IEooc_Background1_Exercise1: Energy service cascade and stock-flow-service nexus

Goal: *Understand the way the social, economic, and environmental aspects of sustainability are linked in the field of industrial ecology and socio-metabolic research. Quantify product functions and estimate the impacts of energy supply and material production for providing these functions.*

Introduction: The energy service cascade. Sustainable development aims at transforming the global economy to reach wellbeing and nature protection objectives at the same time. The classic three pillars of sustainability, the environmental, social, and economic, are not independent, but form a cascade of services (like transport, thermal comfort) to wellbeing, functions (car driving, building heated) to services, products (cars, houses) to functions, energy and material to build products, energy and material to operate products, energy carriers and raw materials, resource extraction and energy conversion technologies, and the impact of all these activities on the environment (Kalt et al. 2019). Here, the economy (blue) is constrained by both social and environmental sustainability objectives (see also IEooc_Background1_Reading4). That means:

- Sustainability emerges at the system level, when the steps of the energy service cascade below are combined together in a way that meets both social and environmental objectives. All steps of the cascade are crucial, but no single step alone can be called sustainable or not, as sustainability is a system- level property. There are no sustainable products, materials, or technologies.
- Each step in the energy service cascade provides an opportunity for decoupling, that is, for achieving more positive outcomes with the same or less costs, resource use, or impacts, but also for rebound effects, i.e., more service, functions, products, energy, or material flows as a consequence of higher efficiency.

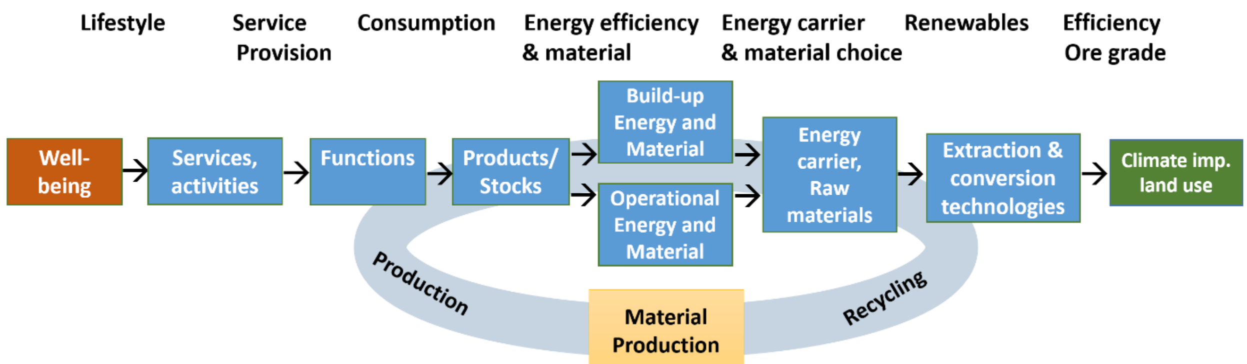

Figure 1: The energy service cascade by Kalt et al. (2019), in the conceptualisation for this exercise. Red: social sustainability aspects, blue: economic aspects, green: environmental aspects. For details, see the text.

Central in the energy service cascade is the so-called stock-flow service nexus, which is comprised of the blue boxes ‘services/activities’, ‘functions’, ‘products/stocks’, and build-up and operational energy and material flows (Haberl et al. 2017). This nexus is an important system linkage in society’s metabolism, as it links energy and material flows to service provision for human wellbeing:

- Services are provides by functioning products (i.e., products in operation). For example, a driving car (function) provides the service of transportation.
- Most functions require in-use stocks (short: stocks), which are capital goods that can be used multiple times to provide the same function over and over again. For example, a house provides shelter and thermal comfort for many years, and a fridge cools down food for many years.
- In-use stocks have a certain lifetime, after which they have to be replaced. Materials (like steel or plastics) and energy are needed to build new products that than either replace old products (maintenance of the stock) or contribute to stock growth (stock expansion).
- Materials and energy are also needed to operate the stocks/products to provide the function, e.g., gasoline to drive a car.

The stock-flow-service nexus thus contains four couplings. Services to product functions (coupling via the number of people in a vehicle, for example), functions to stocks (kilometres driven per vehicle and year, for example), stocks to build-up and replacement material and energy flows (number of new cars each year to maintain the fleet size, for example), and stocks to operational energy and material flows (gasoline to drive the cars, for example).

In the following exercise, the energy service cascade and the stock-flow service nexus shall be quantified for selected human activities.

Questions and tasks:

Consider three services (e.g., thermal comfort/dwelling, transportation, nutrition, ...) and address the following questions, both with a quantitative analysis and a critical discussion! Select a meaningful population scope (e.g., for a single person, a family, a city with a certain population, or an entire country).

1) What functions do these services require and how can they be described quantitatively?

2) What products and in-use stocks are needed to provide these functions in the use phase, and how can these be meaningfully quantified (e.g. m^2 for buildings, xyz appliances for household activities)?

3) What material and energy flows does it typically take to build and to operate some of these product stocks? (e.g., washing machine: x kg of different materials for manufacturing, 12 years lifetime corresponds to 1/12 new washing machine needed per year on average, y kWh of electricity, and z litres of water per year for operation...) Select one or two stocks for each function from those you have listed.

4) Approximately how large are the environmental impacts (GHG, land use, water use, and resource use) of these material and energy flows for each service?

5) Think of a climate-friendly sufficiency and efficiency scenario! Where in the stock-flow-service nexus can there be less consumption and higher efficiency! Choose one of the sectors above and change the calculations for a sufficiency and efficiency scenario. What is the difference in the different function, stock, flow, and impact indicators between the default impacts and those identified for the sufficiency scenario?

6) Discuss your assumptions and results! For example:

+ What are the mechanisms, strategies, and incentives for more or less sufficiency at the individual, neighbourhood, industry, policy, etc. level?

+ Are your results realistic and does the question of sufficiency make sense at all, or should rather general economic incentives be set through e.g. CO_2 pricing?

+ How do your results compare with those of other studies or limits?

Hints:

This exercise requires you to search for own data and make a number of assumptions, e.g., on gasoline consumption per distance driven, average vehicle lifetime, etc. Don't forget to document your data sources and assumptions!

Environmental footprints per unit of material or energy carriers are provided in the accompanying data file IEooc_Background1_Exercise1_Stock_Flow_Service_Nexus_Data.xlsx

References:

Kalt, G., Wiedenhofer, D., Görg, C. & Haberl, H. Energy Research & Social Science Conceptualizing energy services : A review of energy and well-being along the Energy Service Cascade. Energy Res. Soc. Sci. 53, 47–58 (2019).

Haberl, H., Wiedenhofer, D., Erb, K. H., Görg, C. & Krausmann, F. The material stock-flow-service nexus: A new approach for tackling the decoupling conundrum. Sustain. 9, 1049 (2017).