IEooc_Methods4_Exercise1: Comparative life cycle assessment of a passenger-km

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?

>> While solar cells have virtually no emissions during their use, their production requires energy and materials, and the generation/production of those causes CO_2 emissions from fuel use. Main contributors to the CO_2 emissions from producing solar cells include the production of the silicon wafers, the glass substrate, and the production of aluminium and steel for the framing and mounting of the modules.

For coal-based electricity the main source of CO_2 emissions is the combustion of coal for electricity generation. Unlike with PV, where the production phase dominates life cycle impacts for coal-based electricity the use-phase emissions are dominant by far.

2) Why is the energy demand per km for an electric vehicle about 3 times smaller than for a gasoline-driven vehicle?

>> The main reason is that internal combustion engines have a conversion efficiency of 35-40% whereas the conversion efficiency of electric motors is 95% and higher. This difference can be explained with the different exergy content of gasoline and electricity.

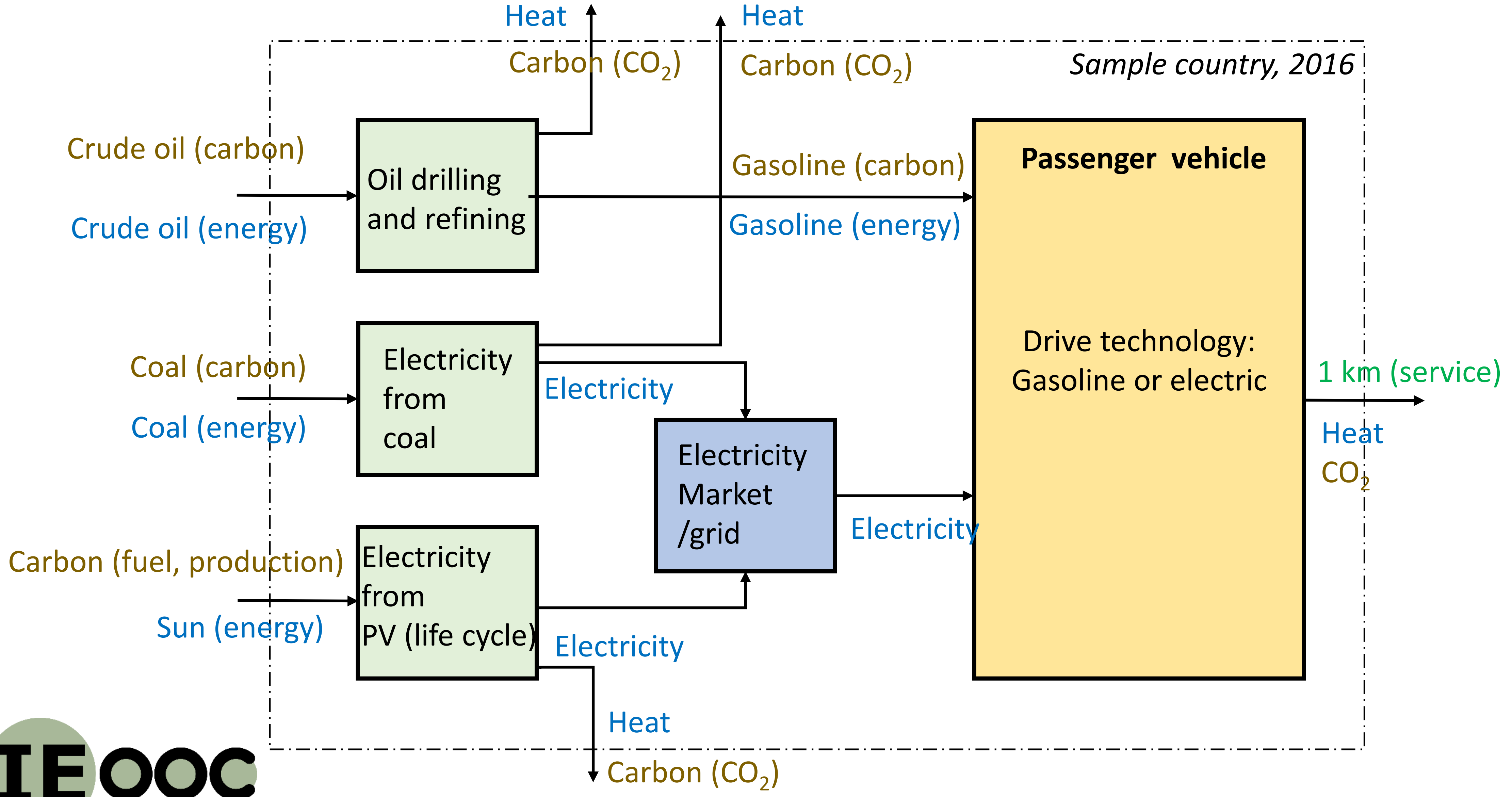
Version June 9, 2020

IEooc_Methods4_Exercise1: Comparative life cycle assessment of a passenger-km

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!
>> We first develop the system definition showing which processes are included (next slide). We need to include the Use phase of the vehicle and the energy supply (3 options: gasoline, PV, and coal-fired power plant). In addition we Include the market for electricity to simulate the grid mix (optional).
This leaves us with five processes.

We are interested in energy and carbon flows and therefore balance the system on two layers: Energy and carbon.

Exercise: System definition



Exercise: Quantifying the system

1 kWh = 3.6 MJ

1 kg CO_2 contains 12/44 kg = 0.2727 kg C

Part a) Reference case. Gasoline: for 1 km, we need 2.2 MJ gasoline, which leads to 2.2 MJ / 14 (MJ/kg) CO_2 direct and 2.2 MJ *0.01 kg/MJ CO_2 indirect emissions.

The direct emissions (**157 g CO_2 or 43 g C**) are emitted from the use phase and the indirect emissions (**22 g CO_2 or 6 g C**) are emitted by the refinery.

Results for reference emissions: **179 g CO_2 or 49 g C** for 1 km with the gasoline-driven vehicle.

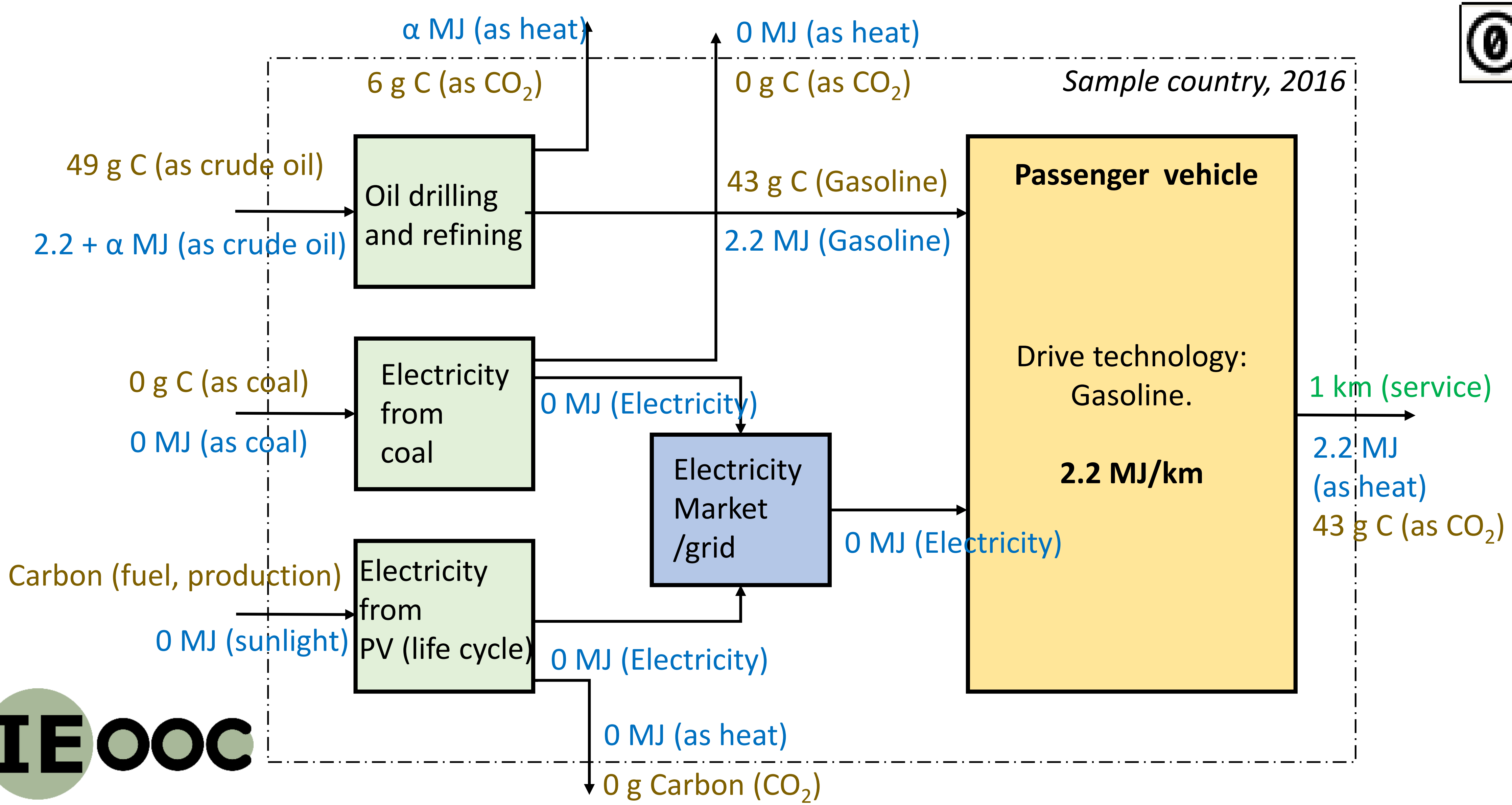
With that info we quantify the system (next slide) and make sure the process balances hold. This leads us to introduce the energy losses at the refinery, which we don't know and don't need to know, and hence set to an unknown parameter α.

IEOOC

Version June 9, 2020

UNI FREIBURG

Exercise: System conv. Vehicle, functional unit: 1km



https://en.wikipedia.org/wiki/Energy_content_of_biofuel

Exercise: Quantifying the system

1 kWh = 3.6 MJ

1 kg CO_2 contains 12/44 kg = 0.2727 kg C

Part b) Electricity need: 0.85 MJ.

We don't know the share of solar electricity in the grid and thus set it to x. Hence, of that 0.85 MJ, a fraction x is from PV with a carbon intensity of 30 g CO_2 per kWh or 8.33 g CO_2 per MJ, and a fraction 1-x is from coal with a carbon int. of 850 g CO_2 per kWh or 236.1 g CO_2 per MJ.

Break even: Reference missions of CO_2: 179 g. For break even,
this must equal x * 0.85 MJ * 8.33 g CO_2 /MJ + (1-x) * 0.85 MJ * 236.1 g CO_2 /MJ,
which gives us x as 0.11.

This gives a minimum share of renewables in the grid of ca. 11 %
to reach a break even between the carbon emissions of a gasoline and of an electric vehicle.

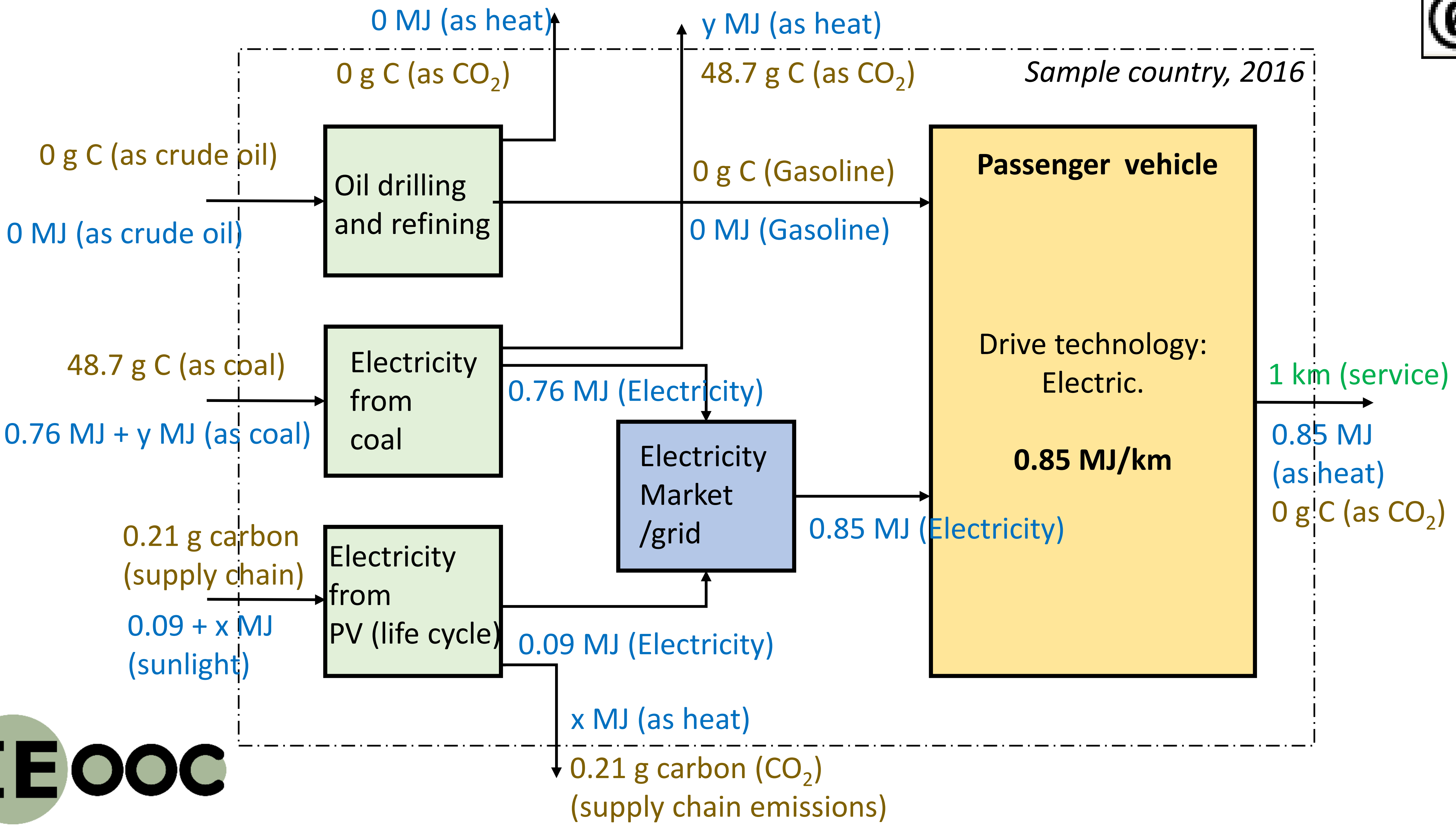
Exercise: Quantifying the system

1 kWh = 3.6 MJ
1 kg CO_2 contains 12/44 kg = 0.2727 kg C

Part b) (Ctd.)
With x = 0.11, we need
+ Coal-based electricity: (1-0.11)*0.85 MJ = 0.76 MJ
+ PV-sourced electricits: 0.11*0.85MJ = 0.09 MJ

Corresponding to
+ Coal-based: = 0.2727*236.1*0.76 g C = 48.7 g C
+ PV-sourced: C-footprint = 0.2727*8.33*0.09 g C = 0.21 g C

Exercise: System electr. Vehicle, functional unit: 1km



Exercise: Including impacts from vehicle production

4) How would the result change if emissions from vehicle production and disposal were included in the calculation? (Qualitative answer)

>> The supply chain GHG emissions from electric vehicle production are significantly higher than those for a internal combustion engine (ICE) vehicle production (Source: DOI: 10.1111/j.1530-9290.2012.00532.x)
For ICE vehicles the carbon footprint of production accounts for about 15% of the footprint of the service provided (vehicle-km). For electric vehicles, this figure can be around 30%.

To compensate for the higher footprint of the electric vehicle production, the share of low carbon electricity in the grid needs to increase.