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Creating a Resource Efficient India

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Resource Efficiency and Circular Economy in the Indian Context

Module 4

Tools, standards and indicators for RE and CE:

Material Flow Analysis

adelphi | Confederation of Indian Industry | CII-ITC Centre of Excellence for Sustainable Development | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH | teri

Course overview

Basic modules

1	Introductory session
2	Foundations of RE and CE in the international context
3	Towards RE and CE through sectoral strategies in India

Applied and advanced modules

4	Tools, standards and indicators for RE and CE
4a	Material Flow Analysis
4b	Life Cycle Assessment
4c	RE and CE Standards
4d	RE and CE Indicators
4e	Public Procurement
4f	Circular Business Models
4g	RE and CE Funding

Recap and evaluation

5	Summary, outlook and evaluation

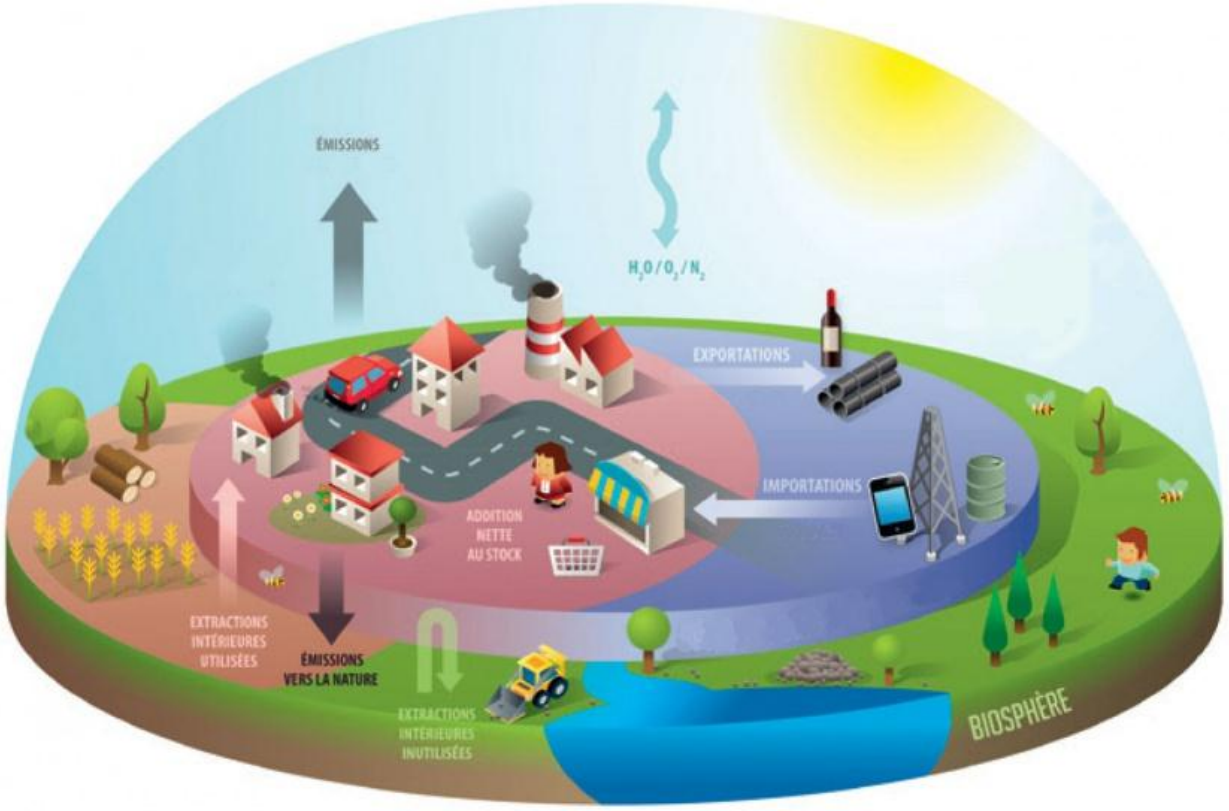
Learning objectives: module 4a

After completion of module 4a, participants will be able to

- relate to salient features of MFA as a decision-making support tools;
- define the steps of MFA;
- describe and illustrate techniques of analysing and documenting material flows.

Material Flow Analysis

Material Flow Analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time.



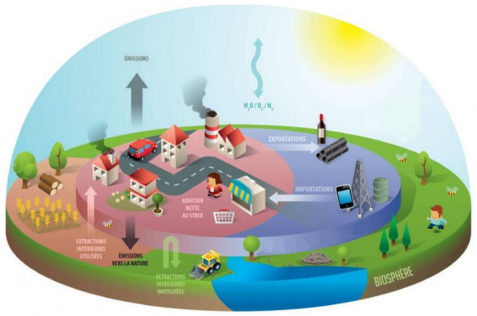
Picture source: https://sofiesgroup.com/wp-content/uploads/2016/04/MFA_Alsace_MetabolismeTerritoire-900x600.jpg

Material Flow Analysis

Material Flow Analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time.

Systemic assessment with the following main steps:

1. **Identification** of relevant material flows
2. **System analysis**
3. **Quantification** of mass flows of matter and indicator substances
4. **Identification** of weak points
5. **Development and evaluation** of scenarios, **interpretation** of the results



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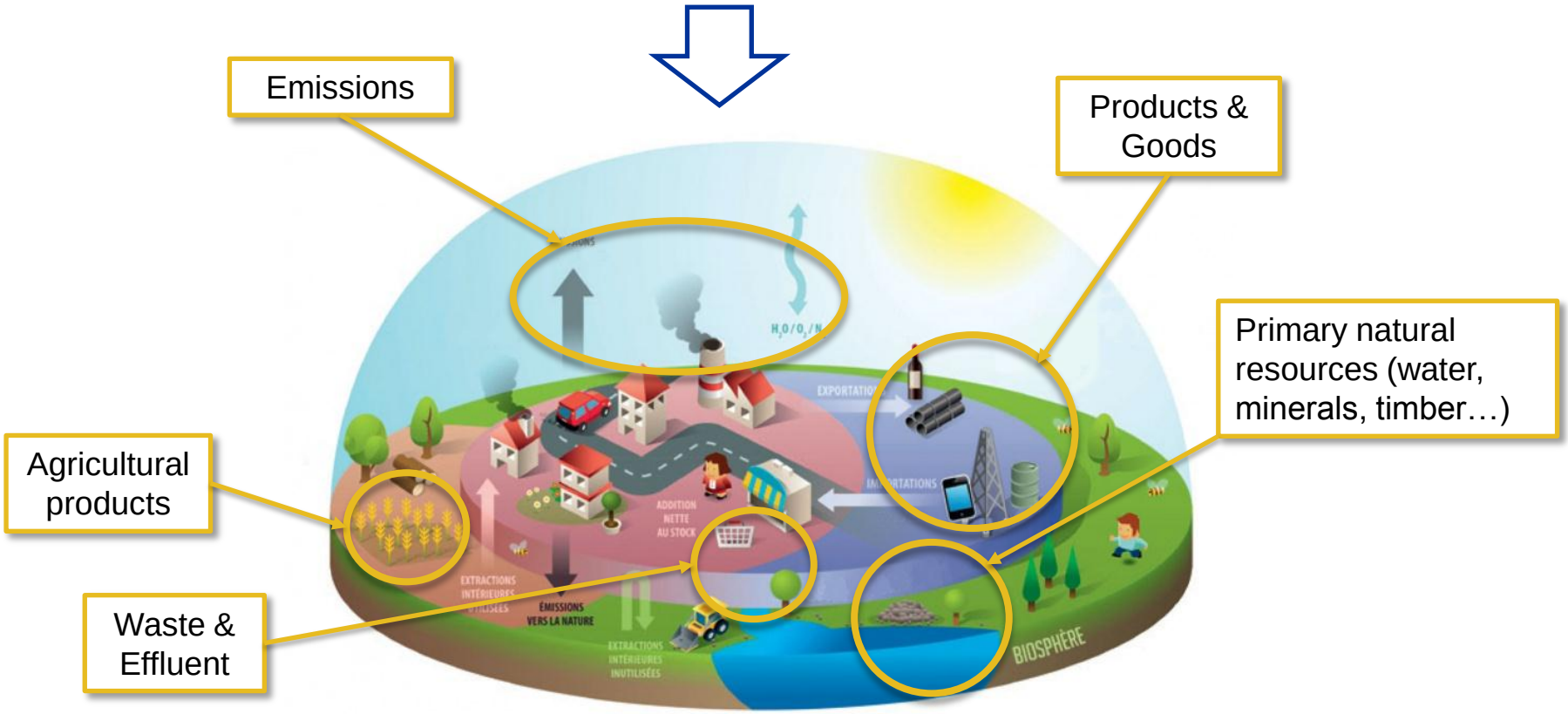

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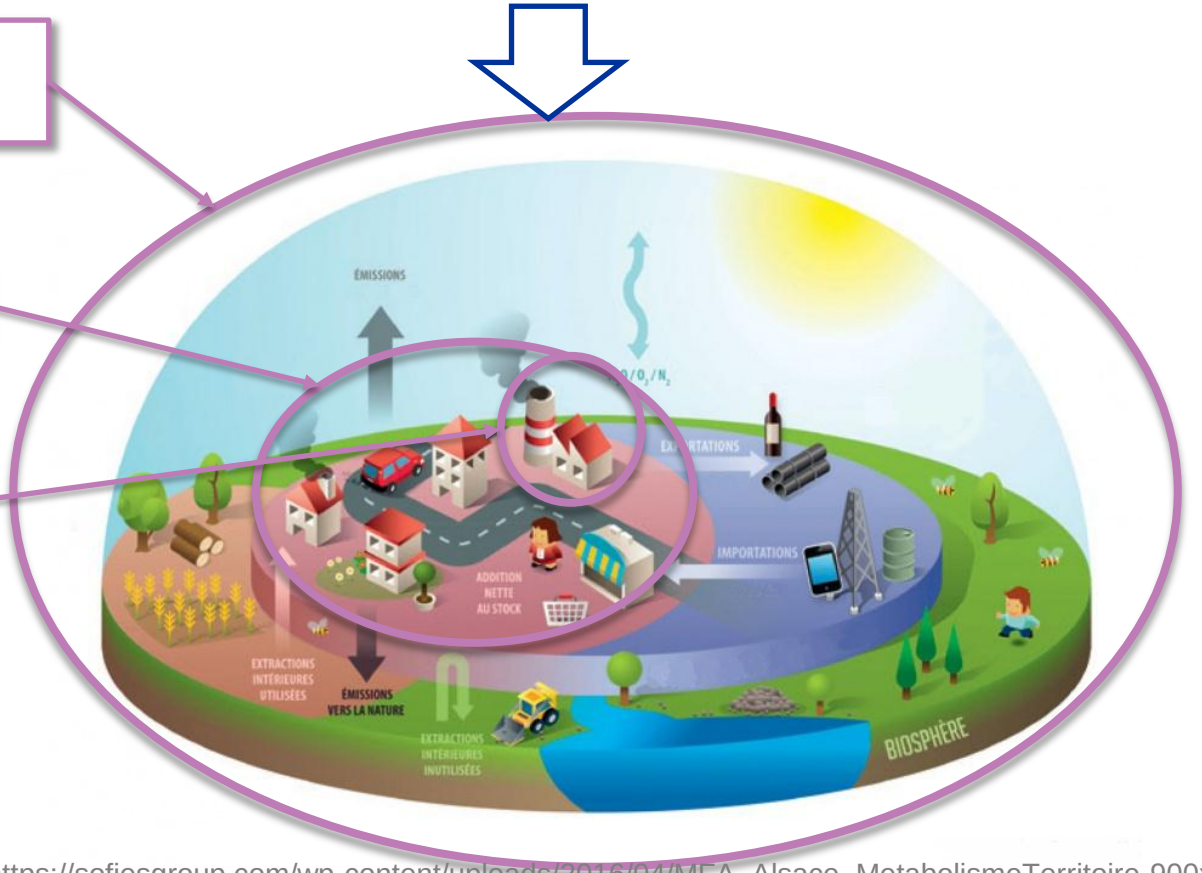
Material Flow Analysis

Material Flow Analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time.

Globally or nation-wide

City-level

Industry/ Company-level



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Material Flow Analysis

Objectives:

- Reducing complexity of systems
- Quantitative assessment of relevant flows and stocks
- Checking mass balances, sensitivities and uncertainties
- Providing basis for decision making

Material Flow Analysis

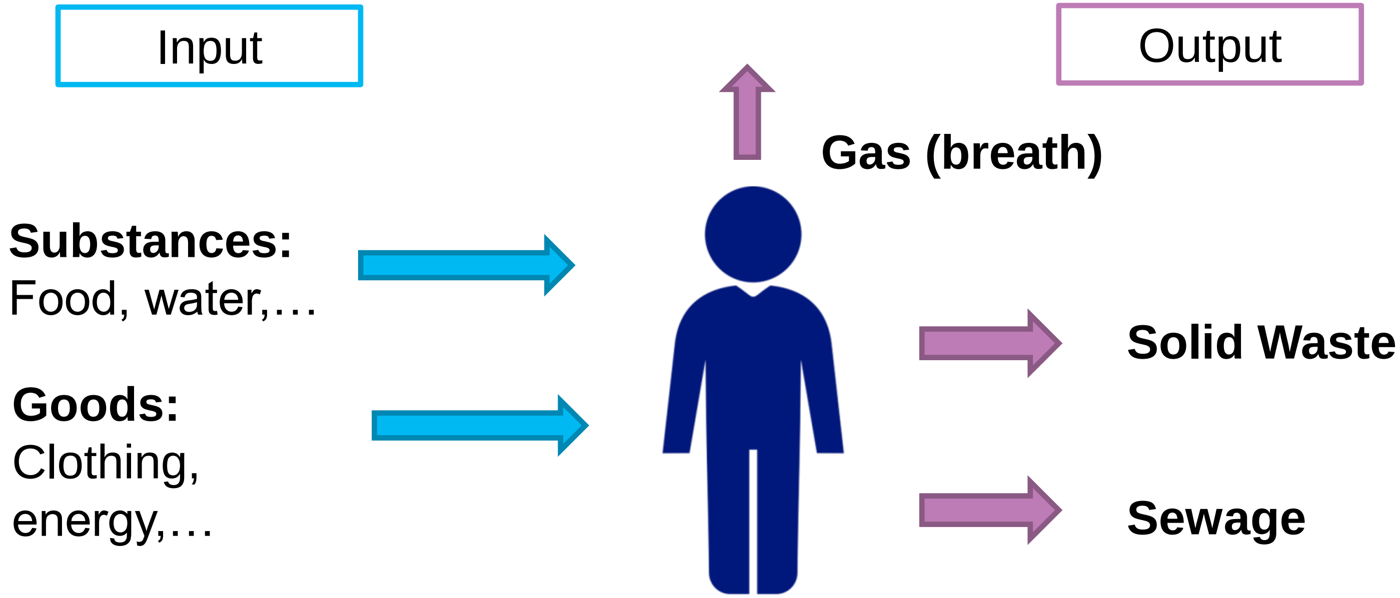
M aterial flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time.

F Flows in a system are based on the law of conservation of matter, thus balancing all inputs and outputs or process over a given timeframe.

A nalysing the system to make all flows visible and identify the allocation, the interactions and the stock of resources.

Brainstorming: MFA of the human metabolism

System: Human metabolism



Material Flow Analysis

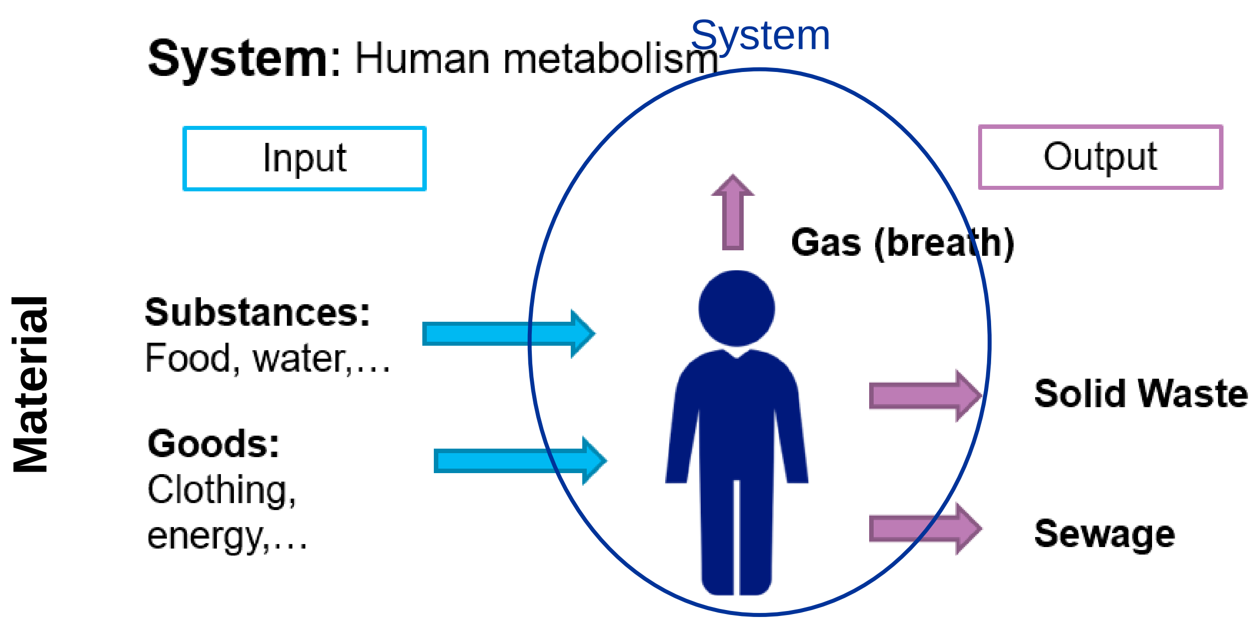
MFA terminology

Material: substances and goods (individual or aggrated elements)

Substance: Single type of matter (elements, compounds)

Goods: (mixtures) of substances that have market value (including energy and services)

System: Set of material lows, stocks, and prcesses within a defined boundary



Material Flow Analysis

MFA terminology

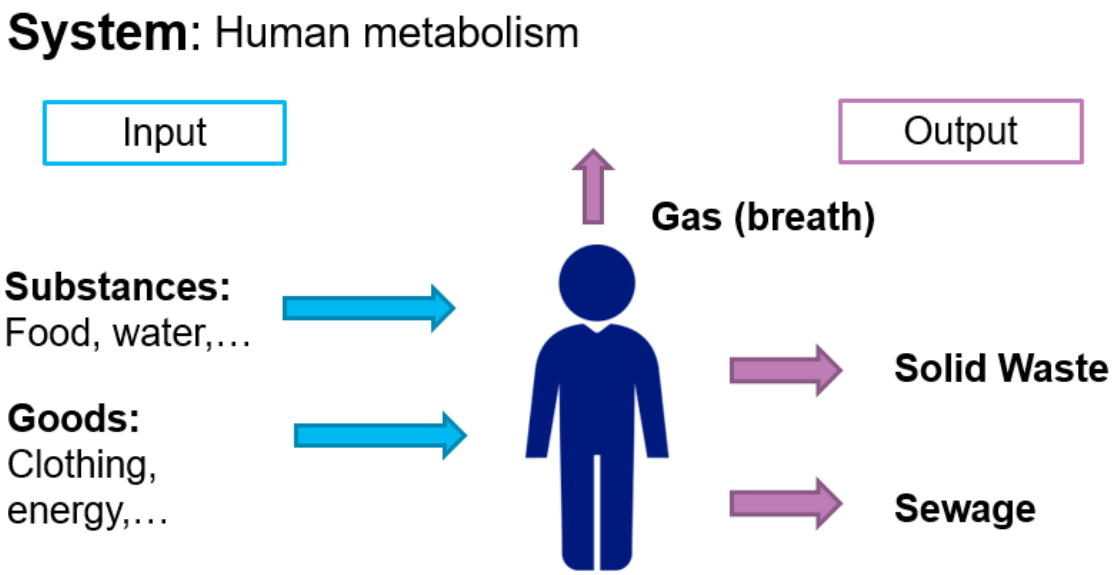
Process: transport, transformation or storage of materials

Stocks: material reservoirs within the system

Flow: mass per time

Fluxes: mass per time and cross section

Input/Output: flows/fluxes across process boundries

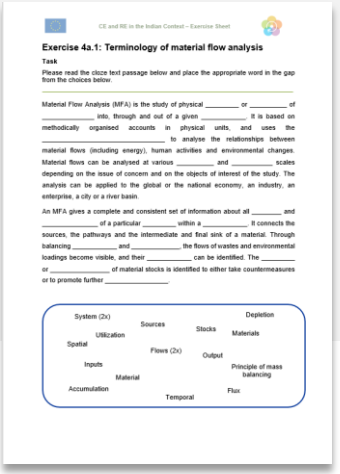


Exercise: Terminology of MFA

Exercise 4a.1: Terminology of MFA

- Use exercise sheet and complete cloze text passage about MFA
- Discuss completed text passage in the group

Estimated time requirement: 10 min



CE and RE in the Indian Context – Exercise Sheet

Exercise 4a.1: Terminology of material flow analysis

Task

Please read the cloze text passage below and place the appropriate word in the gap from the choices below.

Material Flow Analysis (MFA) is the study of physical _____ or _____ of _____ into, through and out of a given _____. It is based on methodically organised accounts in physical units, and uses the _____ to analyse the relationships between material flows (including energy), human activities and environmental changes. Material flows can be analysed at various _____ and _____ scales depending on the issue of concern and on the objects of interest of the study. The analysis can be applied to the global or the national economy, an industry, an enterprise, a city or a river basin.

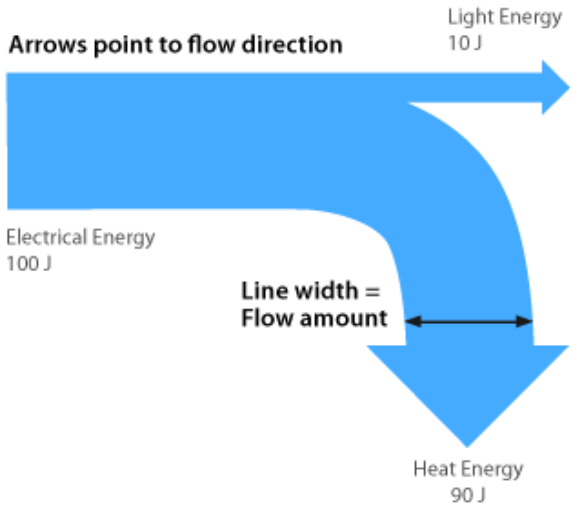
An MFA gives a complete and consistent set of information about all _____ and _____ of a particular _____ within a _____. It connects the sources, the pathways and the intermediate and final sink of a material. Through balancing _____ and _____ the flows of wastes and environmental loadings become visible, and their _____ can be identified. The _____ or _____ of material stocks is identified to either take countermeasures or to promote further _____.

System (2x) Depletion
Sources
Stocks
Utilization
Materials
Spatial
Flows (2x)
Output
Inputs
Principle of mass balancing
Material
Accumulation
Flux
Temporal

MFA: Types and steps

Visualising MFAs using Sankey diagrams

- Displays flow and their quantities in proportion to one another
- Width of arrows or lines show the magnitude of the flow
- Colors can be used to show transition from one state of the process to another



Picture source: https://educatingphysics.com/gcse/electricity/work-done-on-a-charged-particle/

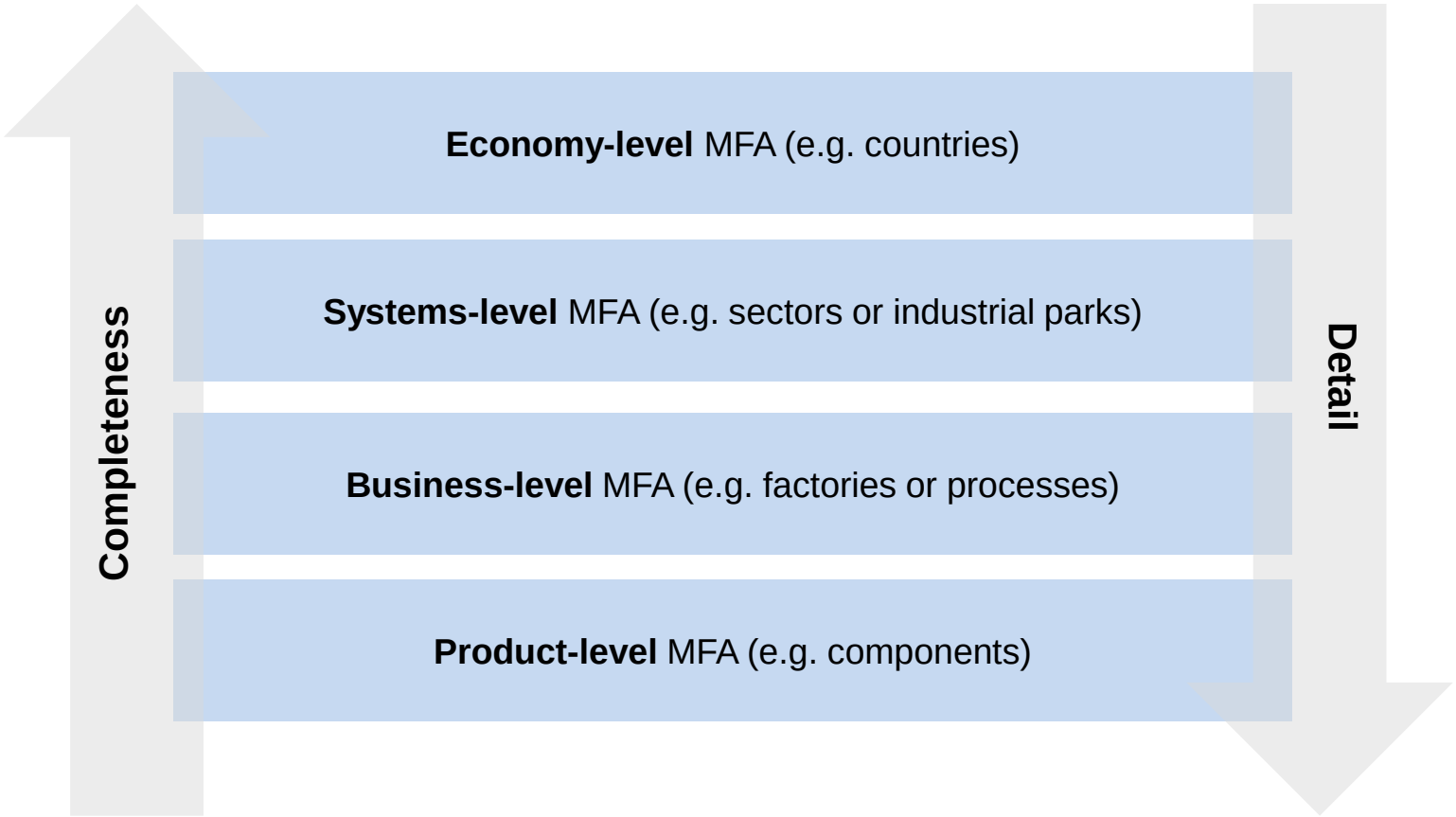
MFA: Types and steps

Types of MFA	
Descriptive	**Exploratory**
quantification of material flows in a specific system to characterize the throughput of materials	providing understanding of processes governing material flows to investigate management options
e.g. economy-level Material Flow Analysis (MFA)	*e.g. business-level Material Flow Cost Accounting (MFCA)*

Application of MFCA guided by „ISO 14051:2011 Environmental management — Material flow cost accounting — General framework“

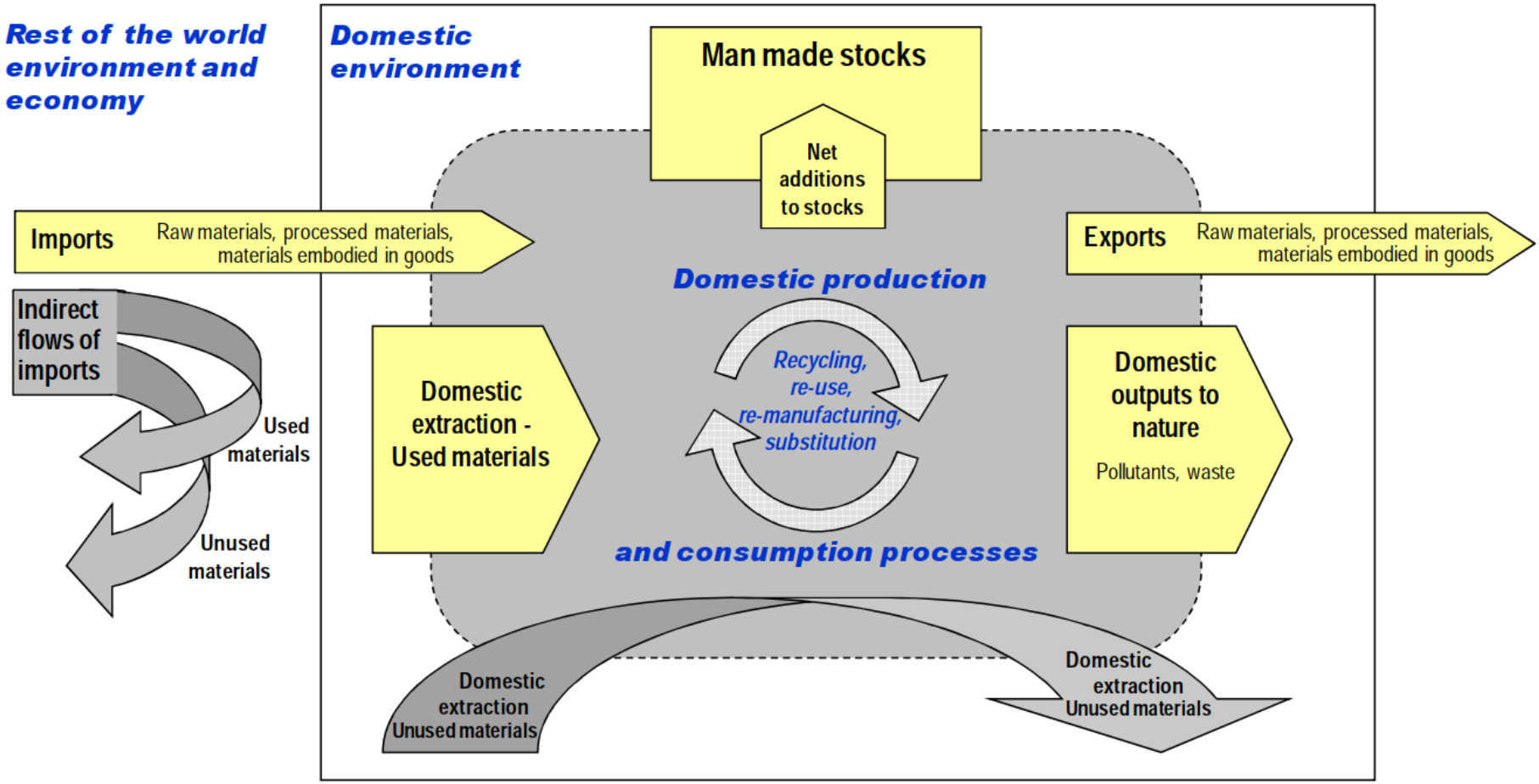
Picture source: https://www.iso.org/home.html

MFA: Types and steps



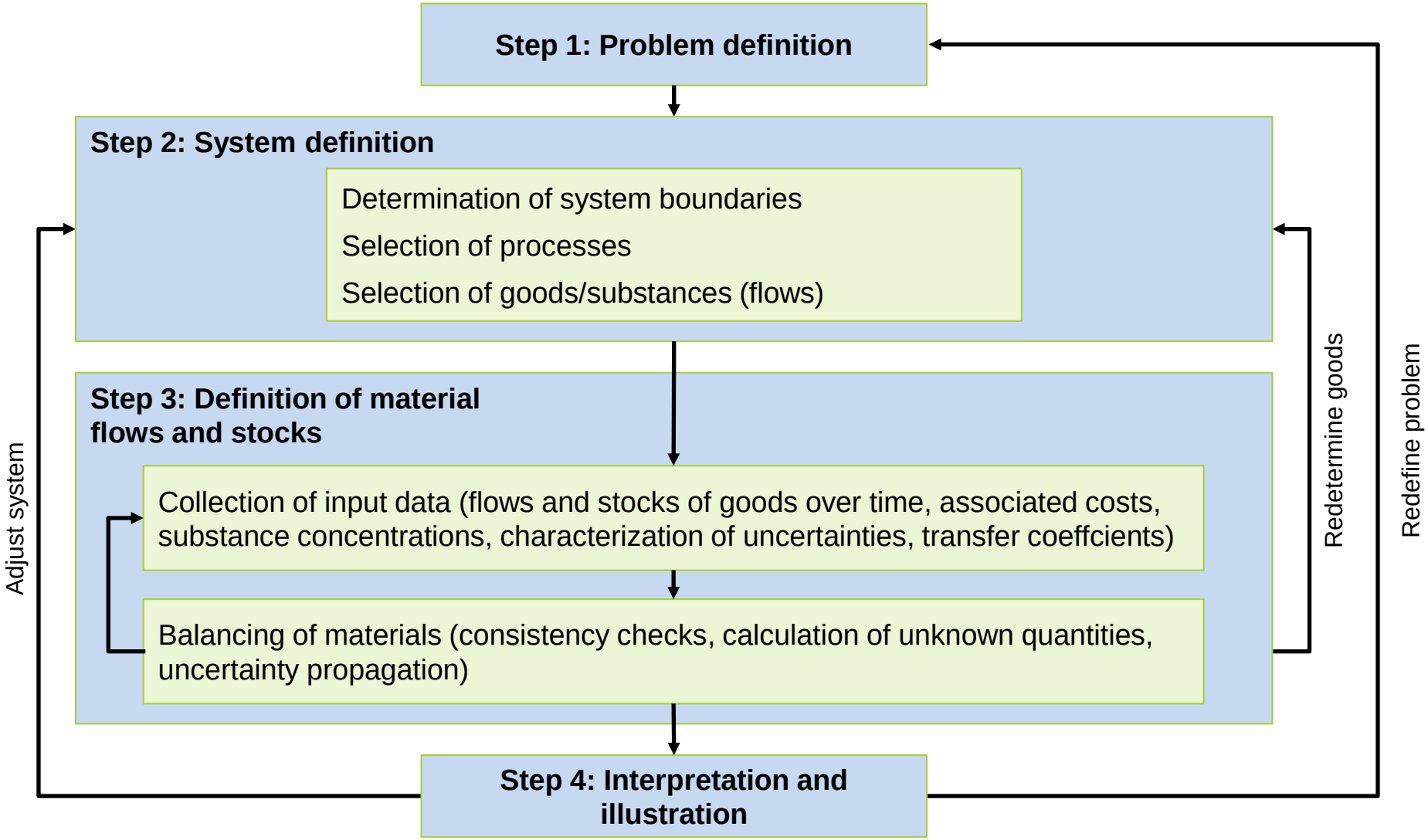
MFA: Types and steps

Schematic for economy-level MFA



Picture source: https://www.semanticscholar.org/paper/Evaluation-of-Environmental-Life-Cycle-Approaches-Kathy-Matthias/8553b0877dfc6a784f10938a2c76e4a0ed4996d3

MFA: Types and steps



MFA: Types and steps

The National Productivity Council followed four case studies of Indian manufacturing companies which conducted MFCAs with the help of japanese experts

Company	Investments (INR)	Savings (INR/year)
Sainest Tubes manufacturer of carbon steel seamless pipes	2,00,000	35,00,000
Bhagwati Spherocast manufacturer of high duty grey iron and ductile iron castings	4,95,000	2,09,43,924
Somany Ceramics a manufacturer of ceramics	1,00,00,000	1,74,17,496
Baroda Moulds and Dies a manufacturer of moulds and dies	10,000,000	2,47,00,000

MFA: Types and steps

SAINEST TUBES PVT. LTD.

Observation	Solution	Investments (INR)	Savings (INR/year)
Process scrap due to insufficient gripping	Additional vertical pneumatic cylinder is attached for sufficient gripping	1,000	6,58,944
The abrasive cutting machine was running when not loaded	Switch off machine when idle	2,400	1,10,160
Insufficient cooling of annealed material, which reduces the furnace loading capacity	An additional cooling zone was introduced, so loading could be increased by 50%	35,000	78,00,000
6 Men @ unloading at blast furnace	Introduced pneumatic cylinder & 3 Men used for unloading	50,000	4,50,000

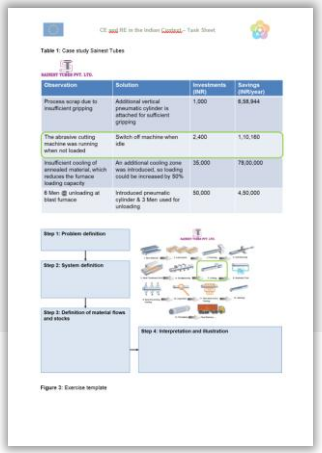
Picture source: https://www.sainest.com/

Exercise: Steps in MFA

Exercise 4a.2: Defining the steps in MFA

- Form groups of 2-3 people.
- Define steps 1-4 in for the MFA case study on Sainest Tubes
- Focus on abrasive cutting and try to be as specific as possible

Estimated time requirement: 10 min

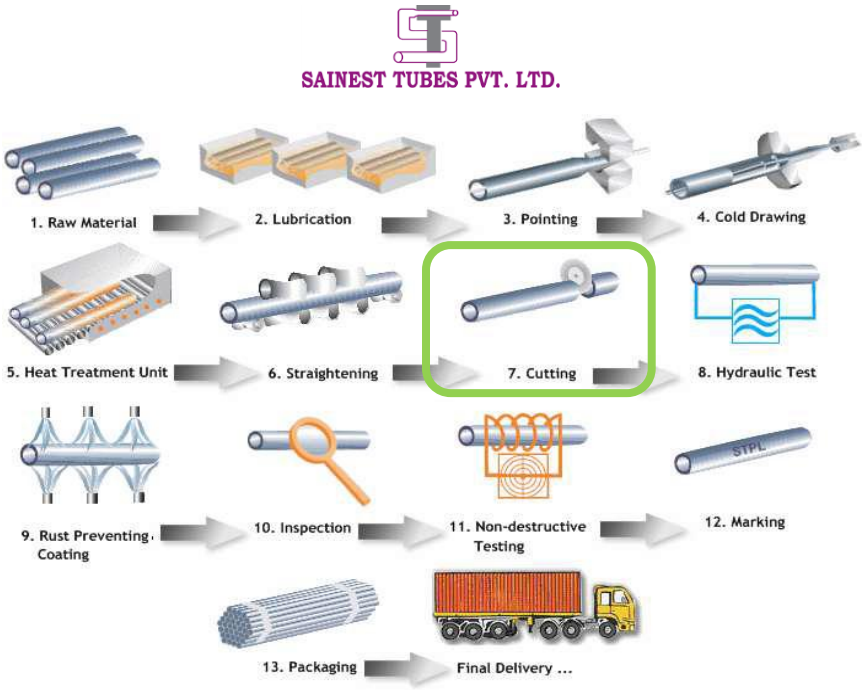


Exercise: Steps in MFA

Step 1: Problem definition

Step 2: System definition

Step 3: Definition of material flows and stocks



Step 4: Interpretation and illustration

Picture source: https://www.sainest.com/

Exercise: steps in MFA

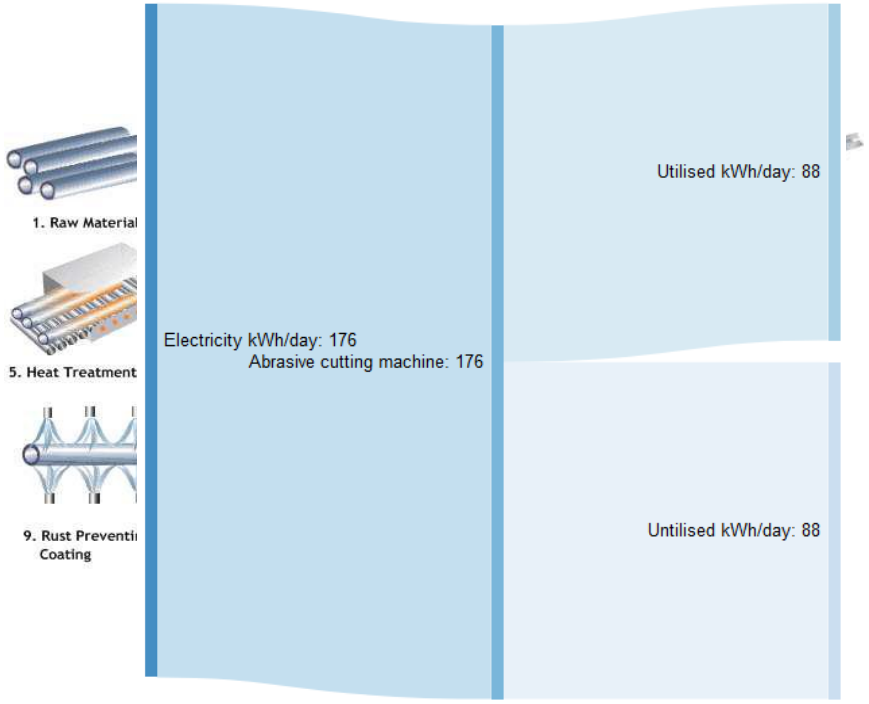
Solutions

Step 1: Problem definition
High production costs due to process ineffciencies

Step 2: System definition
Process:
- Abrasive cutting

Flows in cutting process:
- Electricity consumption (kWh/day)

Step 3: Definition of material flows and stocks
Input data:
- Power of abrasive cutting machine = 22,032 kW
- Electricity price = 5 INR/kWh
- Abrasive cutting machine running for 8 hrs/day
- Abrasive cutting machine running idle for 4 hrs/day



Step 4: Interpretation and illustration
Calculation of savings:
- Turning off abrasive cutting machine while idle results in savings of 22,032 kW * 4 hrs/day * 5 INR/hr = 440,64 INR/day
- 440,64 INR/day * 250 working days in India = savings of <u>1,10,160 INR/year</u>

Picture source: https://www.sainest.com/

Material Flow Analysis

Advantages

- ✓ Reduces the complexity of comprehensive systems
- ✓ Provides a good overview of input-output flows cross systems
- ✓ Helps identify optimization potentials and supports for decision-making
- ✓ Brings attention to neglected flows due to balance principle

Disadvantages

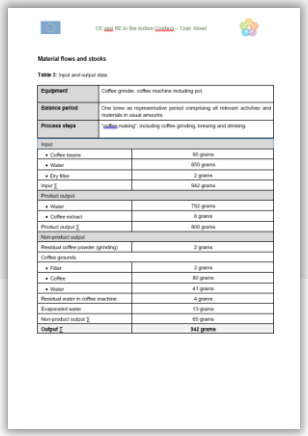
- × Does not avoid sub-optimisation due to trade-offs
- × Large amounts of data required; collection may be time consuming and resource-intensive
- × Quality of analysis largely relies on reliability of data

Exercise: Material Flow Analysis

Exercise 4a.3: MFA of a Coffee Machine

- Work in groups of 2-3
- Analyze the production process described in the case study
- Quantify the process flows and visualise your findings
- Identify and compile at least three measures for improvement
- Re-assess the proposed improvement measures in terms of their lifecycle implications

Estimated time requirement: 80 min



Material flows and stocks

Table 1: Input and output data

Equipment	Coffee grinder, coffee machine including pot
Balance period	One brew as representative period comprising all relevant activities and materials in usual amounts
Process steps	"coffee making", including coffee grinding, brewing and drinking.
Input	
• Coffee beans	90 grams
• Water	850 grams
• Dry filter	2 grams
Input Σ	942 grams
Product output	
• Water	792 grams
• Coffee extract	8 grams
Product output Σ	800 grams
Non-product output	
Residual coffee powder (grinding)	2 grams
Coffee grounds	
• Filter	2 grams
• Coffee	80 grams
• Water	41 grams
Residual water in coffee machine	4 grams
Evaporated water	13 grams
Non-product output Σ	85 grams
Output Σ	942 grams

Exercise: Material Flow Analysis

Solutions

Equipment	Coffee grinder, coffee machine including pot.
Balance period	One brew as representative period comprising all relevant activities and materials in usual amounts.
Process steps	“coffee making”, including coffee grinding, brewing and drinking.

Exercise: Material Flow Analysis

Solutions

Input	
• Coffee beans	90 grams
• Water	850 grams
• Dry filter	2 grams
Input ∑	942 grams
Product output	
• Water	792 grams
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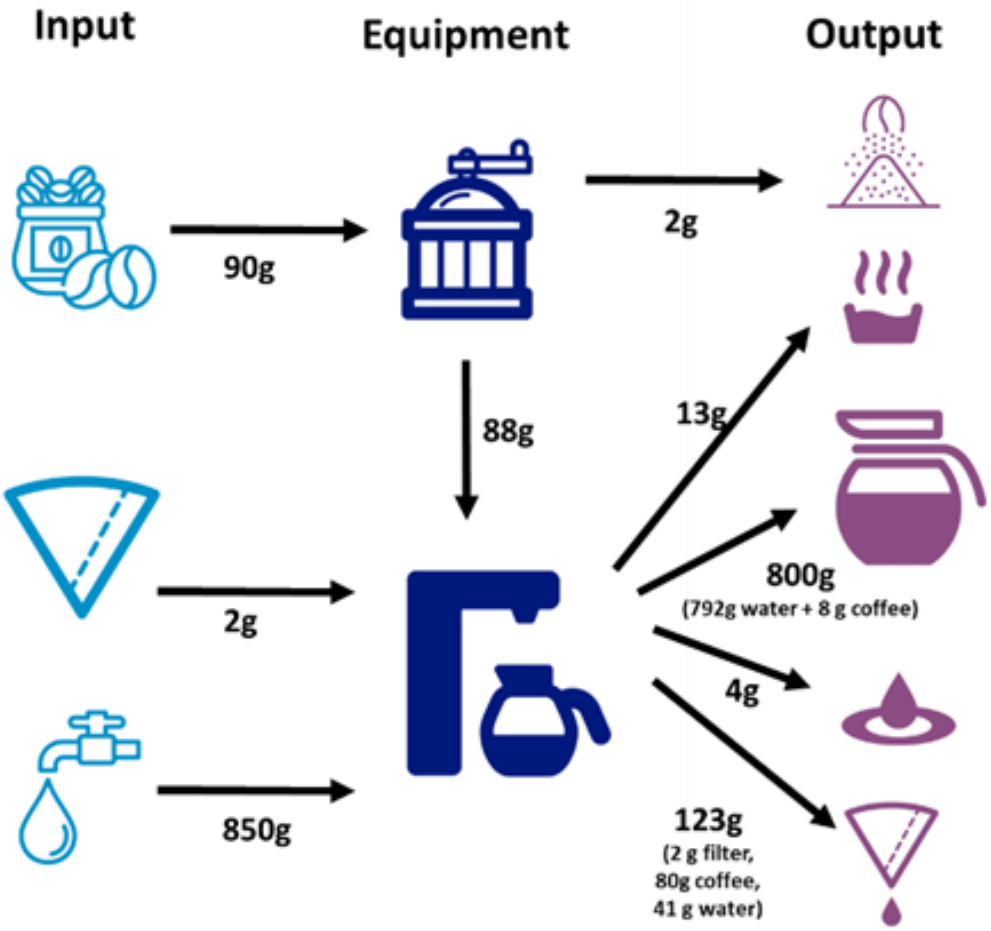
Product output ∑	800 grams
Non-product output	
Residual coffee powder (grinding)	2 grams
Coffee grounds	
• Filter	2 grams
• Coffee	80 grams
• Water	41 grams
Residual water in coffee machine	4 grams
Evaporated water	13 grams
Non-product output ∑	65 grams
Output ∑	**942 grams**

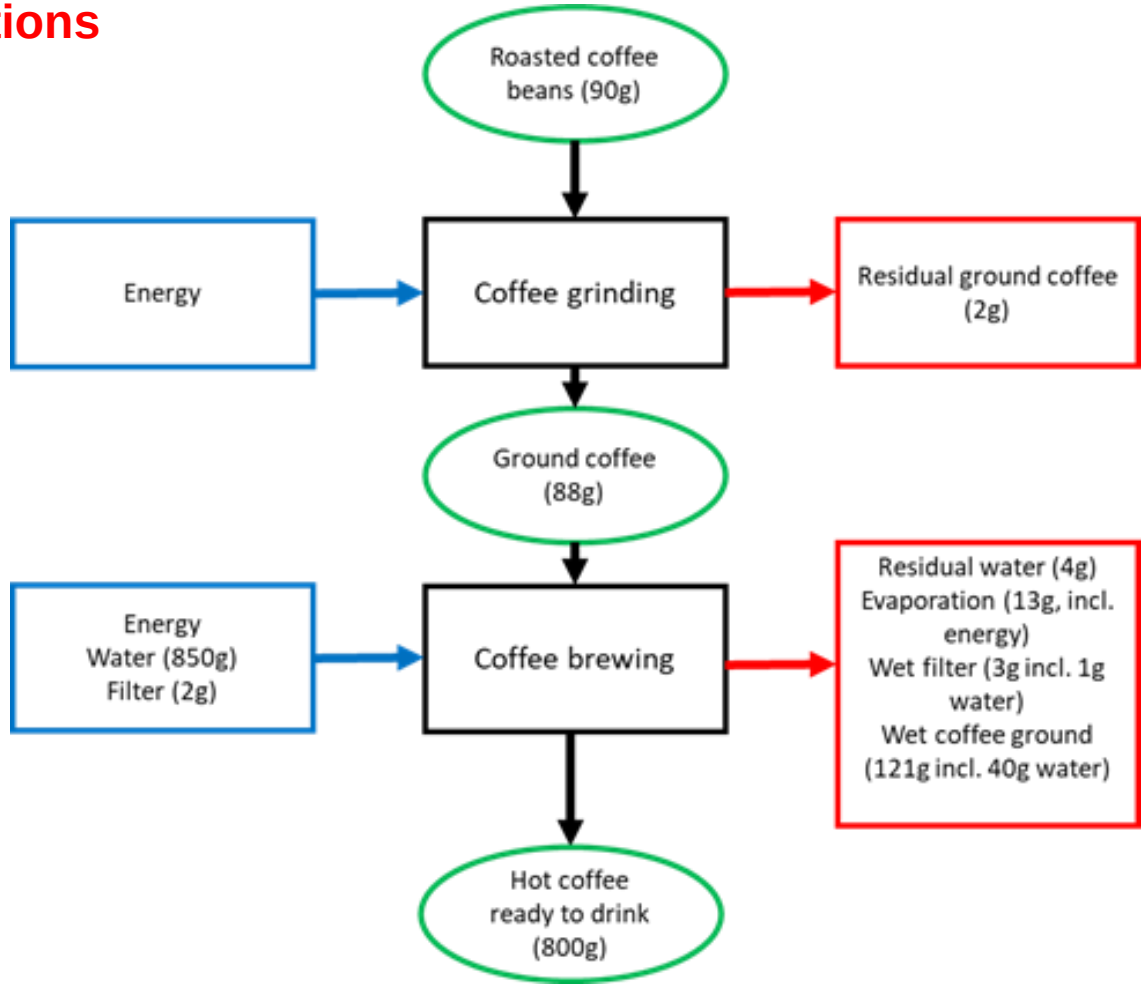
Exercise: Material Flow Analysis

Solutions



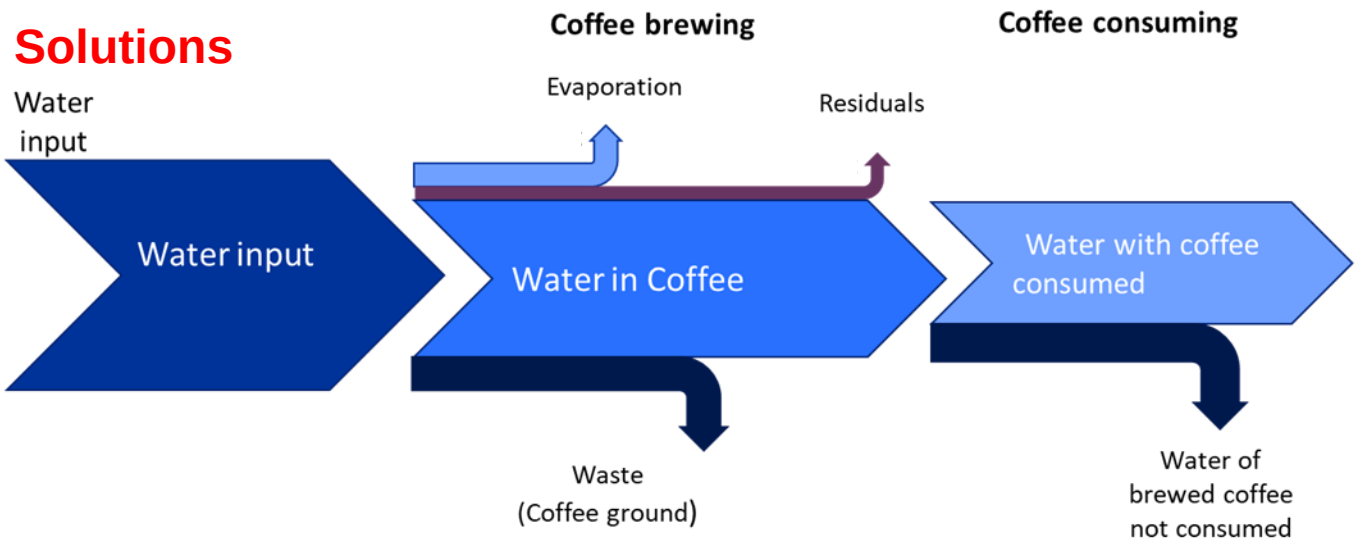
Exercise: Material Flow Analysis

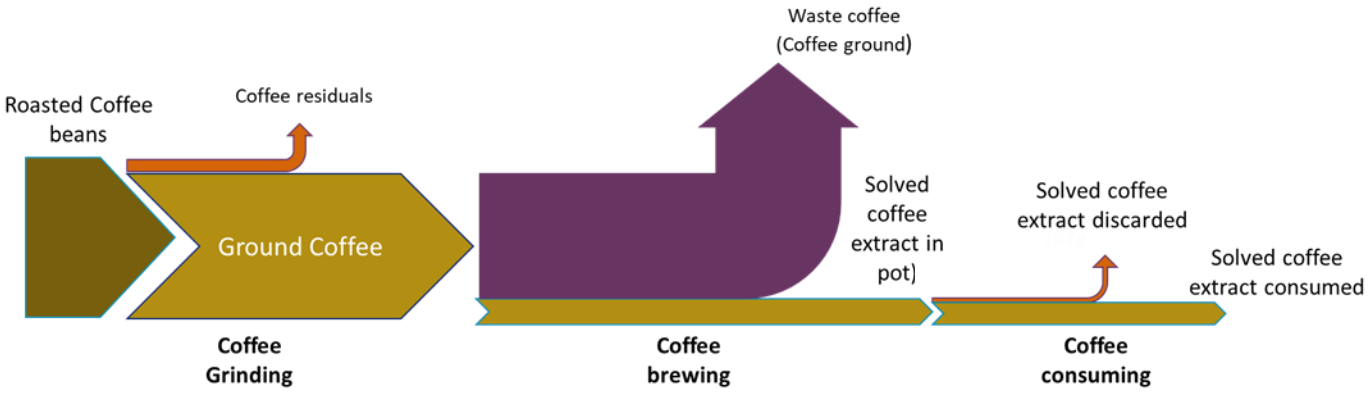
Solutions



Exercise: Material Flow Analysis

Solutions





Summary

Take-home messages

- MFAs are useful tools when analysing specific cases with regards to RE and CE
- MFA requires large amounts of high quality data
- Although RE and CE are often portrayed as win-win solutions, MFAs often reveal how solutions can create adverse impacts across lifecycle stages

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