

Assessing climate neutrality and circularity potentials - A LCA case study on city buses

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EXTENDED ABSTRACT

Reaching climate neutrality by GHG reduction and circularity by closed material cycles is a societal challenge. Climate neutrality and circularity are addressed by the methodology of dynamic Life Cycle Assessment (LCA), where GHG emissions with its radiative forcing potential and material flows with its (non-)circular flows are calculated over the entire lifetime. In the Technology Collaboration Program (TCP) of the International Energy Agency (IEA) on Electric Vehicles (EV) experts from 20 countries cooperate on LCA of electric vehicles since 2010, where Task 46 performed a case study for 100% climate neutral buses with a newly developed methodological framework, to compare buses with different propulsion & fuel combinations, e.g. battery & hydrogen electric city buses, diesel and e-diesel using wind energy. To reach 100% climate neutrality these systems are combined with a Carbon Capture & Storage (CCS) system. So far, there was no common framework to assess climate neutrality and circularity scientifically. Now in this international cooperation of researchers an initial methodology was developed and tested in various applications. In this methodology Climate Neutrality and Circularity can be assessed in LCA based on the GHG emissions and the mass flows over the lifetime. Therefore, a LCA based definition of Climate Neutrality and Circularity is necessary. To keep the wording

appropriate to LCA nomenclature, in the Impact Assessment two new impact categories - “Climate Neutrality Potential (CNP)” and a “Circularity Potential (CPO)” - are developed and applied. These definitions were developed in IEA EV Task 46 (<https://ieahev.org/tasks/46/>) and applied for the first time in this LCA Case study on city buses. The definition is: A product or service is “climate neutral” and “circular”, if its whole life cycle - production, operation and end-of-life - uses only reused components, recycled material, renewable energy and makes no waste and no GHG emissions. The indicator for the assessment of circularity is the CPO calculated in the dynamic LCA. The CPO is based on data of the Inventory Analysis using the material flows in and out of the considered systems in its total lifetime including non-renewable energy inputs. The material flows are used to calculate the Material Circularity Index (MCI). The MCI is 100%, when the system is completely circular, whereas an MCI of 0% means a total linear material use. The MCI is calculated using the Linear Flow Index of materials (LFI_{material}) and the Utility Factor of a product (UF_{product}) covering the lifetime and the intensity of the use. The Climate Neutrality Potential (CNP) is based on the cumulated GHG emissions in the Impact Assessment of dynamic LCA. The total top-of-atmosphere radiative forcing potential based on the GHG emissions over lifetime is calculated in W per m^2 . A 100% Climate Neutrality is reached if W/m^2 is 0. The key findings are 1) Climate Neutrality Potential & Circularity Potential are additional environmental impacts in dynamic LCA not yet covered in the existing Impact Categories. 2) Only systems using renewable energy have the potential towards Climate Neutrality and Circularity. 3) Only in combination with CCS all buses might have zero GHG emissions and can be “100% climate neutral”. 4) The Circularity Potential of electric (57 – 58%), hydrogen (55%) and e-diesel buses (48%) are quite similar due to renewable electricity use, for diesel it is very low (3%) due to diesel use. 5) The diesel bus has the highest environmental impacts, except primary energy demand lower than for e-diesel. 6) For 100% Climate Neutrality the electric bus with CCS needs the same amount of additional renewable energy than the diesel bus with CCS; and it needs 5 times less additional renewable electricity to use fossil diesel with CCS than making e-diesel with CCS.