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Material Flow Analysis as a Tool for Resource Accounting

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Why resource accounting?

- Some resources are classified as *critical*.

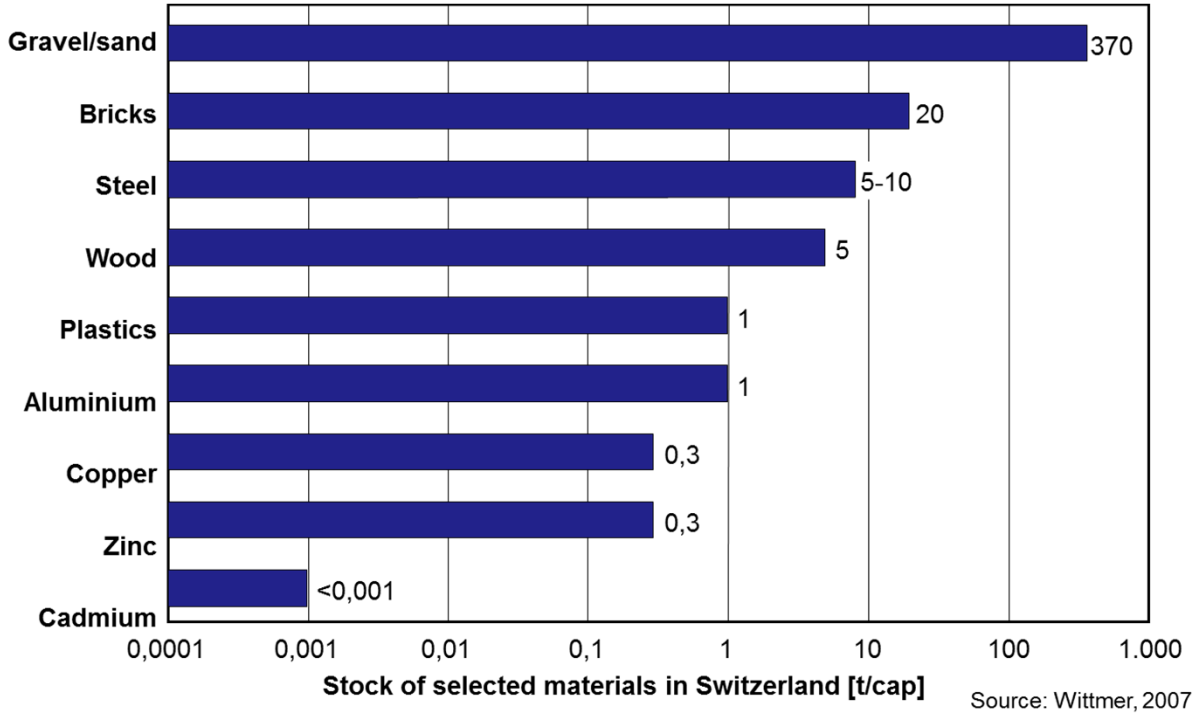
- Communication from the commission: Roadmap to a Resource Efficient Europe

  3. Transforming the economy:

  "...better management of resources over their whole life cycle."

- Large and growing anthropogenic stocks.

Build-up of large urban stocks (US)



Separate collection of

Plastics:	18 kg/cap.yr
Metals:	15 kg/cap.yr
Wood:	23 kg/cap.yr

Source: BAWP 2011

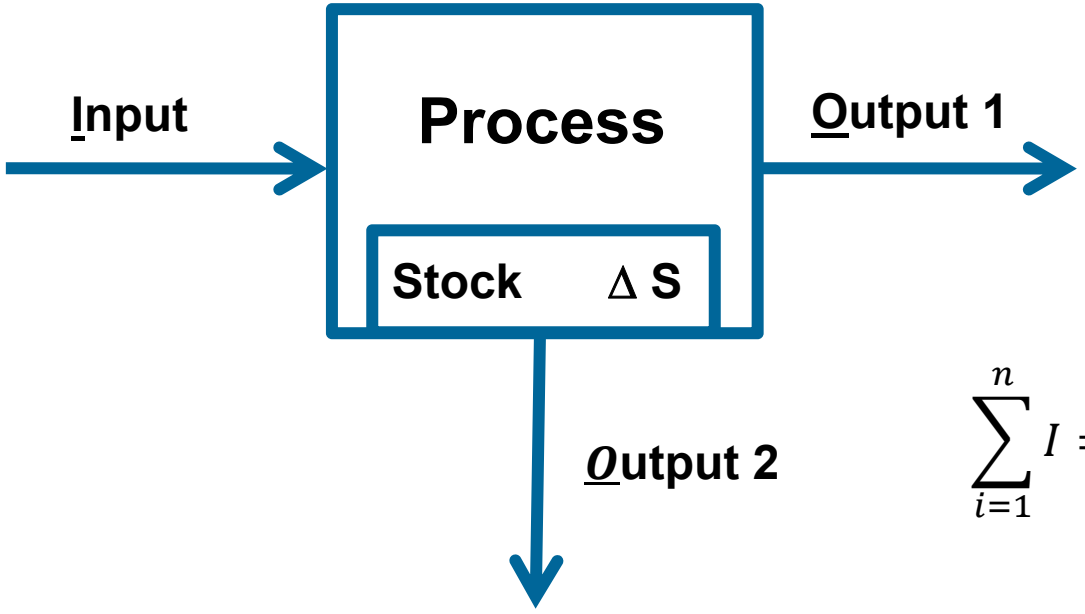
Comparison between US and reserves

Copper:	300 Mio. t	580 Mio. t
Iron:	14 800 Mio. t	77 000 Mio. t
Zinc:	205 Mio. t	200 Mio. t

Source: Rechberger, 2004; Rauch 2009, USGS 2011

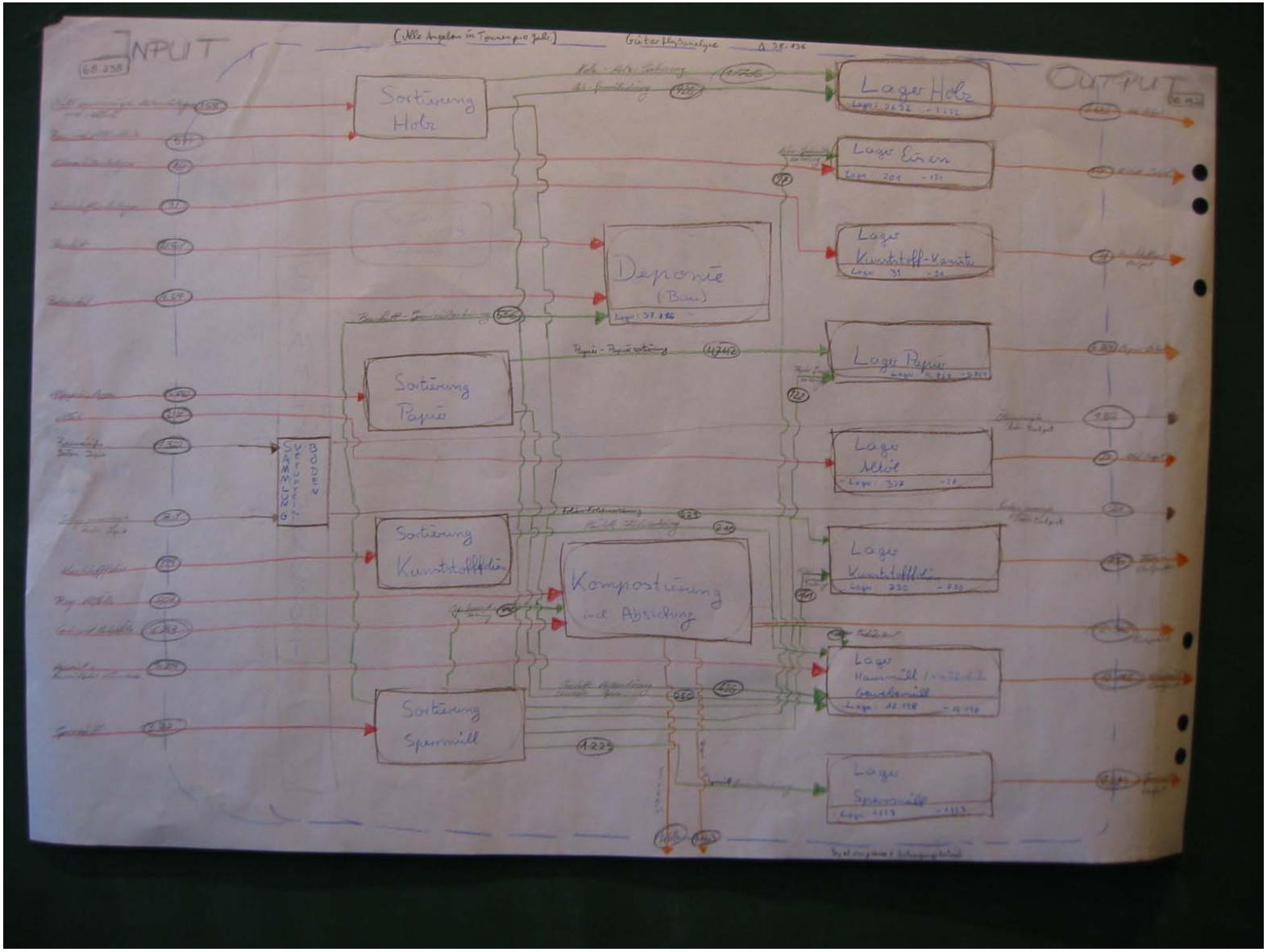
What is Material Flow Analysis (MFA)?

- MFA is a systematic assessment of flows and stocks of materials within a system defined in space and time.
- It connects the sources, the pathways, and the sinks of a material.
- MFA is based on the law of the conservation of matter.

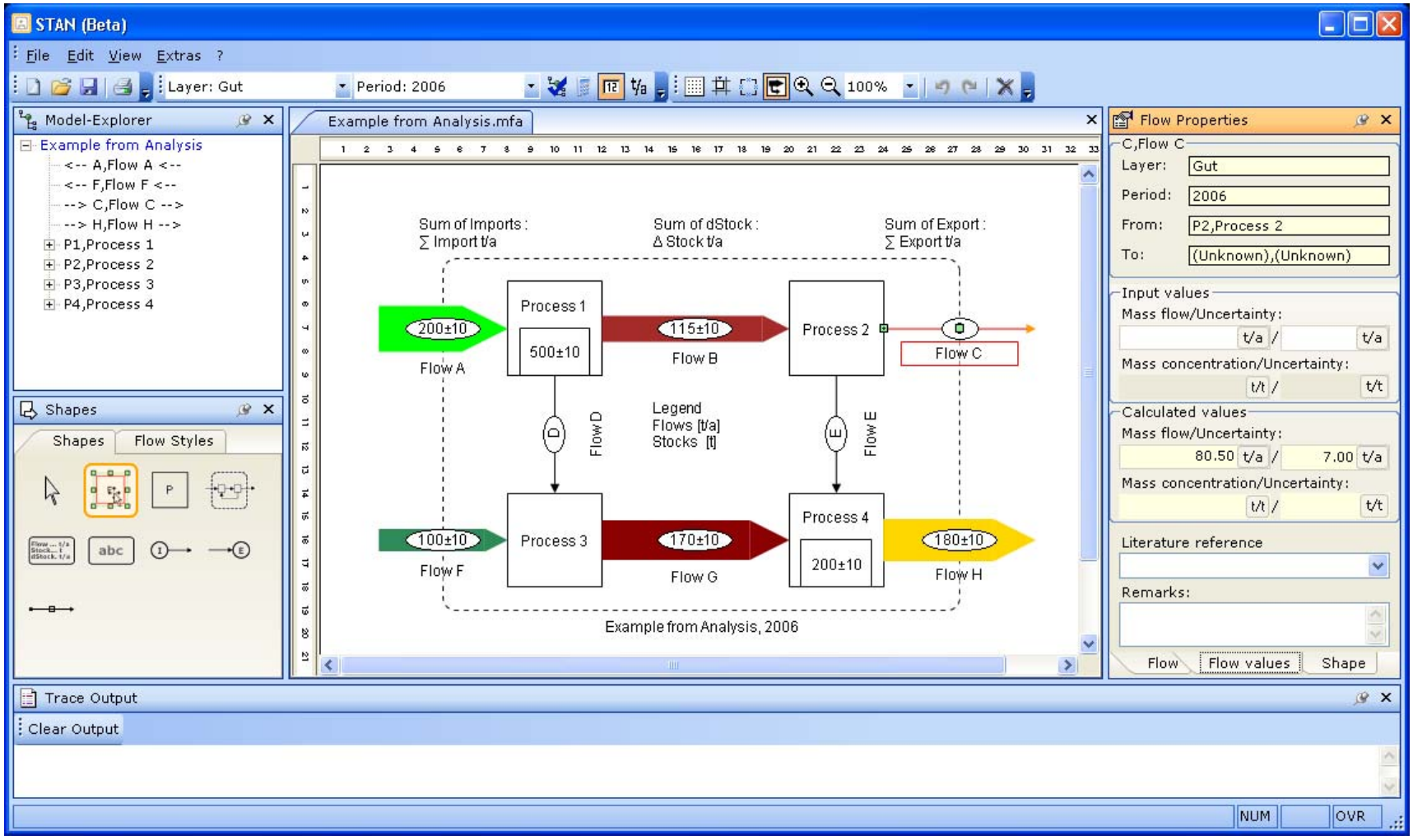


$$\sum_{i=1}^{n} I = \sum_{j=1}^{m} O + \Delta S$$

MFA before STAN

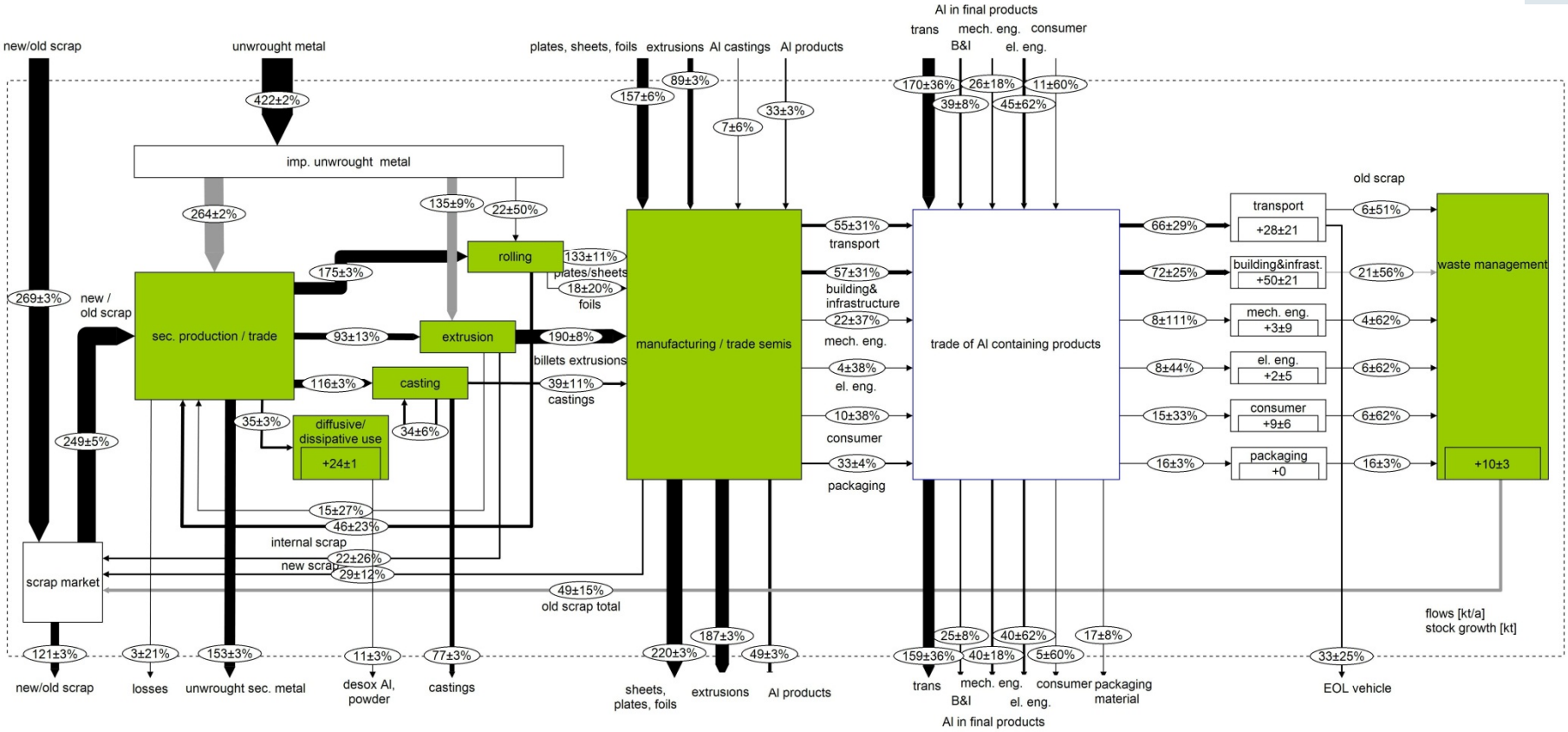


Free software STAN: www.stan2web.net



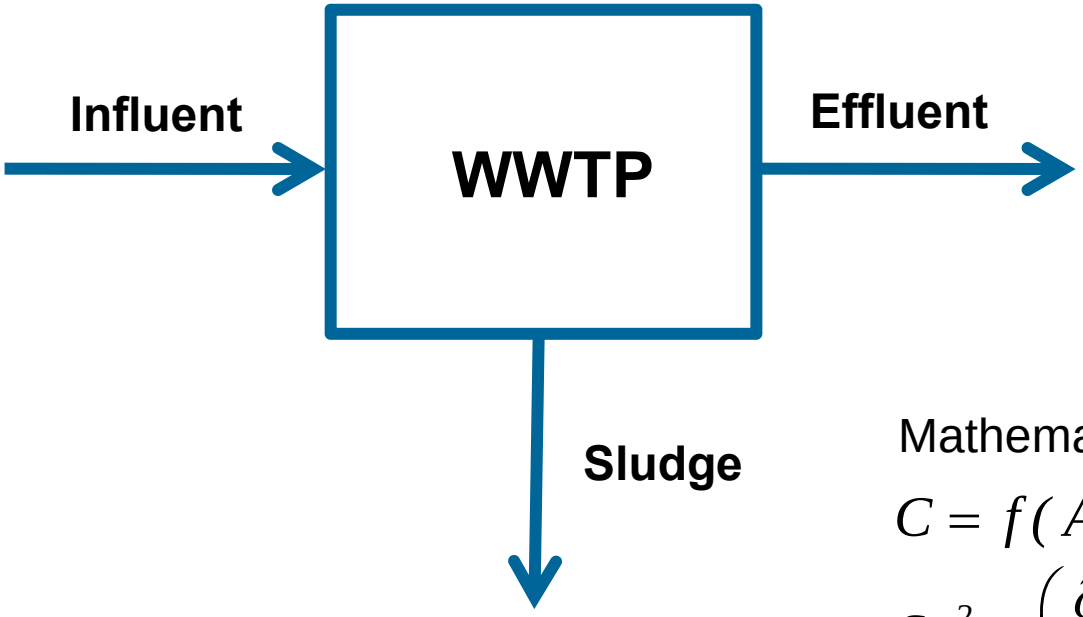
MFA with STAN

The Austrian budget for Aluminium for 2011, flows in kt/yr



Source: Bucher et al., 2014

Advantages of a software[1]: Error propagation



$M_{effluent}$ = 10 000 kg/h

$c_{P,effluent}$ = 2 mg/kg

$X_{P,effluent}$ = M · c = 20 g/h

Mathematical basics

$$C = f(A, B, \ldots)$$

$$S_C^{\,2} = \left(\frac{\partial C}{\partial A}\right)^2_{\bar{A},\bar{B}} \cdot S_A^{\,2} + \left(\frac{\partial C}{\partial B}\right)^2_{\bar{A},\bar{B}} \cdot S_B^{\,2} + \ldots$$

Considering uncertainty of data:

$M_{effluent}$ = 10 000 ± 1000 kg/h

$c_{P,effluent}$ = 2 ± 0.3 mg/kg

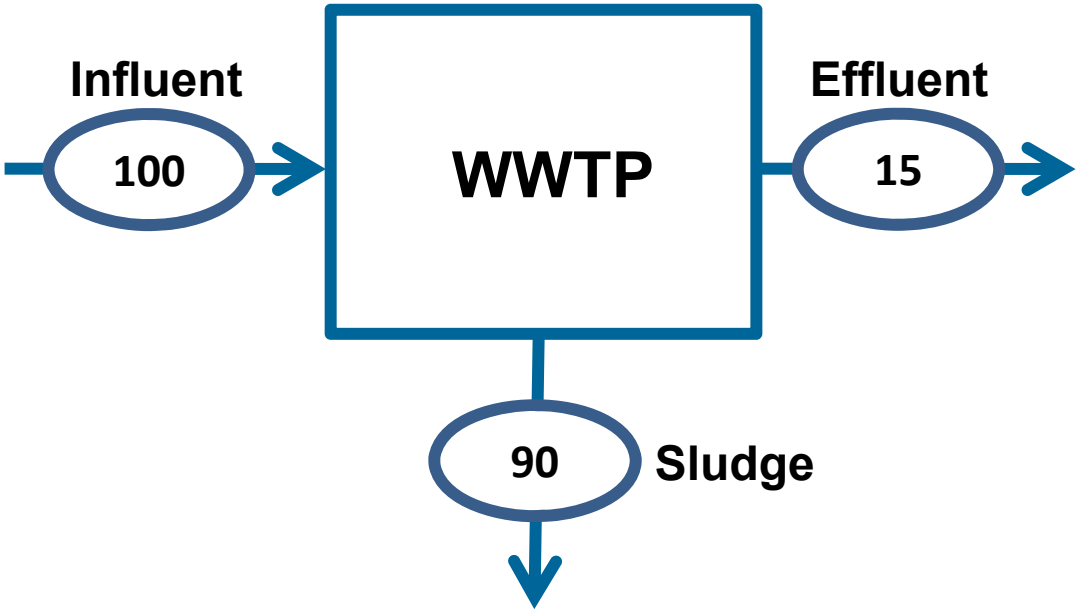
$X_{P,effluent}$ = M · c = 20 g/h

$$C = A \cdot B: \quad S_C^{\,2} = \bar{B}^2 \cdot S_A^{\,2} + \bar{A}^2 \cdot S_B^{\,2}$$

$S_X = (10\,000^2 \cdot 0.0003^2 + 0.002^2 \cdot 1000^2)^{1/2}$ = 4.7 g/h

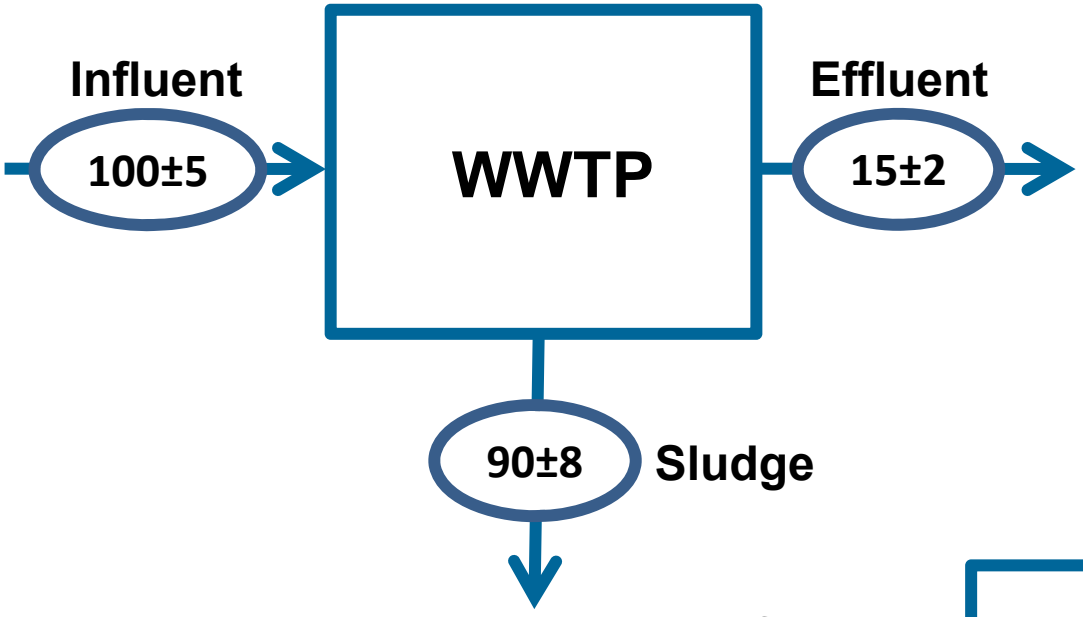
<u>$X_{P,effluent}$ = 20 g/h ± 24%</u>

Advantages of a software2: Data reconciliation



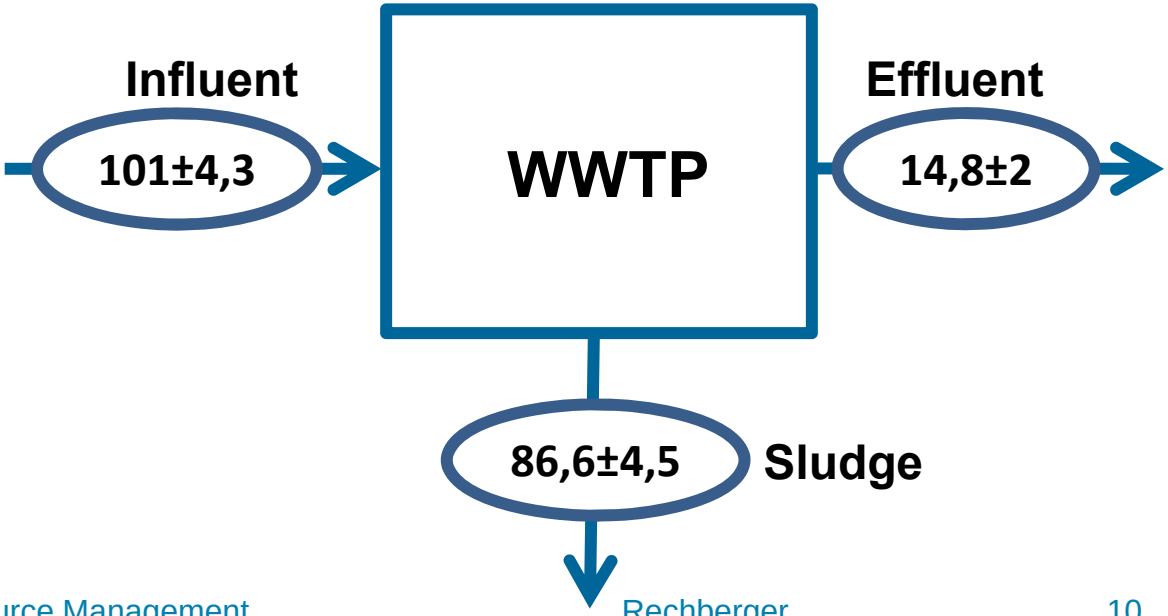
Input ≠ Output

Advantages of a software2: Data reconciliation



Input ≠ Output

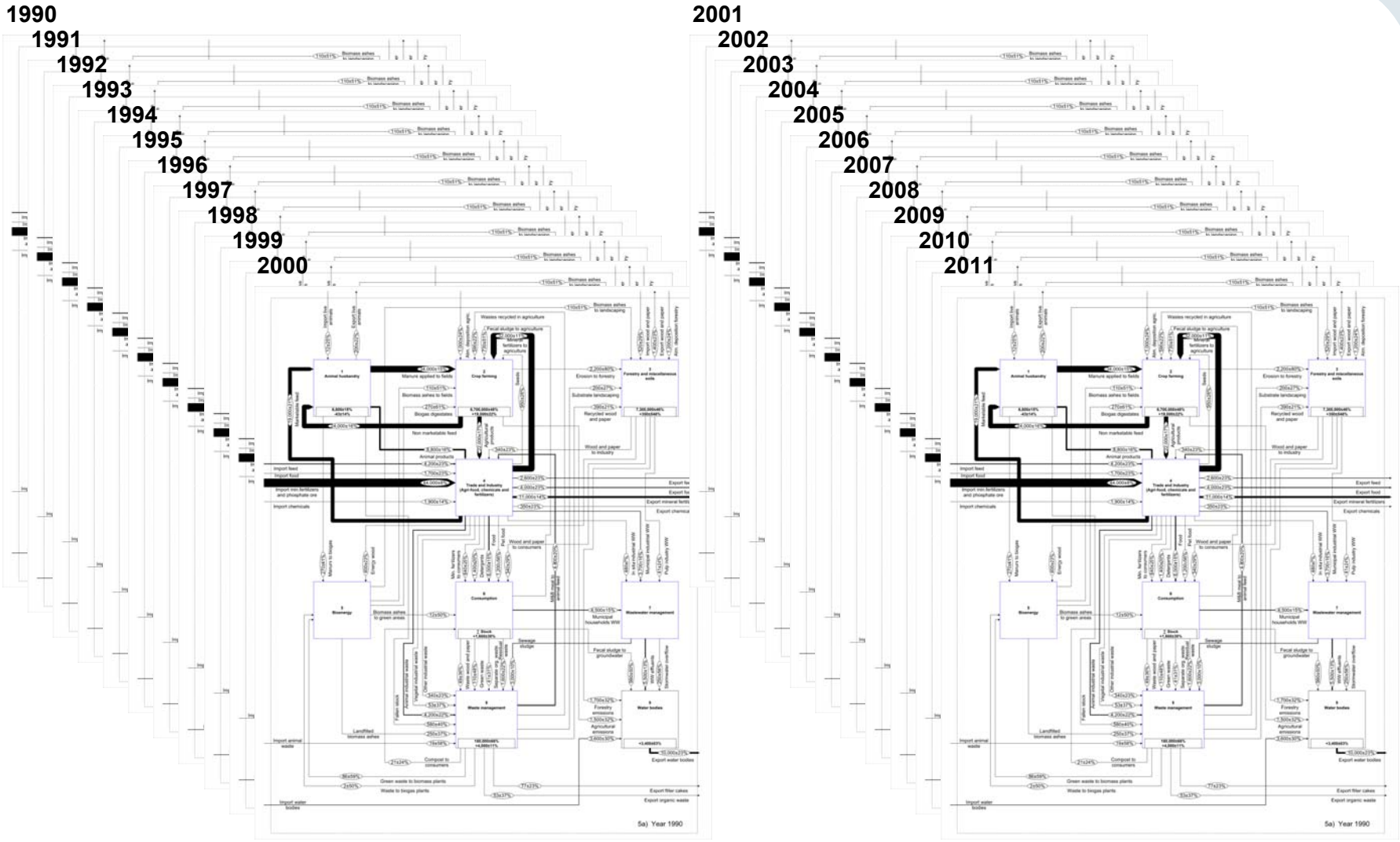
Reconciled process
Input = Output



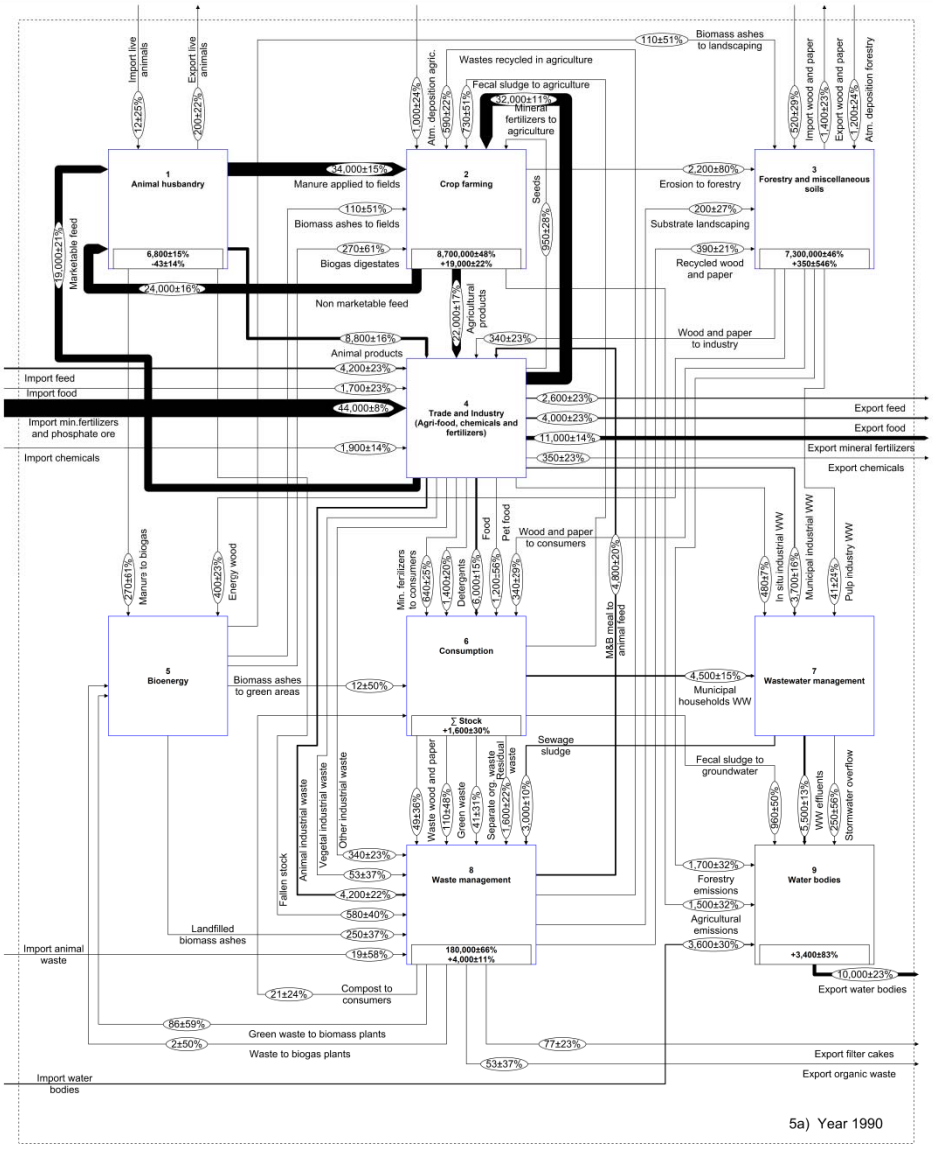
Why Phosphorus?

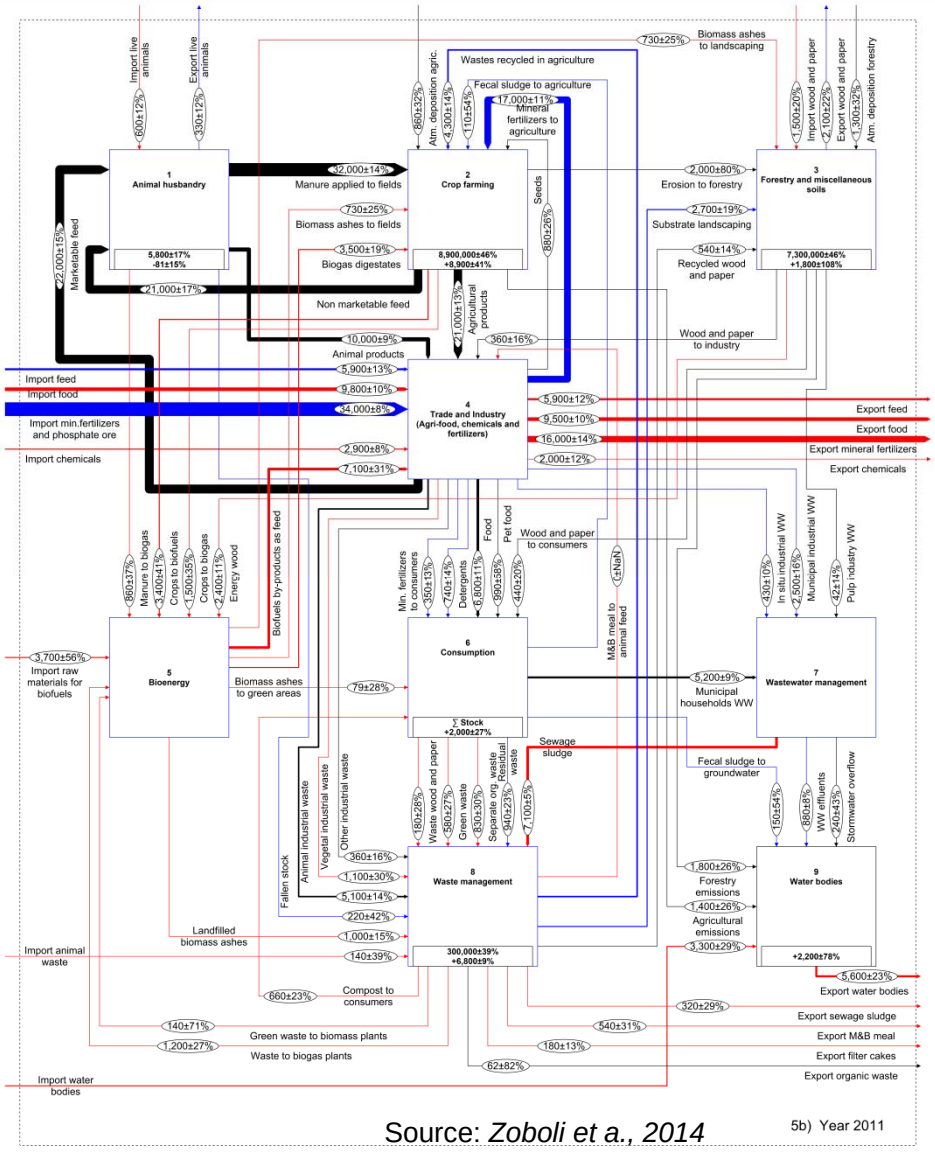
Source: *Ad hoc Working Group on defining critical raw materials, 2014*

A time series for the Austrian P-budget



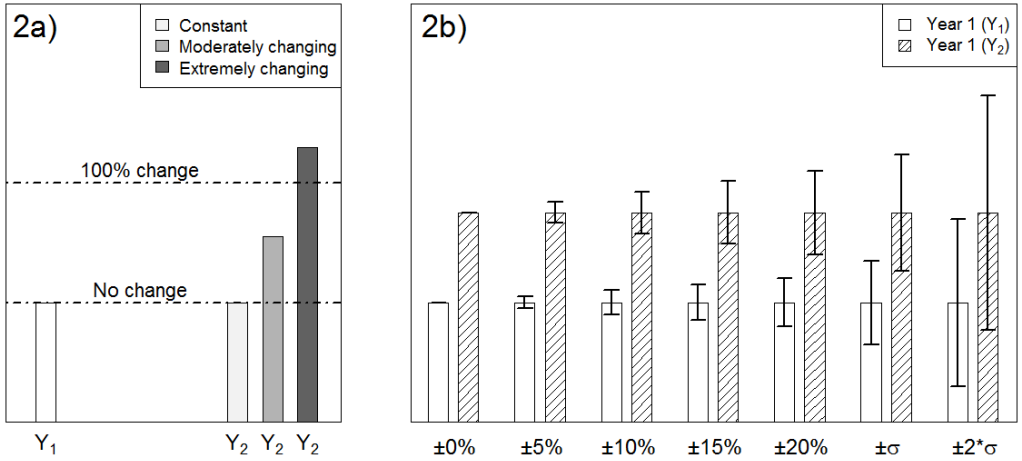
P-budget: Comparison between 1990 and 2011



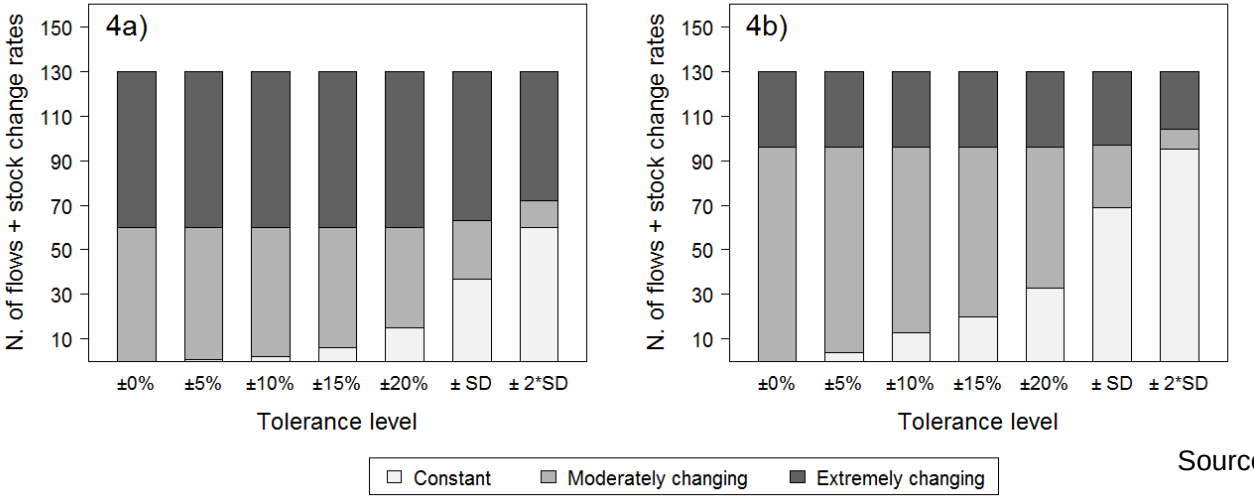


Source: *Zoboli et a., 2014*

Statistical evaluation of flows



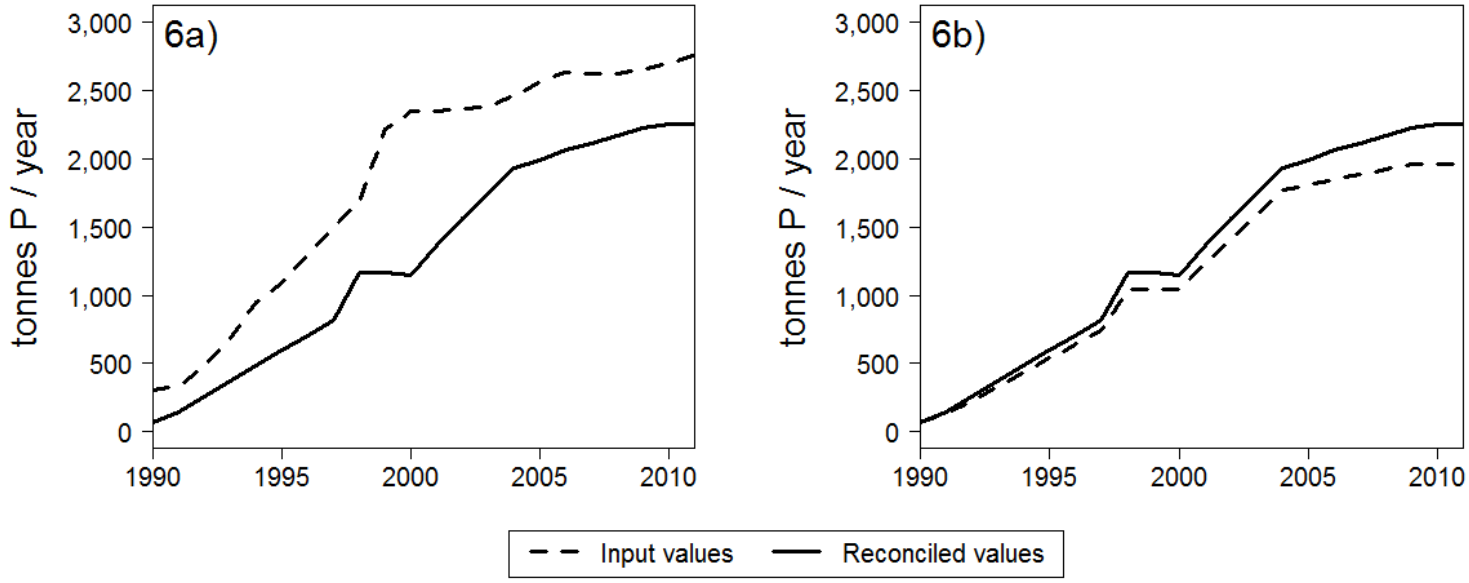
4a) Categorization according to the change with respect to the reference year 1990
4b) Categorization according to annual change.



Source: *Zoboli et a., 2014*

Detection of systematic errors

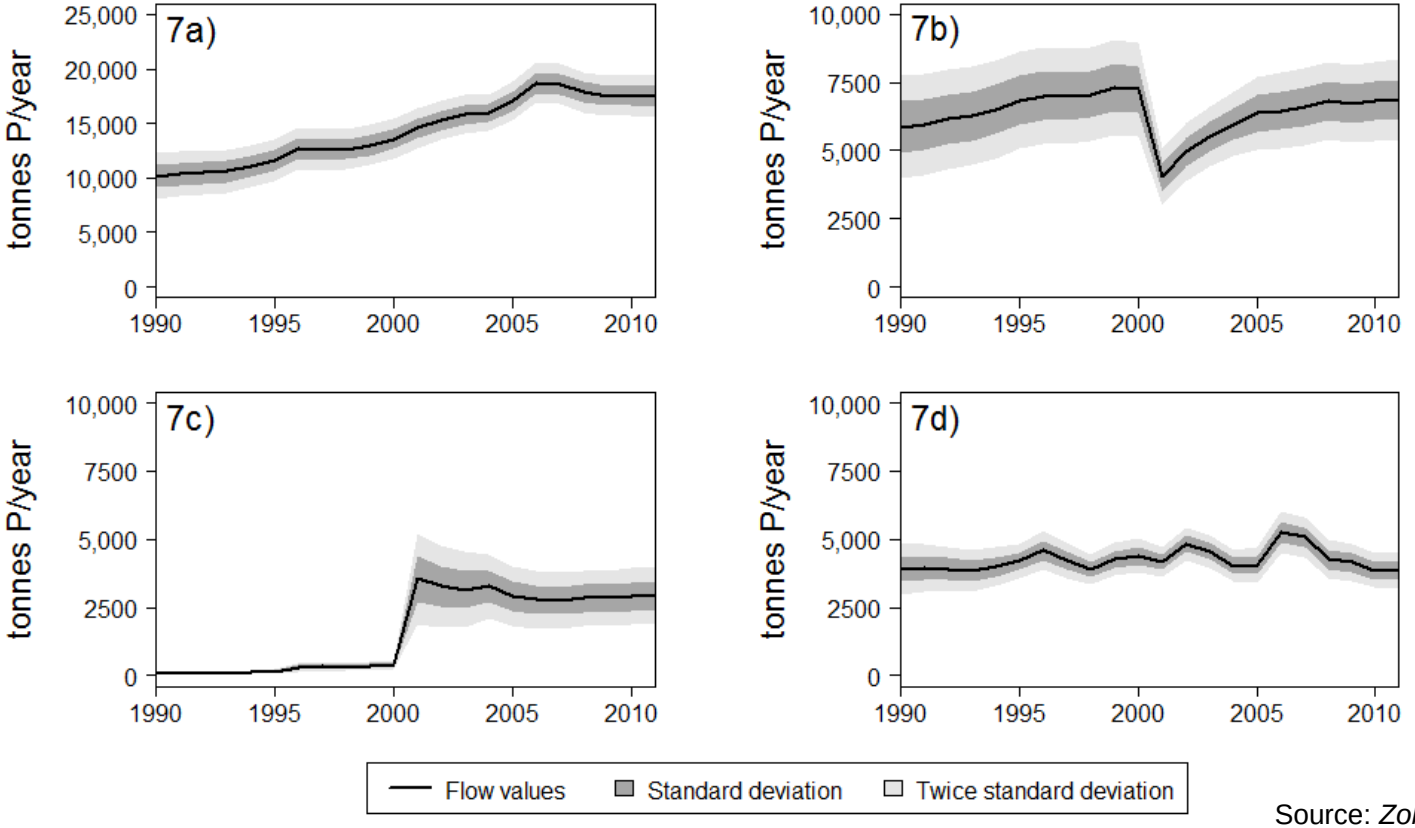
Comparison between input and reconciled values of the *Composting* sub-process; 6a) sum of input flows; 6b) sum of output flows.



Source: *Zoboli et a., 2014*

Monitoring of flows

7a: Total P to Waste Management
7b:Total P recovery within Waste Management
7c: Total P used in cement kilns
7d: Total disposal of P in landfills



Source: *Zoboli et a., 2014*

Conclusions

- Resource accounting is feasible in practice
- It helps to better understand a resource system (detect points of action)
- It helps to detect systematic errors
- It helps to define sectors/branches where better data is needed

The example of P shows that

- a single-year analysis is not adequate
- the system shows considerable variance over time