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sustainability consulting + software

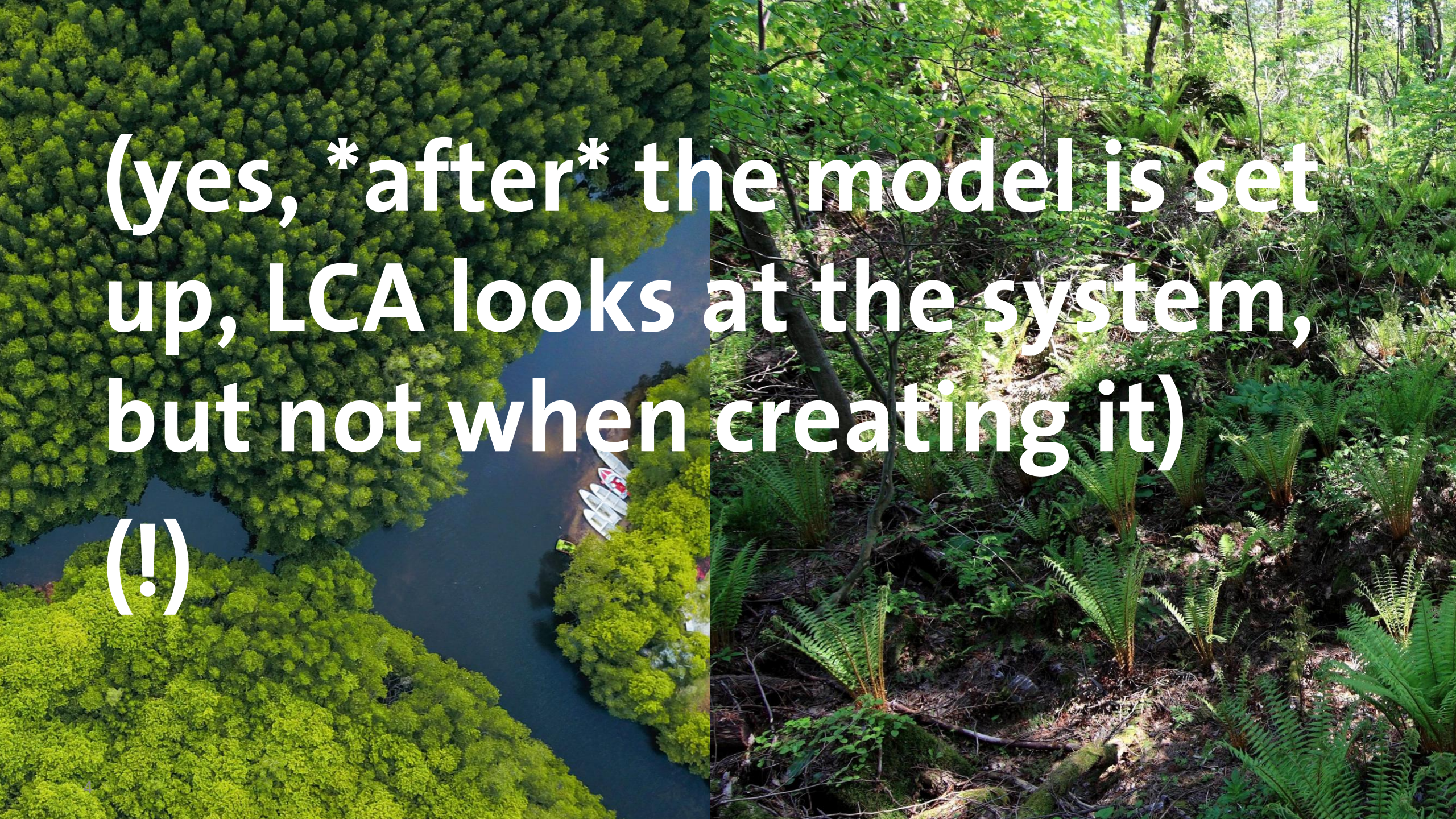
System dynamics models to better address sustainability decision situations over the life cycle

From less bad to good enough, DTU, Sept 30 2025

Dr. Andreas Ciroth
GreenDelta GmbH


The LCA view

The systems view



(yes, *after* the model is set up, LCA looks at the system, but not when creating it)

(!)

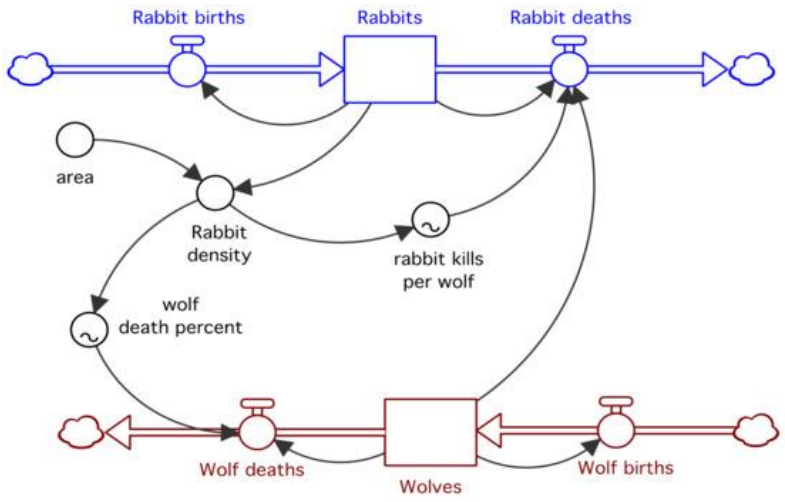
Topics

- System dynamics models
- Nine Sustainability Decision Situations over the life cycle
- Why “better address”?
- An example from the STOPP project
- Next steps

System dynamics models

System dynamics

- Idea: modeling a system as a combination of stocks and flow rates
- Any system(!)
- Scope and level of detail totally up to the modeler
- E.g., wolves and rabbits



Fisher, Diana M. 2018. "Reflections on Teaching System Dynamics Modeling to Secondary School Students for over 20 Years" *Systems* 6, no. 2: 12. https://doi.org/10.3390/systems6020012

System dynamics

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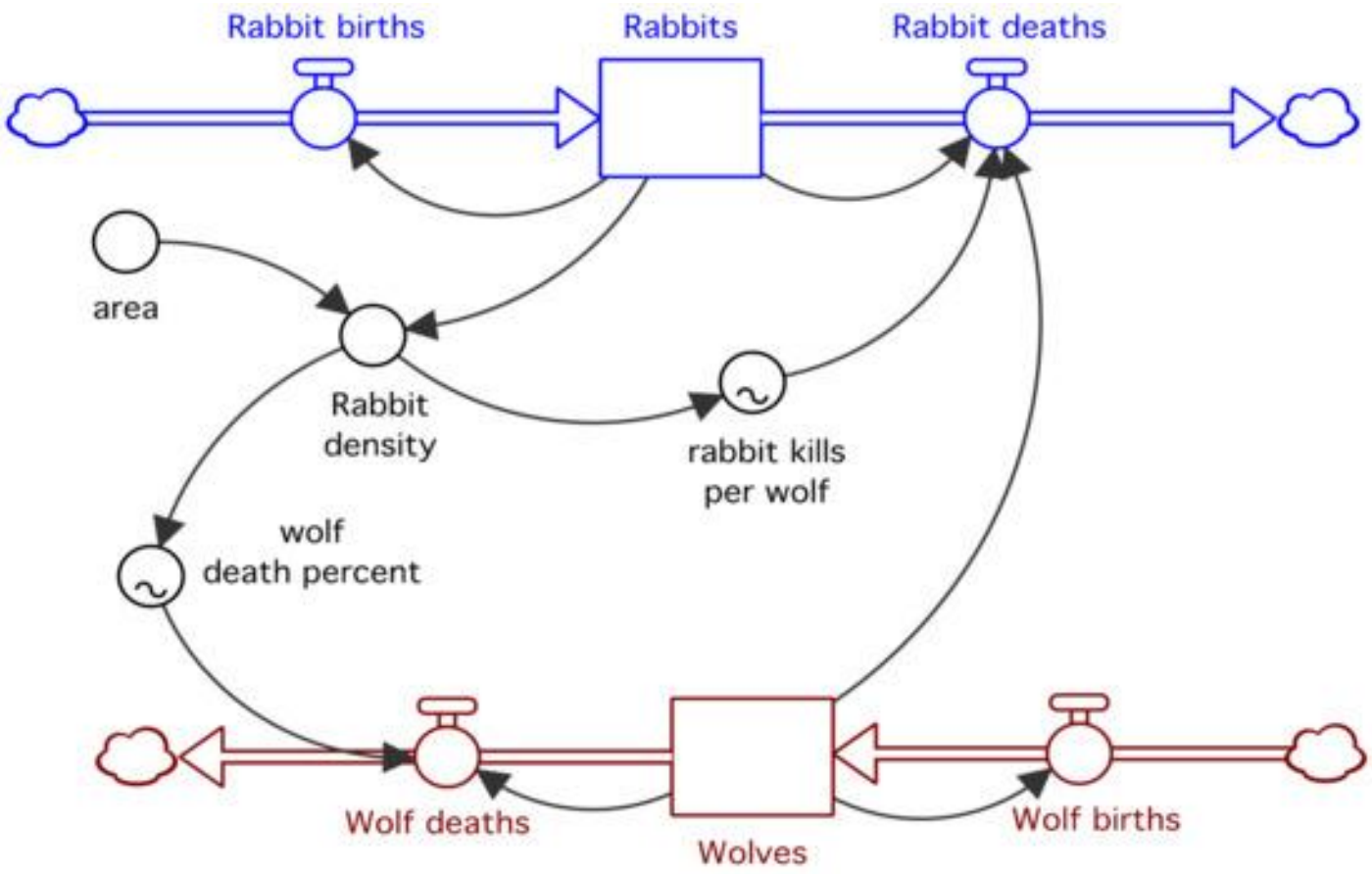
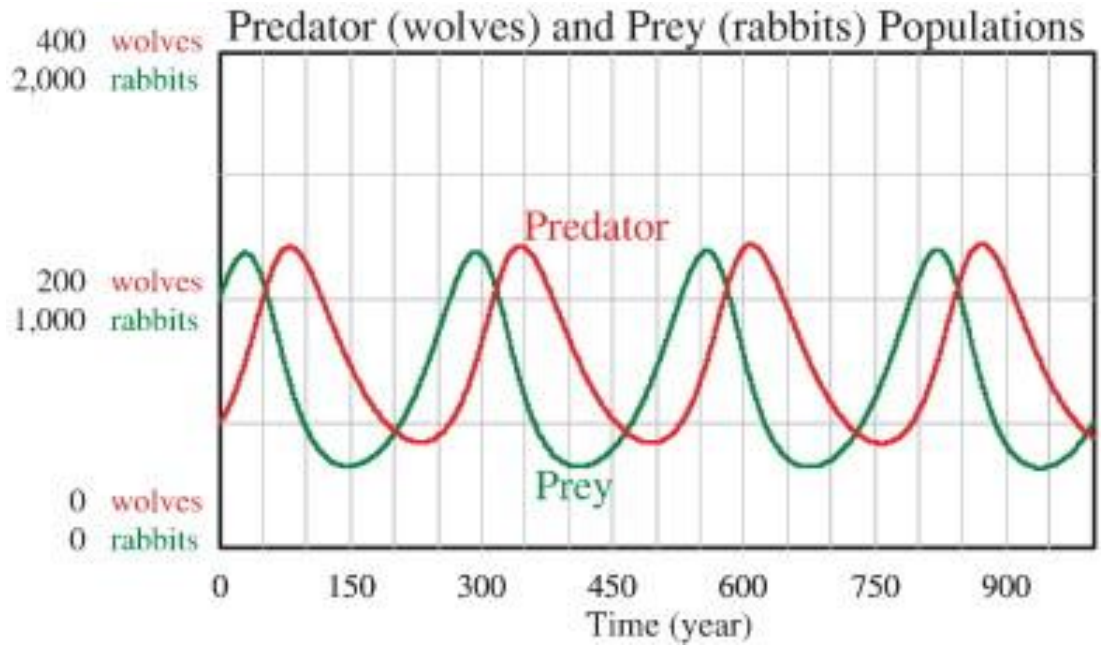


System dynamics

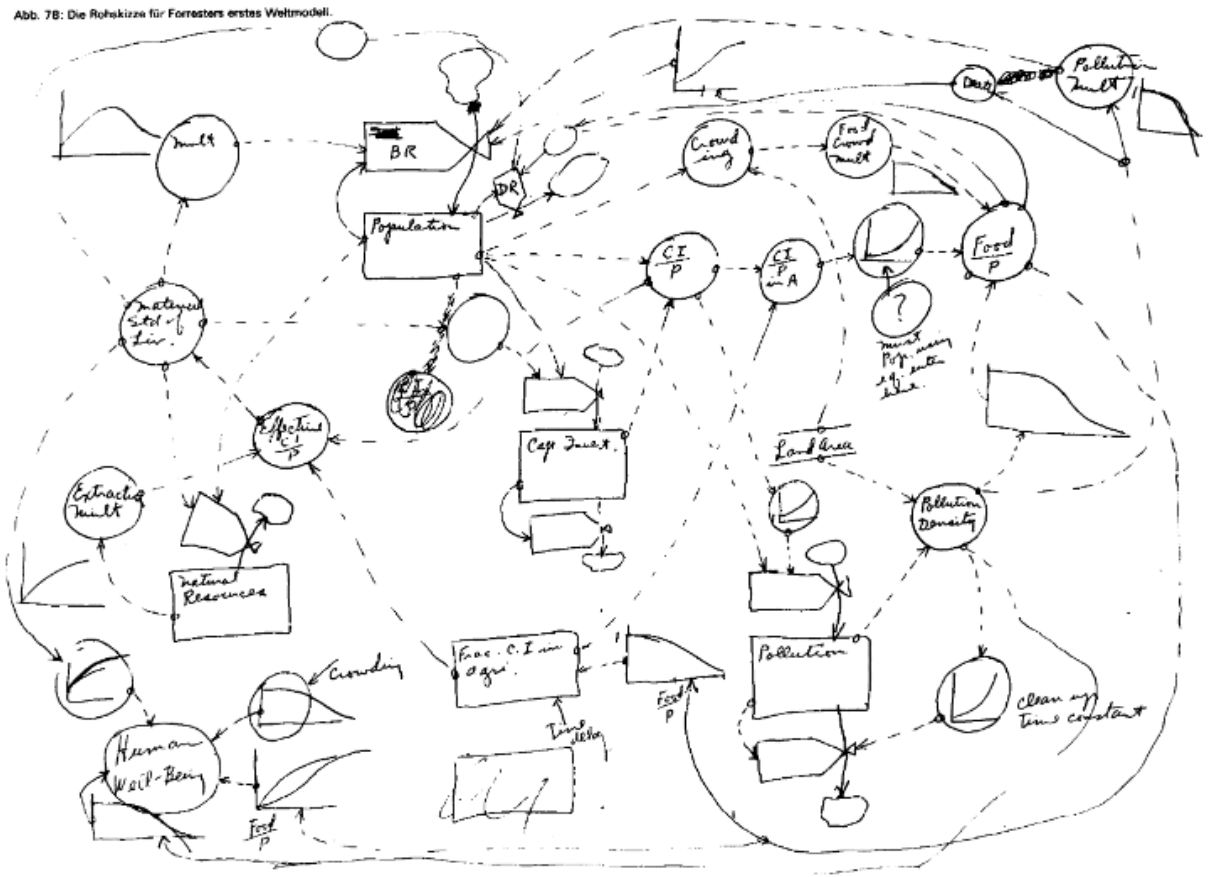
- E.g., wolves and rabbits

Motesharrei, Safa & Rivas, Jorge & Kalnay, Eugenia. (2014). Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies. Ecological Economics. 101. 90–102. 10.1016/j.ecolecon.2014.02.014.



System dynamics and environmental modeling

- Forrester et al. 1970's: a model of the entire world



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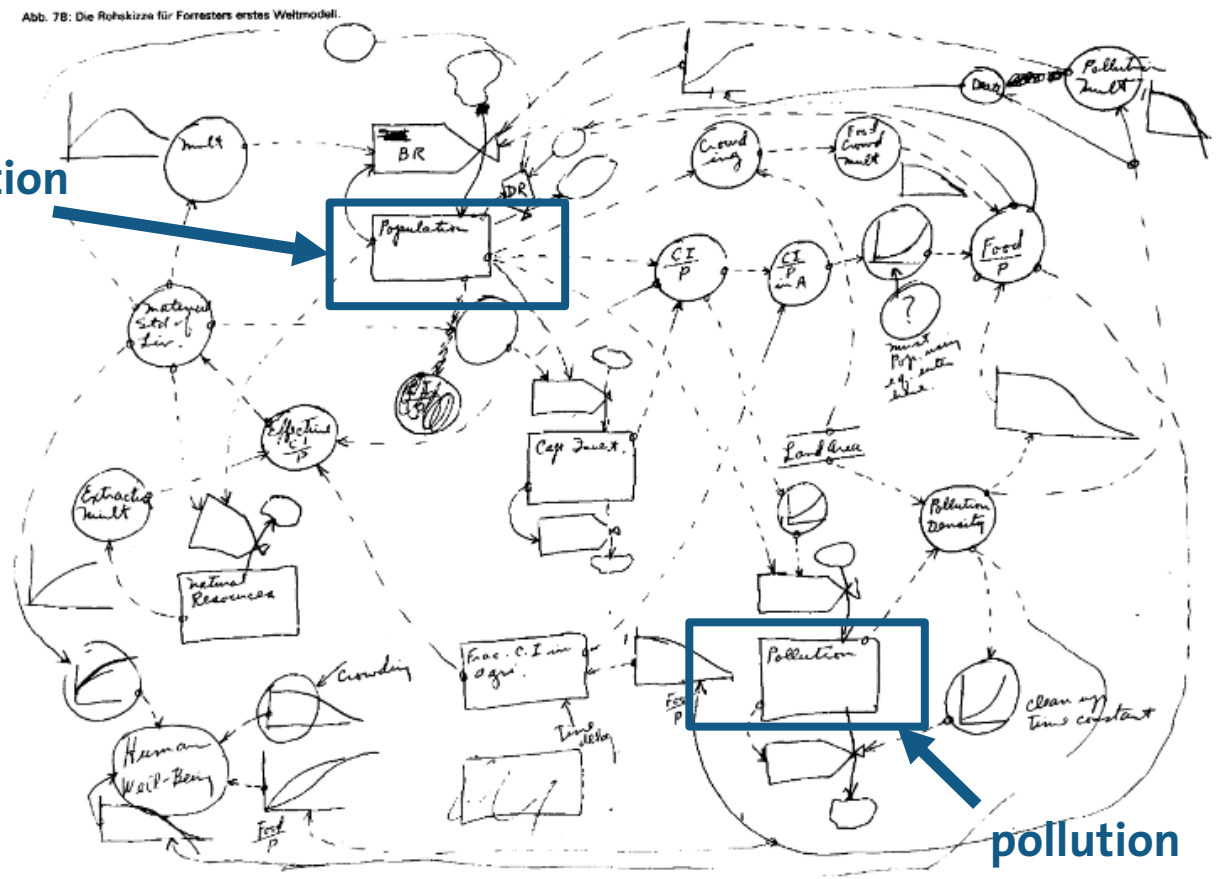

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System dynamics and environmental modeling

Forrester et al. 1970's: a model of the entire world

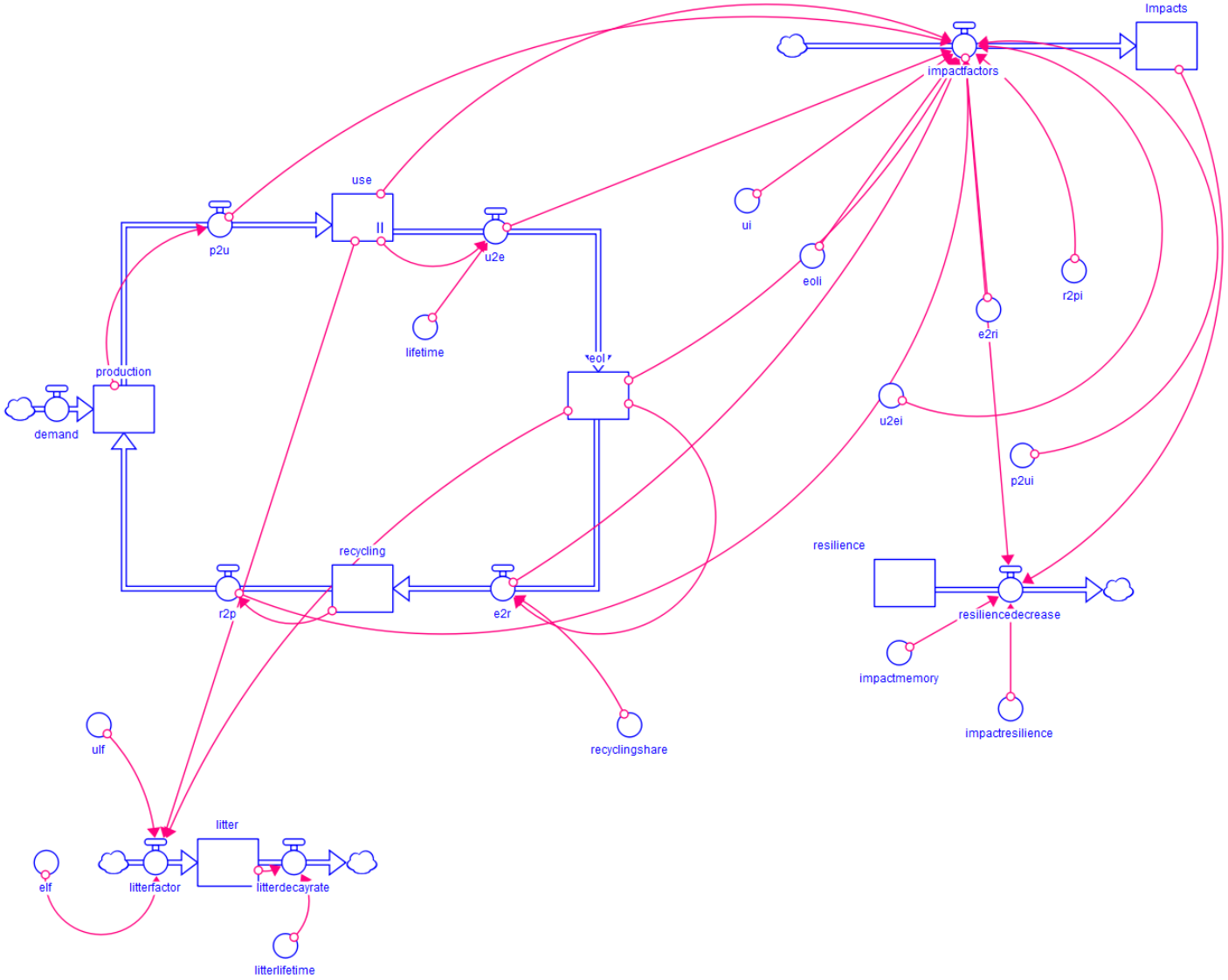
- Quite well able to reflect sustainability
- Data demand not necessary high (in quantity): "population" …
- ..but demanding in quality: system behavior and "results" depend a lot on whether the population reproduction rate is 1.0 or 1.01 (e.g.)

Nine Sustainability Decision Situations over the life cycle

Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

1 a is clearly better
2 a has recycling
3 a has a longer life time
4 a is substituted by another product
5 a has one less step in the life cycle
6 a contains toxic substances
7 a has littering
8 a has an upscaled production
9 a has a learning curve

A generic system dynamics model for these questions



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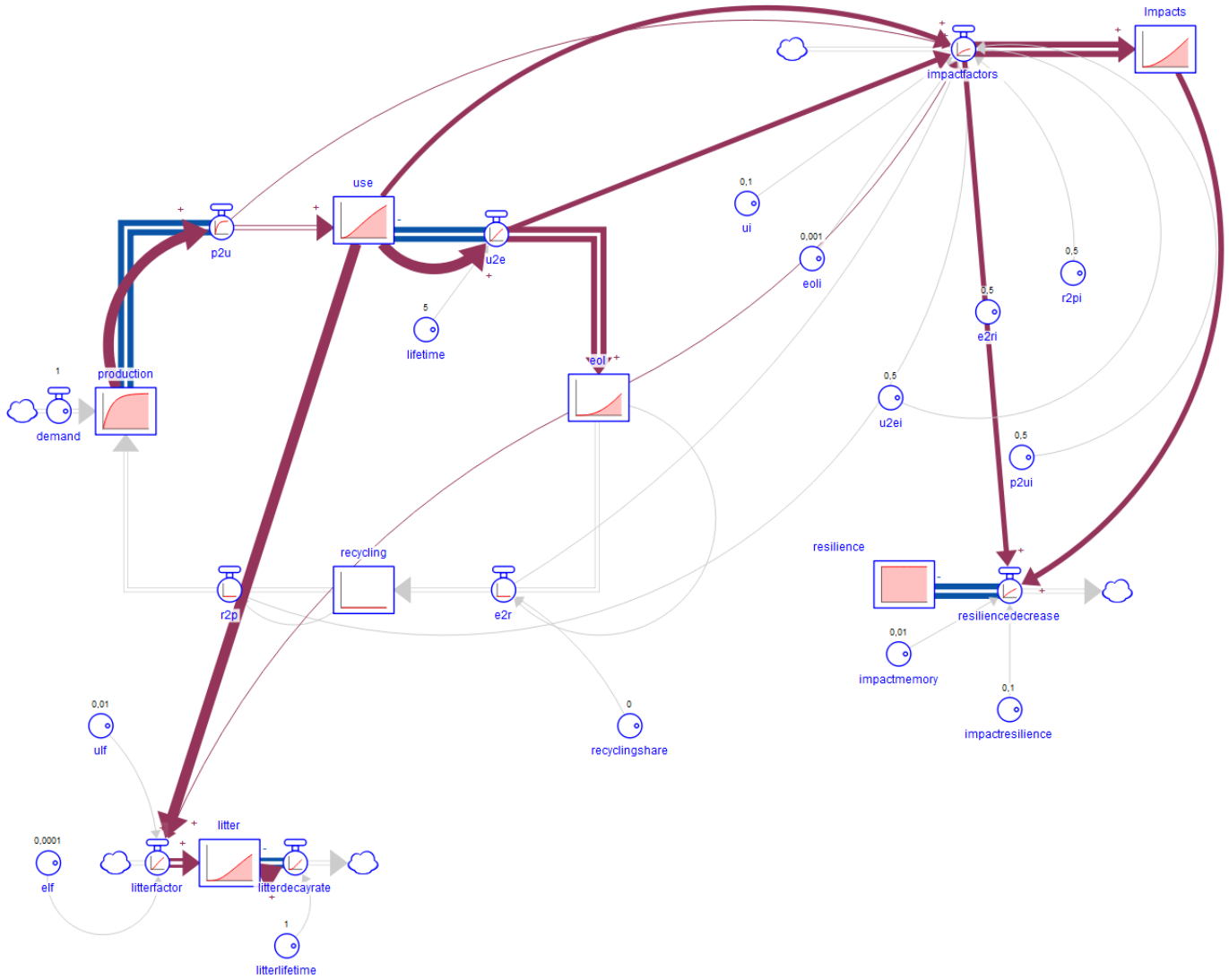
A generic system dynamics model for these questions



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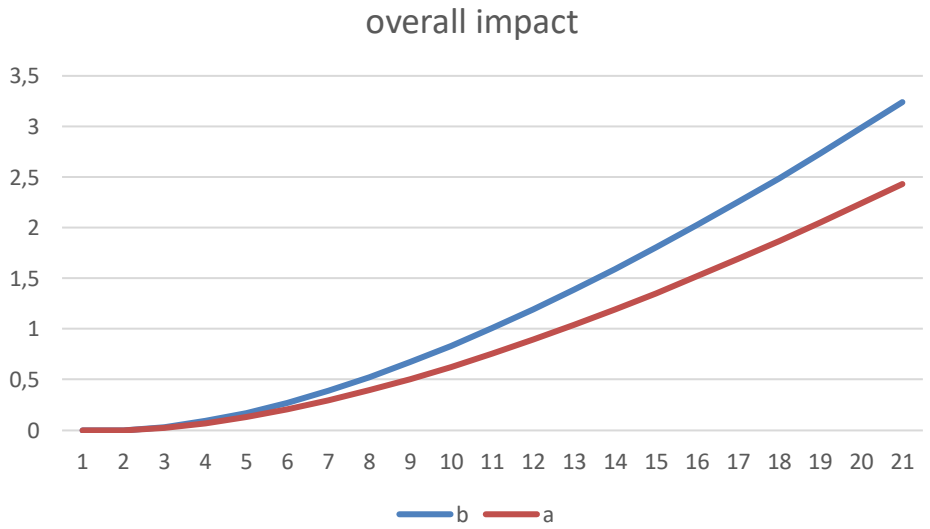
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

1 a is clearly better

(e.g., all impact factors for a are only 75% of the ones for b)



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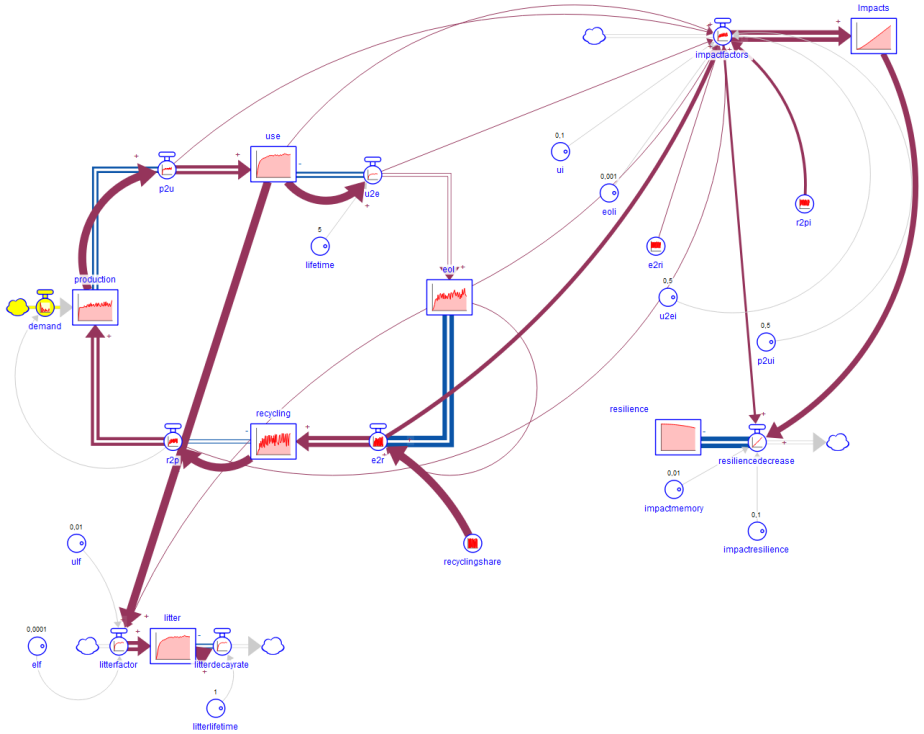
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

2 a has recycling

→ set recycling-rate and recycling related impacts random



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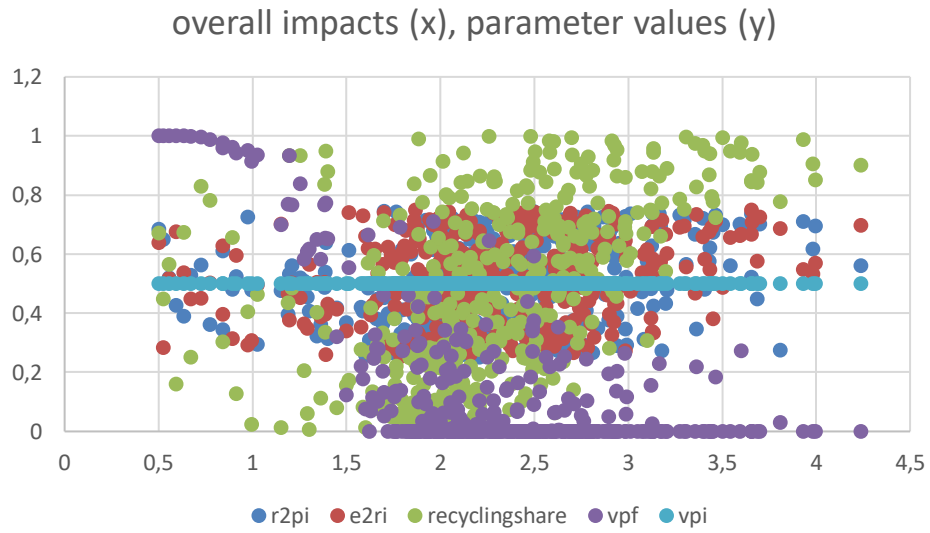

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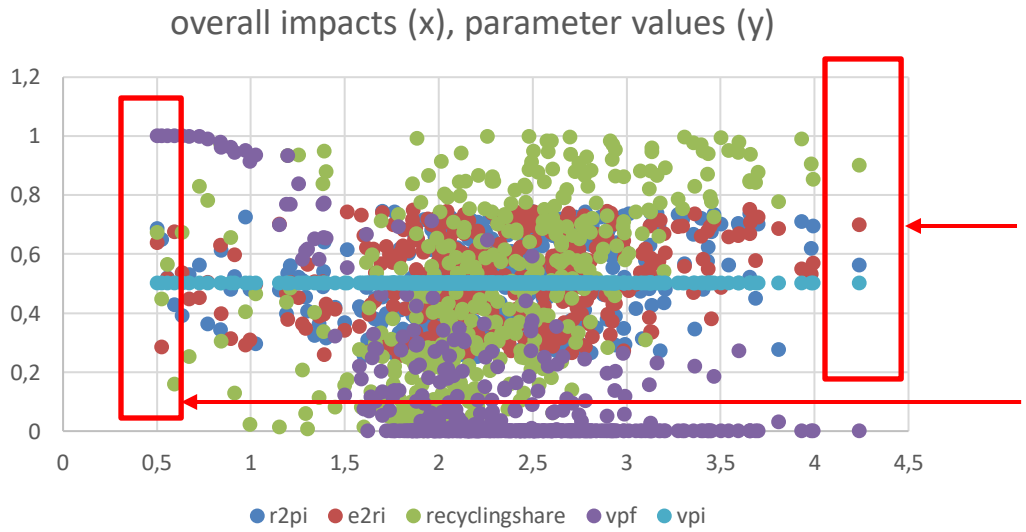

If impact for recycling (r2pi, e2ri) is higher than virgin production impact (vpi), ...

... overall impact is higher

... and vice versa

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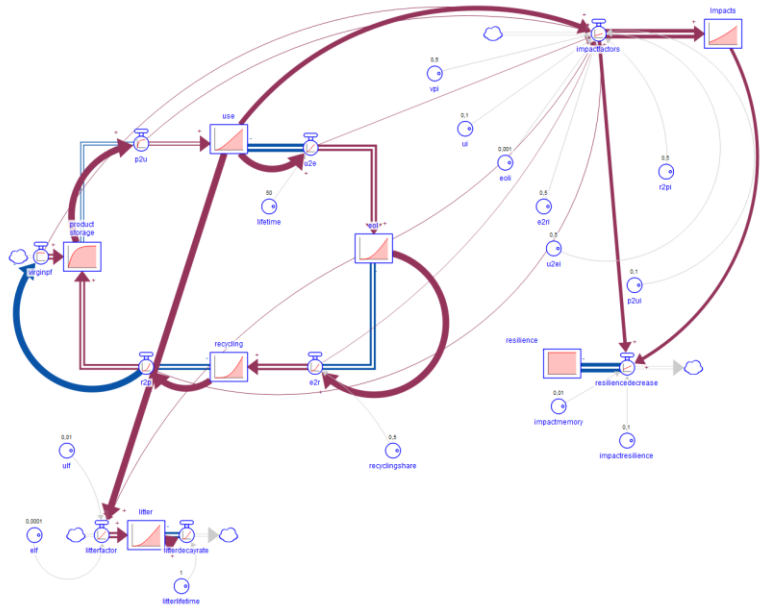
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

3 a has a longer lifetime

→ has effect on production effort, eol effort



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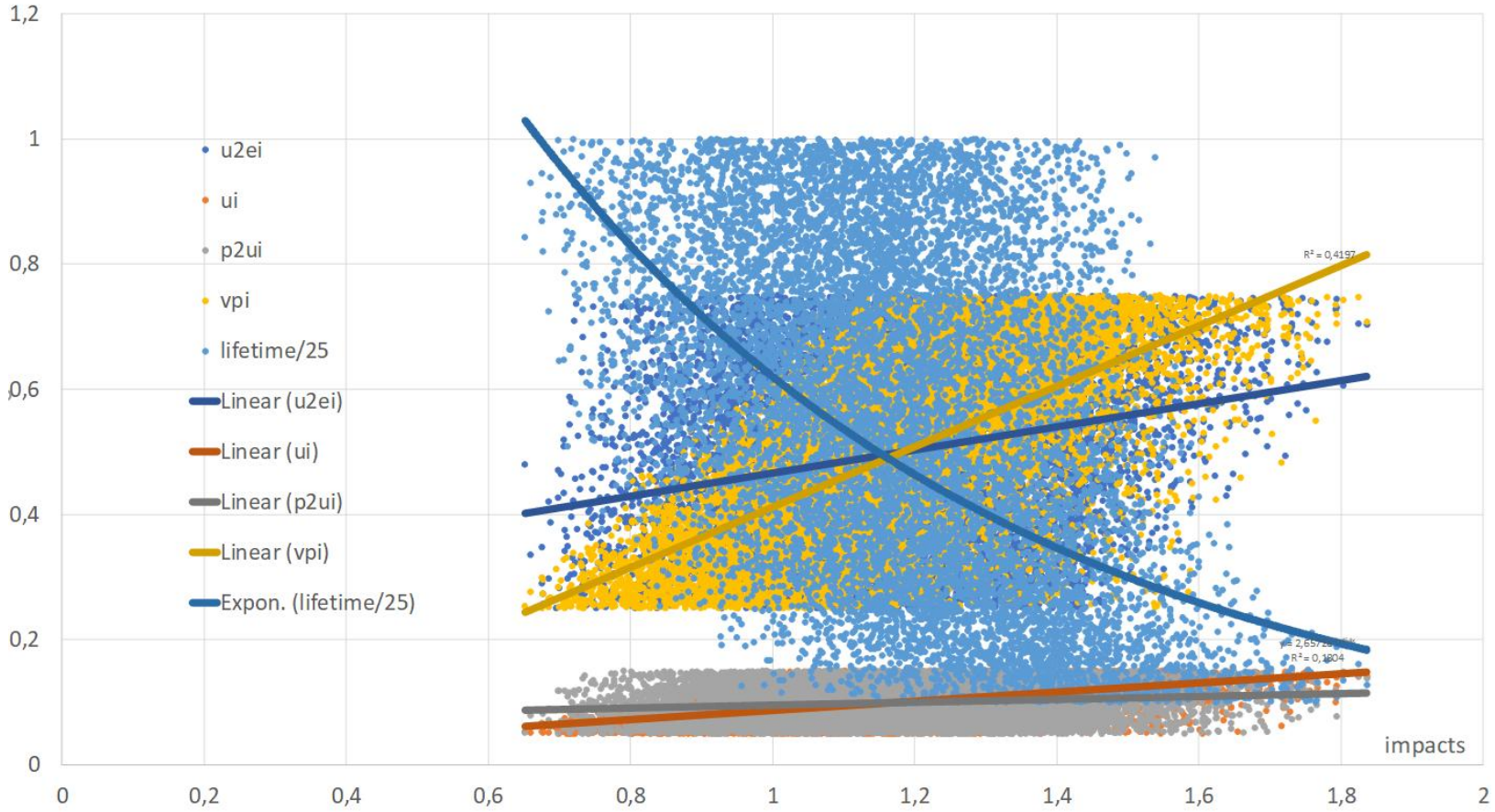

Shorter lifetime has higher impacts, if production (vpi), sales (use (ui), end of life (u2ei) are higher

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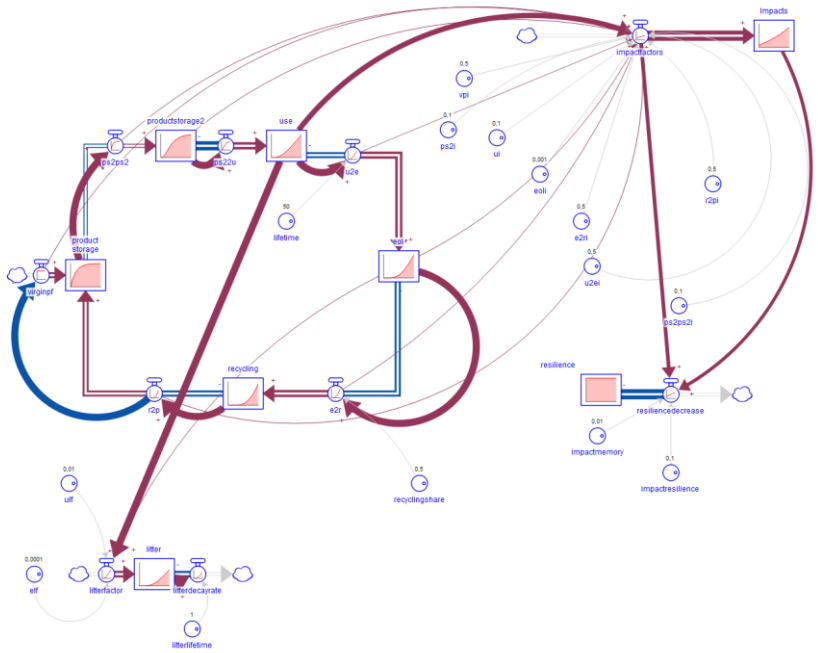
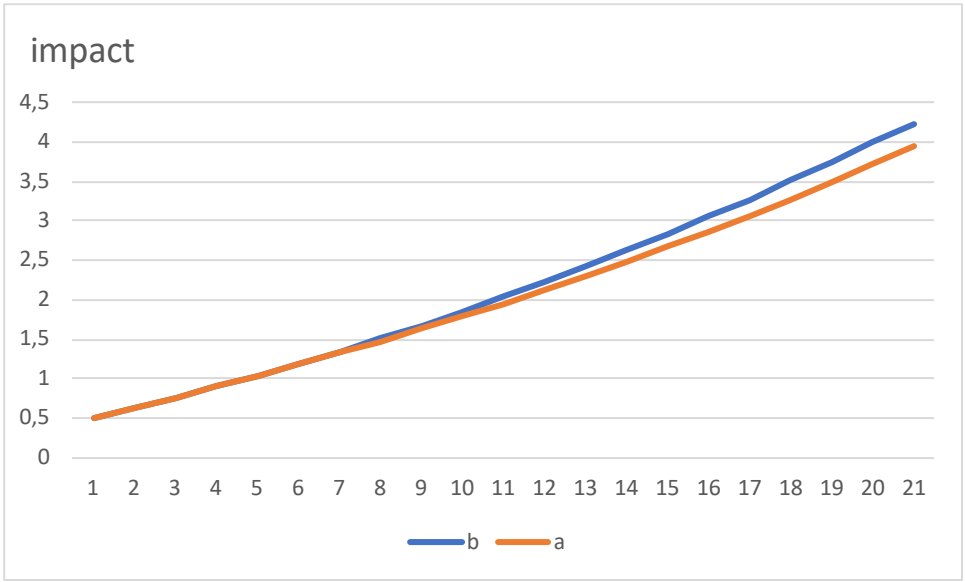
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

5 a has one less step in the life cycle (ceteri paribus)





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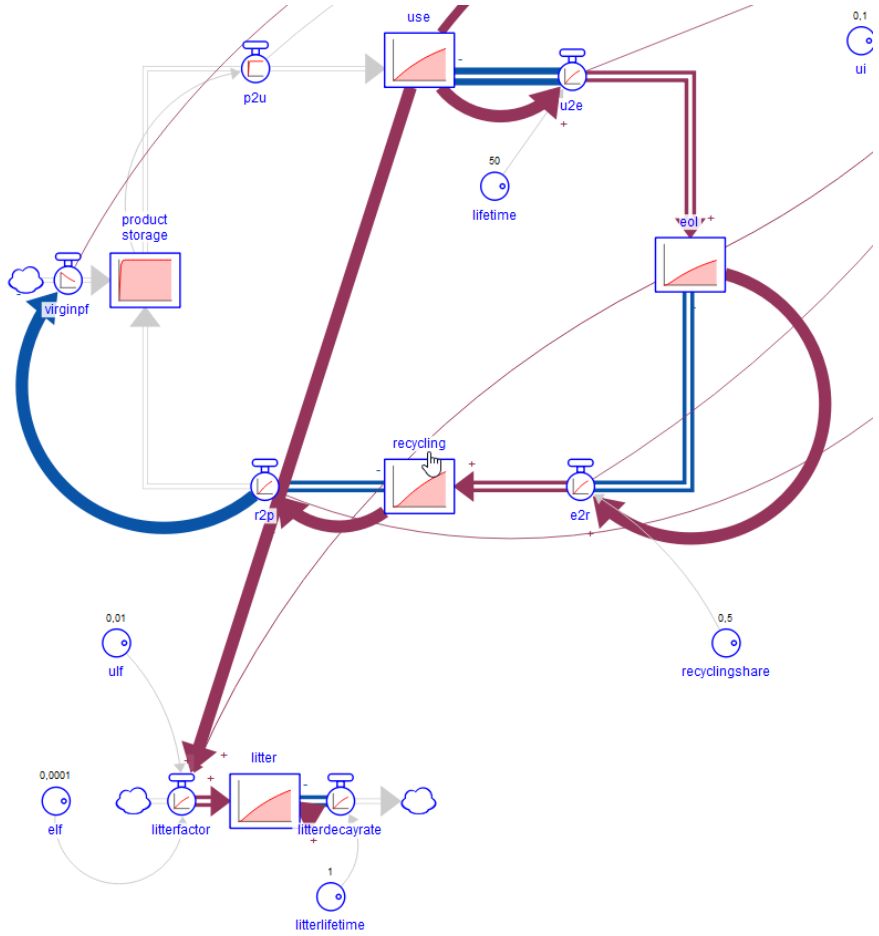
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

7 a has littering



Use and end of life contribute to litter; litter has a decay rate that depends on litter life time

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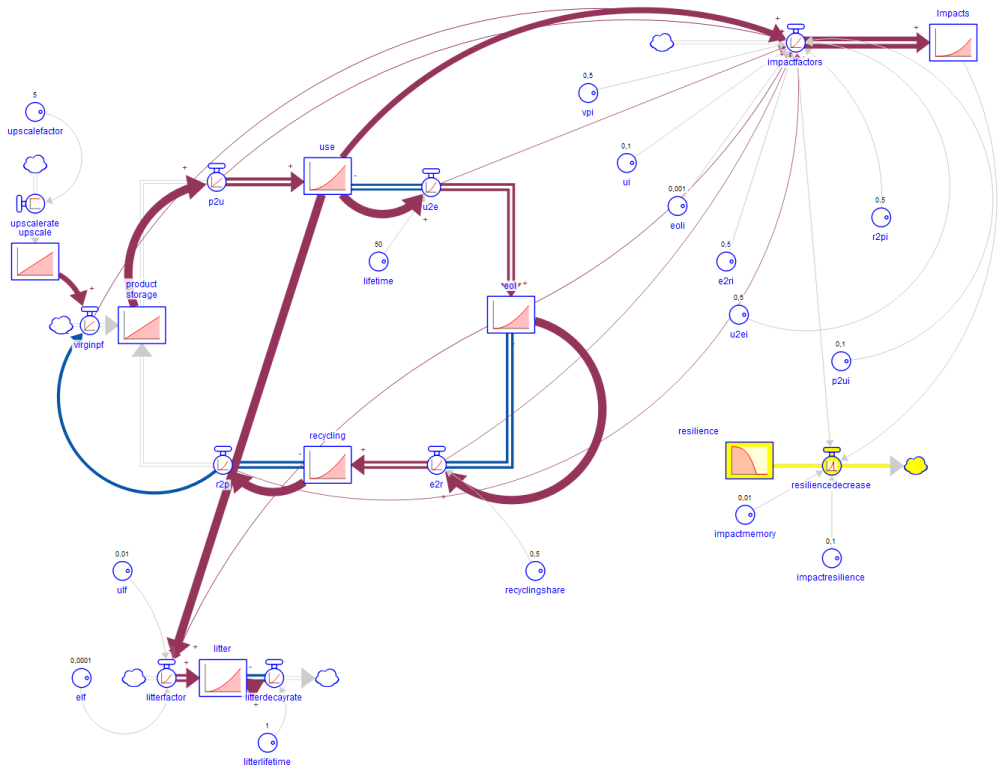
Nine Sustainability Decision Situations over the life cycle, comparison of two products a, b

8 a has an upscaled production



Drastically upscaled production leads to exponential increase of impacts and to “depletion of resilience”

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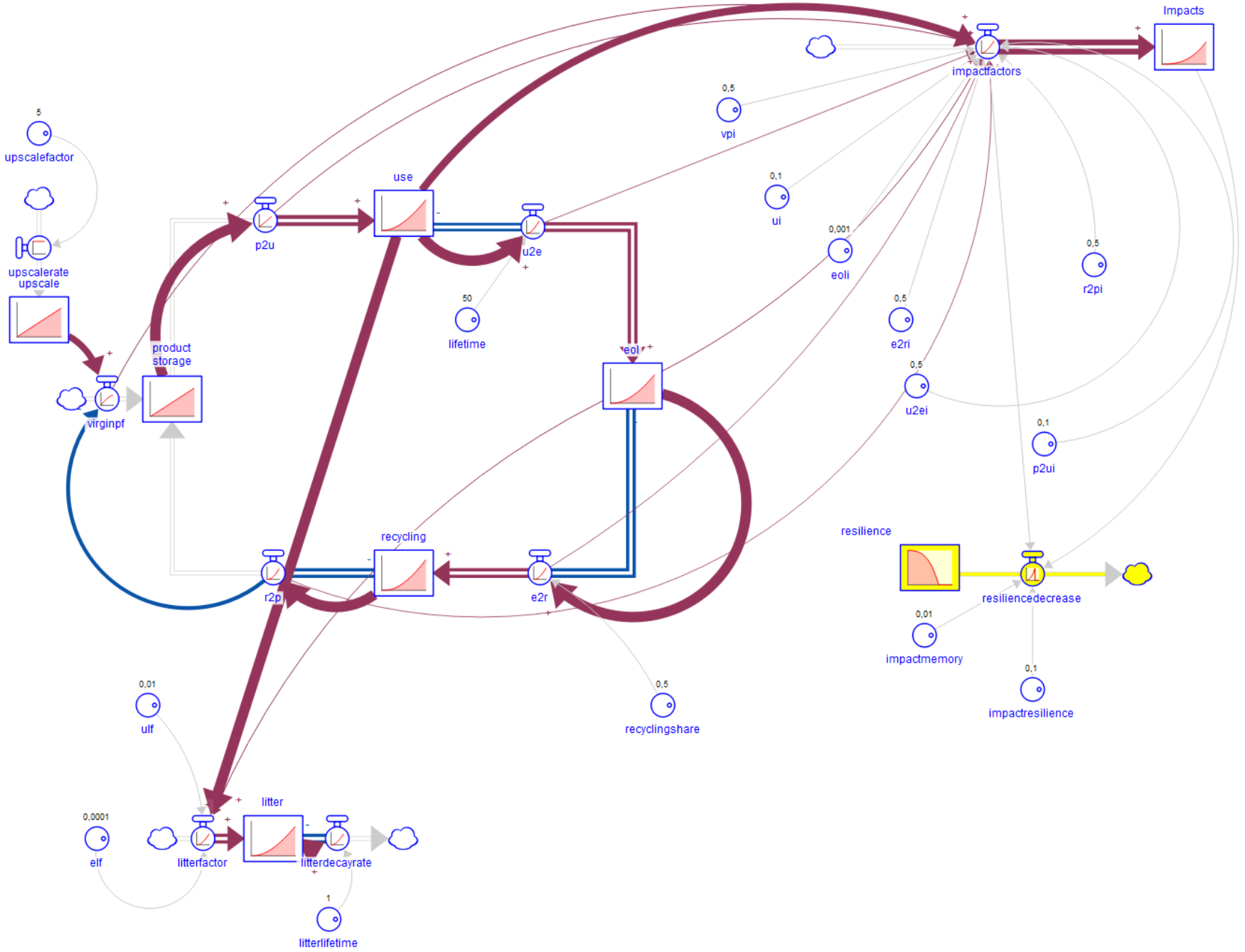

Drastically upscaled production leads to exponential increase of impacts and to “depletion of resilience”

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System dynamic models to better address sustainability decision situations over the life cycle –

why better address?

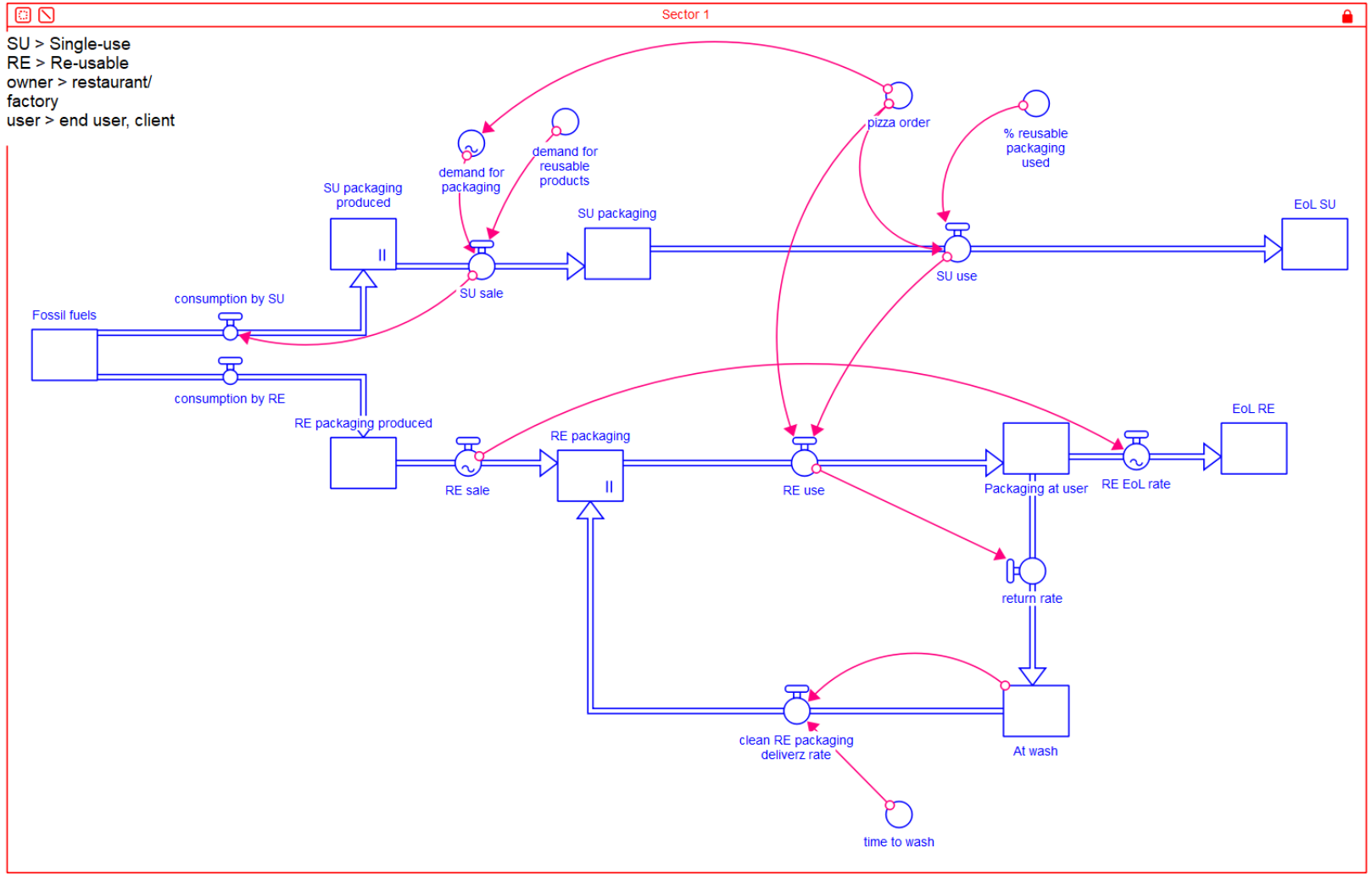
What are advantages of system dynamics models in sustainability assessment?

1) They use a top down approach that uses system information. LCA does not do that.
2) Attention to system structure helps to focus on points that matter
3) Many real-world life cycle structures can directly be modeled in system dynamics models. Including absolute sustainability questions and developments over time
4) Level of detail is very flexible, in contrast to LCA (world model from 1970's)

An example from the STOPP project

An example from the STOPP project: food plastic one way or reuse

https://stopp-project.eu/



Stopp

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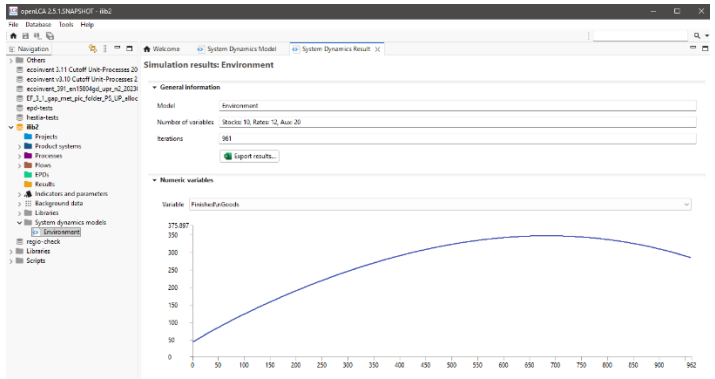
Next steps

Next steps

1) Discuss, write a publication
2) Refine concepts on model validation, and disseminate
3) LCA of course still has a place, in future, as well-established, simple, linear and yet also time and data consuming method -> seek and refine a smart combination
4) Software is an issue for SD modeling, for the combination but also stand-alone

   → Develop an openLCA version that allows System Dynamics calculation, currently ongoing (Treasource EU project, Alexander Koch presentation)



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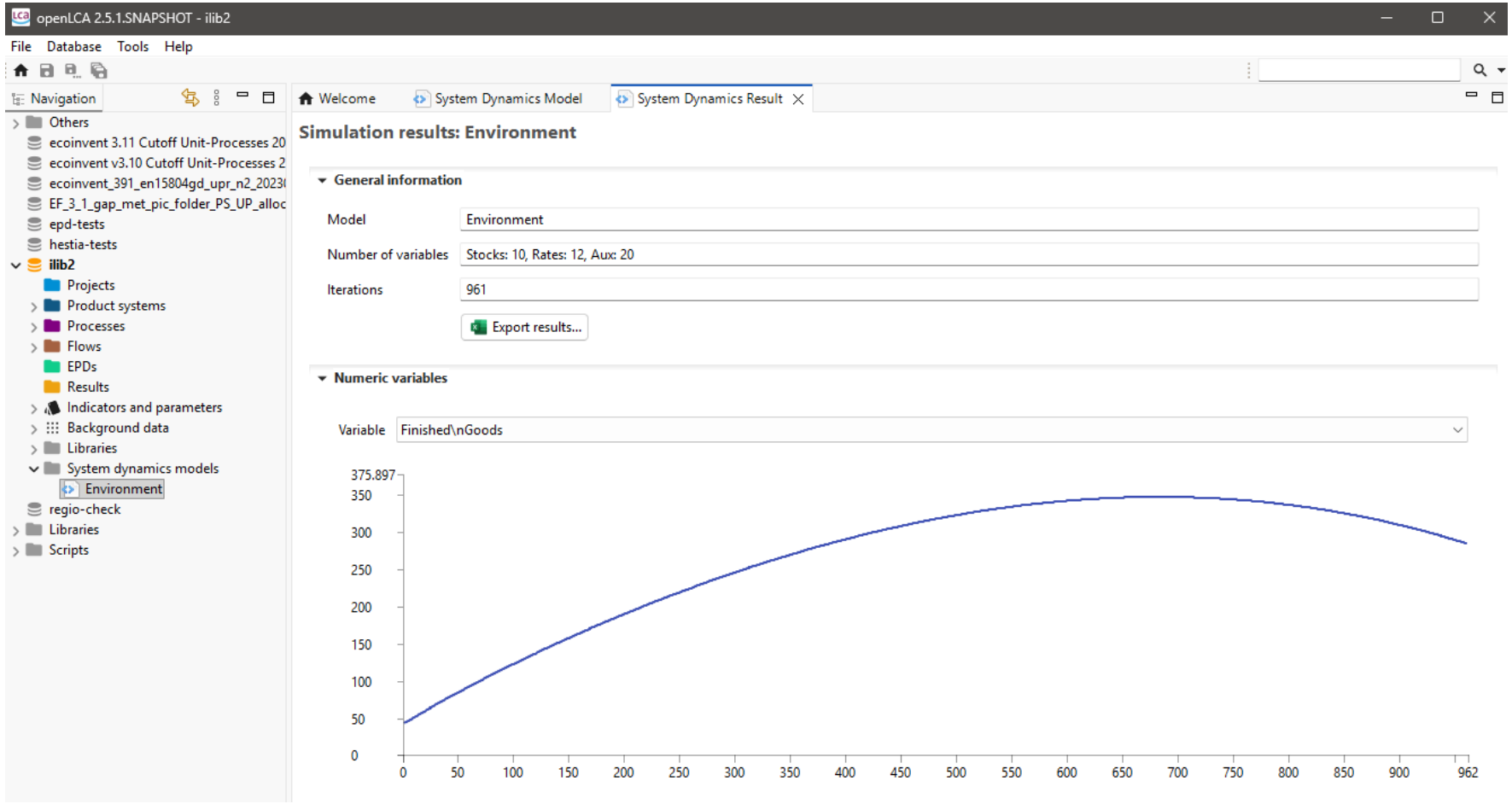

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Thank you very much!

Dr. Andreas Ciroth, ciroth@greendelta.com

GreenDelta GmbH, Alt-Moabit 130/131, 10557 Berlin