# IEooc_Methods4_Exercise1: Life cycle thinking and electric vehicles

***Goal:*** *Practice systems thinking and quantitative systems analysis; work with system definitions; life cycle thinking; electric vehicles.*

Electric vehicles are a key strategy to use electricity from renewable sources in the transportation sector. Some countries (Norway, EU) even have started to debate a ban of internal combustion engine vehicles for new registrations in the midterm future (from 2025-2030 onwards). While the benefits for local air quality are undisputed the system wide contribution of electric vehicles to climate change mitigation and human health depends on the electricity mix of the region where these vehicles are driven. This exercise shall illustrate the importance of systems thinking for transportation solutions with renewable energy.

**Research question:** Given a country that promotes the transition of its vehicle fleet from mostly gasoline/diesel vehicles to electric vehicles. How big does the share of renewable electricity need to be for electric vehicles to be net positive contributors to climate change mitigation?

**The following methods are to be applied:** Explicit system definition, process balance checks where possible, life cycle thinking (Matthews et al., 2015).

**Data:** Assume two types of electricity supply are present in a country's grid mix: renewables (with 30 g $CO_2$/kWh for PV as proxy for renewables (Hertwich et al., 2015)), and coal-based electricity (with 850 g $CO_2$/kWh (Hertwich et al., 2015)). The share of these two sources is unknown, it is to be determined during this exercise.

**More data and assumptions:** Energy need of passenger cars during the use phase: 0.85 MJ/km (electricity, for battery electric vehicles), and 2.2 MJ/km (gasoline for internal combustion engine vehicles) (Modaresi et al., 2014), The useful energy per unit of combustion $CO_2$ for gasoline is 14 MJ/kg $CO_2$ (derived from the energy and carbon content of gasoline), and the $CO_2$ – intensity of gasoline supply is 10g $CO_2$/MJ of gasoline (Modaresi et al., 2014). Emissions from vehicle production and disposal are neglected here.

**The following questions are to be answered:**

1) Why is the carbon intensity of PV not zero? What are the main contributors to that carbon footprint? What about the coal-based electricity?
2) Why is the energy demand per km for an electric vehicle about 3 times smaller than for a gasoline-driven vehicle?
3) For a functional unit of 1 km driven, calculate the break-even point of the share of renewable electricity in the grid beyond which the electric vehicle km is less carbon-intensive than the gasoline vehicle km. Provide an explicit definition of the system you are working with and check whether all processes are balanced!
4) How would the result change if emissions from vehicle production and disposal were included in the calculation? (Qualitative answer)

**References:**

Hertwich, E.G., Gibon, T., Bouman, E.A., Arvesen, A., Suh, S., Heath, G. a., Bergesen, J.D., Ramirez, A., Vega, M.I., Shi, L., 2015. Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies. Proc. Natl. Acad. Sci. 112, 6277–6282.

Matthews, H.S., Hendrickson, C.T., Matthews, D.H., 2015. Life Cycle Assessment: Quantitative Approaches for Decisions that Matter. www.lcatextbook.com/.

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.