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System dynamics and LCA in openLCA - 8 archetype models and questions What do we learn from them?

openLCA.conf 2026, Berlin, April 2026

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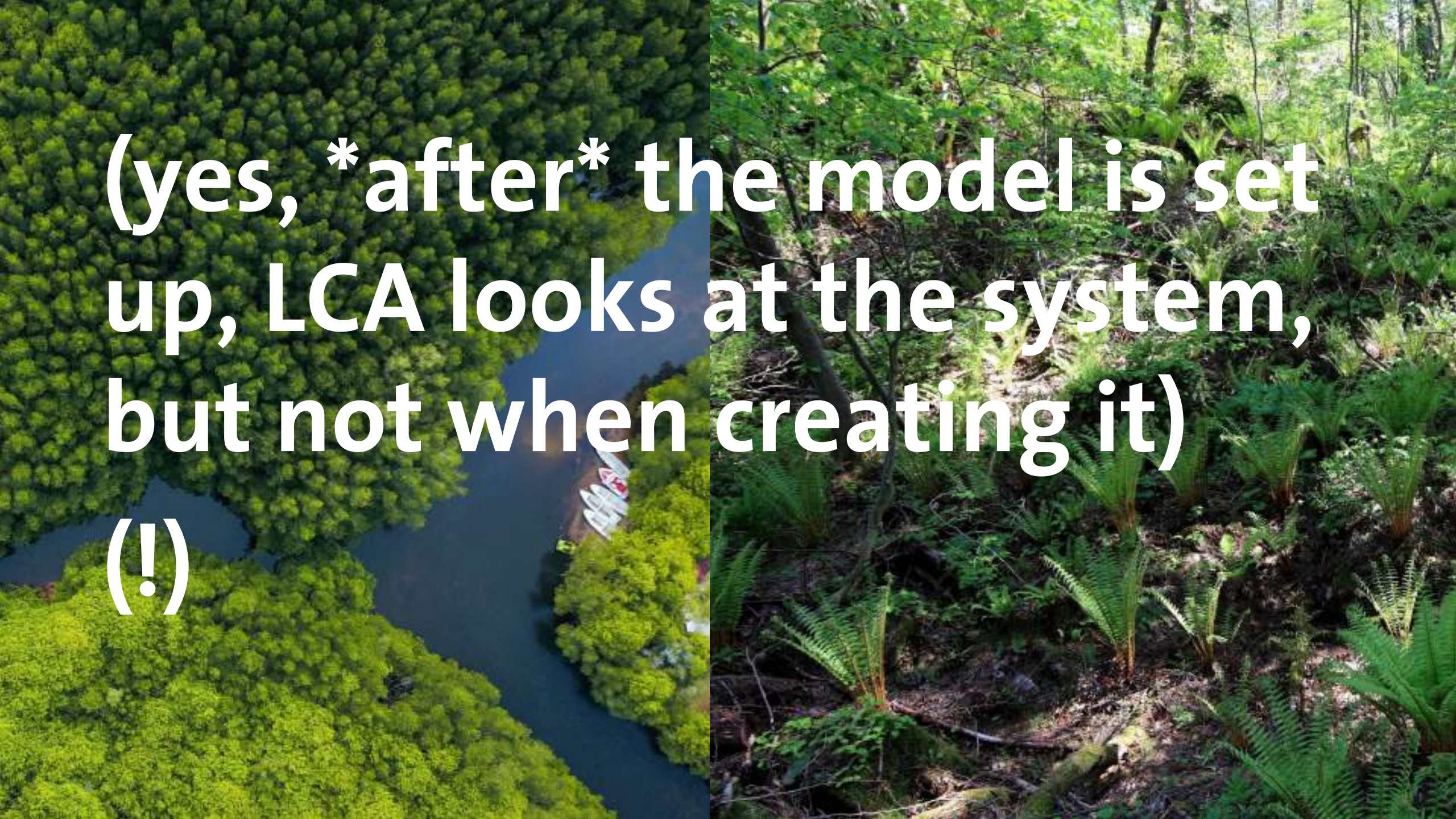
GreenDelta GmbH

The LCA view

The systems view



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

(!)

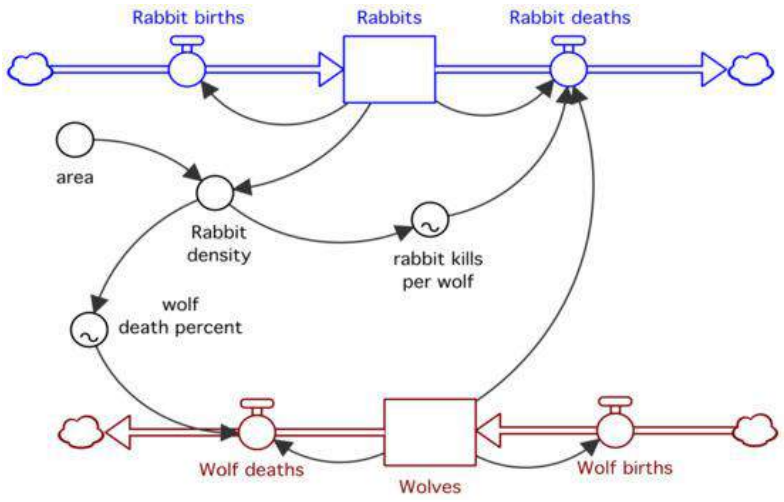
Topics

- System dynamics models
- Eight Sustainability Decision Situations over the life cycle:
  What do we learn from them?
- LCA and System dynamics in openLCA
- 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



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System dynamics

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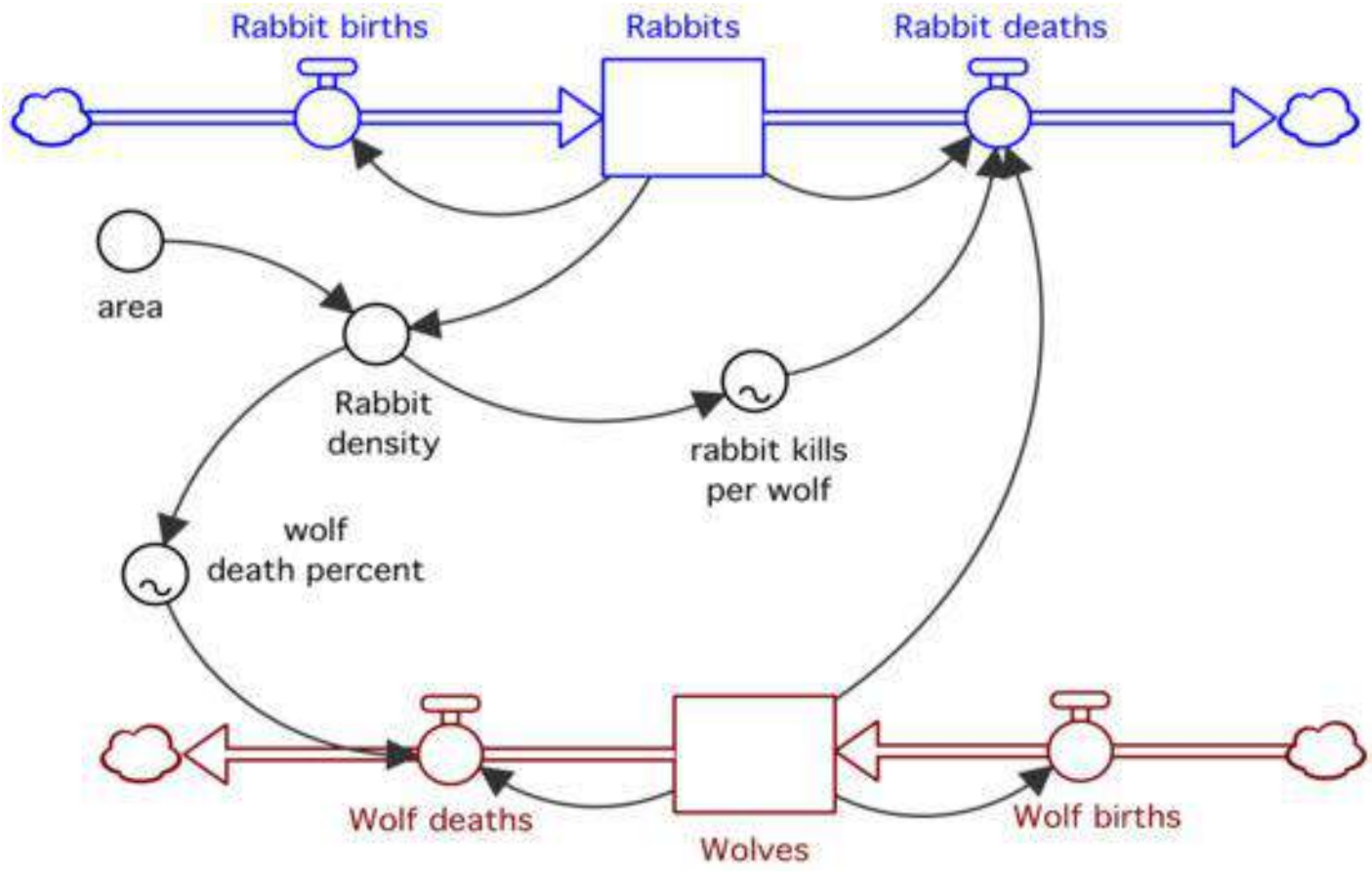

System dynamics

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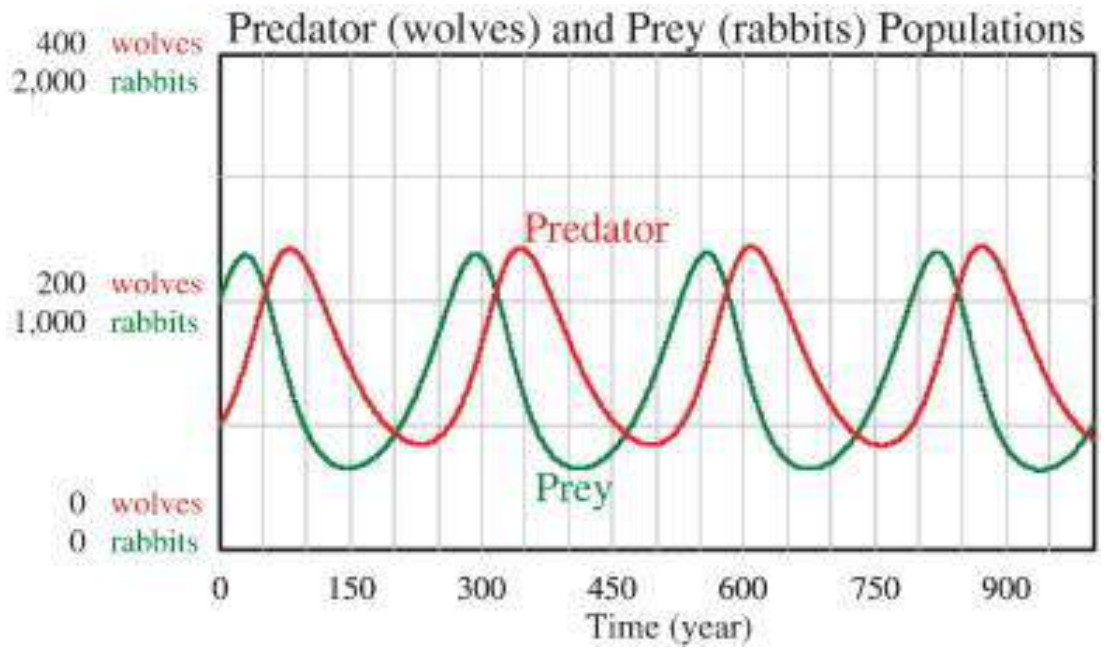
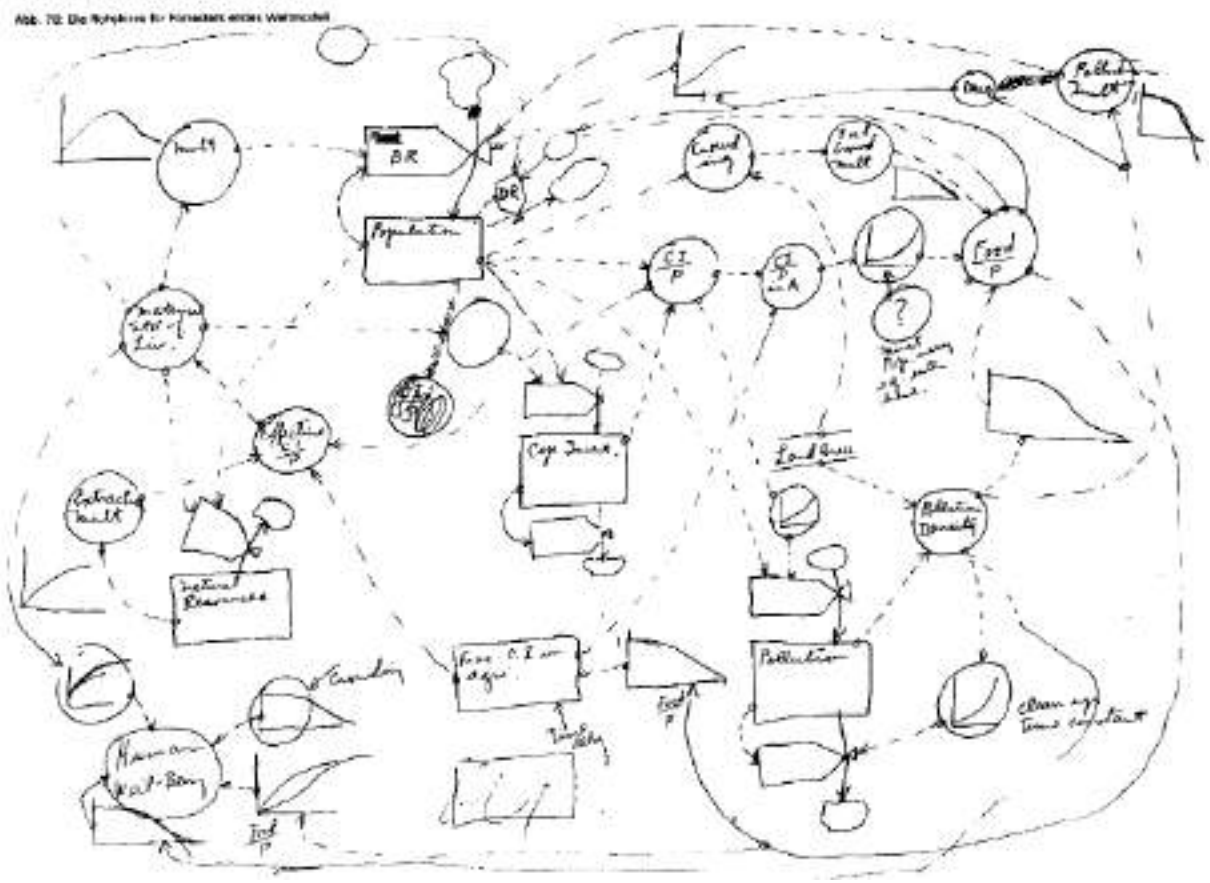
Motesharrei, Safa & Rivas, Jorge & Kalnay, Eugenia. (2014). Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies. Ecological Economics. 101. 90–102. 10.1016/j.ecolecon.2014.02.014.



System dynamics and environmental modeling

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



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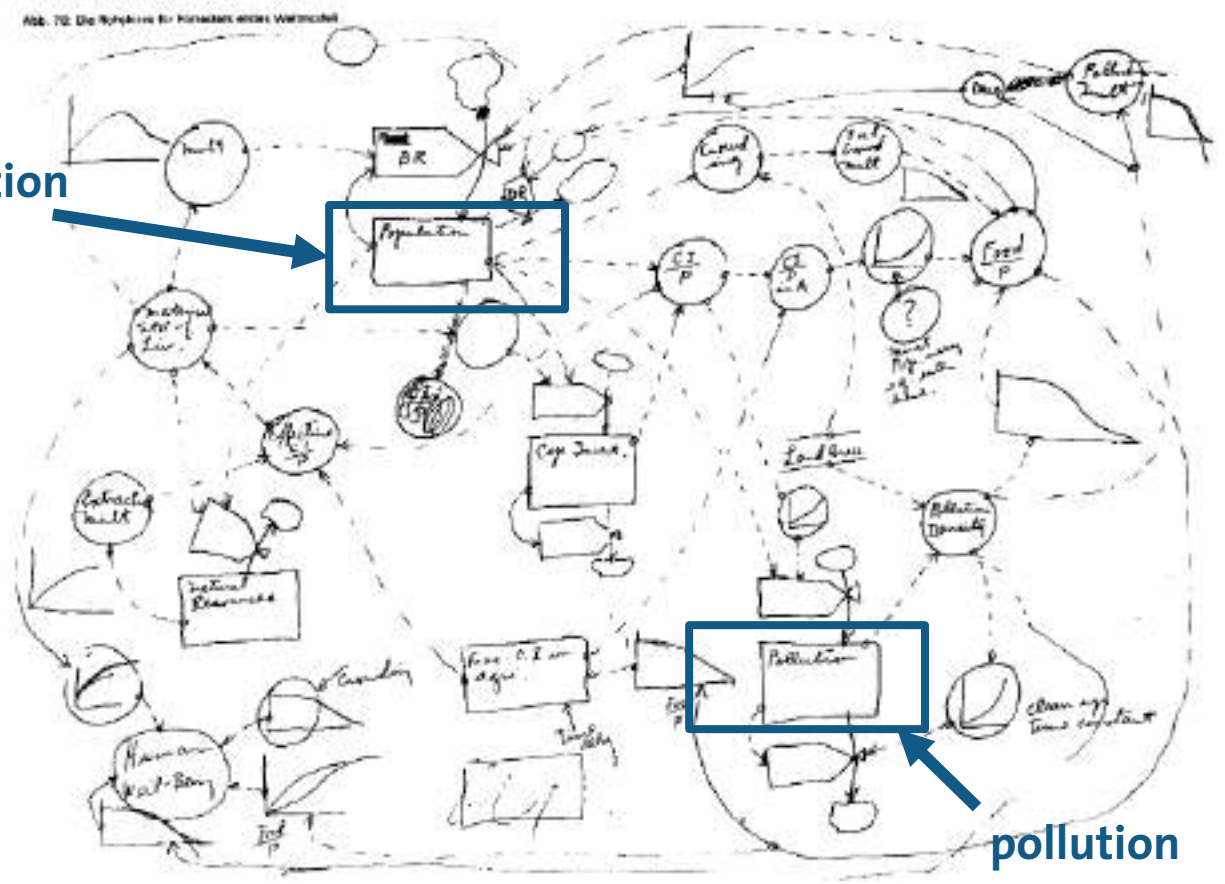

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System dynamics and environmental modeling

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

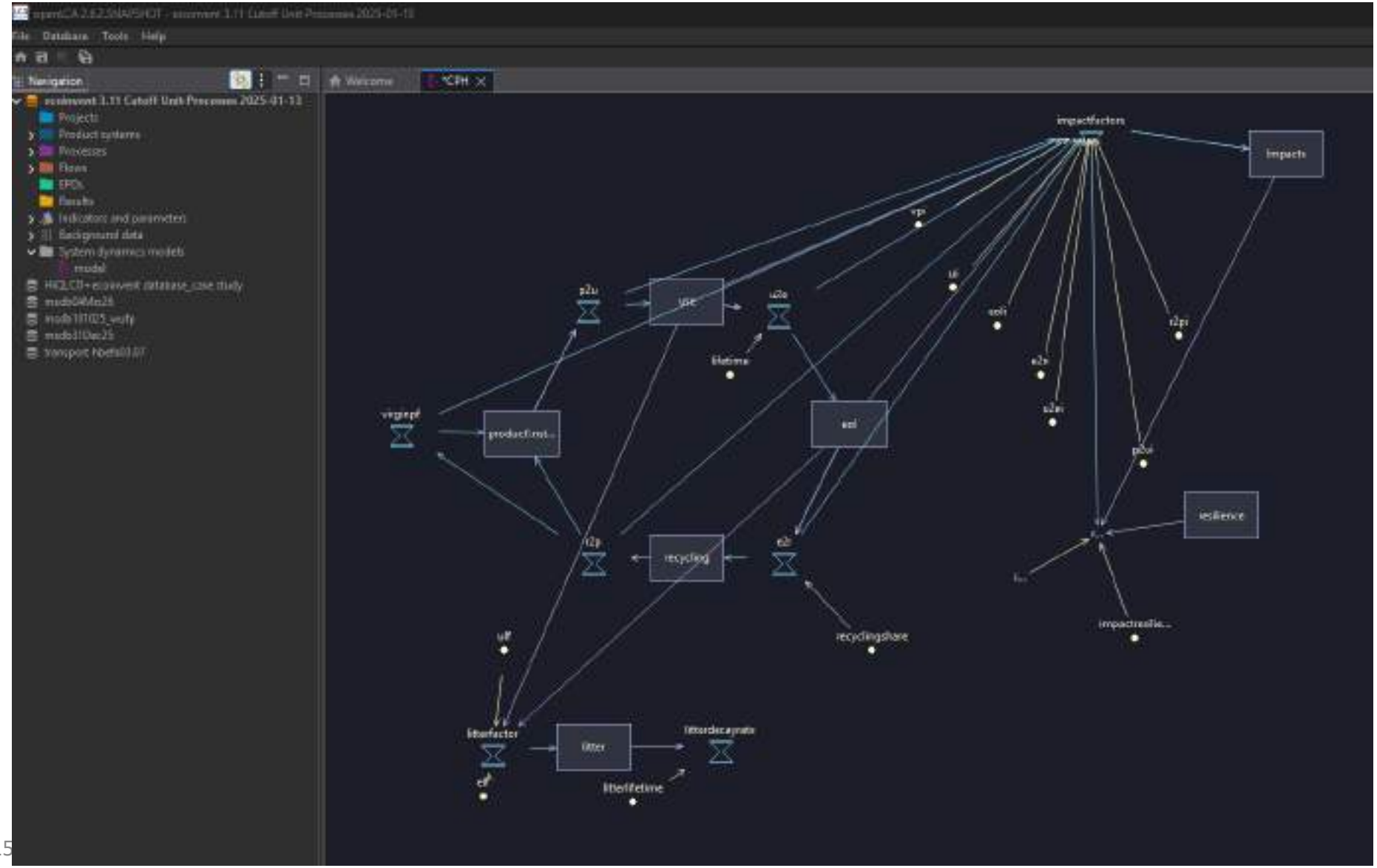
- Quite well able to reflect sustainability
- Data demand not necessary high (in quantity): "population" ...
- ..but demanding in quality: system behavior and "results" depend a lot on whether the population reproduction rate is 1.0 or 1.01 (e.g.)

Eight Sustainability Decision Situations over the life cycle

Eight Sustainability Decision Situations over the life cycle

1. Comparison of two products a and b, a is clearly better
2. Product a and b have different recycling rates
3. Product a and b have different life times
4. Product a has one less step in the life cycle than product b
5. Product a contains toxic substances
6. Product a is littered
7. Product a has an upscaled production
8. Product a has a learning curve

A generic system dynamics model for these questions



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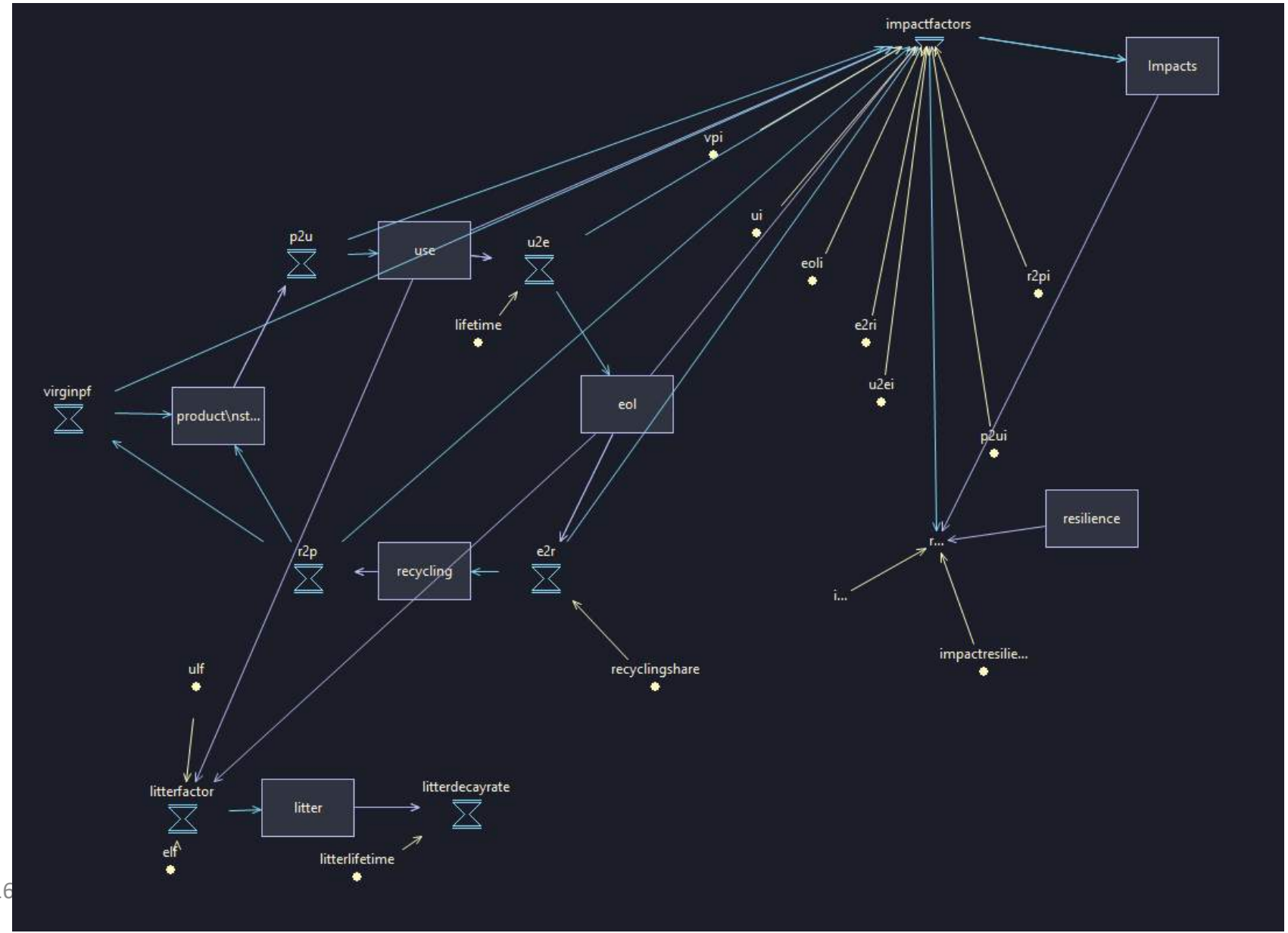

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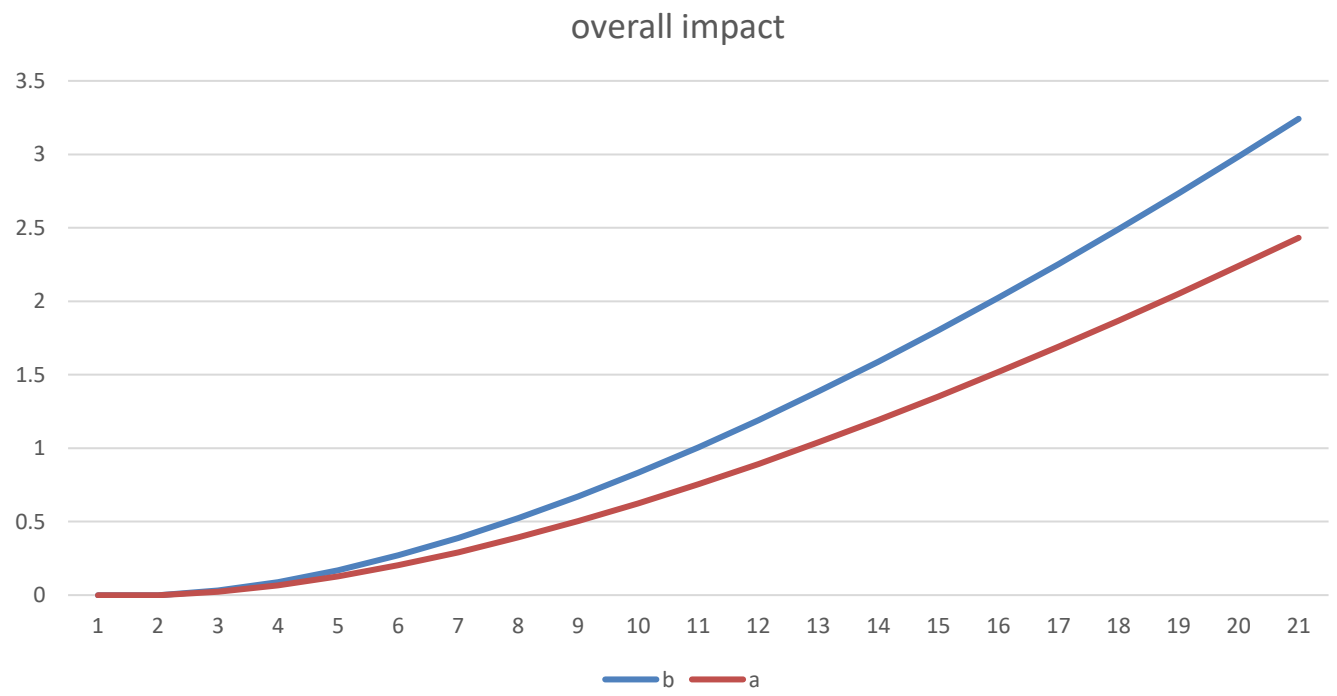
1 Comparison of two products a, b; a is clearly better

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



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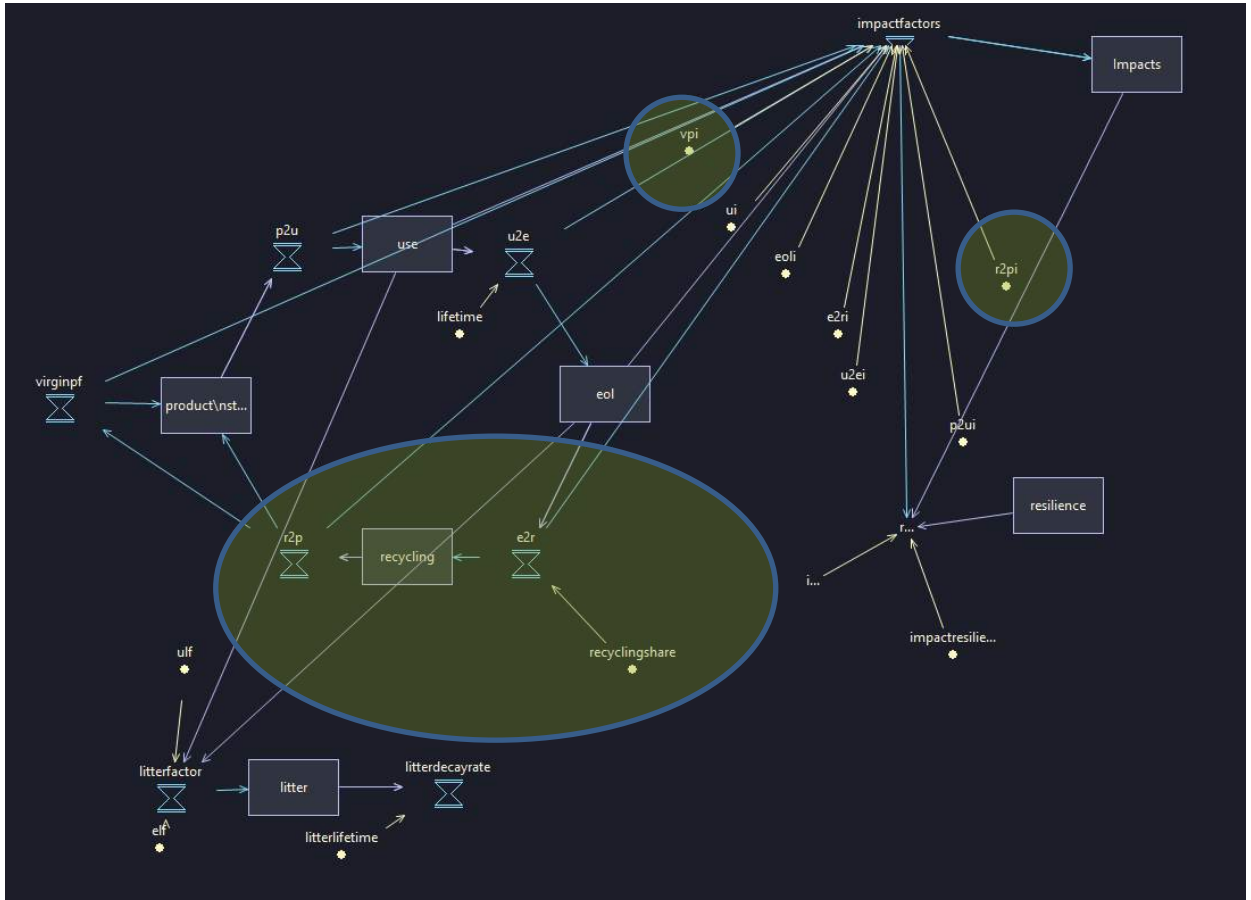
2, comparison of two products a and b, with different recycling rates

→ set recycling-rate and impacts related to recycling & virgin production random



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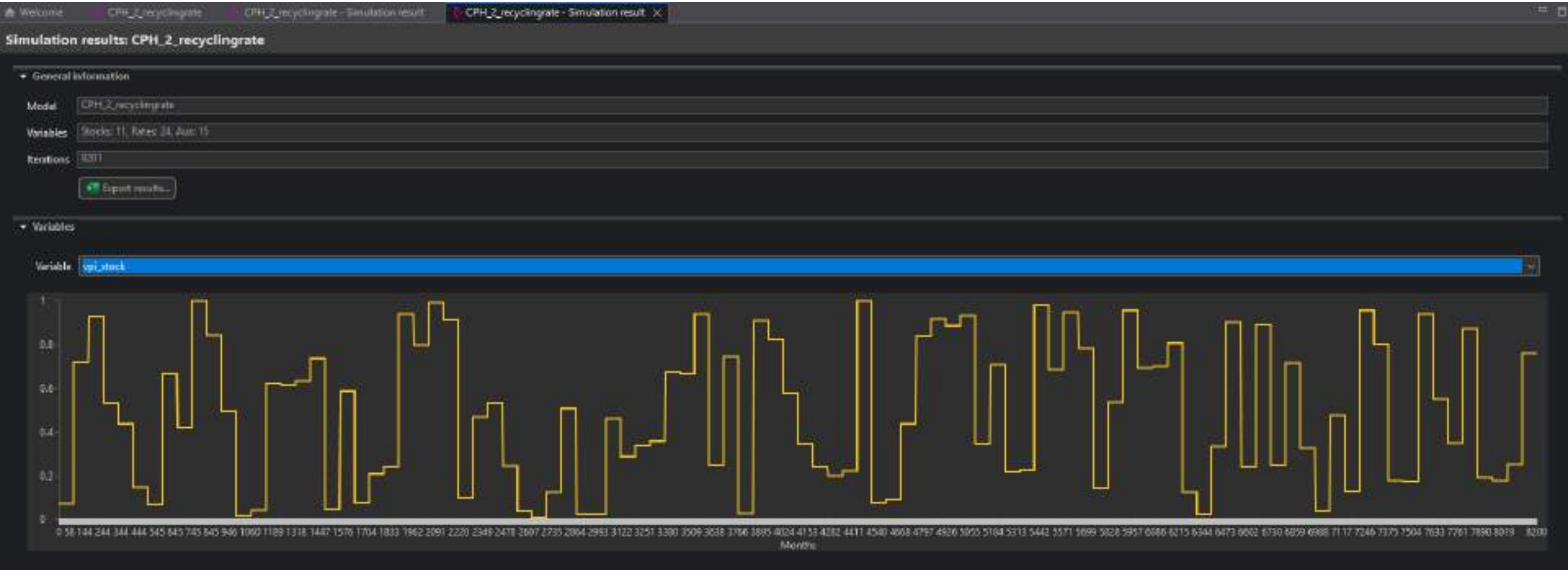

2, the product has different recycling rates

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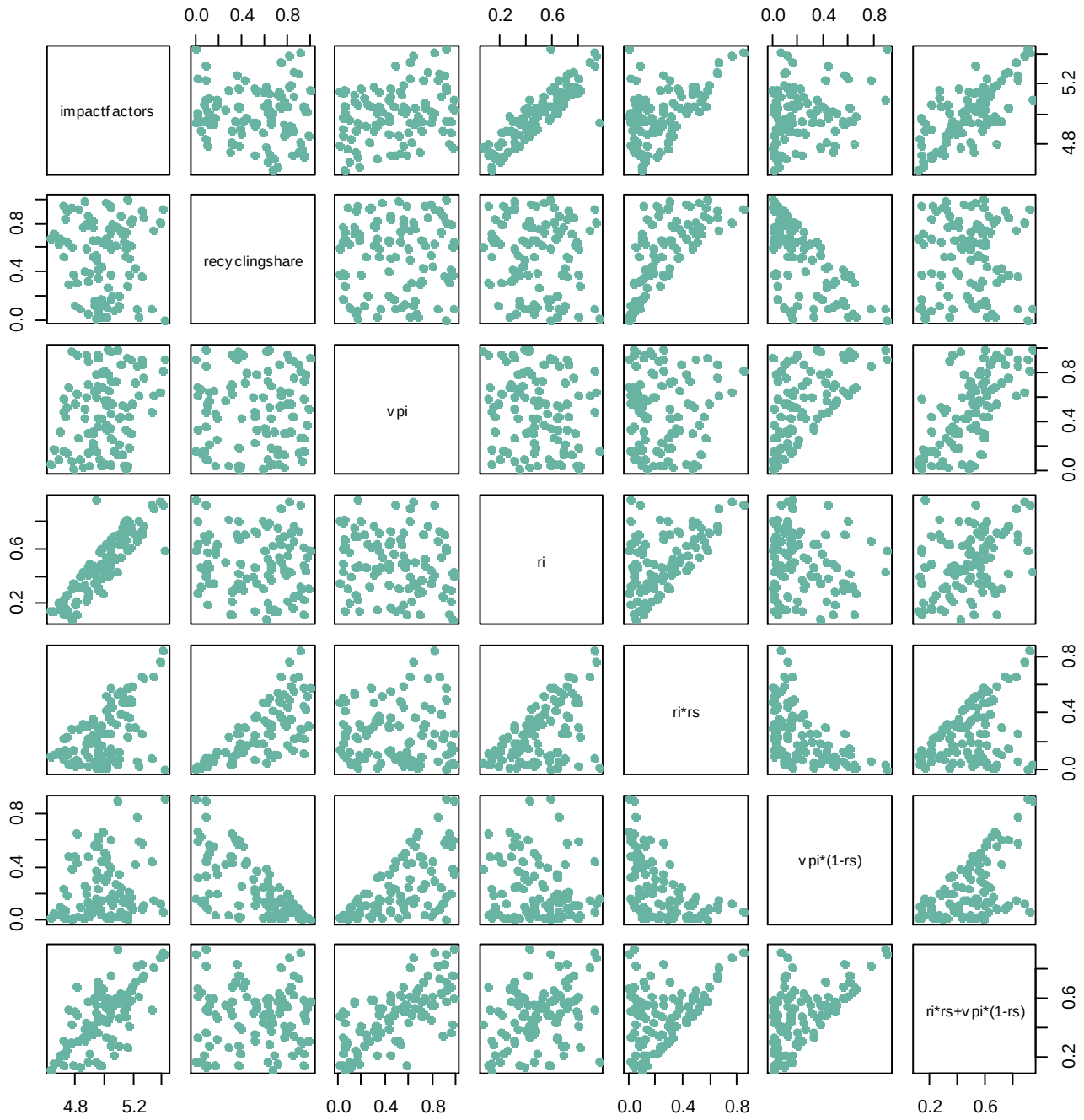
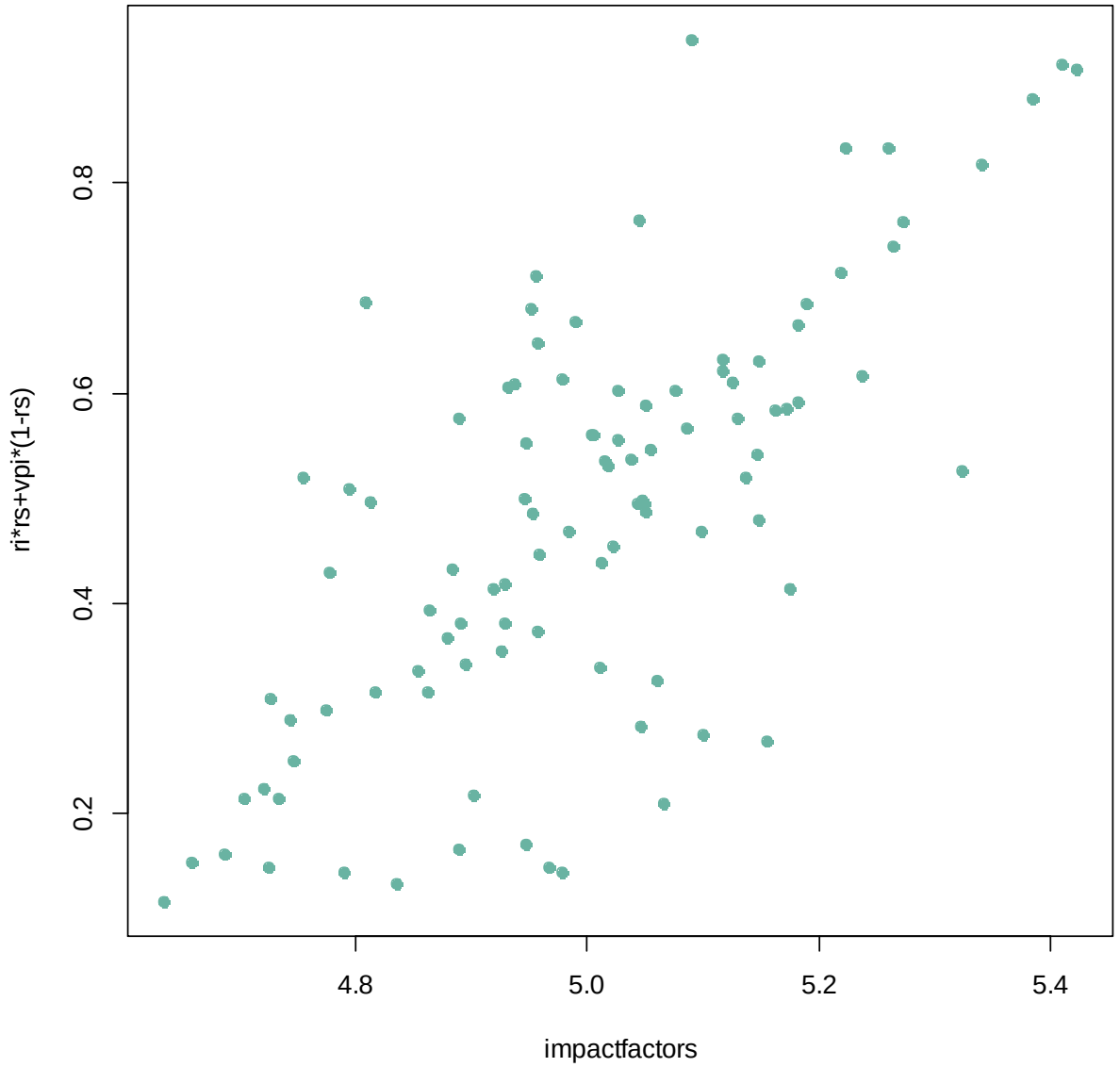


2, the product has different recycling rates

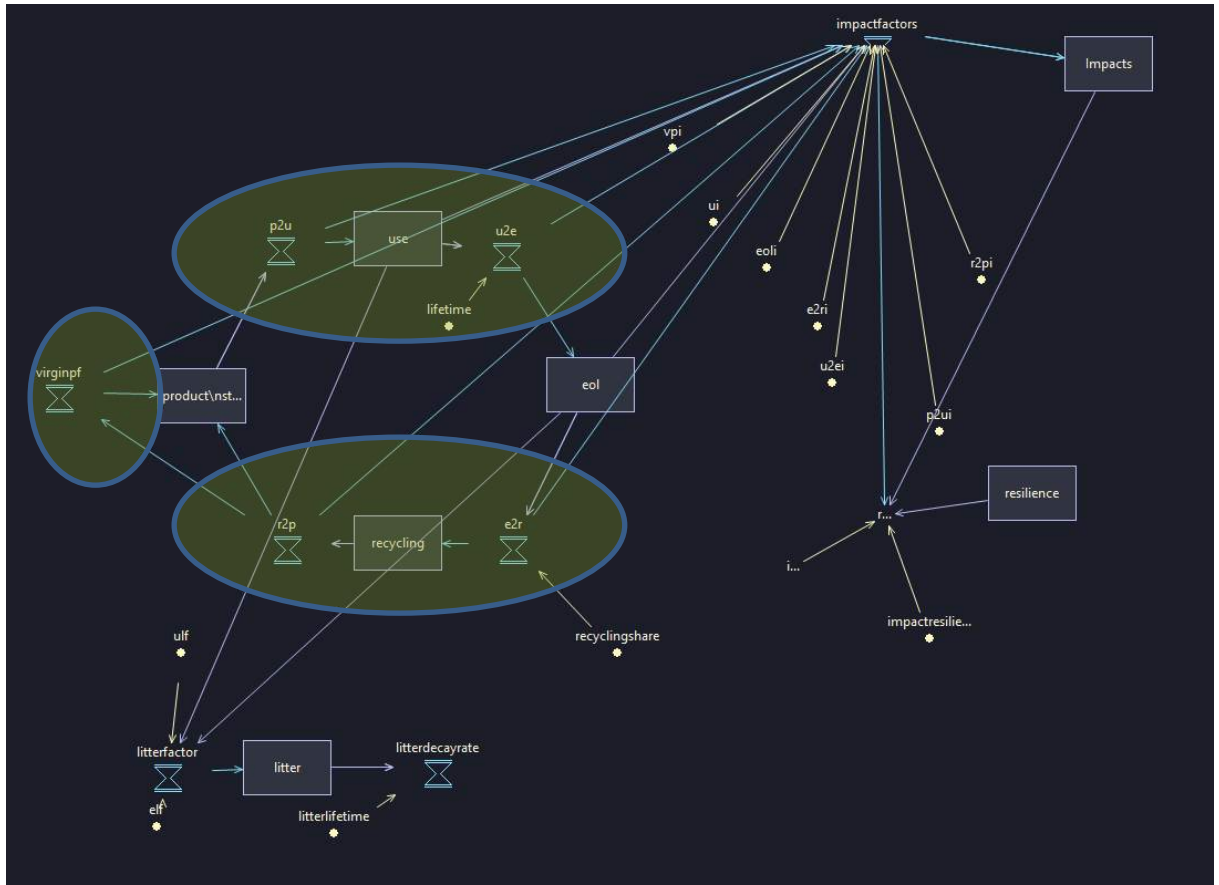
Impact ~
Recycling_impact*recyclingrate +
Virgin_production_impact*(1-recyclingrate)

→ interpretation: Impact is highest if impact for recycling is high and recyclingrate is high, or if impact for virgin production is high and recyclingrate is low.



3, product a has longer lifetime than product b

→ This has effect on production effort, eol effort



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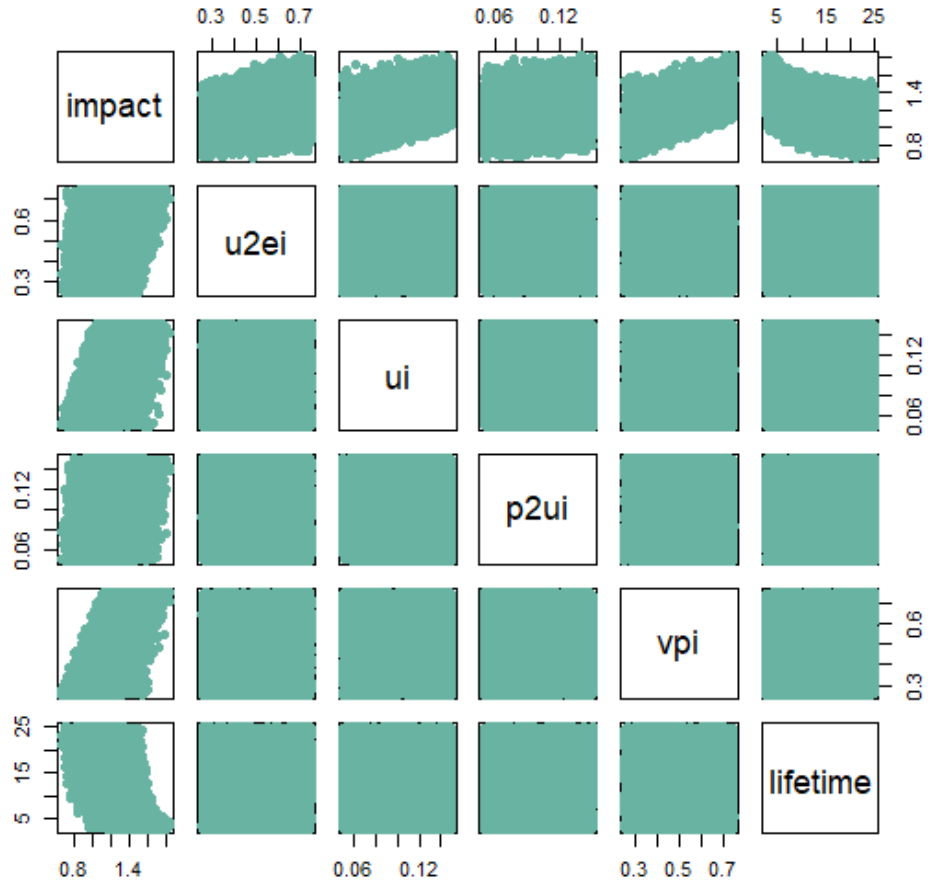

Shorter lifetime has higher impacts, if production (vpi), sales & use (ui), end of life (u2ei) are higher

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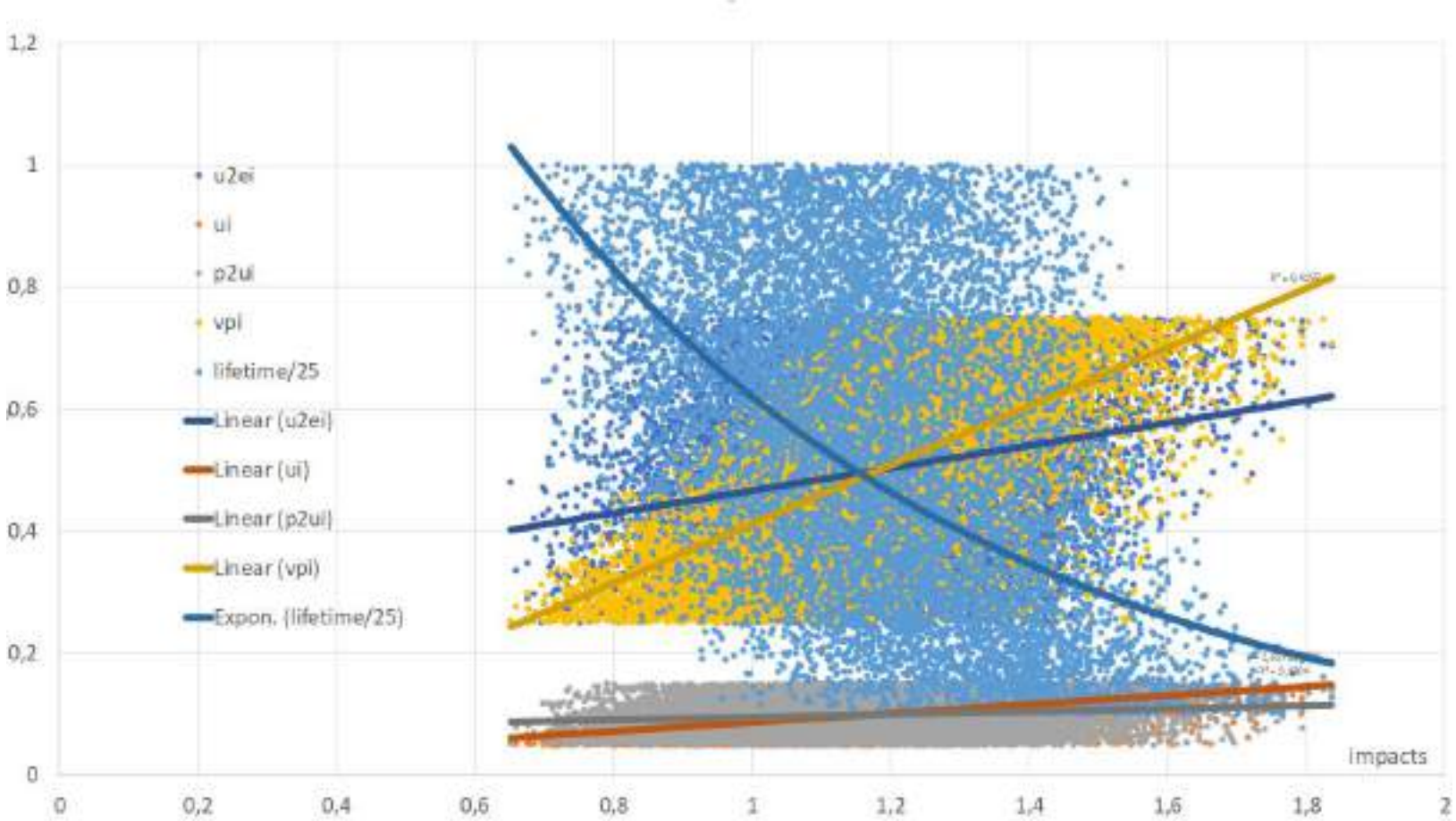

Shorter lifetime has higher impacts, if production (vpi), sales & use (ui), end of life (u2ei) are higher

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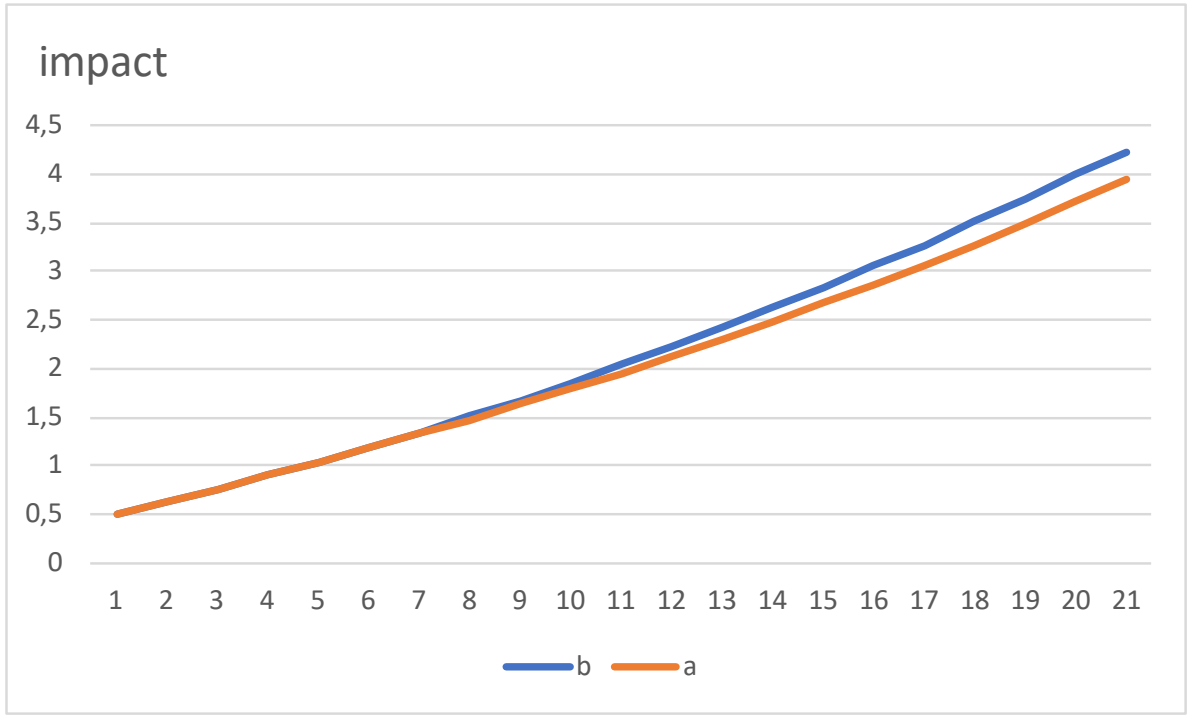
4, product a has one process less in the life cycle than product b

(ceteri paribus) -> this is the identical to case 1 (product a is always better)



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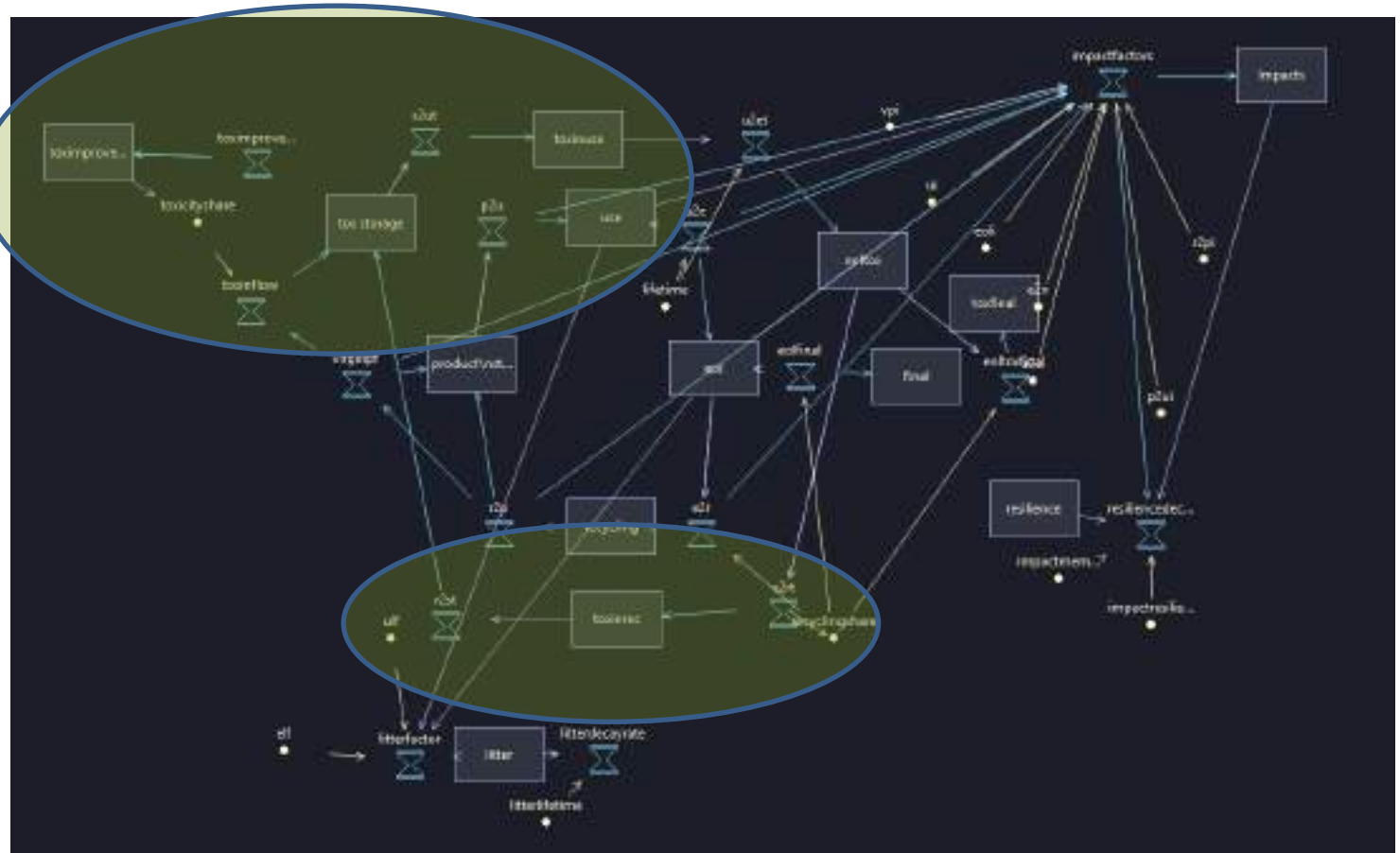
5, product a contains toxic substances

The toxic substances decrease over time in new products but are not decreased in products once they are on the market



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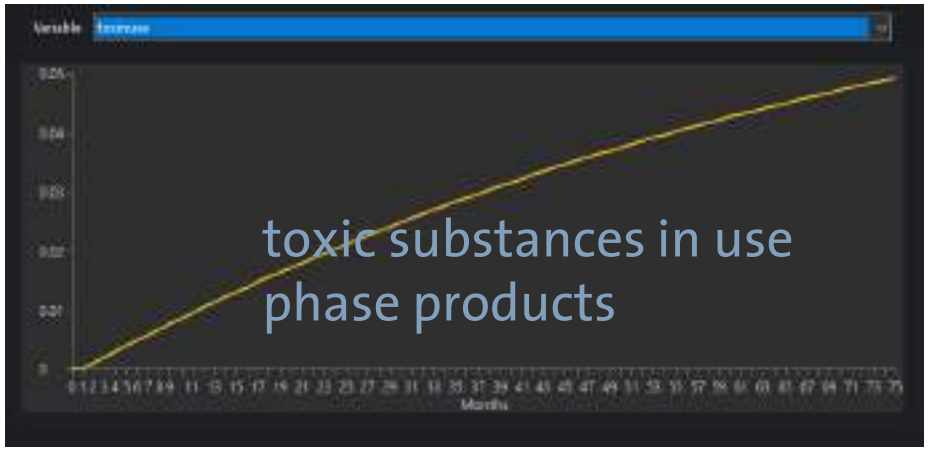
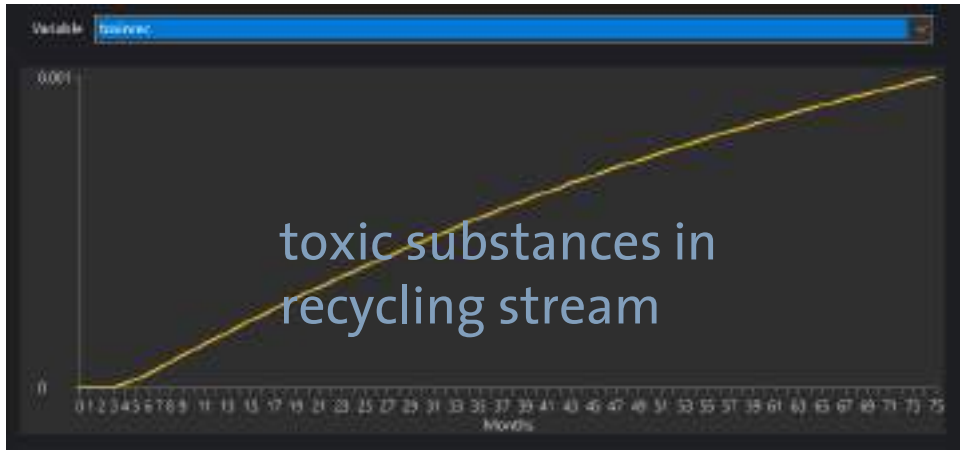
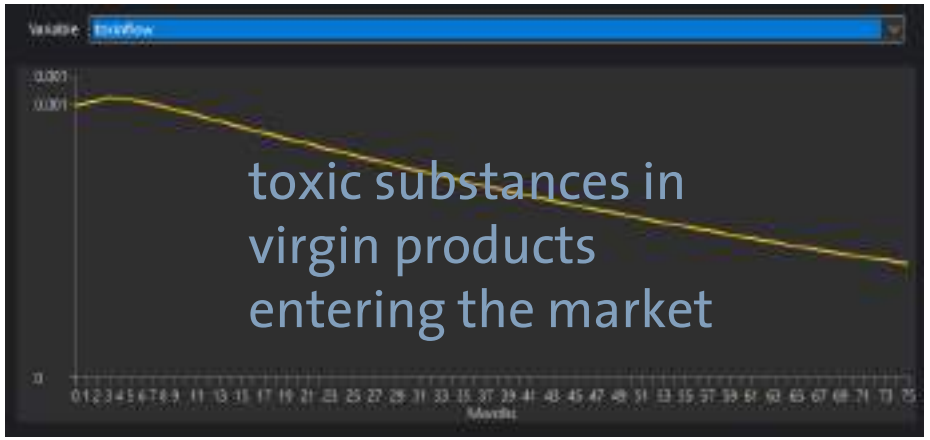
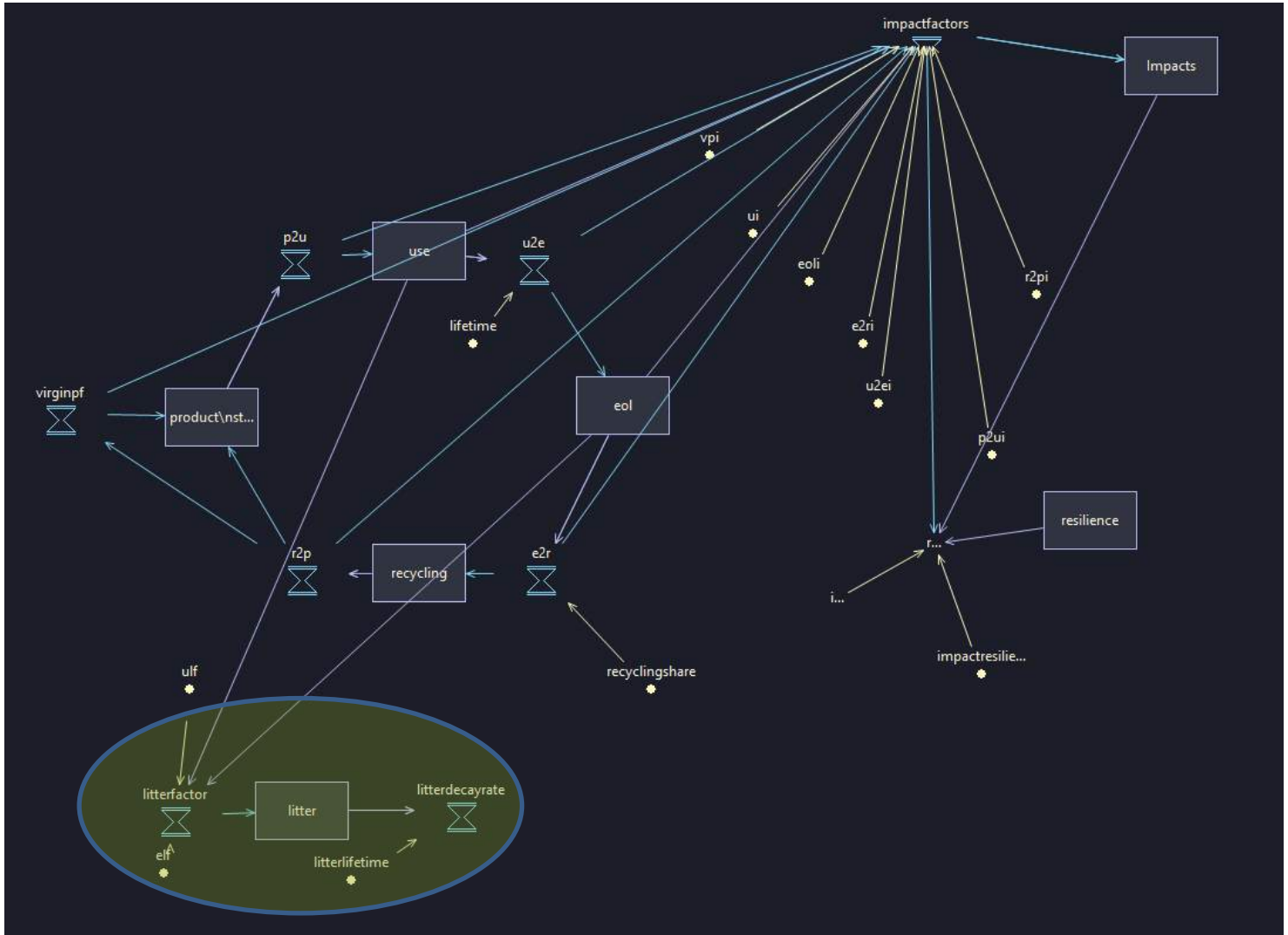






Recycling increases the content of toxic substances in the products on the market
(here: 50 % recycling, constant)

6, product 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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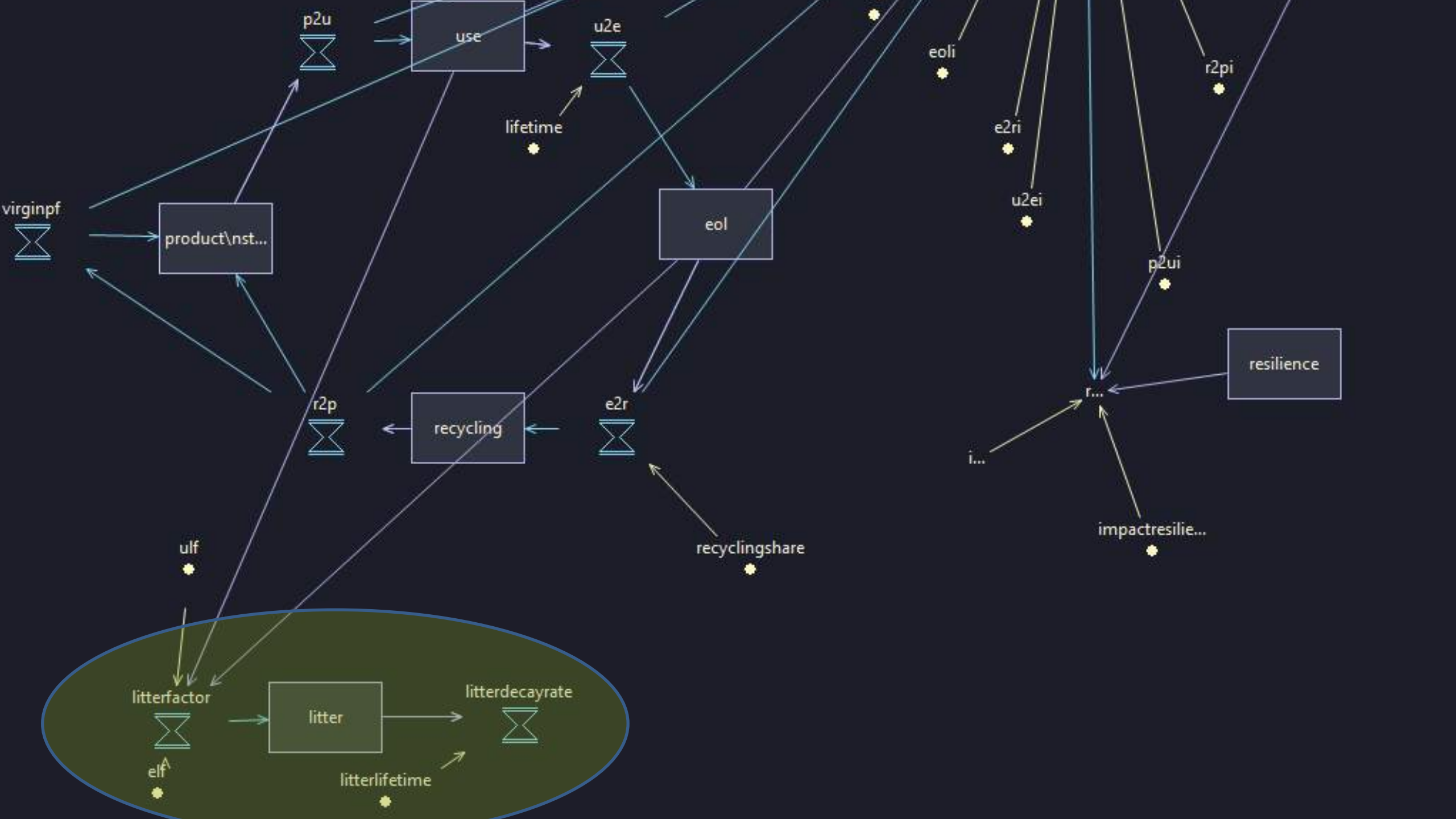
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litterdecayrate
elf
litterlifetime

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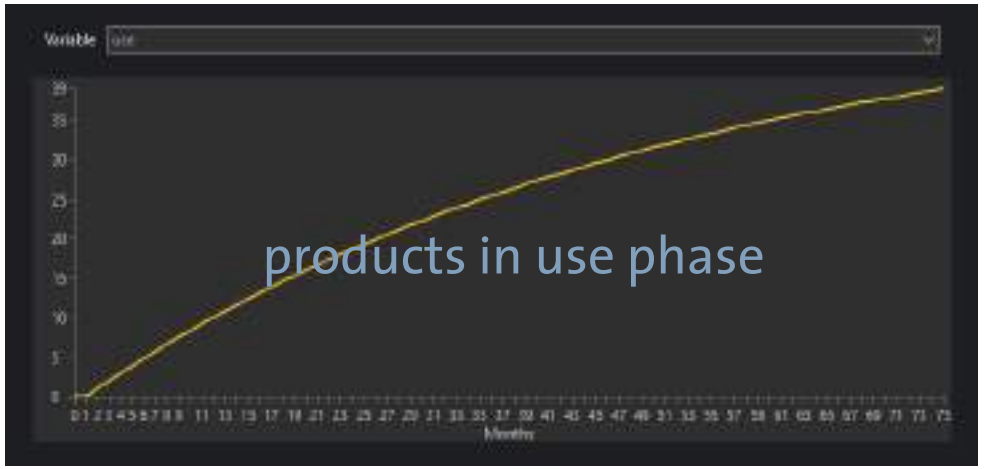

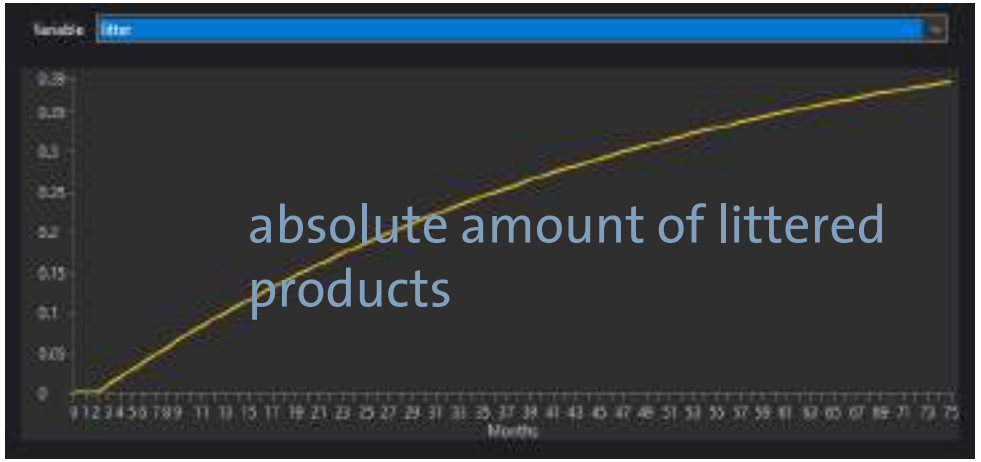

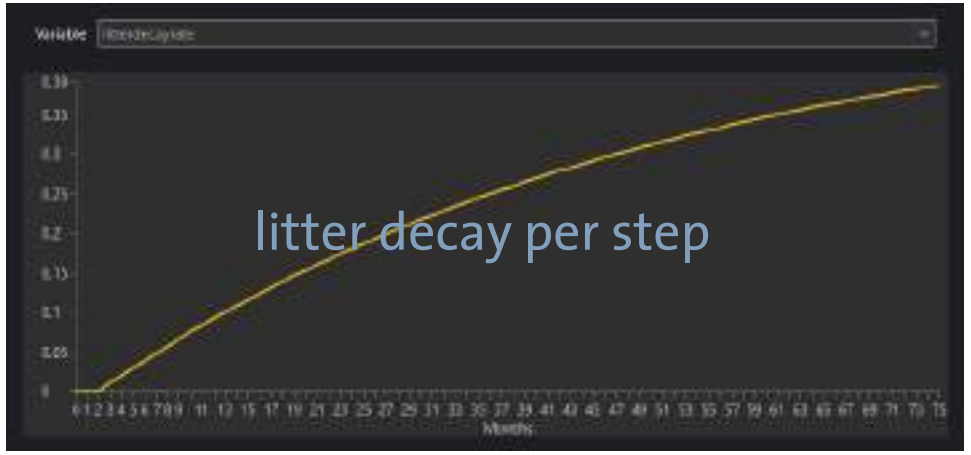

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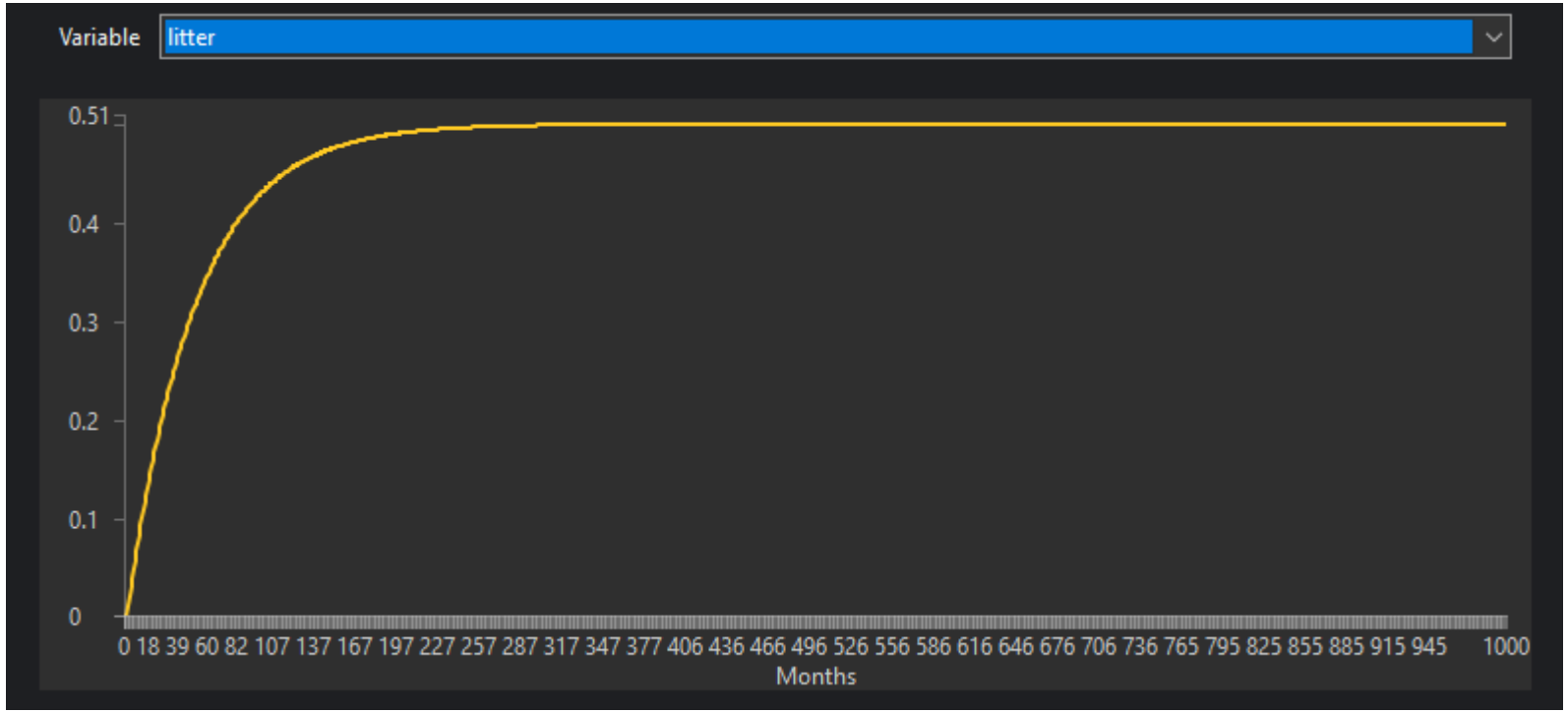
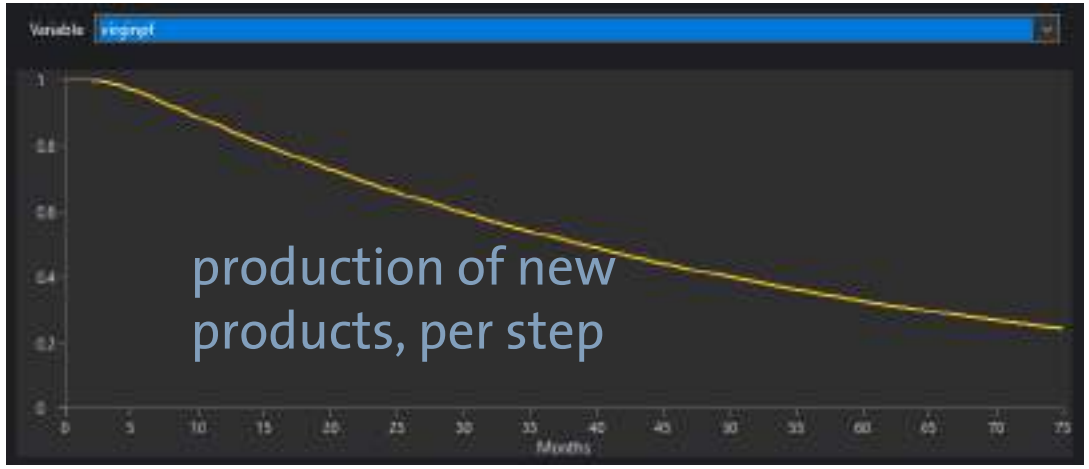
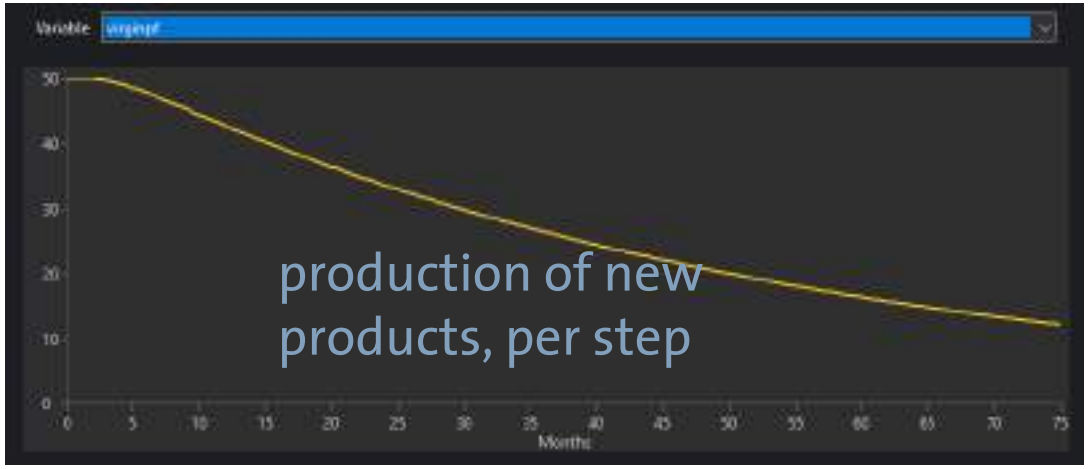


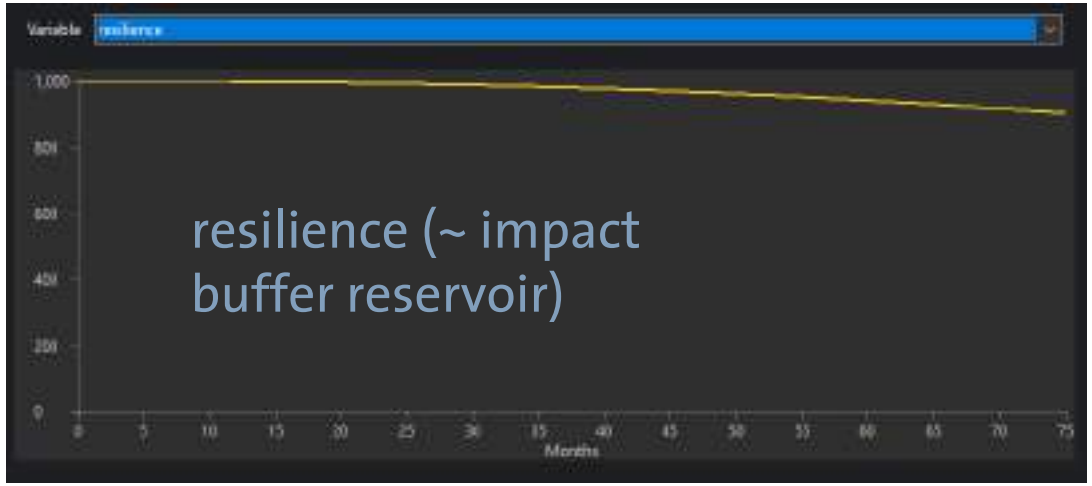
In the long run, litter decay rate equals litter “production” rate, reaching a stable state, for these settings

7, product a has an upscaled production

Virgin production: 50 units per months instead of 1 unit per month ->



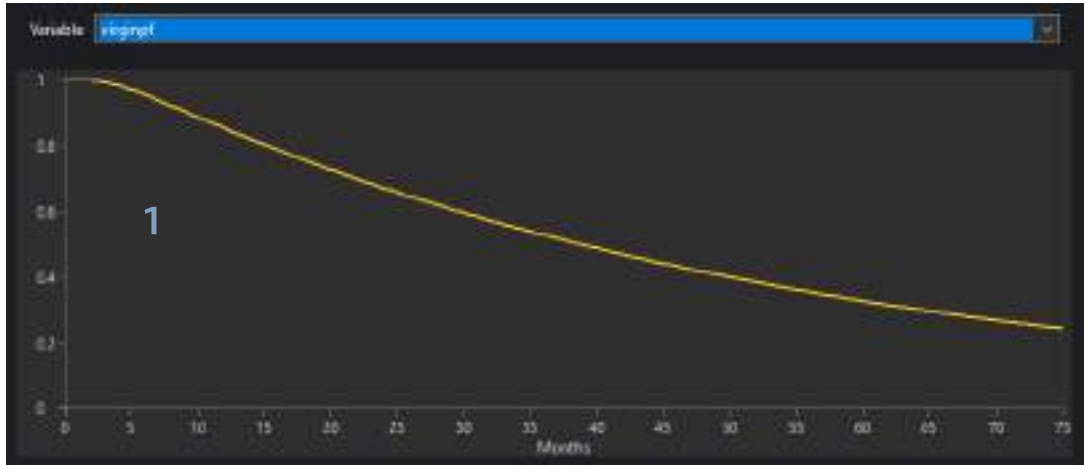


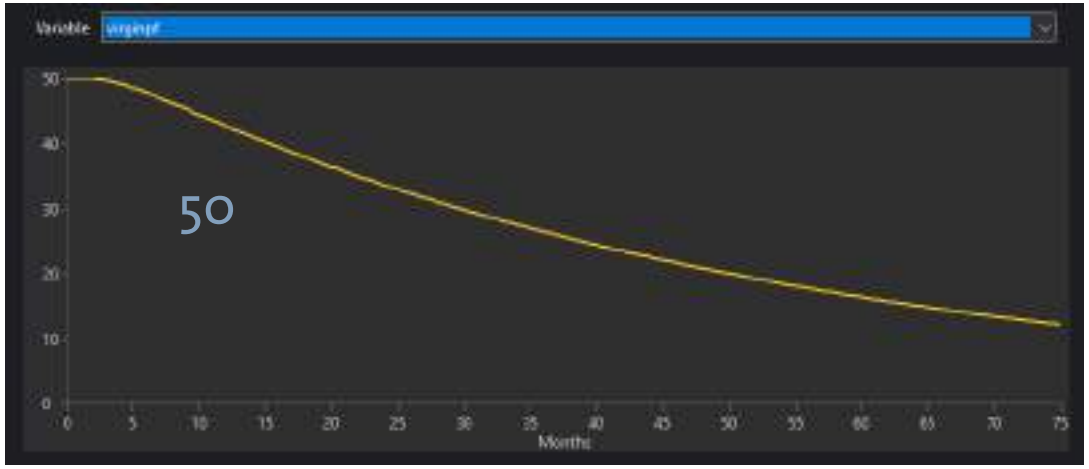


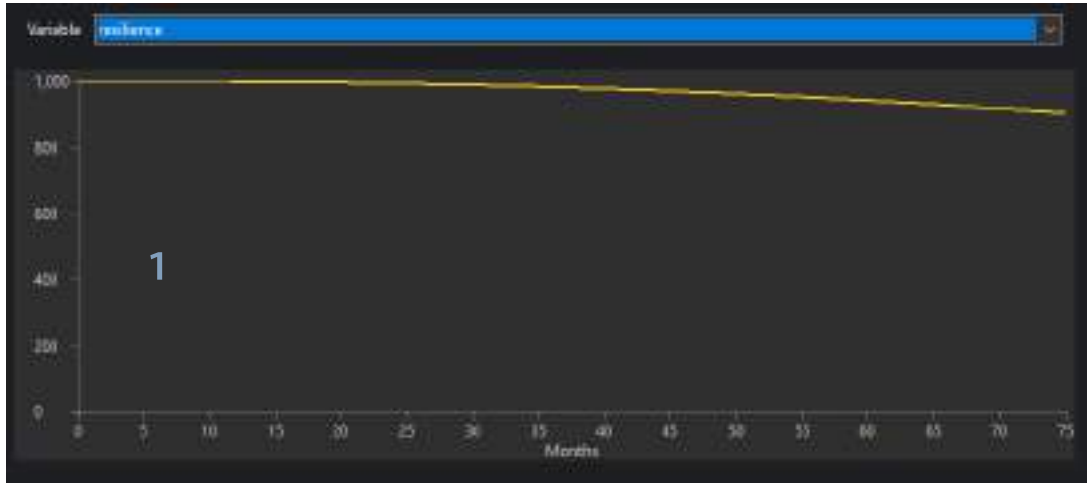
7, product a has an upscaled production

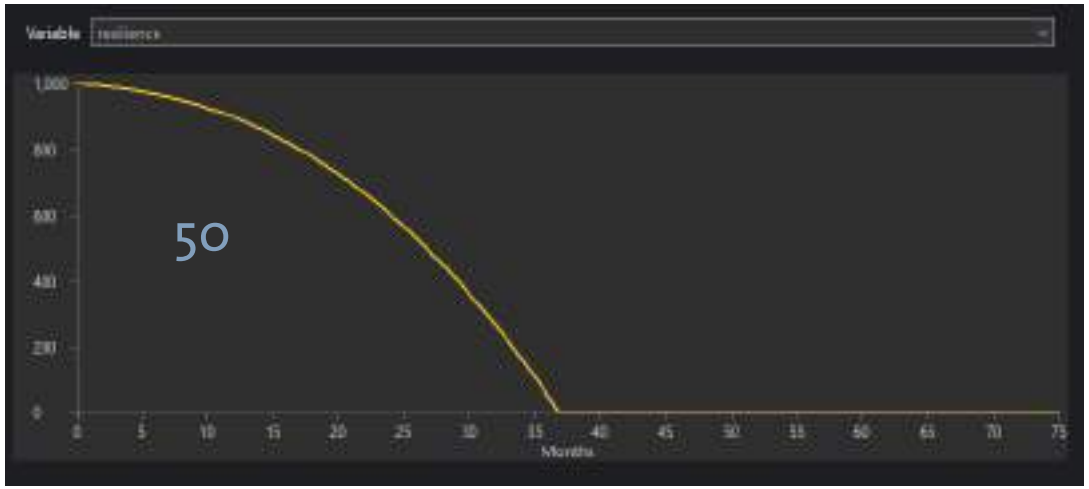
Drastically upscaled production leads to exponential increase of impacts and to “depletion of resilience”

Virgin production: 50 units per months instead of 1 unit per month ->









8, product a has a learning curve

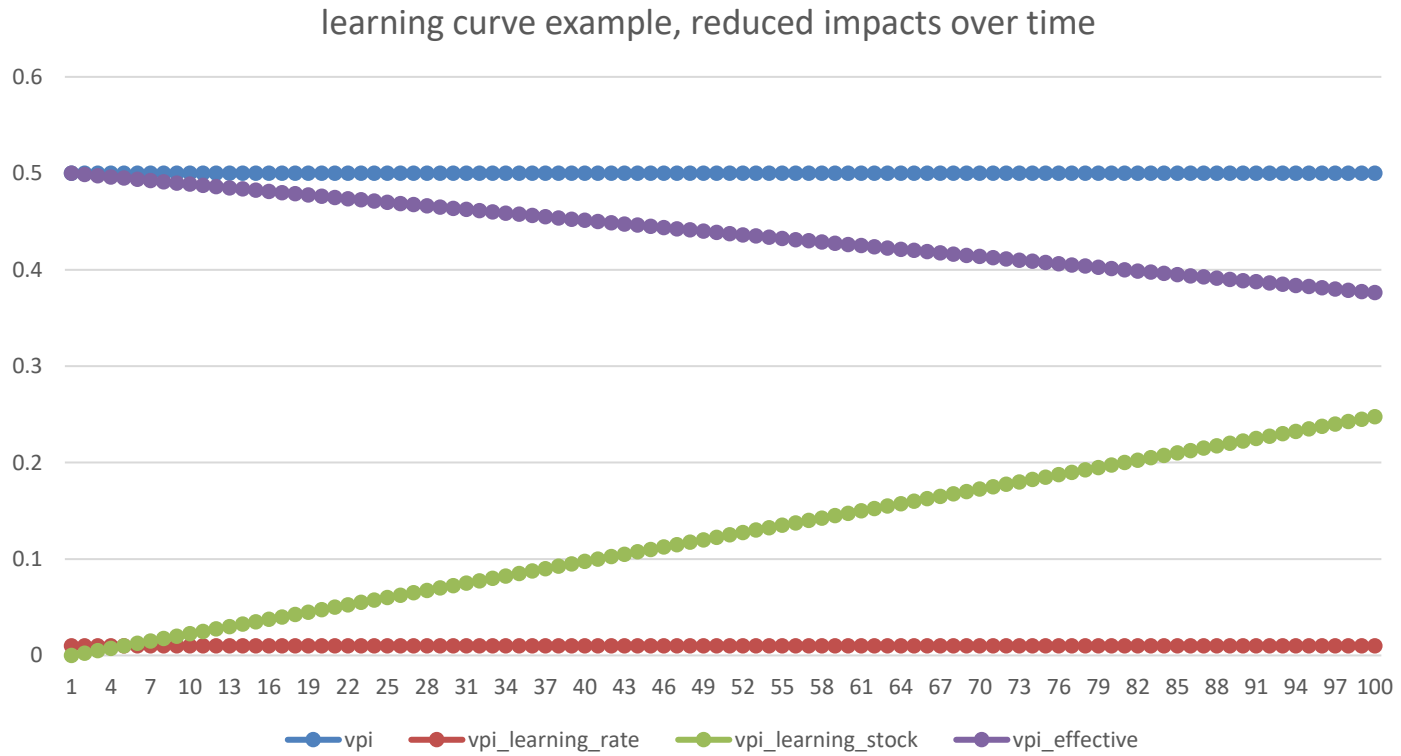
-> over time, the processes become more efficient and cause less impacts.

For example, for the virgin production process: vpi is reduced over time

8, product a has a learning curve

-> over time, the processes become more efficient and cause less impacts.

For example, for the virgin production process: specific impact vpi is reduced over time



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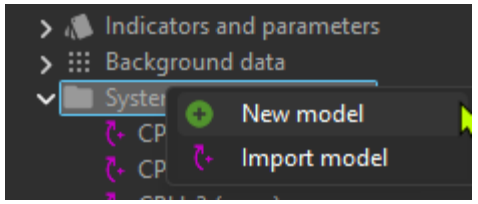
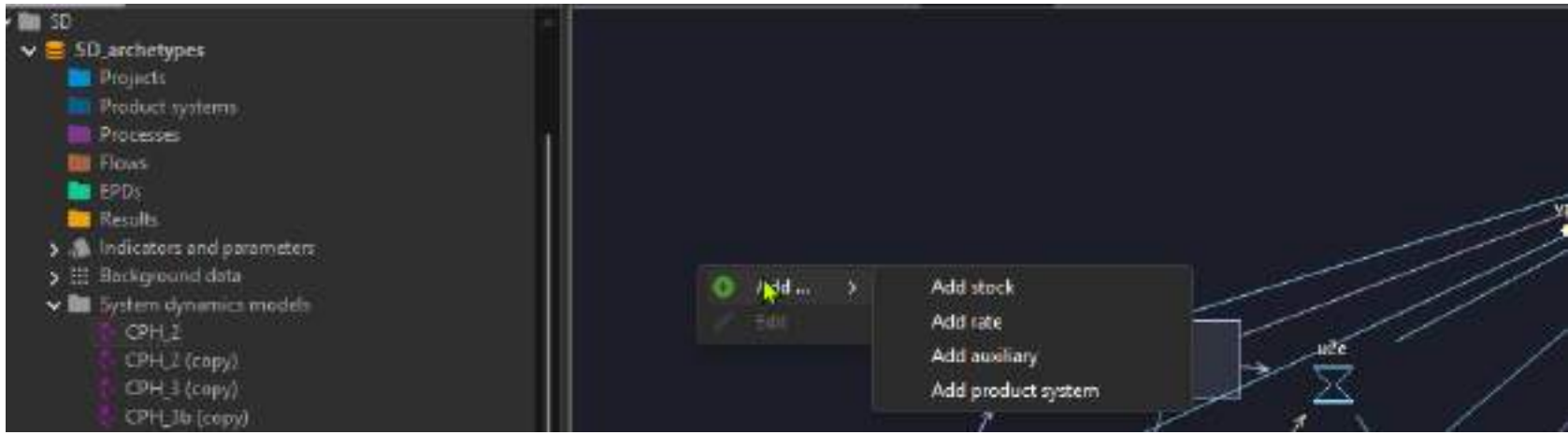
LCA and System Dynamics in openLCA

In openLCA 2.6.2, System Dynamics modeling is implemented so that you can

1) Import models that follow the XMILE standard (from Vensim, Stella)
2) Make own models
3) Run simulations
4) Link to product systems and thus LCA
5) Check simulation results
6) Export results to excel





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Conclusions & discussion

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)

Discussion

1) The 8 decision situations are common in LCA and often difficult or cumbersome to implement. System dynamics modeling offers an easy and “natural” way to implement these
2) Interpretation of these cases based on a generic model offers generally valid conclusions that could find a way into design rules and guidelines for sustainability decisions
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) openLCA integration really helps to link System Dynamics with LCA and sustainability assessments – more to come!

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Thank you very much!

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