The application of MFA/SFA for decision making in resource and waste management

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First MFA by Santorio 16th century: “human metabolism”

input = output?
The balance does not close - what happens at night?
Typical lessons learned from Santorrio and early MFA:

1. How to measure?
   -> MFA and balance principle

2. Balance does not close!
   -> uncertainty treatment
   -> systems understanding

3. What do the results serve for?
   -> “cure the patient”
   -> MFA requires a goal!
Following generations of MFA (1950-1990)

- Regional and national MFA
  - Metabolism of cities (Duvigneaud et al, 1977)
  - National TMR-MFA (Wuppertal Institute a.o.)

Mainly descriptive, not on an operational level yet
From MFA to SFA (1980-2000)

• Substance level
  -> crucial for resources and environment
• Regional SFA
  -> Ayres, Stigliani, Baccini, and others
• MFA/SFA on all scales:
  -> molecular to global
  -> static to dynamic (cf. ES&T Müller et al, 2014)
• Software STAN, SIMBOX, and others
• Exploration phase completed!
• MFA/SFA a tool for:
  -> problem solving
  -> decision making
• MFA/SFA applied for:
  -> Resource management
  -> Waste management
  -> Environmental management
• MFA/SFA requires assessment methods like LCA!
Example 1: Decision making for plastic recycling

PBDE/BFRs in video tapes (5/5)  
(Hirai et al, BFR 2007.)

PBDEs in coffee cup (J. Samso- nek & F. Puype, FAC, 2013)

PBDE in children toys  
(Chen et al, ES&T, 2009)
Identifying the problem by MFA/SFA of cPentaBDE
PBDE in plastics - clean cycles and safe final sinks?

EoL vehicles

0.6 t/y

consumption
stock 76 t (-3.2)

construction wastes
stock 2.6 t/y

waste management
stock (+2.6)

recycling

key system for control

Vyzímková et al, 2013

Vienna city limits, 2012
Ex. 2: From single processes to complex systems

Decision making in waste management - How to find the “best” waste management system?

- Define goals
- Select indicators and criteria (resources & emissions)
- Comprehensive MFA/SFA model (flows and stocks -> resources & emissions)
- Evaluation of results (LCA, SCE, and others)
- Scenario analysis

-> Optimized wm system

-> transparent and reproducible process
-> acceptance of stakeholders
MFA / SFA for decision making in waste management I

System boundary “Waste Management Austria, 2010”

- **Goods Flows in 1,000 t/yr**
  - Stock in 1,000 t
- **Imported waste**: 110
- **Waste**: 49,000
- **Resources for maintenance**: 7,600
- **Contribution waste and maintenance resources**
  - Maintenance resource OT
  - Waste OT
  - Waste TT
  - Maint. res. TT
  - Waste CTP-TT
  - Waste OT-BT
  - Waste BT
  - Maint. res. BT
  - Waste LF
  - Maint. res. LF
  - Waste CPT
  - Maintenance resource CPT

- **Other treatment (OT)**
  - Waste OT-TT
  - Waste BT-TT
  - Waste BT-LF
  - Waste LF
  - Maint. res. LF

- **Thermal treatment (TT)**
  - Waste TT
  - Maint. res. TT

- **Biological treatment (BT)**
  - Waste BT
  - Maint. res. BT

- **Chemico-physical treatment (CPT)**
  - Waste CPT
  - Maintenance resource CPT

- **Recycling**
- **Emissions transport**
- **Re-use**
- **Waste export**
- **Emissions export**
- **Products OT**
- **Export OT**
- **Emissions TT**
- **Products TT**
- **Export TT**
- **Emissions LF**
- **Products LF**
- **Export LF**
- **Emissions CPT**
- **Products CPT**
- **Export CPT**

**System boundary calculations**

- **Import**: 57,000 kt/yr
- **Stock**: 12,000 kt/yr
- **Export**: 45,000 kt/yr

**Subsystems**

- Maintenance resource (OT-LF)
- Maintenance resource (CPT-TT)

**Key values**

- Maintenance resource OT: 45
- Waste OT: 16,000
- Waste TT: 2,400
- Maint. res. TT: 6,000
- Waste CTP-TT: 16
- Waste OT-BT: 28
- Waste BT: 3,400
- Maint. res. BT: 20
- Waste LF: 840
- Maint. res. LF: 1,200
- Waste CPT: 9,400
- Maintenance resource CPT: 670
- Waste LF: 1,500
- Maint. res. LF: 1,800
- Waste CPT: 1,100
- Maintenance resource CPT: 160
- Waste LF: 160
- Maint. res. LF: 430

**Other treatment**

- Waste OT-TT: 2,000
- Waste BT-TT: 930
- Waste BT-LF: 170
- Waste LF: 1,800
- Maint. res. LF: 430
- Waste CPT: 1,400
- Maintenance resource CPT: 12
- Waste LF: 12
MFA / SFA tomorrow

- MFA/SFA for optimizing the “Metabolism of the Anthroposphere”
  -> the activity concept using MFA/SFA
  -> more service and less material turnover
- Linking MFA and economics
  -> using MFA/SFA to optimize industrial processes
**The activity concept using MFA**

**Material turnover in European private households**

to satisfy basic human needs

<table>
<thead>
<tr>
<th>activity</th>
<th>input [t/c.y]</th>
<th>sewage output [t/c.y]</th>
<th>solid residues</th>
<th>stock [t/c]</th>
</tr>
</thead>
<tbody>
<tr>
<td>to nourish</td>
<td>5,7</td>
<td>0,9 4,7 0,1</td>
<td></td>
<td>&lt; 0,1</td>
</tr>
<tr>
<td>to clean</td>
<td>60</td>
<td>60 0 0,02</td>
<td>0,1</td>
<td>0,1</td>
</tr>
<tr>
<td>to reside</td>
<td>10</td>
<td>0 7,6 1</td>
<td>100 + 1</td>
<td></td>
</tr>
<tr>
<td>to transport</td>
<td>10</td>
<td>0 6 1,6</td>
<td>160 + 2</td>
<td></td>
</tr>
<tr>
<td><strong>Total turnover</strong></td>
<td><strong>86</strong></td>
<td><strong>61</strong> 19 2,7</td>
<td>260 + 3</td>
<td></td>
</tr>
</tbody>
</table>
Activity concept

• How to satisfy basic human needs in view of changing technology and economy?
• Example “to transport”
How to satisfy the need for transportation in view of limited resources of Lithium?

*Signorelli, Schindall, Kassakian*
Optimizing the “Metabolism of the Anthroposphere”
- the activity concept using MFA/SFA
- more service and less material turnover

Linking MFA and economics
- using MFA/SFA to optimize industrial processes
Linking material flows and cost-flows

Import 450 €/p  
Export 476 €/p  
Change in stock -26 €/p

Flow costs [€/unit of good]

System boundary “production of panels, 2011”
Conclusions

- Input equals output – transparent and rigid methodology
- Substance level decisive
- All scales from household to planet
- Future indispensable tool for:
  - early recognition
  - assessing and solving metabolic problems
  - designing new strategies and concepts
  - new knowledge base about metabolism
  - governance!
Recycling is not the final sink

The End

is the final sink
Activity “to clean” – which substances are appropriate?

NPnEO Input: 0.3 Mol/c.y

NPnEO Output: 0.12 Mol/c.y

Nonylphenol [g/c.y]
(figures in italic stand for NPnEO)

Nonylphenolpolyethoxylat NPnEO

C_{9}H_{19}
From MFA to SFA: carbon flows from thermal waste treatment

MFA / SFA for decision making in waste management III

System boundary “Thermal treatment Austria, 2010”

Carbon Flows in 1,000 t/yr
Stock in 1,000 t

Import: 1,700 kt/yr
Stock 0 kt/yr
Export 1,700 kt/yr
The application of MFA for decision making in resource and waste management Analysis, evaluation, design (examples for all three)

Goal oriented, the phase of methodological development is over: there must be a problem stated in order to solve it with MFA
Which problems can be solved: all problems, but for which MFA is effective???

1. The law on conservation of matter: input equals output
2. What is MFA: goods and substances
3. All scales from person to planet
4. For waste management
5. For regional materials management
6. Environmental management
7. Resource management
8. For governance (V.EFB)

Mention the surprise about nutrients (MFA of private hh)
Mention the surprise of stocks (Lohm) when there were deltas in MFA between I/O