

A large, dense pile of discarded tires, illustrating material stocks and flows in a circular economy. The tires are stacked and scattered across the ground, creating a textured, dark surface. The perspective is from a slightly elevated angle, looking down into the pile. The tires vary in size and wear, with some showing significant tread loss and others appearing more intact. The overall scene conveys a sense of massive waste and the need for circular economy solutions.

Material stocks and flows in the circular economy

Edward Burtynsky 1999: Oxford tyre pile #1

Material stocks and flows in the circular economy

*a prospective material flow analysis of vehicles
in the Netherlands for 2000 - 2050*

MSc Industrial Ecology thesis presentation by Jochem Date van der Zaag

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Universiteit
Leiden



Planbureau voor de Leefomgeving

The Netherlands

Land area: 0.03%

Population: 0.2%

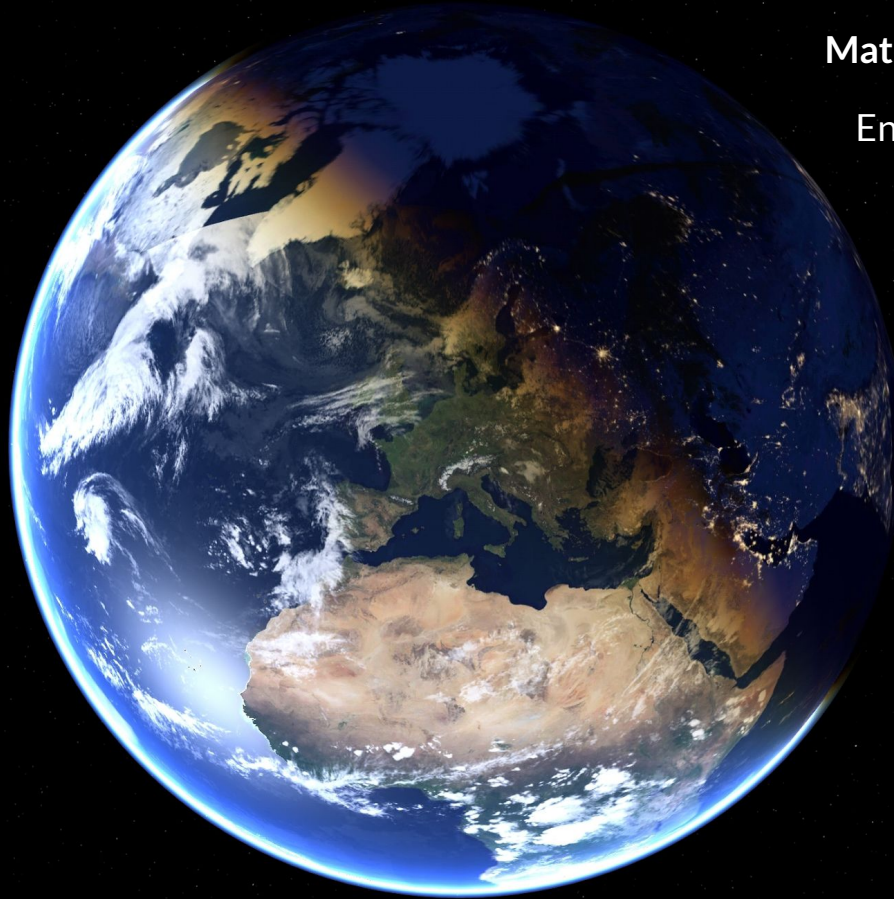
Ships: 0.6%

Cars: 0.9%

CO₂: 0.7%

GDP: 1%





Materials used in vehicles

Environmental footprint

We've figured out
how to reuse...

...but we don't!

(yet)

A red Tesla Roadster is shown in space, orbiting Earth. The car is positioned in the lower-left foreground, with its front wheel and side mirror visible. The Earth's blue and white surface is the dominant background. The car's interior, including the white seats and steering wheel, is visible through the open top.

Materials used in vehicles

Environmental footprint

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(yet)

BBC (2018): "The Tesla car that Elon Musk launched into space is likely to stay there for tens of millions of years before crashing into the Earth or Venus."

photo: SPACE-X / AFP

An aerial, top-down view of an aircraft boneyard. The ground is dry, dusty, and light brown. Several large commercial jet aircraft are scattered across the area, some partially disassembled. One prominent aircraft in the center-left has a blue and white livery. Another on the right has a purple and yellow tail. The word "Background" is written in a white, serif font in the center of the image. In the bottom right corner, there is a caption in a smaller, white, sans-serif font.

Background

Mike Kelley 2017: Mojave boneyard (the Life Cycle of Planes)

Circular Economy and the Urban Mine

It is essential to reduce primary material consumption in order for society to operate within the Earth's planetary boundaries.

If we want to maintain societies' wellbeing, we need to access the Urban Mine by reusing secondary materials (from vehicles)

The Dutch government: reduce primary material consumption by 50% by 2030 and be fully Circular Economy by 2050 (and have zero emission mobility)

Understanding the quantities of required materials, and the availability of materials at end-of-life from the Urban Mine is essential to developing Circular Economy



Method

Lucy Nicholson 2018: Volkswagen cars from the "dieseltgate scandal" buyback

Material Flow Analysis (MFA)

bottom-up:

all* materials in all* Dutch road, rail, water, and air vehicles

prospective:

historical 2000-2017; prospective 2000-2050 (based on WLO-low scenarios for transportation)

comparative:

Explore sustainable transportation developments, as different transition pathways, compared to a reference pathway

stock-driven:

using Weibull lifespan distributions based on demographic data



Results

historical

Public domain: tugboats aid in mooring a container ship, Vostochny

Vehicle stock compared to ...

Eiffel tower

0.010 million tons



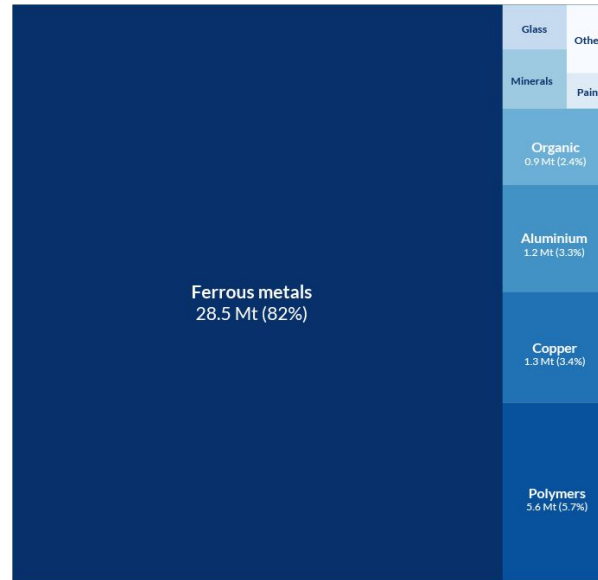
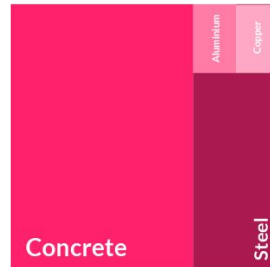
Golden gate bridge

0.805 million tons



Dutch electricity infrastructure

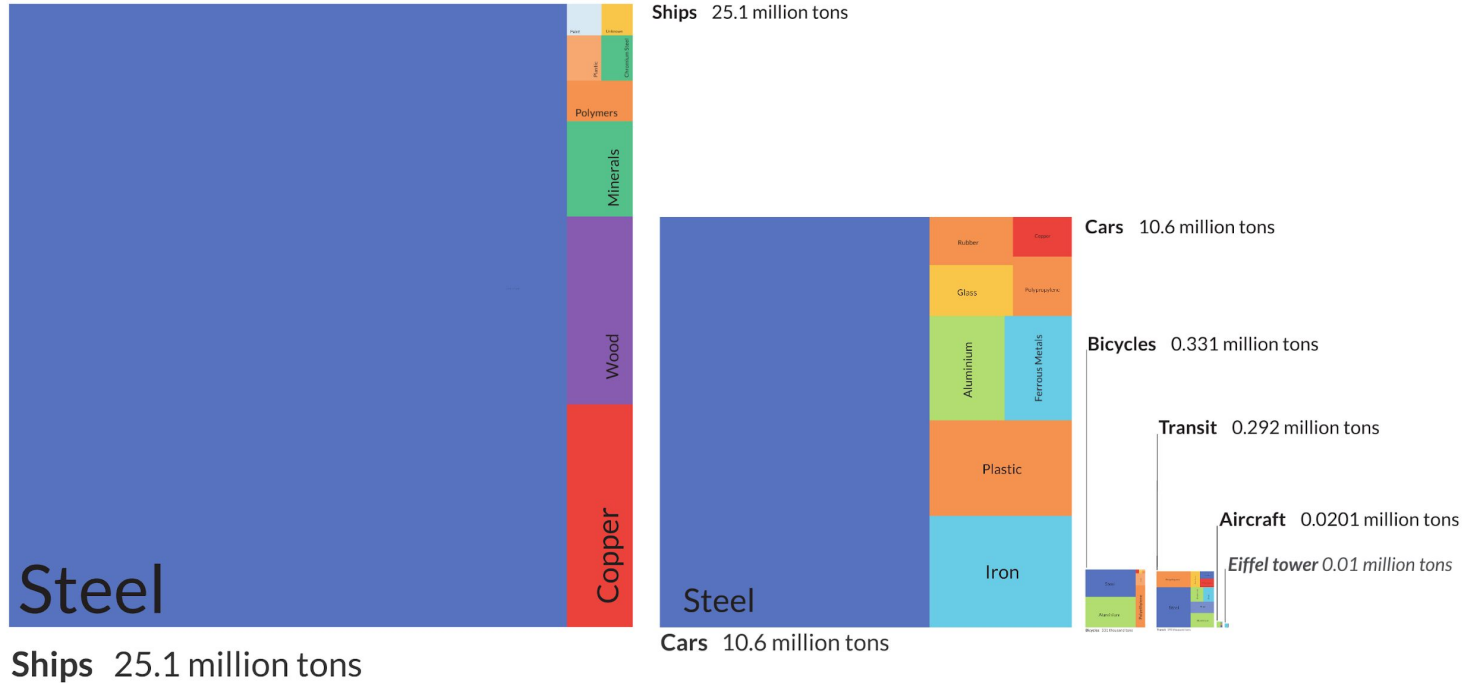
(Van Oorschot, 2019) 7.45 million tons



total mass of vehicles: 36.3 million tons

in the Netherlands, in 2017, area represents weight

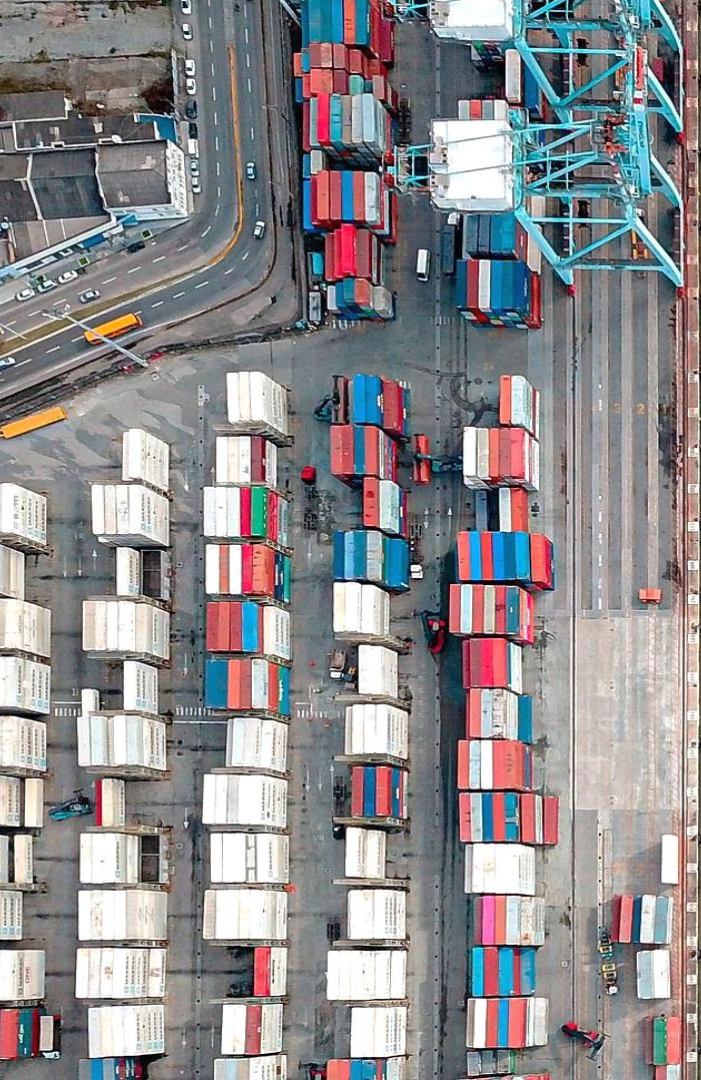
Vehicle stock compared to ...



<https://prezi.com/z-dwv-1kox03/materialsvehiclesnetherlands2017/>

Vehicle material stock over time, by type





Results

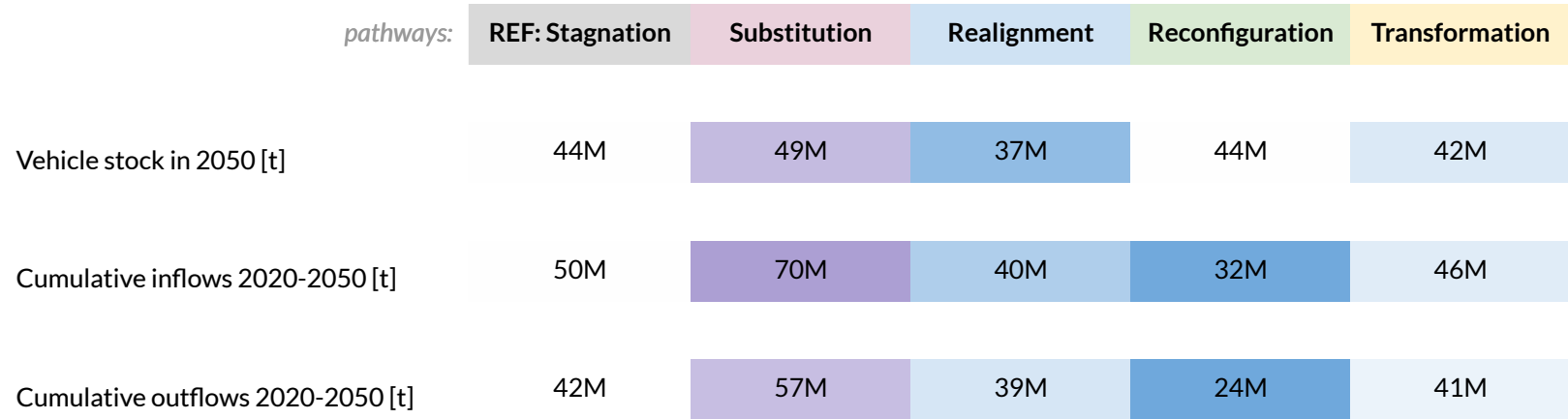
projection

Public domain: tugboats aid in mooring a container ship, Vostochny

Developments & transition pathways

<i>Transportation Development</i>		<i>Pathways</i>				
		REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Passenger	Low-emission vehicles		x			
Freight	Vehicle enlargement		x			
Passenger	Transport as-a-service			x		
Freight	Two-way-trade			x		
Passenger	Lifespan elongation				x	
Freight	Lifespan elongation				x	
Passenger	Modal shift					x
Freight	Modal shift					x

results: material requirement



results: material requirement

<i>pathways:</i>	REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Steel inflow compared to REF	40.4M	13%	-18%	-34%	-6%
Steel outflow compared to REF	33.6M	16%	-7%	-42%	-4%
Polymers inflow compared to REF	3.4M	101%	-32%	-41%	-28%
Polymers outflow compared to REF	3.1M	77%	-12%	-43%	-7%
Aluminium inflow compared to REF	2.4M	105%	-27%	-41%	-3%
Aluminium outflow compared to REF	2.3M	76%	-10%	-43%	2%
Copper inflow compared to REF	1.2M	153%	-21%	-35%	-13%
Copper outflow compared to REF	1.0M	110%	-8%	-42%	-6%
CRM inflow compared to REF	5.04K	114781%	-24%	-42%	-33%
CRM outflow compared to REF	4.81K	66428%	-9%	-44%	-6%

A high-angle, wide shot of a massive bicycle graveyard. The scene is dominated by thousands of blue bicycles, packed tightly together in neat, parallel rows that stretch far into the distance. The perspective is from an elevated position, looking down on the sea of wheels and frames. The ground is a light-colored, flat surface, possibly concrete or asphalt. In the upper right corner, a portion of a light-colored brick building is visible. The overall impression is one of overwhelming scale and order.

Conclusions

The Guardian (2018): The unexpected beauty of China's bicycle sharing graveyards

conclusions

- A prospective, stock-driven MFA was used to compare material demand/release for different pathways.
- The material stock of vehicles grew to 36 million tons in 2017. The reference pathway increases the primary* material demand by 22% in 2050 compared to 2017
- Population/GDP growth, electrification, ineffective utilisation of vehicles indicate an increase in material demand for transportation.
- Lifespan elongation, Servitization of mobility, Two-way freight, and Modal shift all reduce material requirements, allowing for growth in transportation demand.



Discussion & Recommendations

The Atlantic (2018) The Bike-Share Oversupply in China

discussion & recommendations

limitations

material content data / lifespan data

interpretation

WLO laag scenario provides a minimum: the expected material demand/release is higher

scientific context

case study of more vehicles / quantitative results in a socio-technical context

societal relevance

MFA is used as a comparative tool to understand material implications of decisions

further research

availability of materials in the Urban Mine (export!)

discussion & recommendations

for public/private decision makers:

Material implications should be part of decision making processes

Reconfigure practices for lifespan & reuse

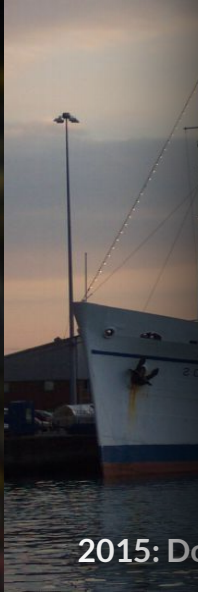
Transition to low emission modes of transport like mass transit

for end users of transportation:

Lifespan elongation, reuse, & modernisation

Embrace low-emissions modes of transport

Recognise & criticise the status-quo



2015: D



Henk Reins (2018) Ombouw van een 1972 klassieker naar elektrische wagen





Thank you.

The Atlantic (2018) The Bike-Share Oversupply in China



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Substitution pathway

Freight transportation:



Passenger transportation:



De- and realignment pathway

Freight transportation:



Passenger transportation:



Reconfiguration pathway

Freight transportation:



SS Medina (1914) = Doulos Phos (2015)

Passenger transportation:



SGM passenger train after modernisation

Reconfiguration pathway

Freight transportation:



2015: Doulos Phos

Passenger transportation:



1911: SS Medina



SS Medina (1914) = Doulos Phos (2015)

SGM passenger train after modernisation

Transformation pathway

Freight transportation:

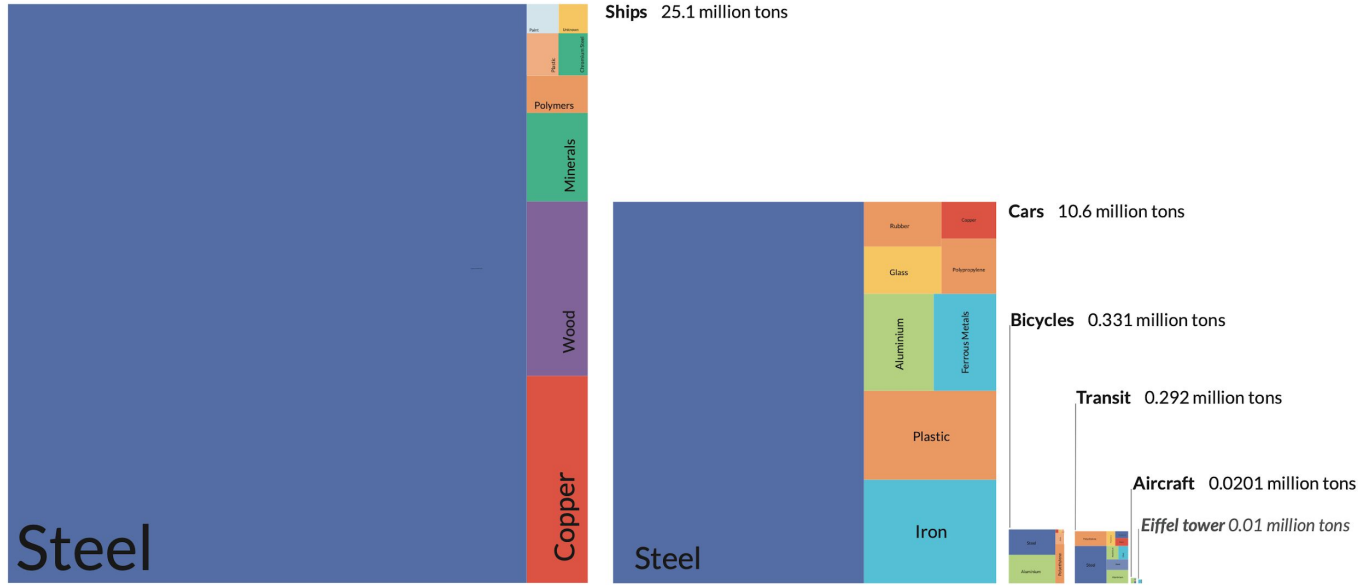


Passenger transportation:



Afb. 2. Een anti-metrodemonstratie passeert de Dam, maart 1975. Foto ANP. Gemeentearchief Amsterdam.

What is the mass of vehicles in society?



<https://prezi.com/z-dwv-1kox03/materialsvehiclesnetherlands2017/>

* area represents mass

results from transition pathways

<i>Transportation Development</i>		<i>Pathways</i>				
		REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Passenger	Low-emission vehicles		x			
Passenger	Transport as-a-service			x		
Passenger	Lifespan elongation				x	
Passenger	Modal shift					x
Freight	Vehicle enlargement		x			
Freight	Two-way-trade			x		
Freight	Lifespan elongation				x	
Freight	Modal shift					x

Developments & transition pathways

Pathways

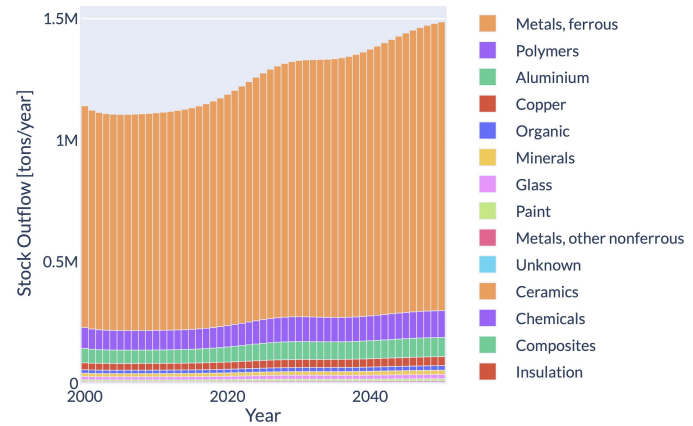
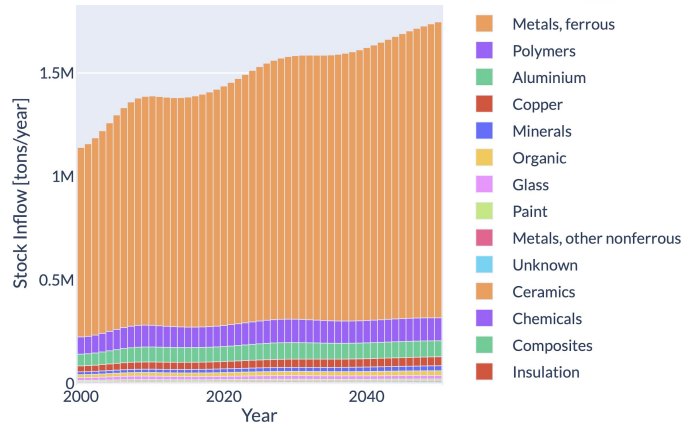
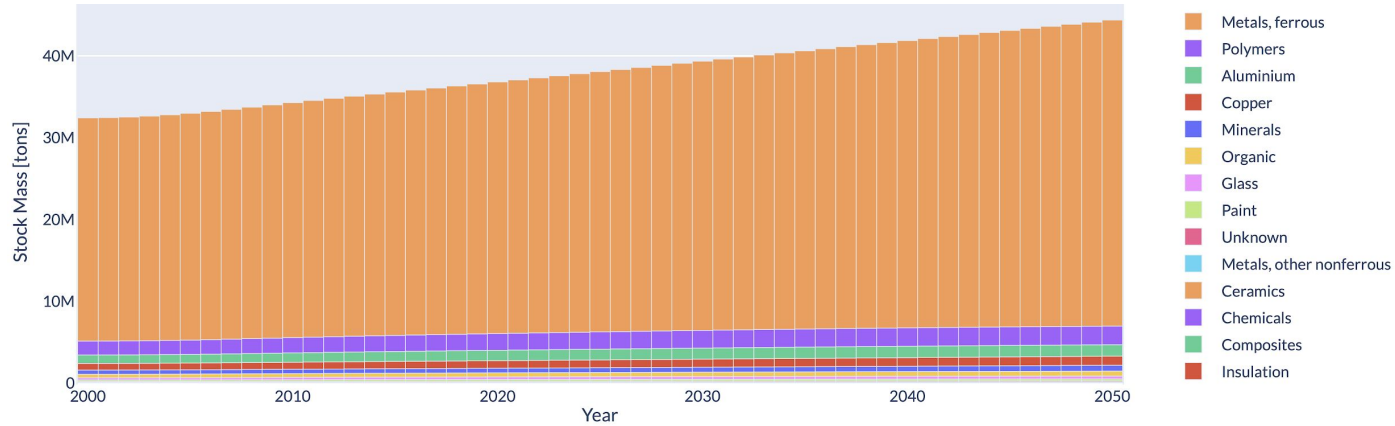
Development

	REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Interaction (Geels & Schott 2007)		competition between incumbent and new firms	multiple new actors competing for niche market share	regime actors and competing suppliers	regimes responding to criticism from outsider groups
Coordination (Berkhout 2004)		planned, vision driven	Unplanned, emergent	Planned, vision driven	Unplanned, emergent
Resources (Berkhout 2004)		Internal	Internal	External	External
Landscape pressure (Kamp et al 2010)		Large and sudden	Large and sudden	Moderate and slow	Moderate and slow

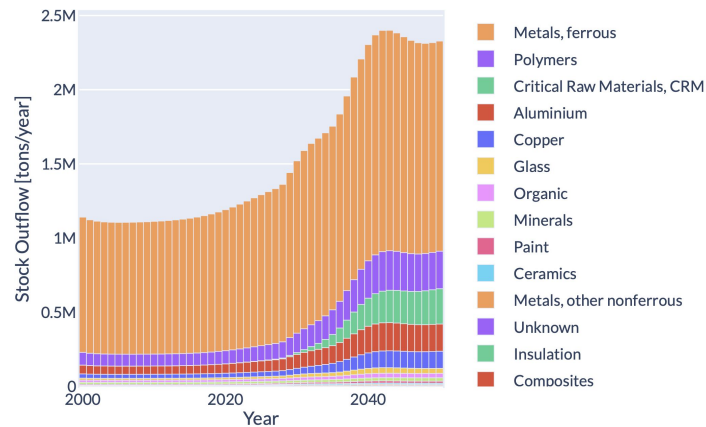
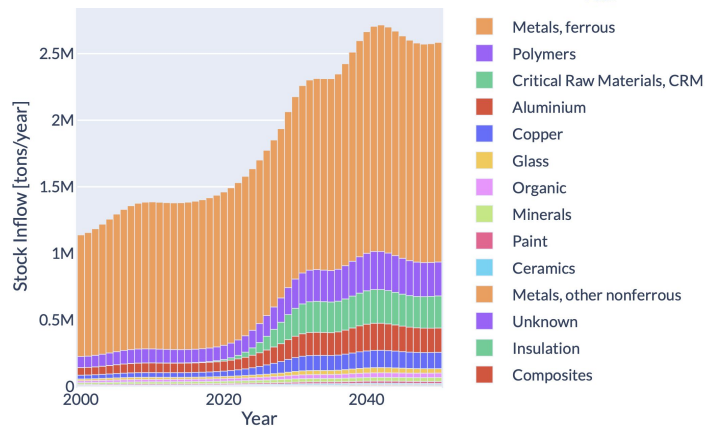
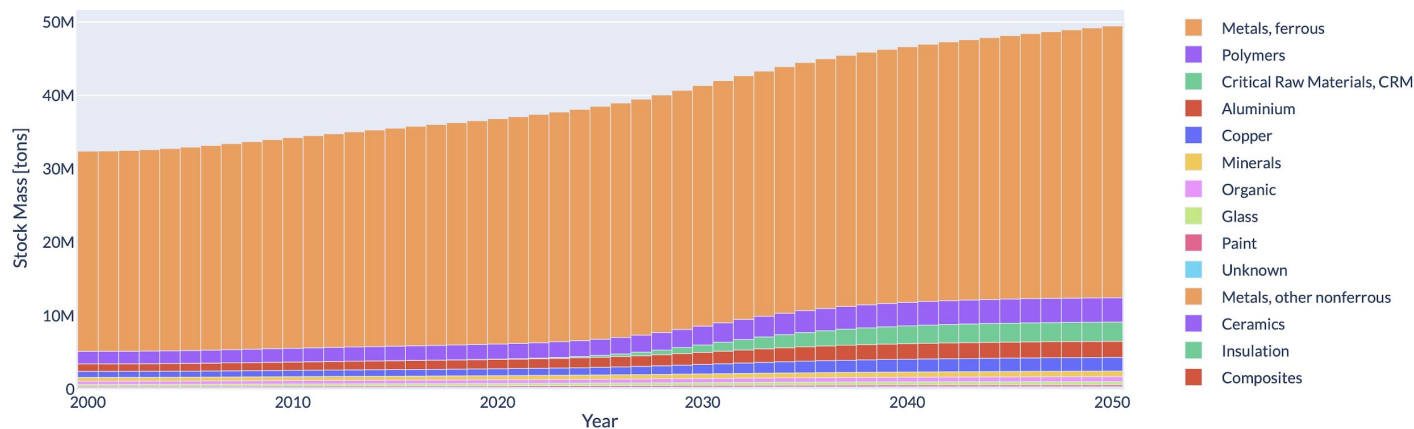
results: cumulative inflow

<i>pathways:</i>	REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Vehicle stock in 2050 [t]	44.4M	49.5M	37.2M	44.4M	42.1M
Cumulative inflows 2020-2050 [t]	49.9M	69.8M	40.0M	32.3M	46.2M
Cumulative outflows 2020-2050 [t]	42.1M	57.0M	39.0M	24.5M	40.6M
Steel inflow	40.4M	45.5M	33.0M	26.5M	38.1M
Steel outflow	33.6M	39.0M	31.3M	19.6M	32.4M
Polymers inflow	3.4M	6.8M	2.3M	2.0M	2.5M
Polymers outflow	3.1M	5.6M	2.8M	1.8M	2.9M
Aluminium inflow	2.4M	4.9M	1.8M	1.4M	2.3M
Aluminium outflow	2.3M	4.0M	2.0M	1.3M	2.3M
Copper inflow	1.2M	3.1M	974.00K	802.00K	1.1M
Copper outflow	1.0M	2.2M	963.00K	606.00K	988.00K
CRM inflow	5.04K	5.8M	3.82K	2.94K	3.37K
CRM outflow	4.81K	3.2M	4.38K	2.71K	4.50K

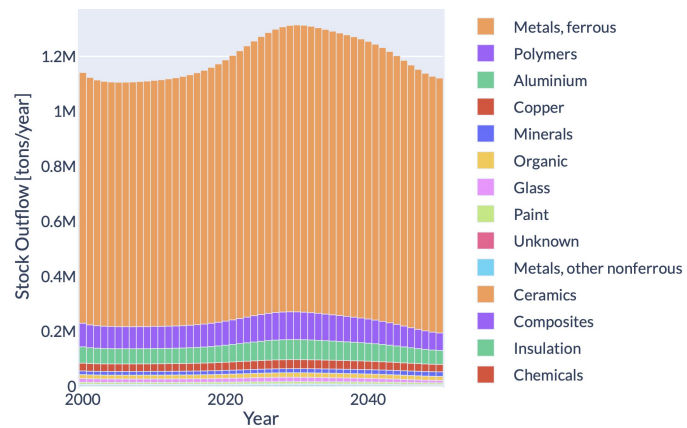
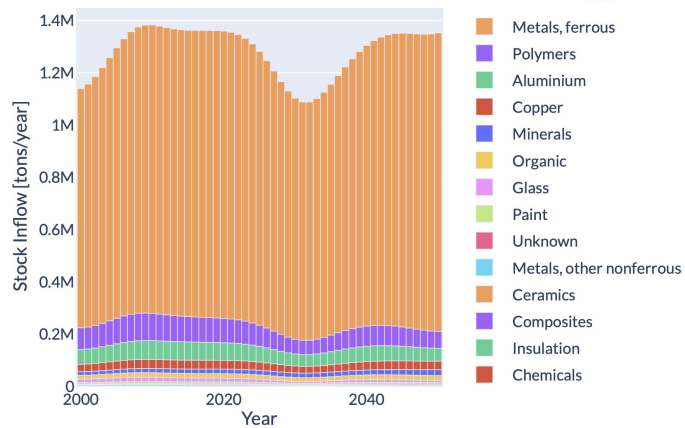
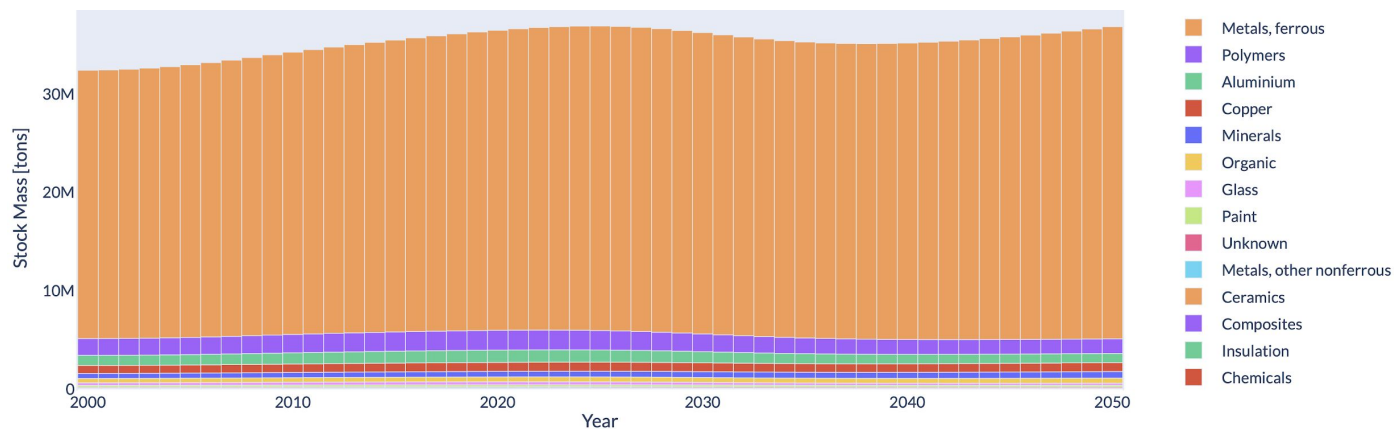
stocks, in- and outflow: reference



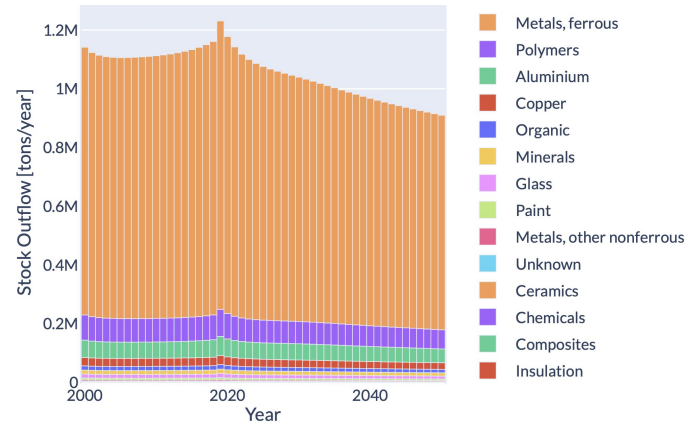
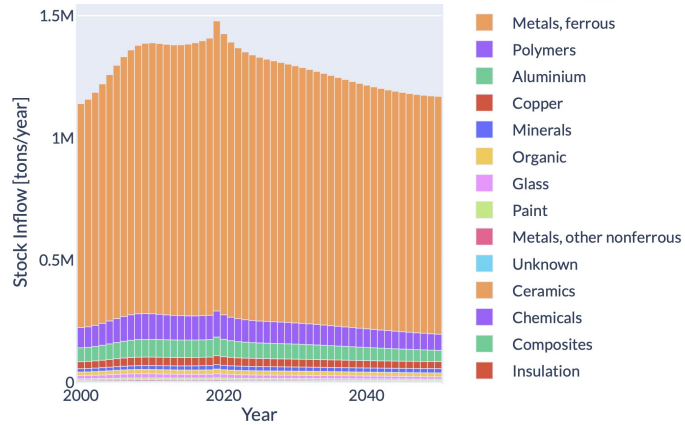
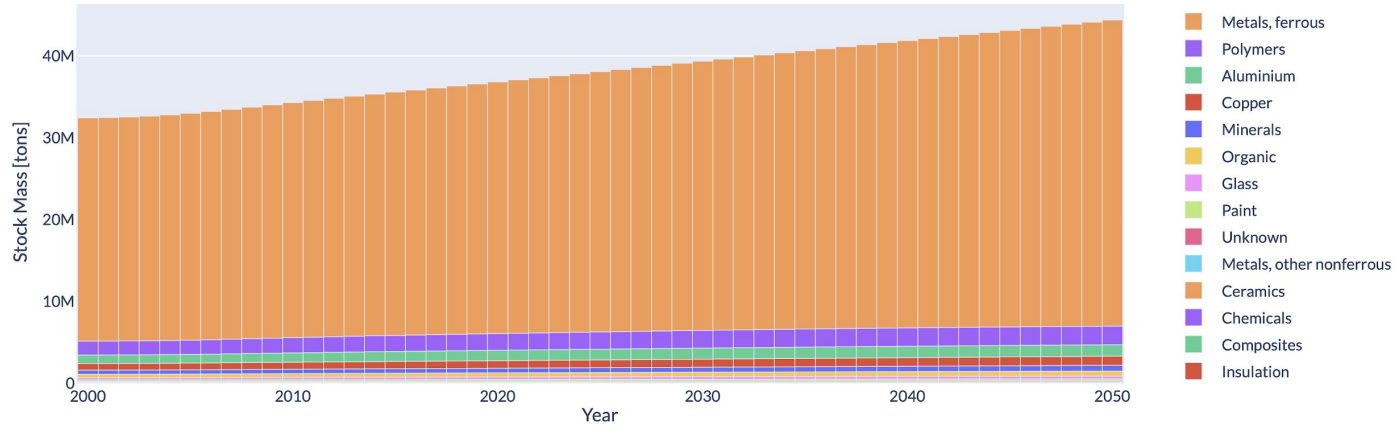
stocks, in- and outflow: substitution



stocks, in- and outflow: realignment



stocks, in- and outflow: reconfiguration



stocks, in- and outflow: transformation

