

A vast, sprawling pile of discarded tires, likely from an industrial source, filling the entire frame. The tires are stacked haphazardly, creating a dark, textured landscape that stretches to the horizon. A few small, colorful objects (a green and a red item) are visible among the tires, highlighting their scale.

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%

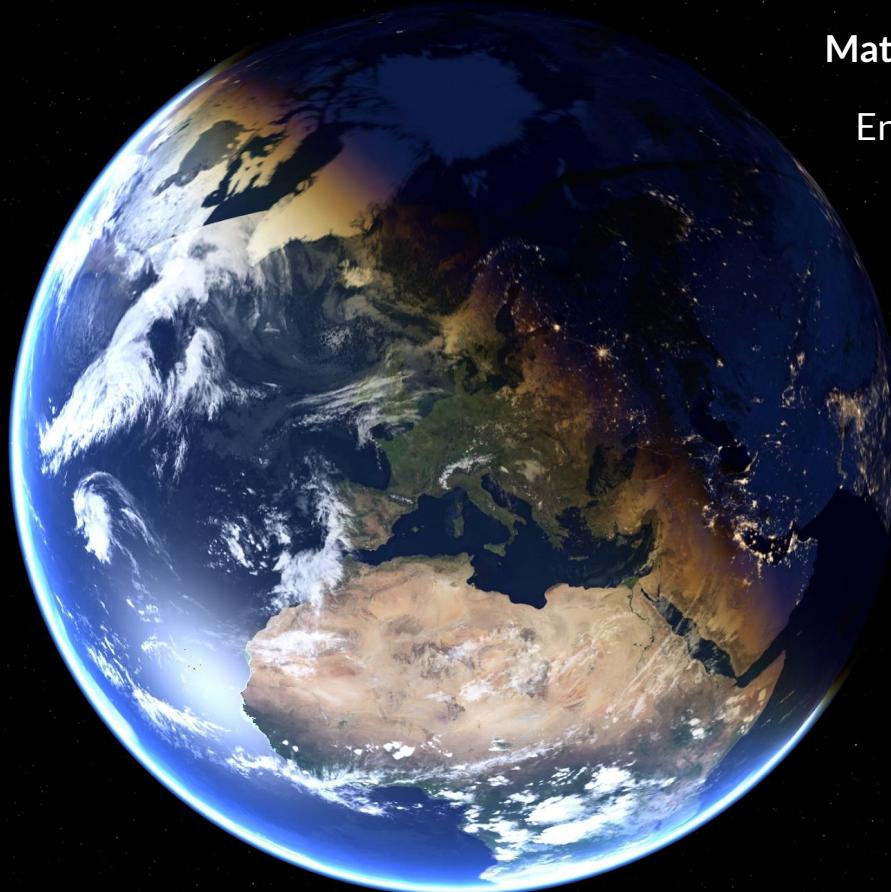
Ships: 0.6%

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)



Materials used in vehicles

Environmental footprint

We've figured out
how to reuse...

...but we don't!
(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 photograph of a vast, desolate aircraft boneyard. The ground is a light tan or beige color, suggesting dry, sandy soil. Numerous aircraft components are scattered across the landscape, including fuselages, wings, and tail sections. Some planes are partially buried in the sand. In the center, there is a large, roughly rectangular area where many smaller parts, like engines and wings, are piled together. The overall scene is one of waste and environmental impact.

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

An aerial photograph of a vast parking lot, likely located in a desert or arid region given the surrounding terrain. The lot is filled with thousands of cars, primarily dark-colored sedans, arranged in long, narrow rows. Interspersed among them are several red cars, which stand out against the darker vehicles. The parking area is bounded by dirt roads and some low-lying industrial buildings in the background. In the far distance, a range of mountains with snow-capped peaks is visible under a clear blue sky.

Method

Lucy Nicholson 2018. Volkswagen cars from the "dieselgate scandal" buyback

Material Flow Analysis (MFA)

bottom-up:

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

prospective:

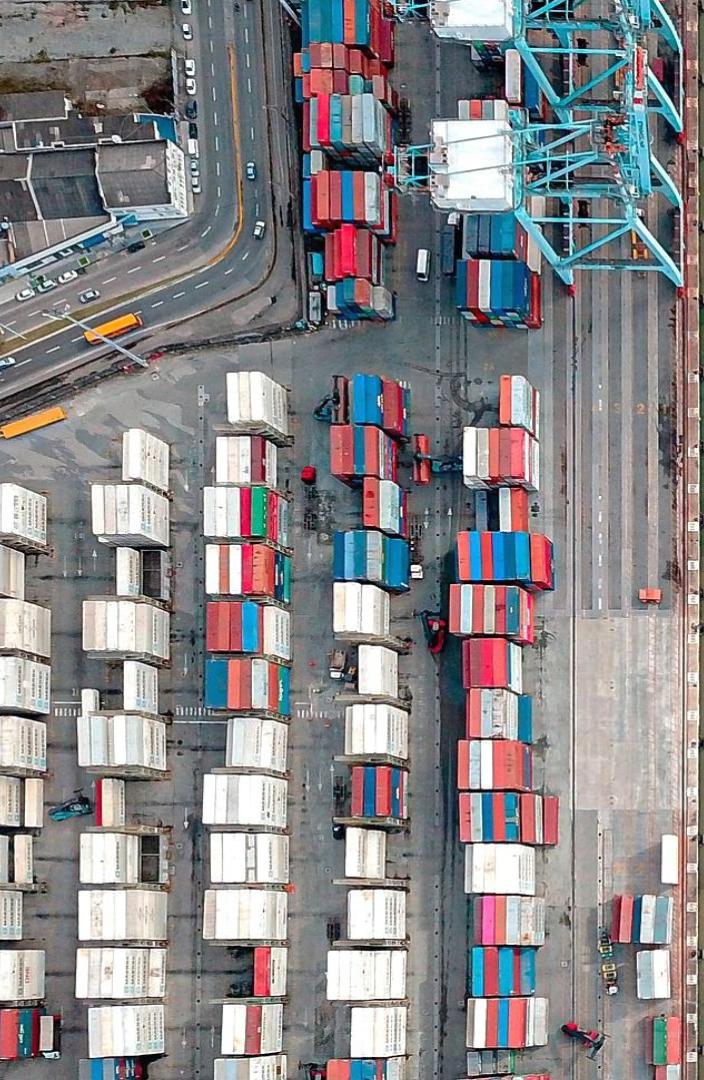
historical 2000-2017; prospective 2000-2050 (based on WLO-low scenarios for transportation)

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



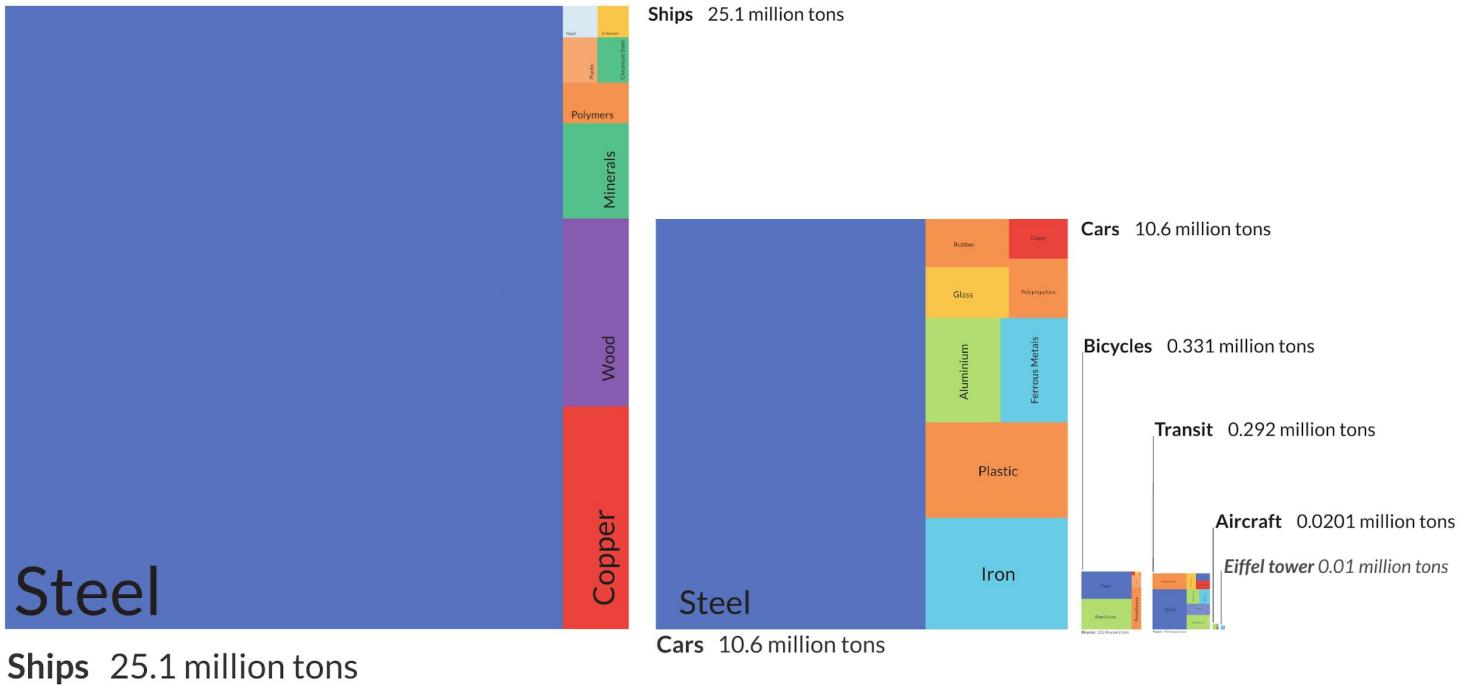
Ferrous metals
28.5 Mt (82%)



total mass of vehicles: 36.3 million tons

in the Netherlands, in 2017, area represents weight

Vehicle stock compared to ...



Steel

Ships 25.1 million tons

Steel

Cars 10.6 million tons



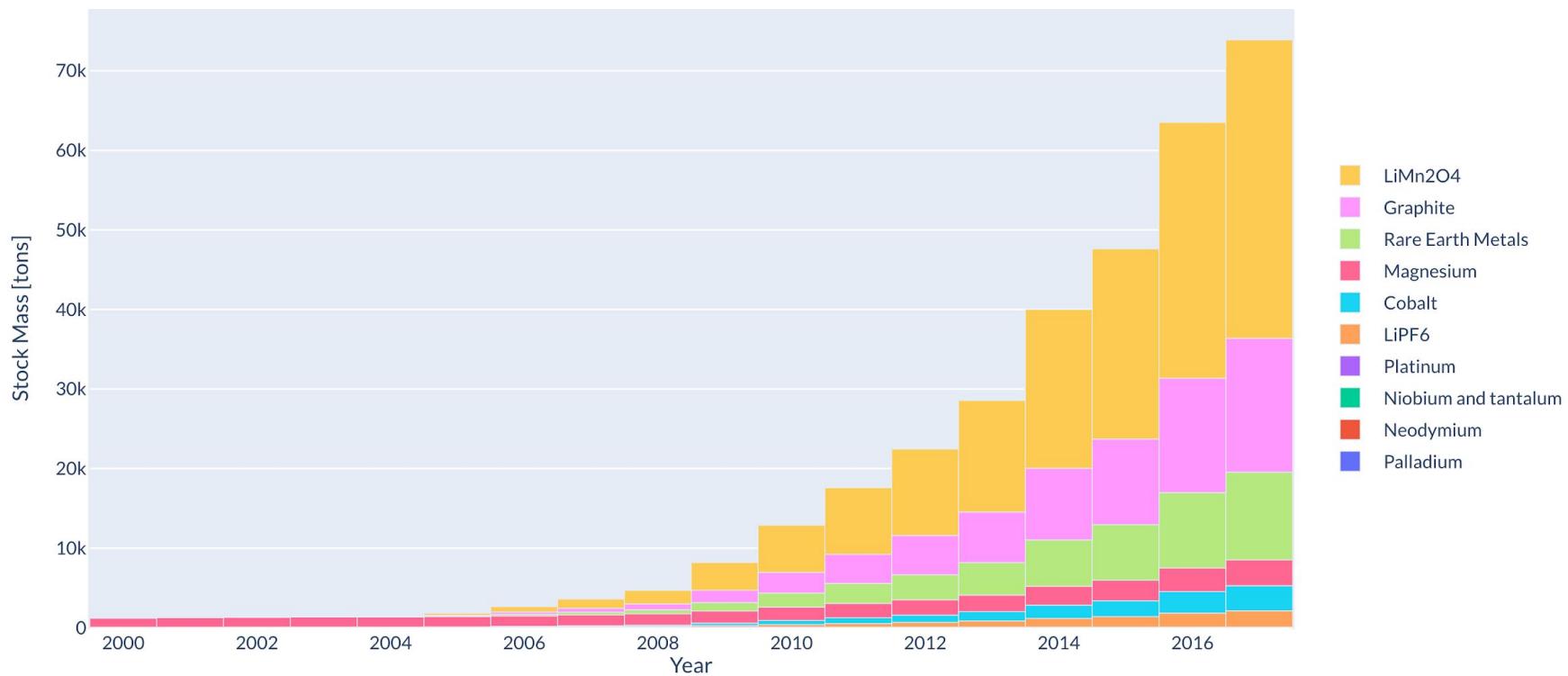
Steel
Copper
Wood
Minerals
Polymers
Glass
Rubber
Ferrous Metals
Plastic
Aluminum
Iron
Brass
Lead
Zinc
Tin
Copper
Nickel
Manganese
Cobalt
Chromium
Uranium
Gold
Silver
Diamond

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

Vehicle material stock over time, by type



Mass of critical raw materials over time



An aerial photograph of a port terminal. On the left, numerous shipping containers are stacked in organized rows. In the center, several large blue industrial cranes stand ready for loading or unloading. To the right, a long container ship is docked at the pier, its deck filled with containers. A small tugboat is visible near the ship's bow. The overall scene is one of a bustling commercial port.

Results

projection



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

Developments & transition pathways

Transportation Development		Pathways				
		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

<i>pathways:</i>	REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Vehicle stock in 2050 [t]	44M	49M	37M	44M	42M
Cumulative inflows 2020-2050 [t]	50M	70M	40M	32M	46M
Cumulative outflows 2020-2050 [t]	42M	57M	39M	24M	41M

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 photograph showing a massive, sprawling graveyard of discarded blue bicycles. The bicycles are piled high in several large mounds across a paved area, stretching from the foreground to the background. Some individual frames are visible, showing the branding of companies like Ofo and Mobike. The sheer volume of bikes creates a dark, almost black, texture against the light-colored concrete.

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

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

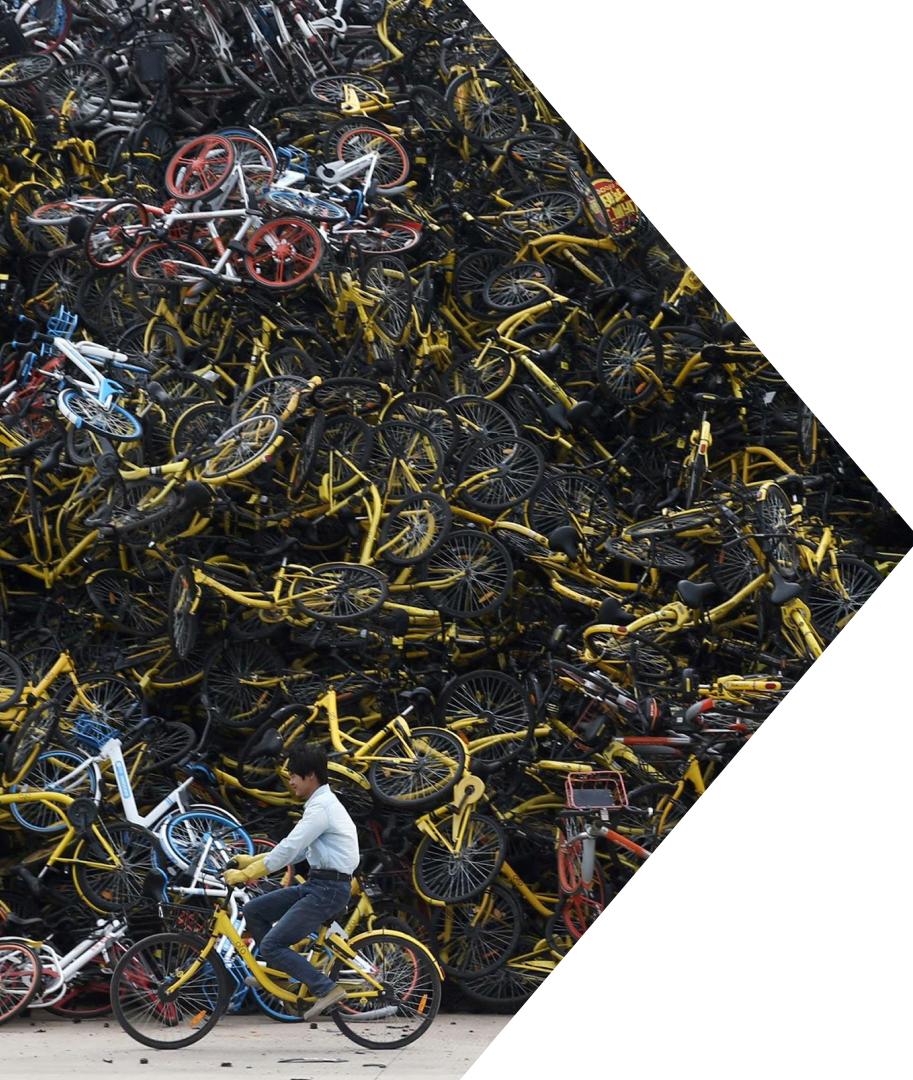


2015: Do

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



Thank you.



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Substitution pathway

Freight transportation:



Passenger transportation:



De- and realignment pathway

Freight transportation:



Passenger transportation:



Reconfiguration pathway

Freight transportation:



Passenger transportation:



SS Medina (1914) = Doulos Phos (2015)

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:

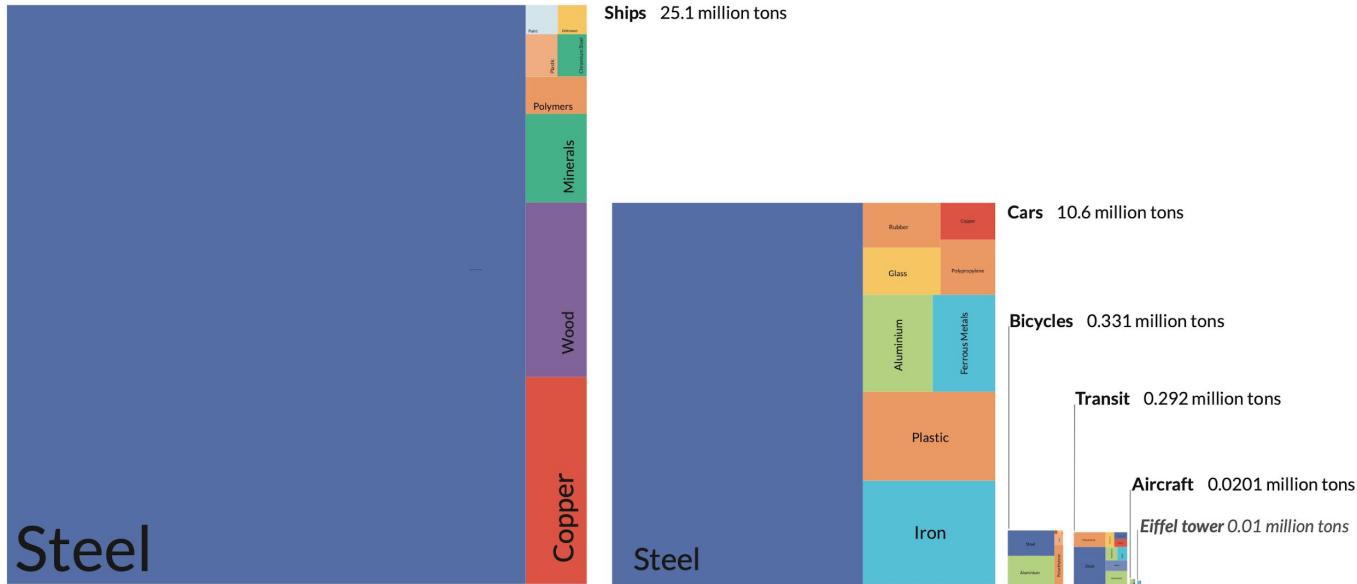


Passenger transportation:



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

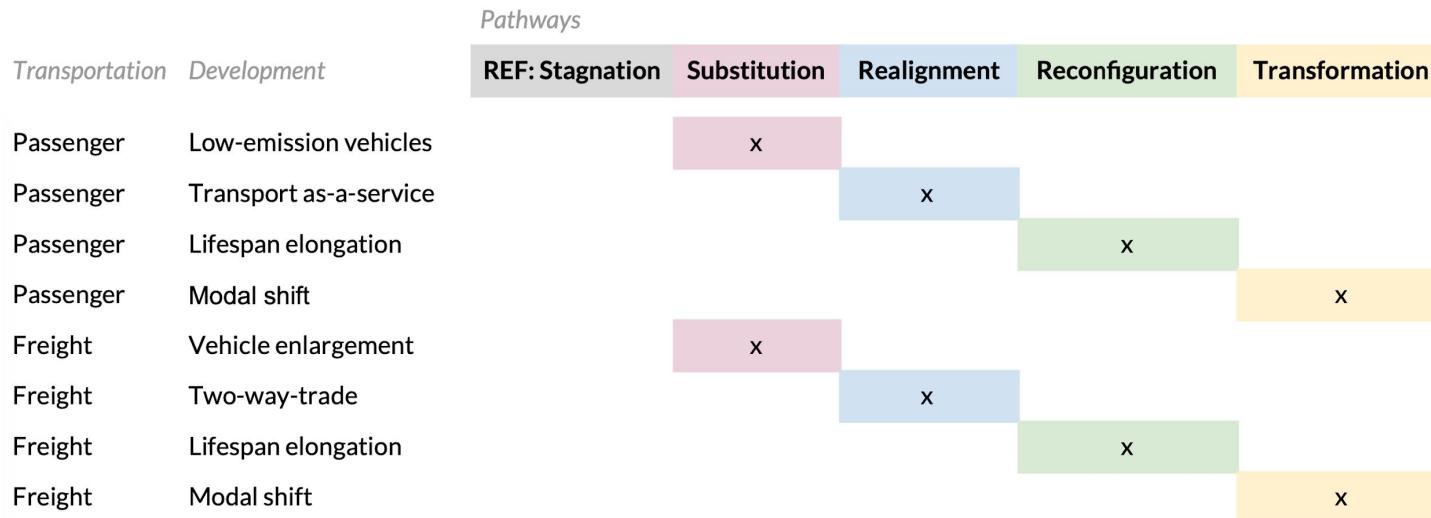
What is the mass of vehicles in society?



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

* area represents mass

results from transition pathways



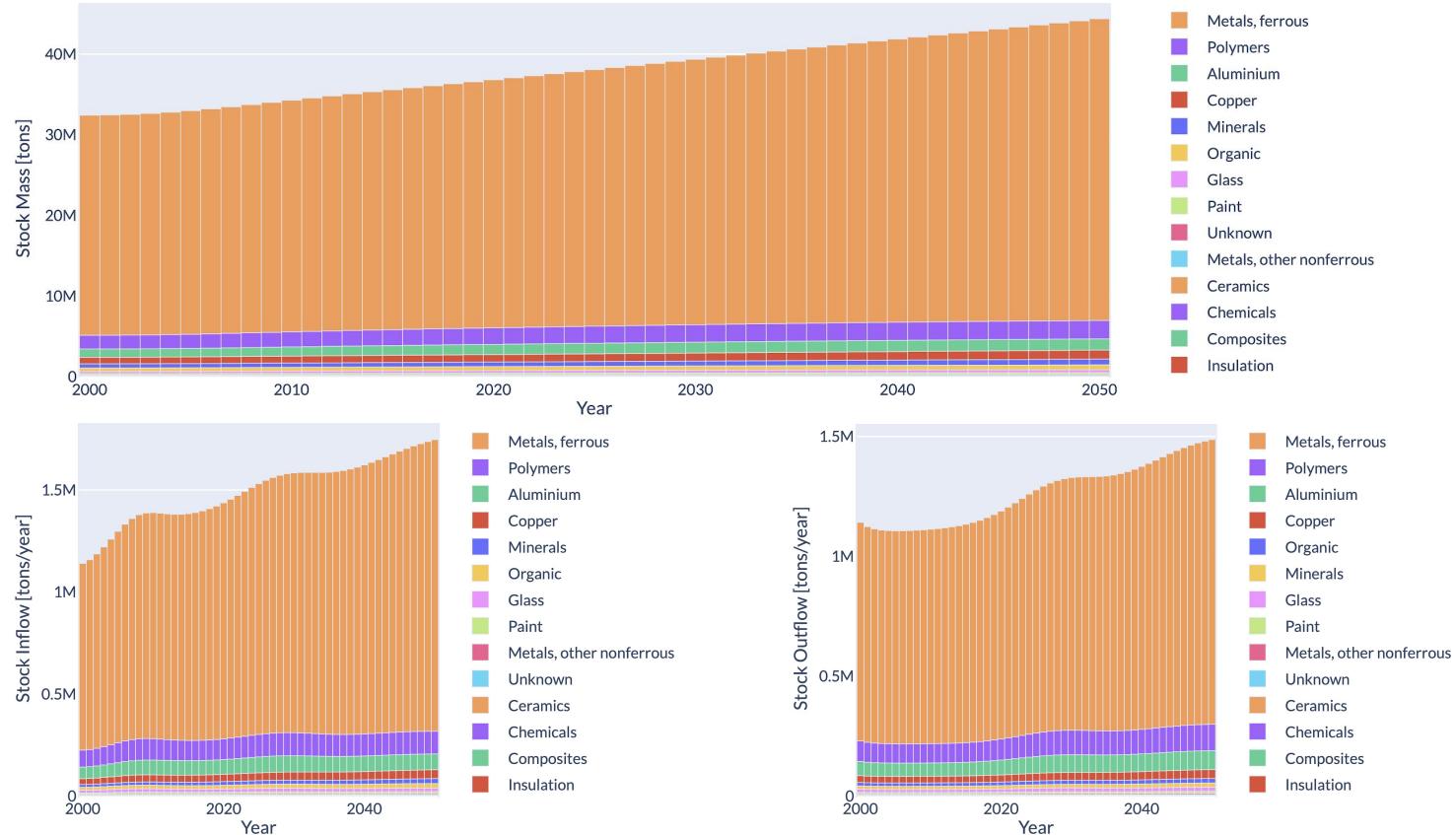
Developments & transition pathways

Development	Pathways				
	REF: Stagnation	Substitution	Realignment	Reconfiguration	Transformation
Interaction (Geels & Schott 2007)		competition between incumbent and new firms	<i>multiple new actors competing for niche market share</i>	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

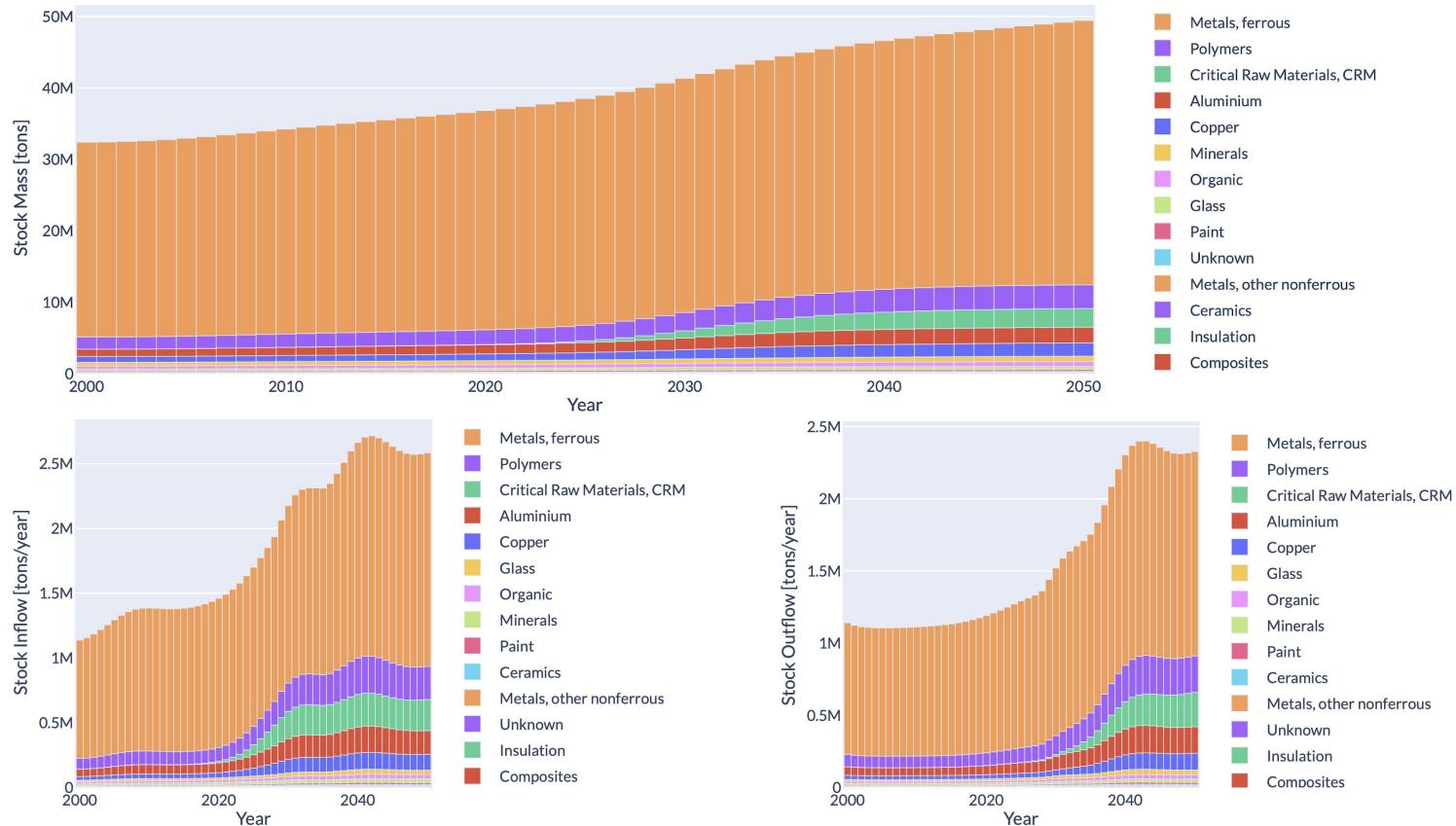
results: cumulative inflow

	<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

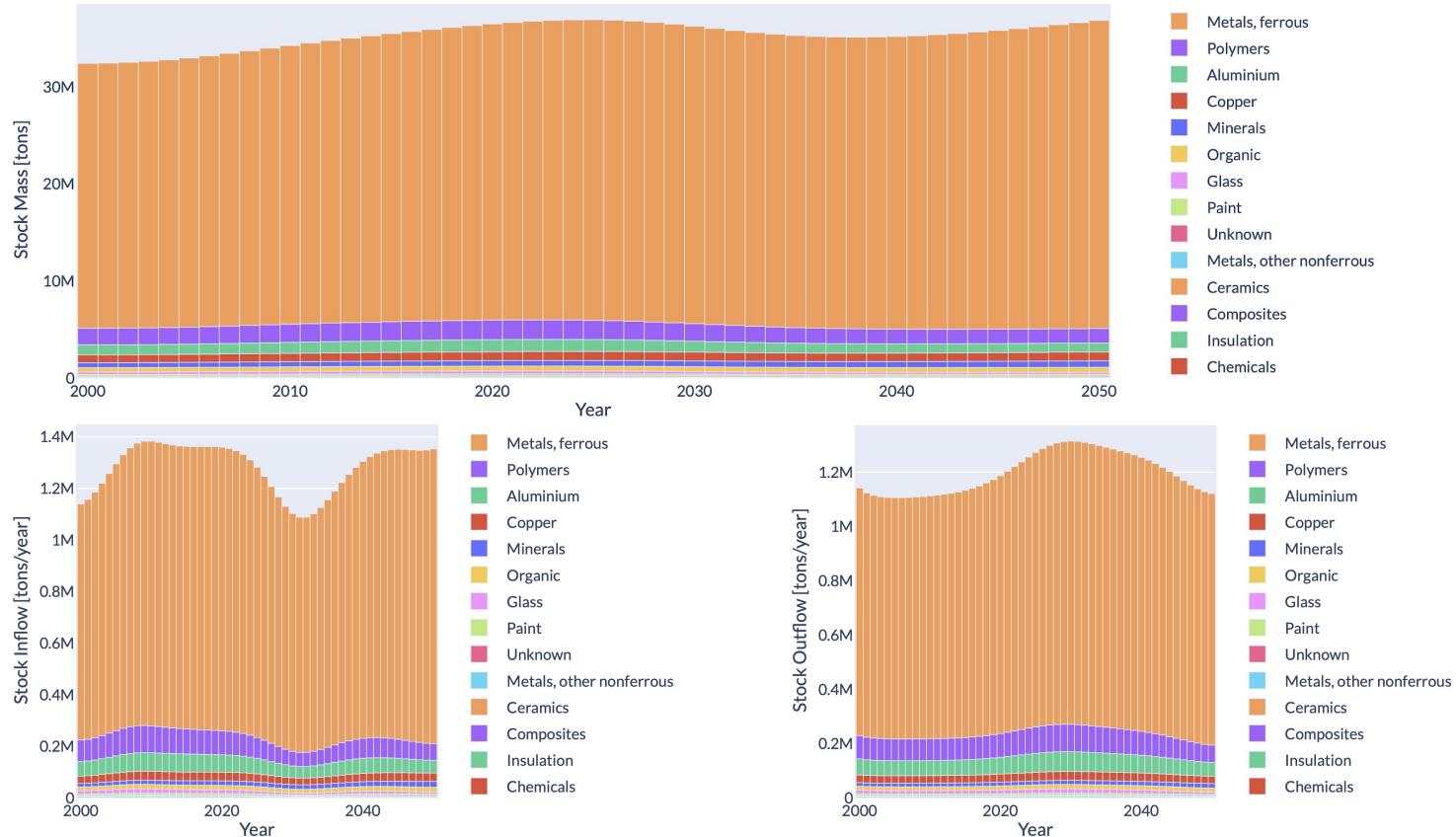
stocks, in- and outflow: reference



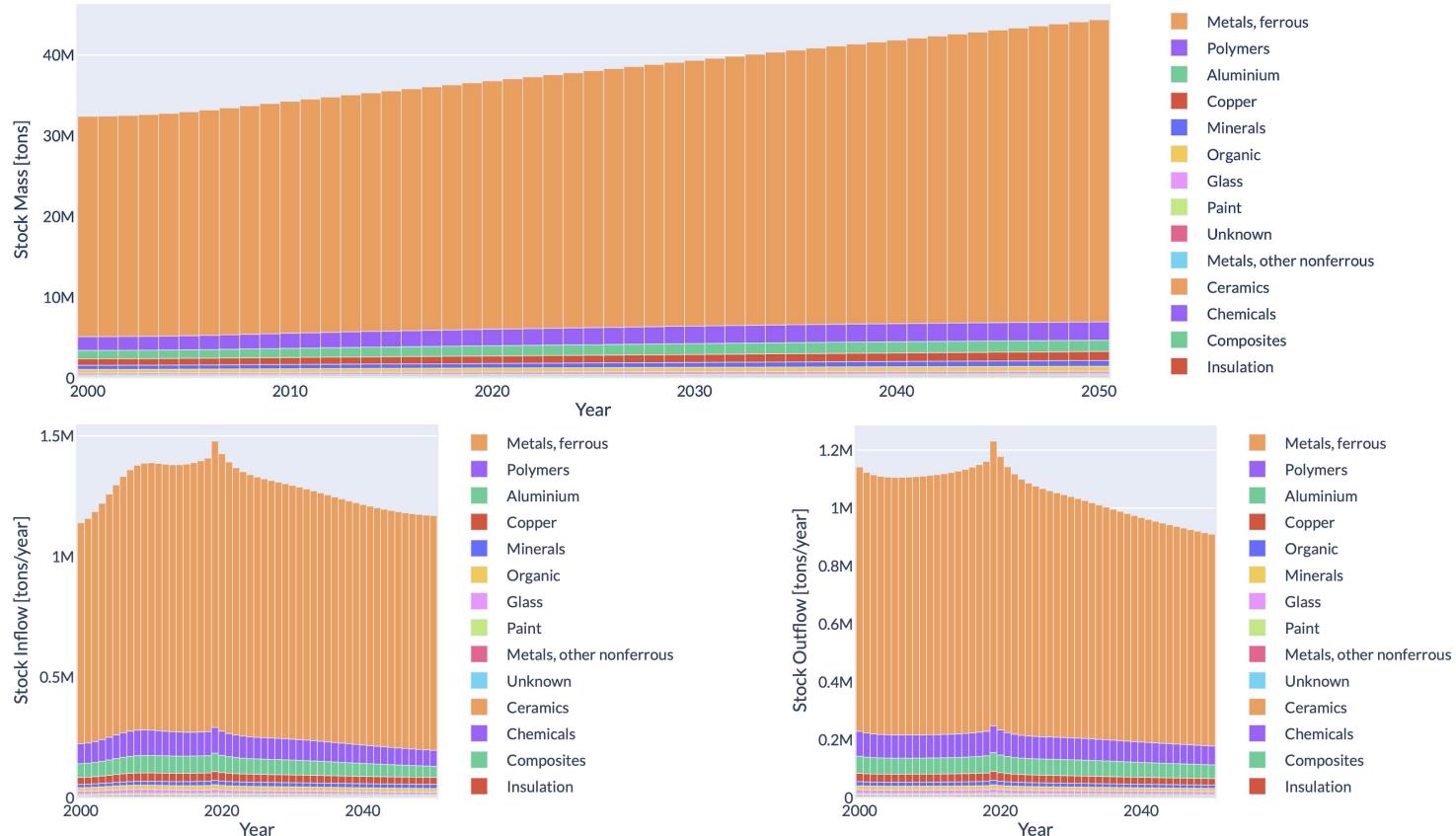
stocks, in- and outflow: substitution



stocks, in- and outflow: realignment



stocks, in- and outflow: reconfiguration



stocks, in- and outflow: transformation

