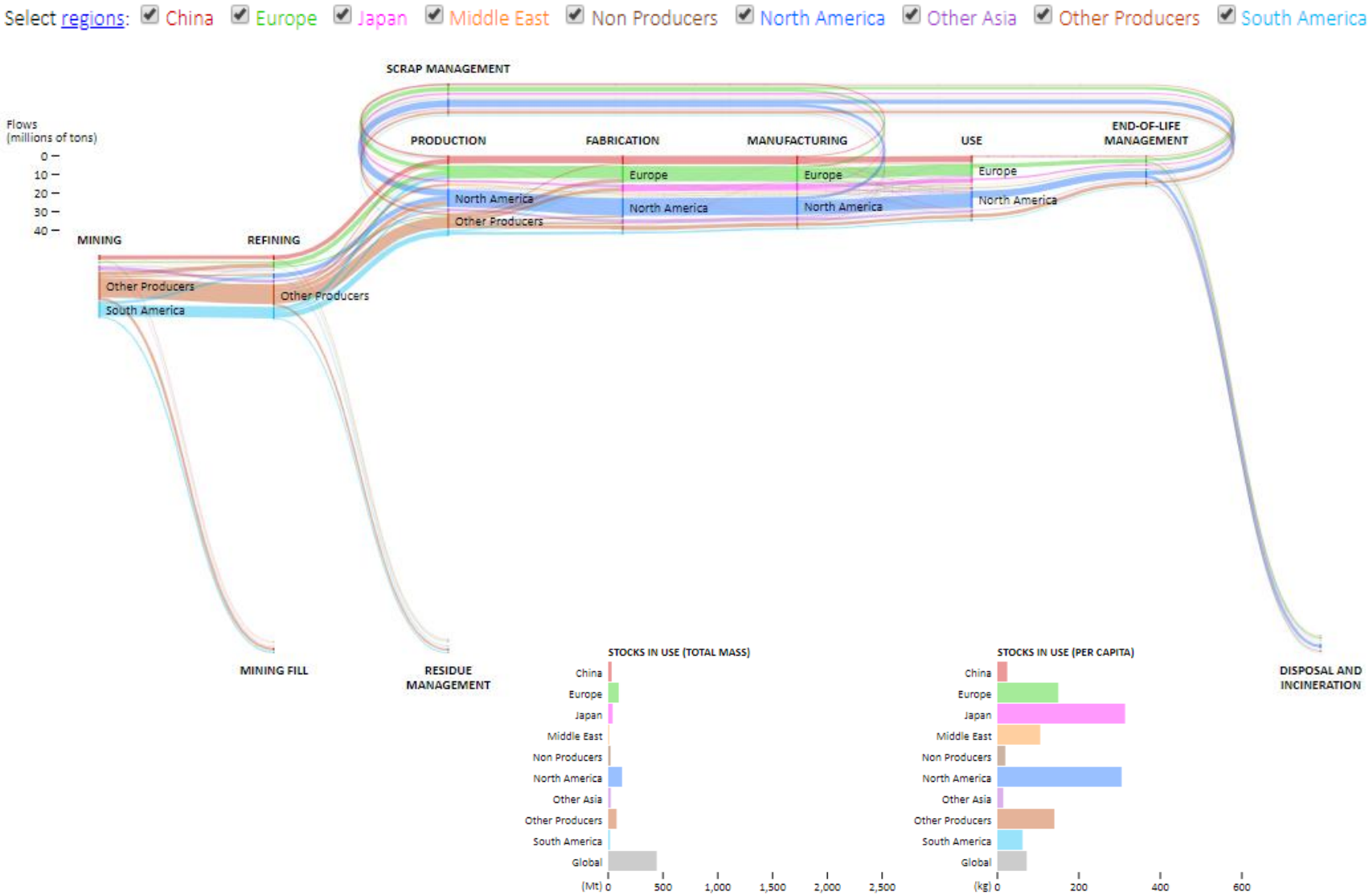
1. Motivation and research questions

2. Why using in-use and technology stocks as drivers for scenario analysis?

3. Application to the future growth of primary aluminium production capacity

Motivation

How will this look in 2050?



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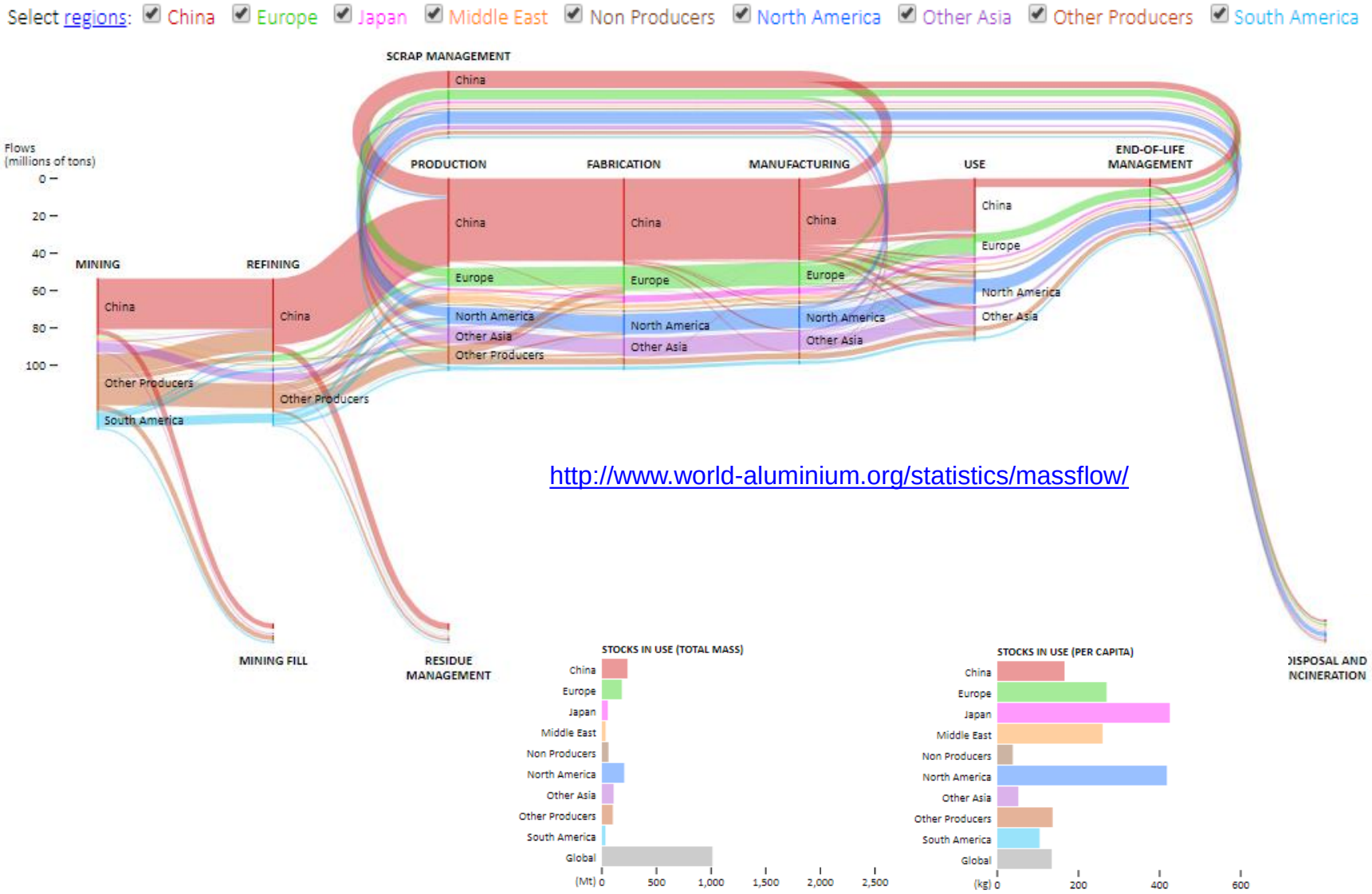


http://www.world-aluminium.org/statistics/massflow/

Motivation

Research questions

- ✓ What will be the future share of primary vs. secondary Al production, depending on future demand and scrap availability?
- ✓ Will future developments in primary production be impacted by future increases in scrap availability?
- ✓ How fast can technology improve? Should we fear potential lock-in effects?
- ✓ What are consequences of extending the lifetime of existing infrastructure?

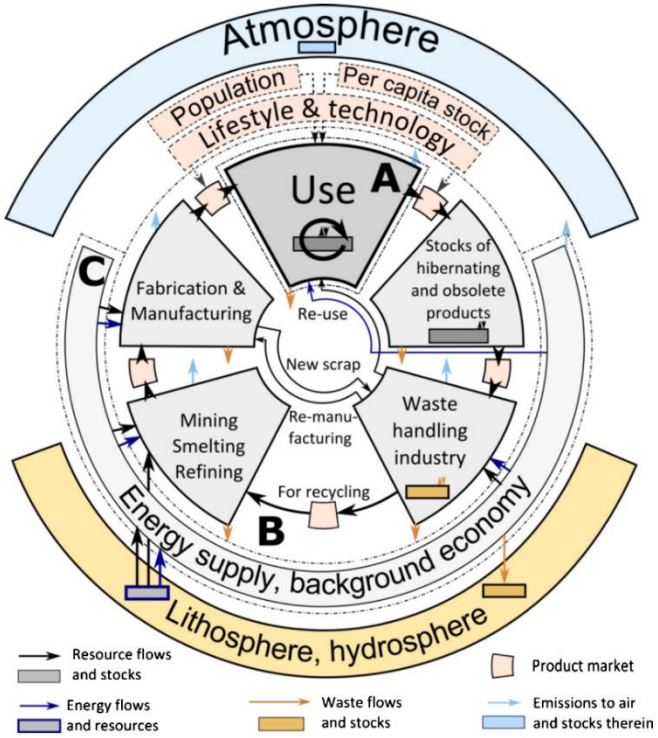
Introducing Technology Stocks

In-use metal stocks are drivers of the socioeconomic metabolism

The study of metal cycles and stocks is paramount to understand the relationships between materials and society:

- ✓ In-use stocks link the services enjoyed by humans to energy and material consumption.
- ✓ Climate change mitigation requires us to transform current in-use stocks to decouple energy and material throughput from service provision.
- ✓ The dynamics of in-use stocks have a large influence on future sustainable development strategies.

S. Pauliuk, D.B. Müller / Global Environmental Change 24 (2014) 132–142



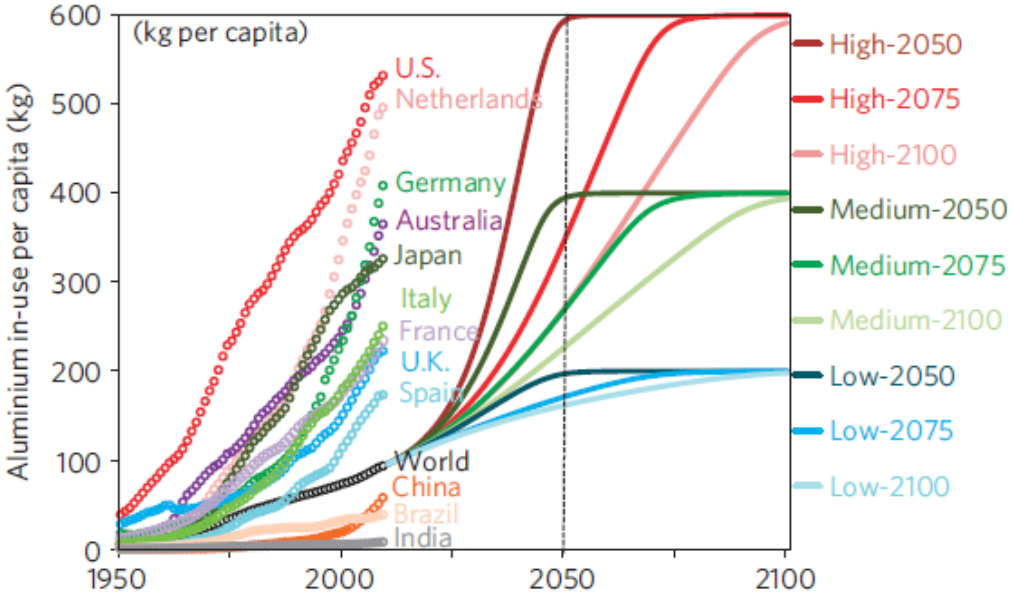
Stocks represent the lock-ins of the material cycles.

Introducing Technology Stocks

In-use stocks are used as drivers in dynamic models

Future demand scenarios can be created using projections for stock levels:

- ✓ Saturation level per country for different end-use categories (kg Al /capita)
- ✓ Year in which the saturation level should be reached
- ✓ Lifetime and standard deviation for different product categories

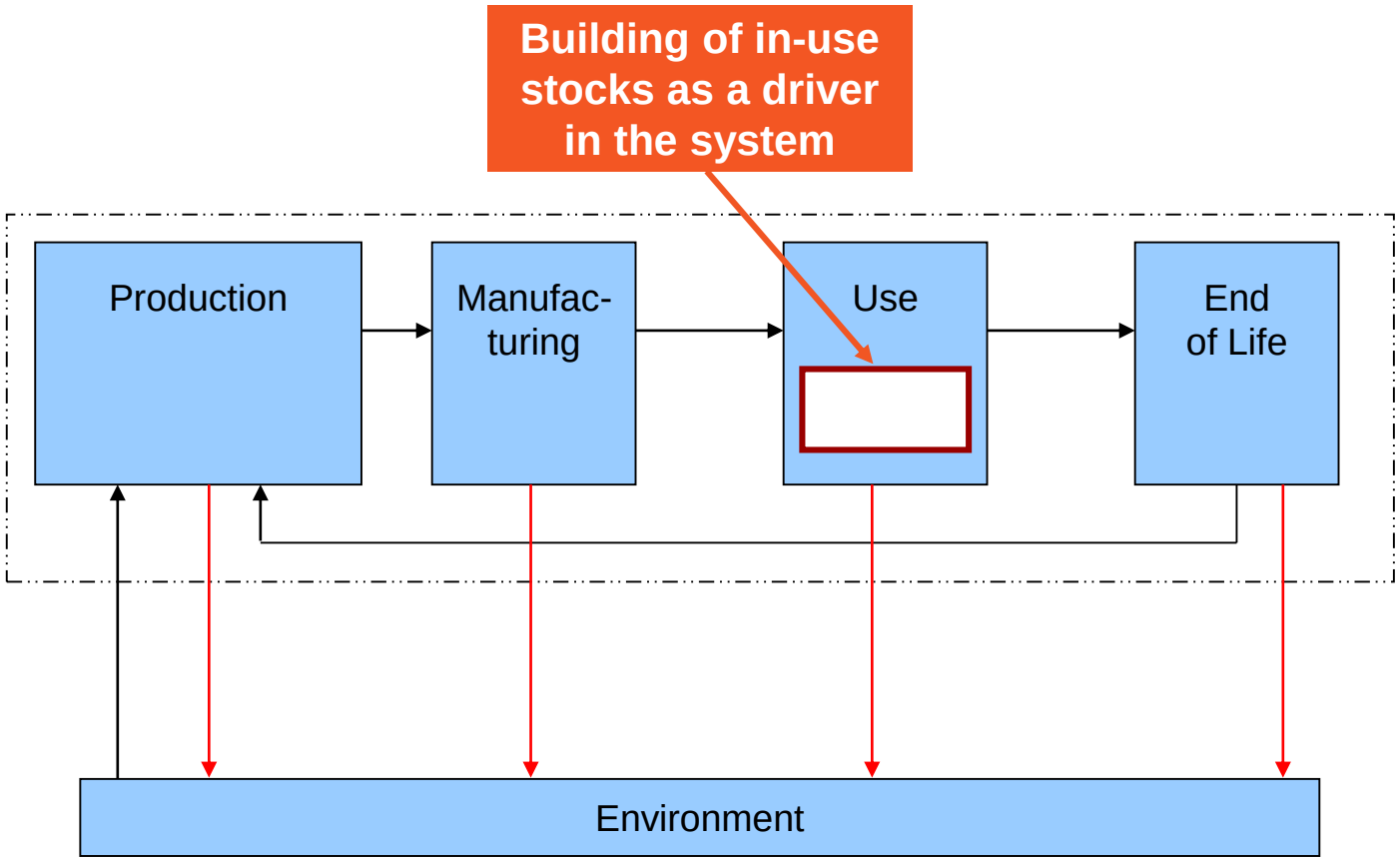


Example of demand scenarios from Liu, Müller and Bangs, 2013

Stocks are more robust than flows in the long term

Introducing Technology Stocks

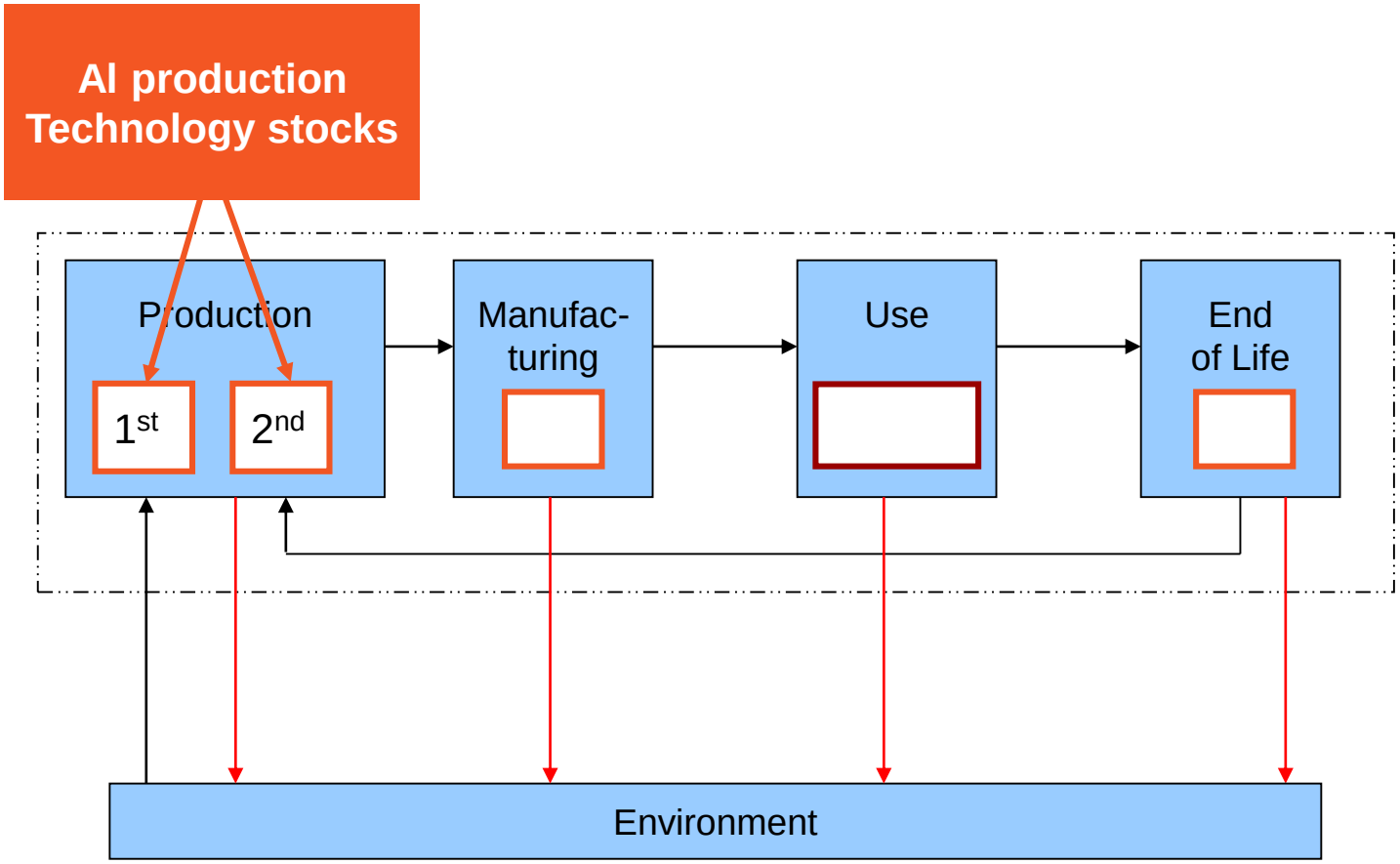
MFA has a strong history of studying in-use stocks



For products with long lifetimes, current and future in-use stocks influence future investments in technology

Introducing Technology Stocks

But what about technology stocks?



Technology and infrastructure stocks determine possible pathways for production and associated impacts

Introducing Technology Stocks

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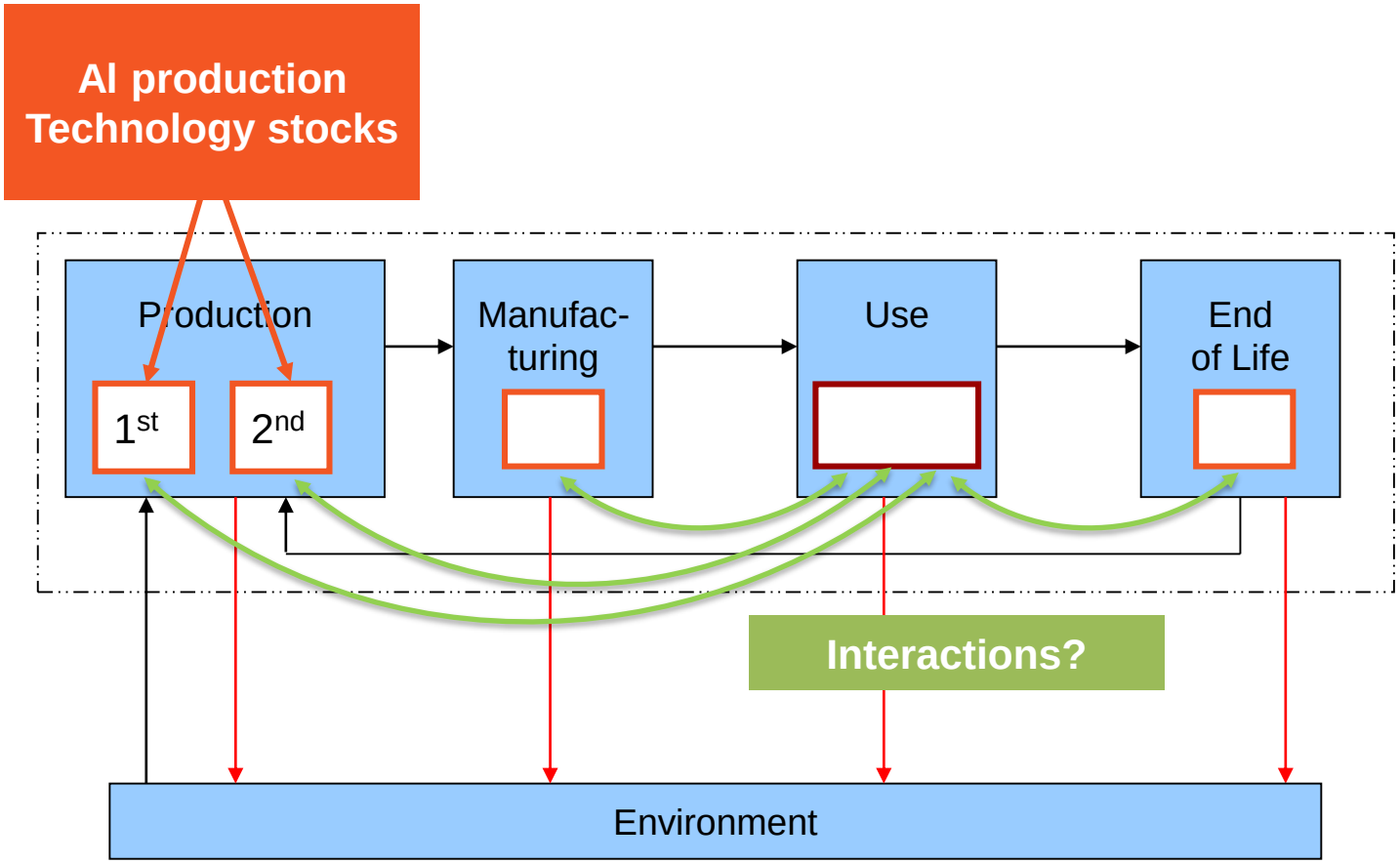


Technology and infrastructure stocks determine possible pathways for production and associated impacts

Introducing Technology Stocks

Rationale for studying technology stocks

Assumptions on technology stocks:

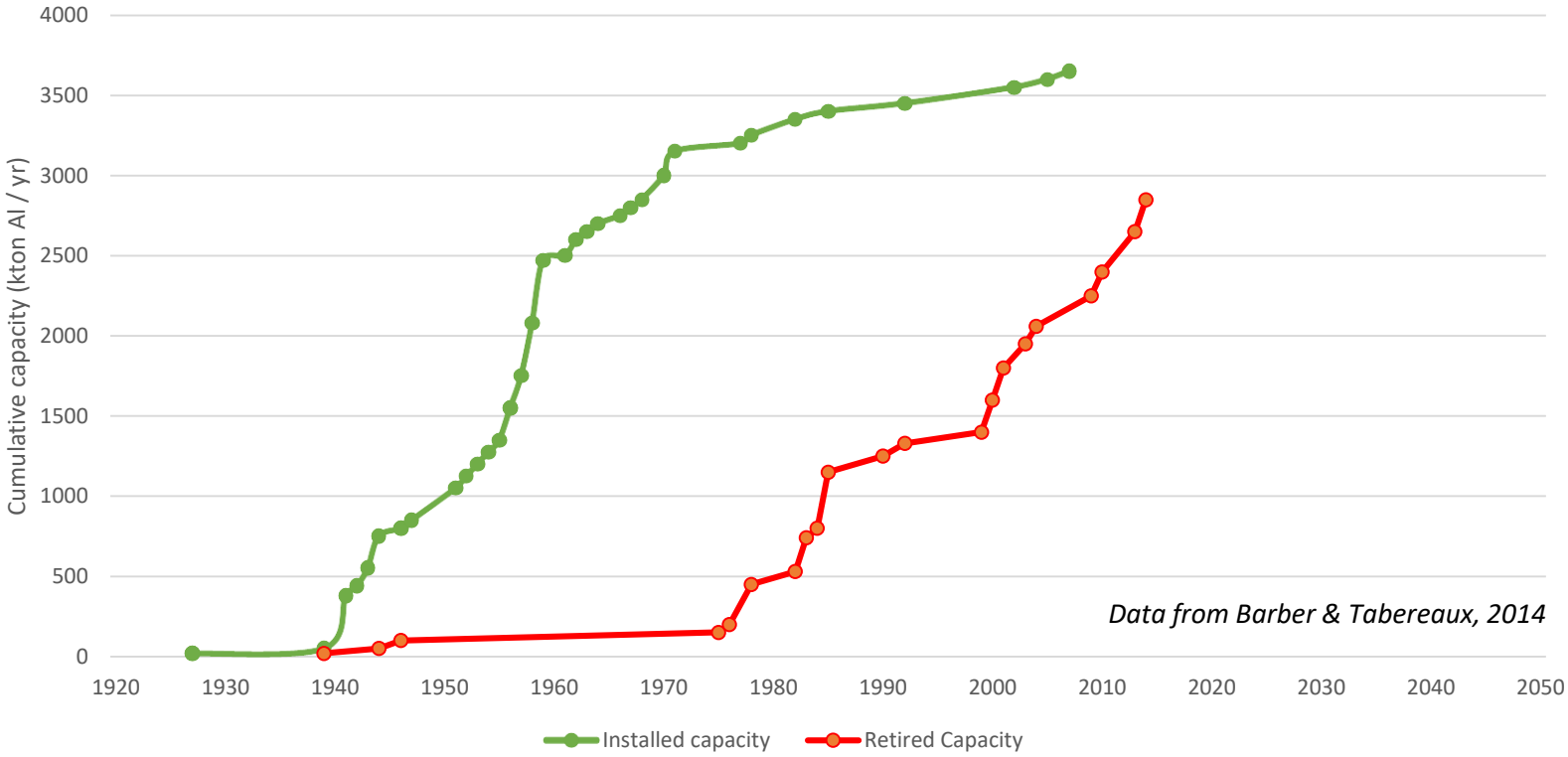
- ✓ All technology and infrastructure assets have a **finite lifetime** (because of aging, obsolescence, decreasing ore grades, etc.).
- ✓ Even if economic and politic factors have the largest influence in the short term, replacement of technology stocks in the long run can be statistically modelled using **stock dynamics**.
- ✓ The further upstream on the value chain, the more stable and long-lived technology and infrastructure assets are.
- ✓ They can be responsible for strong **lock-in effects**:
  - Most technology stocks have an even **longer lifetime** than in-use stocks
  - They require large investments, with long payback times
  - The penetration of new technologies takes time

Technology stocks are the most robust proxy for the evolution of transfer coefficients in the global aluminium cycle

Lifetime of Al technology stocks

Historical evidence: replacement of smelting capacity

Replacement of Søderberg technology in North and South American smelters

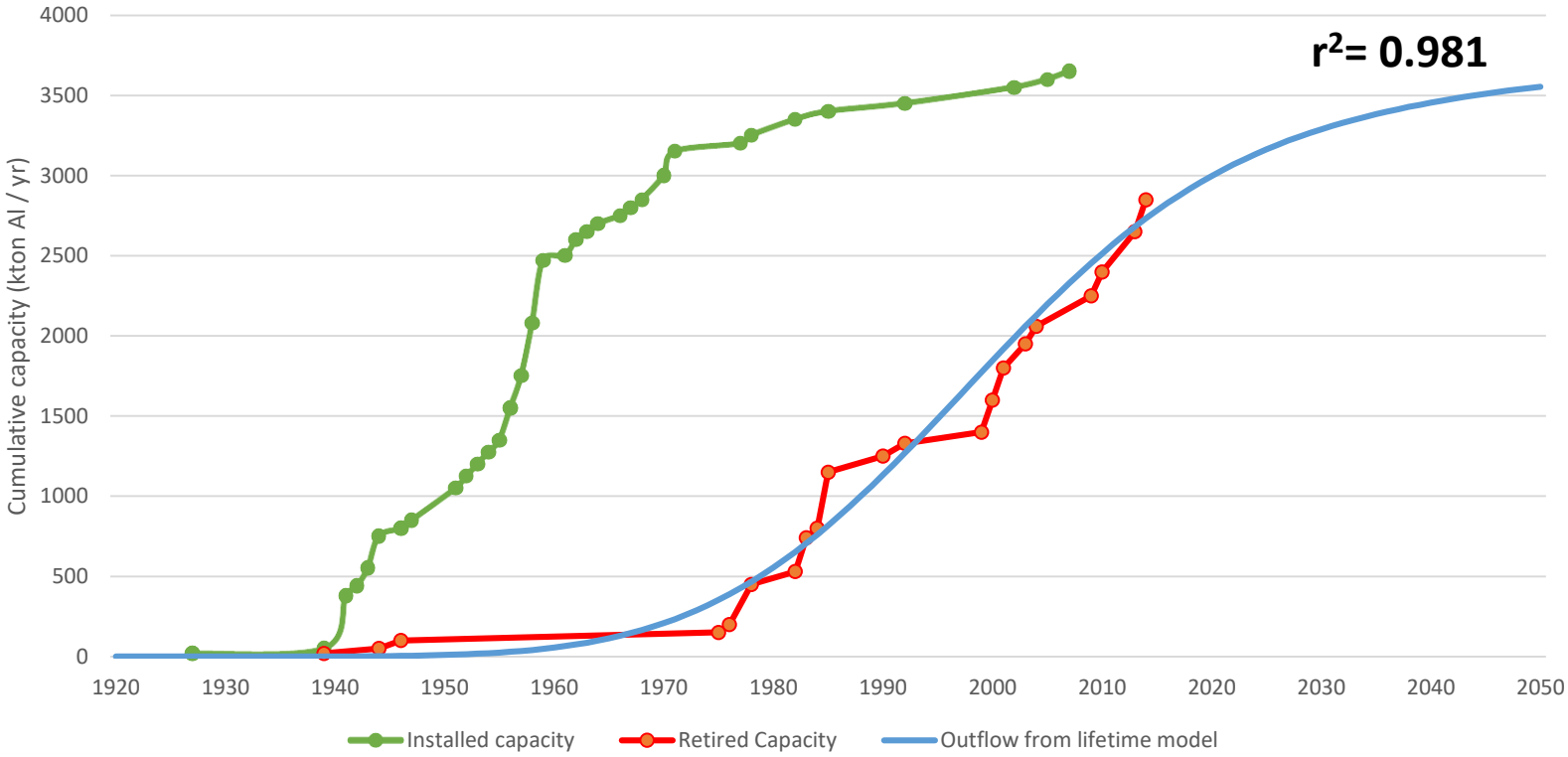


Is it possible to use a lifetime model for technology stocks?
Is the lifetime linked to physical characteristics of the plants, and not only to Al price?

Lifetime of Al technology stocks

Historical evidence: replacement of smelting capacity

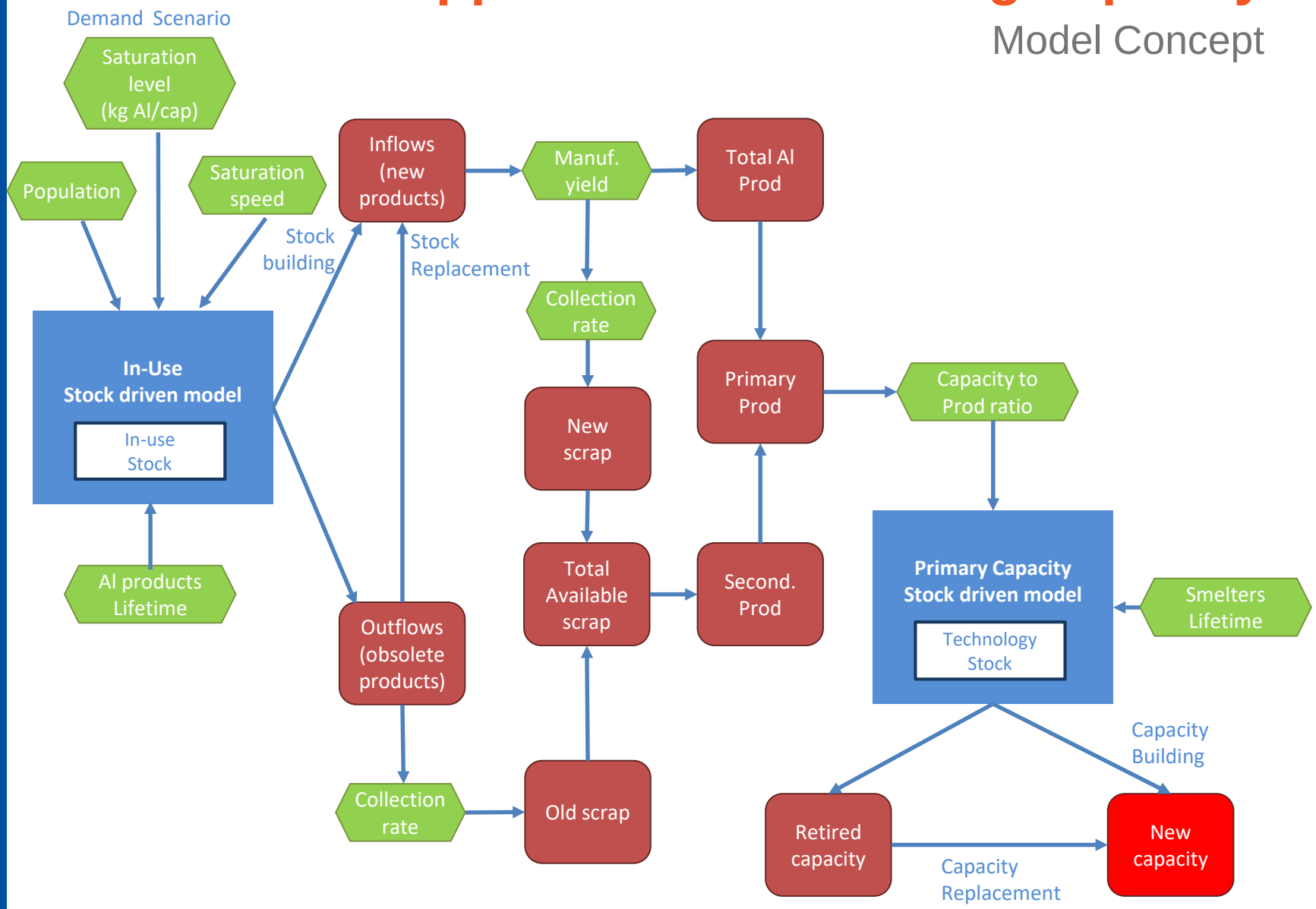
Replacement of Søderberg technology in North and South American smelters



Results with a normally distributed lifetime
Mean: 42 years; standard deviation: 15 years

Application to smelting capacity

Model Concept



Results

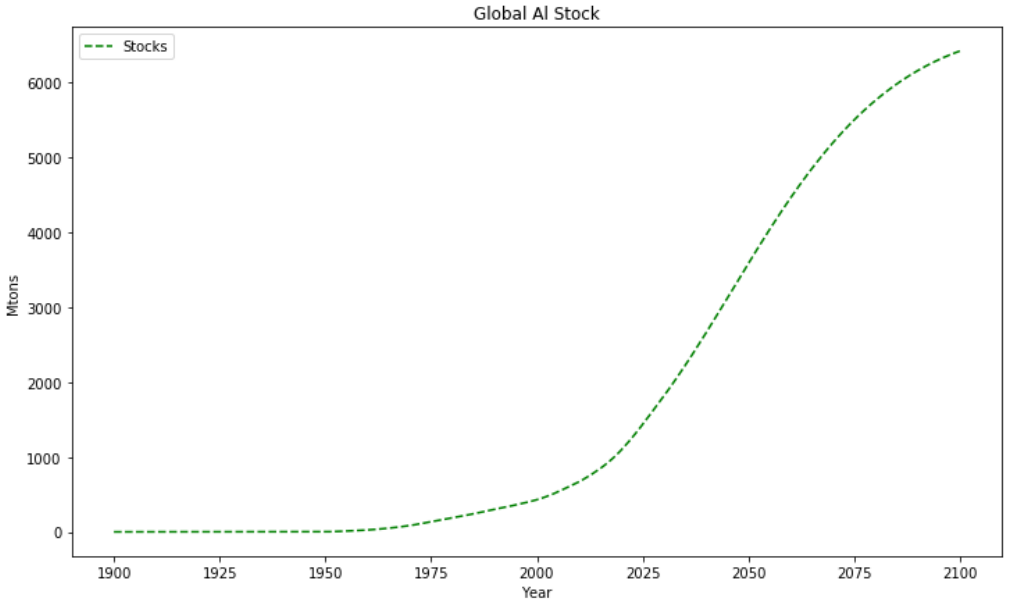
Parameters for the baseline scenario

Lifetime and transfer coefficients:

- Lifetime of primary capacity: 40 years ± 15
- Lifetime of Aluminium in-use stocks: 23 years ± 15
- New scrap collection and recycling ratio: 0,98
- Old scrap collection and recycling ratio: 0,8
- Production to use ratio: 1,15
- Capacity to production ratio: 1,05

Demand parameters:

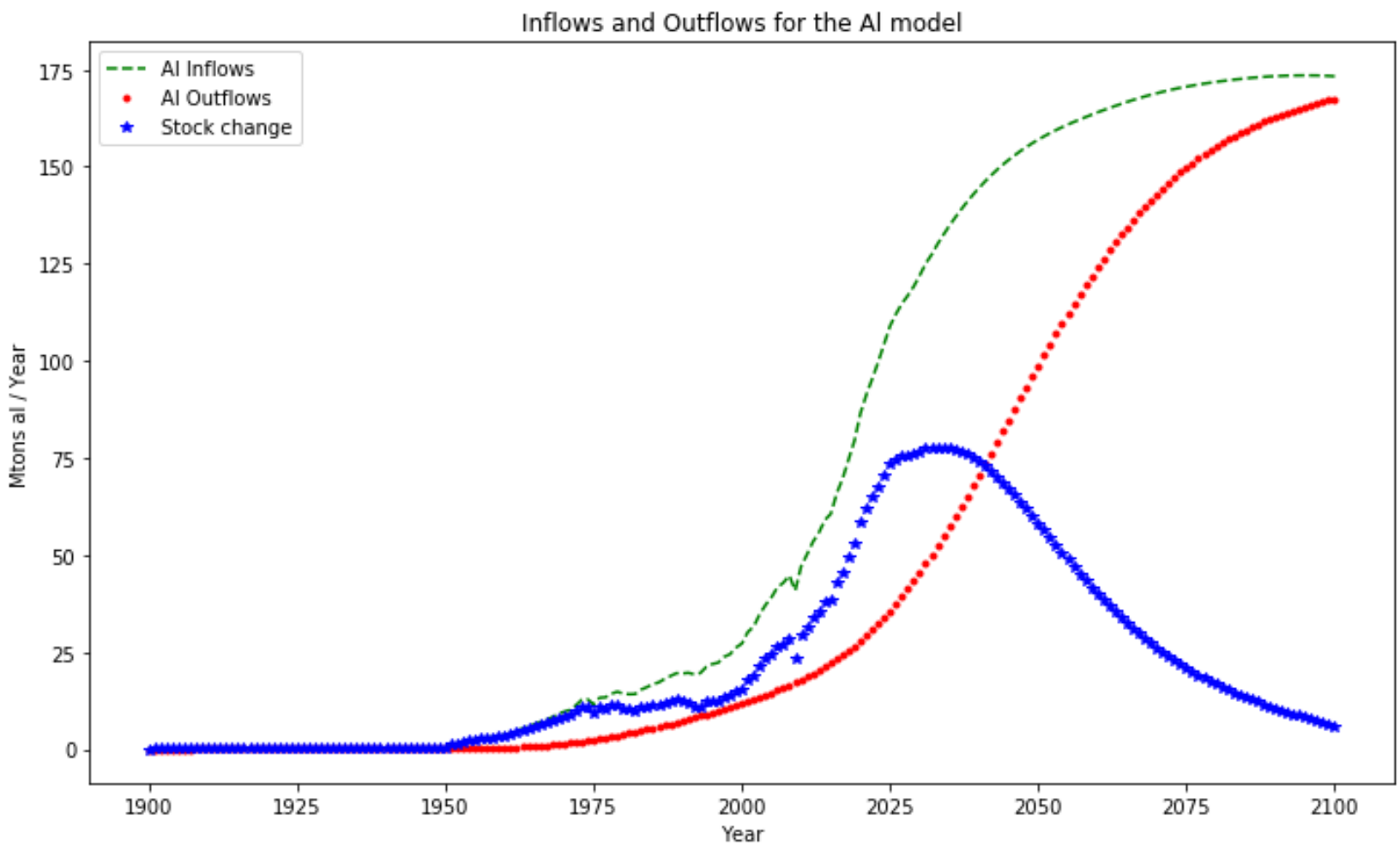
- Saturation level :
  400 kg Al/cap globally
- Saturation speed:
  Medium (2075)
- Population:
  Medium UN scenario
  (11,2 billions in 2100)



Results

Baseline scenario

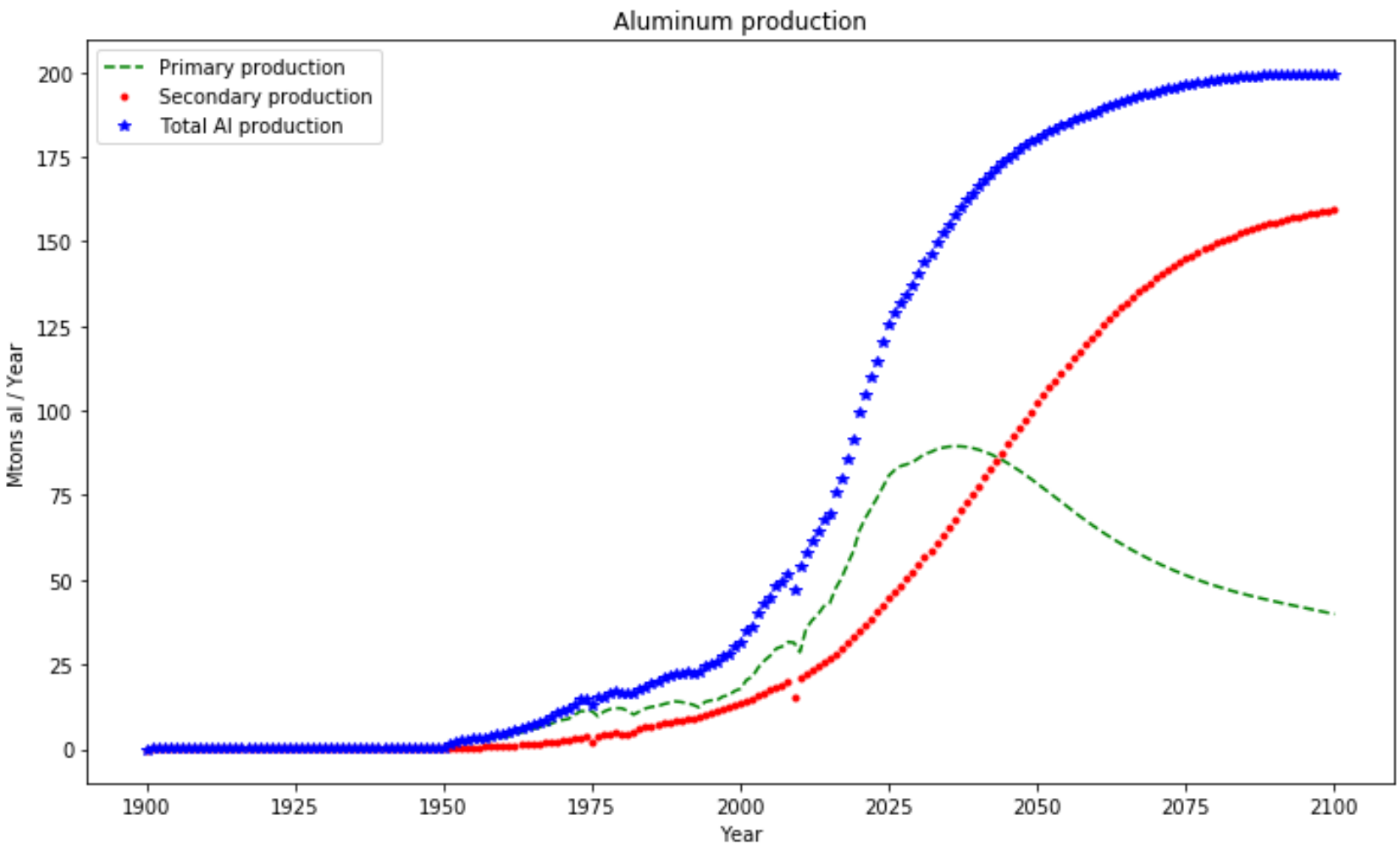
Stock-driven Aluminium model



Results

Baseline scenario

Primary vs. Secondary production



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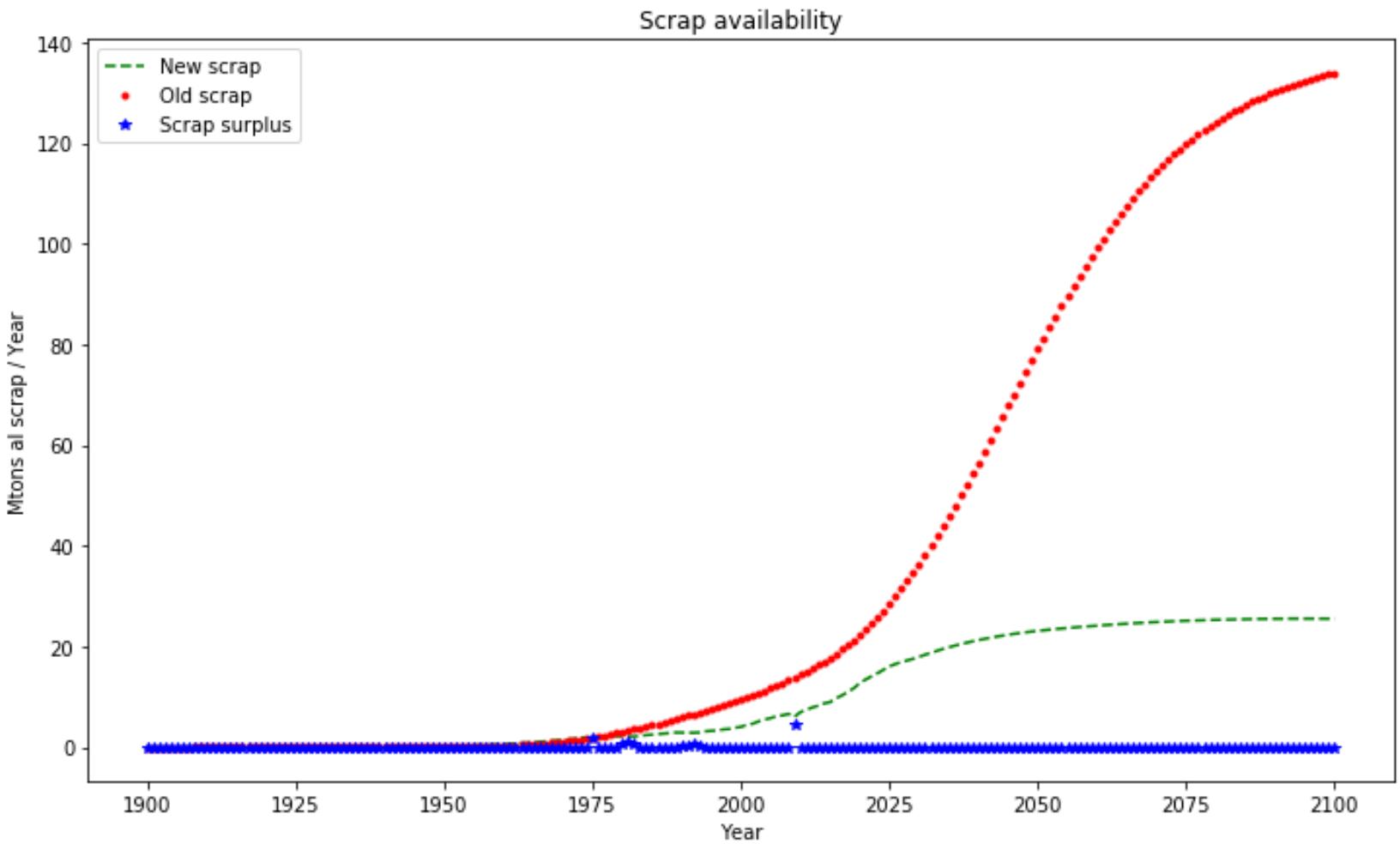
Baseline scenario

Scrap availability:



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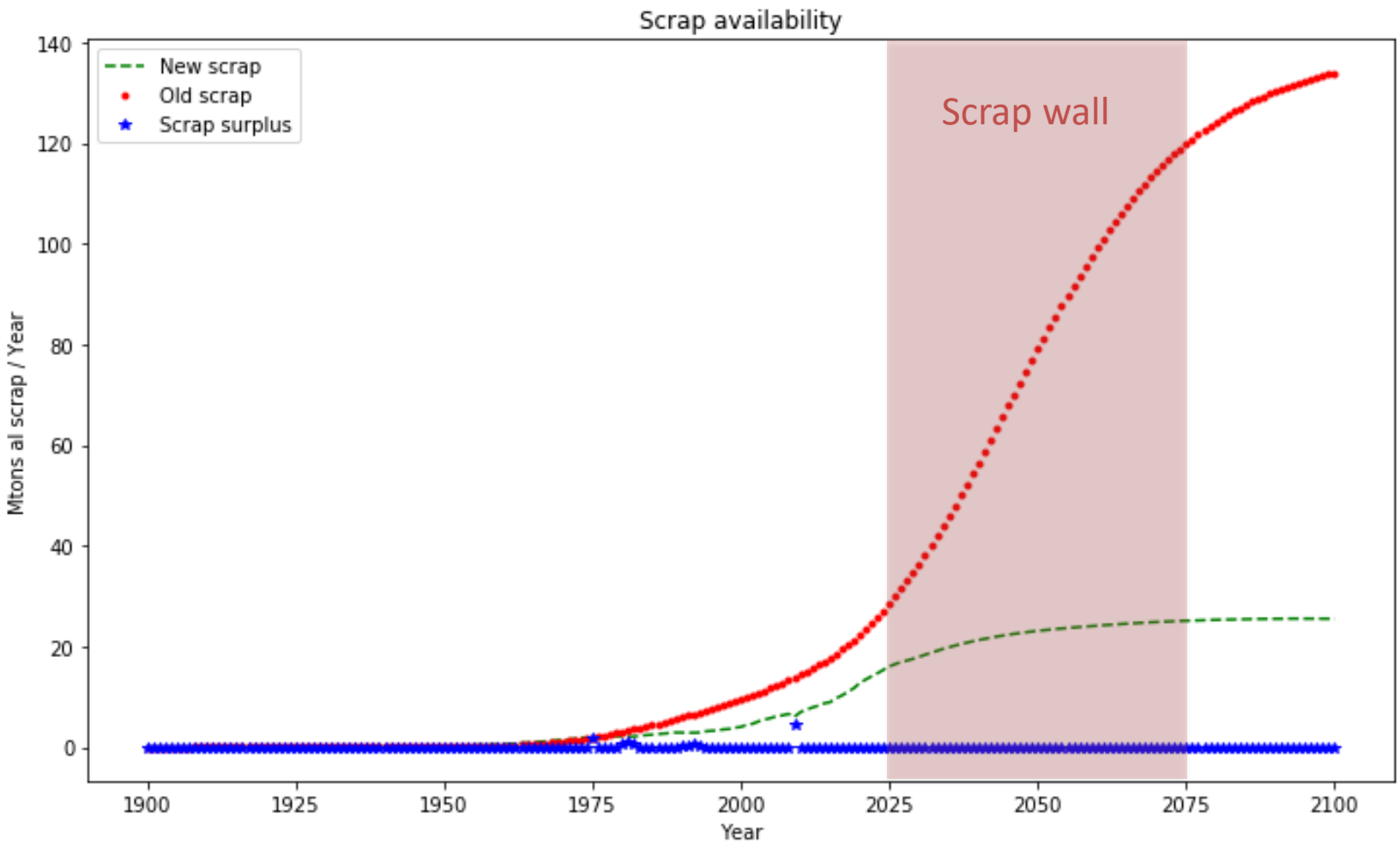

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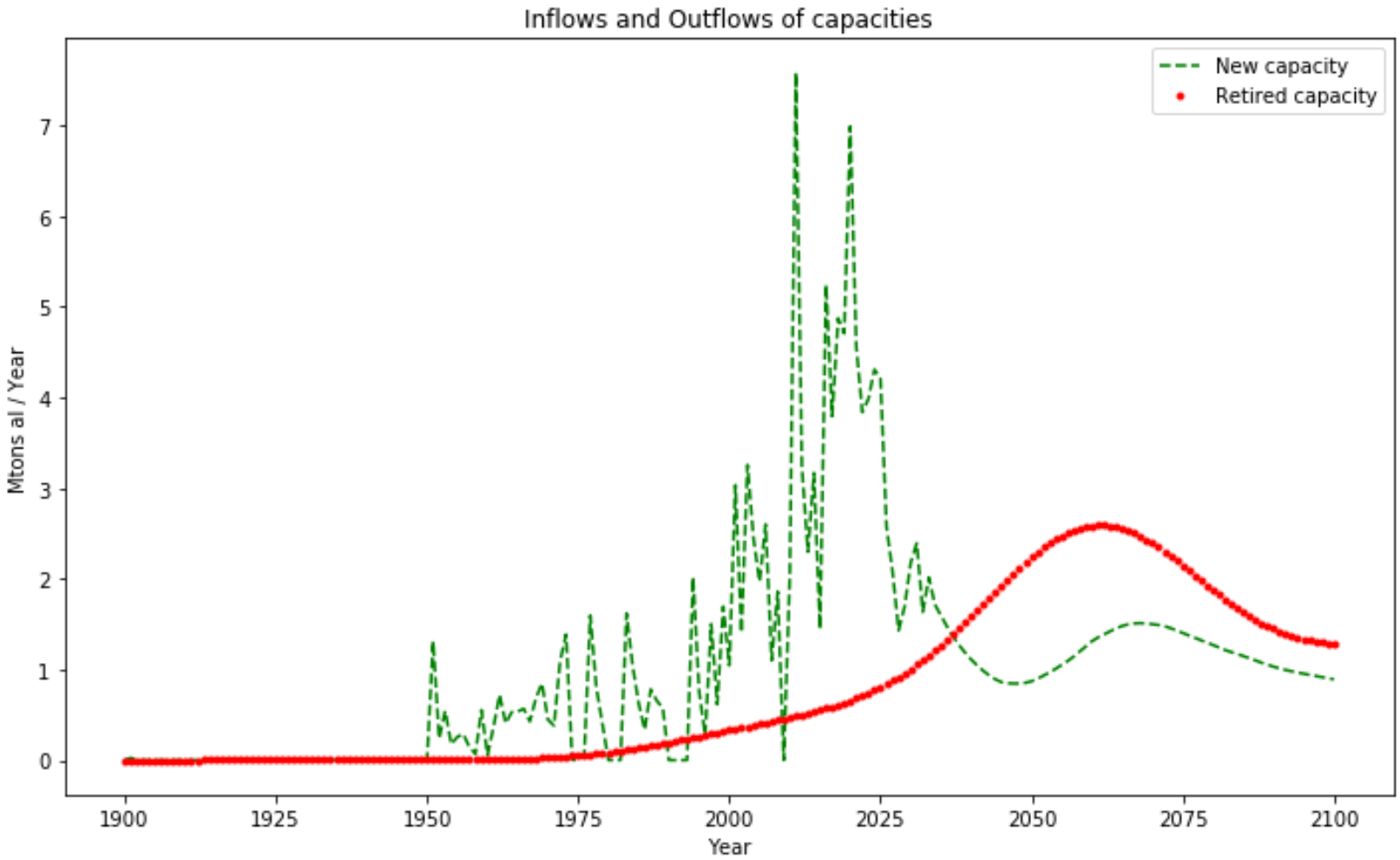
Baseline scenario

Primary production capacity model:



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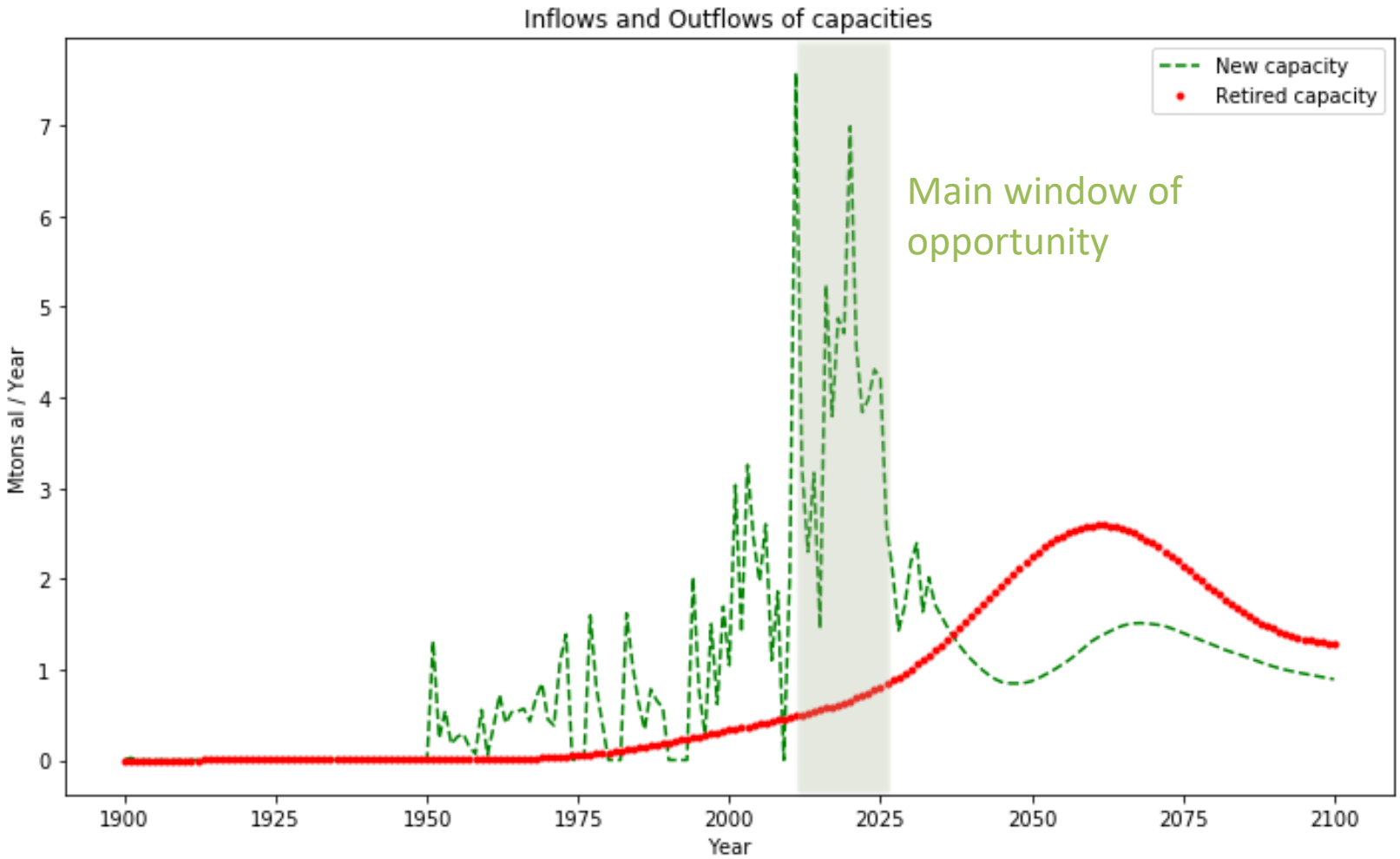

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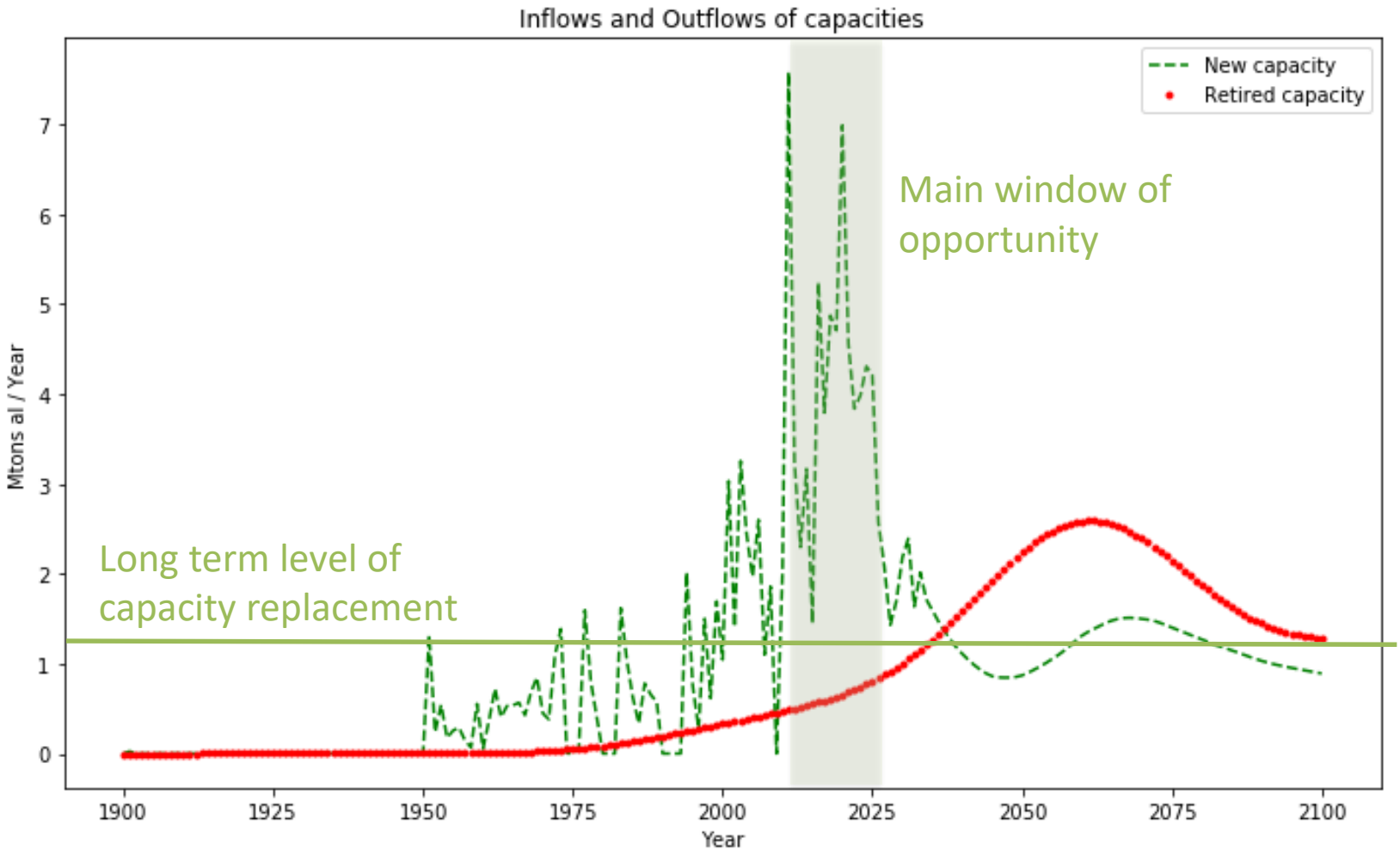

Results

Should we be afraid of what lies behind the scrap wall?

Results

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Results

Should we be afraid of what lies behind the scrap wall?

Even if the model and assumptions are still very crude, some fundamentals emerge:

- ✓ Even in optimistic scenarios for future aluminium demand, the need for **primary capacity saturates quickly** as scrap availability increases
- ✓ The main window of opportunity for new primary tech is short: **before 2030.**
- ✓ **No major risks of scrap surplus are identified globally**. This means no overcapacity of primary and secondary production combined.
  - ➢ How would the system actually react in the real world? Which would be more impacted by a drop in prices, primary or secondary production?
  - ➢ Issues of scrap quality and regional differences are not considered
  - ➢ Trade restrictions might cause other problems
- ✓ No apparent risk of early retirement for secondary production.
  - ➢ But what is the incentive to invest in secondary production when primary is so cheap?

Results

Consequences for primary production

There seems to be little risk of early retirement for primary production, but:

- ✓ Investment in primary production is needed today, despite low prices. The smelters that will be built in the next years will impact the cycle until 2050 and beyond.

- ✓ There is a high risk of a **lock-in effect** which will prevent any decarbonisation of the aluminium cycle, especially:
  - ➢ If smelters are not built up to the best energy efficiency standards
  - ➢ If they rely on carbon-based electricity
  - ➢ If they have a long planned lifetime without options for retrofitting

- ✓ Does it make sense to keep investing in new technologies for primary production?
  - ➢ Future technologies would need to be **mature before 2030**, or allow **retrofitting** to existing smelters.
  - ➢ **Incremental change is favoured**, unless market conditions change drastically: stricter regulations, de-commodification, trade barriers…
  - ➢ In the medium and long term, developing end of life technologies is more important

Conclusion

First findings and challenges for modelling technology stocks

- ✓ Because of their long lifetime and impact on material cycles, technology stocks should be included more frequently in scenario analyses.
- ✓ A technology explicit model has **higher data requirements**, especially if the whole value chain is consider.
- ✓ **Regionalisation** of the model is needed to build relevant scenarios for GHG emissions… but to which extent is the carbon intensity of the electricity used for smelting relevant?
- ✓ Many factors influencing the aluminium cycle remain unpredictable: scenarios will not be forecasts, but strategic tools that can be used on a "what if" basis.
  - ➢ A **visualisation** that allows the update of parameters live would be useful.
- ✓ Possible storylines for more complex scenarios:
  - ➢ Continued regionalisation trends, "trade wars"
  - ➢ De-commodification: responsible sourcing, low GHG labels
  - ➢ Technological breakthroughs (inert or bio-sourced anodes, direct reduction, CCS…) and potential lock-ins
  - ➢ Increasing collection and recycling rates
  - ➢ Linkage between demand-side and technology-side scenarios

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metal production

sfi Senter for forskningsdrevet innovasjon

Thank you!

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SINTEF NTNU teknova HYDRO ALCOA GLENCORE

ERAMET NORWAY FINNFJORD Elkem WACKER TiZir Titanium & Iron

Some facts about smelting capacity

Smelting technology is becoming more energy efficient…

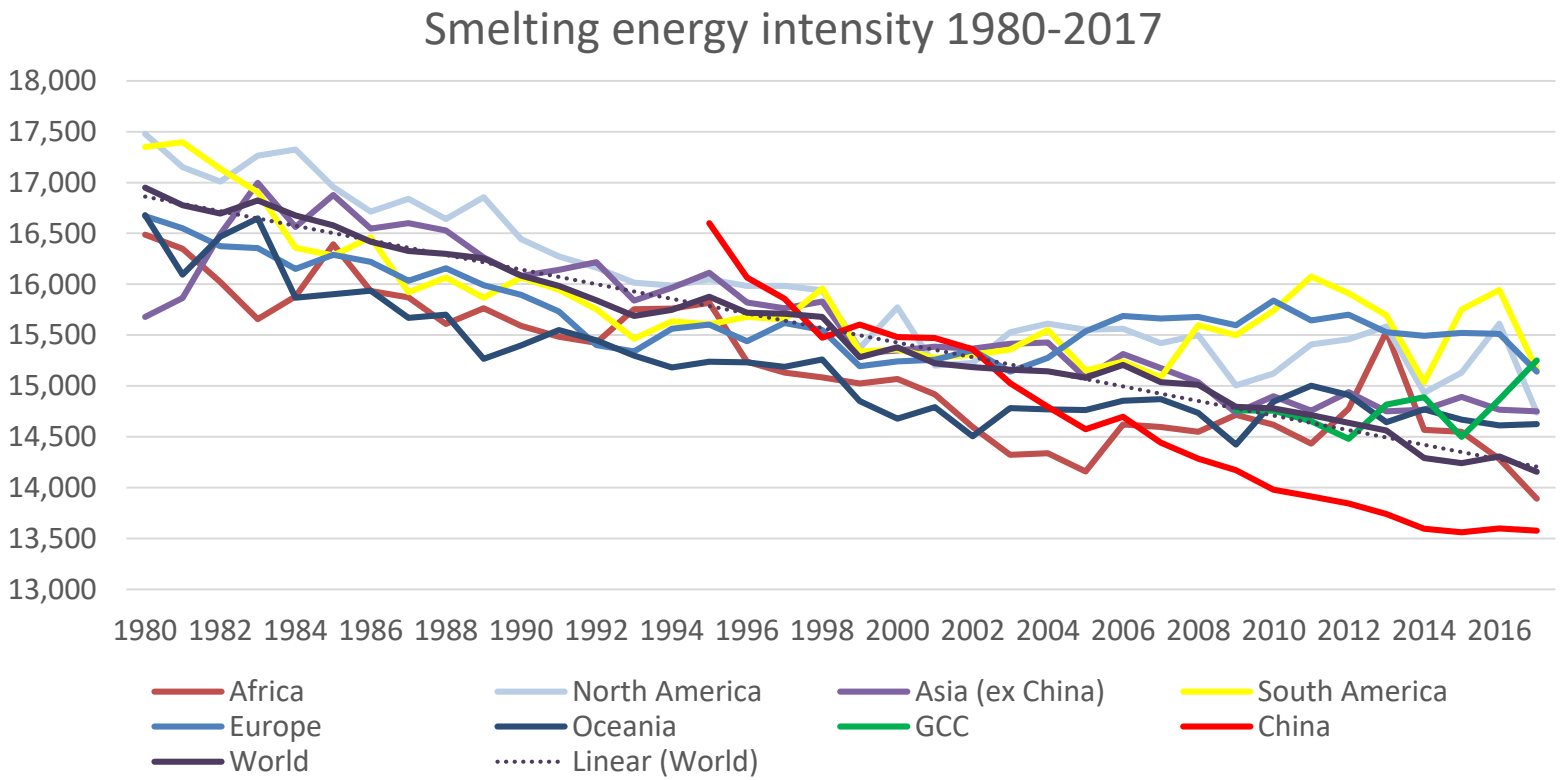
Despite the currently tough market, all future demand scenarios predict that more smelting capacity is needed in the coming years: **when, where and with which technology this capacity will be built?**

- ✓ Is this increase in capacity in line with current technological cycles?
- ✓ How much of the current capacity will remain in use in the coming years?
- ✓ Can a more competitive market actually increase the penetration of new technologies?
- ✓ Given the time horizons of these investments, what are the consequences for global warming of the lock-ins resulting from this new capacity?
- ✓ Which world regions are more likely to absorb this new demand?
- ✓ Which power sources will be used?

Does China have the means and will to keep increasing its capacity as fast as in the recent years?

Application to smelting capacity

Smelting technology is becoming more energy efficient…

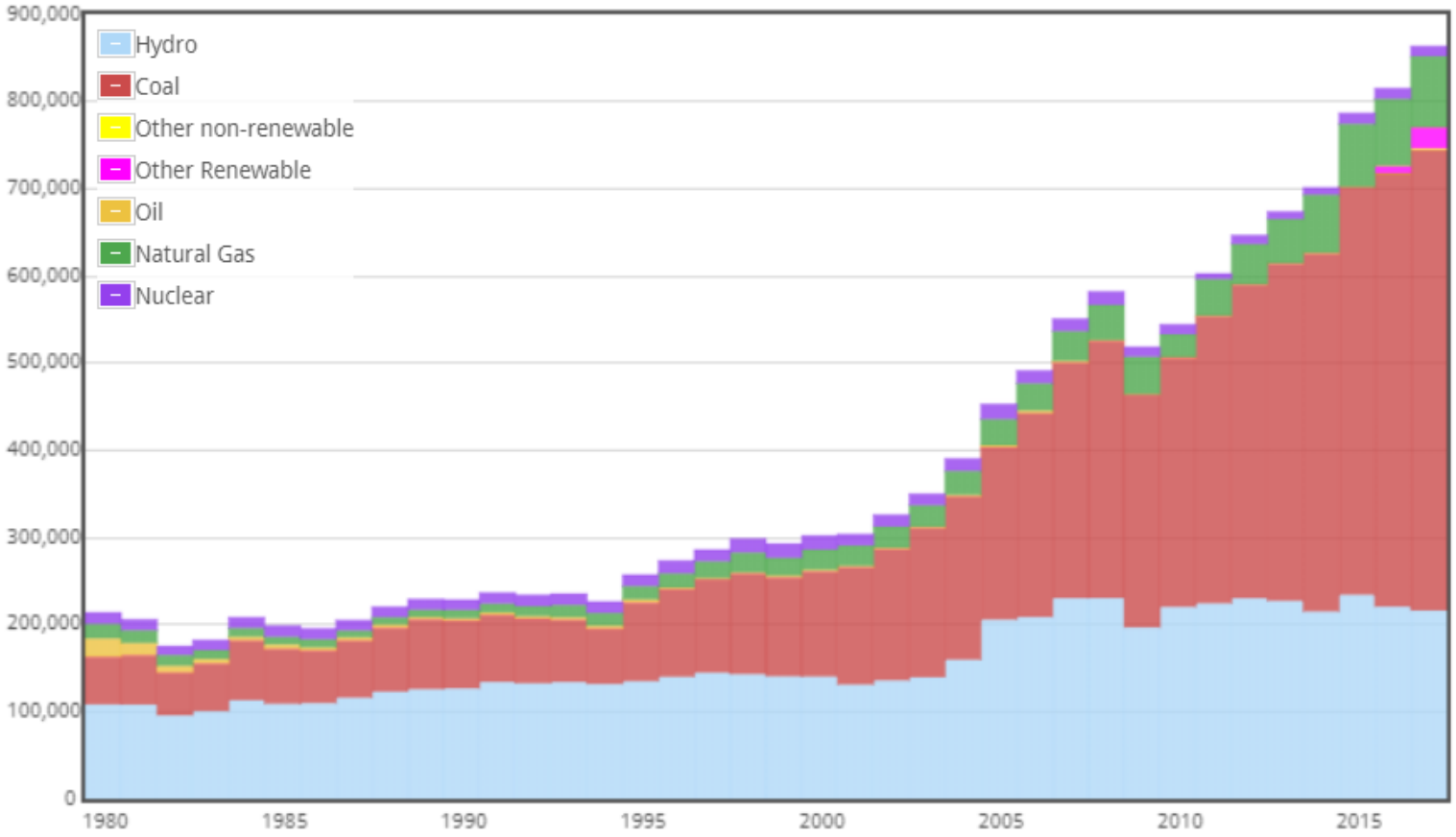


Source: IAI,2019

China has the most modern parc of smelters

Application to smelting capacity

…but less carbon efficient



Source: IAI,2019

Most new smelters rely on cheap fossile energy (coal in Asia, gas in Middle East)