Circular Economy based system thinking

The energy system of northern Sweden has started the transition to a climate neutral society. This is fueled partly by new establishments (attracted by access to clean and cheap power) and partly by the transition of existing iron and steel industry from coal to hydrogen (Hybrit, H2GreenSteel). New establishments are projected to increase the population, which will increase the final energy demand for heating buildings and transportation. Hybrit is building hydrogen storage to balance their energy demand (takes power from grid) and is looking into ways to process waste heat to supply the district heating grid. We see this transformation as an opportunity to transition towards a circular economy (CE), including decreasing energy demand by using services in different ways (e.g., car sharing) and potential for beneficial sector coupling.

As a part of the SureCity EraNet project, Luleå Technical University developed a generic city-based energy system optimization model (TIMES-city), which now is applied to different municipalities in northern Sweden. The model minimizes total system cost over years subjected to meet the given annual demand for energy-intensive goods and services (annual person-km traveling in car etc.) over various constraints (e.g., emissions reduction targets). In this proposal, we revisit the system analysis through the lens of CE.

This project aims to aid local decision-makers in identifying where and how CE can facilitate a more sustainable energy transition. For this, we implement CE strategies into the framework of system thinking. Here CE strategies are integrated into the energy system modeling of municipalities in northern Sweden. It includes three major steps:

Step1: Choosing the CE principle to be implemented: In system analysis, there is always a tradeoff between the level of details to be considered and what makes sense to model. This study uses the 3Rs CE principle, *reuse, recycle and reduce*.

Step2: Identifying the scope of chosen strategy in system analysis: Here, we analyze how the chosen CE strategies can be implemented in each of the system analysis steps; system conceptualization, system representation, scenario development and result analysis.

Step3: Mapping the findings to system analysis framework and include CE strategies.

	Conceptualization	System Representation (examples)	Scenario Development (examples)	Result Analysis (examples)
Technology Inclusion	consider sector coupling – flow of materials and energy both between and within sectors	-increased product life, product efficiency and process efficiency -technologies for capturing and/or producing energy commodities from waste (e.g., waste-heat, biowaste)	-high technology readiness level (TRL) of circular technologies	- analyze emissions from processes causing pollution and global warming - analyze material and energy wastage in processes and consumption
Required Action	Consider behavior change and usage of technologies in new ways	- Include options for sharing cars and other appliances (land-mover etc.) - Investments in new business models - include recycling indicators	- shared economy (focus on service instead of owning cars and appliances) - recycling shares - reduced repair/ maintenance cost	- analyze the level of circularity in results - percent of recycling - percent of renewable and non-renewable sources in supply