Uncertainty Quantification for the Circular Economy

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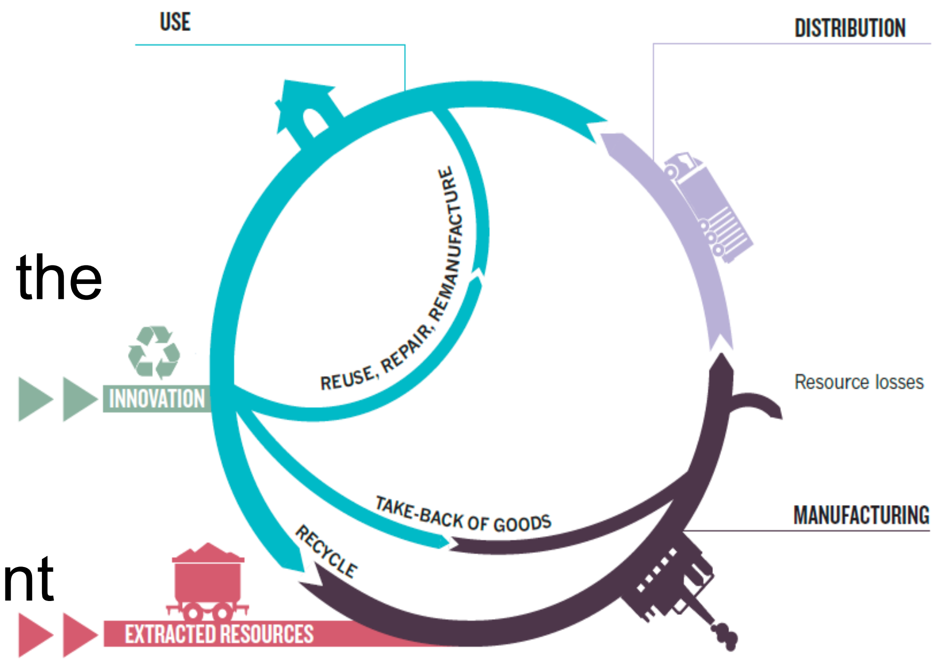
Motivation:

Sustainability requires transitioning products from a "one-way stream" to a circular configuration where materials are recovered and reused

- Circularity carries high uncertainty
  - Material quality: no waste is pure waste
  - Flow rate: collection rates vary
  - Legacy: materials have already accumulated in the environment

Research objectives:

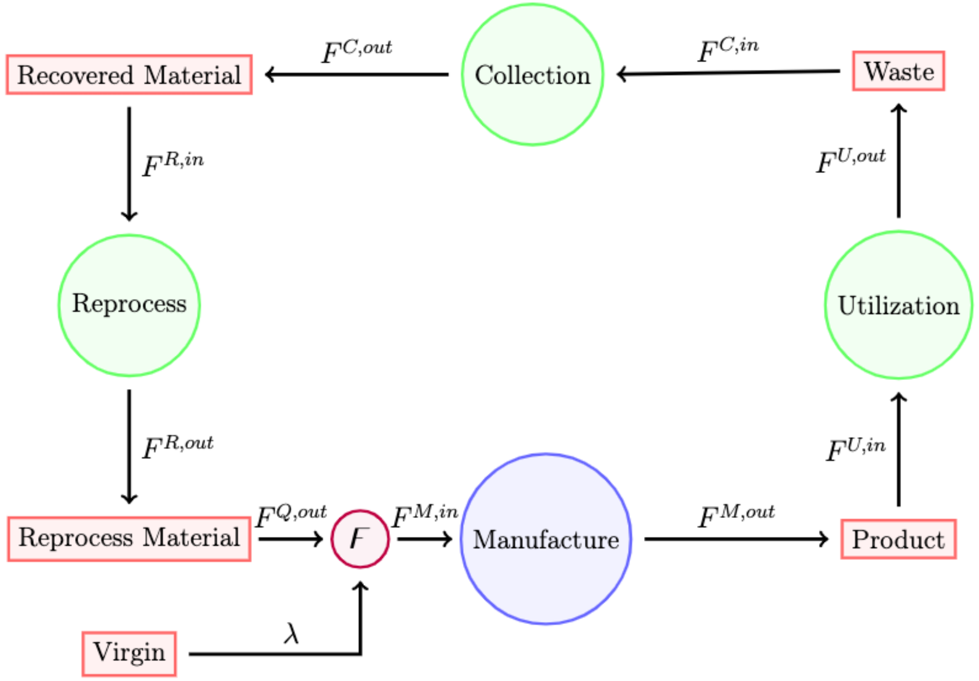
- Develop general model of circular supply chain
- Characterize dynamics and optimal management
- Quantify effect of uncertainty



Stahel (2016)

Model of the Circular Economy: State-Task Network

- Material state
  - Product, waste, recovered material, reprocessed material
  - Modeled as an accumulation term with saturation
- Tasks
  - Manufacture, utilization, collection, reprocess
  - Modeled as first-order system with time delay



- Case Studies
  - Ideal: zero processing delays, unitary efficiency
  - Realistic: non-zero delays, sub-unitary efficiency

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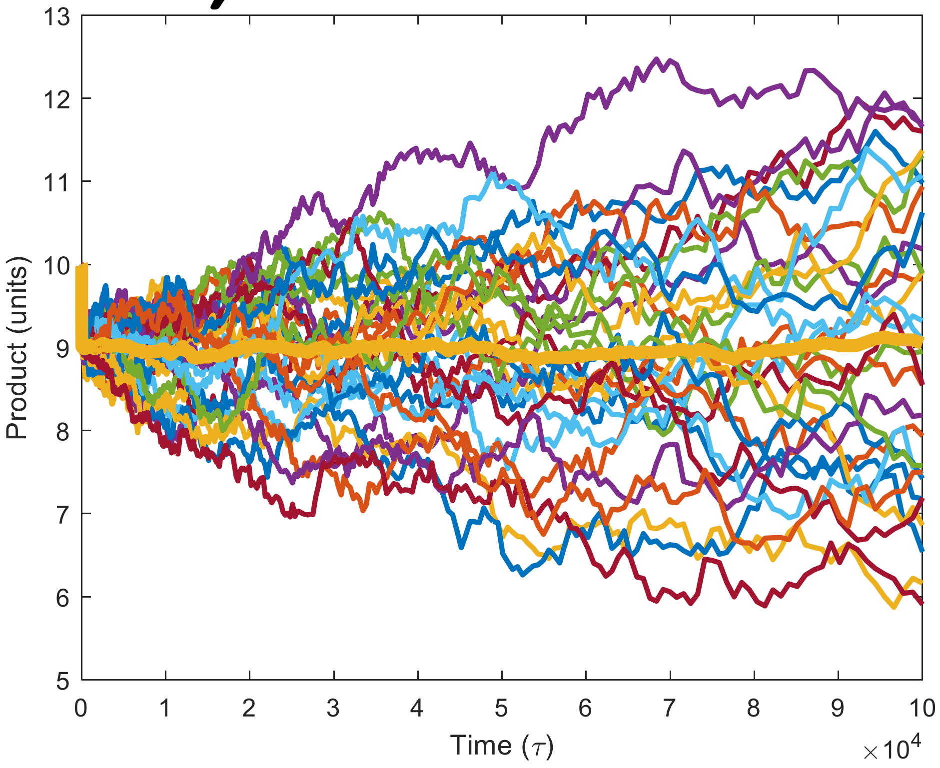
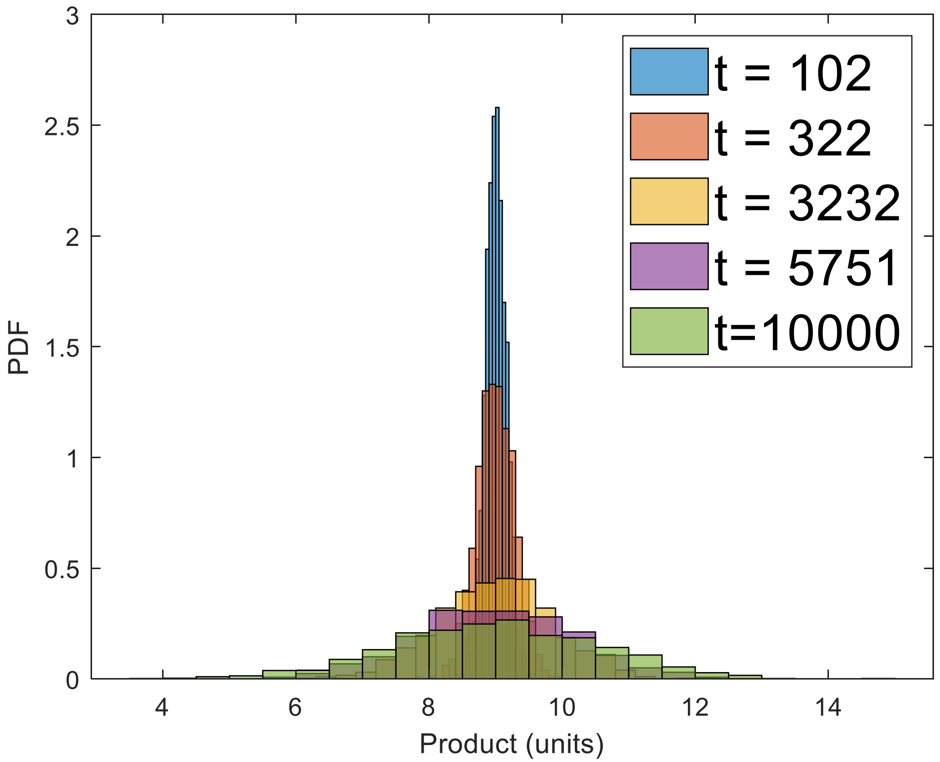
Results, Conclusions and Future Work





- Monte Carlo simulation: strong impact of variability in processing capacity on material inventory of product and virgin material demand
- Need for closed-loop (control inspired) approaches for managing the circular supply chain – orders, production rates updated periodically as new information becomes available
- Future work: optimal supply chain management problem formulation and solution