

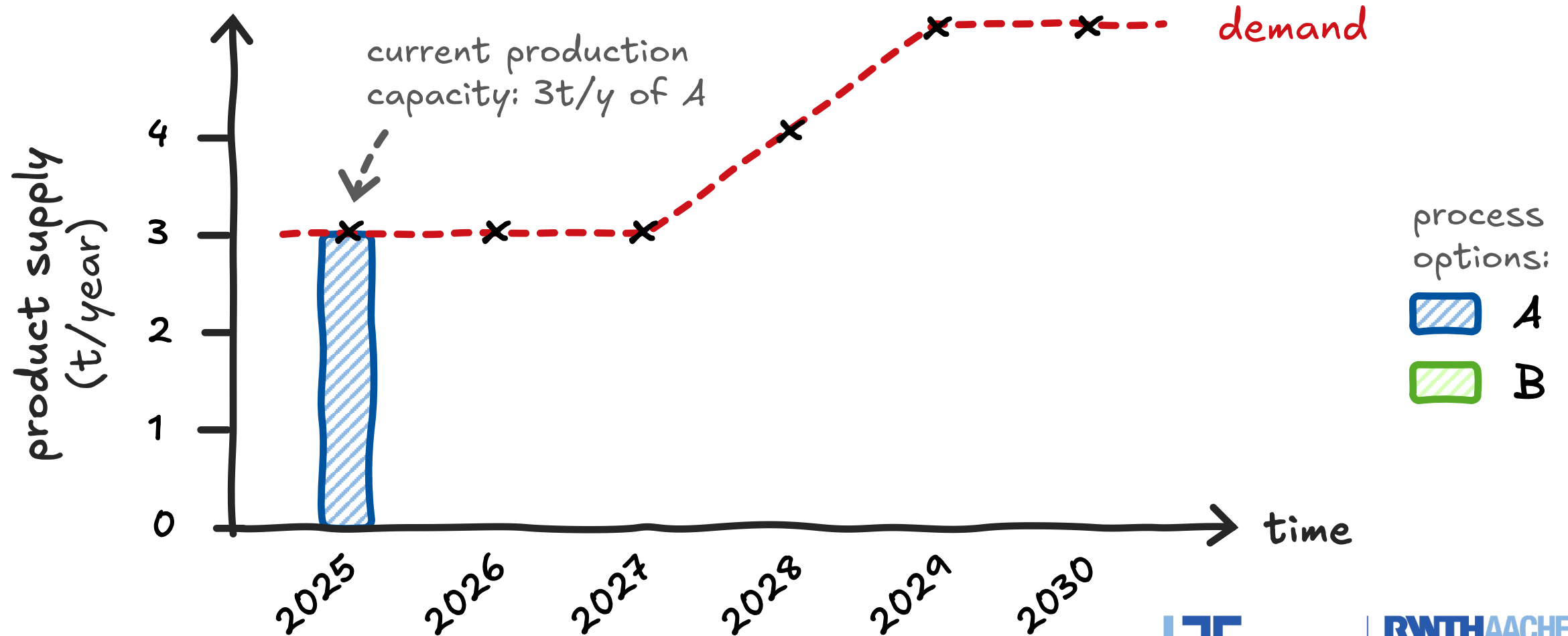


Optimizing Transition Pathways using Time-Explicit LCA

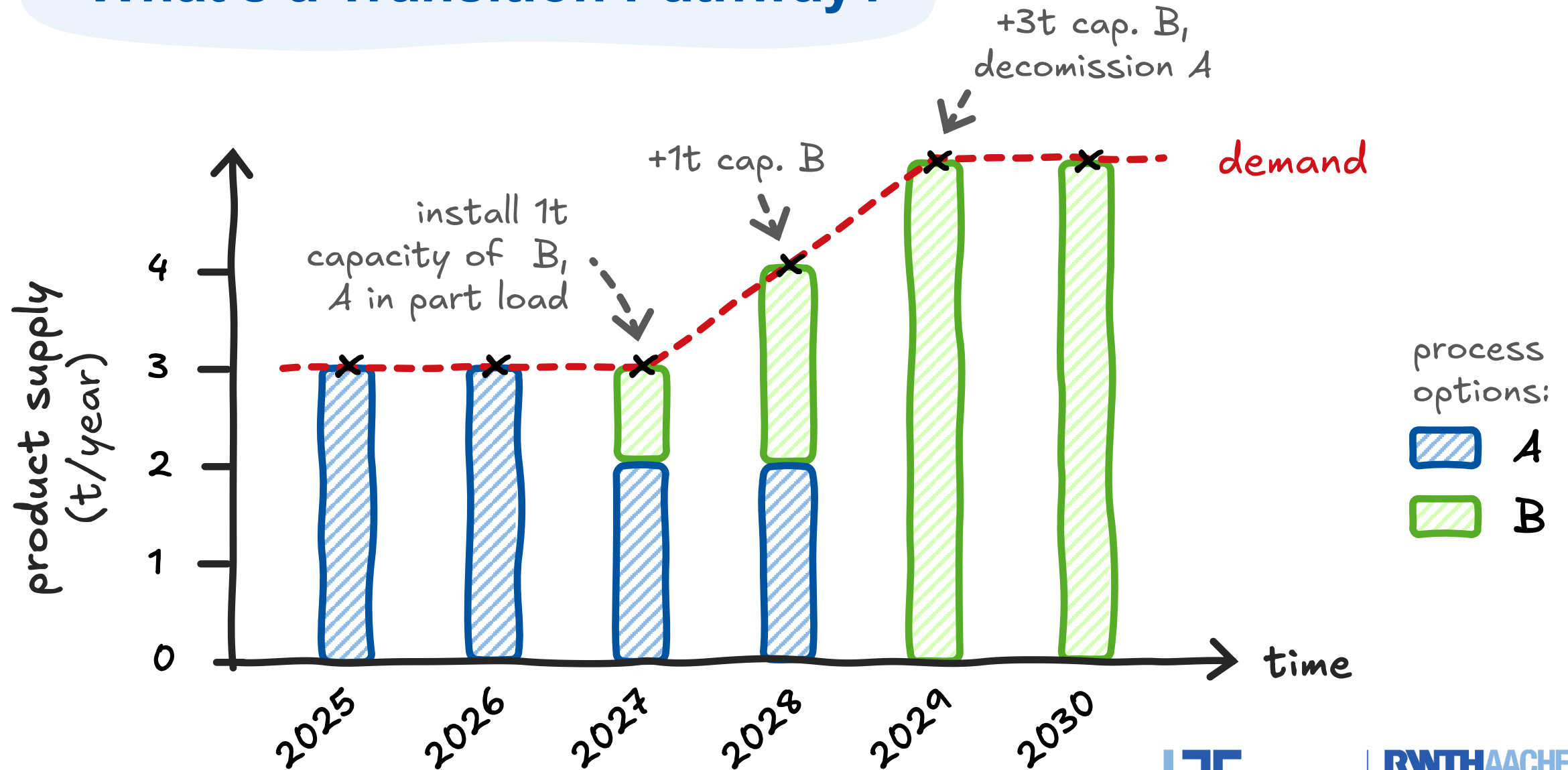
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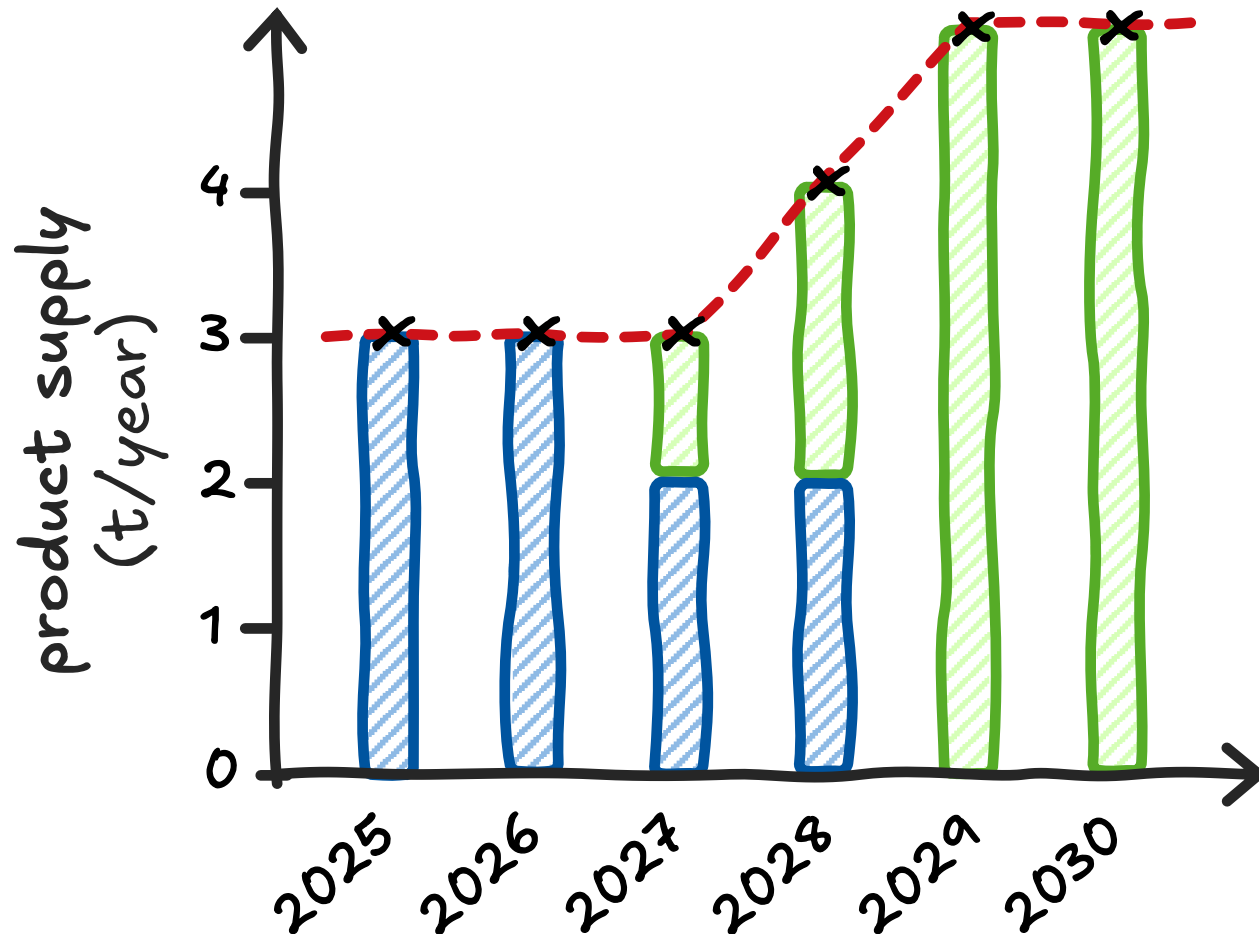
What's a Transition Pathway?



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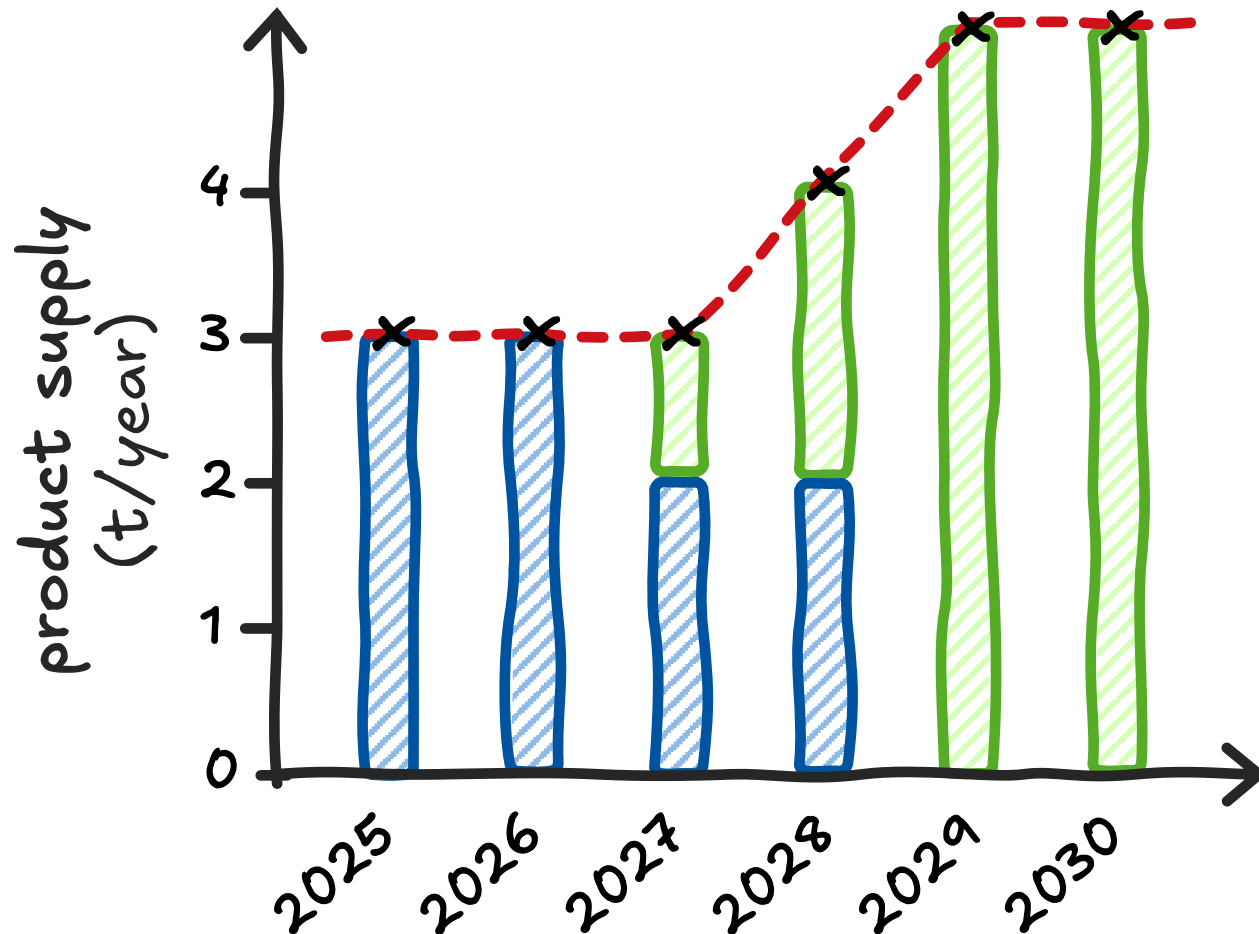


“Trivial” Time Considerations:



- at what timestep to install & operate how much of what?
- production = demand @ each point in time
- production limited by what was previously installed

Impacts of a Transition Pathway?



aggregate supply &
calculate impacts
through LCA, e.g.:

$$\begin{aligned} & \text{GWP100} \left(\sum \text{[blue striped box]} \right) \\ & + \text{GWP100} \left(\sum \text{[green striped box]} \right) \\ & = 1234 \text{ kg CO}_2\text{-eq} \end{aligned}$$

Impacts of a Transition Pathway?

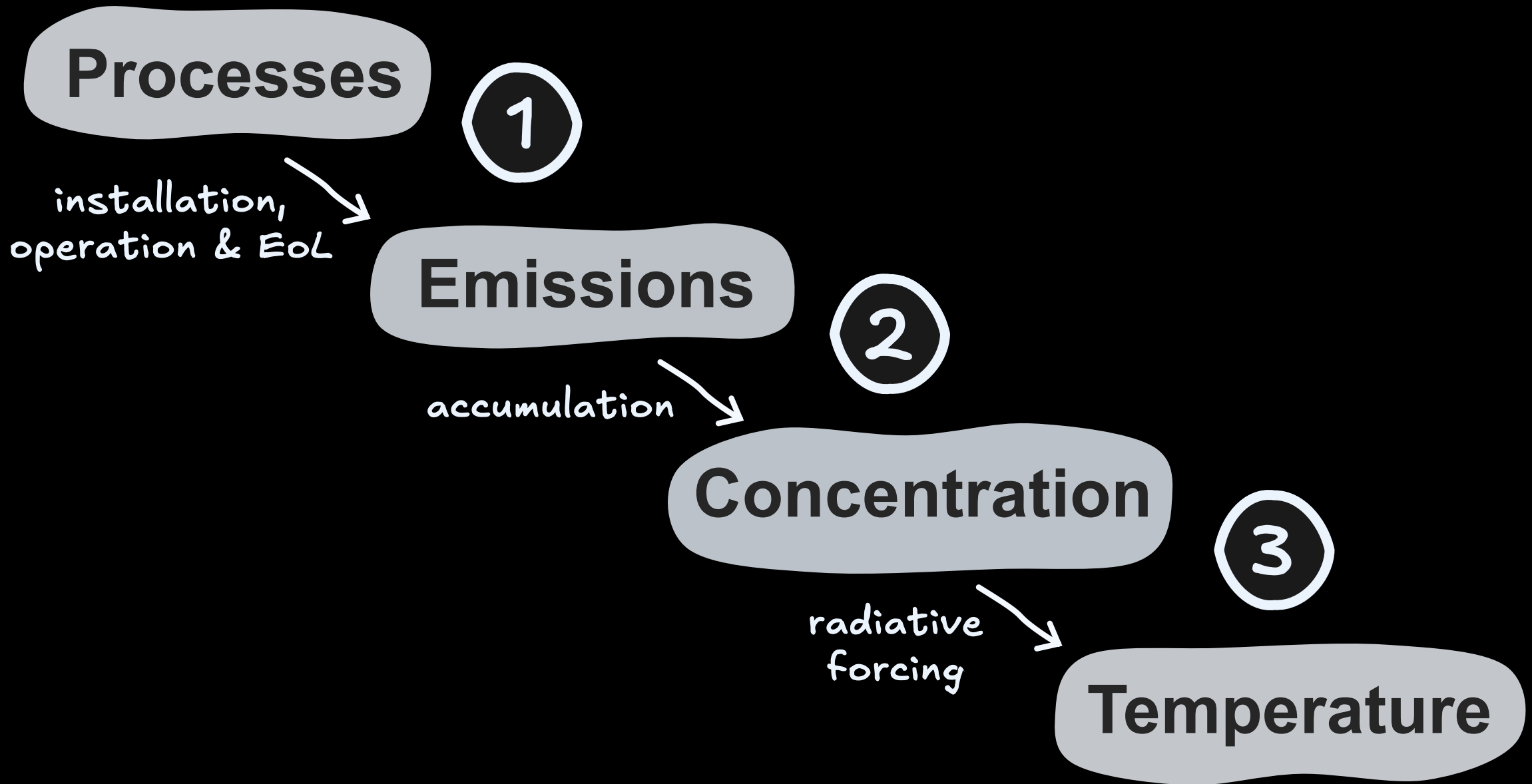
Is this still a good idea if we're talking about...

- power-to-x technologies?
- using short vs. long-rotation biomass?
- CO₂-removal via direct air capture vs. biogenic uptake?
- needing to keep cumulative impact boundaries like the 2° C target?

aggregate supply & calculate impacts through LCA, e.g.:

$$\begin{aligned} &GWP100 \left(\sum \text{[blue hatched box]} \right) \\ &+ GWP100 \left(\sum \text{[green hatched box]} \right) \\ &= 1234 \text{ kg CO}_2\text{-eq} \end{aligned}$$

→ timing might be crucial here!

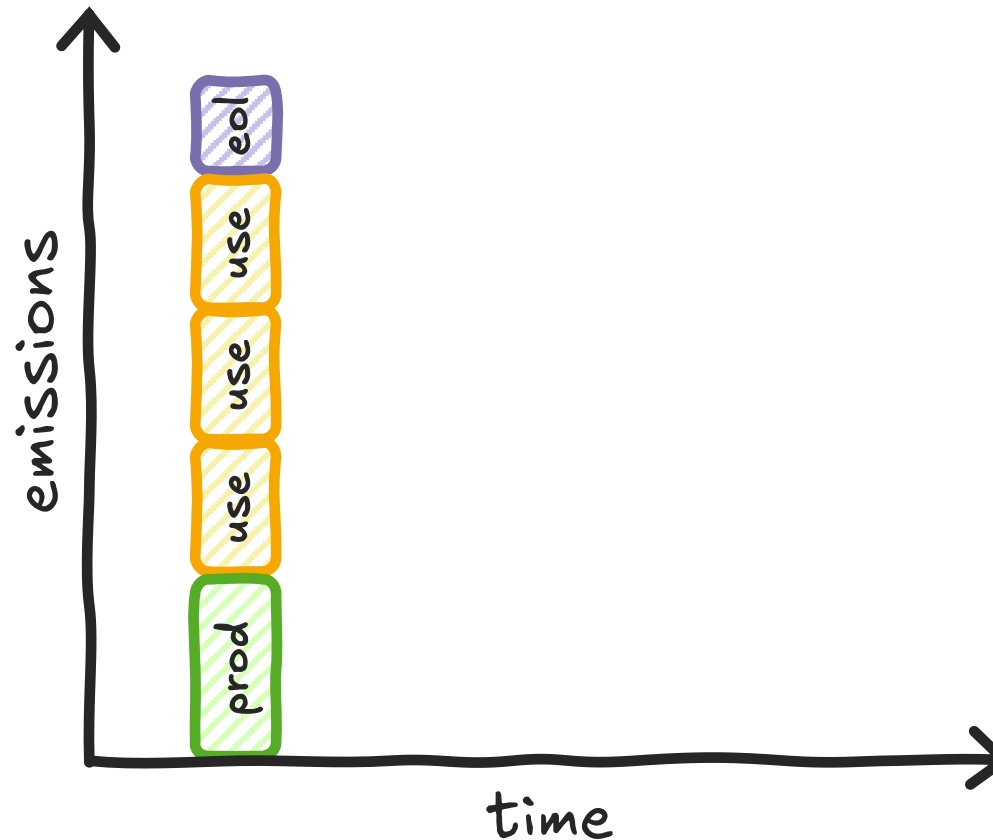


Processes

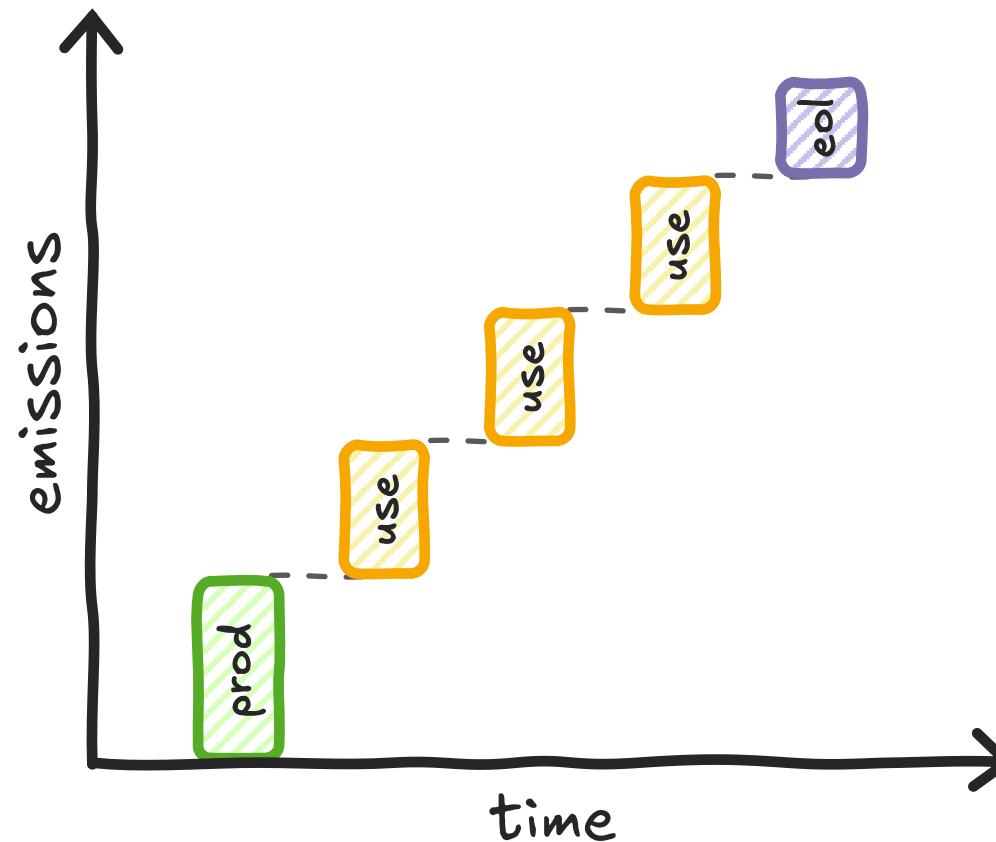
installation,
operation & EoL



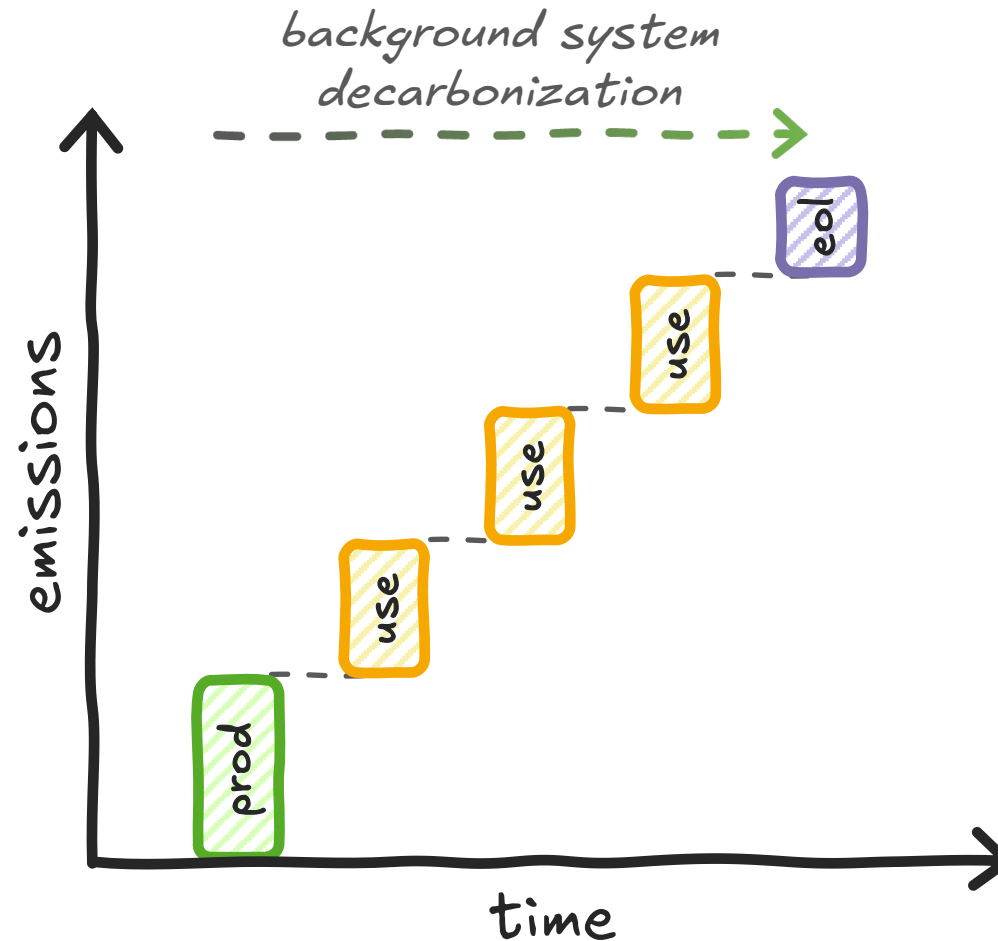
Emissions



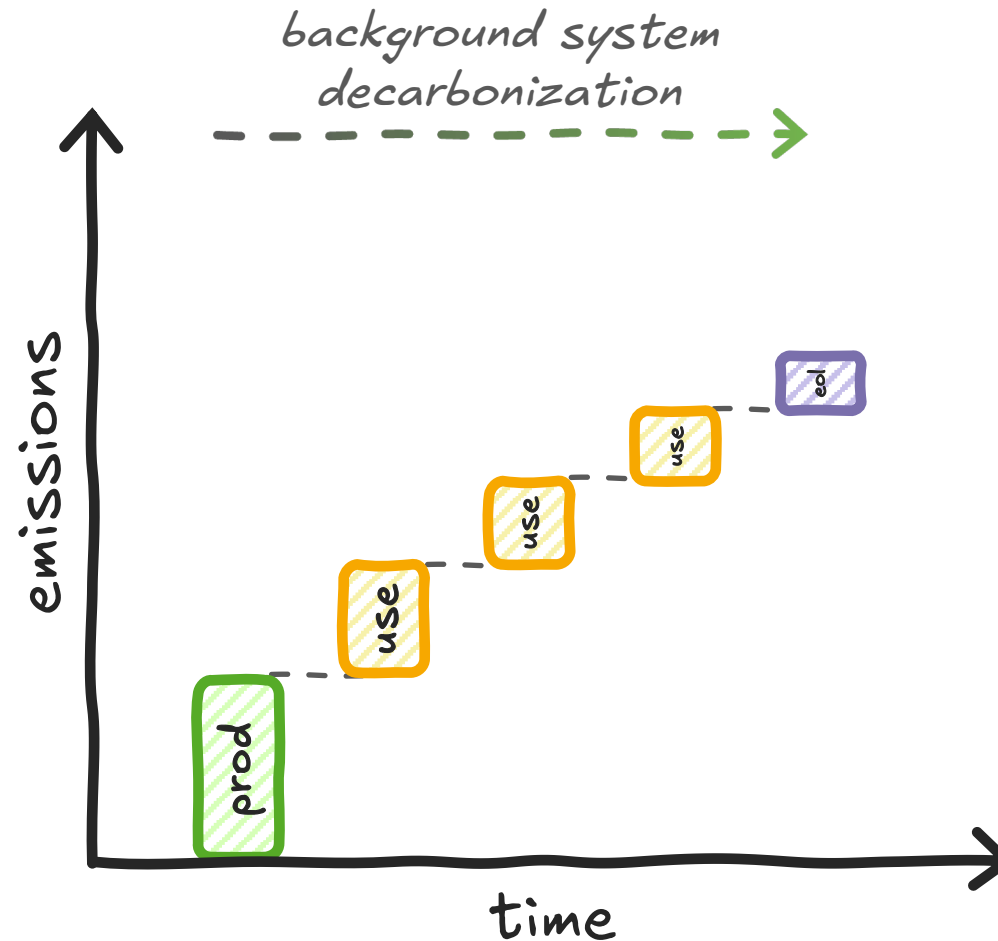
Processes are Temporally Distributed



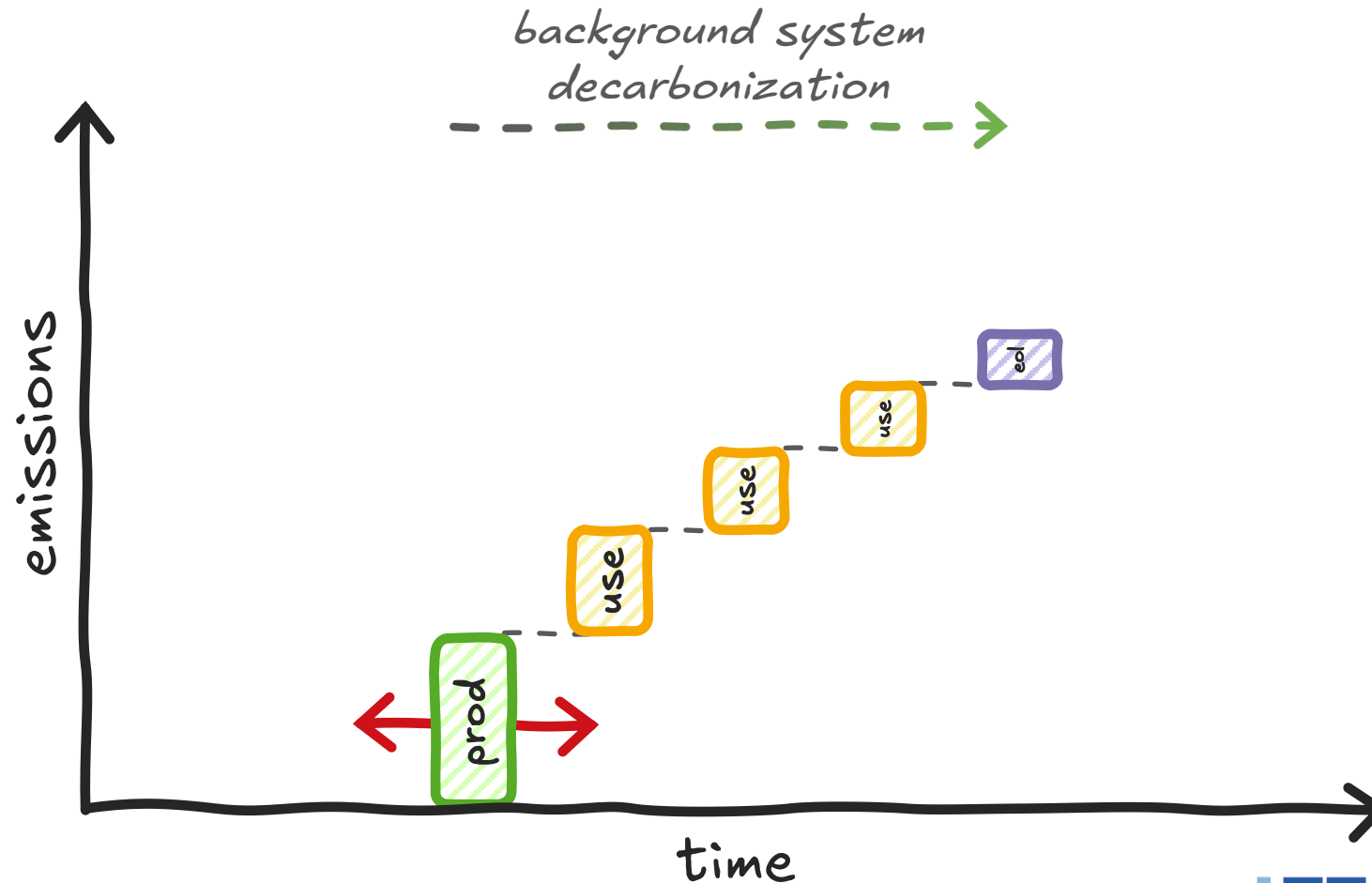
Processes are Temporally Distributed



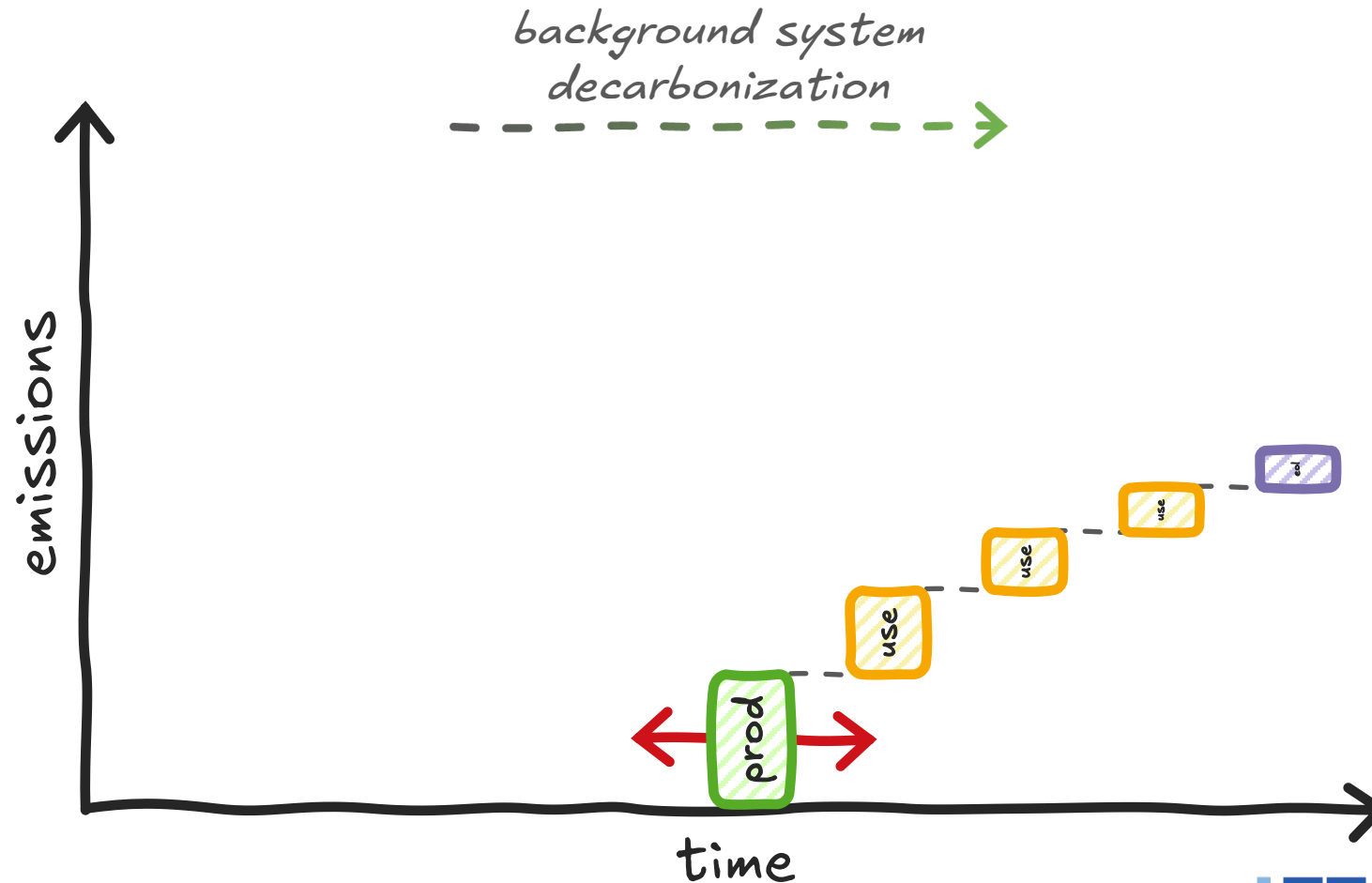
Processes are Temporally Distributed & Evolve over Time



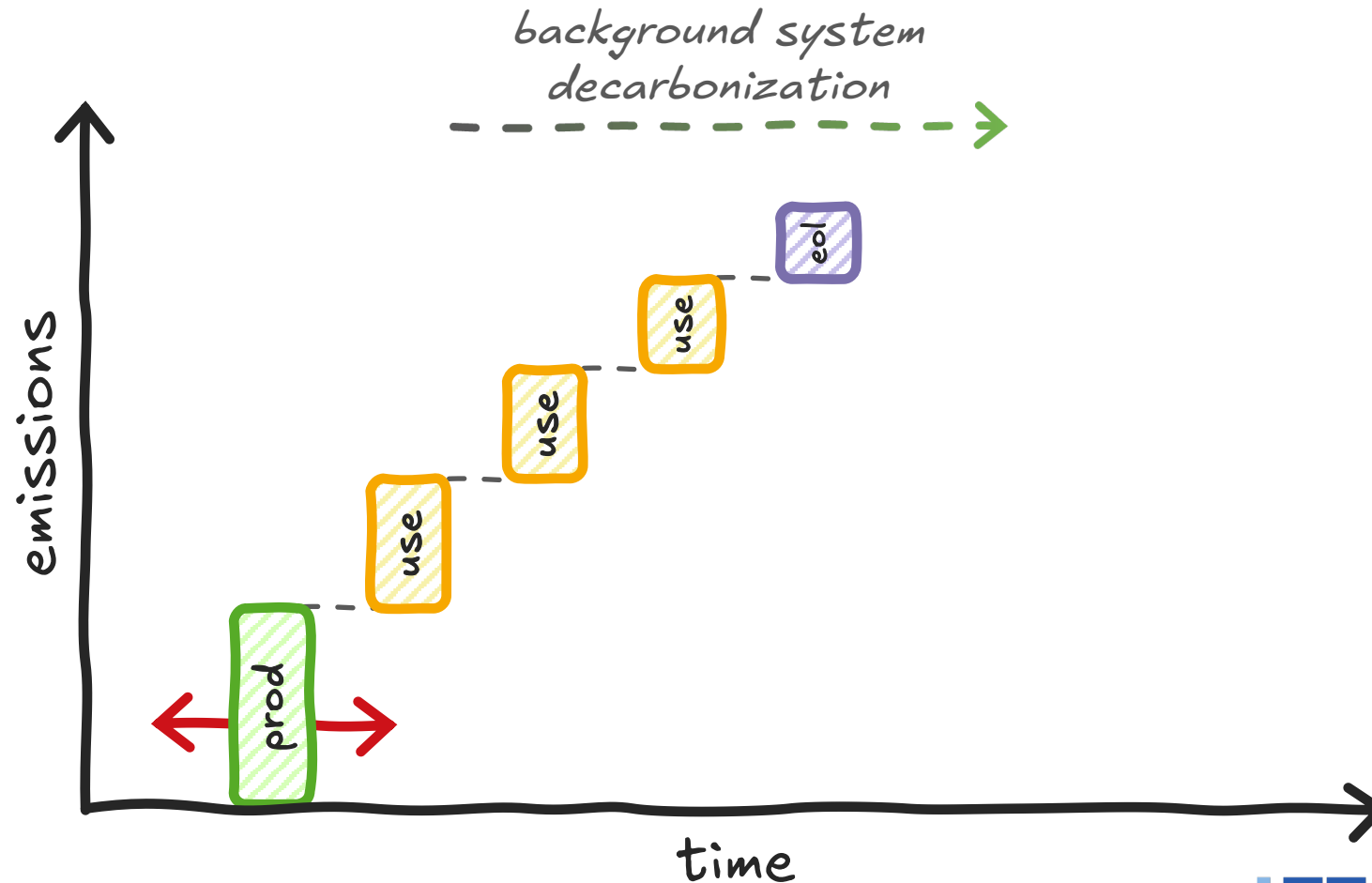
Distributed & Evolving Processes in Transition Pathways

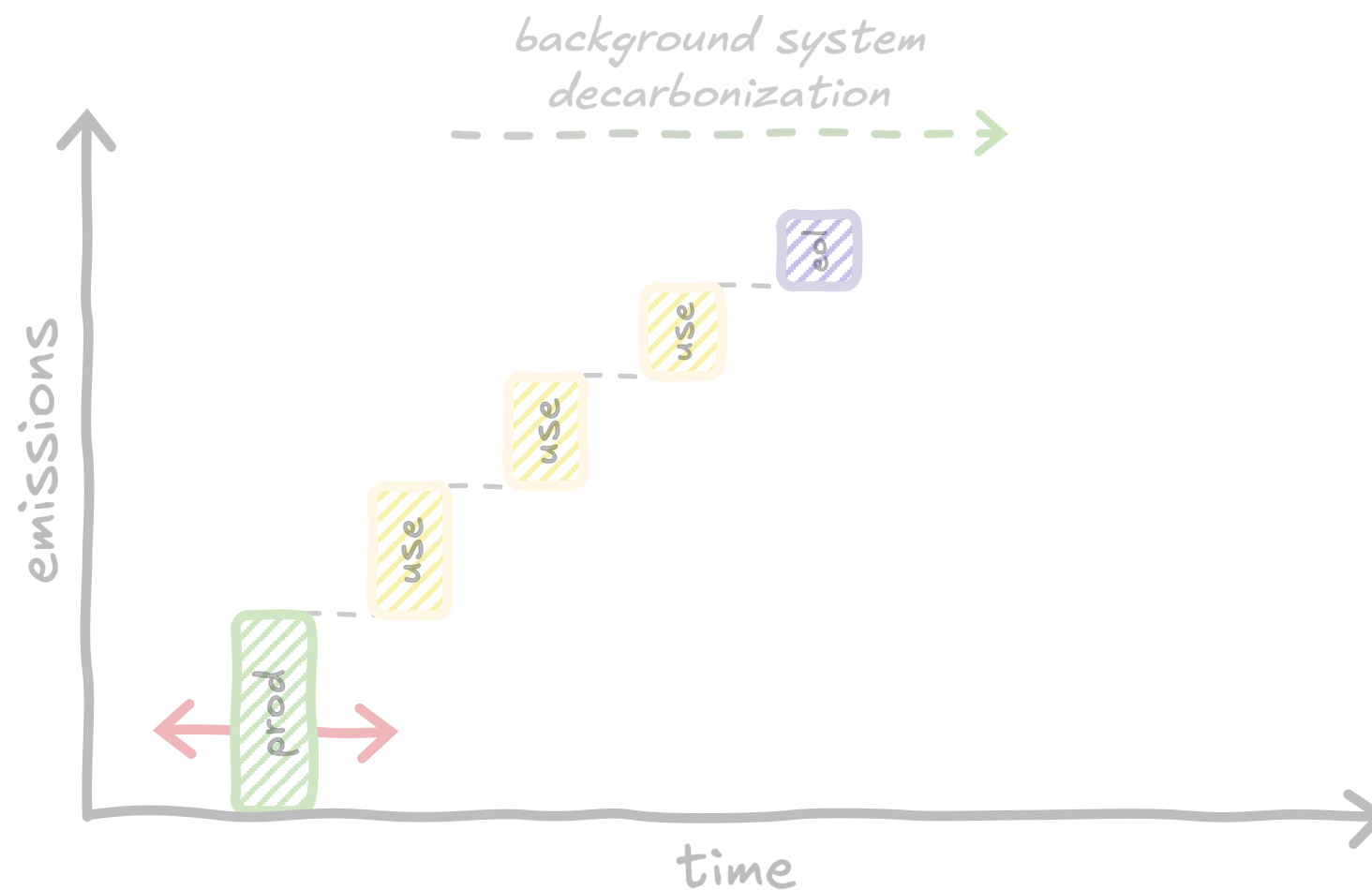


Distributed & Evolving Processes in Transition Pathways

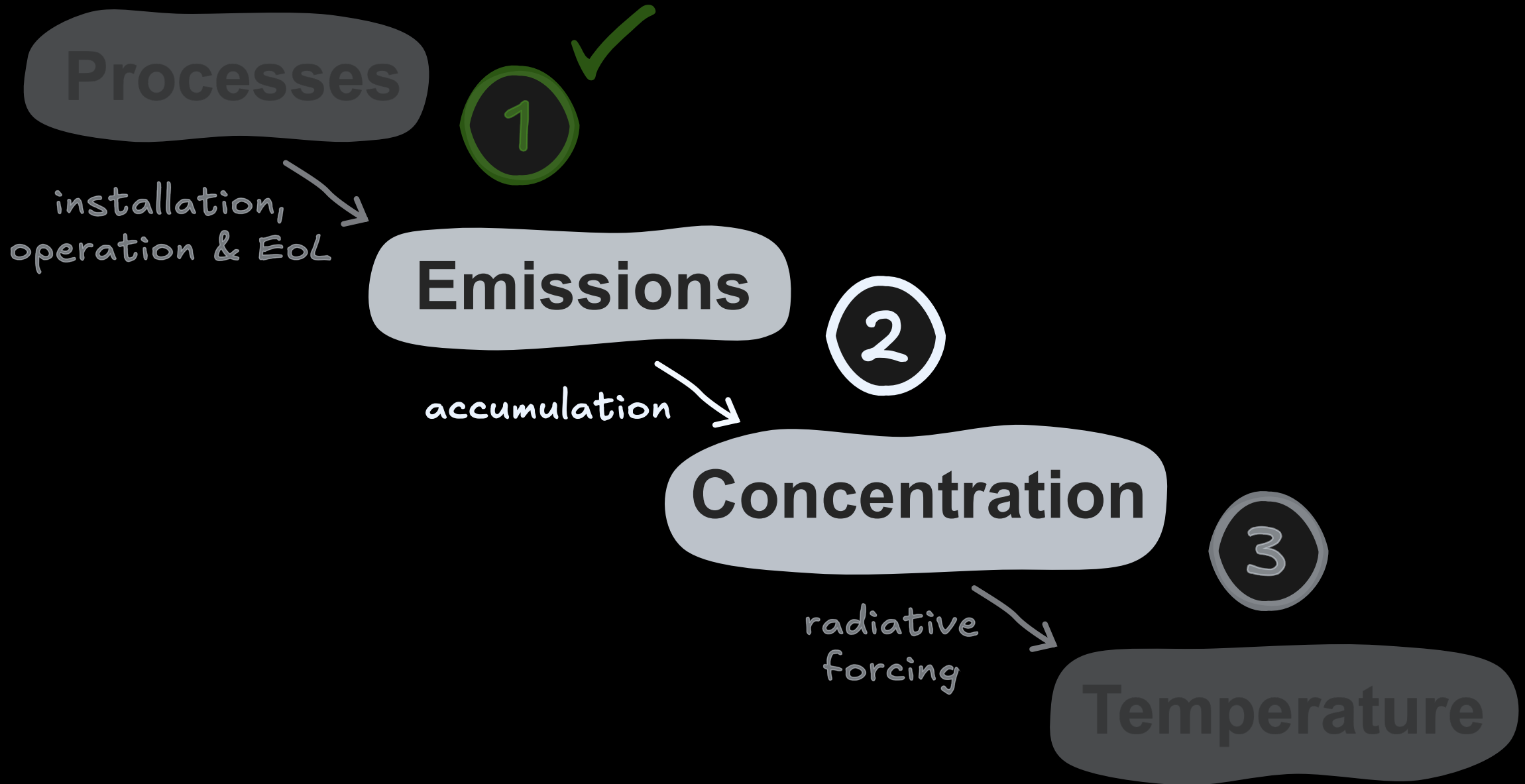


Distributed & Evolving Processes in Transition Pathways





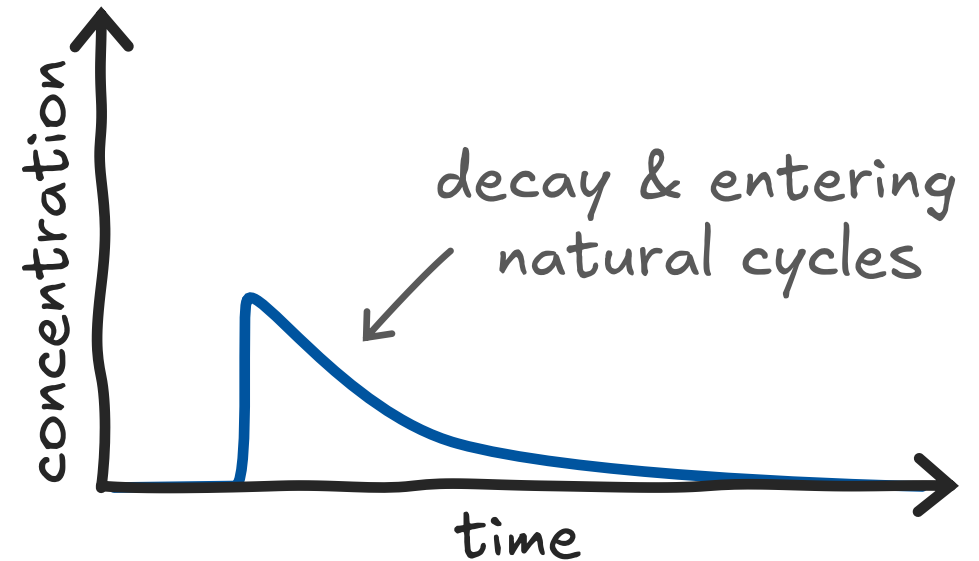
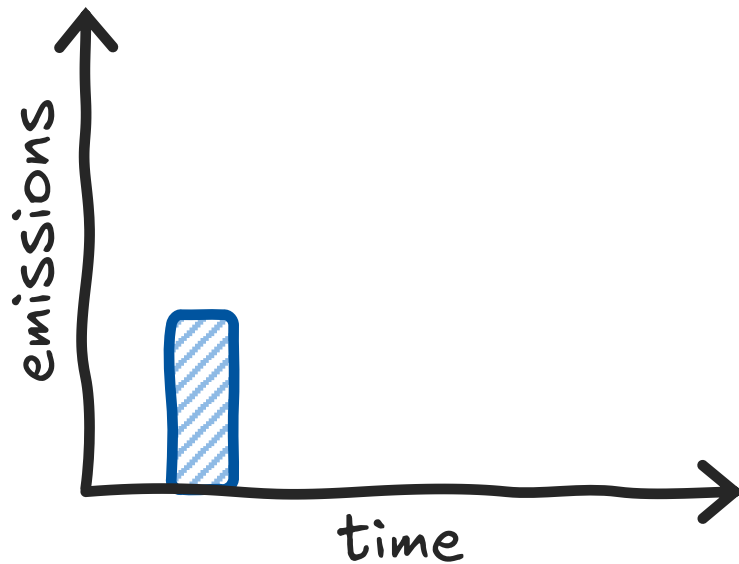
emissions = f (amount & timing of processes)

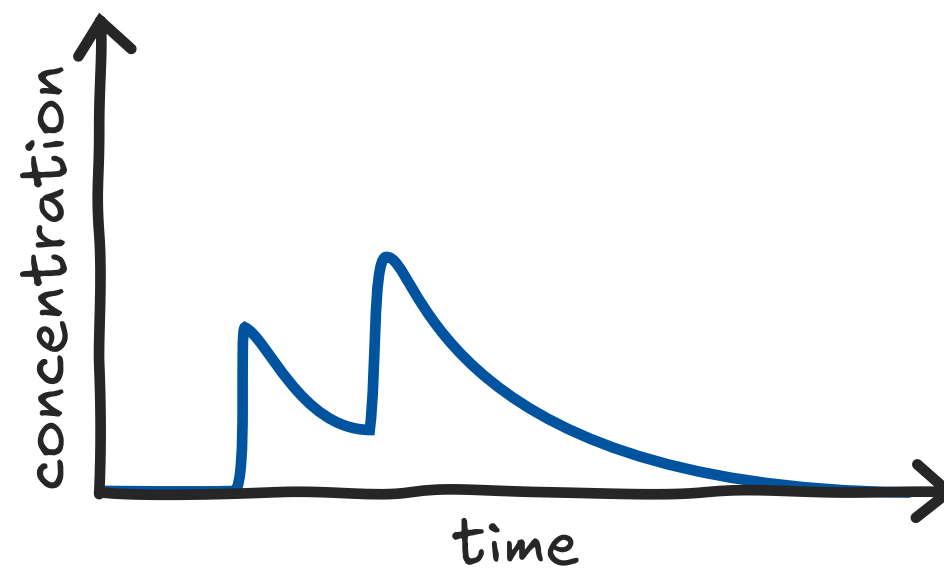
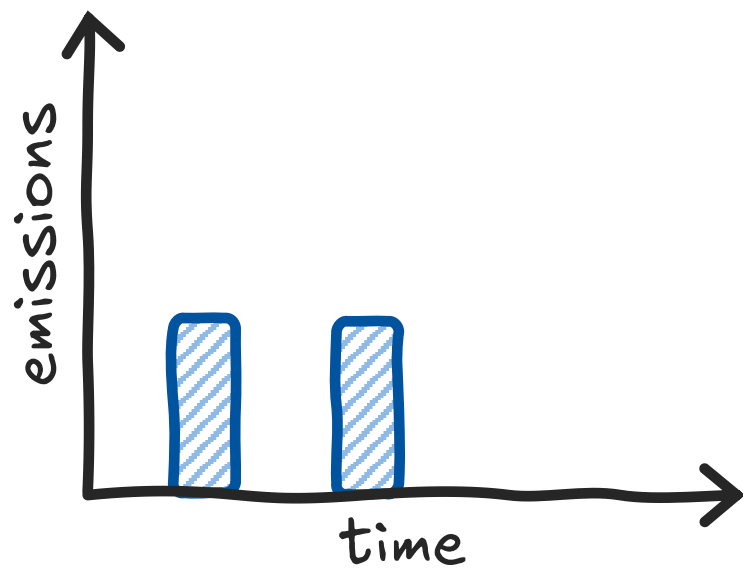
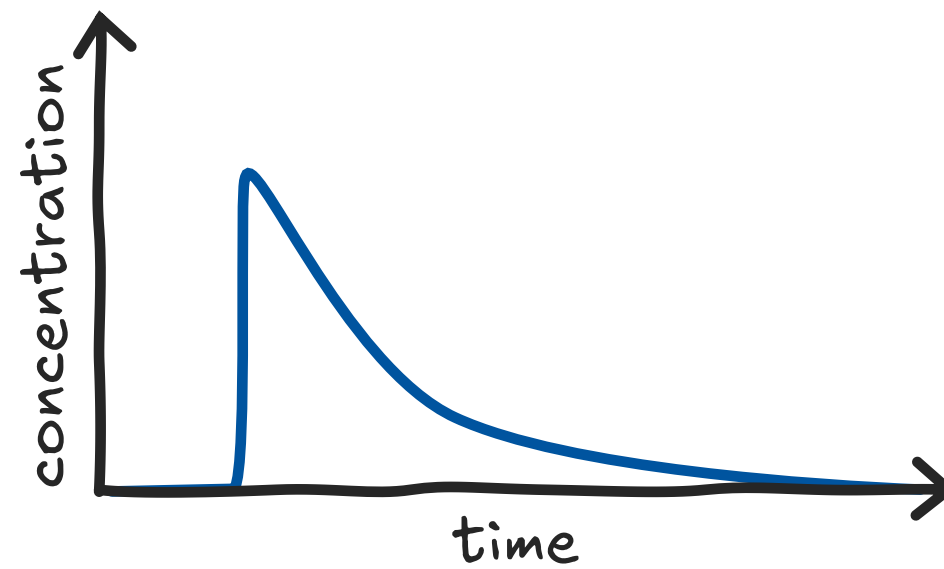
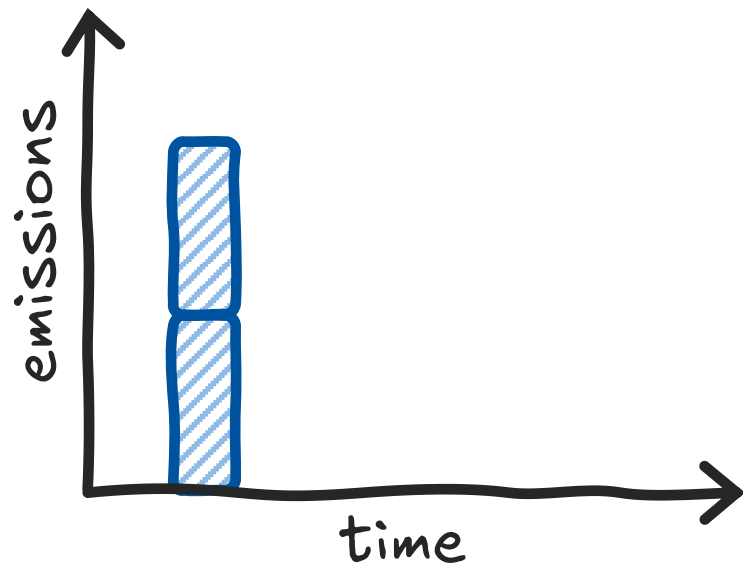


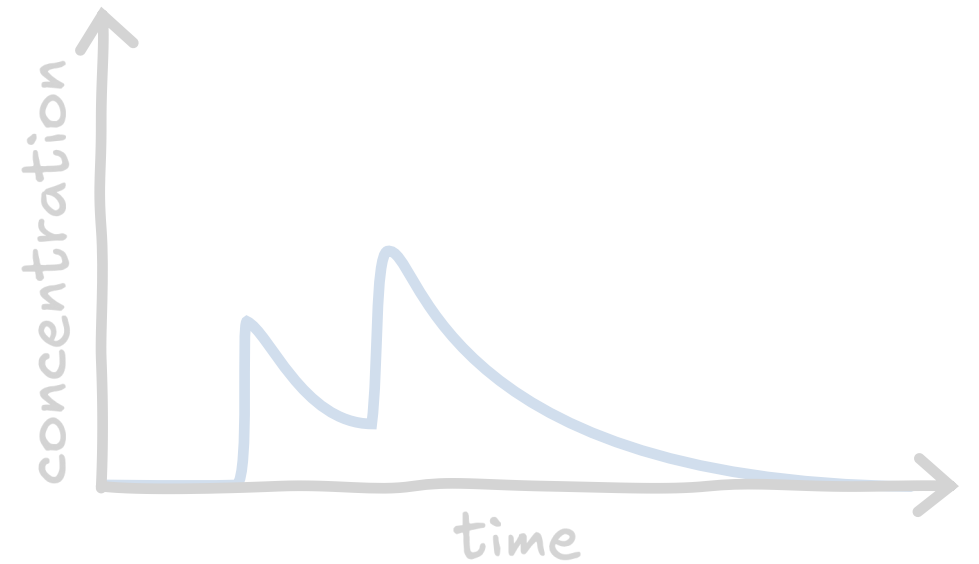
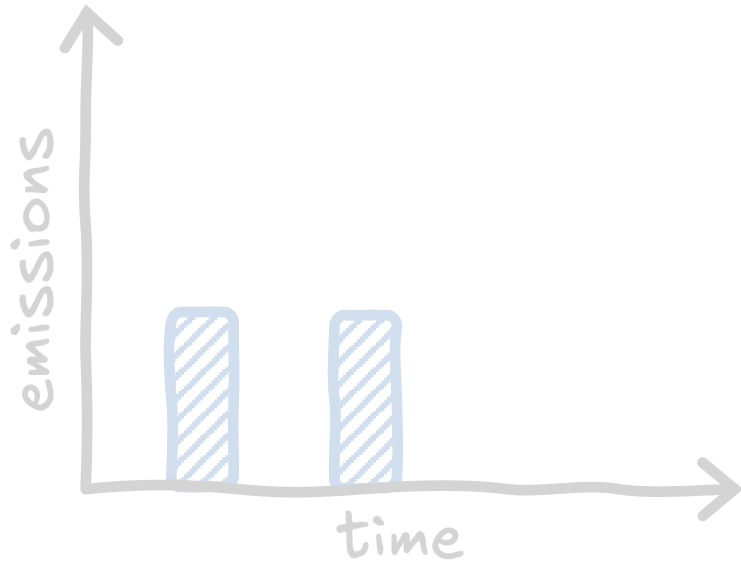
Emissions

accumulation

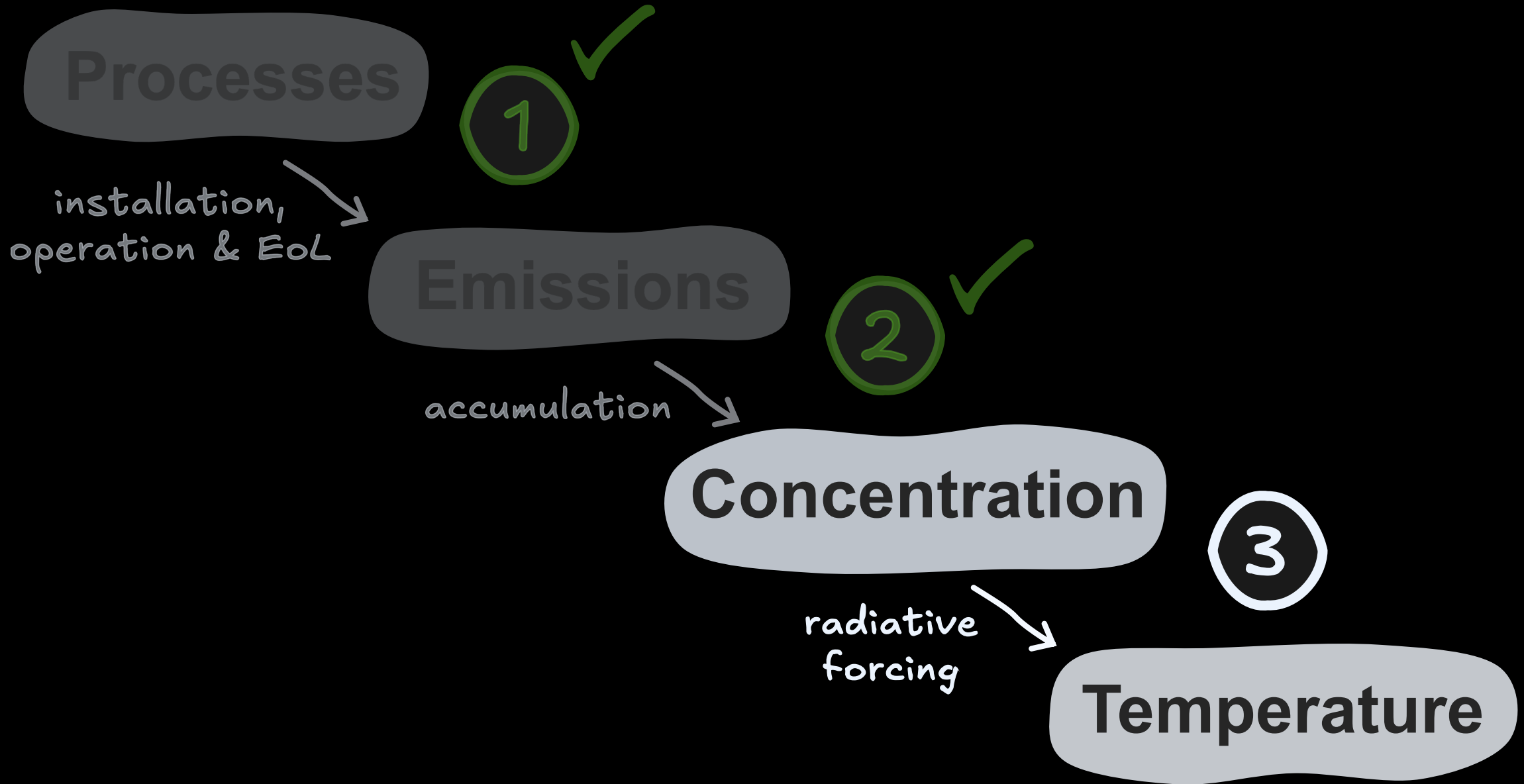
Concentration







concentration = f (amount & timing of emissions)

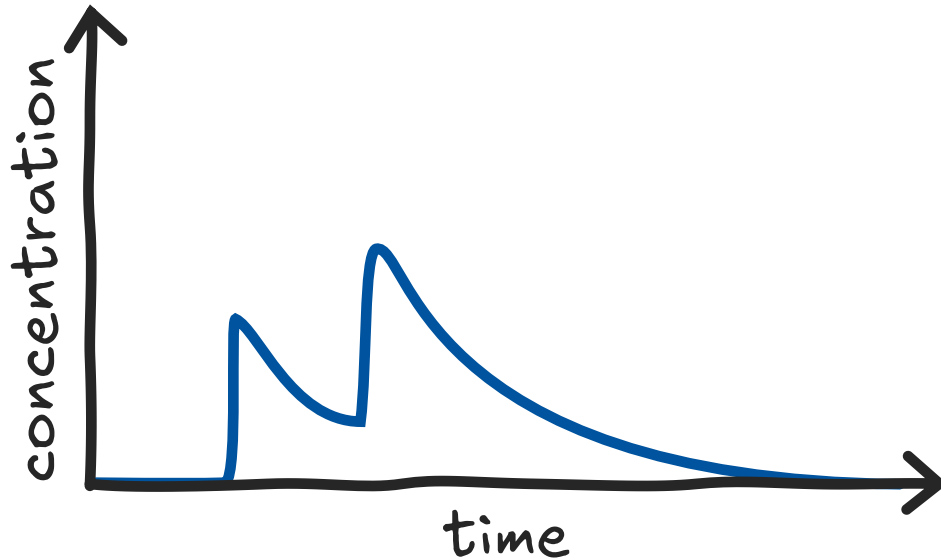


Concentration

radiative
forcing



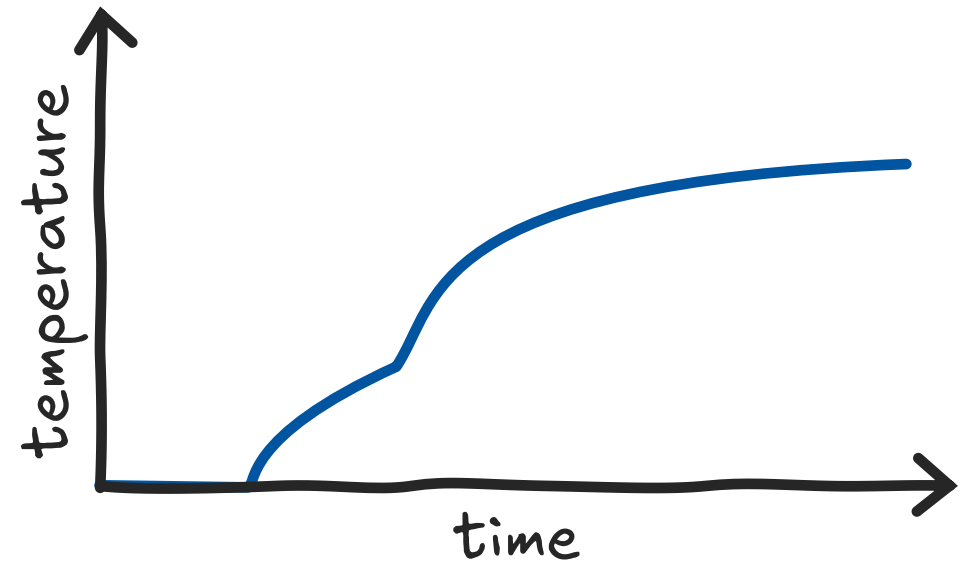
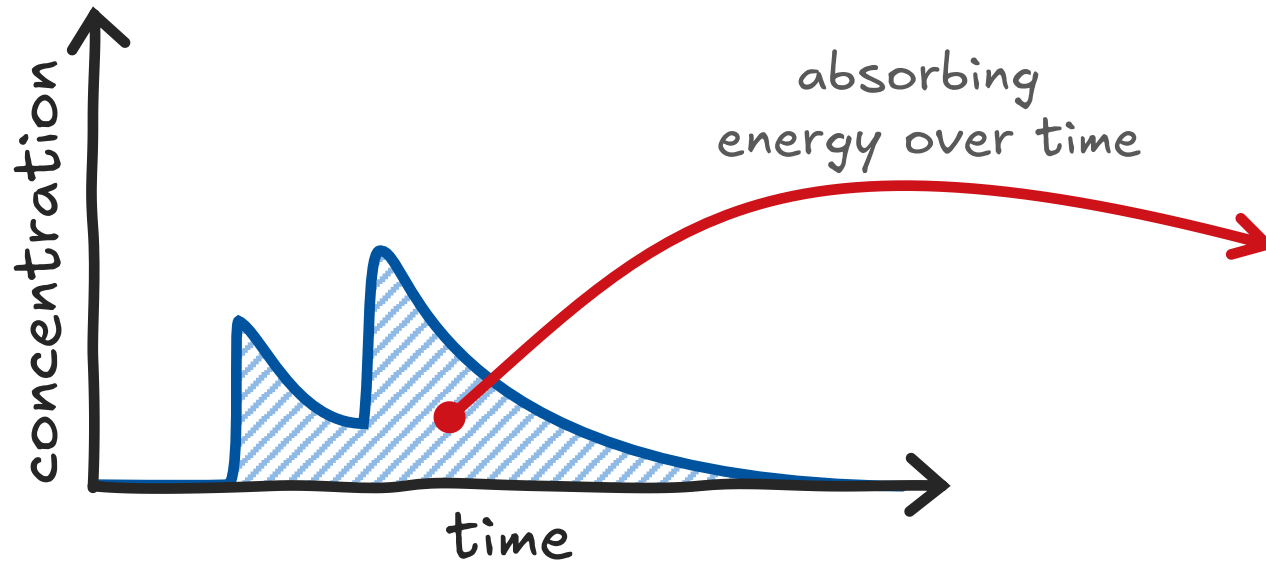
Temperature

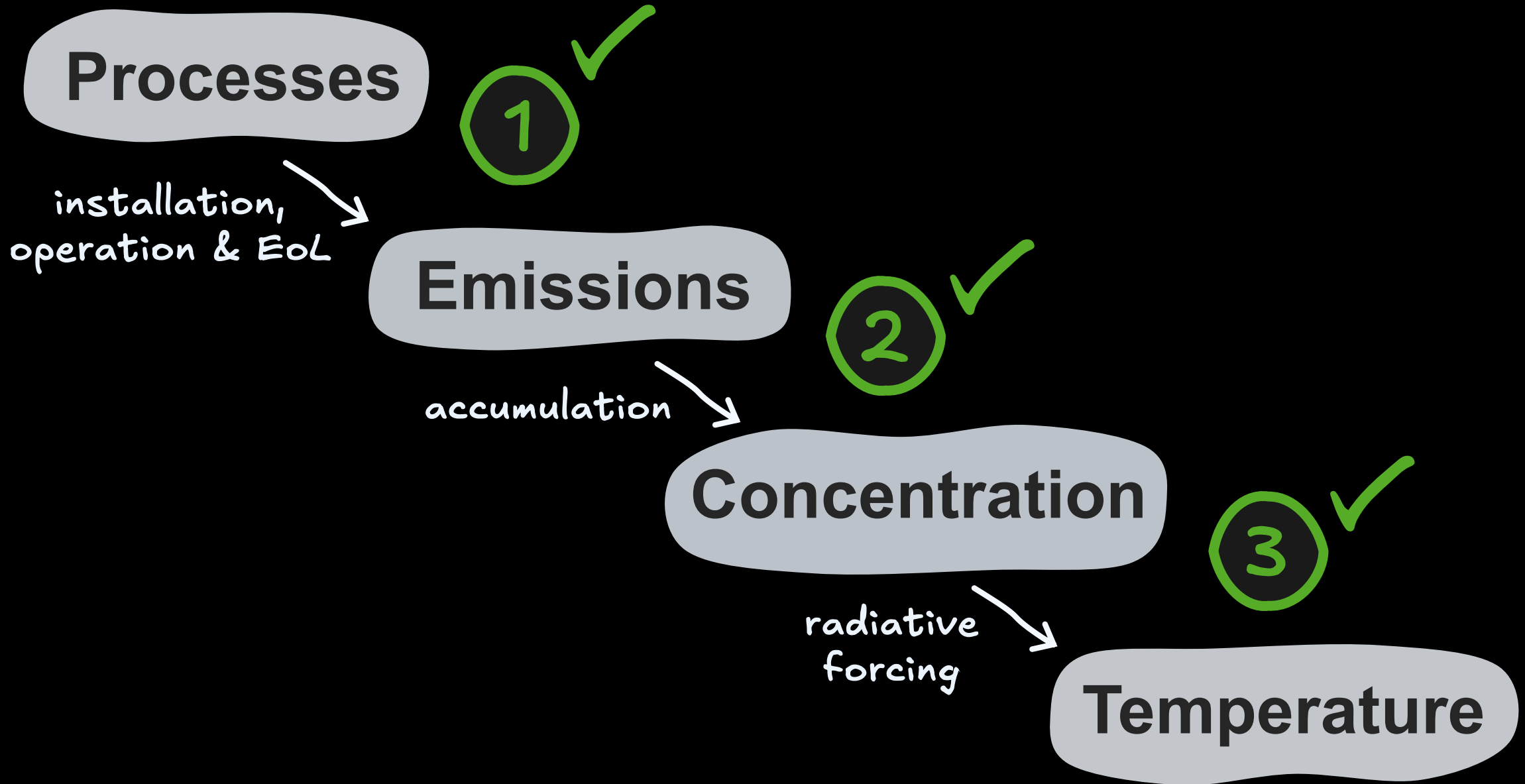


Concentration

radiative
forcing

Temperature





Finding the Optimal Transition Pathway

when to deploy how much of what,
considering:

①

process
distribution
& evolution

②

emission
timing &
accumulation

③

time-
dependent
impacts

Time-Explicit Transition Pathway Optimization

objective ↙
minimize (overall) impacts
s.t. production = demand
↗ *constraint*

Time-Explicit Transition Pathway Optimization

↳ Building on top of Matrix-based LCA

$$^{[1]} \text{minimize } Q \cdot B \cdot s$$

$$\text{s.t. } A \cdot s = f$$

Time-Explicit Transition Pathway Optimization

$$\begin{aligned} &^{[1]} \text{minimize } Q \cdot B \cdot s \\ &\text{s.t. } A \cdot s = f \end{aligned}$$

Idea: adding time as an explicit dimension

1D vectors $\rightarrow$ 2D matrices
2D matrices $\rightarrow$ 3D tensors

$$\begin{aligned} &\text{minimize } \sum_t Q_t \cdot B_t \cdot s_t \\ &\text{s.t. } A_t \cdot s_t = f_t \quad \forall t \end{aligned}$$



built on brightway + pyomo

inputs:

product system
model

process-relative
temporal
distributions

time-specific
databases

objective

demand



optimes

construct
time-explicit
tensors



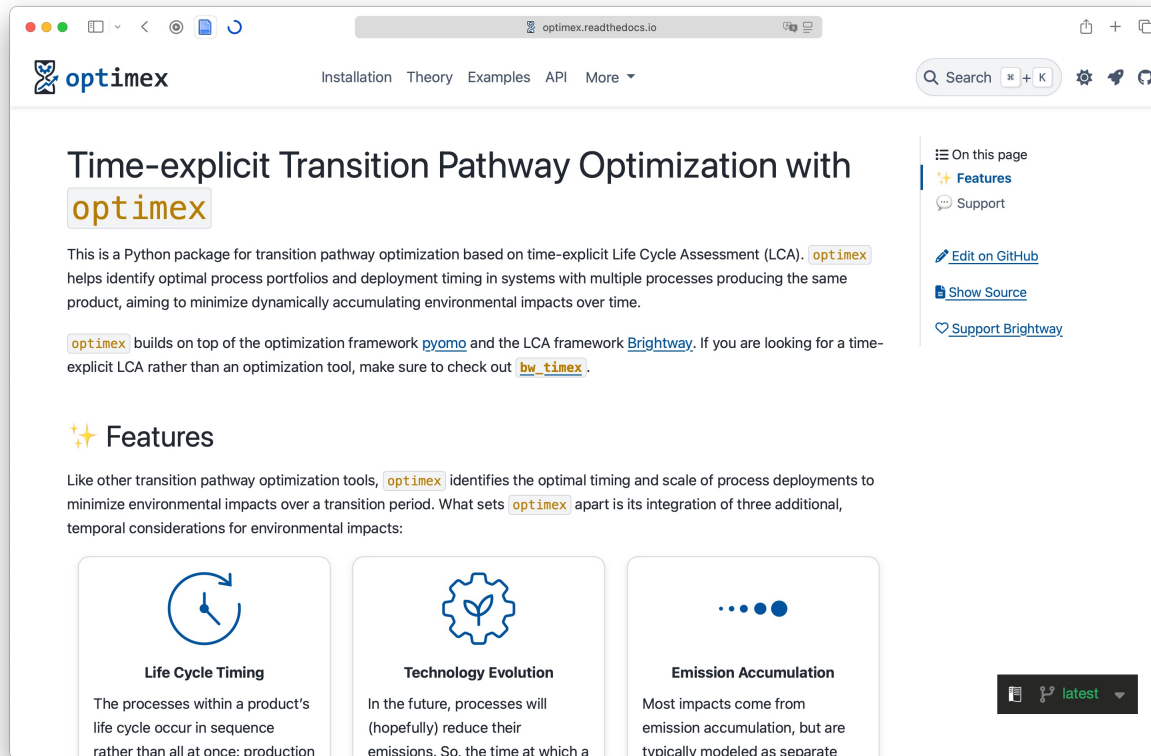
formulate
optimization
problem



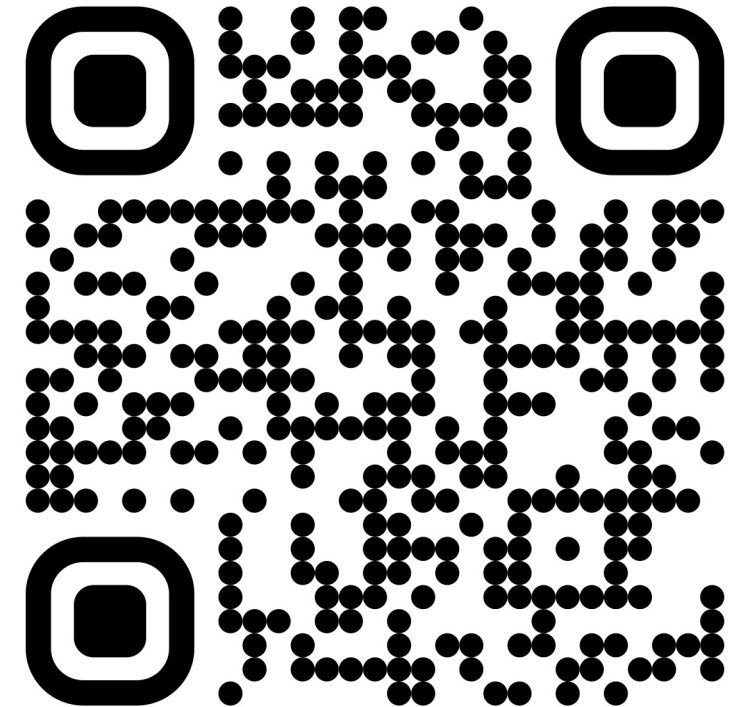
optimal
transition
pathway

additional
constraints

Our new python package



- open source & user friendly
- extensive documentation & examples



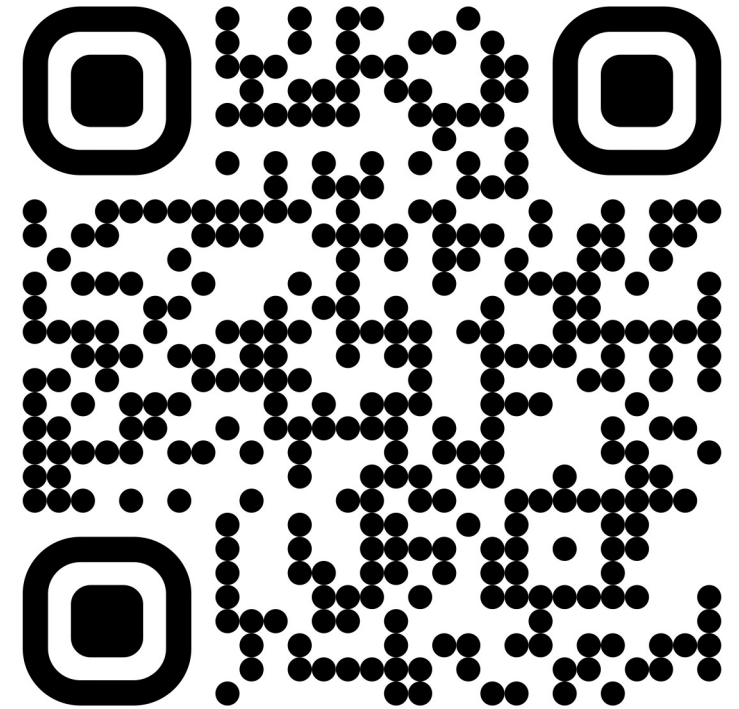
<https://optimex.readthedocs.io/>

Our new python package

optimex particularly shines, if...

- processes heavily **depend on evolving sectors** (e.g., power-to-x technologies)
- processes operate on **different time scales** (e.g., using short vs. long rotation biomass)
- **timing of emission** matters (e.g., landfill activities, or direct air carbon capture vs. biogenic uptake)
- cumulative **impact boundaries** must be kept (e.g., global warming $< 2^{\circ}\text{C}$, resource extraction, ...)

~ thanks for listening ✨



<https://optimex.readthedocs.io/>