TECHNISCHE UNIVERSITÄT CHEMNITZ

Faculty of Economics and Business Administration
Professorship of Management Accounting and Control
Prof. Dr. Uwe Götze

# Material flow cost accounting – methodology, use cases, and perspectives

Uwe Götze, Ronny Sygulla

Cluj Economics and Business Seminar Series (CEBSS) at the University Babeș-Bolyai – Faculty of Economics and Business Administration

Cluj-Napoca, Nov 20th, 2014

# Technische Universität Chemnitz – Campus Reichenhainer Straße

# Chemnitz in Europe and Germany

# Technische Universität Chemnitz

**Facts and Figures:**

- About 11,000 students in 8 Faculties
  → thereof about 18 % from abroad
- About 2,200 employees
- State funding 2013: 75.9 Mio. EUR
- External funding 2013: 75.6 Mio. EUR
- 1,300 PhD students

# Technische Universität Chemnitz

Smart Systems
and Materials

Energy-efficient
Production Processes

Human Factors
in Technologies

Key Areas of Technische Universität Chemnitz
Research Profiles of the Faculties
Fundamental and Application-oriented Research of the Professorships

# Faculty of Economics and Business Administration


**Facts and Figures:**

- More than 2,300 students
- 17 professorships
- 16 “own” study programs

  → thereof:

  6 bachelor, 10 master programs

  2 extra-occupational programs

  7 interdisciplinary programs

# Professorship of Management Accounting and Control

## Facts and Figures:

- 15 academic and research associates
(7 third-party fund financed)
- 15 external postgraduates
- Dean of studies and head of examination board for "industrial engineering and management"
- Member of the advisory board of the university
- Editor of Journal of Management Control (JoMaC) and member of the editorial board of Journal Management & Marketing

## Cooperation partners (selection):

MUGLER

SWZ
SIEBENWURST
WERKZEUGBAU

E-PLUS GRUPPE
BASE e-plus simyo ay yildiz vybemobile

VWA
Sächsische Verwaltungs- und Wirtschafts-Akademie

VOITH
Industrial Services

SIEMENS

# Professorship of Management Accounting and Control

## Research areas:

- Strategic Management
- Investment Appraisal and Management
- Cost Accounting and Management
- Controlling/Management Control
- Cost-oriented Product-design
- Management and Engineering

## Ongoing research projects:

**MERGE – Merge Technologies for Multifunctional Lightweight Structures**

**Energy-efficient Product and Process Innovations in Production Engineering**

**SFB 692 – High-strenght Aluminum-based Lightweight Materials for Safety Components**

**EcoTrain**

**NeMoS – Freiluftlabor "Neue Mobilität" am Sachsenring**

**eBEn – eBusiness Engineering**

# Agenda

1. Sustainability – the Managerial Challenges
2. Material Flow Cost Accounting (MFCA) – a Method for Sustainability Management
3. Refinements and Extensions of the MFCA Methodology
4. Conclusions

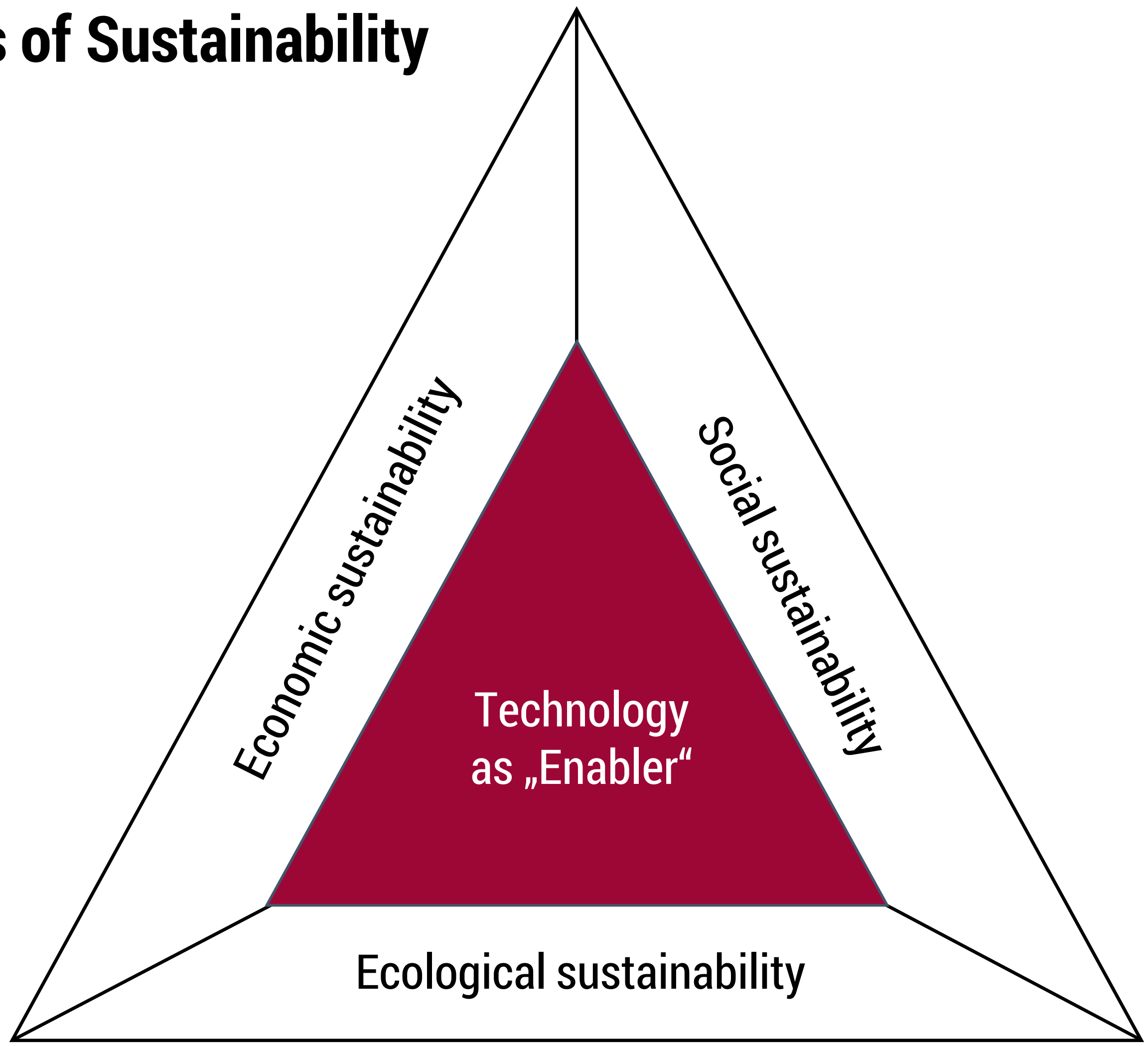
# Sustainability as a global need

- Resource scarcity, pollution, economic crises, demographic change, social distortions etc. call for sustainable thinking and acting of individuals, companies and societies

- "Sustainable development is the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
(United Nations: (Report)).

- „Wird derhalben die größte Kunst/Wissenschaft/Fleiß und Einrichtung hiesiger Lande darinnen beruhen / wie eine sothane Conservation und Anbau des Holtzes anzustellen / daß es eine continuierliche beständige und nachhaltende Nutzung gebe / weiln es eine unentberliche Sache ist / ohne welche das Land in seinem Esse nicht bleiben mag."
(Carlowitz: (Sylviculura), p. 105 f.)

# Dimensions of Sustainability




Source: translated from: Neugebauer and Götze (Bilanzierung), p. 2.

# Highly relevant managerial challenges

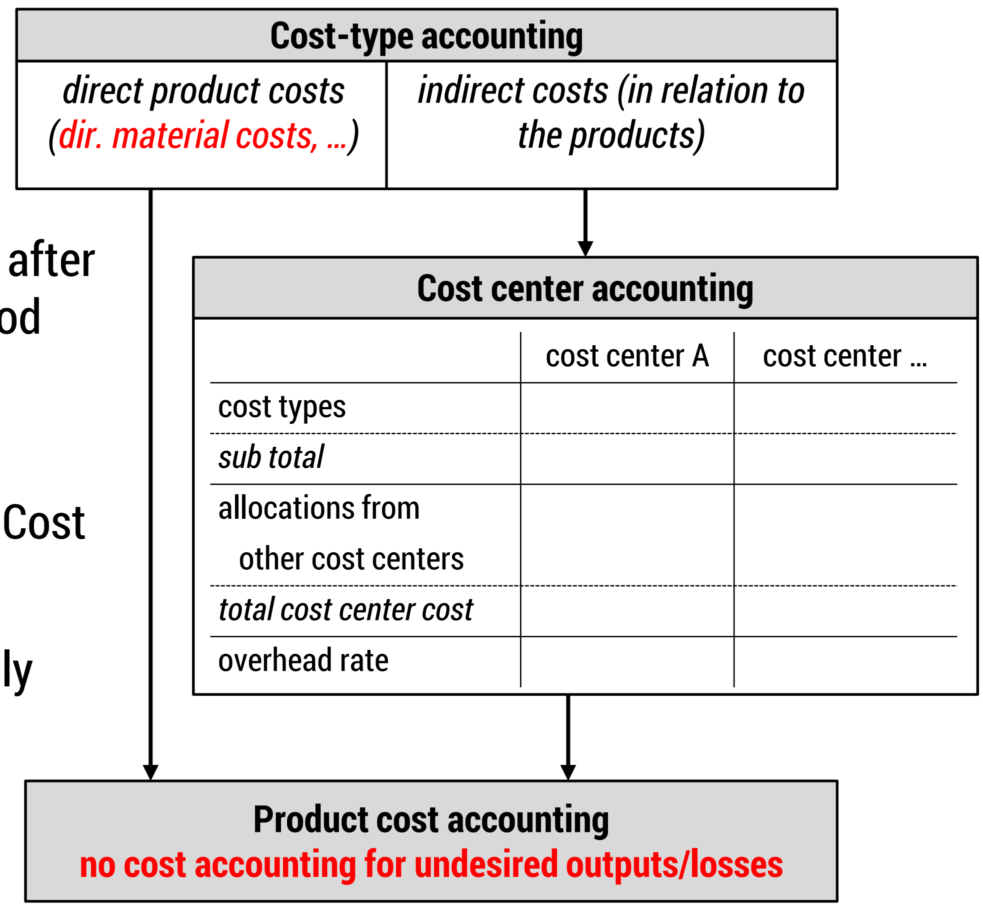
- Establishing long-term thinking
- Developing and implementing methods and measures that foster the achievement of the dimension-related targets: long-term economic success, eco-friendly behavior, social responsibility
- Promoting technological innovations that support the achievement of these targets
- Balancing and integrating the dimension-related targets, methods and measures

→ MFCA contributes to balance and achieve economic and ecological targets

# History and notion

- Late 1990's: The German 'Institut für Management und Umwelt' developed a new concept of cost accounting and initialized few pilot projects
- Beginning in 2000: Breakthrough in Japan, after successful first implementations the method was strongly promoted and more than 300 Japanese companies adopted it
- 2011: ISO standard 14051 – Material Flow Cost Accounting
- Forthcoming: ISO standard 14052 for supply chain-wide Material Flow Cost Accounting

Standard procedure of conventional cost accounting




Source: modified from Sygulla et al. (Tool for Designing), p. 113.

# Profile

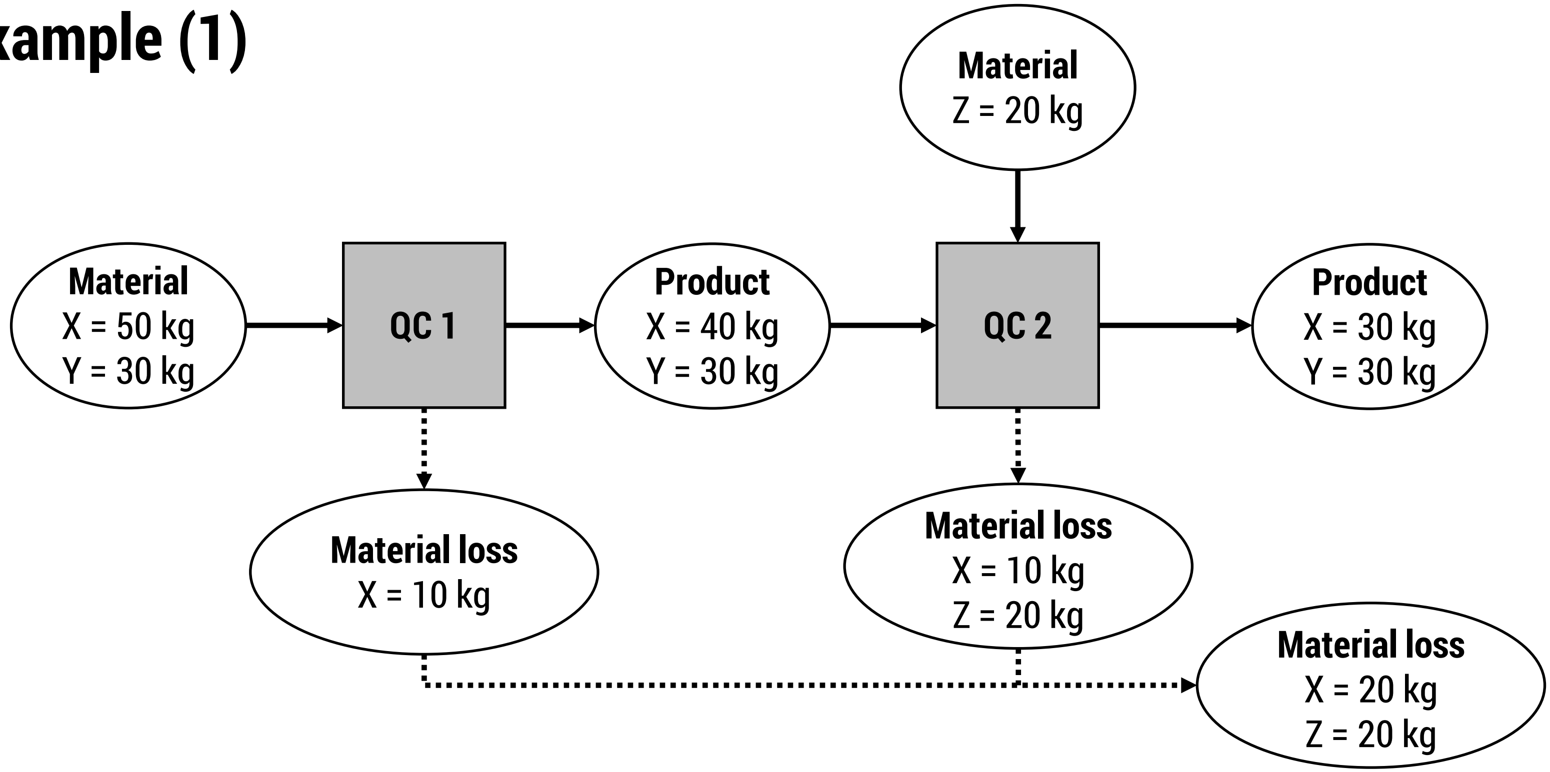
- **Aims:**
  - Identifying material (and energy) inefficiencies with significant economic impact
  - Contributing to an economic **and** ecological sustainable production
- **Characteristics:**
  - Cost accounting approach (one-period analysis)
  - Based on material (and energy) flows
  - Cost carriers: desired *and* undesired flows
- **Steps (*models*)**

  I. Modeling system's flow structure (*flow structure model*)

  II. Quantifying flows in physical units (*flow quantity model*)

  III. Appraising flow system in monetary units (*flow cost model/matrix)*
- **Application scenarios:**
  - Efficiency analysis of existing processes and process chains
  - Design of new processes and process chains contributing

# A simple example (1)




Flow towards products

Flow towards material losses

QC: Quantity Center

| Material costs | |
|---|---|
| Material X | 100 €/kg |
| Material Y | 40 €/kg |
| Material Z | 20 €/kg |

| Quantity center costs | Total | QC 1 | QC 2 |
|---|---|---|---|
| Energy costs | 700 € | 400 € | 300 € |
| System costs | 2,000 € | 800 € | 1,200 € |
| Wast management costs | 700 € | 300 € | 400 € |

Source: modified from DIN EN ISO 14051, p. 46 f.

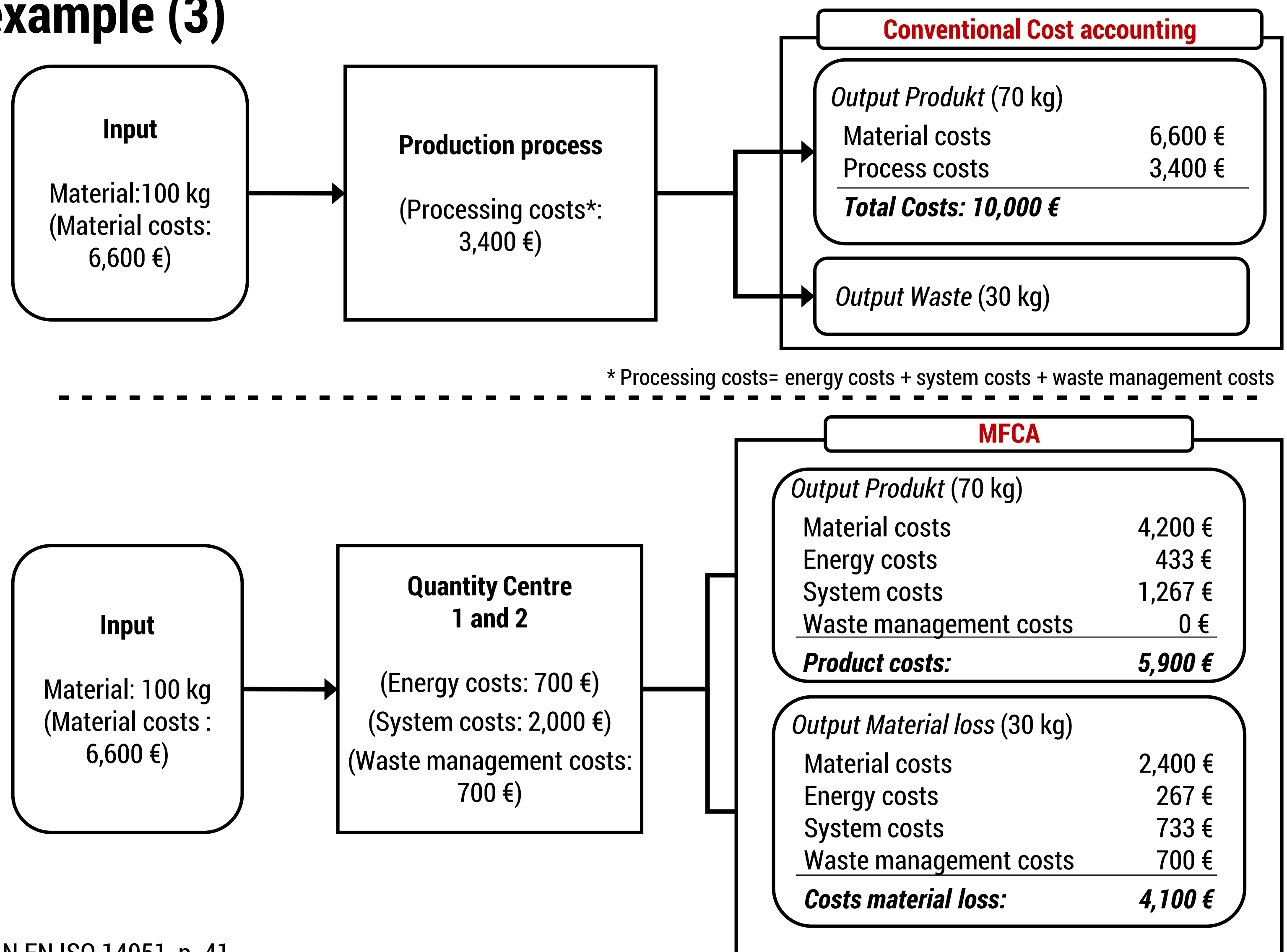
# A simple example (2)

Material flow costs matrix (all values in €)

| | Quantity Center 1 | | | | | Quantity Center 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Material costs | Energy costs | System costs | Waste mgmt. costs | Total QC 1 | Material costs | Energy costs | System costs | Waste mgmt. costs | Total QC 2 |
| Imputs from pervious QC | | | | | | 5,200 | 350 | 700 | | 6,250 |
| New inputs in QC | 6,200 | 400 | 800 | 300 | 7,700 | 400 | 300 | 1,200 | 400 | 2,300 |
| Product flow | 5,200 | 350 | 700 | | 6,250 | 4,200 | 433 | 1,267 | | 5,900 |
| Material loss flow | 1,000 | 50 | 100 | 300 | 1,450 | 1,400 | 217 | 633 | 400 | 2,650 |
| Total costs of material losses | | | | | | 2,400 | 267 | 733 | 700 | 4,100 |
| **Total** | **6,200** | **400** | **800** | **300** | **7,700** | **6,600** | **700** | **2,000** | **700** | **10,000** |

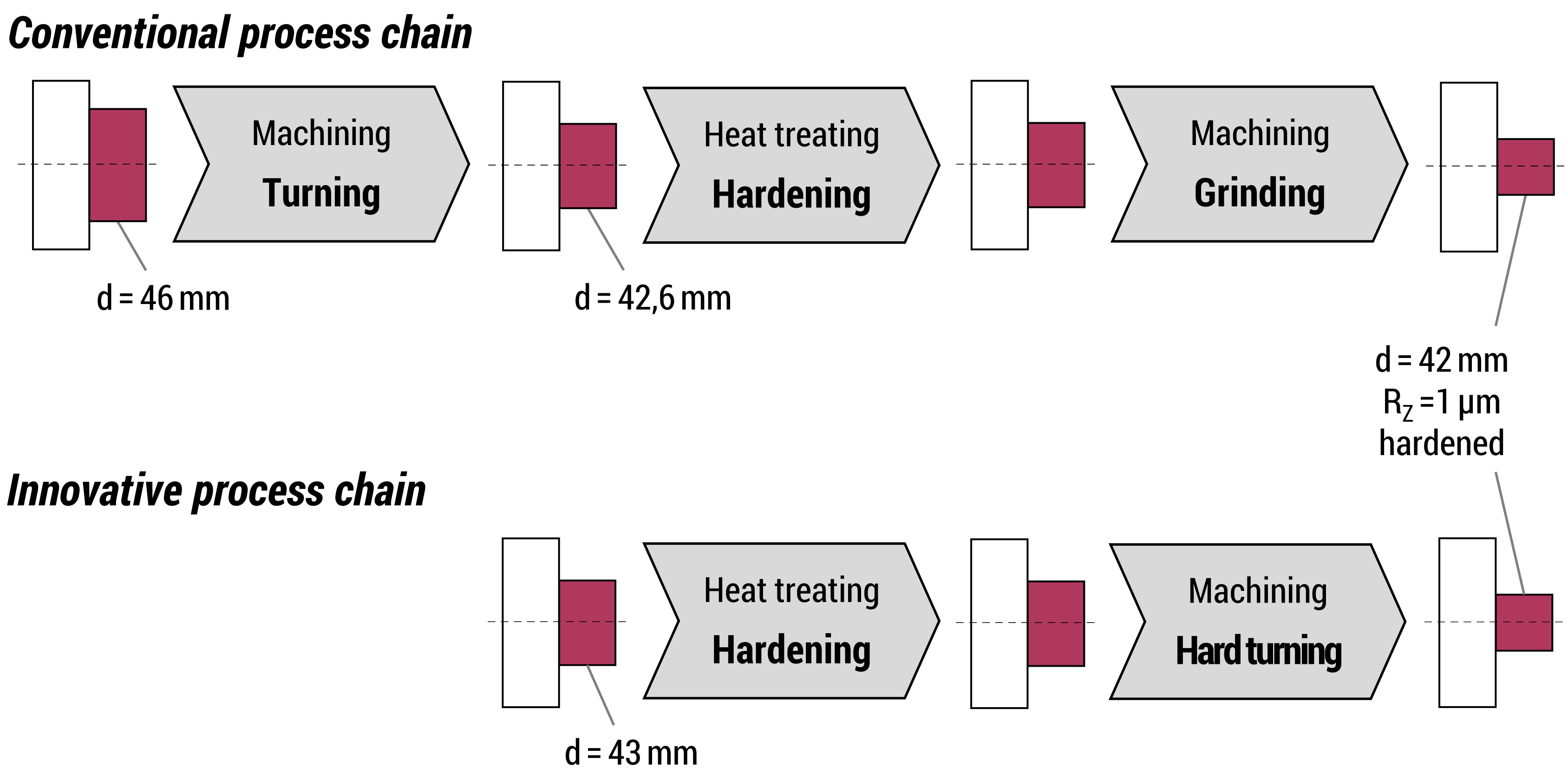
Source: modified from DIN EN ISO 14051, p. 57.

# A simple example (3)




Source: modified from DIN EN ISO 14051, p. 41.

# Use case 1: Bearing surface of a gear shaft




Source: translated from Götze et al.: (Material- und Energieflussanalyse), p. 117. See also Götze and Schmidt: (Innovation Control) p. 104.

# Use case 1: Flow cost analysis of grinding


| Grinding | | | | | |
|---|---|---|---|---|---|
| **Input** | €/Year | **Throughput** | €/Year | **Output** | €/Year |
| **Material (steel)** | | | | **Material (product)** | |
| Material cost | 377,793.12 | **System cost** | 47,095.31 | Material cost | 287,602.44 |
| *(incl. Coolant)* | *88,000.00* | | | | |
| System cost | 78,208.52 | | | System cost | 124,356.60 |
| Energy cost | 2,538.78 | | | Energy cost | 2,640.58 |
| Energy-related system cost | 210.84 | | | Energy-related system cost | 219.26 |
| | | | | **Material loss** | |
| | | | | Material cost | 90,190.68 |
| | | | | *(incl. Coolant)* | *88,000.00* |
| | | | | System cost | 947.23 |
| | | | | Energy cost | 20.11 |
| | | | | Energy-related system cost | 1.67 |
| **Energy** | | | | **Energy loss** | |
| Energy cost | 866.85 | | | Energy cost | 744.94 |
| Energy-related system cost | 1,760.61 | | | Energy-related system cost | 1,750.52 |

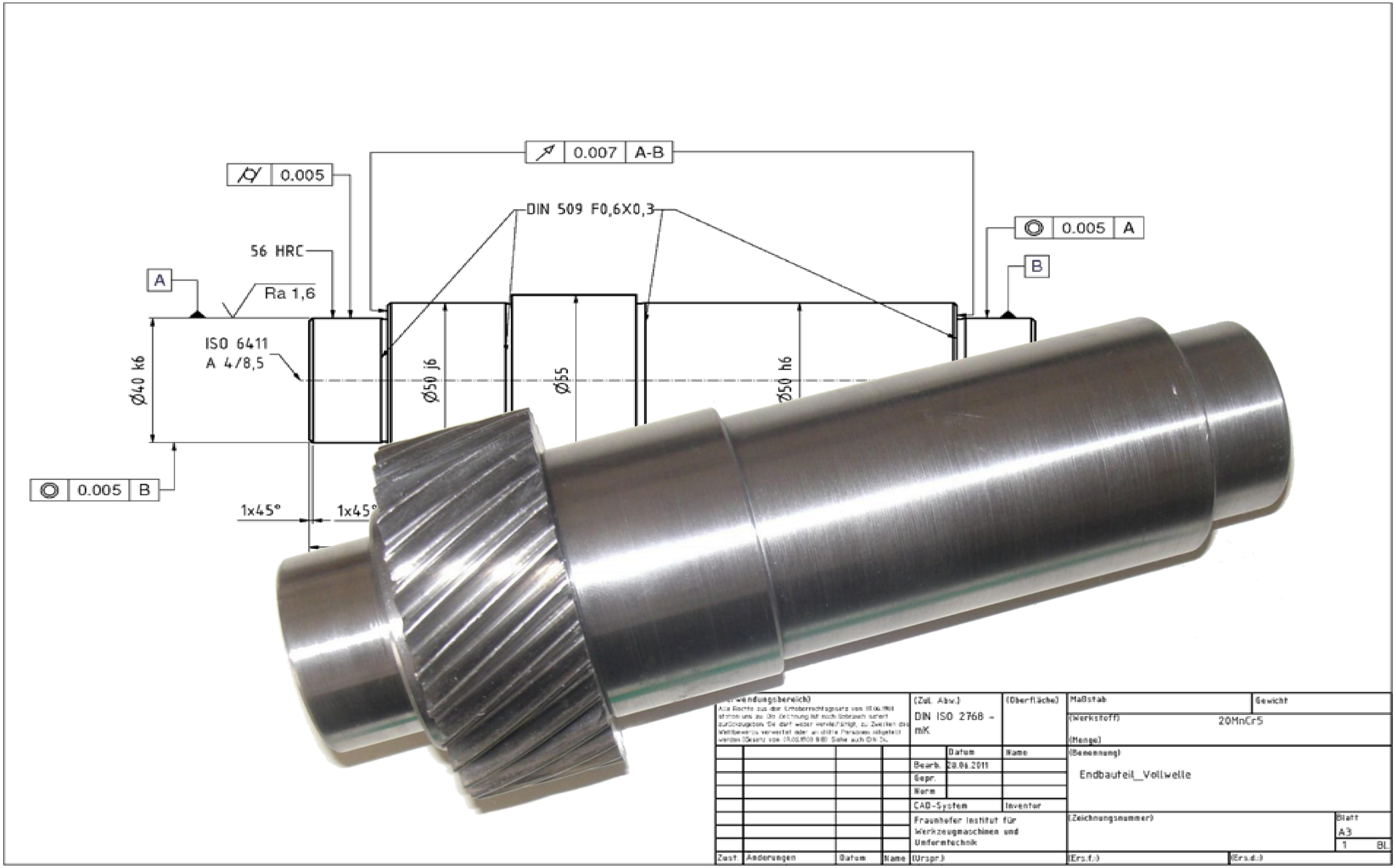
Source: translated from Götze et al. (Material- und Energieflussanalyse), p. 127.

# Use case 1: Comparison of results

| Conventional process cain | | Innovative process cain | |
|---|---|---|---|
| **Product costs** | | **Product costs** | |
| Material costs | 287,602.44 [€/year] | Material costs | 287,602.44 [€/year] |
| System costs | 124,356.60 [€/year] | System costs | 92,438.54 [€/year] |
| Energy costs | 2,640.58 [€/year] | Energy costs | 2,555.51 [€/year] |
| Energy related system costs | 219.26 [€/year] | Energy related system costs | 211.43 [€/year] |
| **Product total costs:** | **414,818.88 [€/year]** | **Product total costs:** | **382,807.92 [€/year]** |
| **Material loss costs** | | **Material loss costs** | |
| Material costs | 103,191.49 [€/year] | Material costs | 3,668.40 [€/year] |
| *included lubricant* | *88,000.00* [€/year] | | |
| System costs | 2,837.07 [€/year] | System costs | 1,179.06 [€/year] |
| Energy costs | 22.99 [€/year] | Energy costs | 32.60 [€/year] |
| Energy related system costs | 1.91 [€/year] | Energy related system costs | 2.70 [€/year] |
| **Material loss total costs:** | **106,053.45 [€/year]** | **Material loss total costs:** | **4,882.75 [€/year]** |
| **Costs „Energy loss“** | | **Costs „Energy loss“** | |
| Energy costs | 1,484.40 [€/year] | Energy costs | 1,191.95 [€/year] |
| Energy related system costs | 2,478.65 [€/year] | Energy related system costs | 2,661.08 [€/year] |
| **Total Costs „Energy loss“** | **3,963.05 [€/year]** | **Total Costs „Energy loss“** | **3,853.04 [€/year]** |

Source: translated from Götze et al.: (Material- und Energieflussanalyse), p. 123.

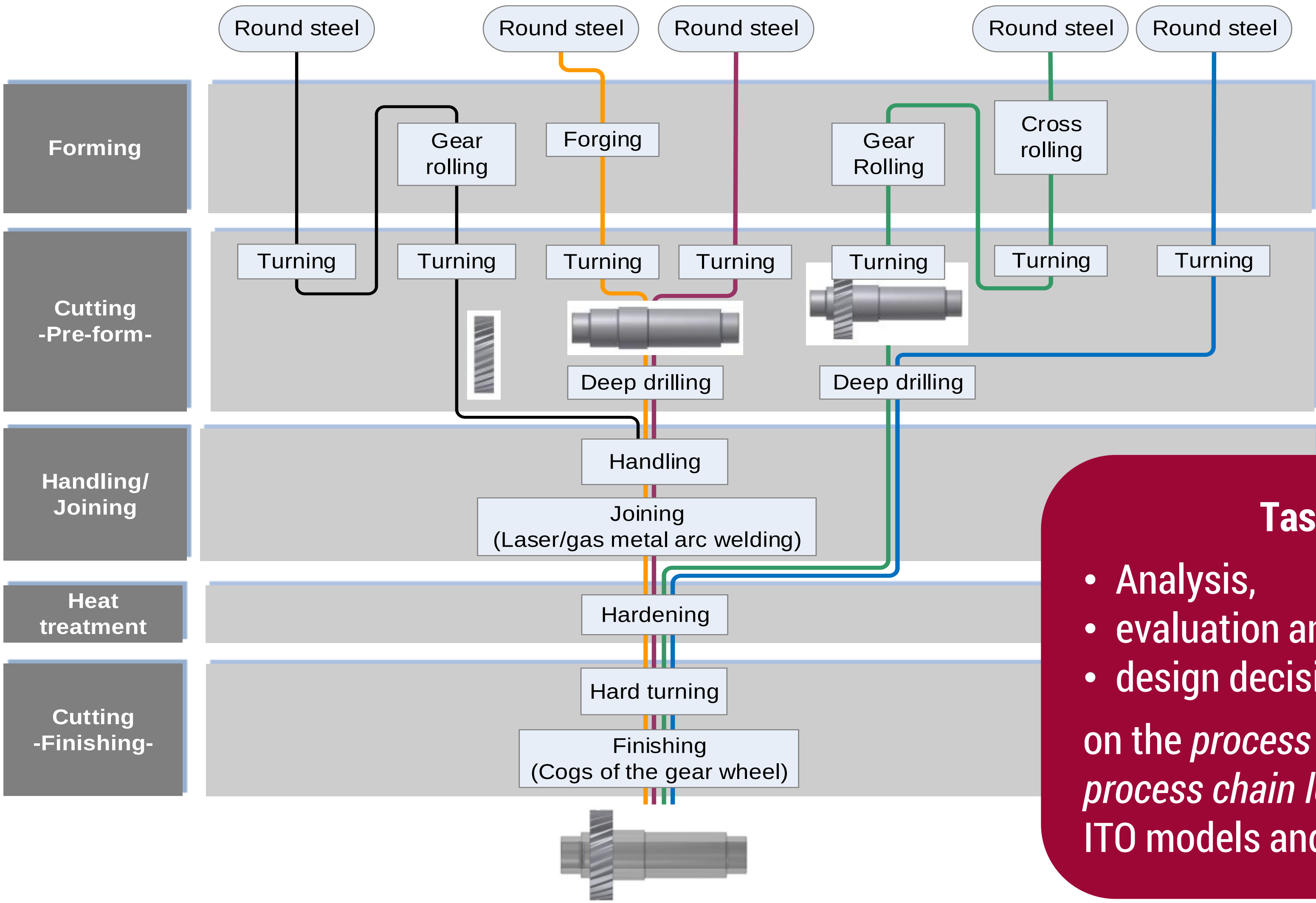
# Use case 2: Demonstrator 'Gear Shaft'



# Use case 2: Manufacturing strategies on the process chain level

| | | Gear wheel and shaft | |
|---|---|---|---|
| | | Separate manufacturing + joining | Integrated form |
| Main form manufactured by | Cutting | I | II |
| | Forming | III | IV |

# Use case 2: Basic process chain configurations




**Tasks:**

- Analysis,
- evaluation and
- design decisions

on the *process* and on the *process chain level* by using ITO models and MFCA

# Use case 2: Joining (process level)

| | III (forming, joining) | |
|---|---|---|
| | Gas metal arc welding | Laser welding |
| **Gear shaft** | | |
| *Mass* | *214,229 kg* | *210,000 kg* |
| *Energy* | *243,311 kWh* | *240,561 kWh* |
| Material cost | 268,389.95 € | 249,436.62 € |
| Energy cost | 26,764.22 € | 26,461.74 € |
| System cost | 1,137,433.59 € | 1,135,127.44 € |
| ***Total cost*** | ***1,432,587.76 €*** | ***1,411,025.80 €*** |
| **Material loss** | | |
| *Mass* | *309,616 kg* | *308,641 kg* |
| *Energy* | *57,748 kWh* | *58,028 kWh* |
| Material cost | 410,165.23 € | 404,070.40 € |
| Energy cost | 6,352.30 € | 6,383.10 € |
| System cost | 859,497.60 € | 862,241.88 € |
| ***Total cost*** | ***1,276,015.14 €*** | ***1,272,695.38 €*** |
| **Energy loss** | | |
| *Energy* | *2,046,750 kWh* | *2,057,611 kWh* |
| ***Energy cost*** | ***236,030.21 €*** | ***237,224.87 €*** |
| **Total** | | |
| *Mass* | *523,846 kg* | *518,641 kg* |
| *Energy* | *2,347,810 kWh* | *2,356,200 kWh* |
| **Total cost** | **2,944,633.10 €** | **2,920,946.06 €** |

## Laser welding

- ✗ Higher depreciations
- ✗ 2.5 times higher (absolute) energy demand
- ✓ No filler material
- ✓ Cycle time is 3 times lower, so
  - ✓ less shielding gas (material cost) and
  - ✓ less labor is needed.

➢ ***Laser welding is favorable here.***

# Use case 2: Results (process chain level)

| | I (cutting, joining) | II (cutting, integrated form) | III (forming, joining) | IV (forming, integrated form) |
|---|---|---|---|---|
| **Gear shaft** | | | | |
| *Mass* | *210.000 kg* | *210.000 kg* | *210.000 kg* | *210.000 kg* |
| *Energy* | *242.150 kWh* | *226.677 kWh* | *240.561 kWh* | *234.951 kWh* |
| Material cost | 249.436,62 € | 249.436,62 € | 249.436,62 € | 249.436,62 € |
| Energy cost | 26.636,53 € | 24.934,48 € | 26.461,74 € | 25.844,59 € |
| System cost | 863.419,60 € | 744.887,72 € | 1.135.127,44 € | 1.111.385,49 € |
| ***Total cost*** | ***1.139.492,75 €*** | ***1.019.258,82 €*** | ***1.411.025,80 €*** | ***1.386.666,70 €*** |
| **Material loss** | | | | |
| *Mass* | *332.644 kg* | *450.916 kg* | *308.641 kg* | *324.981 kg* |
| *Energy* | *63.520 kWh* | *85.596 kWh* | *58.028 kWh* | *71.965 kWh* |
| Material cost | 407.463,20 € | 538.354,12 € | 404.070,40 € | 388.724,65 € |
| Energy cost | 6.987,22 € | 9.415,51 € | 6.383,10 € | 7.916,13 € |
| System cost | 481.918,58 € | 583.208,39 € | 862.241,88 € | 842.466,30 € |
| ***Total cost*** | ***896.369,00 €*** | ***1.130.978,03 €*** | ***1.272.695,38 €*** | ***1.239.107,08 €*** |
| **Energy loss** | | | | |
| *Energy* | *257.481 kWh* | *320.933 kWh* | *2.057.611 kWh* | *2.050.209 kWh* |
| ***Energy cost*** | ***39.217,54 €*** | ***53.380,61 €*** | ***237.224,87 €*** | ***236.172,30 €*** |
| **Total** | | | | |
| *Mass* | *542.644 kg* | *660.916 kg* | *518.641 kg* | *534.981 kg* |
| *Energy* | *563.152 kWh* | *633.206 kWh* | *2.356.200 kWh* | *2.357.125 kWh* |
| **Total cost** | **2.075.079,28 €** | **2.203.617,46 €** | **2.920.946,06 €** | **2.861.946,08 €** |
| **Ranking:** | ① | ② | ④ | ③ |

# Sub-Agenda

## 3.1 Deficits of MFCA Methodology

| Deficits | Approaches for refinements/extension |
|---|---|
| Limitation on full and actual cost | Design of a marginal and/or plan MFCA<br>(for a plan MFCA see Sygulla et al.: (Material Flow Cost Accounting), pp. 4 f and Sygulla et al.: (Tool for Designing), pp. 122 ff.) |
| Use of aggregated cost categories | Refinement of cost categories according to traditional cost accounting<br>(see Sygulla et al.: (Material Flow Cost Accounting), pp. 4 f.) |
| Allocation of overhead costs | Refinement of allocation rules |
| Handling of stocks and internal recycling loops | Pulling out cost of inventories<br>(see Sygulla et al.: (Tool for Designing), p. 116 ff.)<br><br>Pulling out costs of recycled material or linear equation systems<br>(see Viere et al.: (Implications) pp. 654 f.) |

# 3.1 Deficits of MFCA Methodology (2)

| Deficits | Approaches for refinements/extension |
| --- | --- |
| Neglecting energy flows | Modeling of energy flows and costs *(see 3.2)* |
| Neglecting revenues and other differing outputs | Inclusion of revenues and other differing outputs via virtual quantity centers *(see 3.3)* |
| Neglection of investments and limitation on one period | MFCA-based investment appraisal *(see 3.4)* |
| Problems of data acquisition, divergences between MFCA and traditional cost accounting | Integration with traditional cost accounting *(see 3.5)* |
| Focus on manufacturing processes | Life-cycle wide MFCA *(see 3.6)* |

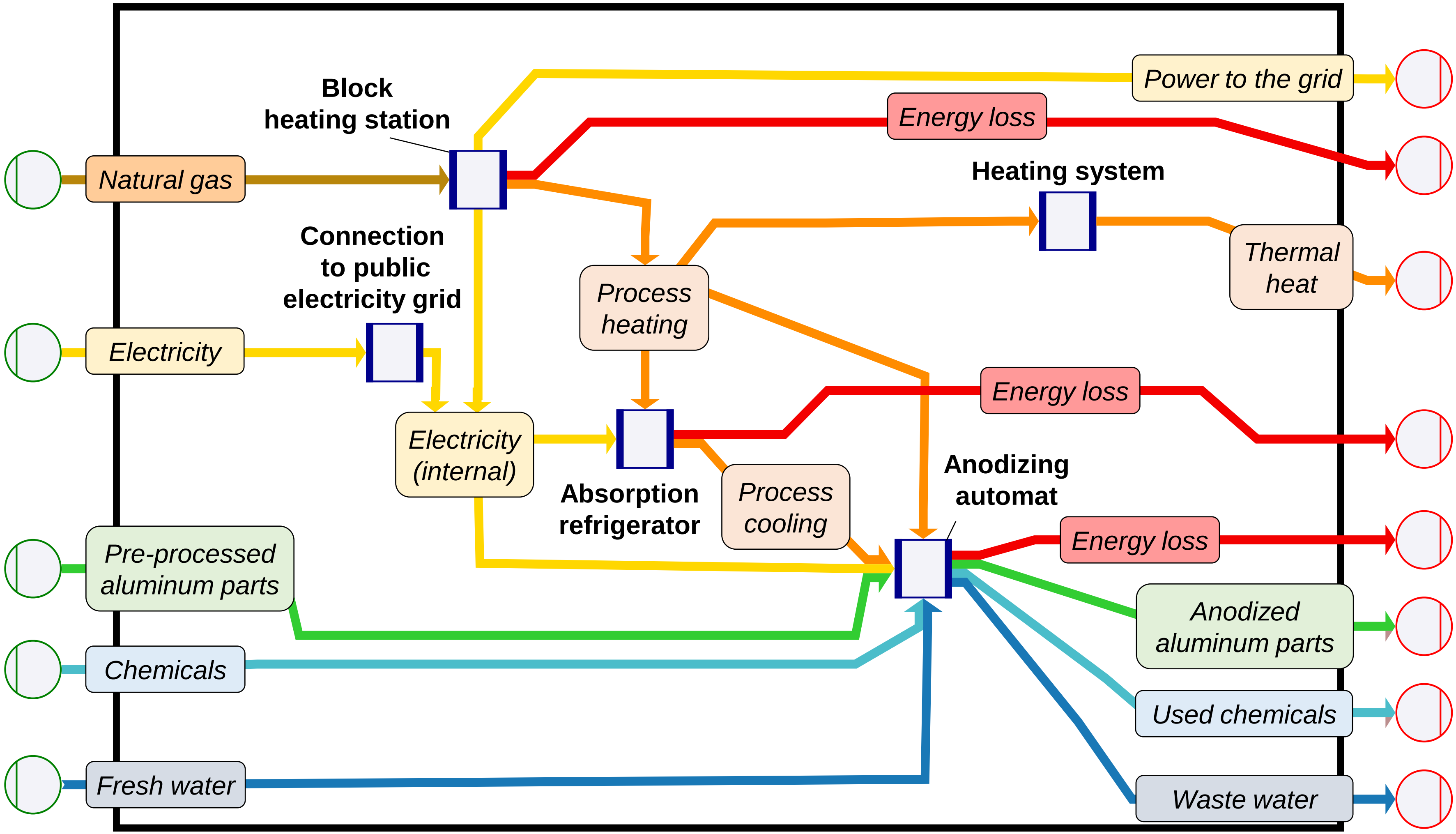
# Motivation, deficits and approach

- **Motivation:**
  - General necessity to reduce energy consumption
  - Energy costs as a major cost item in some industries
- **Deficits:**
  - Energy is only considered via a cost category
  - No separate modeling of energy flows → inaccuracies
- **Approach**
  - Step 1: Separate modeling of energy flows: introduction of energy quantity centers, no focus on energy carriers (as “material”), including electricity; differentiating between desired (active energy, “embodied” energy) and undesired energy output (energy loss)
  - Step 2: Using energy units; “measuring” energy flows, including the amount of active energy in production processes
  - Step 3: Treating energy costs as direct costs, formulating specific allocation rules

# Use case 'Anodizing of Aluminum Parts'

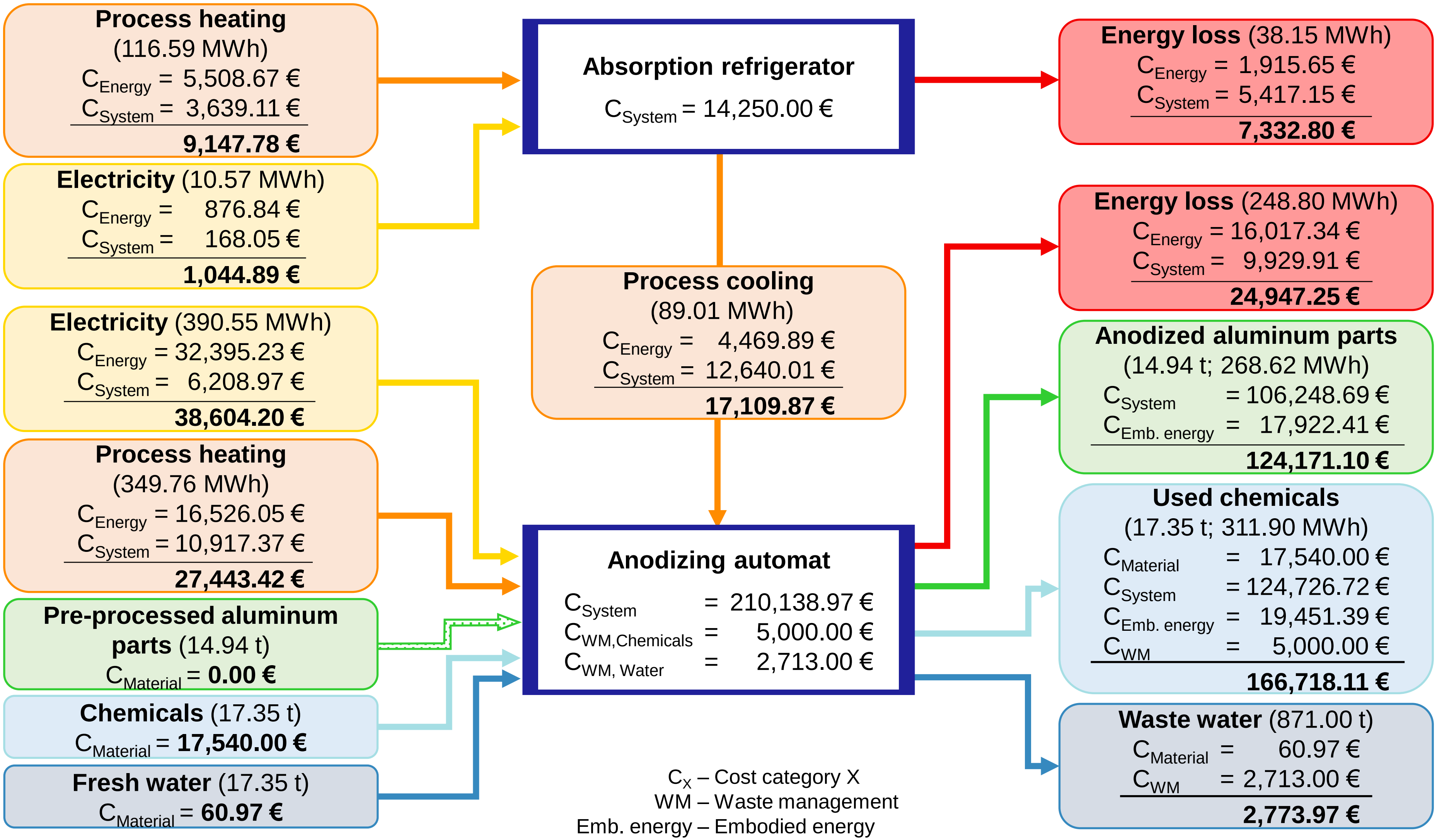
- **Industrial partner:**
  - small-sized company with approximately 25 employees
  - focusing anodizing of aluminum parts
  - Anodizing: "[f]orming a conversion coating on a metal surface by anodic oxidation"; "frequently applied to aluminum" (Davis: (Metals), p. 5)
- **Challenge:**
  - high consumption of resources (particularly energy) by anodizing
  - re-configuration of the process chain consisting of the anodizing process and its auxiliary processes (e. g., supply of electricity, heating, and cooling) was considered
  - method for enabling the identification and valuation of inefficiencies and supporting decision-making about different process chain configurations was needed → MFCA
- **Alternatives**
  - I: Hand-feeding device
  - II: Anodizing automat (and hand-feeding device for special parts)
  - III: Anodizing automat/block heating station (and hand-feeding device for special parts)

## 3.2 Modeling of energy flows and costs



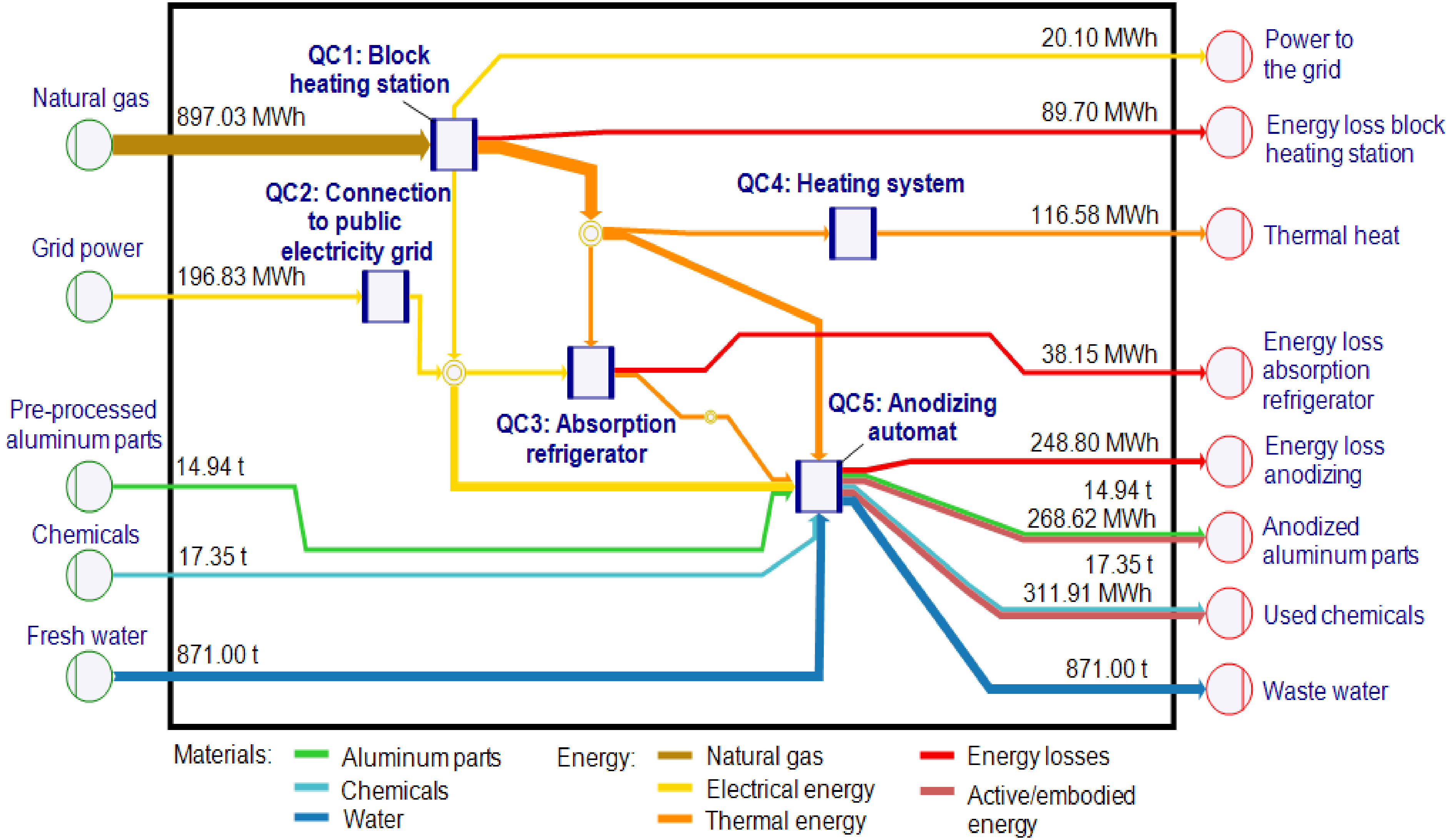

Source: Schmidt et al.: (Extending the scope), p. 4.

## 3.2 Modeling of energy flows and costs



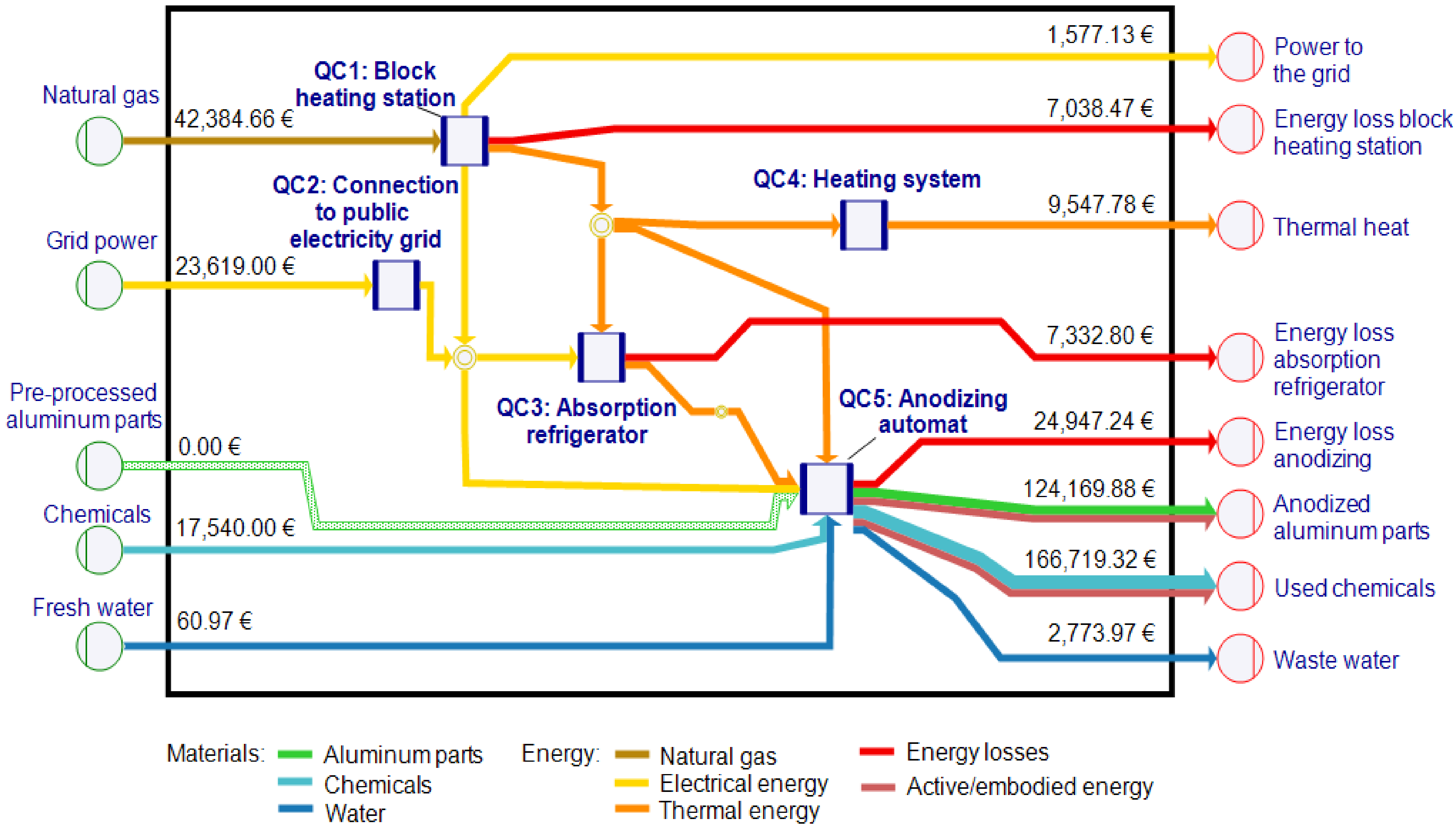

Source: Schmidt et al.: (Extending the scope), p. 6.

## 3.2 Modeling of energy flows and costs




Source: Schmidt et al.: (Extending the scope), p. 7.

# 3.2 Modeling of energy flows and costs

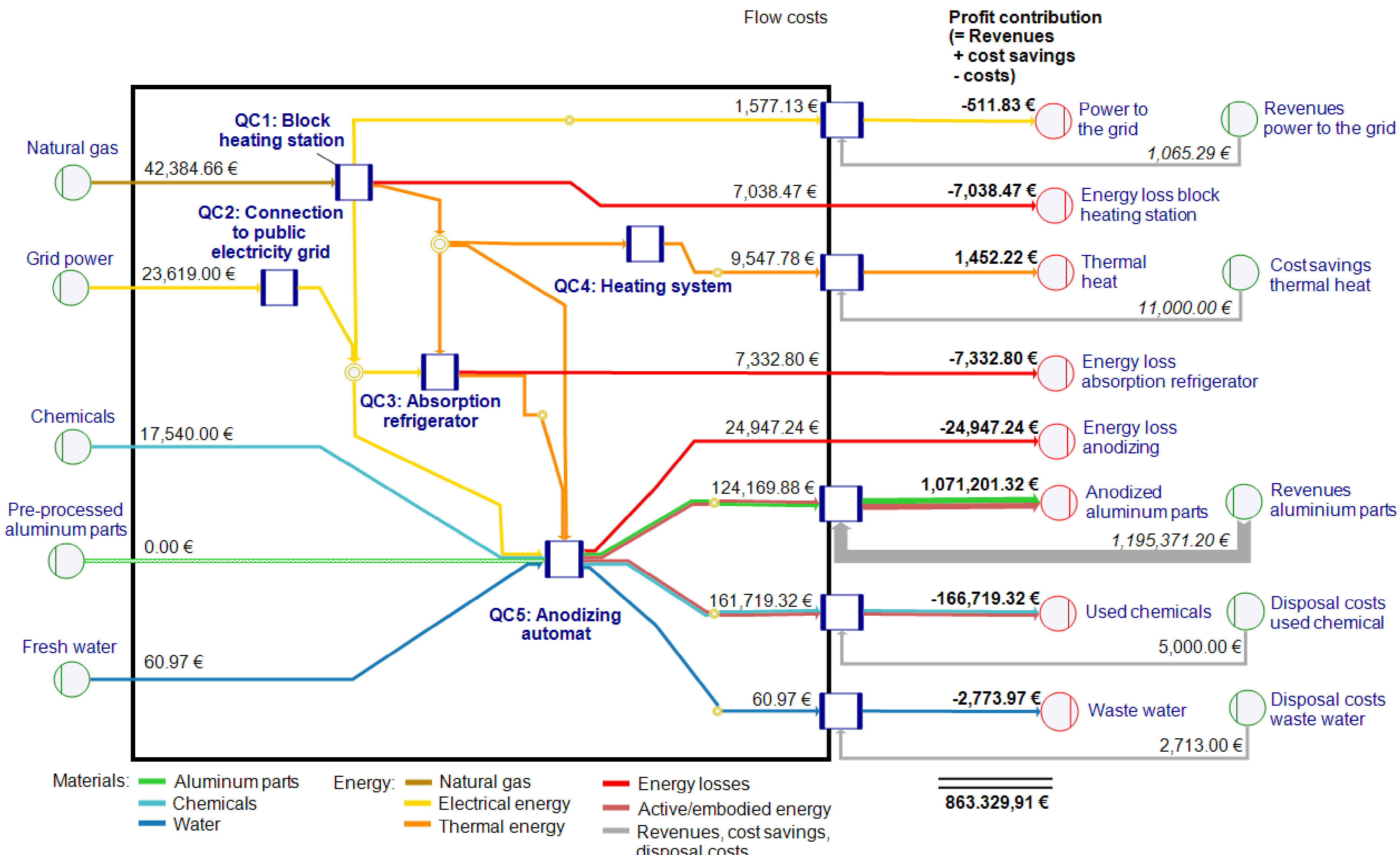



Source: Schmidt et al.: (Extending the scope), p. 8.

# Motivation, deficits and approach

- **Motivation:**
  - Revenues (e. g., for waste) influence the “degree of ineffectiveness” of process chains
  - Revenues and other differing outputs (e. g., causing costs in subsequent processes) influence the profitability of competing process chain alternatives
- **Deficits:**
  - Revenues are neglected in MFCA
  - Waste management costs are the only “internalized” form of other differing outputs
  - If outputs and revenues differ, the profitability of alternatives cannot be compared
- **Approach**
  - Step 1: Introducing additional “virtual output quantity centers”
  - Step 2: –
  - Step 3: Displaying the revenues and other monetary consequences of differing outputs at the virtual output quantity centers and calculating a profit contribution

# 3.3 Inclusion of non-identical outputs and revenues




Source: Schmidt et al.: (Extending the scope), p. 9.

# Motivation, deficits and approach

- **Motivation:**
  - Improvements of process chains often imply investment needs
  - Investment costs/payments influence the profitability
- **Deficits:**
  - MFCA generates static, one period models
  - The inclusion of investment costs/payments is not conceptualized
- **Approach**
  - Embedding the results of MFCA in an investment appraisal approach
  - Transferring costs and revenues into cash inflows and outflows, forecasting for the economic life of the investment
  - Using a method of dynamic investment appraisal, e. g. the net present value method

# Net present value method

## Net present value

$$NPV = \sum_{t=0}^{T} (CIF_t - COF_t) \cdot (1+i)^{-t}$$

NPV…Net present value
$CIF_t$…Cash inflow
$COF_t$…Cash outflow
i…interest rate

## Net present value of differential investment

$$NPV_{Diff} = NPV_A - NPV_B$$
$$= \sum_{t=0}^{T} ([CIF_{tA} - COF_{tA}] - [CIF_{tB} - COF_{tB}]) \cdot (1+i)^{-t}$$

## Transformation from profit to net cash flows

Profit (= revenues – costs)
\+ Costs, not cash outflows (e. g., depreciation, set up of accruals, consumption of material that had already been paid)
– Revenues, not cash inflows (e. g., sale on credit)
– Cash outflows, not costs (e. g., cash purchase and storing of material)
\+ Cash inflows, not revenues (e. g., payment of an account)
=Net cash flows

## Transformation from profit to net cash flows

| | |
|---|---|
| 863,329.91€ | Profit contribution |
| + 96,866.67 € | Depreciation |
| + 36,325.00 € | Imputed interest |
| = 996,521.58 € | Net cash flows |

## Cash flows and net present value

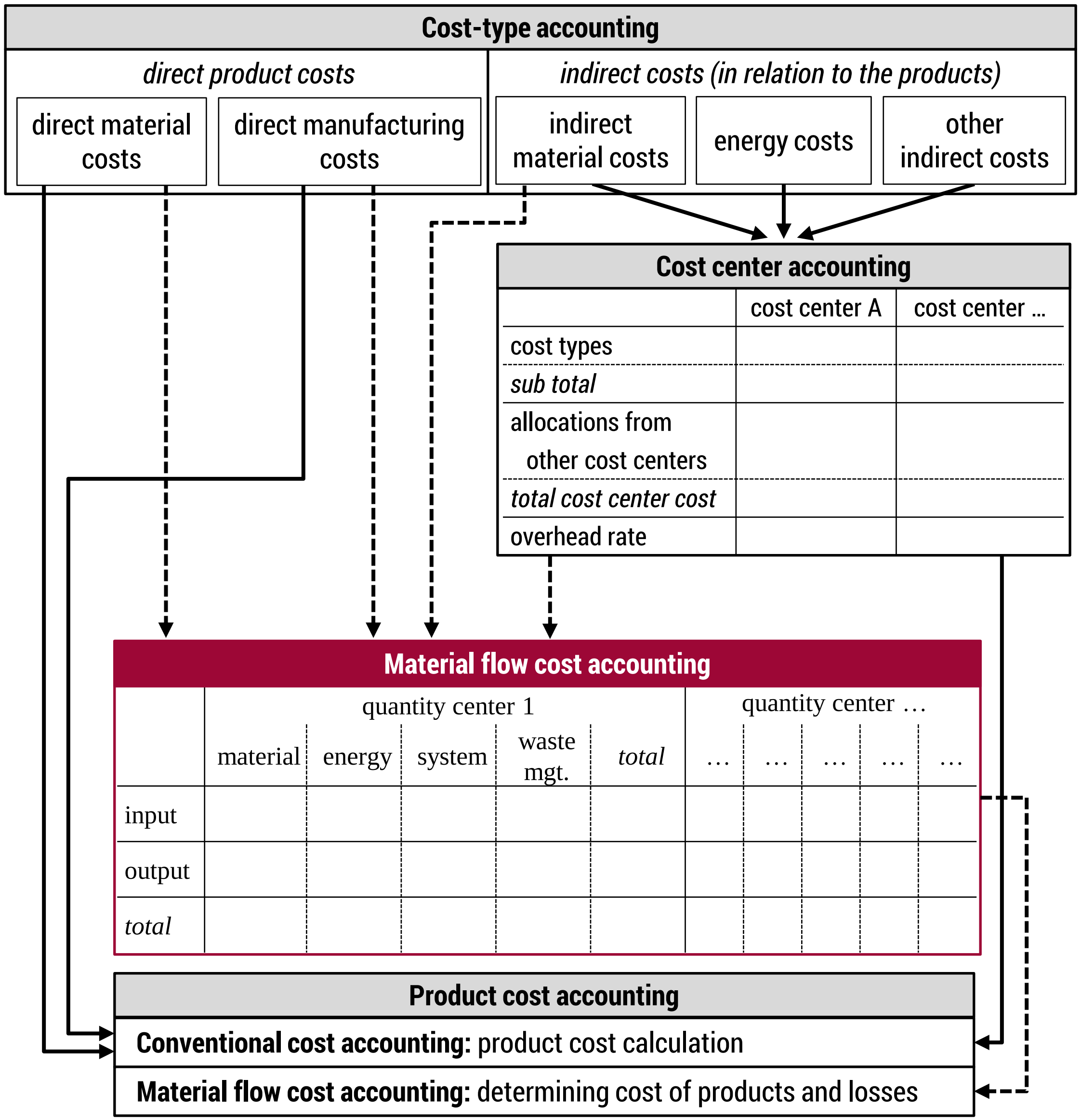
| t | 0 | 1 | 2 | 3 | … | 11 | 12 |
|---|---|---|---|---|---|---|---|
| $(CIF_{III} - COF_{III}) - (CIF_{I} - COF_{I})$ | -1,450,000.00 € | 237,358.34 € | 242,105.50 € | 246,947.61 € | … | 289,338.49 € | 495,125.26 € |

$$NPV_{Diff} = -1{,}450{,}000.00\,€ + (237{,}358.34\,€) \cdot 1{,}1^{-1} + (242{,}105.50\,€) \cdot 1{,}1^{-2} + \ldots + (495{,}125.26\,€) \cdot 1{,}1^{-12}$$
$$= 381{,}746.34\,€$$

# Motivation, deficits and approach

- **Motivation:**
  - Two separate cost accounting systems will hardly be accepted
  - Two separate cost accounting systems will cause inconsistencies and double efforts of data acquisition
- **Deficits:**
  - MFCA´s structuring of the analyzed system (flows and quantity centers), definition of cost carriers (desired and undesired flows), categorization of cost items, and allocation rules differ from that of traditional cost accounting
  - No decision support for program and pricing decisions ("total" costs of products are not displayed)
- **Approach**
  - Embedding the analyzed flow system into the cost center structure of traditional cost accounting
  - Harmonization of 'labeling' of the single cost items
  - Harmonization of the cost allocation rules
  - Integrated analysis of cost carriers (flows and products)

# 3.5 Integration with Traditional Cost Accounting

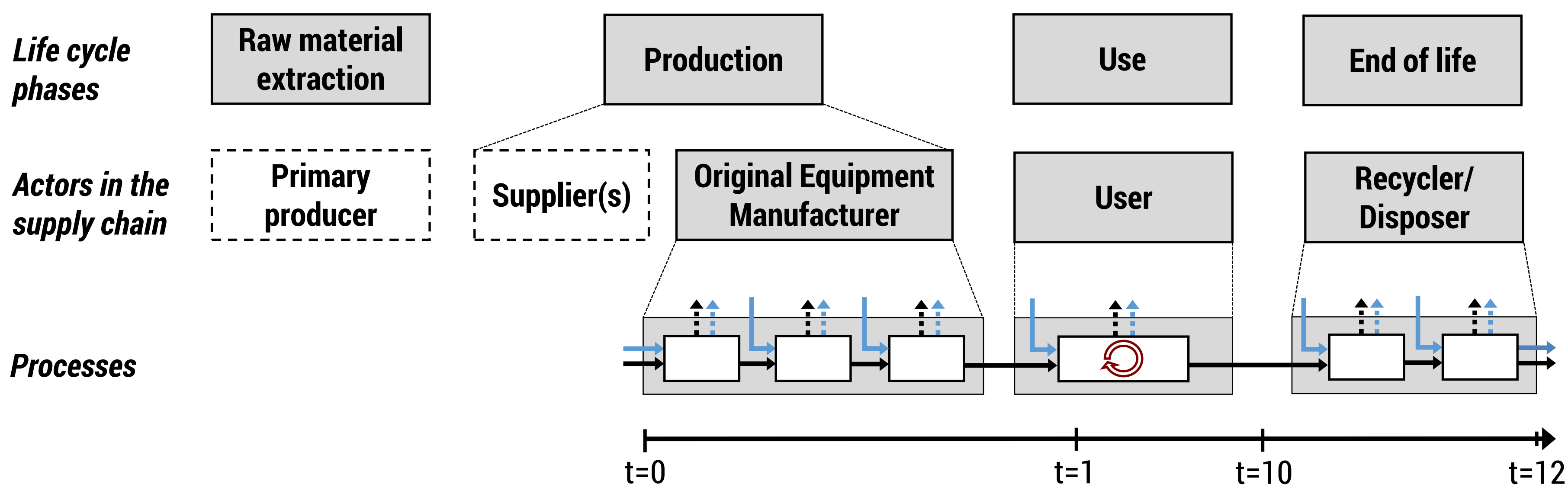



Source: Sygulla et al.: (Tool for Designing), p. 113.

# Motivation, deficits, and approach

- **Motivation:**
  - MFCA shows potential for the identification of inefficiencies in **all life cycle phases**
  - MFCA may be used as tie between life cycle costing and life cycle assessment
- **Deficits:**
  - MFCA is limited to the manufacturing phase
- **Approach**
  - Extending the application of MFCA to the entire life cycle
  - Phase-specific flow modeling
  - Using a method of dynamic investment appraisal, e. g., the net present value method, for economic considerations
  - Transferring costs and revenues into cash inflows and outflows, forecasting for the life cycle

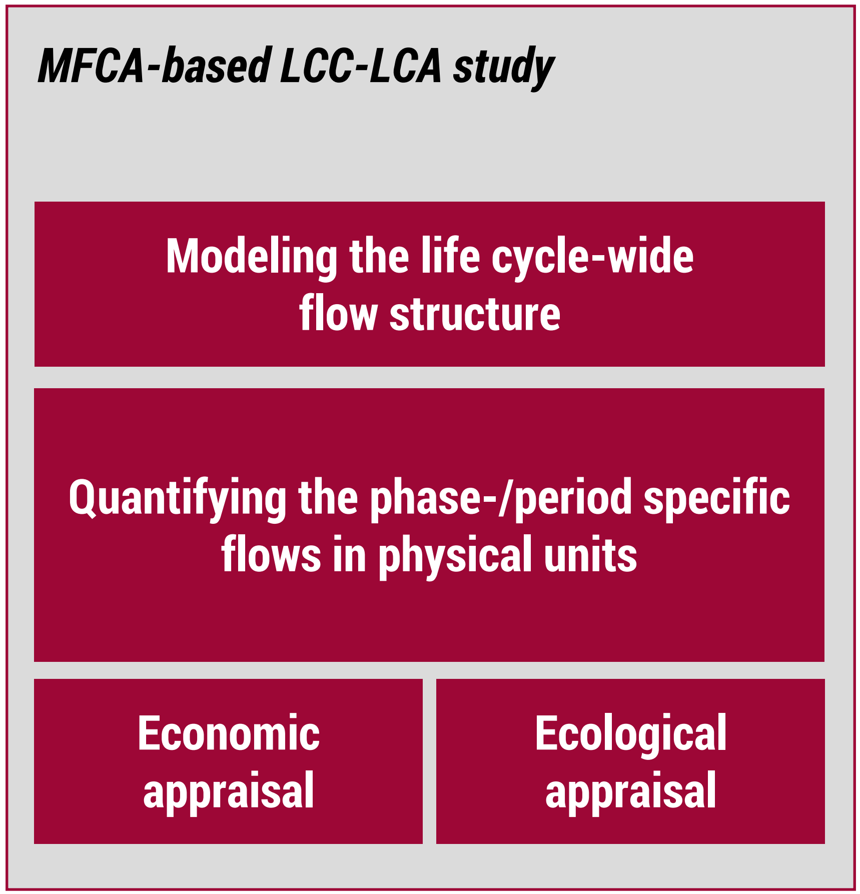
# Life cycle-wide flow modeling




→/- - ► Desired/undesired material flow →/- - ► Desired/undesired energy flow t – point in time

Source: modified from Bierer et al.: (Integrating), p. 9.

# MFCA as a tie between life cycle costing (LCC) and life cycle assessment (LCA)




Source: modified from Bierer et al.: (Integrating), p. 9.

# 4. Conclusions

- MFCA is a promising tool enabling management of sustainability
- MFCA is still in an early phase of its own life cycle
- Some methodical refinements and extensions for reducing existing deficits have been presented
- Further theoretical work should focus on allocation rules, life cycle-wide modeling, etc.
- Intense application of MFCA is necessary for gaining experiences, competencies and inspiration for further development

# Literature


Bierer, A., et al.: (Integrating) life cycle costing and life cycle assessment using extended material flow cost accounting, Journal of Cleaner Production, 2014. DOI: 10.1016/j.jclepro.2014.08.036

Carlowitz, H. C. von: (Sylviculura) Oeconomica oder Hausswirthliche Nachricht und Naturmäßige Anweisung zur Wilden Baum-Zucht, Leipzig 1713.

Davis, J.R. (Ed.): (Metals) Handbook, 2nd ed., 3rd print, ASM International, Materials Park, Ohio, 2006.

DIN EN ISO 14051:2011-12: Environmental management – Material flow cost accounting – General framework

Götze, U., Schmidt, A.: (Innovation Control) - Framework, Methods, and Applications, in: Nistor, R.; Zaharie, M.; Gavrea, C. (Hrsg.): Managerial Challenges of the Contemporary Society, Jg. 5, Cluj-Napoca (Romania), 2013, S. 100-105.

Götze, U., et al.: (Material- und Energieflussanalyse) – Methodik zur Optimierung von Prozessen und Prozessketten, in: R. Neugebauer (ed.): Ressourceneffiziente Technologien für den Powertrain – Proceedings of International Chemnitz Manufacturing Colloquium ICMC 2012/2nd International Colloquium of the Cluster of Excellence eniPROD, Auerbach, 2012, pp. 99–128.

Neugebauer, R., Götze, U.: Energetisch-wirtschaftliche (Bilanzierung) – Herausforderungen und Erkenntnisse, in: Neugebauer, R., et al. (eds.): (Energy-related) and Economic Balancing and Evaluation – Results from the Cluster of Excellence eniPROD, 3rd workbook of the cross-sectional group 'Energy-related and economic evaluation' of the Cluster of Excellence eniPROD, Auerbach, 2014, pp. 1–9.

Schmidt, A., et al.: (Extending the scope) of Material Flow Cost Accounting e methodical refinements and use case, Journal of Cleaner Production, 2014. DOI: 10.1016/j.jclepro.2014.10.039

Sygulla, R. et al.: (Material Flow Cost Accounting) – Proposals for Improving the Evaluation of Monatery Effects of Resource Saving Processes, 44th CIRP International Conference on Manufacturing Systems, 2011. URL: www.tu-chemnitz.de/wirtschaft/bwl3/DownloadAllgemeinOffen/Publikationen/44thCIRP_MFCA.pdf [2014-11-14]

Sygulla, R., et al.: Material Flow Cost Accounting: A (Tool for Designing) Economically and Ecologically Sustainable Production, in: E. Henriques et al. (eds.), Technology and Manufacturing Process Selection, London, 2014.

United Nations: (Report) of the World Commission on Environment and Development: Our Common Future, 1987. URL: www.un-documents.net/wced-ocf.htm [2014-11-14]

Viere, T. et al.: (Implications) of Material Flow Cost Accounting for Life Cycle Engineering, in: Hesselbach, J., Herrmann, C. (Eds.): Glocalized Solutions for Sustainability in Manufacturing: Proceedings of the 18th CIRP International Conference on Life Cycle Engineering, Berlin, 2011, pp. 652–656.

**Prof. Dr. Uwe Götze**
Technische Universität Chemnitz
Faculty of Economics and Business Administration
Professorship of Management Accounting and Control
09107 Chemnitz

E-mail: uwe.goetze@wirtschaft.tu-chemnitz.de