

Circularity: a critical ingredient for a resilient, responsible and sustainable energy transition

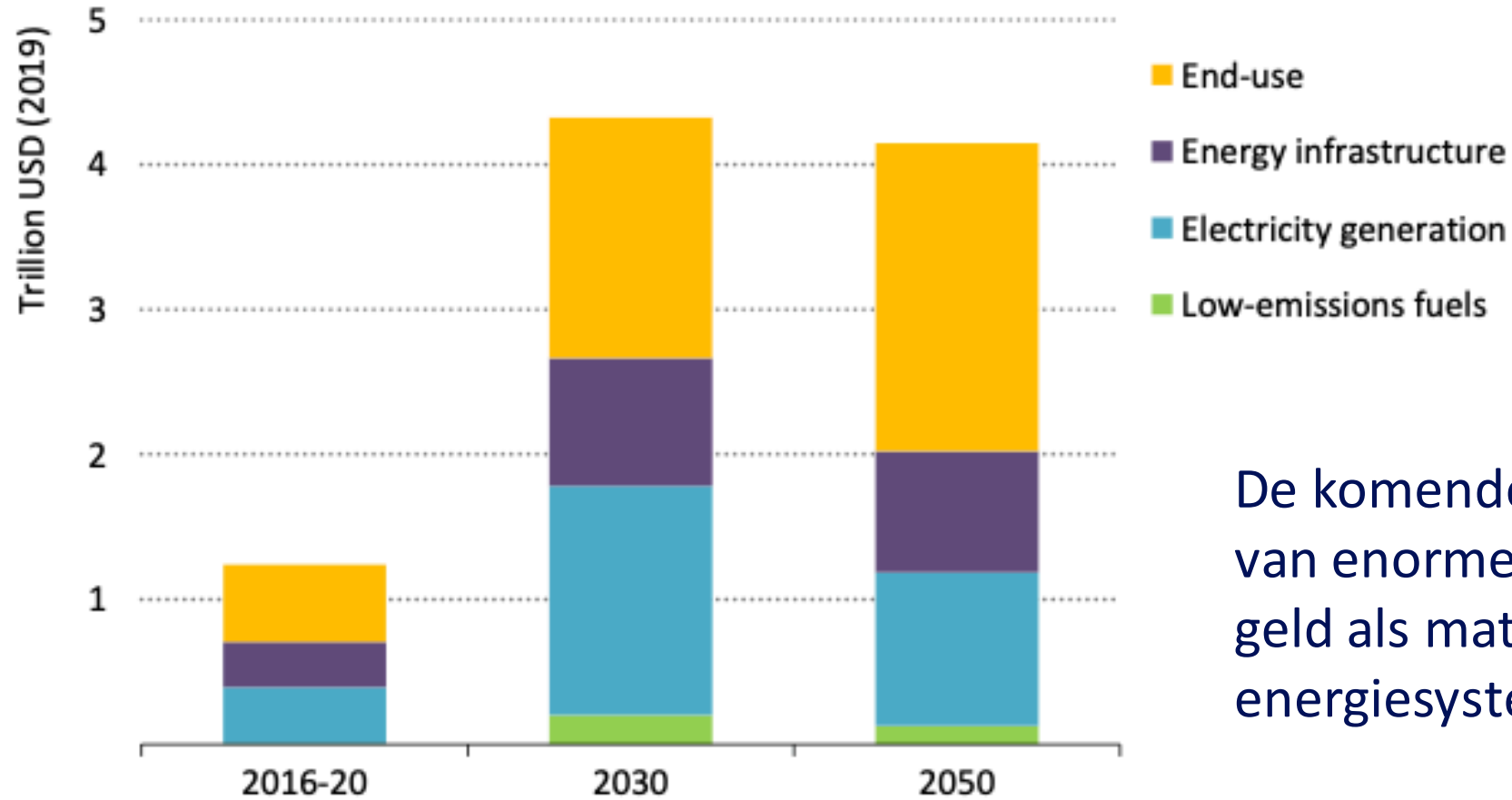
René Kleijn, Institute of Environmental Sciences (CML)



**Universiteit
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The Netherlands

Green ambitions

Clean energy investment in the net zero pathway



Net Zero by 2050

A Roadmap for the Global Energy Sector

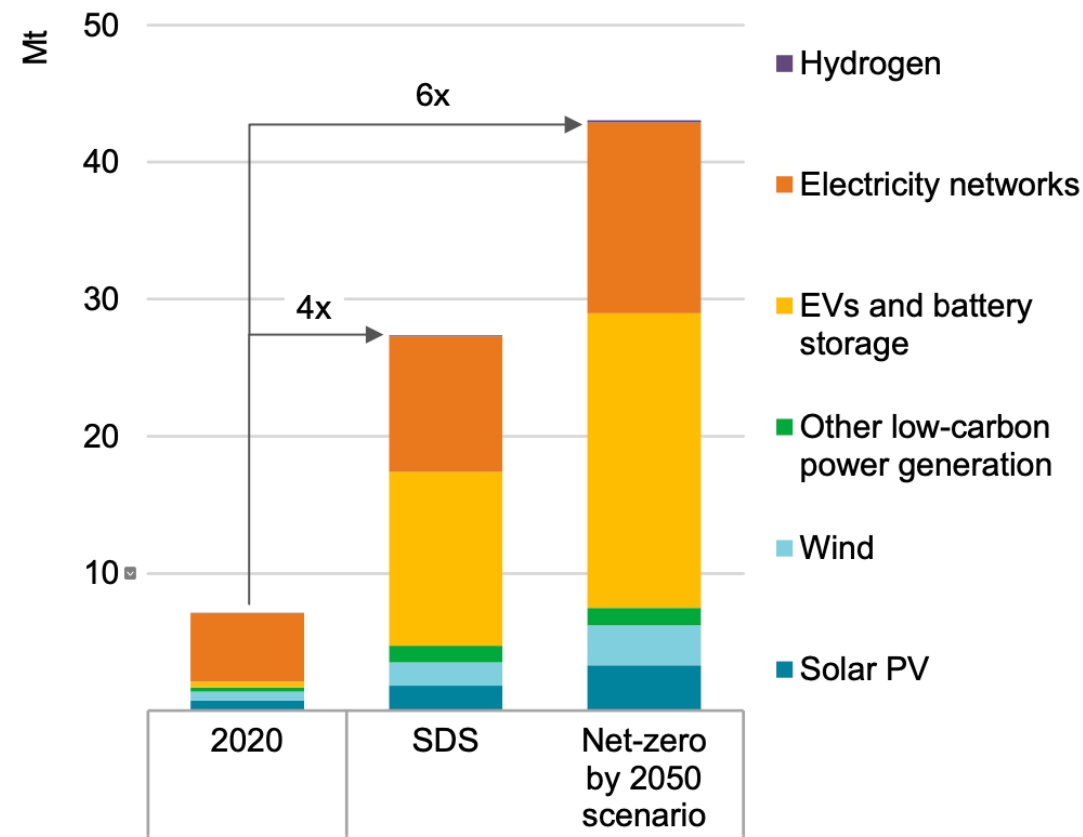
International
Energy Agency

De komende 30 jaar staan in het teken van enorme investeringen van zowel geld als materiaal in het hernieuwbare energiesysteem

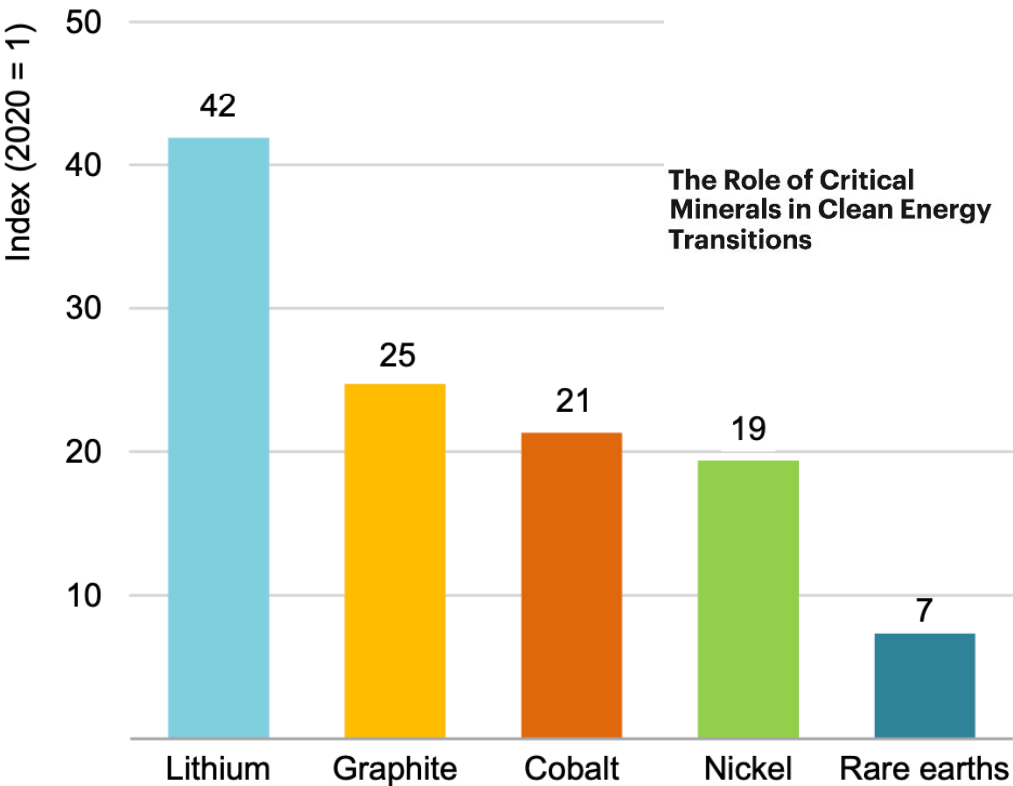
Critical minerals for the energy transition

Mineral demand for clean energy technologies by scenario

Growth to 2040 by sector



Growth of selected minerals in the SDS, 2040 relative to 2020



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Notes: Mt = million tonnes. Includes all minerals in the scope of this report, but does not include steel and aluminium. See Annex for a full list of minerals.

Supply of raw metals is under pressure

S&P Capital IQ PRO

Copper demand to outstrip supply amid energy transition, China Molybdenum says

Wednesday, March 30, 2022 11:58 AM ET

S&P Capital IQ PRO

Lithium producers unable to meet near-term demand

Tuesday, March 15, 2022 8:57 AM ET

Bloomberg

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Nickel-Price Surge Adds Pressure Onto Stainless-Steel Products

By [Thomas Gualtieri](#)

March 17, 2022, 12:03 PM GMT+1

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Chinese Electric Carmaker Calls Battery Price Hikes 'Ridiculous'

- Li Auto CEO took to social media platform Weibo over weekend
- Xpeng, BYD, WM Motor have all increased prices in recent weeks

The war in Ukraine hampers supply

The image shows the top section of a news article. At the top, there is a dark, textured banner. Below it, on a light beige background, is the article's header. On the left, it says 'The Big Read' in black, followed by 'Renewable energy' in red. To the right of this is a red pill-shaped button with the white text '+ Add to myFT'. The main title of the article, 'Will the Ukraine war derail the green energy transition?', is written in a large, bold, black serif font. Below the title is a thick black horizontal line. Underneath the line, a sub-headline in a smaller black serif font reads: 'As Europe scrambles to find alternatives to Russian oil and gas and global energy prices soar, coal could be the winner'. At the bottom of this section, the authors 'Leslie Hook and Neil Hume' are listed in black, followed by the date 'MARCH 8 2022' in a lighter grey font. On the far right, there is a small icon of a speech bubble and the number '292' in black.

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The war also geares up the transition

Bloomberg Green

Energy Crunch Spurs 'Insane' Rush for Industrial Rooftop Solar

- Demand for on-site solar power has surged in recent weeks
- Europe's industry can cut costs by boosting renewable power

Bloomberg

Sig

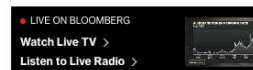
U.K. to Ramp Up Offshore Wind Targets in Energy Security Push

- Government set to publish energy supply plan next week
- Johnson wants to lower dependence on Russia due to Ukraine



Photographer: Kiyoshi Ota/Bloomberg

By Alex Morales
March 17, 2022, 6:13 PM GMT+1



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There are many ways to change the energy future using technology, finance, planning and permission, public perception, and policy

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There are many ways to change the energy future using technology, finance, planning and permission, public perception, and policy

National governments see opportunities and seek bilateral deals

The New York Times

Daily Business Briefing >

Biden Invokes Cold War Statute to Boost Critical Mineral Supply

The action aims to enhance American production of crucial materials for electric vehicles, defense systems and other technologies.

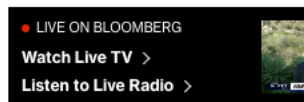
Bloomberg

Australia Plans Rare Earths Boost to Fight China 'Dominance'

- PM Morrison will announce \$175 million for four projects
- U.S. and allies want to diversify suppliers of critical metals

By Ben Westcott

March 16, 2022, 12:17 AM GMT+1 Updated on March 16, 2022, 3:49 AM GMT+1



Bloomberg

World Taps Canada for Potash, Uranium as War Roils Markets

- Russia's invasion of Ukraine has disrupted global supplies
- 'We have been approached,' Canadian government confirms



FINANCIAL TIMES

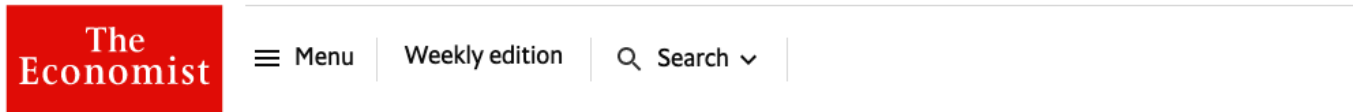
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China merges 3 rare earths miners to strengthen dominance of sector

Broader geopolitical consequences



Environmental impacts of green ambitions

S&P Capital IQ ^{PRO}

Miners face 'enormous' challenge to make copper cleaner for energy transition

Thursday, March 31, 2022 11:05 AM ET

By Kip Keen
Market Intelligence

S&P Capital IQ ^{PRO}

Responsible cobalt from Congo artisanal mining proving a challenge for industry

Friday, March 25, 2022 3:06 AM ET

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Biden faces green dilemma in push to build US rare earths capacity

White House wants to reduce reliance on China for critical materials but environmentalists have raised objections

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Greenland election won by party opposed to rare earths mining project

Left-green victory likely to be watched by US and China amid geopolitical fight over Arctic's future

Building the material stocks in renewables

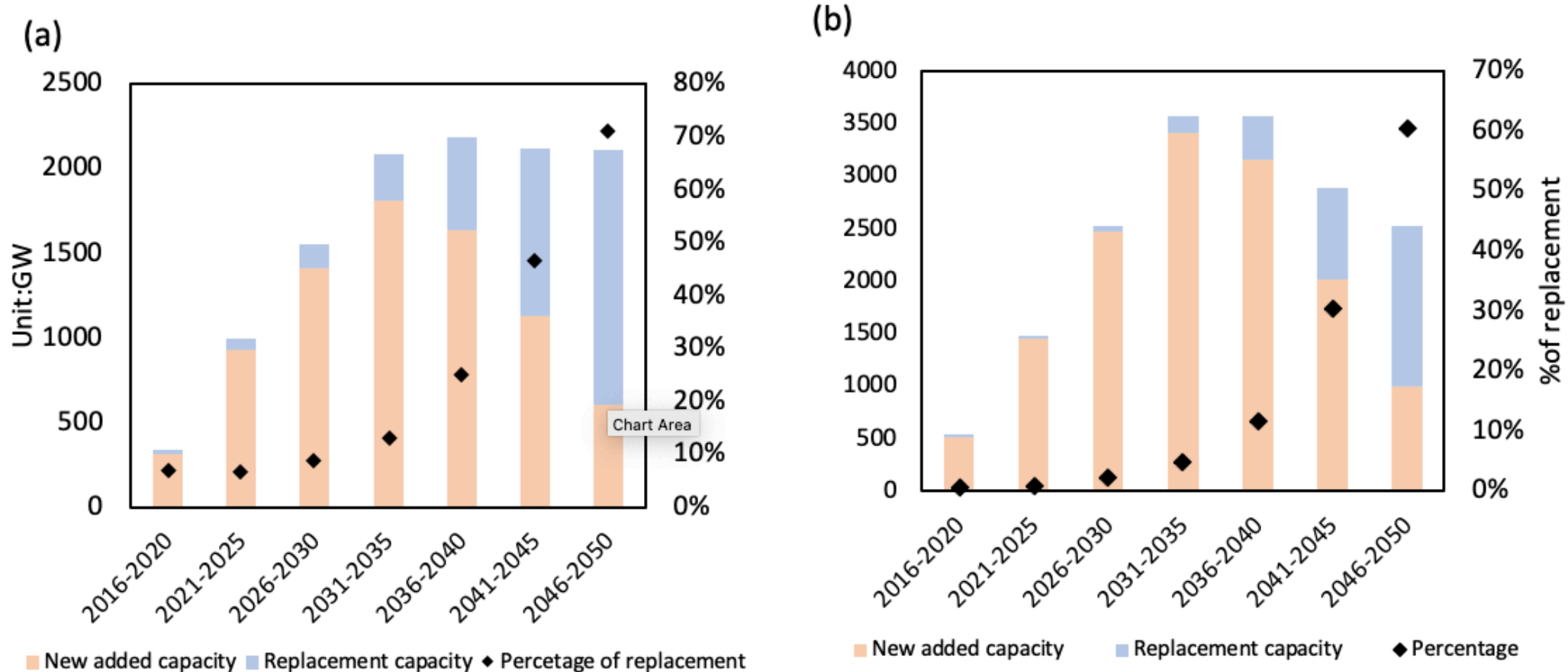
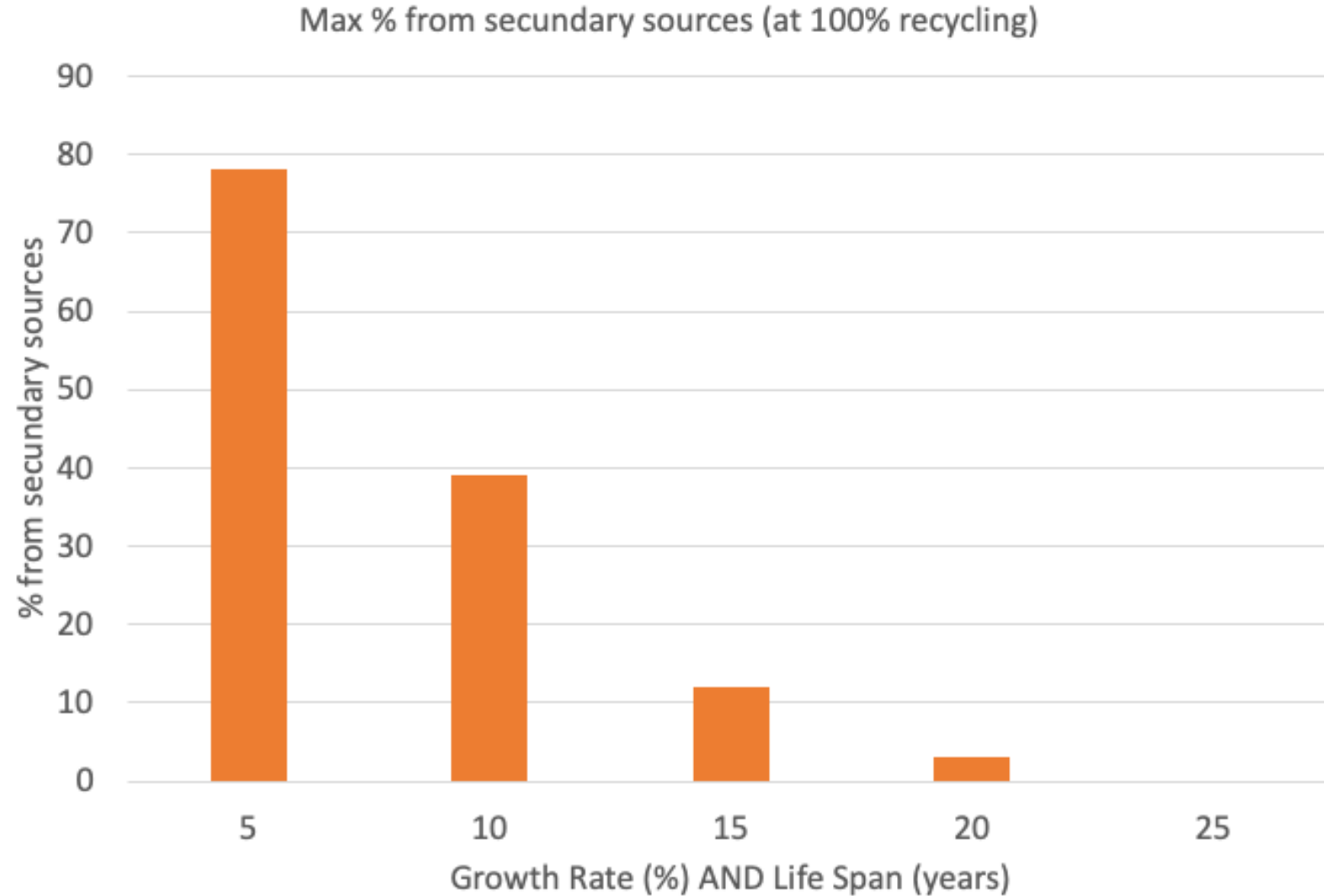


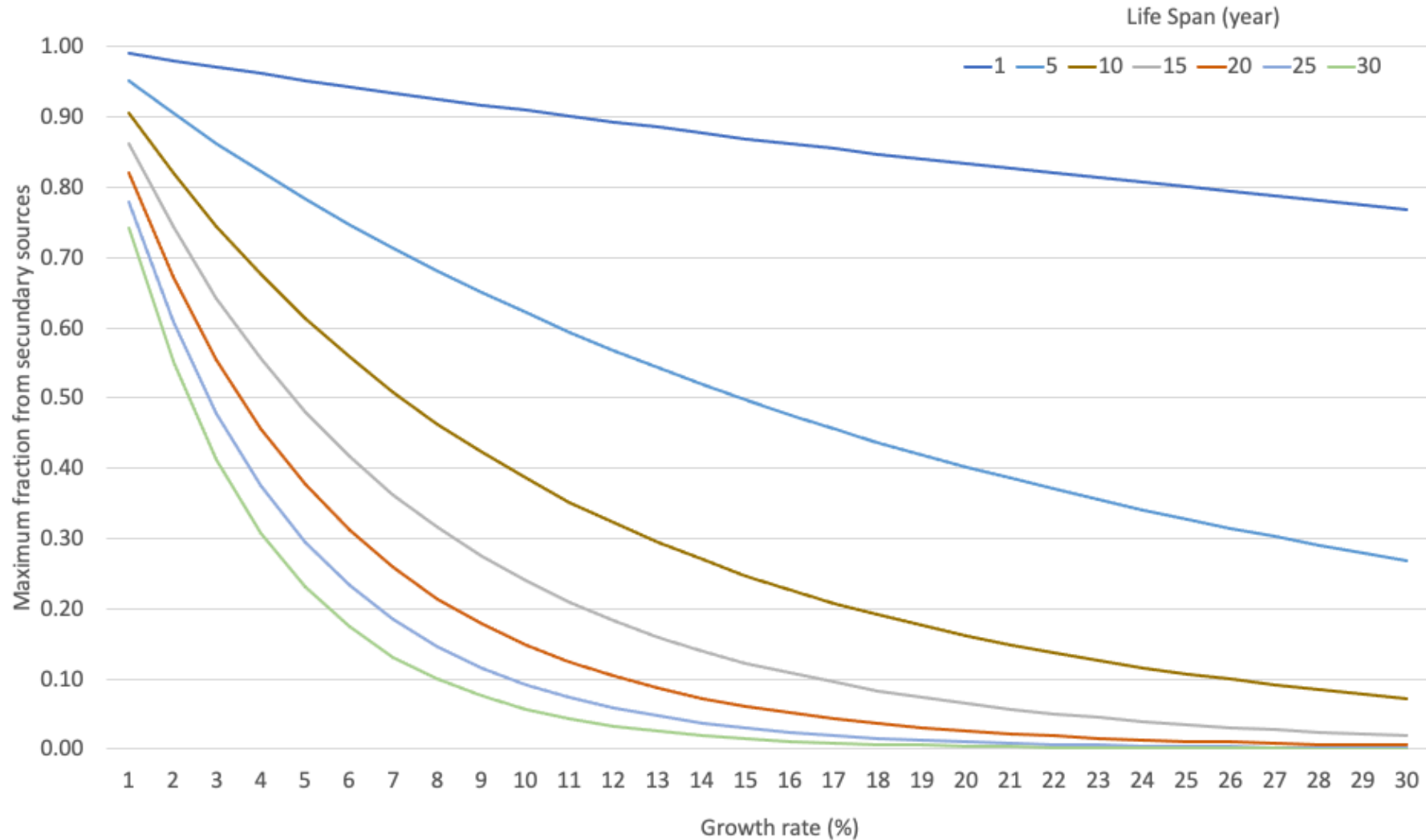
Figure 2. Newly installed capacities (for expansion and replacement). (a): Global wind power, and (b) global PV.

Source: Yanan Liang, in prep.

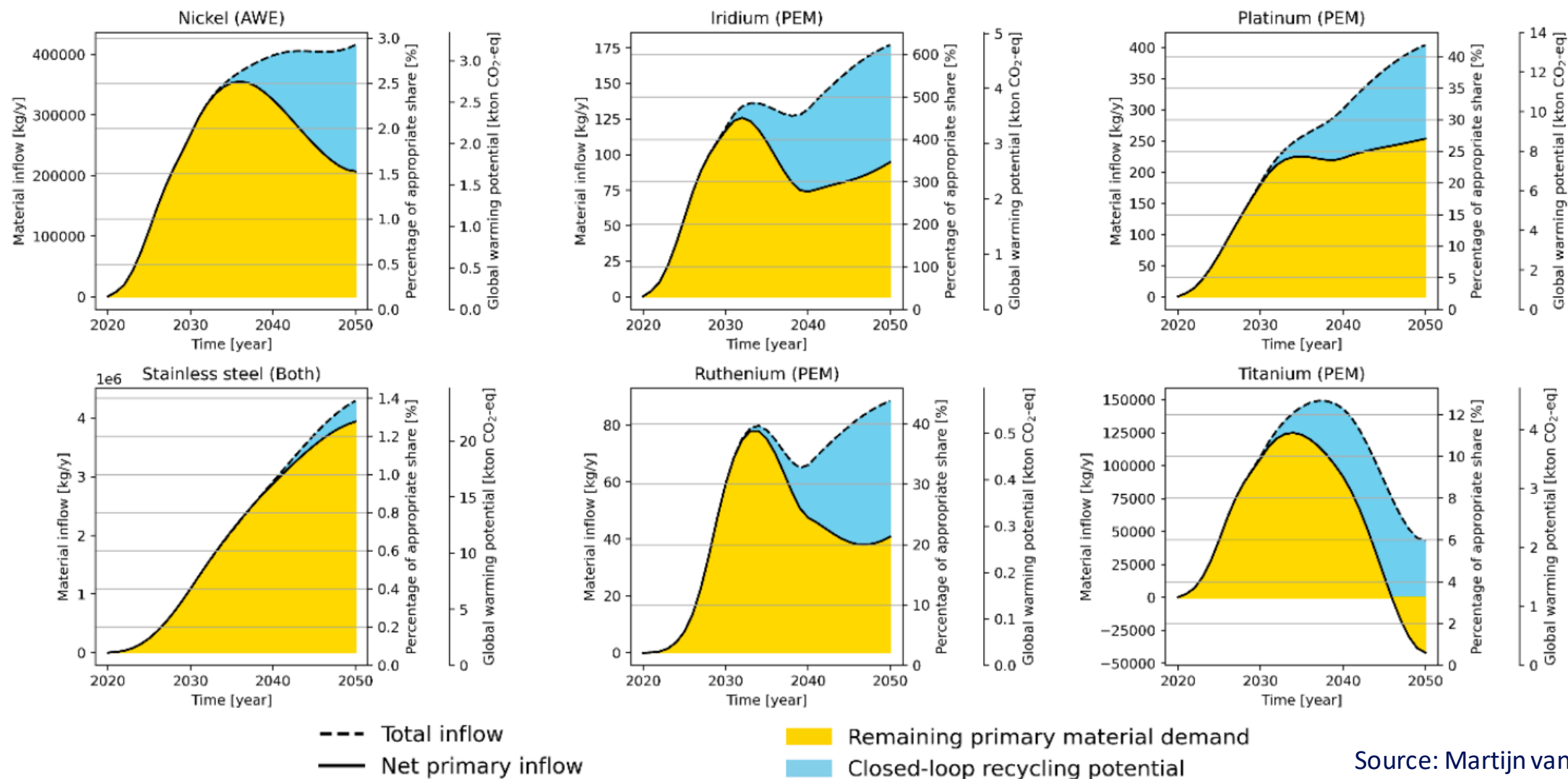
Mathematical limits to recycling



Mathematical limits to recycling



Example: electrolyzers



Source: Martijn van der Star, 2022

In short:

- The energy transition speeds up: strive to become less dependent on Russian fossils and increasing urgency (IPCC)
- Autocratic '*Oil states*' will be replaced by autocratic '*Electrostates*'
- China is very dominant for the supply of 'green' metals, materials and technologies
- Prices of oil and gas are high: stimulates the transition (?)
- War and sanctions results in higher metal prices
- And what consequences will 'the end of globalization' mean for the transition?

Important lessons from Industrial Ecology

- The coming three decades the metal requirements for the energy transition will increase rapidly
- It is not at all certain that supply can keep up with demand
- Circularity is crucial but will be significant only when the period of rapid growth of wind/solar/ batteries is completed
- A fossil based system needs a continuous **inflow** of raw materials (fossil fuels), a renewable based system requires a maar een hernieuwbaar systeem is gebaseerd op een large-scale **stock** of materials (in windturbines, PV cells, batteries, ...)
- We have to build these stocks first with input of primary materials

How can material science help ?

- Do more with less:
 - reduce material content in current technologies
 - develop technologies / materials that require less materials (perovskites?)
- Develop new technologies based on abundant materials (sodium based batteries ?)
- Develop materials that will last longer
- Develop materials that can easily be re-used / recycled
- Develop efficient recycling processes for complex products like batteries and PV solar