IEooc_Methods6_Exercise1: Coupling between sectors. The example of passenger vehicle light-weighting

Goal: *Estimate the system-wide impact of a climate change mitigation strategy in a specific sector. Learn about light-weighting of vehicles as emissions savings option.*

Task 1) The global passenger vehicle fleet:
Given a global population of 9 billion people in 2050, an average car ownership of 250 per 1000, an average kilometrage of 14.000 km/car*yr, an average fuel efficiency of 2.2 MJ/km, and the emissions from producing and burning gasoline of 0.02 and 0.07 kg CO2-eq/MJ, respectively.
What are the total GHG emissions for operating this fleet for one year, and how does it compare to current (2015) total annual emissions, both total and from passenger vehicles?

Task 2) The relation between light-weighting (vehicle weight reduction) and fuel consumption:
Most passenger vehicles show a weight fuel relation of 0.6 (means that 10% weight reduction lead to a reduction of fuel consumption of 6%) (Johannaber et al., 2007). Why?

Task 3) Material substitution using high-strength steel:
Given an original car weight of 1400 kg, a weight fuel relation of 0.6 (means that 10% weight reduction lead to a reduction of fuel consumption of 6%), the CO_2-intensity of making steel (3 tons CO2-eq per ton of steel), the CO2-intensity of making high-strength steel
(4 tons CO2-eq per ton of steel), and the substitution rate of 1.5 (1 kg of high-strength steel replaces 1.5 kg of ordinary steel).
How big are life-cycle emissions savings for all the cars on the road in 2050, if the car lifetime is 15 years and the actual car weight (after substituting normal steel with high-strength-steel) is 1200 kg?

How do results change if aluminium is used instead of high-strength steel? The CO_2-intensity of producing 1 ton of aluminium is about 13 tons of CO_2-eq and 1 kg of aluminium replaces about 2.5 kg of ordinary steel. What would be the new weight of an individual vehicle if the same amount of ordinary automotive steel would be substituted with aluminium as in the case for high-strength steel?

Task 4): Burden shift to other sectors:
How big is the burden shift (increasing emissions in other sectors, in this case the metal production industries)? Calculate both absolute results (Mt/yr) and relative results (burden shift in % of gross and net emissions savings).

Task 5) Reflection:
Provide a brief, but concise reflection: Who benefits from ever-increasing levels of material production and why?
What are obstacles that need to be overcome when implementing the decoupling strategies proposed in the papers?
Who has the power to change the system and why?

Additional literature:

(Allwood et al., 2011)

(Modaresi et al., 2014)

References:

Allwood, J.M., Ashby, M.F., Gutowski, T.G., Worrell, E., 2011. Material efficiency: A white paper. Resour. Conserv. Recycl. 55, 362–381.

Johannaber, M.E.., Wohlecker, R.., Wallentowitz, H., Leyers, J., 2007. Determination of Weight Elasticity of Fuel Economy for Conventional ICE Vehicles, Hybrid Vehicles and Fuel Cell Vehicles. Aachen, Germany.

Modaresi, R., Pauliuk, S., Løvik, A.N., Müller, D.B., 2014. Global carbon benefits of material substitution in passenger cars until 2050 and the impact on the steel and aluminum industries. Environ. Sci. Technol. 48, 10776–10784.