Internship Topic: Energy Modeling of Socio-Technical Structures.

Host Laboratory : Laboratoire Interdisciplinaire des Energies de Demain (LIED, UMR 8236)
Université Paris Cité, Campus des Grands Moulins, 75013 Paris.
Contacts : eric.herbert@u-paris.fr, petros.chatzimpiros@u-paris.fr
Required level : Master's 2 or equivalent.
Duration : 5-6 months within the period from January to July 2025.
Gratification : set according to the national scale (~650 €/month).

Description

Every human society relies on technology to organize the flows of matter and energy that pass through it. In industrial societies, technology is omnipresent through infrastructures and technologies across all sectors of activity. This is characterized by a high energy consumption required both for establishing these structures and for their operation. Generally, the energy consumption associated with the operation of these structures is more noticeable than that associated with their establishment, the latter being inherent to the industrial sector and largely invisible to users. The amount of energy embedded in these structures, also known as "embodied energy," along with the rate (W) at which this energy is supplied—referred to as "embodied power"—depends on the processes as well as the type and complexity of the materials and structures involved.

The quantification of the embodied energy in objects and structures is typically addressed through "bottom-up" life cycle assessment (LCA) approaches. These involve reconstructing resource usage from an individual description of all stages and flows involved in a process. The main challenge lies in defining the scope of analysis, which should be as inclusive as possible but remains inevitably arbitrary to achieve an accurate reconstruction. Indeed, beyond the limitations related to setting a functional boundary in "space," bottom-up approaches are typically static and struggle to account for the temporal dimension of development, in terms of the legacy of past infrastructures, technologies, and innovations in the production of the present.

In this work, we propose to focus on the embodied energy and power of structures using a top-down approach, starting from macroscopic consumption data to analyze the uses and renewal dynamics of structures. This top-down strategy relies on globally available energy balances over time [i.e., ref. 1], enabling analysis at the scale of the global socio-technical system. In this approach, and as a first approximation, the embodied energy of structures can be considered as the interannual sum of the inflow into the industrial sector, combined with a decay function to account for infrastructure wear and the resource investment needed for their renewal. This study can be conducted using published data from the recent past and can be leveraged to discuss energy transition scenarios.

In a second phase, and based on the established energy balances, we propose to focus on the competition between infrastructure use and production. Some uses are flexible and allow for storage when not in use, for example, a car that can charge at night, while other uses (e.g., a factory) are highly constrained, operating 24/7 and requiring a continuous, fully controllable energy source. To model these dynamics, we propose to construct a usage rate and mobilized power for each use, deriving the characteristics of an energy system compatible with the intermittency of renewable sources and the associated storage needs. This analysis will lead to the development of scenarios inspired by some recent work by the team [ref. 2].

[ref. 1] https://www.sankey-diagrams.com/global-energy-flows-2018-2050-dnvgl/
[ref. 2] https://doi.org/10.1371/journal.pone.0286242