

# CONSEQUENTIAL MODELLING

## - IN LIFE CYCLE INVENTORY ANALYSIS

**BO P. WEIDEMA & JANNICK SCHMIDT**  
PROFESSORS, AALBORG UNIVERSITY  
SENIOR CONSULTANT & CEO, 2.-0 LCA CONSULTANTS

LATEST UPDATED APRIL 2022

# Overview of videos

- 1) Attributional and consequential responsibility
- 2) ISO 14040/44: A standard for consequential LCA
- 3) How to fully reflect both physical and monetary causalities in LCA
- 4) Temporal issues in LCA
- 5) Learning from non-intuitive results
- 6) *The comparability algorithm*: Defining the functional unit
- 7) *The linking algorithm*: Composing a consumption mix
- 8) Identifying determining products
- 9) *The co-product algorithm*
- ➡ 10) Errors in background databases

# Improvement needs:

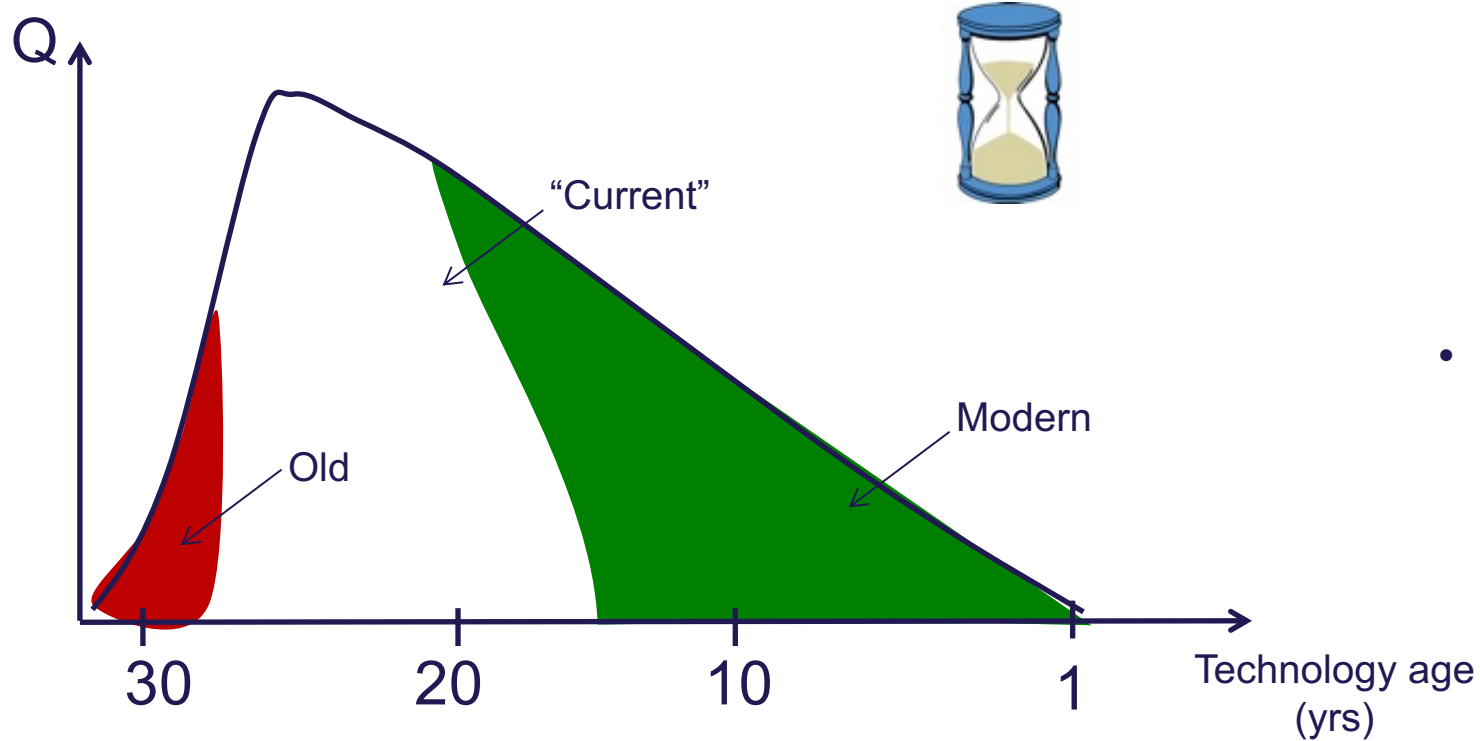
## Reducing errors in background databases

- The required algorithms are available, documented, and implemented reasonably well by **ecoinvent**, although:
  - User interface makes it difficult to follow the modelling of negative physical flows (reductions in demand), especially when the sign changes several times in a supply chain
  - Mass balancing is not implemented in a way that allows to use this functionality to identify errors in the modelling
- Manually induced errors in modelling still appear, e.g.:
  - Some cases of joint production are treated as combined, implicitly using hidden physical allocation, e.g. in forestry
  - Manure emissions still part of crop production instead of the animal husbandry systems
  - Indirect land use not implemented according to causal relations

# More general problem in background databases: Aggregation errors

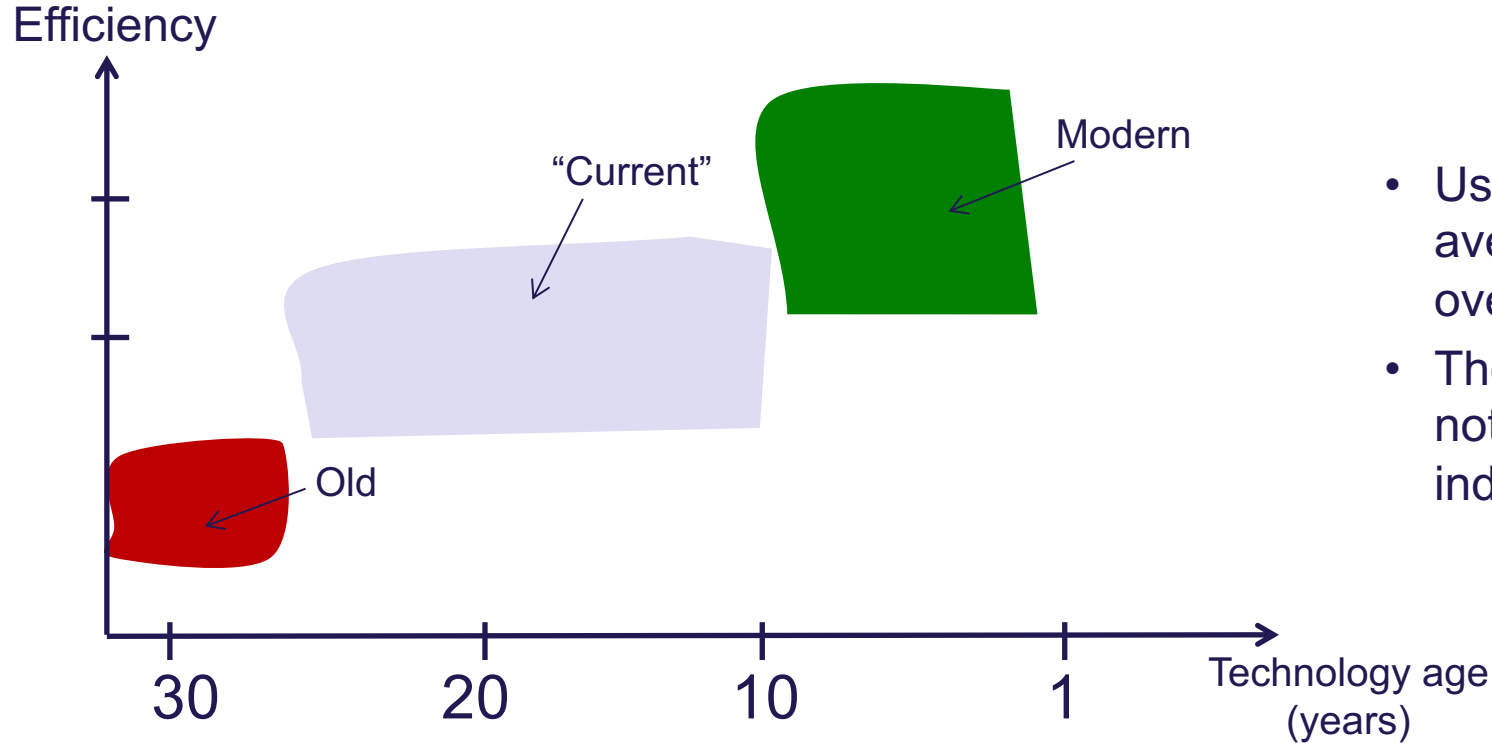
- When only one dataset exist:
  - For a specific activity (or product)
  - For only one geographical location (and a global market)
  - For only one point in time
- Even in the lucky situation that this dataset represents the global average:
  - This is not likely to well represent the technology and/or location of the marginal suppliers
  - This does not inform us of changes over time

# More general problem in background databases: Aggregation errors



- Modern technology is typically what we want to model

# More general problem in background databases: Aggregation errors



- Using aggregated averages will typically overestimate impacts
- The extent of bias will not be uniform across industries / products

# Improvement needs:

## Reducing errors in background databases

Solutions to the aggregation problem:

- Long-term: More differentiated data
- Short-term: Can a correction factor for the marginal/average ratio be estimated (e.g., from learning curves) ?

# Ecoinvent v3 – consequential or allocation

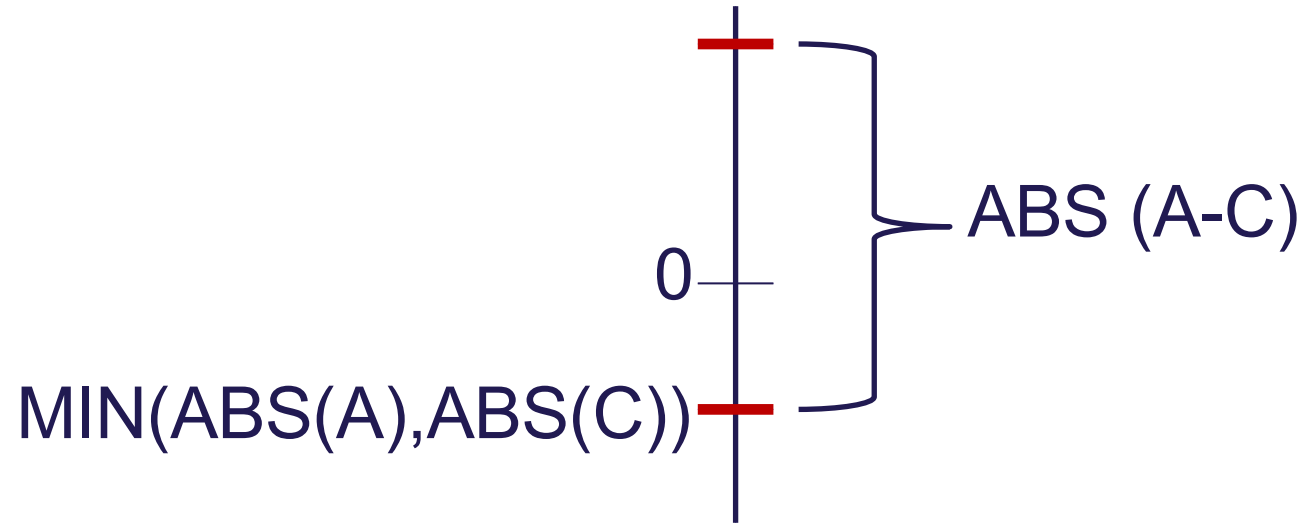
## *Does it matter...*

- ...which system model I choose?
- Comparison of the 11650 products:
  - 1345 product/activity-combinations only found in attributional model, not in consequential: By-products
  - 318 product/activity-combinations only found in consequential model, not in attributional: Conditional exchanges and treatment for wastes not produced
  - The remaining 9987 product/activity-combinations were compared
- The comparison was made on the absolute difference relative to the smallest absolute value:

$$\text{ABS}(A-C)/\text{MIN}(\text{ABS}(A),\text{ABS}(C))$$



Compare  $\text{ABS}(A-C) / \text{MIN}(\text{ABS}(A), \text{ABS}(C))$ :



# Overall results

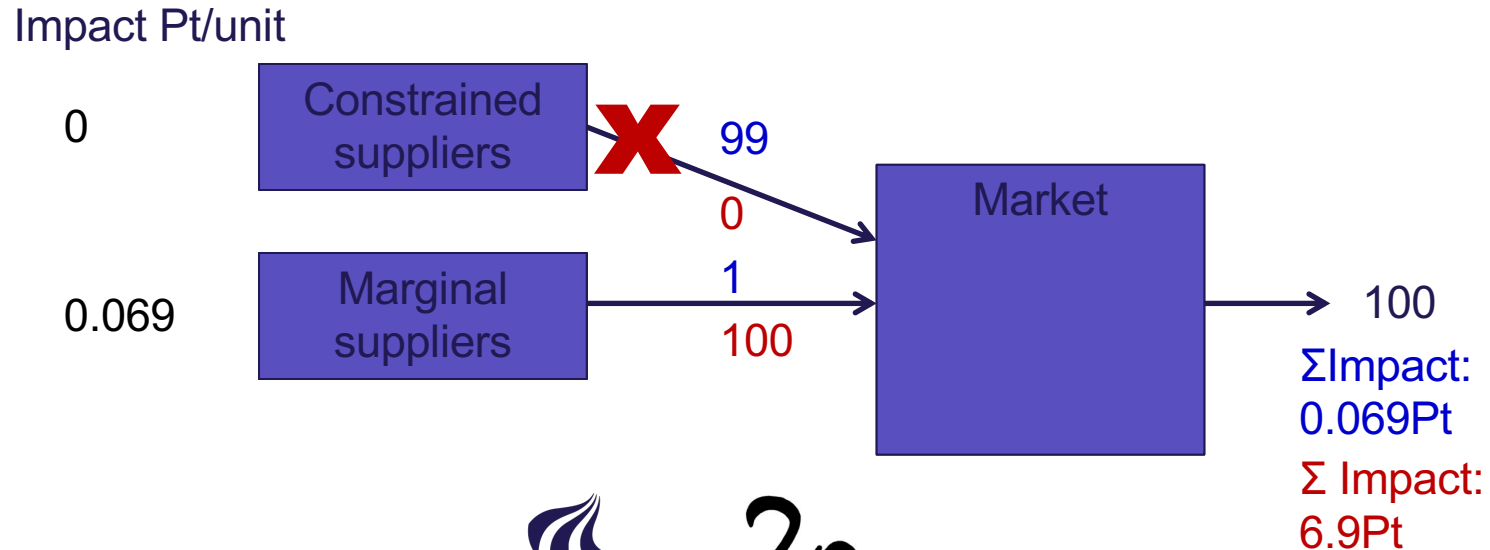
- On average in the 401 impact categories:
  - 67% of the results have > 10% difference
  - 22% of the results have > 100% difference
  - 16% of the results have > factor 2 difference
  - 5% of the results have > order of magnitude difference
- On average in the 11 total single-score categories:
  - 56% of the results have > 10% difference
  - 13% of the results have > 100% difference
  - 9% of the results have > factor 2 difference
  - 3% of the results have > order of magnitude difference

# Analysing the causes for differences

- The causes for the differences can be grouped as:
  - Marginal suppliers very different from average
  - Speciality products
  - Multiple determining products
  - By-products from treatment activities
  - Determining products heavily influenced by by-products

# Marginal vs. average suppliers

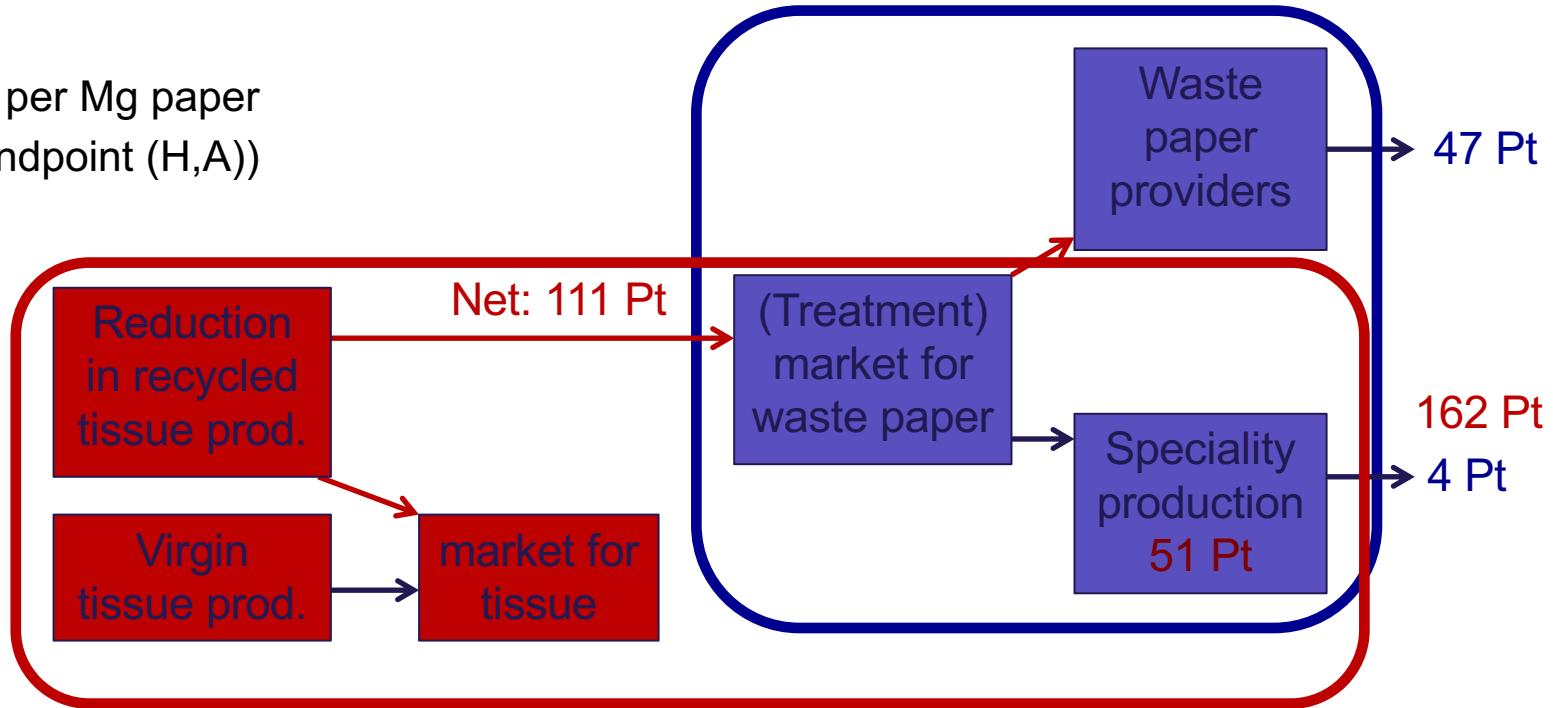
- Products where the unconstrained (**marginal**) suppliers have much more/less impact than the **average**
  - Example: land tenure (ReCiPe Endpoint (E,A):total:total)



# Speciality products

- Example: Graphic paper, 100% recycled
  - In attributional modelling: only the treatment activity is included; allocation with the products of the waste providers
  - The consequential model links to virgin production

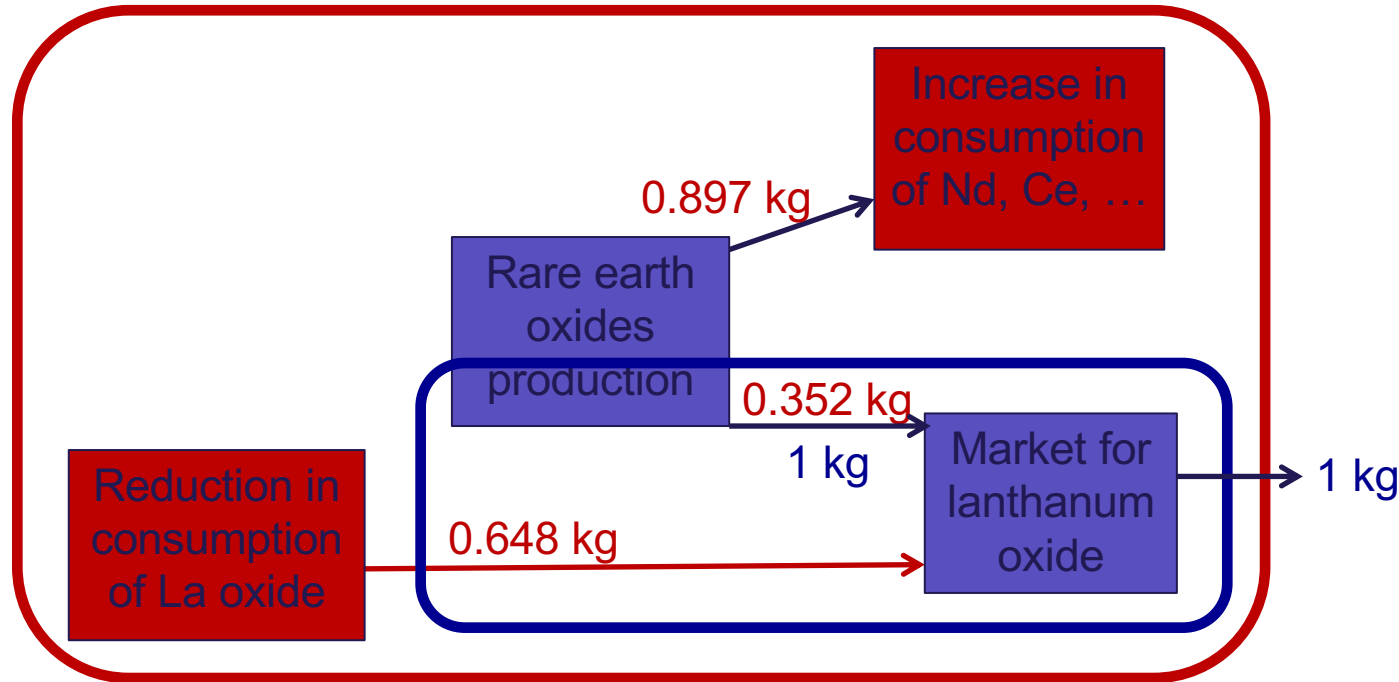
Values are per Mg paper  
(ReCiPe Endpoint (H,A))



# Multiple determining products

- no alternative production routes

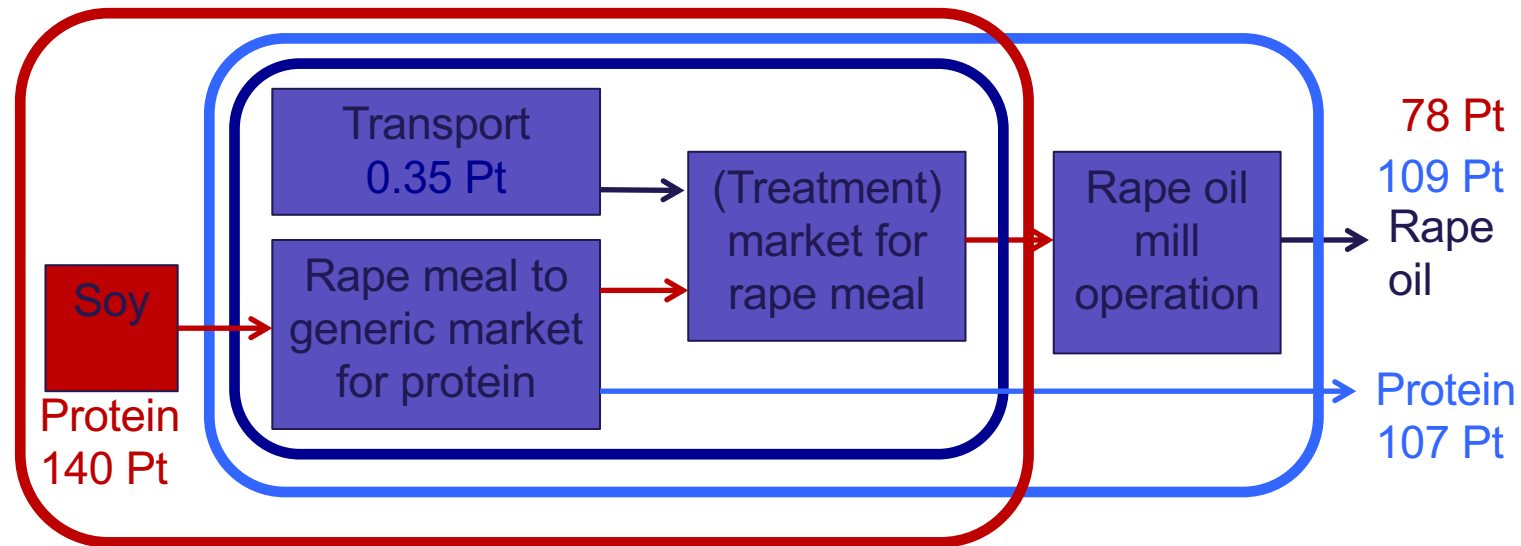
- The **consequential** model includes changes in consumption of the co-products (example: La oxide)



**NOTE:** This example is outdated. REO production is now modelled with only one determining product.

# By-products from treatment activities

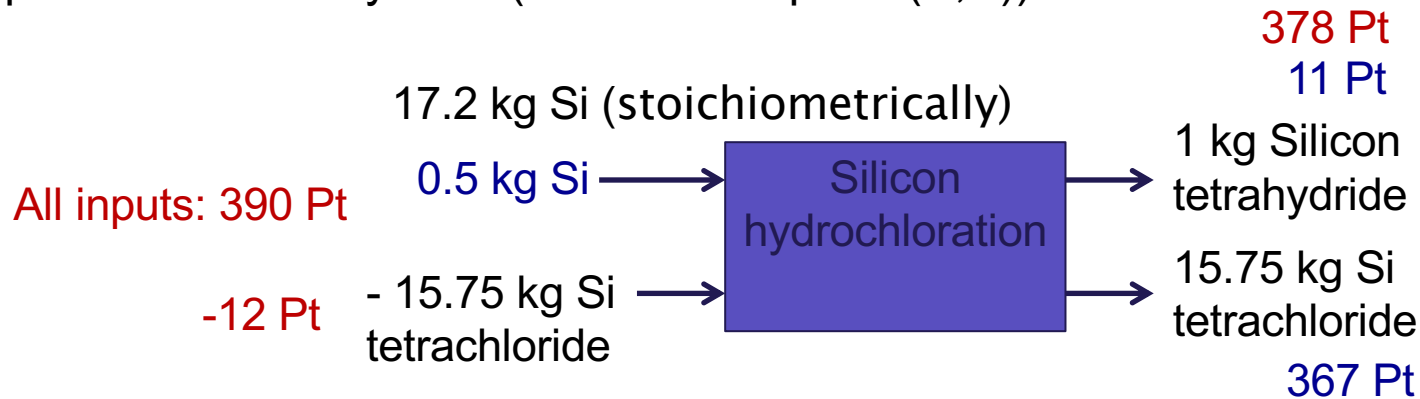
- Attributional data: Only the treatment activity is included
- **Consequential model:** Displacement of other activities
- Real comparison: to the share that is allocated to protein



Values are per Mg rape meal  
(ReCiPe Endpoint (H,A))

# Determining products heavily influenced by by-products

- Determining products produced together with by-products that displace very polluting or very clean activities compared to the burden that is allocated away from the determining product in the attributional model
- Example: silicon tetrahydride (ReCiPe Endpoint (E,A))





# Conclusion on the comparison

- The analysis identifies three situations where consequential modelling is essential for providing correct decision support:
  - When the unconstrained (marginal) suppliers have much more/less impact than the average
  - When analysing the use of by-products
  - When analysing the use of determining products from activities with significant amounts of other co-products

FOR MORE COURSES AND DEEPER LEARNING OF  
ALL ASPECTS OF LIFE CYCLE THINKING  
FOLLOW



**ILCA**  
International  
Life Cycle  
Academy

[www.ilca.es](http://www.ilca.es)