

The handling of uncertainties in ex-ante LCA: a complement to scenario analysis

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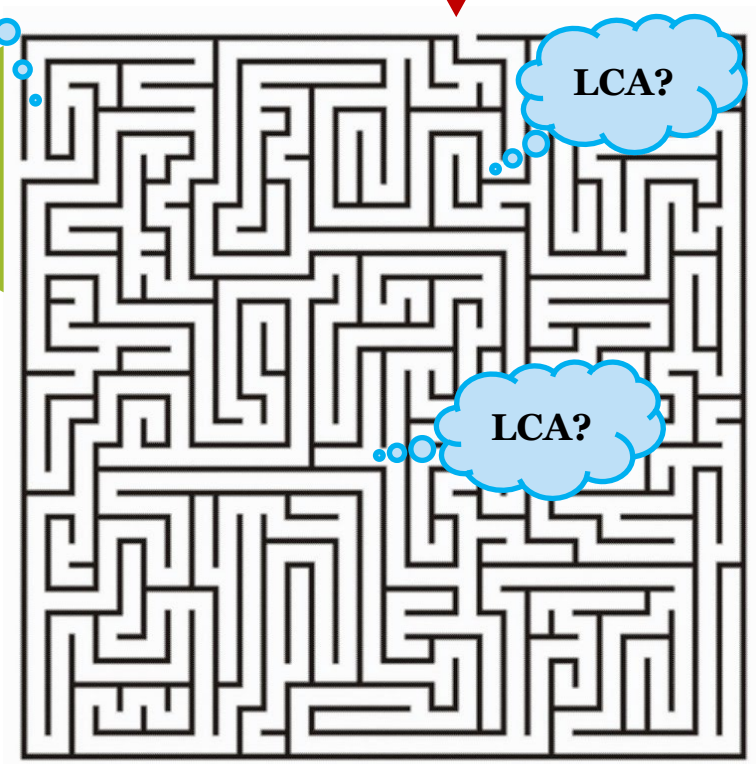
The R&D journey



Designing the future

Uncertain flow quantities

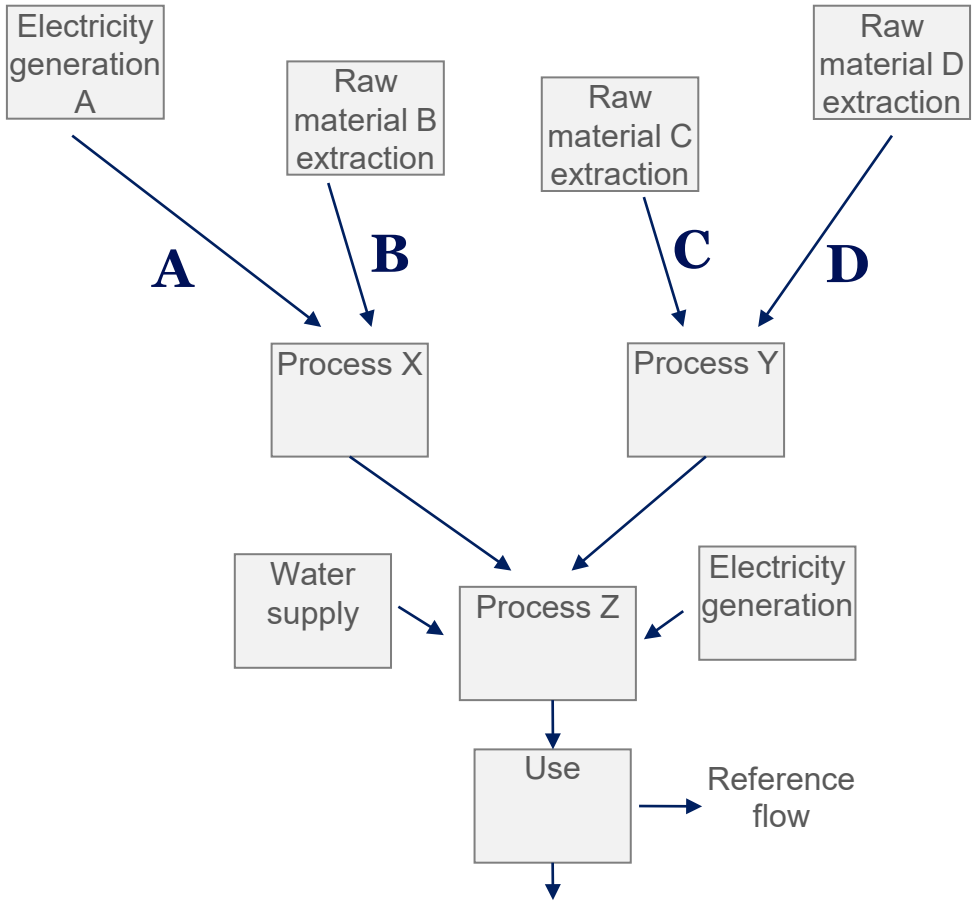
Uncertain processes: competing technical & economic alternatives

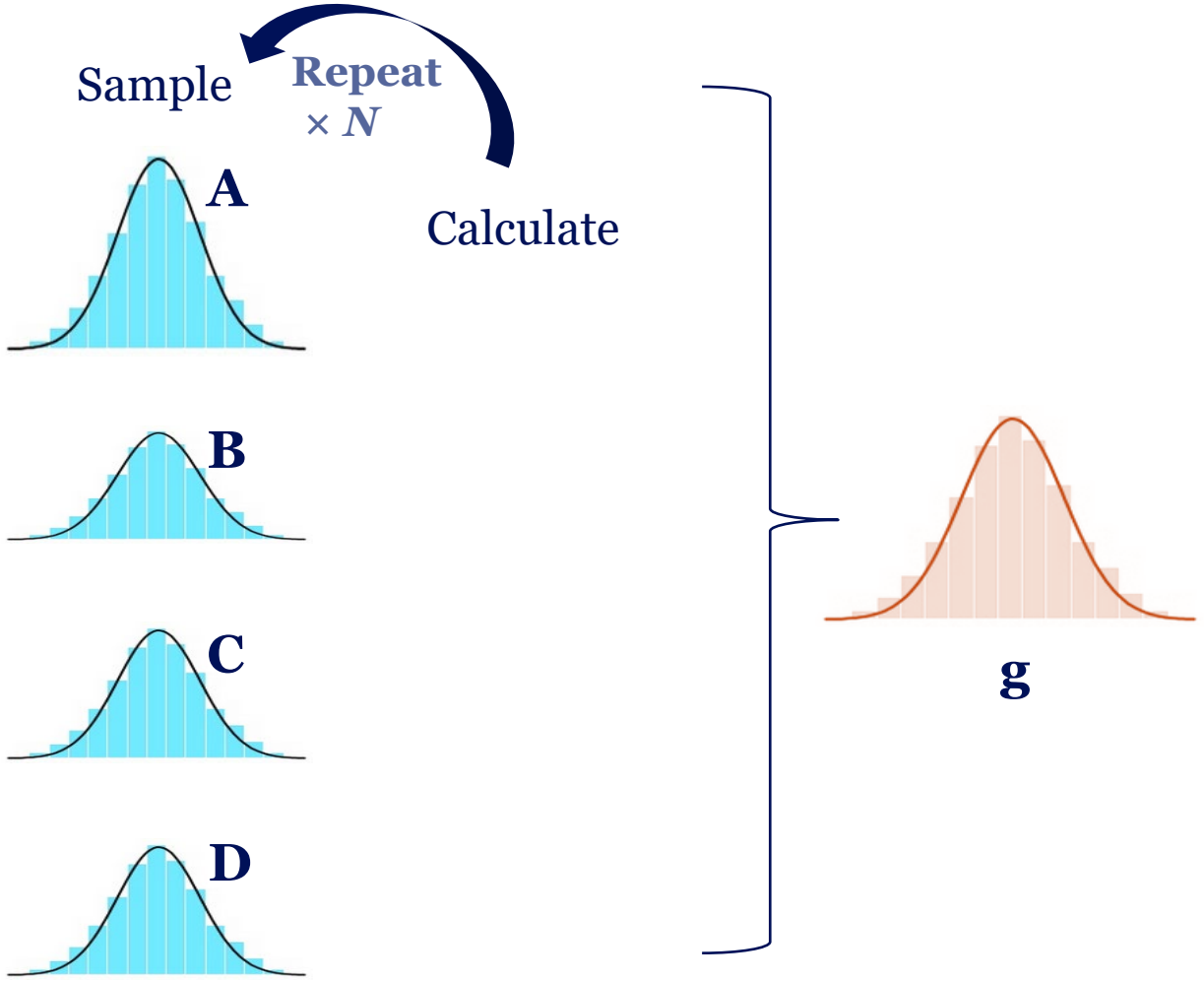
Uncertain scenarios: external factors

Uncertain processes: sustainable choices

Uncertain flow quantities

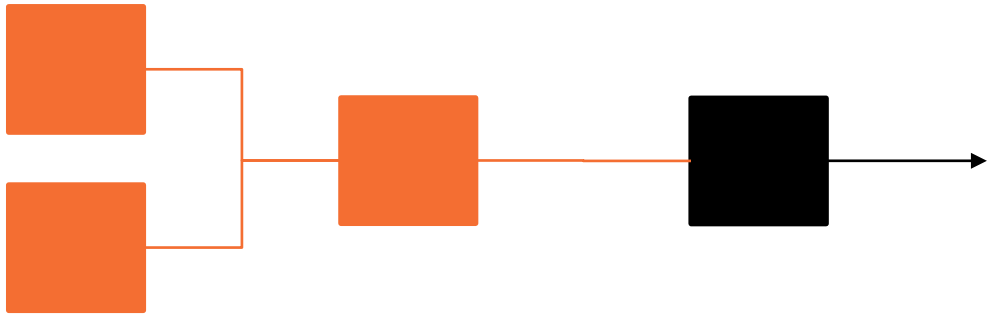
- How much fuel will it consumed per km?

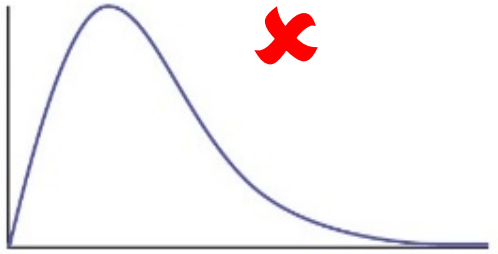




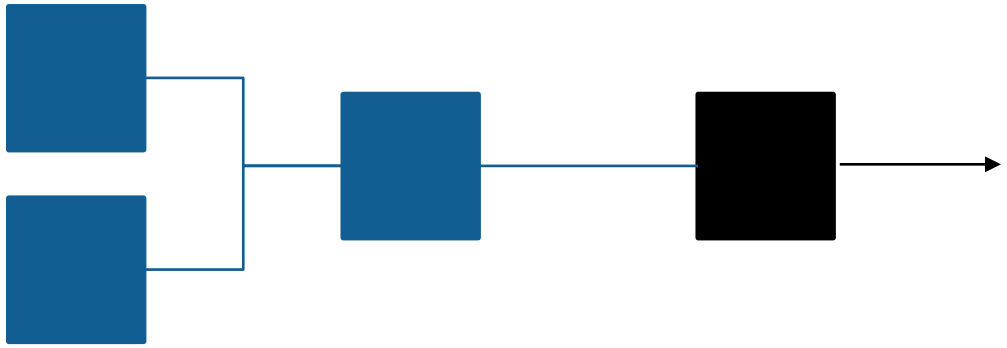
Sustainable design choices

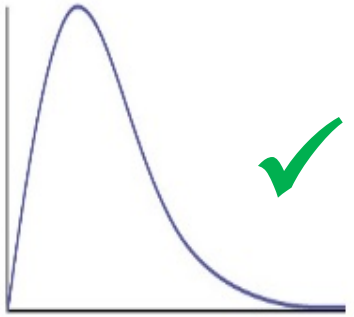
- Should we use leather or recycled textile for the upholstery?





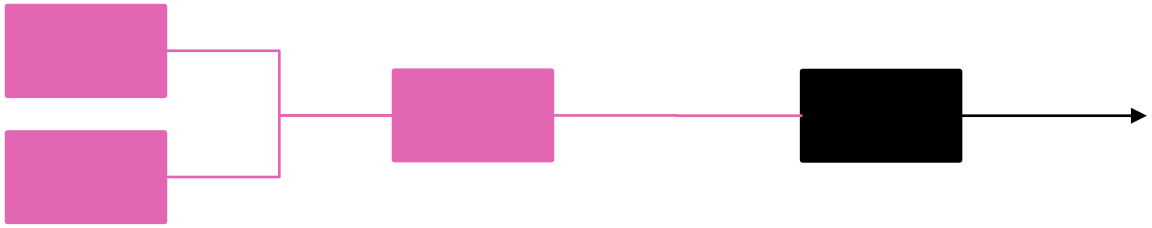
vs.





External factors

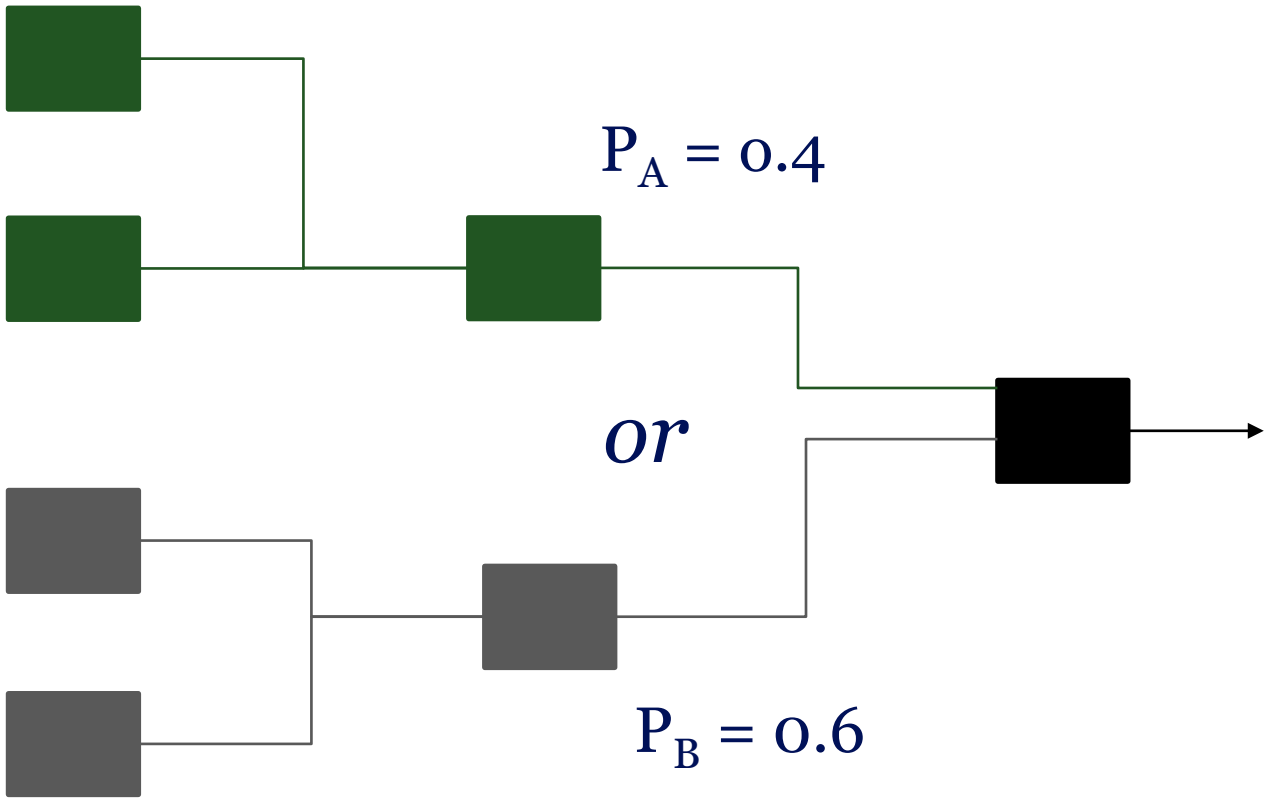
- Will future regulations forbid the use of plutonium fuel?



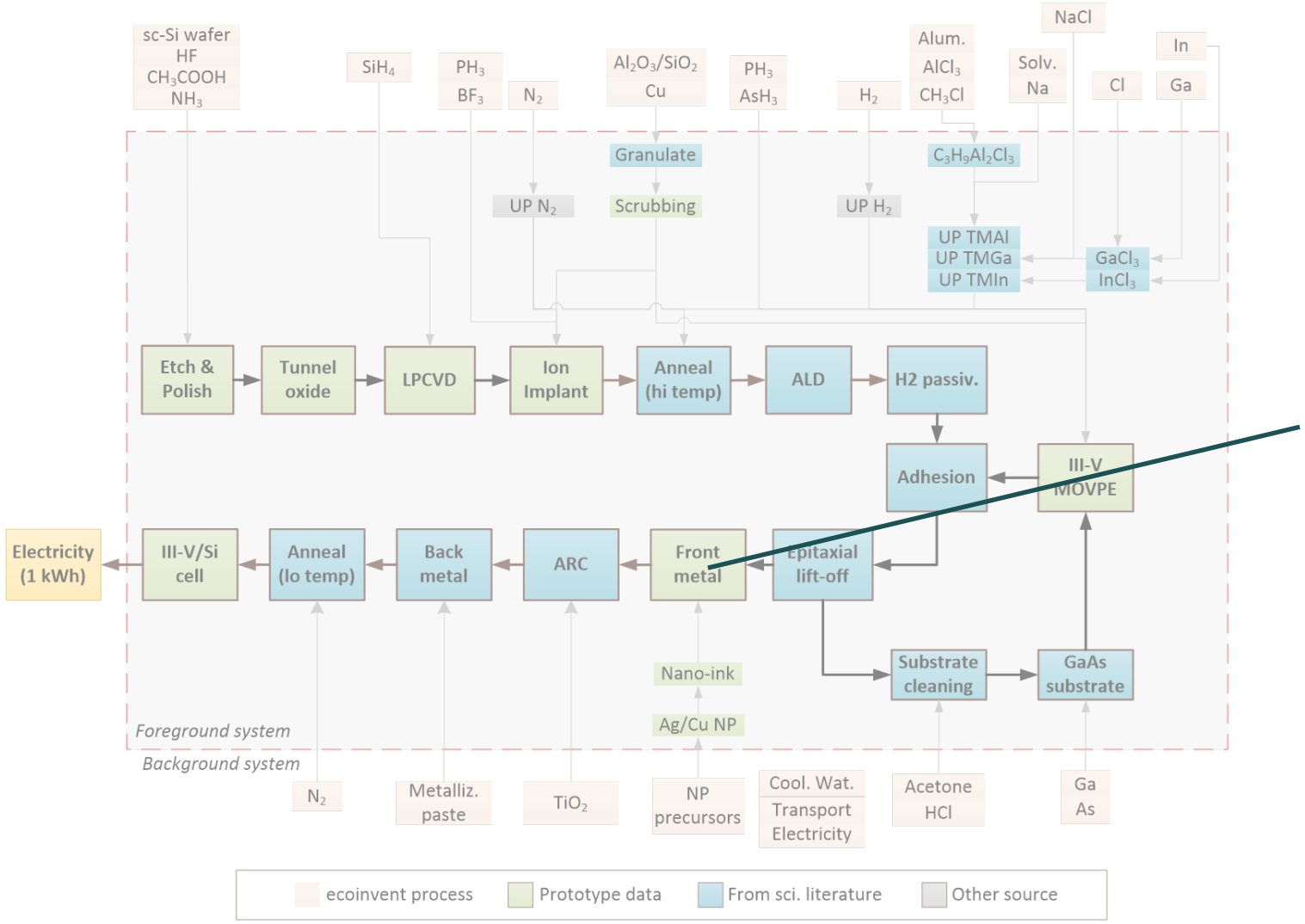
or

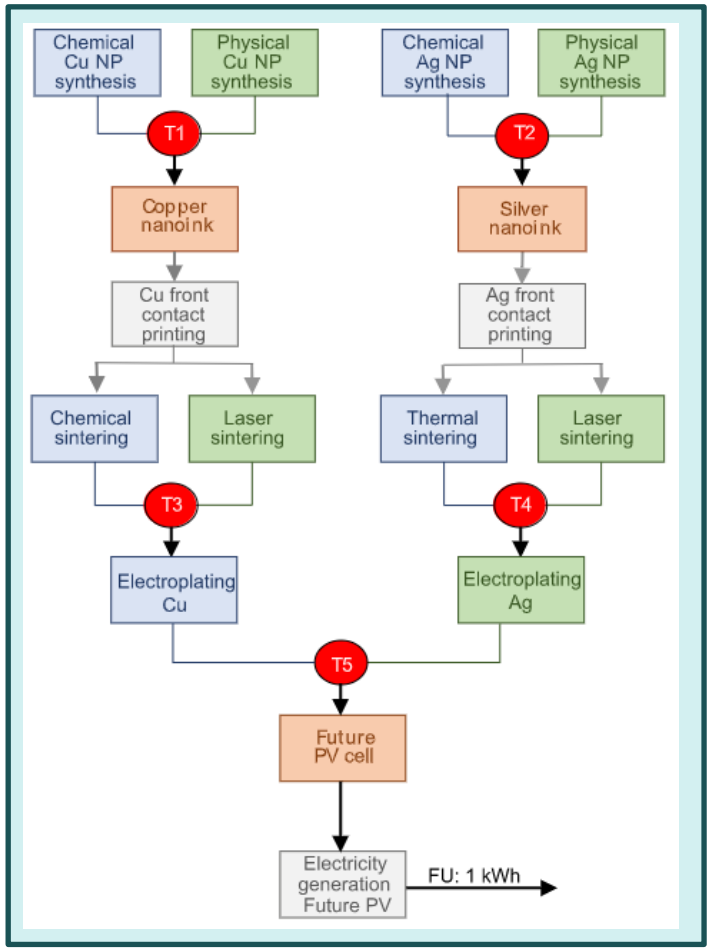
Competing technical & economic alternatives

- Will we meet the durability and cost targets with a steel or aluminium alloy chassis?

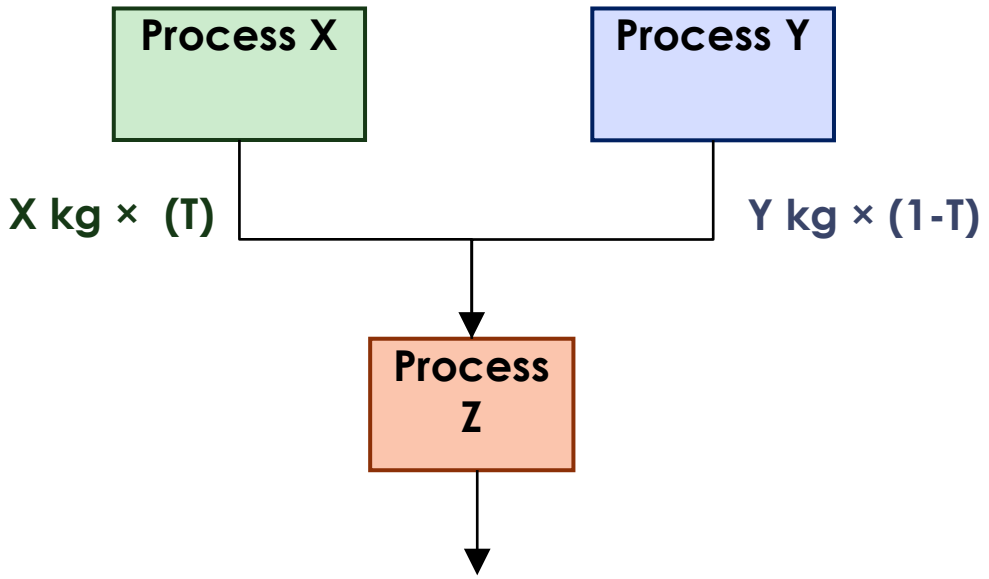


Case study: advanced solar PV





Modeling unresolved technical & economic alternatives in LCA

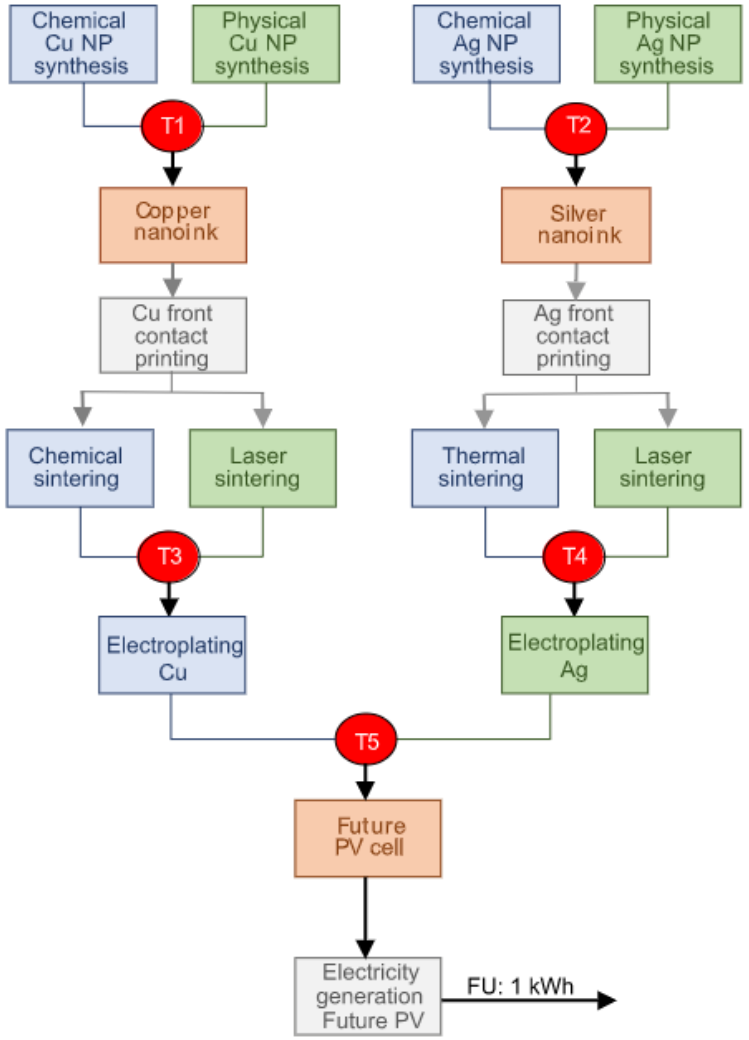


$$T \sim bin(n=1, \pi)$$

where:

π = *probability of success of process X over process Y*

Case study: advanced solar PV



T	Process	Dist. type	Uncertainty parameters	Description
T1	Synthesis method for Cu nanoparticles	Triangular	Min: 0.5 Mode: 0.7 Max: 0.8	Chemical methods provide more control over particle size and shape, which may ultimately be more important for the nanoink.
T2	Synthesis method for Ag nanoparticles	Triangular	Min: 0.2 Mode: 0.3 Max: 0.4	Chemical methods provide more control over particle size and shape, which may ultimately be more important for the nanoink.
T5	Metallic nanoink used for printing of front contacts	Triangular	Min: 0.1 Mode: 0.2 Max: 0.3	Based on preliminary tests for technical feasibility, copper-based nanoink seemed “more promising”, while silver-based nanoink was not yet completely discarded.

Case study: advanced solar PV

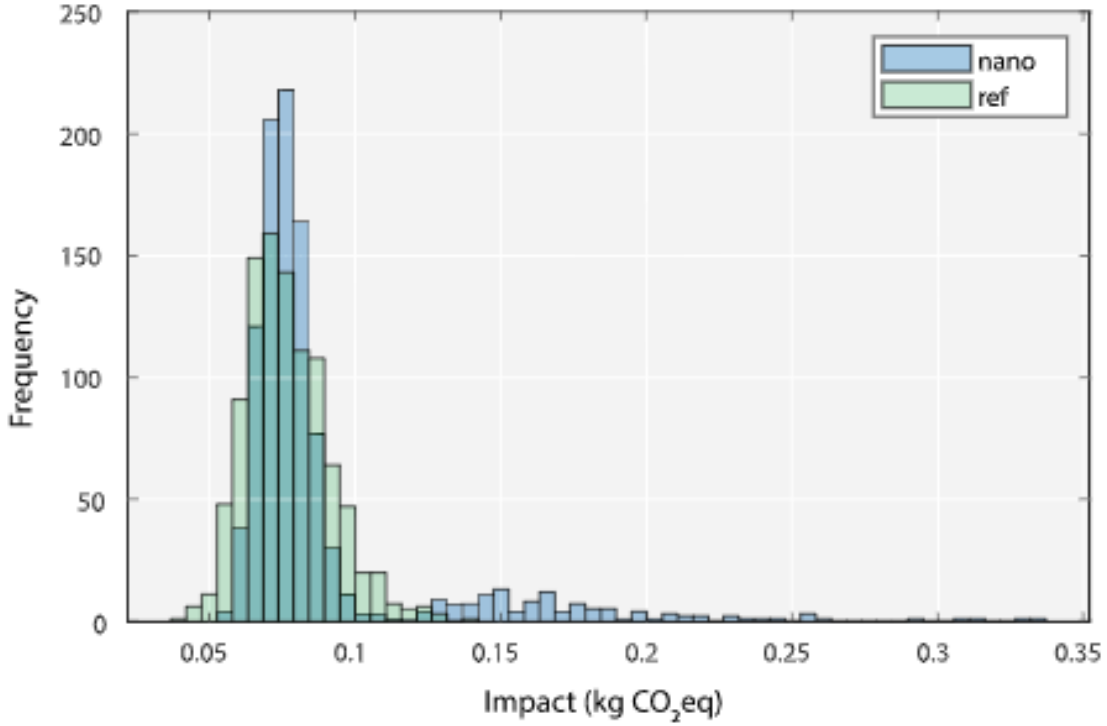
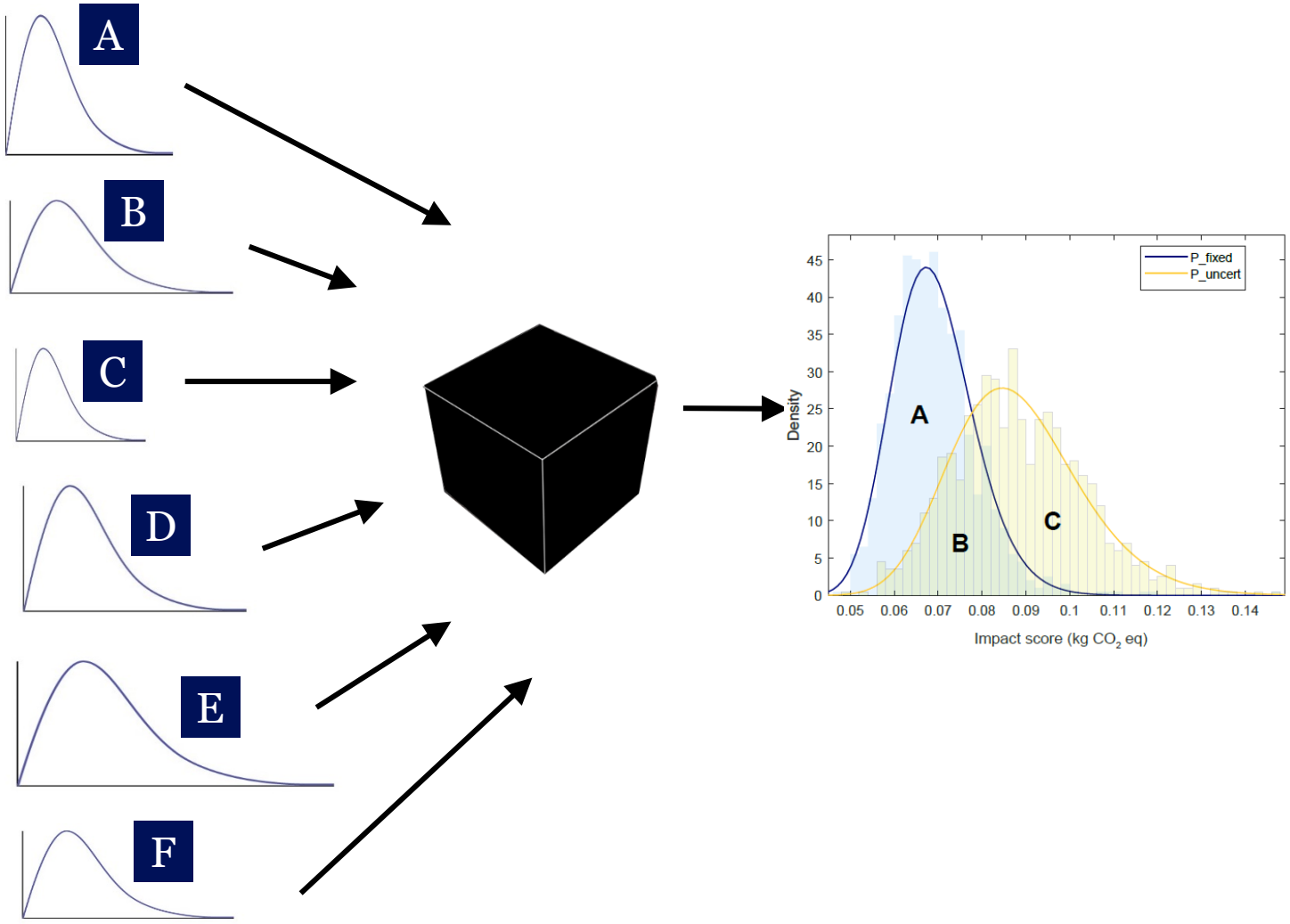


Fig. 3. Comparison of climate change impacts of a PV system with nanoink-printed cells (nano) and a conventional screen-printed cells (ref).

Global sensitivity analysis



Ranking by *Borgonovo* delta index ➔ curve shift

1. Parameter C
2. Parameter A
3. Parameter F
4. Parameter B
5. Parameter D
6. Parameter E

....

Global sensitivity analysis

Table 4
Delta sensitivity measure estimates for the climate change impacts of the PV system with nanoink printed front contacts.

Uncertain input parameter	δ est.	Rank
π1: Chance of success of T1	0.01	10
π2: Chance of success of T2	0.00	6
π3: Chance of success of T3	0.02	5
π4: Chance of success of T4	0.02	4
π5: Chance of success of T5	0.02	9
T1: Chem. vs. phys. synthesis of Cu nanoparticles	0.00	12
T2: Chem. vs. phys. synthesis of Ag nanoparticles	0.01	11
T3: Chem. Vs. laser sintering: Cu ink	0.20	1
T4: Thermal vs. laser sintering: Ag ink	0.01	13
T5: Cu vs. Ag printed front contacts	0.10	2
Qty. of gas mix required for Cu nanoink sintering	0.04	3
Qty. of solution required for electroplating	0.01	7
Cell conversion efficiency increase	0.01	8

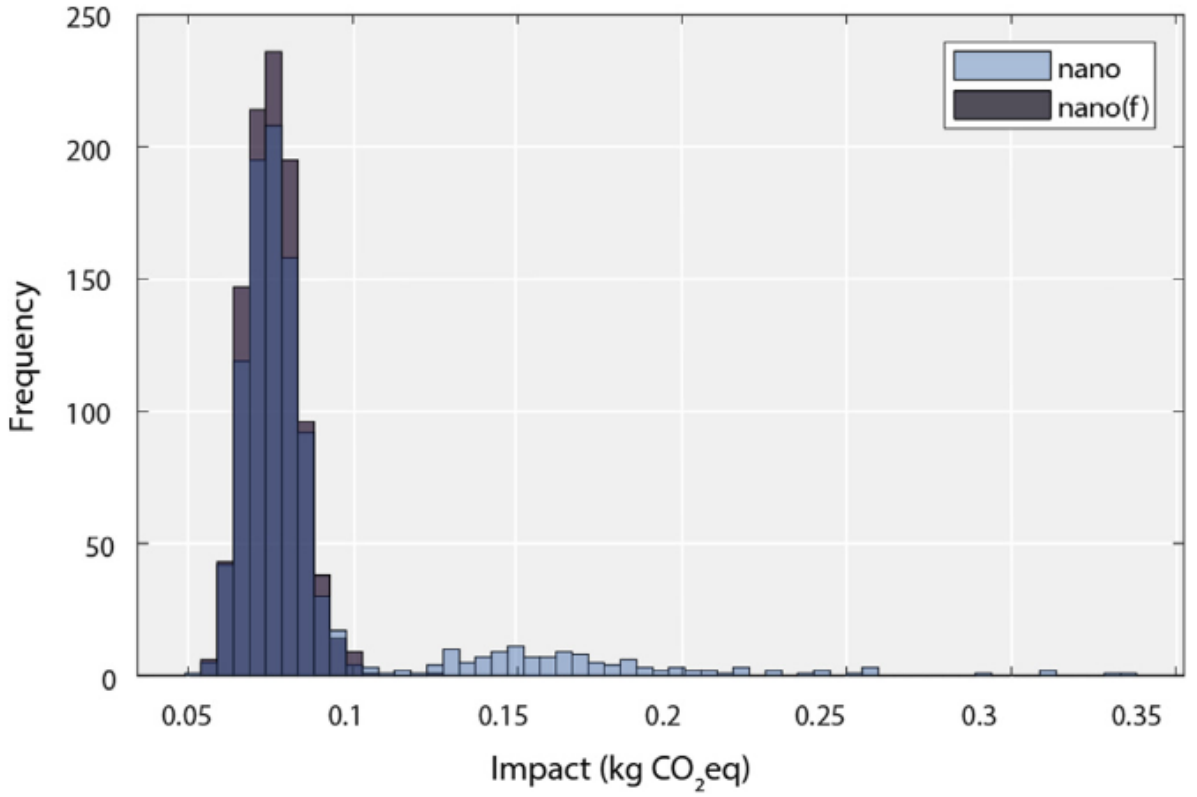


Fig. 5. Comparison of climate change impacts of a PV system with nanoink-printed cells with both laser and chemical sintering alternatives for copper nanoink (nano) and with only laser sintering alternative for copper nanoink (nano(f)).

What can we say?

- Likelihood of outperforming the incumbent technology, considering all types of uncertainty
  - Inform decisions to continue funding

- Identify most sensitive parameters
  - Are future technical / economic choices relevant for impact score?
  - If no: keep going!
  - If yes:
    - Avoid (foreground)
    - influence (background)
    - or investigate further to reduce uncertainty!

A *blurry* future is a good future

Acknowledgement

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Assessing the sustainability of emerging technologies: A probabilistic LCA method applied to advanced photovoltaics

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Eliciting expert knowledge

- In the October 2017 Symposium on Statistical Inference, organized and sponsored by the American Statistical Association, a position article by the participants presented their view that:

  > *We must accept that there is subjectivity in every stage of scientific inquiry, but objectivity is nevertheless the fundamental goal. Therefore, we should base judgments on evidence and careful reasoning, and seek wherever possible to eliminate potential sources of bias. (Brownstein et al. 2018)*

- One way in which expert opinion and judgment enters into statistical inference and decision-making is through expert knowledge elicitation. Elicitation in this context is the process of expressing expert knowledge in the form of probability distributions for uncertain quantities. It is increasingly used to quantify uncertainty about parameters in models that are employed across the whole spectrum of human endeavour. In the context of the Symposium on Statistical Inference, we can think of the elicited probability distributions as forming prior distributions for Bayesian statistical inference, or as directly informing decision-making under uncertainty.

O'Hagan(2019).Expert Knowledge Elicitation: Subjective but Scientific, The American Statistician, 73:sup1, 69-81, DOI: 10.1080/00031305.2018.1518265