System Dynamics Modelling of Food-Energy-Water-Climate Nexus in Urban Circular Economies

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Circular Economy

A model of production and consumption, which involves sharing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible.

• Design out waste and pollution
• Keep products and materials in use
• Regenerate natural systems

(Parsa et al., 2021)
Circular Economy

FEW Nexus

The study of the connections between these three resource sectors, and the synergies and trade-offs that arise from how they are managed, i.e., water for food and food for water, energy for water and water for energy, and food for energy and energy for food.

(Parsa et al., 2021)
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• Case Studies:
  • Bristol ULL (Focus on Food System)
    • Food Waste Minimisation in Supply Chain (i.e. Primary Production, Manufacturing, Wholesale and Retail, Hospitality and Food Services, Households)
    • Food Waste Management Impacts on FEW-C Nexus (i.e. Reduction, Redistribution, Compost, Anaerobic Digestion, Incineration, Landfill)
  • Rotterdam ULL (Focus on Energy System)
  • Cape Town ULL (Focus on Water System)
System Dynamics Modelling (SDM)

• A computer-aided method to build simulation models which are useful for understanding the nonlinear behaviour of complex systems over time.

• The main building blocks of SDM are stocks and flows, and feedback loops.
  • **Stock** accumulates and stores something. It collects whatever flows into it, minus whatever flows out of it.
  • **Flows** fill and drain accumulations.
  • **Feedback** occurs when outputs of a system are routed back as inputs as part of a chain of cause-and-effect that forms a circuit or loop.
Food Supply Chain Module
Food Waste Module
- Water Footprint Module
- Energy Footprint Module
- Carbon Footprint Module
Reduction or Redistribution?

- 5% per year Food Waste Reduction (left)
- 5% per year Food Waste Redistribution (Right)
Household Food Waste Dynamics:

- 5% annual food waste REDUCTION
- 5% annual food waste REDISTRIBUTION
- 5% annual food waste COMPOSTING
- 5% annual food waste INCINERATION
- 5% annual food waste AD

Food Footprint

Energy Footprint

Carbon Footprint

Water Footprint
Summary

- The total food waste of Bristol in the supply chain is around 93 K tonne (~ one quarter of the total food consumption)
- Food system has a significant energy, carbon and water footprint (i.e. equivalent to 20%, 53% and 10% of the total Bristol energy, CO2 and water footprint, respectively)
- The modelling results echoes the prioritisation of waste hierarchy framework. However, it shows any waste reduction and redistribution at consumption-level can increase the amount of food waste in upstream (i.e. yet, the net amount of total food waste decreases)
- The food waste dynamics in the context of FEW-C Nexus is a representation of a non-linear complex system which requires robust simulation tools. System Dynamics provides a robust and useful method for this purpose.
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