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NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

Material–Energy Nexus for EU Descarbonization: Extending TIMES-EU to Capture Circular Economy Strategies for Transport Sector

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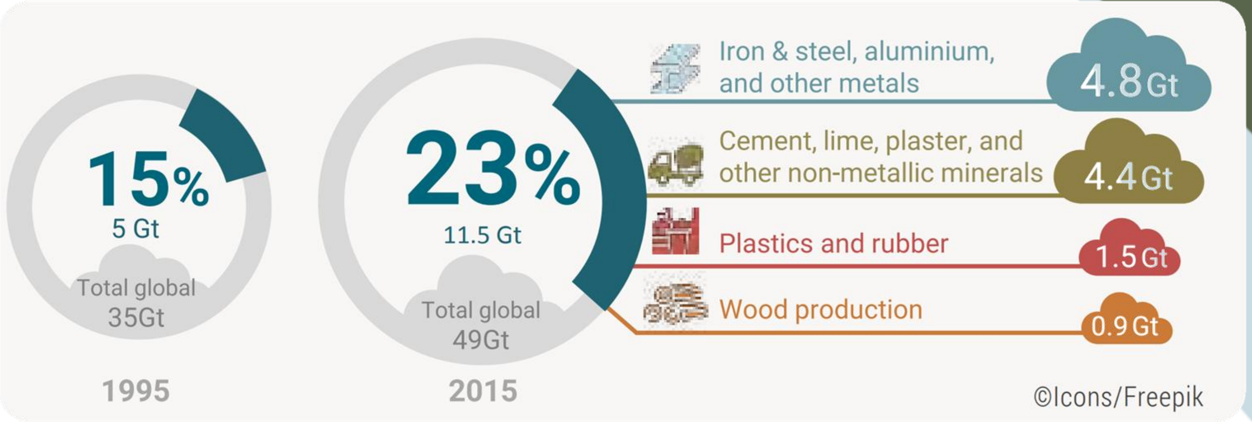
Motivation

› Global material consumption has been increasing, linked to extensive use of products and energy

› Emissions from the production of materials as a share of global GHGs have been increasing - counting almost ¼ of global GHG



Source: IRP, 2020

› Climate budget to avoid suppressing the 1.5°C threshold is reducing as climate policy is failing to achieve the rapid decarbonisation rates required

› Increasing material efficiency and Circular Economy – narrowing, slowing and closing the loops of products – can thus play a critical role in meeting climate targets

TIMES models currently represent linear patterns of economic activity.

- GHG emissions are modelled per economic sector and downstream value chains are generally not considered
- Upstream value-chains are poorly represented – no link between materials production and technology stocks

Goal:

- Develop a new climate mitigation modelling framework for car passenger materials value chain to assess how circular economy measures targeted to transport can contribute to the decarbonisation efforts of the EU27
- Based on extended TIMES-EU model that explicitly links vehicle manufacturing processes, car stock evolution and material flow dynamics.

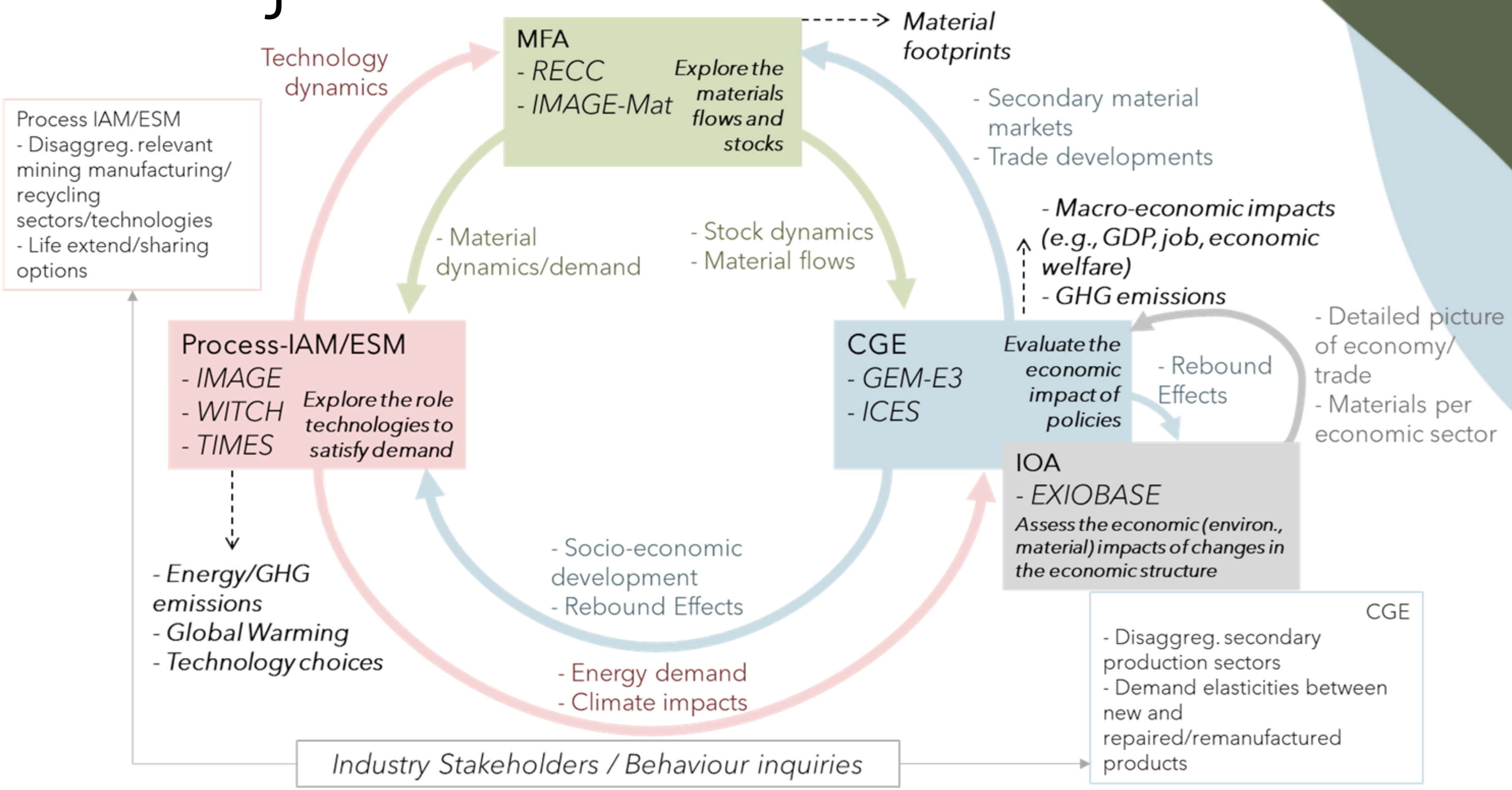
Bulk materials

Why passenger cars?

- The automotive sector is the second-largest consumer of bulk materials in the EU (steel, aluminium and copper).
- Car manufacturing is one of the EU's most important industrial sectors (and a net exporter), making passenger vehicles central to analysing material demand and their role in a circular economy.
- The increasing share of heavier, larger SUVs raises material demand and reduces energy efficiency – reinforcing the need to understand the potential of circular-economy measures in passenger cars.

CIRCOMOD Project

- **Project objective:** Develop a new generation of models/modelling frameworks and model-based scenarios needed for comprehensive, consistent and robust assessment of CE-GHG link
- How circular economy strategies impact GHG emissions and resource efficiency?

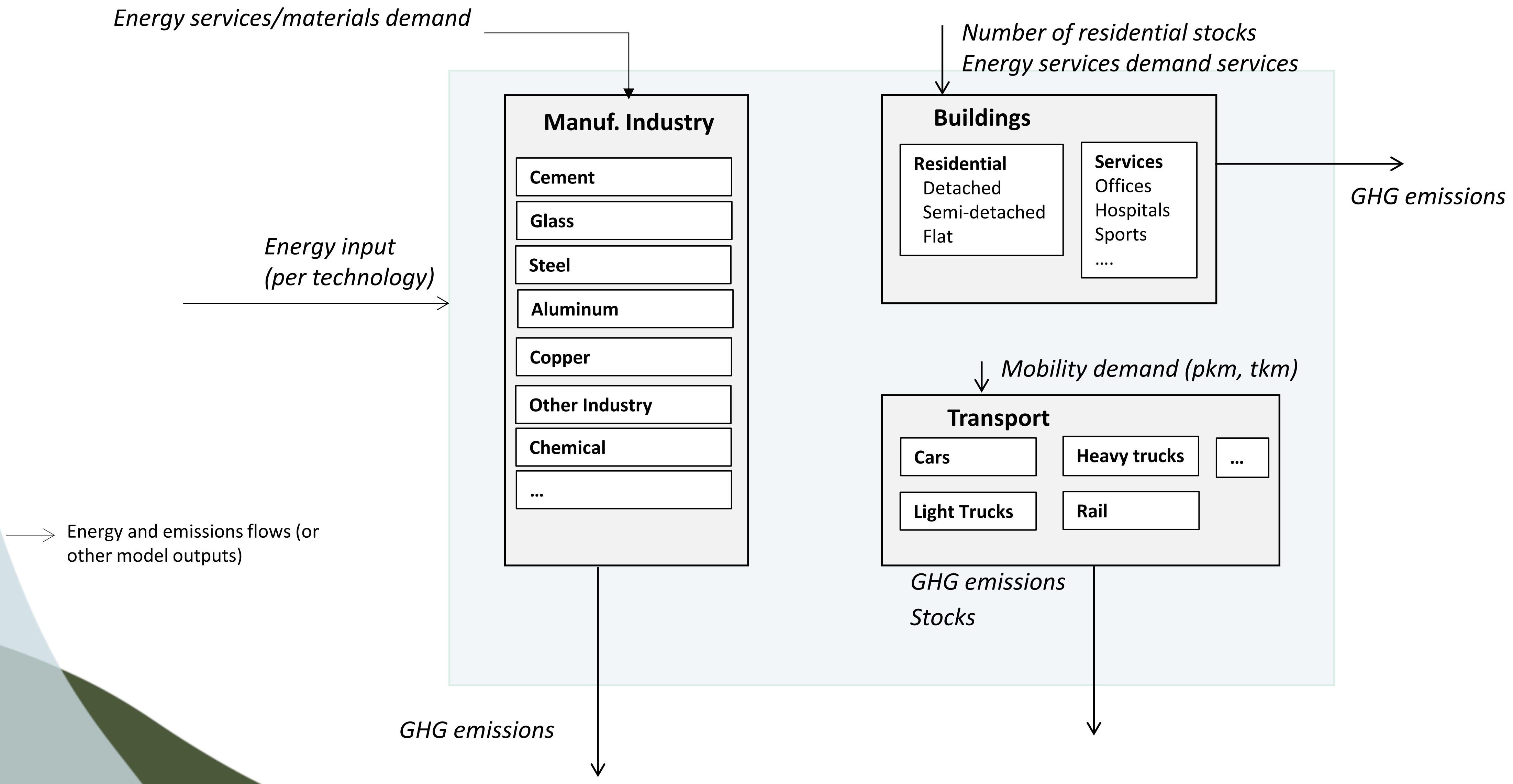


EU-TIMES model

› Based on JRC-EU-TIMES
› Regional scope: EU 27 + UK
› Timeframe 2019 - 2060
› Covers the production of main materials:
  • cement, iron and steel, aluminium, copper, glass, paper and pulp…
  • and stocks that use energy: residential and services buildings, equipment, power technologies, vehicles, namely different car segments and powertrain, ….

  • Vehicle manufacturing industry: each car segment and powertrains manufacturing has specific iron and steel, aluminium, copper, flat glass inputs (energy and manufacturing yield)
  • Vehicles market/materials for vehicles market: only 17 MS+UK are car producers vs all MS have car stocks
  • Cars end-of-life technologies and Reuse cars/materials EU market

STANDARD TIMES – End-use Sectors



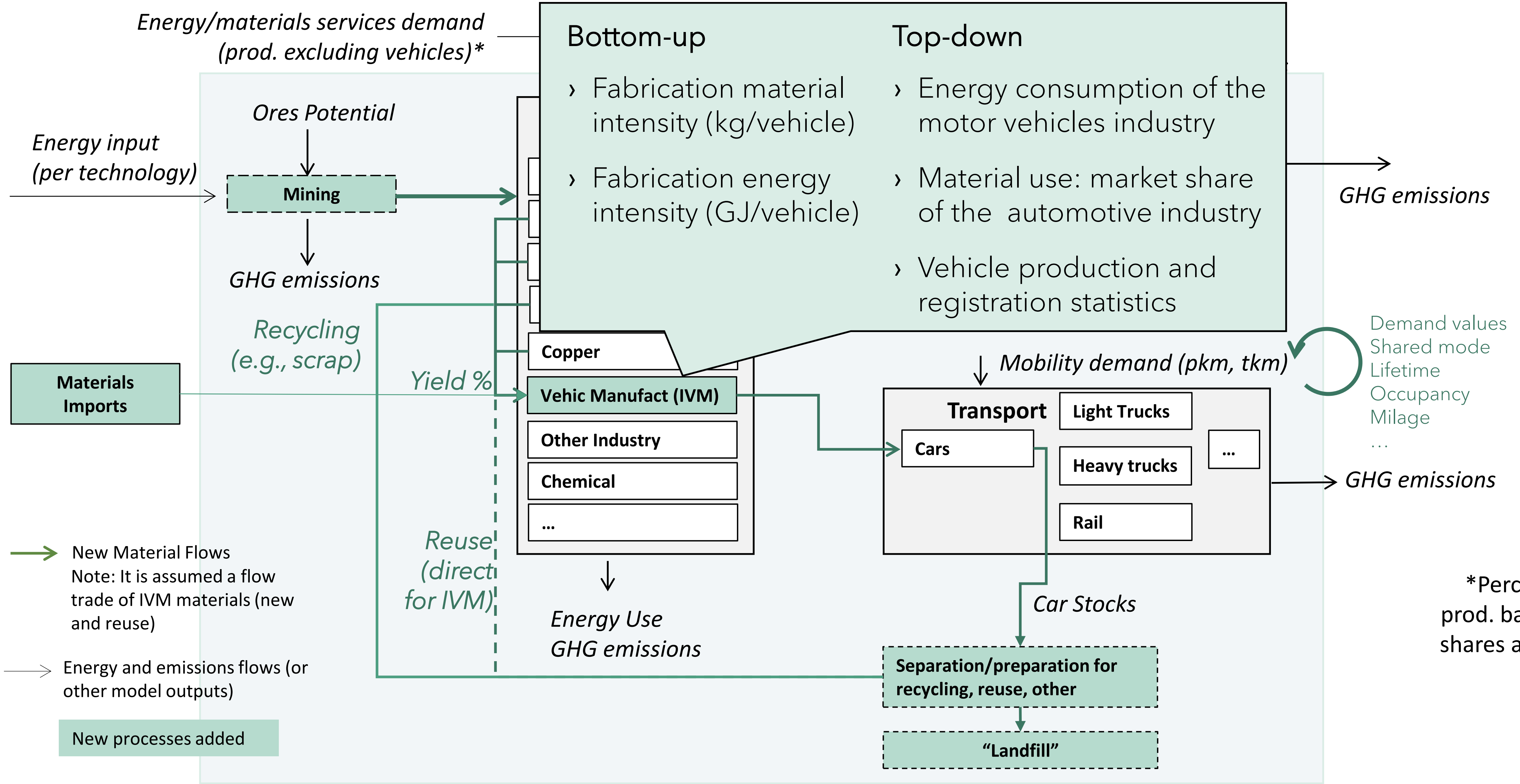
TIMES-CE

Bottom-up

- Fabrication material intensity (kg/vehicle)
- Fabrication energy intensity (GJ/vehicle)

Top-down

- Energy consumption of the motor vehicles industry
- Material use: market share of the automotive industry
- Vehicle production and registration statistics



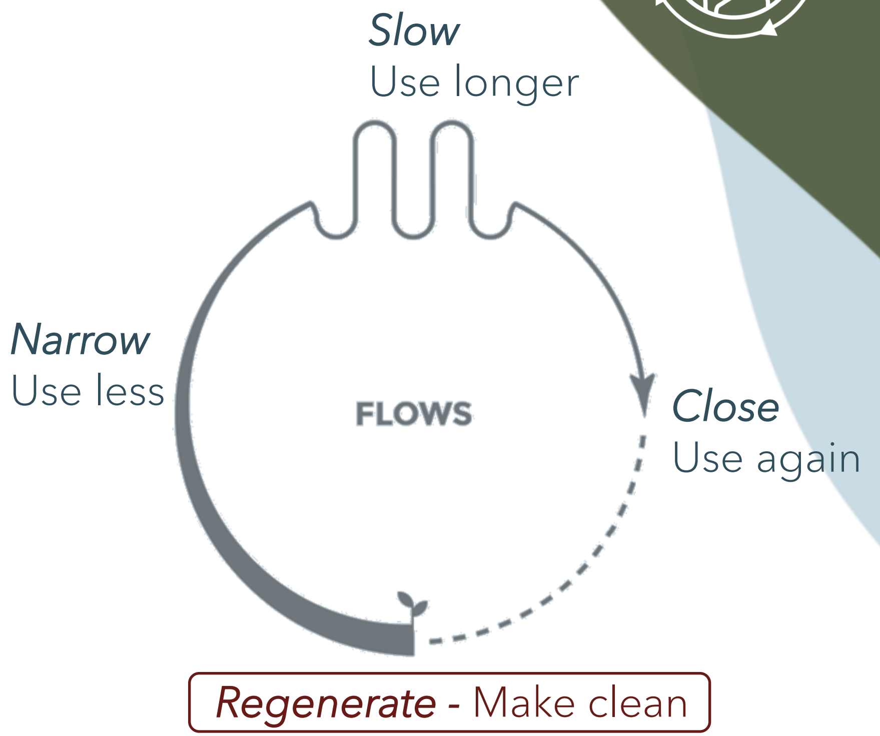
*Percentage of total prod. based on market shares according to EU Associations

Modelling Scenarios

- **Socio-economic scen:** SSP2
- **Temporal Scope:** 2020-2060
- **Regional Scope:** EU27 +UK

	Climate Ambition	
Circular measures	Current Policies (no ambitious target – e.g., ETS and non-ETS targets, REF2020 trends)	Compatible with 1.5-2°C - Carbon Neutrality in 2050 and -90% reduction in 2040 (RCP=1.9W/m2)
None	SSP2	1.9
CE scenarios	SSP2_Narrow SSP2_Slow SSP2_ Close SSP_NSC	1.9_Narrow 1.9_Slow 1.9_ Close 1.9_NSC

10 Scenarios

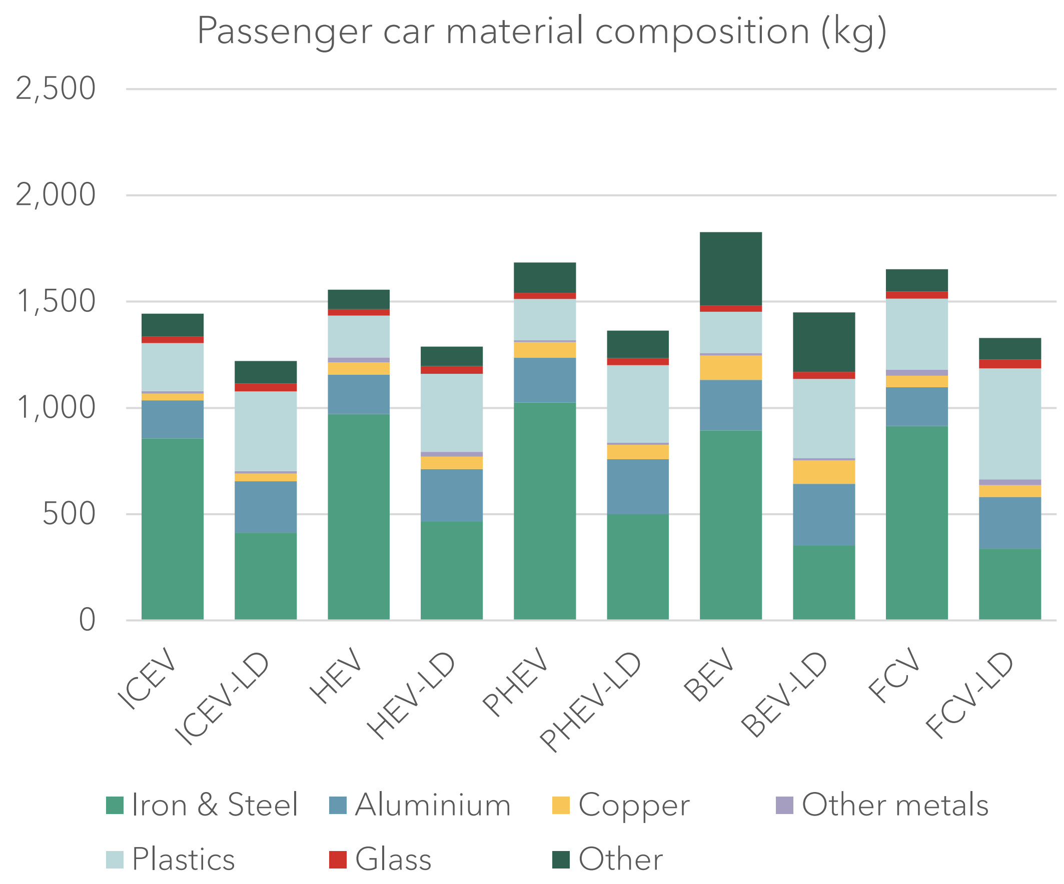


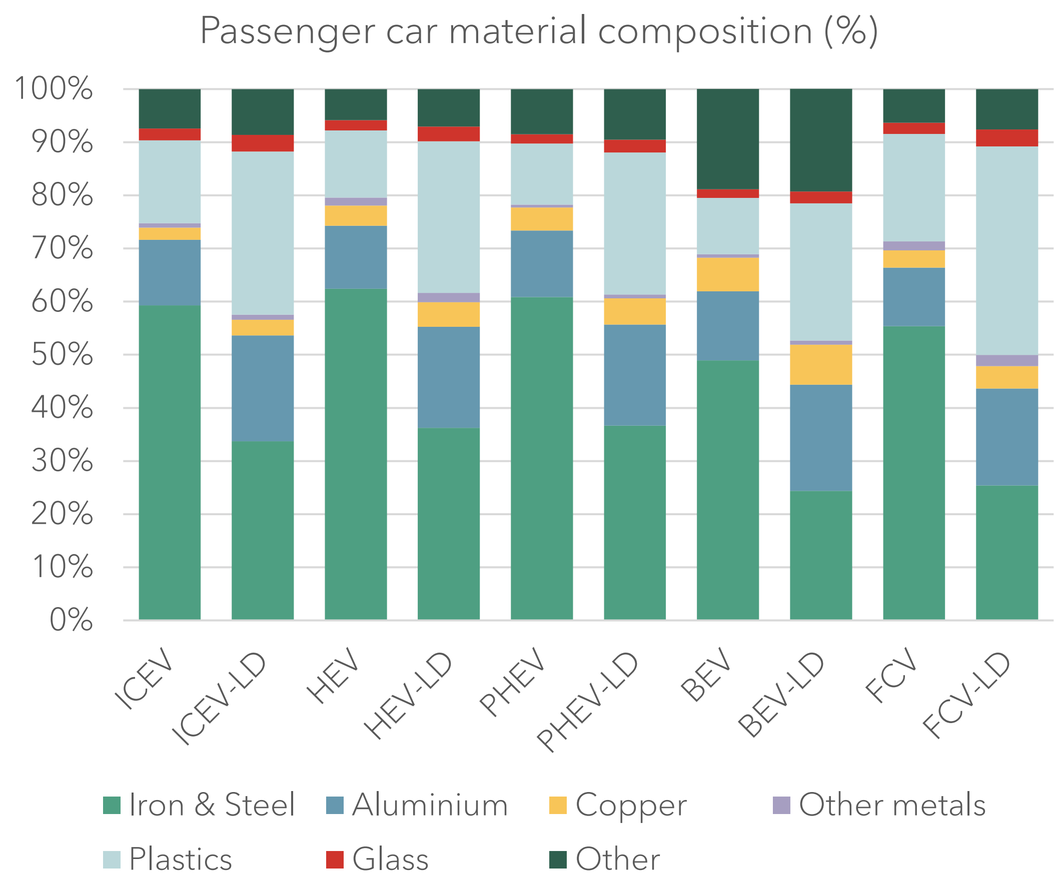
Already cover by ESM optimisation models and climate policies

Circularity Scenarios

	R strategy	Examples	Indicator (2050)
Narrow	Refuse	Teleworking	pkm/cap: -25% compared with baseline
	Modal shift	Private to public transport , air to rail	• 22% of pkm are expected to shift from private cars to public transport modes: 6% to bus and 16% to rail • 100% transition from short-haul aviation to high-speed rail, considering existing and new investments planned
	More intense use	Shared vehicles	30% of shared vehicles by 2050 Occupancy (from 1.5 pass/vehicle to 2.4 pass/vehicle), Mileage: +20%
	Downsizing	Buying smaller cars	90-96% micro+small cars (new capacity)
	Product lightweighting	Material substitution in car design	~75% of lightweight cars (new capacity)
	Fabrication yield improvement	Blanking & stamping of sheet metals	Yield loss: -10%
Slow	Reuse rate	Component recovery at EoL phase	Steel: +5%, Copper: +6%, Aluminum:+4%, Glass: +60%
	Lifetime extension	Improved maintenance	+20%/no CE
Close	Recycling rate	Post–shredding ELV material recovery	Steel: +15%, Copper: +16%, Aluminum:+11%, Glass: +49%
NSC	All above		

Lightweighting through material substitution



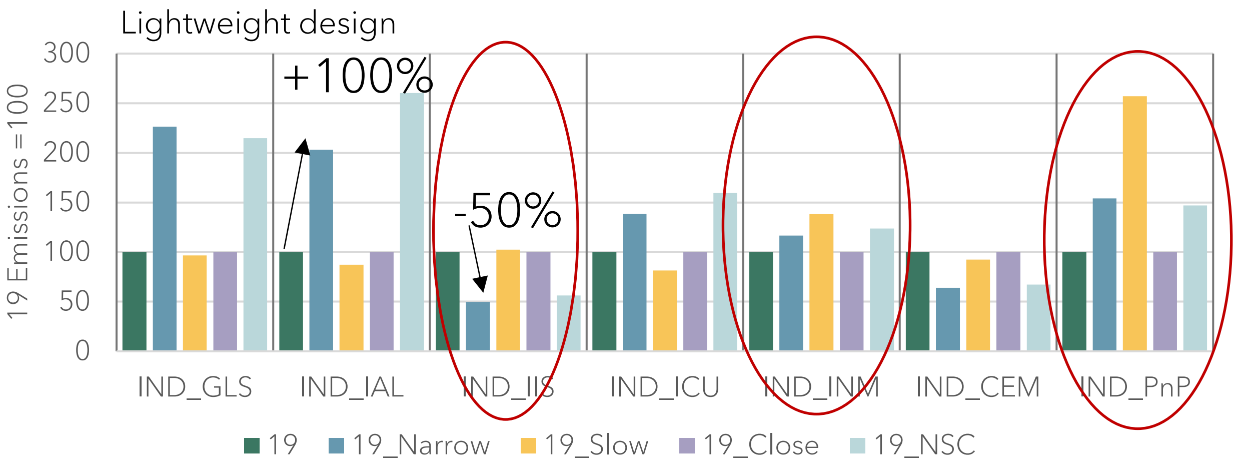


Materials demand based on [GREET Model]

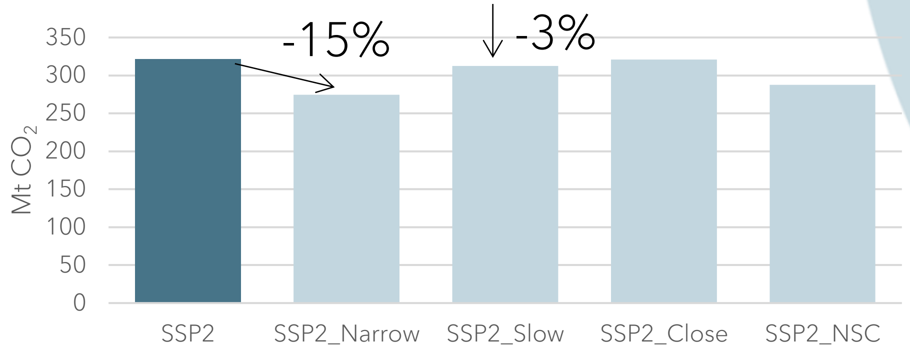
CO_2 Emissions

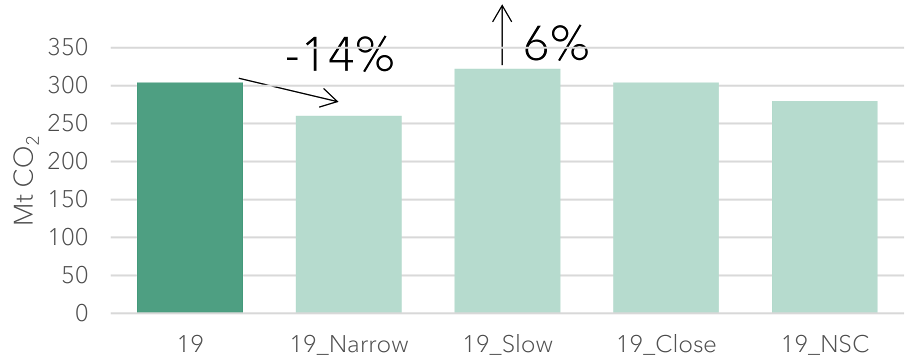
Preliminary Results

- Industry total CO2 emissions with and without CE range between -15% (SSP2_Narrow) and +6% (19_Slow)
- **More circularity does not necessarily translate into relevant lower emissions** – Reducing demand in some sectors can lead to increases in others due to fewer constraints elsewhere – a kind of rebound effect



CO_2 Industry emissions (combustion+process)



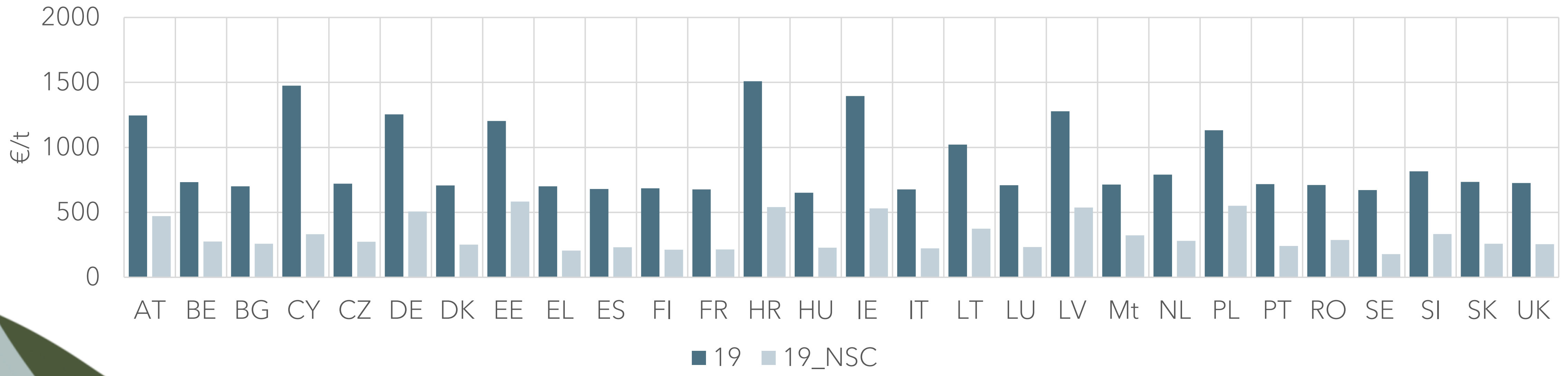


Results

Preliminary Results

Marginal Abatement Cost | 2050

- All CE strategies lead to a reduction on the marginal abatement cost per MS - higher reduction on NC – reduction between 51% to 78%



Final Remarks

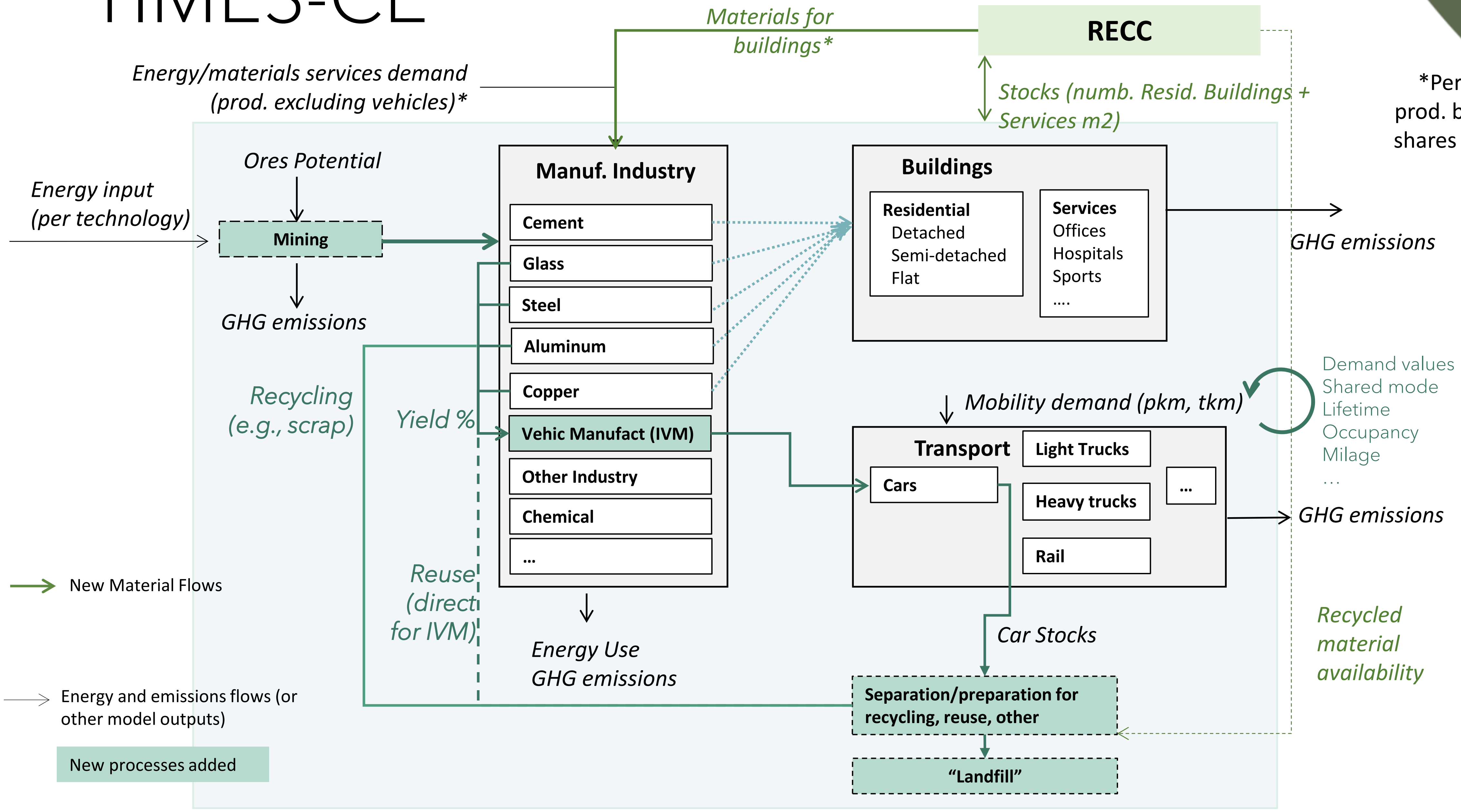
- CE strategies can lower material demand, reducing reliance on less mature technologies and helping decrease overall mitigation costs.
- But…. CE does not always guarantee GHG reductions:
  - Design changes can shift material demand in unexpected ways.
  - Longer product lifetimes may reduce efficiency.
  - Emission reductions in one sector can create flexibility in others, potentially offsetting the CO_2 benefits – a form of rebound effect.

Key question: Are optimisation energy system models (ESMs) the right tools to assess CE effects?

Limitations:

- Impact of **extra-EU trade** on the interaction between the circular economy and climate mitigation
- Scenarios are set exogenously and not based on cost-effectiveness (primary vs secondary production of materials
- Double counting of cost on car passengers: materials + literature CAPEX (includes materials)

TIMES-CE



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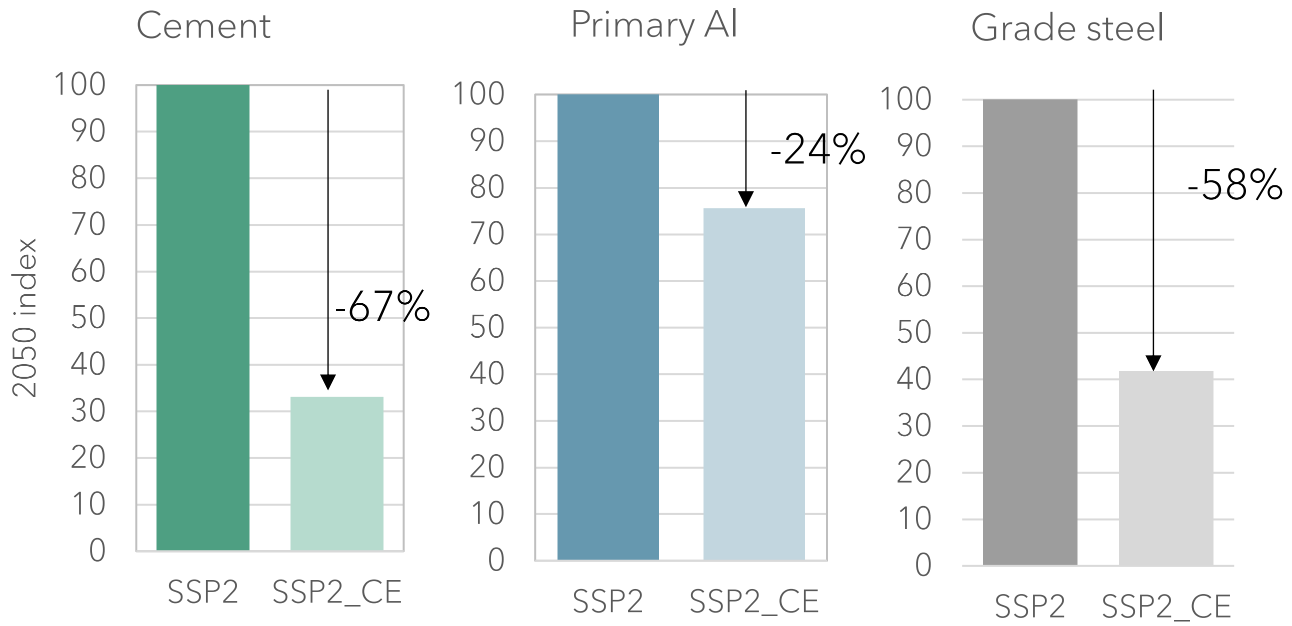
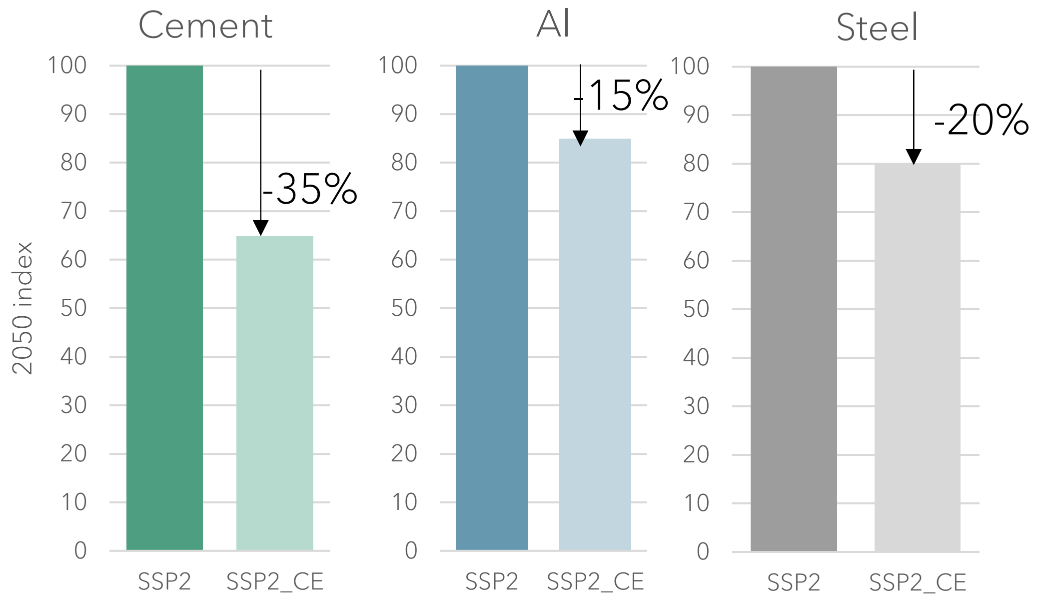
Materials Outcomes

Buildings – RECC ouputs



Total Production – TIMES inputs



Market Share

	Cement	Al	Iron and Steel
Electricity	36%	12%	3.2%
Buildings	50%	25%	21%
Vehicle		23%	17%

EU 2040 Impact Assessment – LIFE scen. outcomes
Cement/Clinker -25% / Al -20% / -15% Steel

circomod.eu

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