Laboratory on Human-Environment Relations in Urban Systems
Swiss Mobiliar Chair in Urban Ecology and Sustainable Living

ENV 370 (GR A332 – GRB001)
Environmental system analysis and assessment – Evaluation et analyse environnementale systémique

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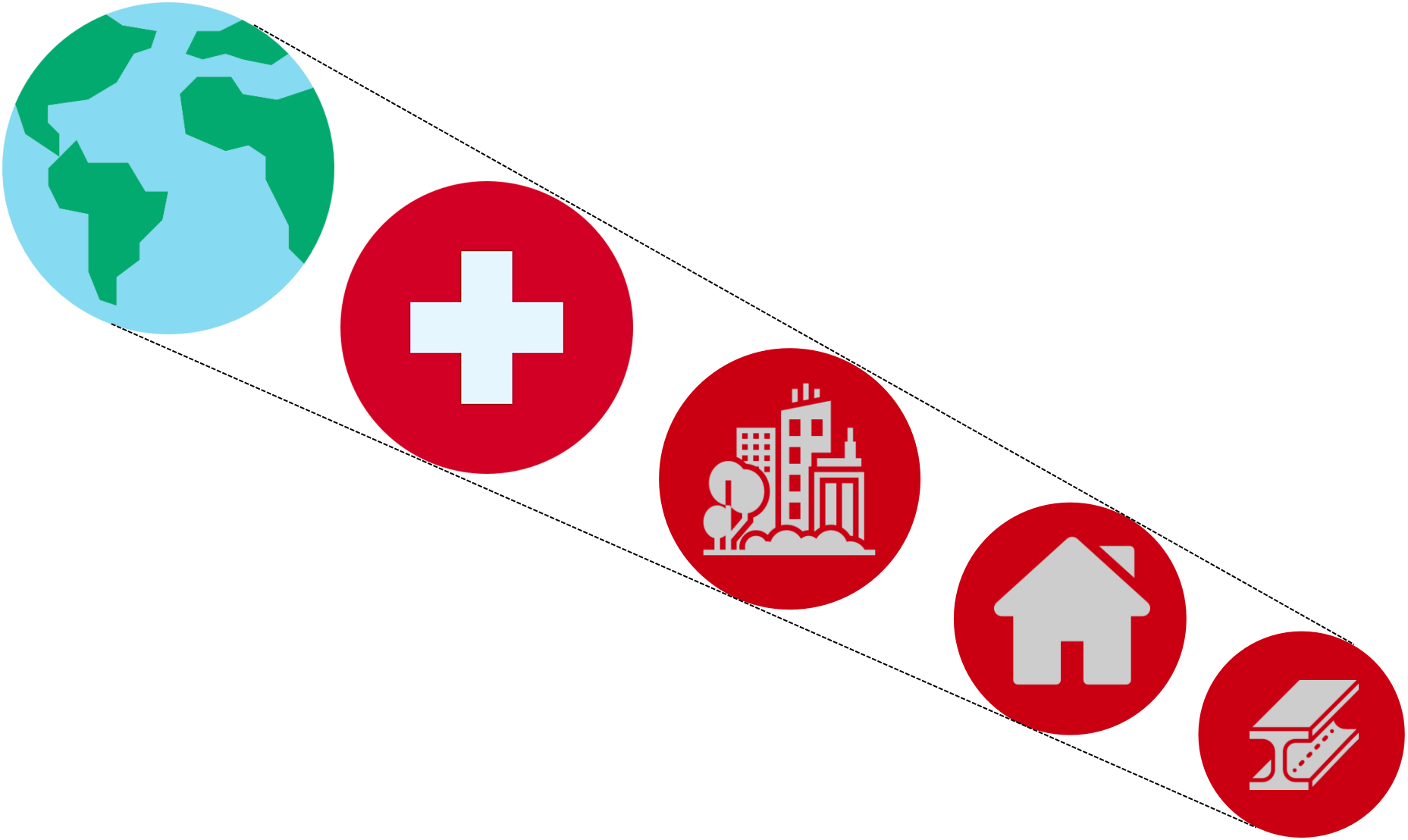
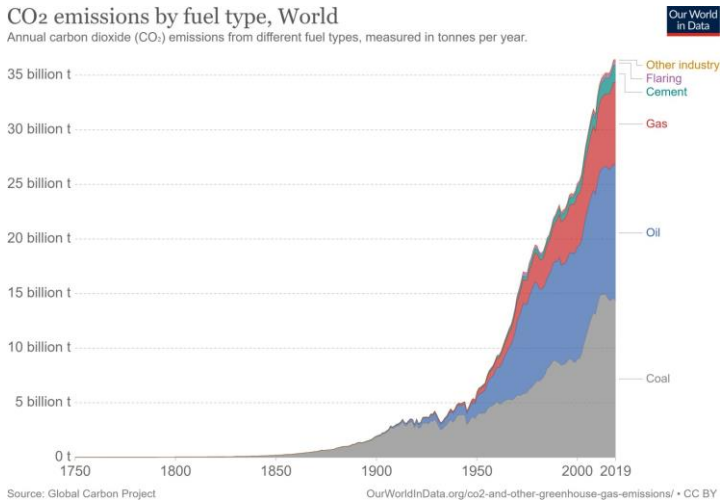
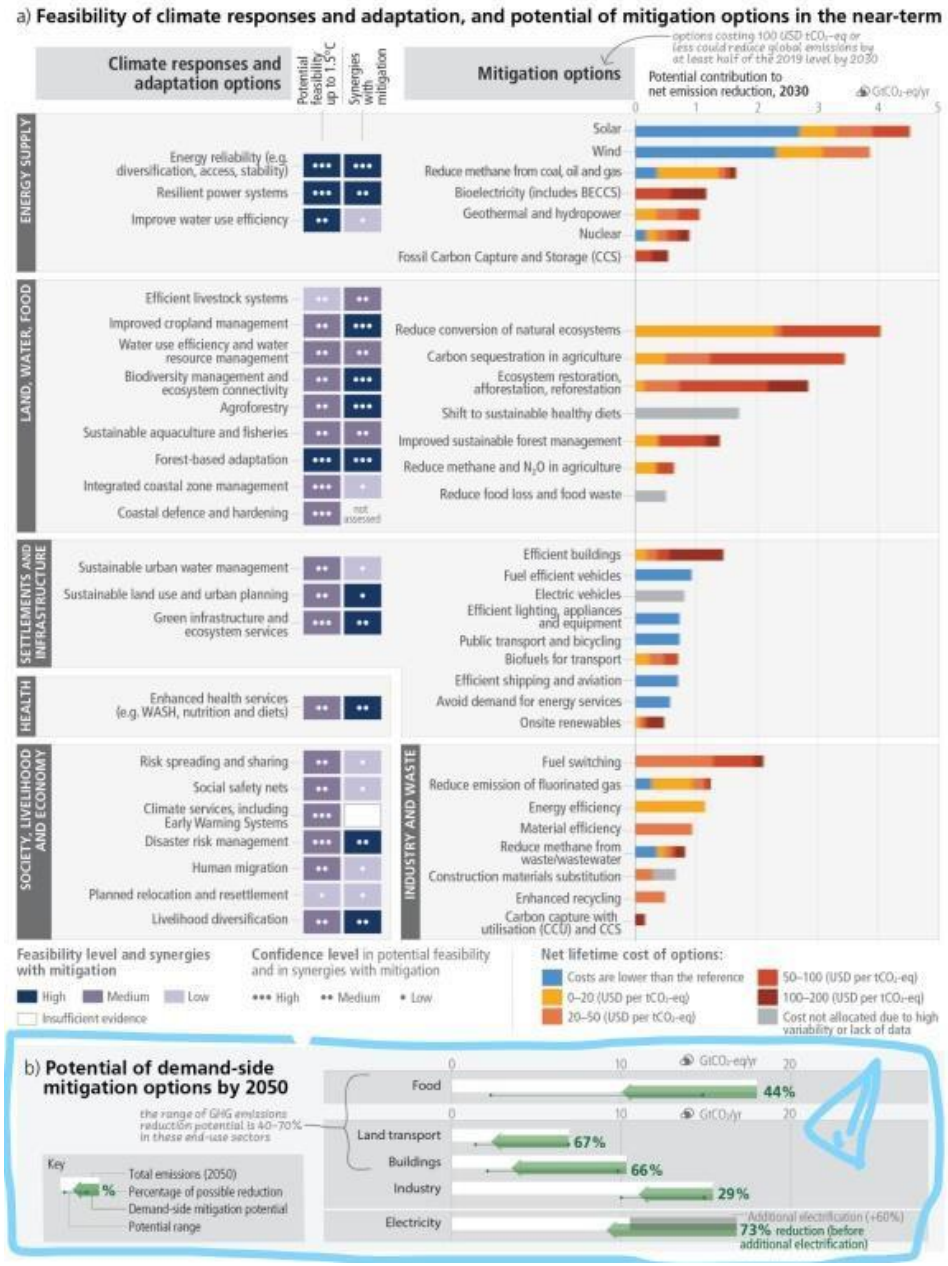
EPFL - Spring 2025

RECAP



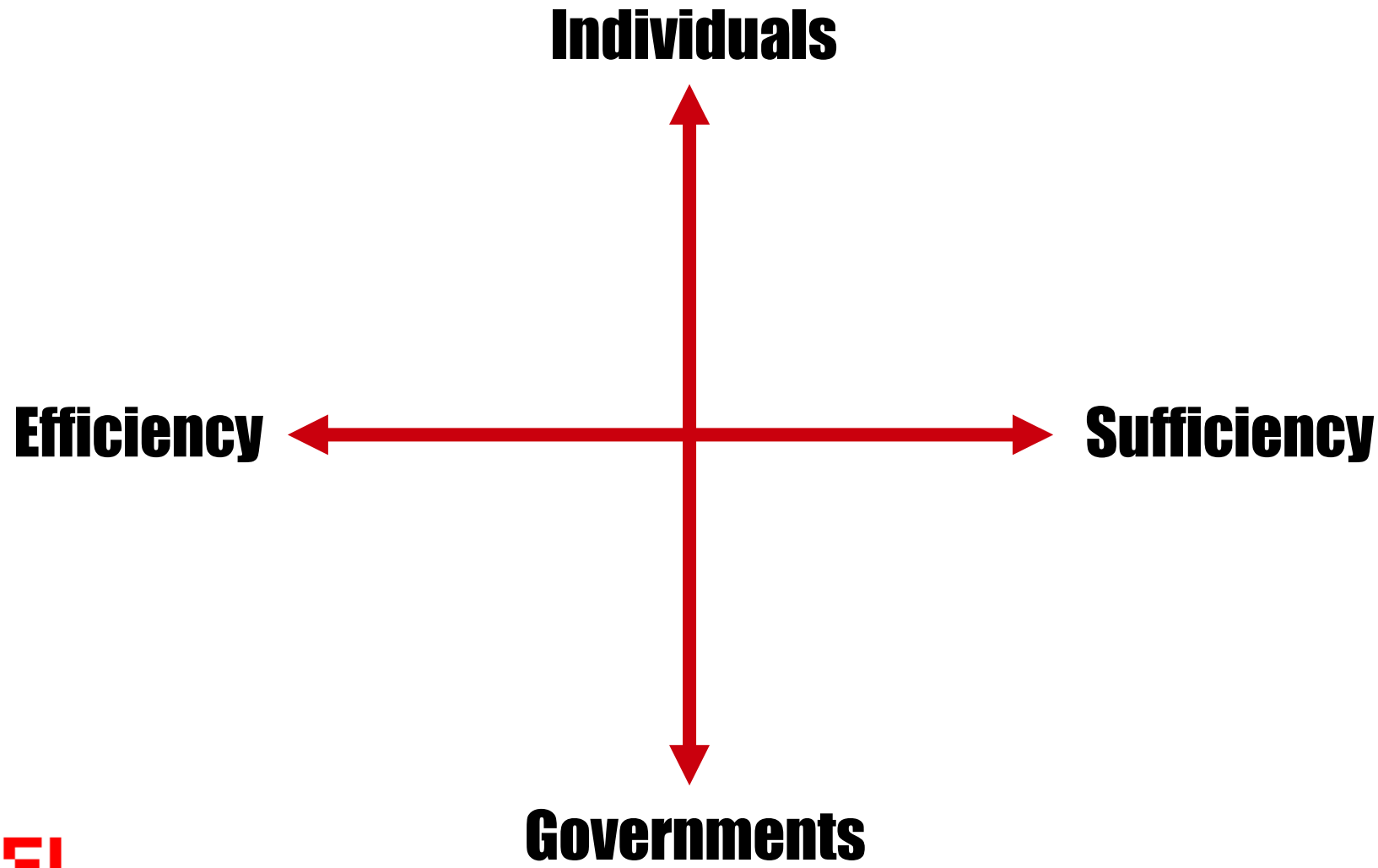
What solutions do we have ?
Technologies



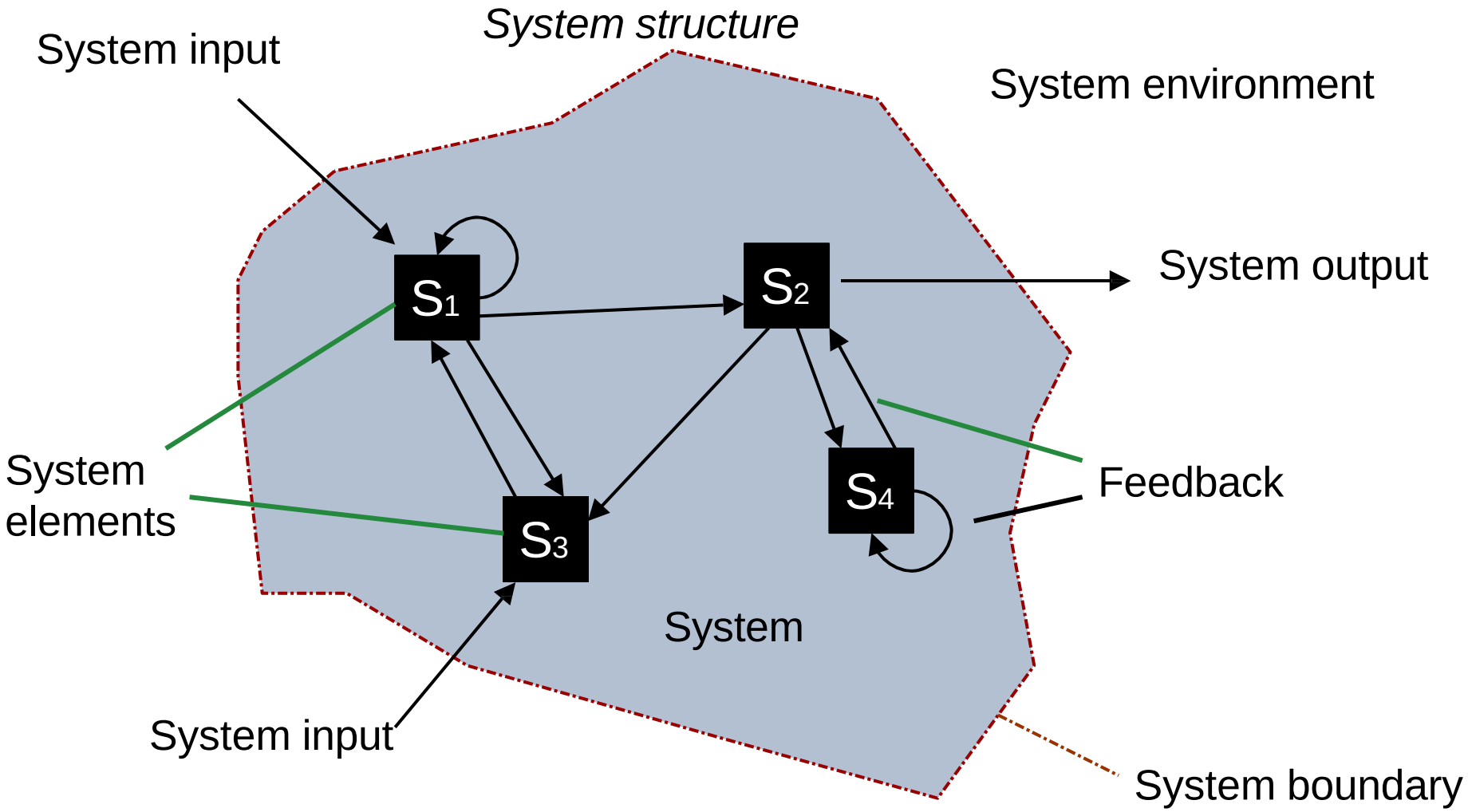


Source: IPCC, 2022: Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.001.

Who has to do something about it ?
How to do it ?
Give me some solutions ?

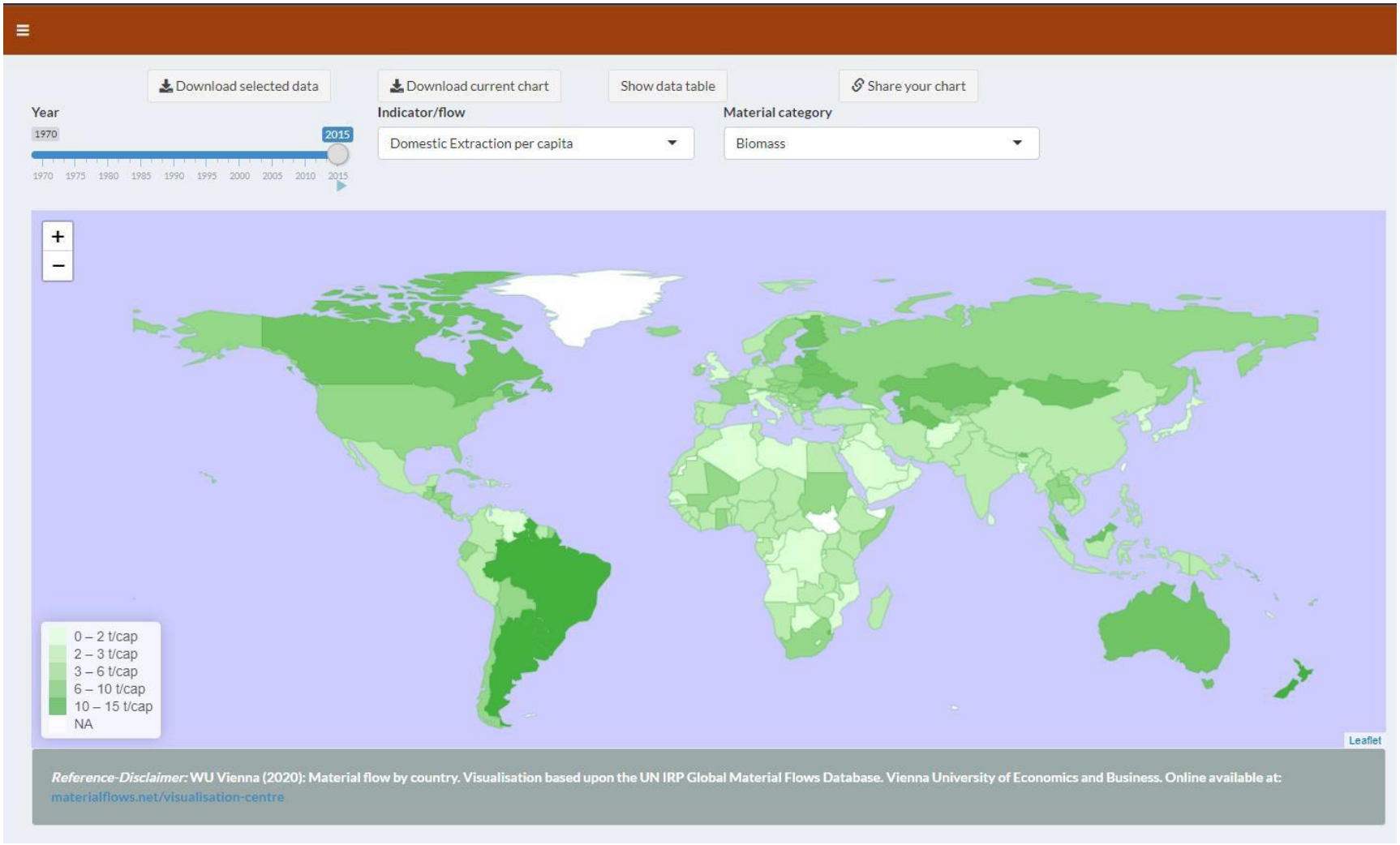


What is a system? Elements, interrelations, system boundaries



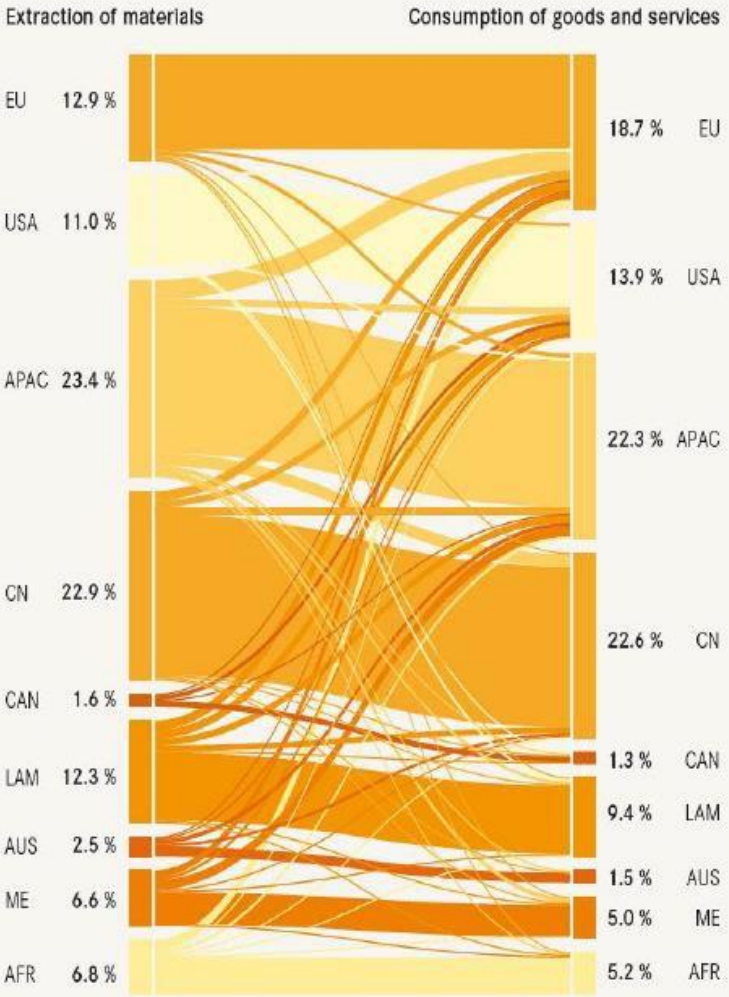
After Bossel, 2004; Mrotzek, 2009

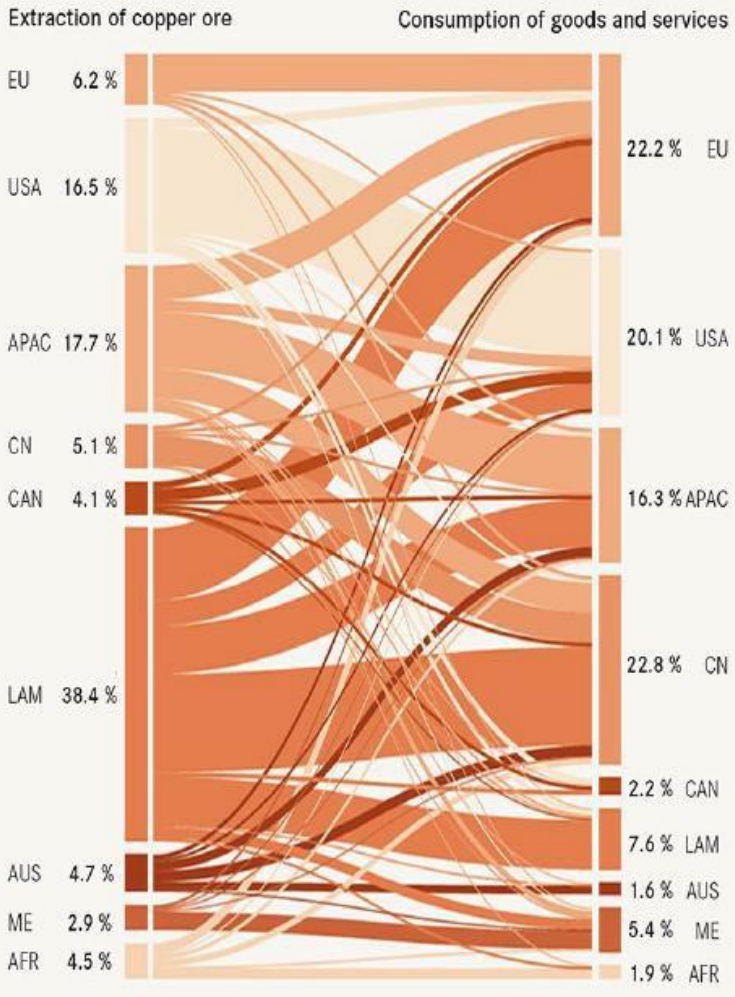
From world to countries (why some countries extract more?)



Source: http://www.materialflows.net/visualisation-centre/data-visualisations

Production (extraction) vs. Consumption



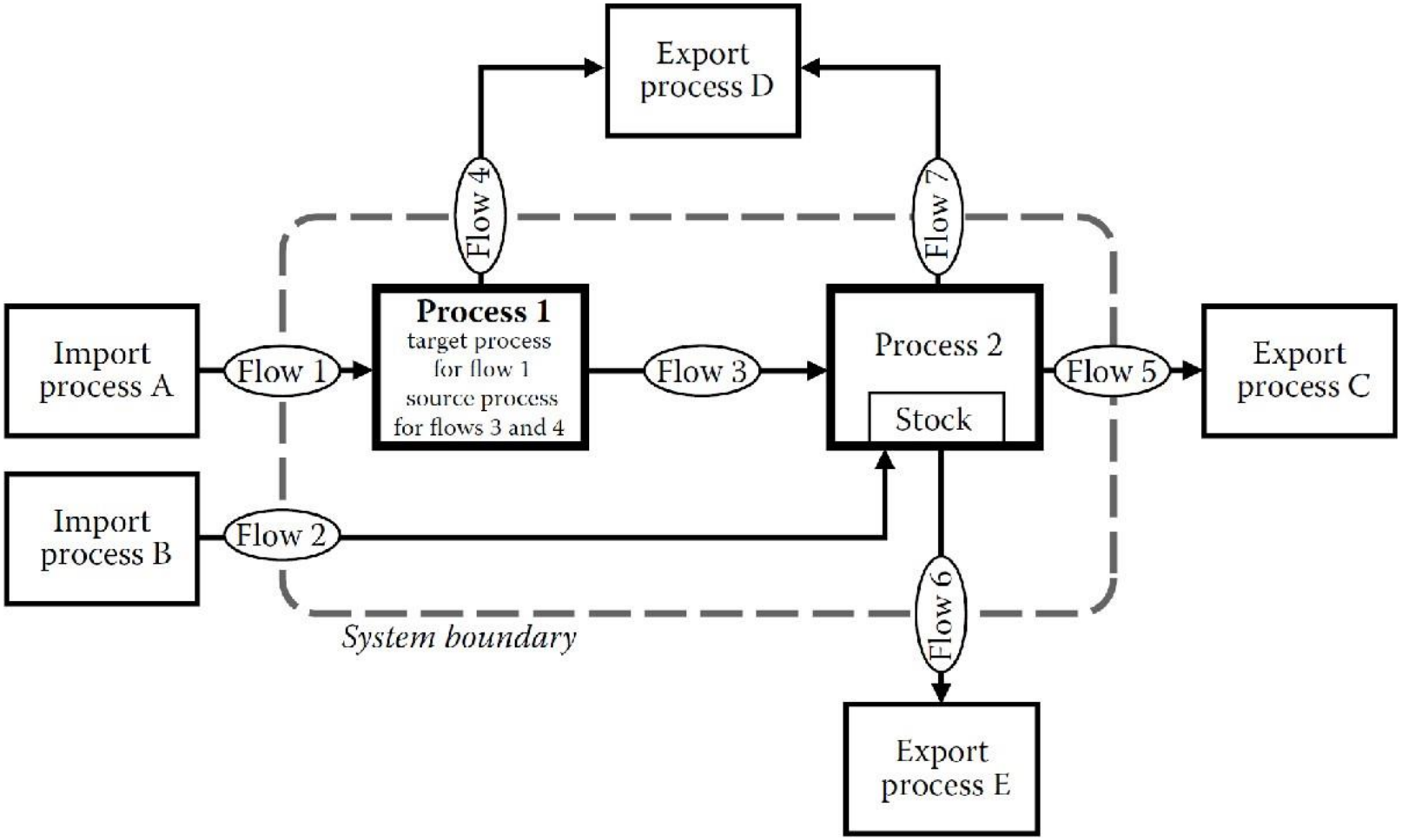


Tukker, A., T. Bulavskaya, S. Giljum, A. de Koning, S. Lutter, M. Simas, K. Stadler, and R. Wood. 2014. *The Global Resource Footprint of Nations. Carbon, water, land and materials embodied in trade and final consumption calculated with EXIOBASE 2.1.* Leiden/Delft/Vienna/Trondheim:

Questions ?

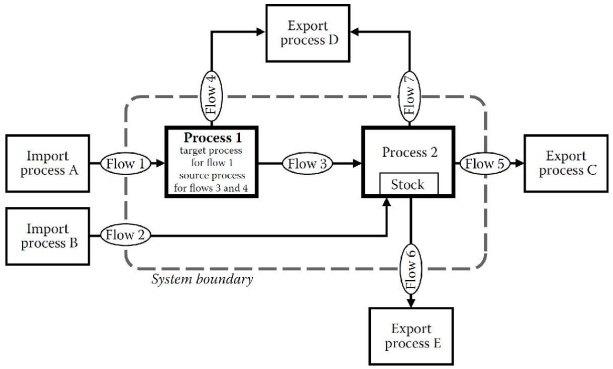
Material Flow Analysis

First method to include in your arsenal: MFA



Brunner & Rechberger, 2016

Definition of MFA

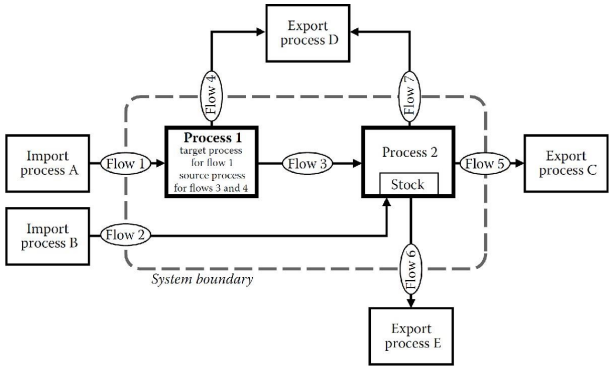


Brunner & Rechberger, 2016

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

- MFA connects the **sources, pathways and sinks** of a material.
- MFA results can be controlled by a **mass balance** comparing all inputs, stocks, and outputs of a process/system measured in kg (principle of mass conservation).

History of MFA



Brunner & Rechberger, 2016

- **Santorio Santorio (1561–1636)**
  Human metabolism
- **Antoine Lavoisier (1743–1794)**
  Law of mass conservation in chemical processes
- **Wassily W. Leontief (1906–1999)**
  Economic input-output tables
- **Abel Wolman (1965), Duvigneaud & Denayeyer-De Smet (1975), Newcombe, Kalma & Aston (1978)**
  Metabolism of cities: hypothetical American city, Brussels, Hong Kong

Santorio's analysis of the human metabolism

Brunner & Rechberger, 2016

Inputs: food, beverages
Outputs: excretions

Santorio's analysis of the human metabolism

Brunner & Rechberger, 2016

Inputs: food, beverages
Outputs: excretions

Mass balance: input ≠ output ???

Santorio's analysis of the human metabolism

Brunner & Rechberger, 2016

Inputs: food, beverages
Outputs: excretions

Mass balance: input ≠ output

Air in and out was not measured!

What is the purpose of MFA ??

Purpose of MFA

- **Early detection** of harmful/useful material accumulation or depletion in anthropogenic/natural subsystems (e.g. metal enrichment in landfills due to the deposition of slag).
- **Prediction** of future quantities in anthropogenic/natural subsystems.
- **Identification of the need for action** in the areas of environmental, resource, waste and policy management.
- **Evaluation** of the effectiveness of current/planned measures.
- **Design** of ecologically-optimized products, processes and systems
  (e.g. green design, eco-design).

Steps of MFA

Step I: System definition
Problem definition, definition of system boundaries, selection of processes and flows of materials/substances (qualitative model)

Step II: Measurement
Data collection of flows and stocks of materials/substances and characterization of uncertainties (measurements, literature data, estimations)

Step III: Calculation
Calculation of unknown quantities by balancing of materials based on the principle of mass conservation (MFA software)

Step IV: Illustration and interpretation
Sources, stocks, flows and sinks

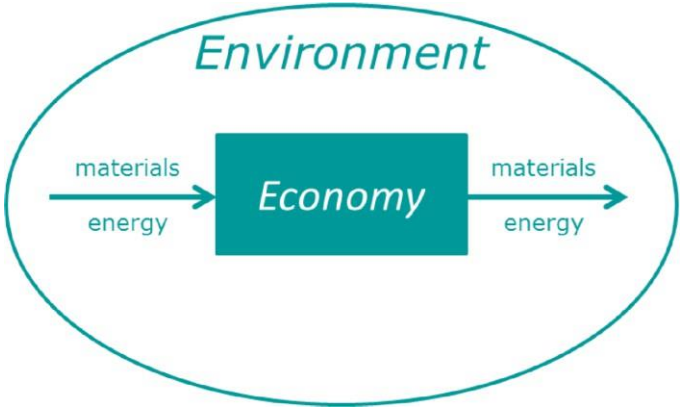
Step V: Recommendations
How can the system be optimized?

Method 1: EUROSTAT Economy–Wide Material Flow Analysis

First way to perform a MFA: EW-MFA Definition

- **Economy-wide material flow accounting and analysis (EW-MFA)**
  is the quantification of the material flows into and out of an economy (socio-economic metabolism).

- **EW-MFA** describes the interaction of the domestic economy with the natural environment and the rest of the world economy.

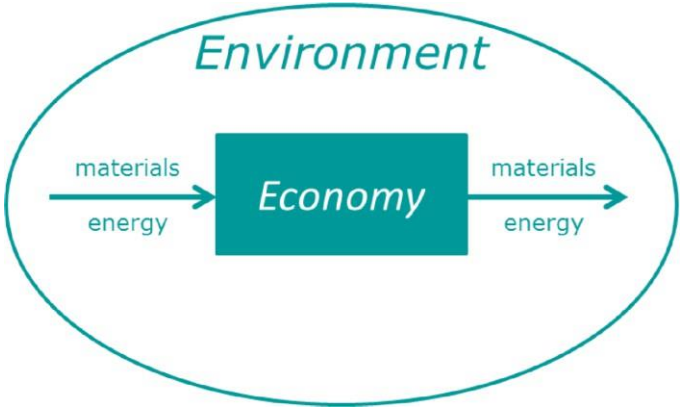


Eurostat, 2018

First way to perform a MFA: EW-MFA Definition

- **EW-MFA** represents national accounts in physical instead of monetary terms.

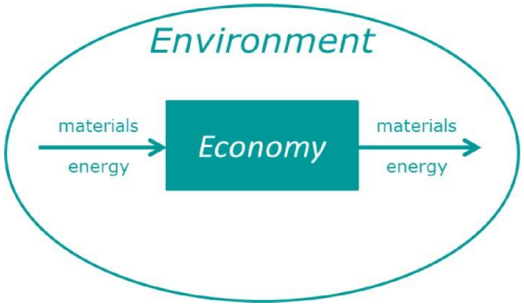
- **EW-MFA** are compatible with other national accounts, enabling integrated analyses of environmental and economic aspects.



Eurostat, 2018

History of EW-MFA (in Europe)

- **1990s:** European Statistical System (ESS) started its work on the integration of environmental and economic information systems.
- **2000:** Eurostat task force developed a methodological framework to record material flows and defined material flow indicators.
- **2004-2006:** Eurostat task force developed a classification of materials, standard tables and harmonized compilation procedures.
- **2011:** EU Regulation No. 691/2011 for member states to report the EW-MFA data to Eurostat.
- **2013:** First mandatory annual data collection.
- **2018:** Latest methodology out

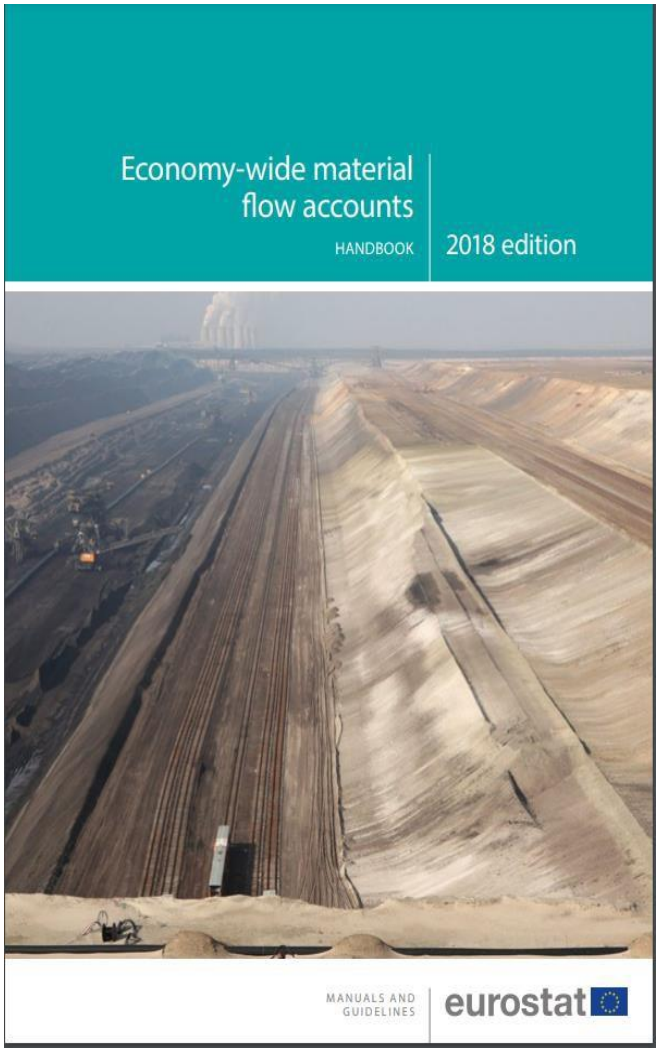


Eurostat, 2018

EW-MFA (globally -2021)

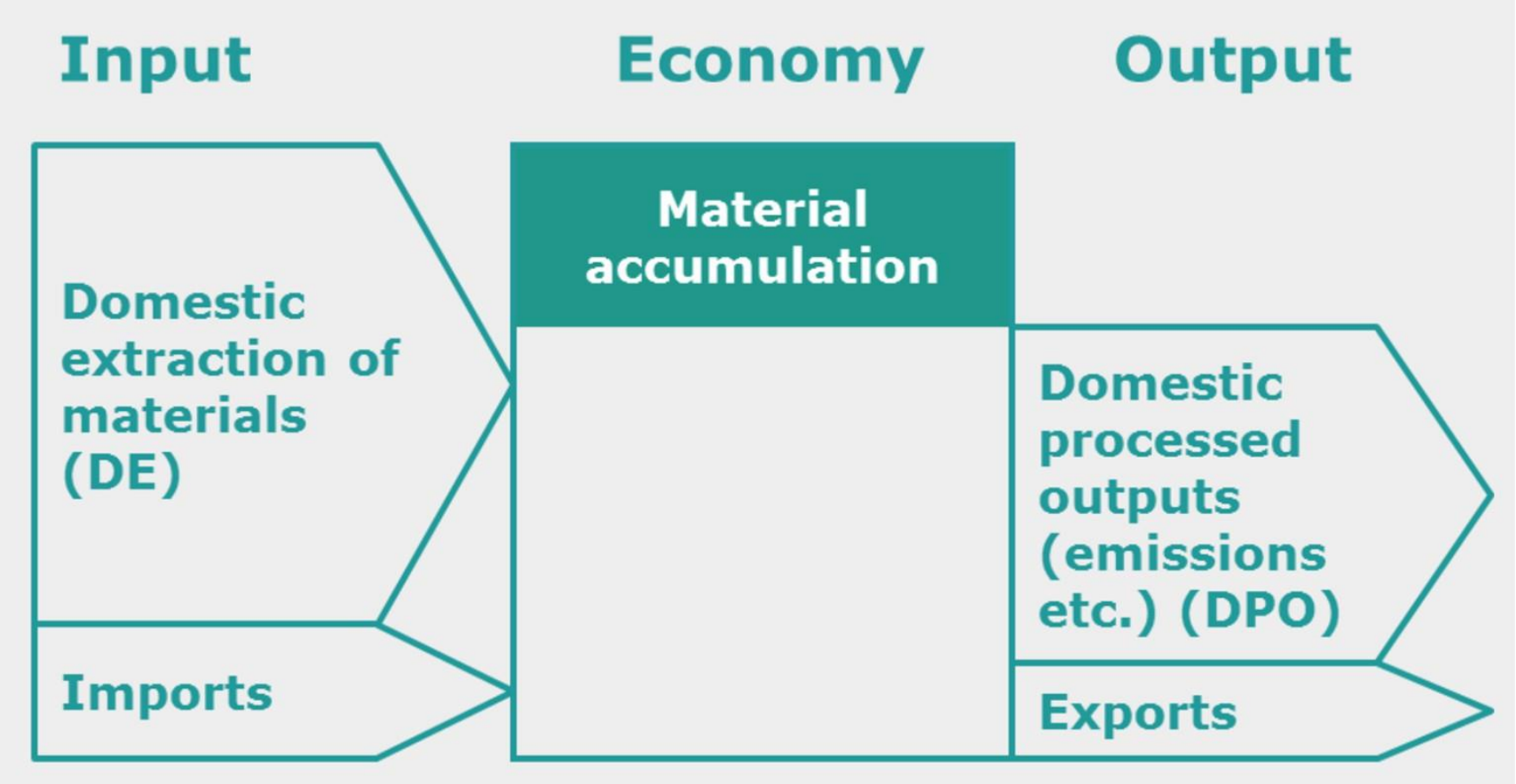
https://www.resourcepanel.org/reports/global-manual-economy-wide-material-flow-accounting

EW-MFA (in Europe): detailed method



Source: https://ec.europa.eu/eurostat/documents/3859598/9117556/KS-GQ-18-006-EN-N.pdf/b621b8ce-2792-47ff-9d10-067d2b8aac4b?t=1537260841000

EW-MFA (in Europe): detailed method



Material flows within the economy, Water flows and electricity flows are not represented in EW-MFA

EW-MFA (in Europe): detailed method

eurostat

Enable automatic checks when closing workbook

Check the whole questionnaire

Economy-wide material flow accounts (EW-MFA)

2020 EW-MFA questionnaire

INTRODUCTION

version 25 August 2020

This is Eurostat's electronic questionnaire for the 2020 data collection on **economy-wide material flow accounts** (EW-MFA). It includes a number of sheets – an overview is provided in sheet '***structure***'. Reporting Tables A, B, and D are based on Regulation (EU) No. 691/2011.

Please specify your country by selecting from the drop-down list:

Deadline for returning back the 2020 EW-MFA questionnaire is: 31 December 2020

The sheet '***instructions***' provides you with detailed information on filling in the questionnaire. Please address any questions to the following e-mail address:

ESTAT-MFA@ec.europa.eu

This electronic questionnaire shall be submitted to Eurostat using the **EDAMIS** reporting system (Electronic Data files Administration and Management Information System). Please ensure that the following EDAMIS parameters are entered:

Domain: **ENVPFLAC**

Data set: **ENVPFLAC_MFA_A**

Year: **2018** (which is the most recent legally mandatory reference year). Eurostat greatly appreciates receiving EW-MFA data starting from 2000 ranging up to 2019.

The eDAMIS system has been installed in all National Statistical Institutes and your local eDAMIS coordinator will give you a user-id and password.

Should you have any questions regarding data transmission, please contact your local eDAMIS coordinator or the Eurostat eDAMIS helpdesk at:

estat-support-edamis@ec.europa.eu

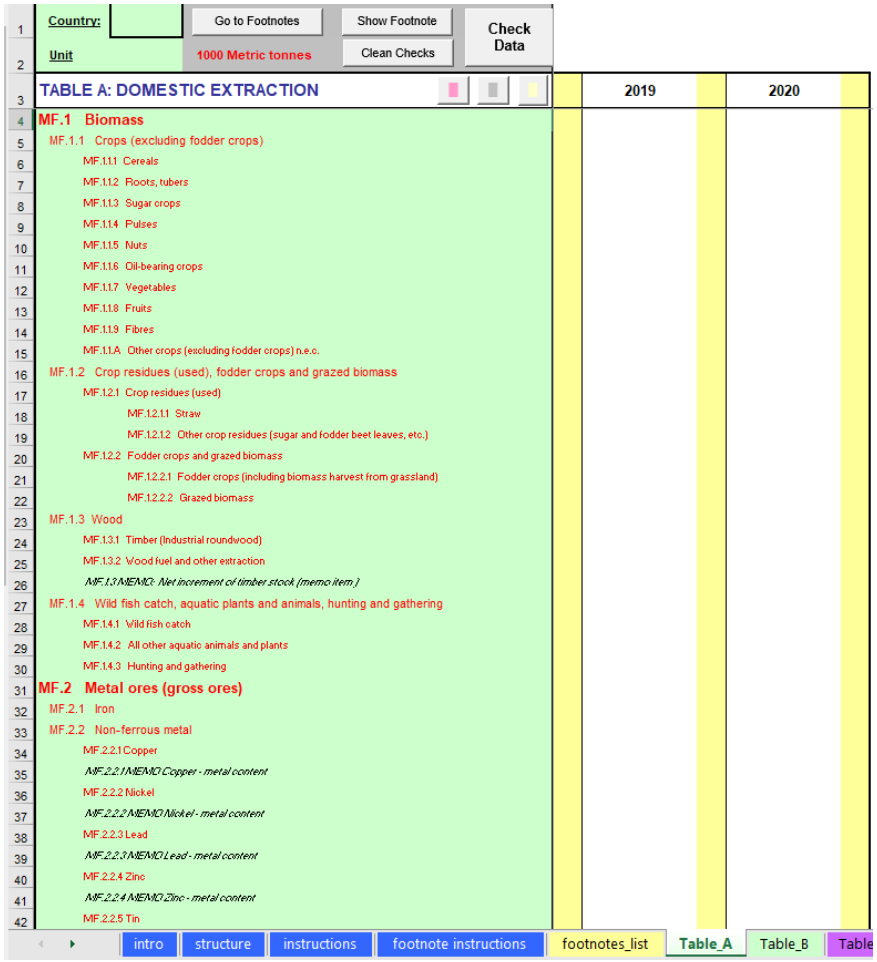
or call +352 4301 33213.

Please provide the **primary contact person for EW-MFA in your country** (*institution, unit, name, email, telephone*):

intro | structure | instructions | footnote instructions | footnotes_list | Table_A | Table_B | Table_C | Table_D | Table_E | Table_F | Table_G | Table_H | Table_I

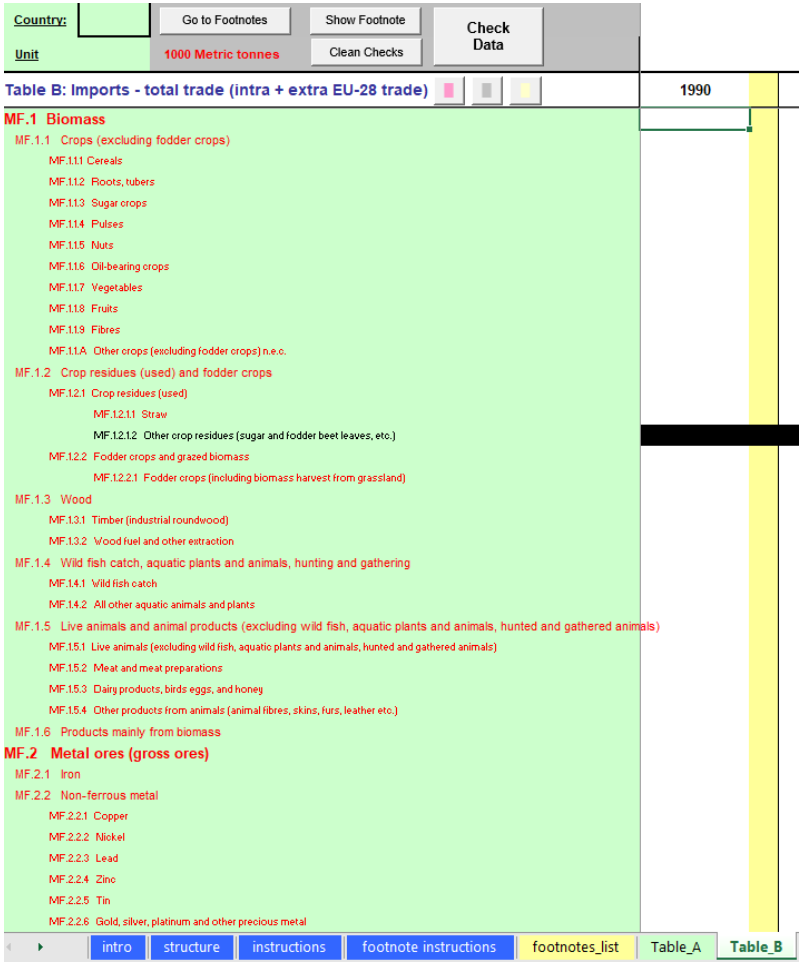
Source: https://ec.europa.eu/eurostat/documents/1798247/6191533/Economy-wide+material+flow+accounts+%28EW-MFA%29+questionnaire

EW-MFA (in Europe): detailed method



Country:		Go to Footnotes	Show Footnote	Check Data	
Unit		1000 Metric tonnes	Clean Checks		
TABLE A: DOMESTIC EXTRACTION				2019	2020
MF.1	Biomass				
MF.1.1	Crops (excluding fodder crops)				
MF.1.1.1	Cereals				
MF.1.1.2	Roots, tubers				
MF.1.1.3	Sugar crops				
MF.1.1.4	Pulses				
MF.1.1.5	Nuts				
MF.1.1.6	Oil-bearing crops				
MF.1.1.7	Vegetables				
MF.1.1.8	Fruits				
MF.1.1.9	Fibres				
MF.1.1.A	Other crops (excluding fodder crops) n.e.c.				
MF.1.2	Crop residues (used), fodder crops and grazed biomass				
MF.1.2.1	Crop residues (used)				
MF.1.2.1.1	Straw				
MF.1.2.1.2	Other crop residues (sugar and fodder beet leaves, etc.)				
MF.1.2.2	Fodder crops and grazed biomass				
MF.1.2.2.1	Fodder crops (including biomass harvest from grassland)				
MF.1.2.2.2	Grazed biomass				
MF.1.3	Wood				
MF.1.3.1	Timber (industrial roundwood)				
MF.1.3.2	Wood fuel and other extraction				
MF.1.3 MEMO	*Net increment of timber stock (memo item)*				
MF.1.4	Wild fish catch, aquatic plants and animals, hunting and gathering				
MF.1.4.1	Wild fish catch				
MF.1.4.2	All other aquatic animals and plants				
MF.1.4.3	Hunting and gathering				
MF.2	Metal ores (gross ores)				
MF.2.1	Iron				
MF.2.2	Non-ferrous metal				
MF.2.2.1	Copper				
MF.2.2.1 MEMO	*Copper - metal content*				
MF.2.2.2	Nickel				
MF.2.2.2 MEMO	*Nickel - metal content*				
MF.2.2.3	Lead				
MF.2.2.3 MEMO	*Lead - metal content*				
MF.2.2.4	Zinc				
MF.2.2.4 MEMO	*Zinc - metal content*				
MF.2.2.5	Tin				

intro | structure | instructions | footnote instructions | footnotes_list | Table_A | Table_B | Table

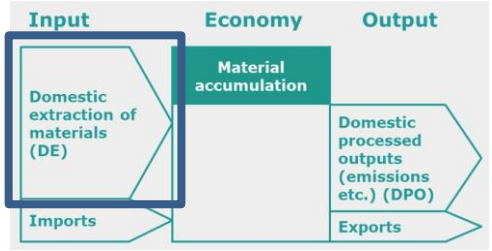


Country:		Go to Footnotes	Show Footnote	Check Data	
Unit		1000 Metric tonnes	Clean Checks		
Table B: Imports - total trade (intra + extra EU-28 trade)				1990	
MF.1	Biomass				
MF.1.1	Crops (excluding fodder crops)				
MF.1.1.1	Cereals				
MF.1.1.2	Roots, tubers				
MF.1.1.3	Sugar crops				
MF.1.1.4	Pulses				
MF.1.1.5	Nuts				
MF.1.1.6	Oil-bearing crops				
MF.1.1.7	Vegetables				
MF.1.1.8	Fruits				
MF.1.1.9	Fibres				
MF.1.1.A	Other crops (excluding fodder crops) n.e.c.				
MF.1.2	Crop residues (used) and fodder crops				
MF.1.2.1	Crop residues (used)				
MF.1.2.1.1	Straw				
MF.1.2.1.2	Other crop residues (sugar and fodder beet leaves, etc.)				
MF.1.2.2	Fodder crops and grazed biomass				
MF.1.2.2.1	Fodder crops (including biomass harvest from grassland)				
MF.1.3	Wood				
MF.1.3.1	Timber (industrial roundwood)				
MF.1.3.2	Wood fuel and other extraction				
MF.1.4	Wild fish catch, aquatic plants and animals, hunting and gathering				
MF.1.4.1	Wild fish catch				
MF.1.4.2	All other aquatic animals and plants				
MF.1.5	Live animals and animal products (excluding wild fish, aquatic plants and animals, hunted and gathered animals)				
MF.1.5.1	Live animals (excluding wild fish, aquatic plants and animals, hunted and gathered animals)				
MF.1.5.2	Meat and meat preparations				
MF.1.5.3	Dairy products, birds eggs, and honey				
MF.1.5.4	Other products from animals (animal fibres, skins, furs, leather etc.)				
MF.1.6	Products mainly from biomass				
MF.2	Metal ores (gross ores)				
MF.2.1	Iron				
MF.2.2	Non-ferrous metal				
MF.2.2.1	Copper				
MF.2.2.2	Nickel				
MF.2.2.3	Lead				
MF.2.2.4	Zinc				
MF.2.2.5	Tin				
MF.2.2.6	Gold, silver, platinum and other precious metal				

intro | structure | instructions | footnote instructions | footnotes_list | Table_A | Table_B

Source: https://ec.europa.eu/eurostat/documents/1798247/6191533/Economy-wide+material+flow+accounts+%28EW-MFA%29+questionnaire

EW-MFA: Domestic Extraction



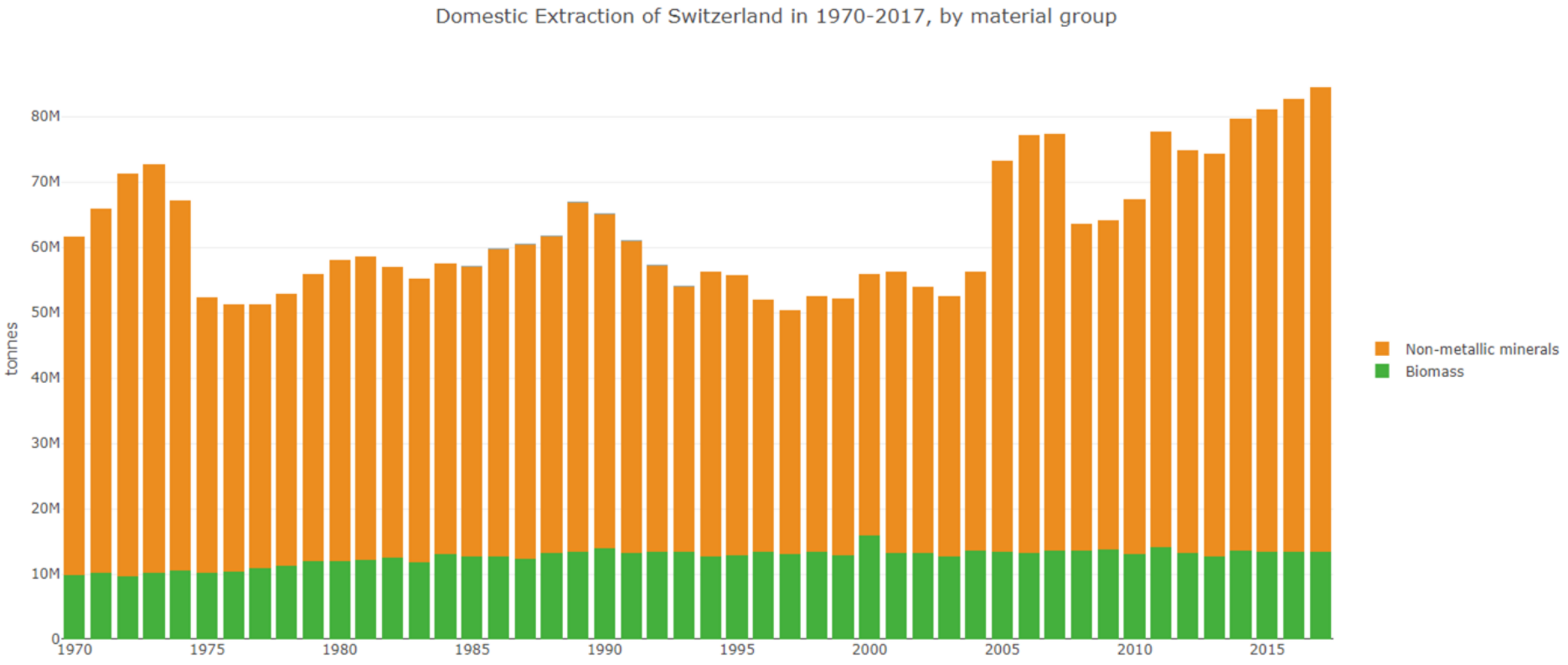
- **Domestic extraction (DE):** all raw materials that are extracted from the domestic environment and further used in production processes (excluding air and water).

- **Raw material classification**
  Biomass (crops, wood, animals, etc.)
  Metal ores (iron, copper, zinc, etc.)
  Fossil energy materials/carriers (coal, oil, natural gas etc.)
  Non-metallic minerals (limestone, sand, salt etc.)

- **Data sources:** national extraction/mining statistics, e.g. crop, forestry or mining statistics. (for instance FAO, USGS, …)

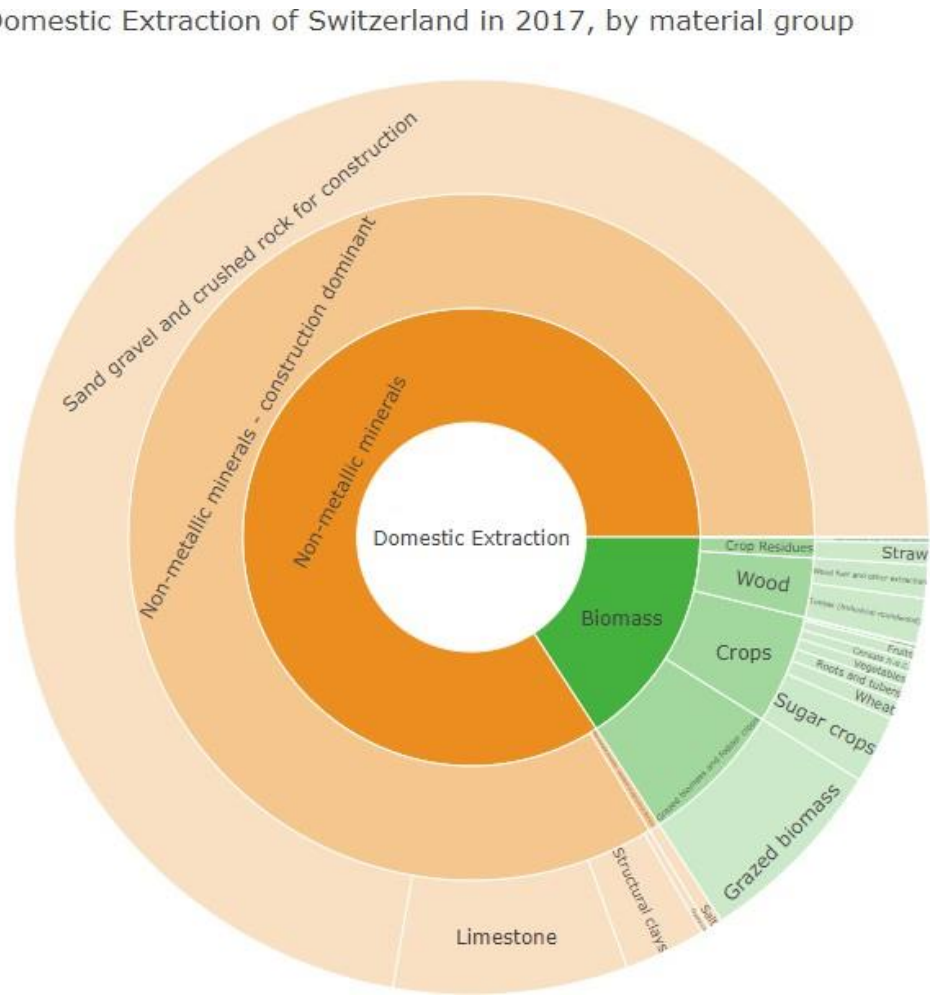
Domestic extraction in CH

What quantities of raw materials are domestically extracted to sustain economic activities?
Which raw material groups contribute most to the domestic extraction and how has this changed over time?



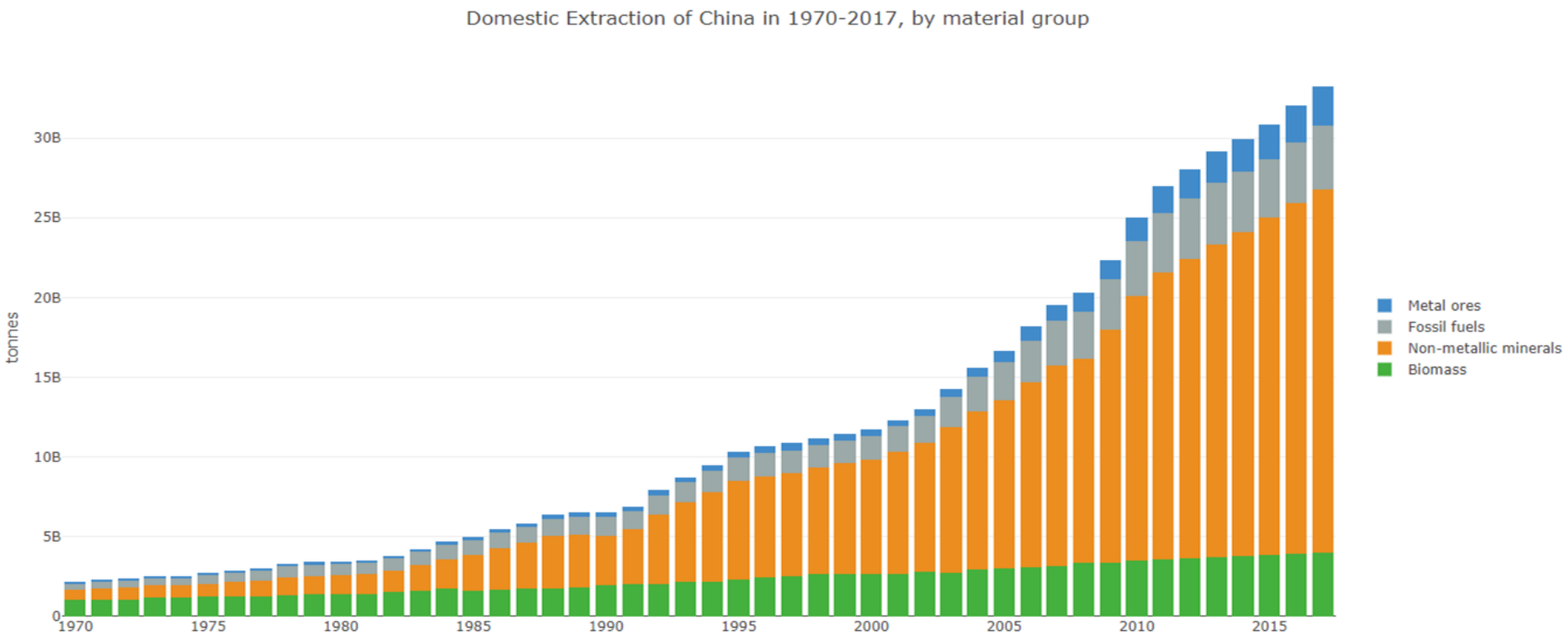
http://www.materialflows.net/

Domestic extraction in CH



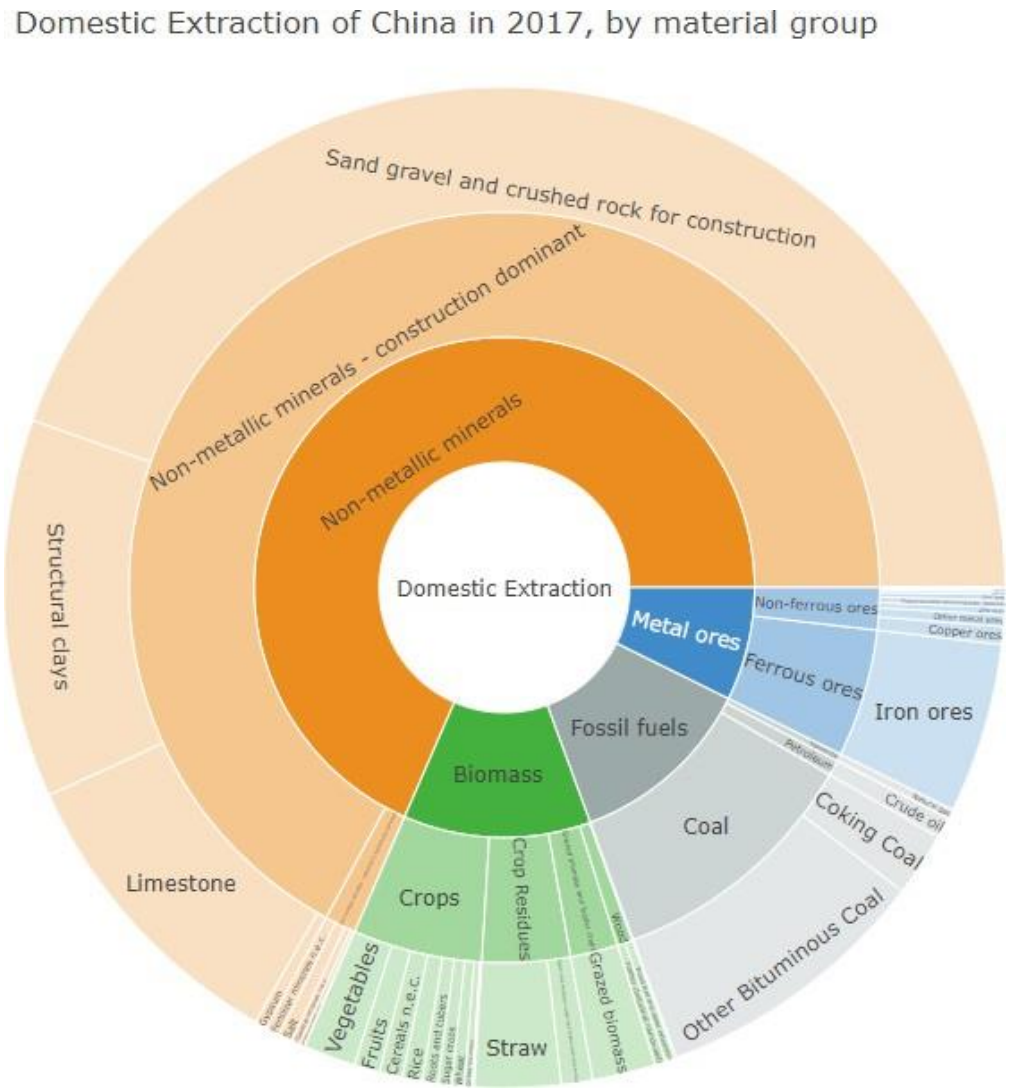
http://www.materialflows.net/

Domestic extraction in China



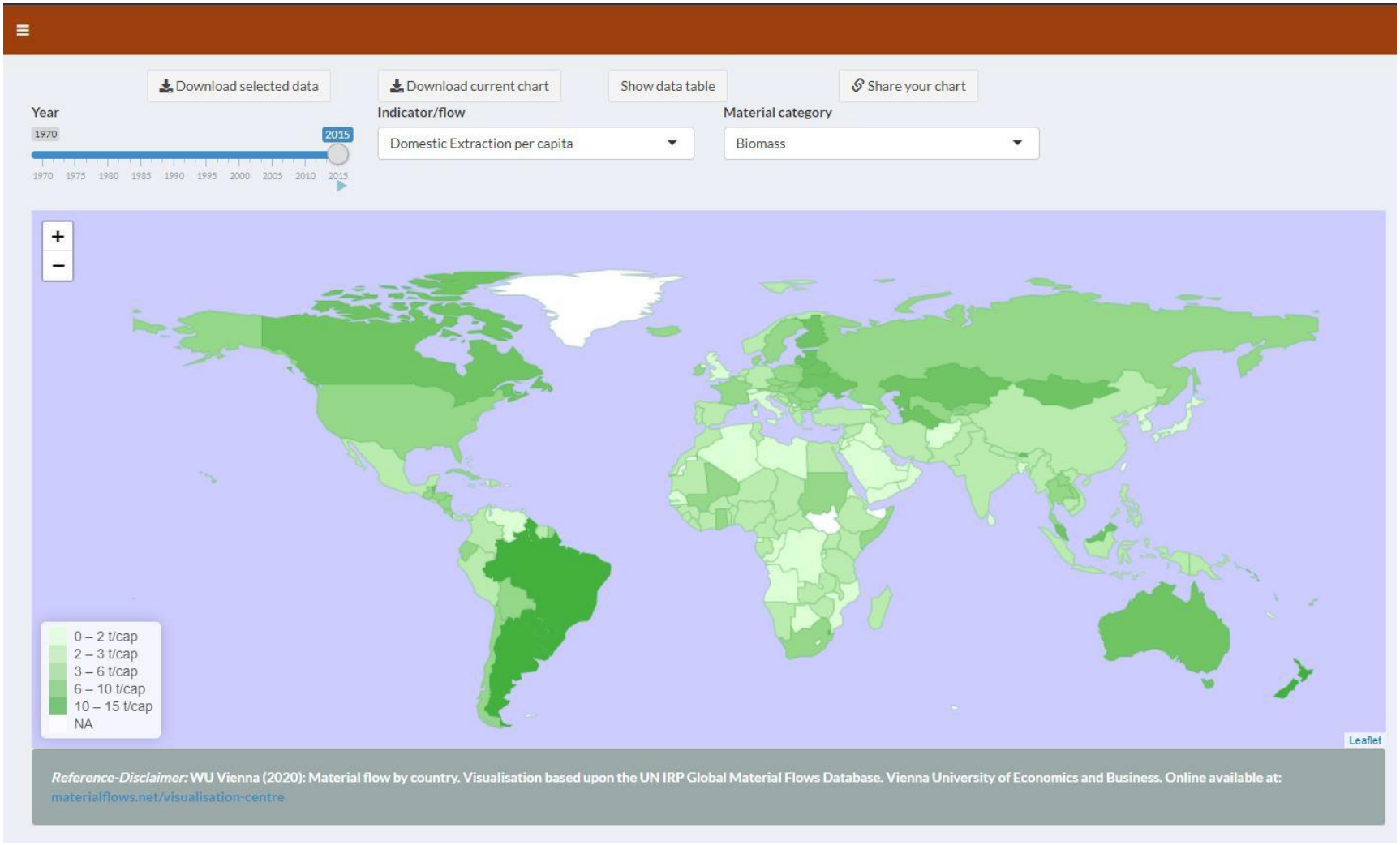
http://www.materialflows.net/

Domestic extraction in China



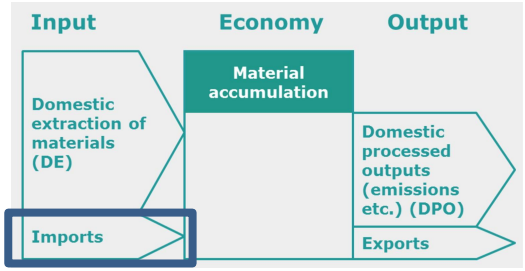
http://www.materialflows.net/

Domestic extraction in countries



http://www.materialflows.net/

MFA (Eurostat): imports



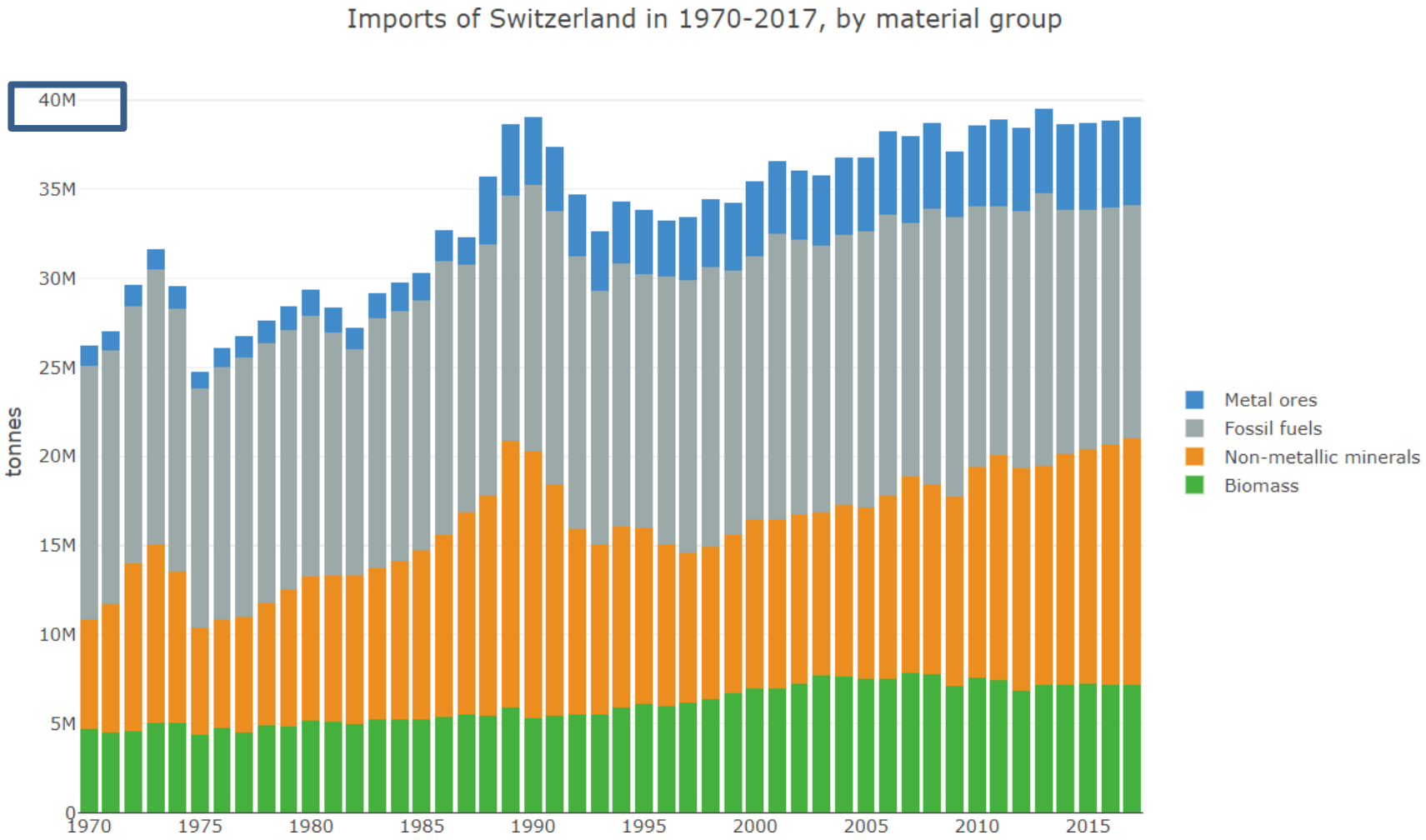
- **Imports (IMP):** imported and traded goods at all stages of processing, from raw materials to highly processed products.

- **Methods:** products are allocated to specific material categories, e.g. imported car produced from steel as the main component is allocated to iron ore.

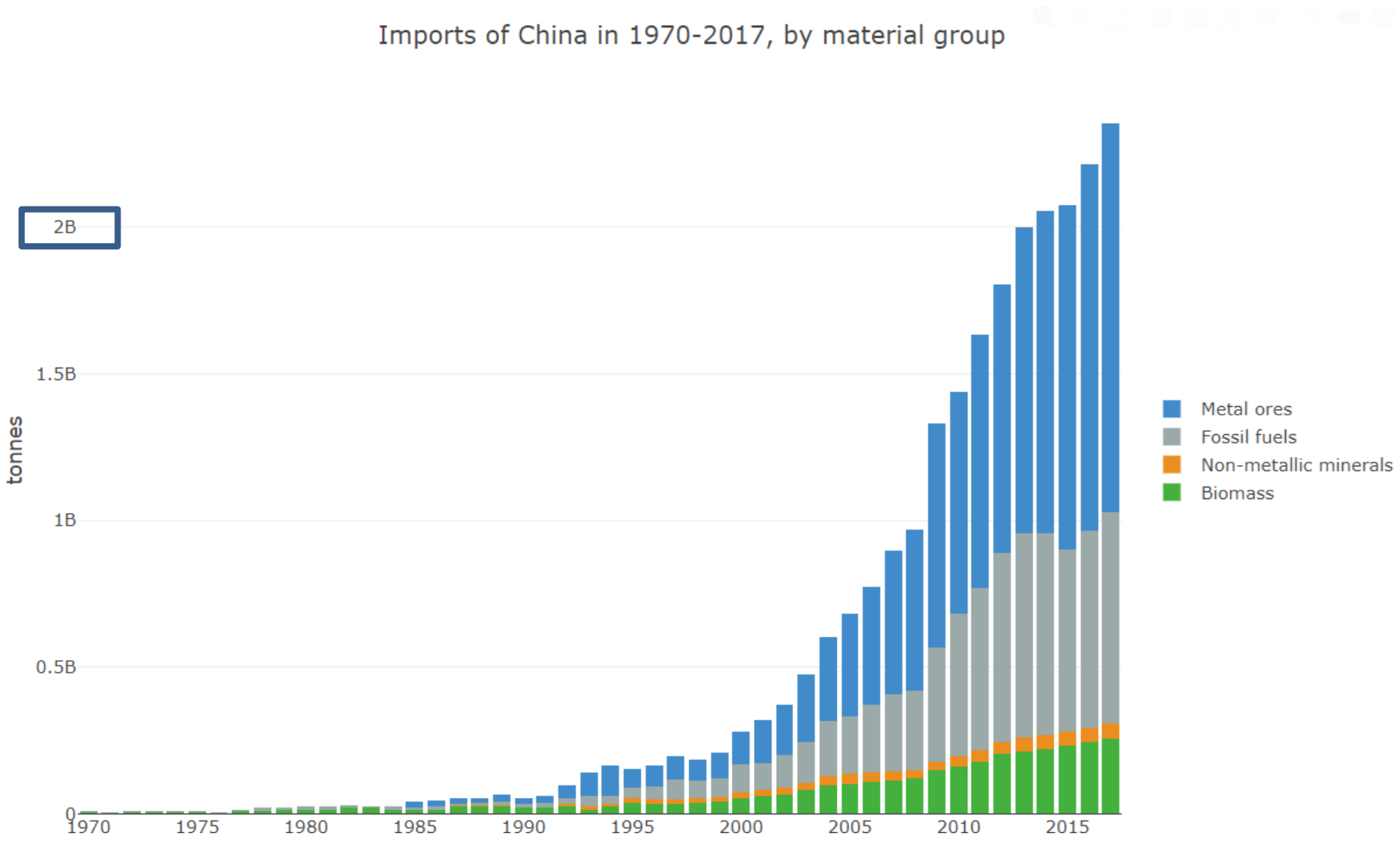
- **Data sources**: foreign trade statistics, either from national or international (EU, UN) statistical sources. (see COMEXT, CN, NST)

Imports in CH

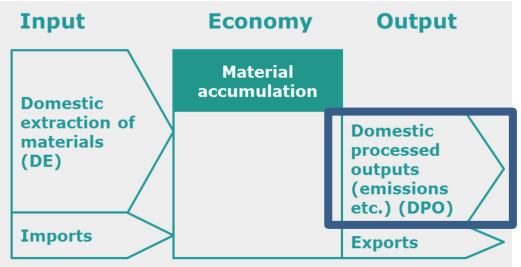
How many goods is a country importing in addition to domestic extraction?
How dependent is the productive sector of an economy on raw material imports?



Imports in China



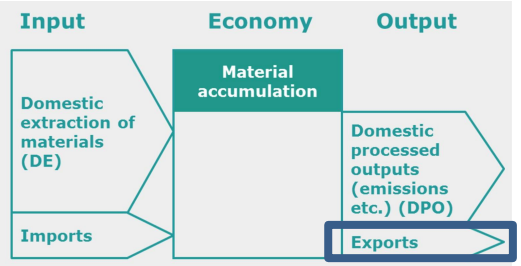
MFA (Eurostat): domestic processed output



- **Domestic processed output (DPO):** total mass of waste materials generated along the value added chain, including resource extraction, processing, manufacturing use, and waste management.

- DPO includes emissions to air, water, and landfill.

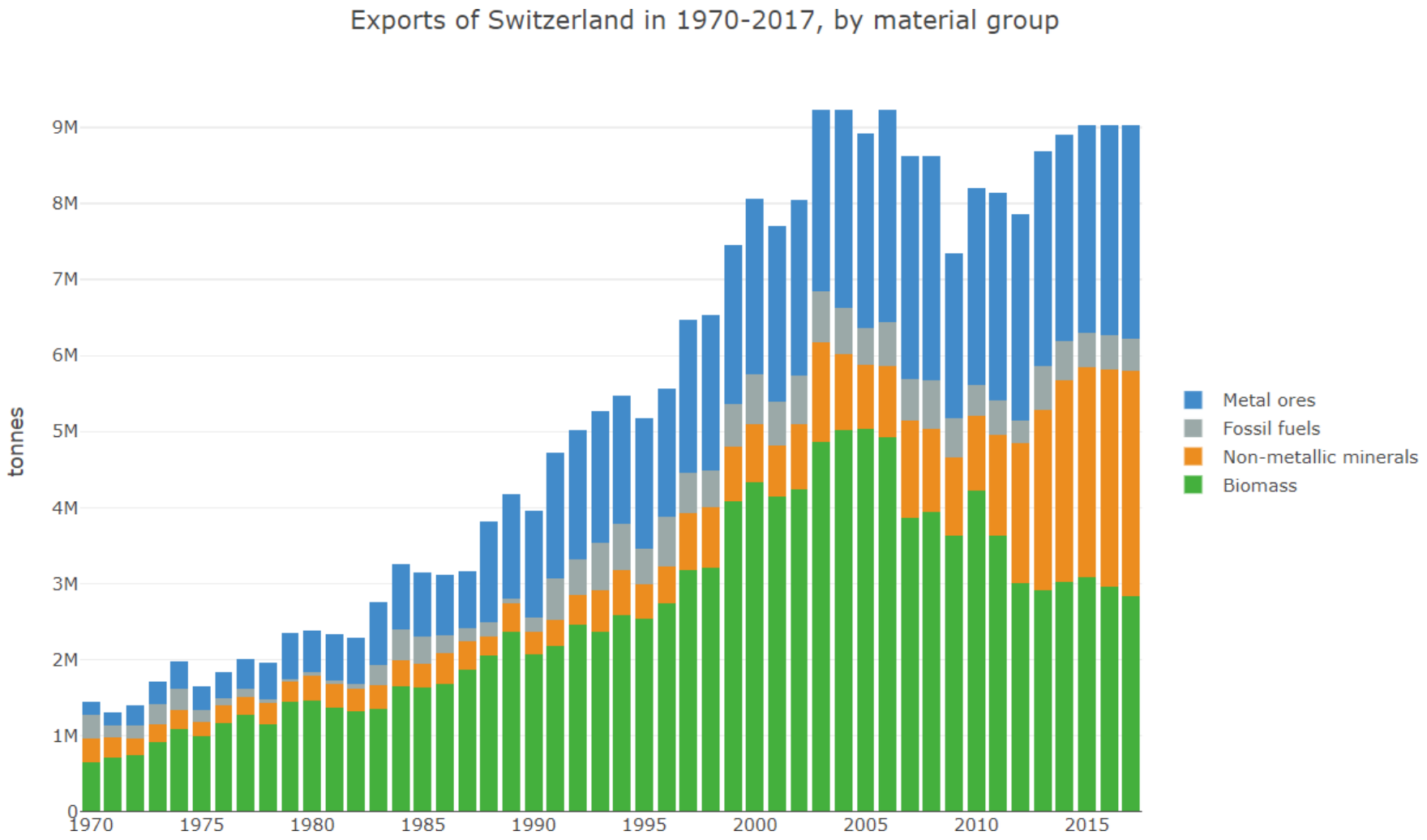
MFA (Eurostat): exports



- **Exports (EXP):** exported and traded goods at all stages of processing, from raw materials to highly processed products.
- **Methods:** products are allocated to specific material categories, e.g. exported car produced from steel as the main component is allocated to iron ore.
- **Data sources:** foreign trade statistics, either from national or international (EU, UN) statistical sources.

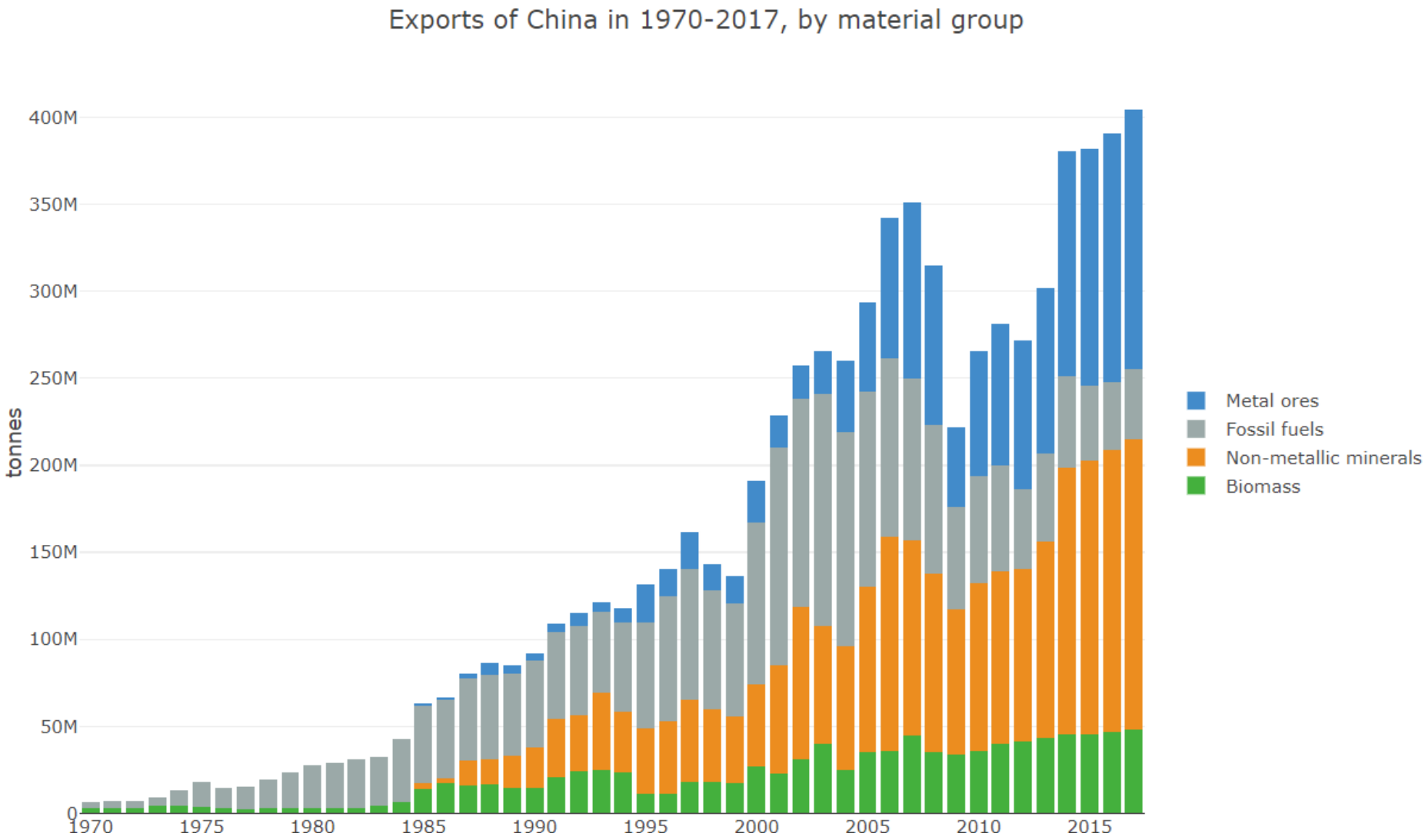
Exports in CH

How many goods is a country exporting?
40M vs 9M

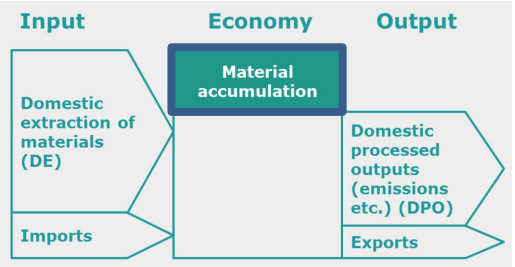


Exports in China

2,5B vs 400M



MFA (Eurostat): material accumulation



- **Material accumulation or net additions to stock (NAS):** measure of physical growth in an economy.

- New materials in form of **buildings, infrastructures, durable goods** such as e.g. cars, industry machinery, or household appliances are added to the economy's material stock each year **(gross additions).**

- Old materials are removed from stock as buildings are demolished, and durable goods disposed of **(removals).**

MFA (Eurostat): indicators

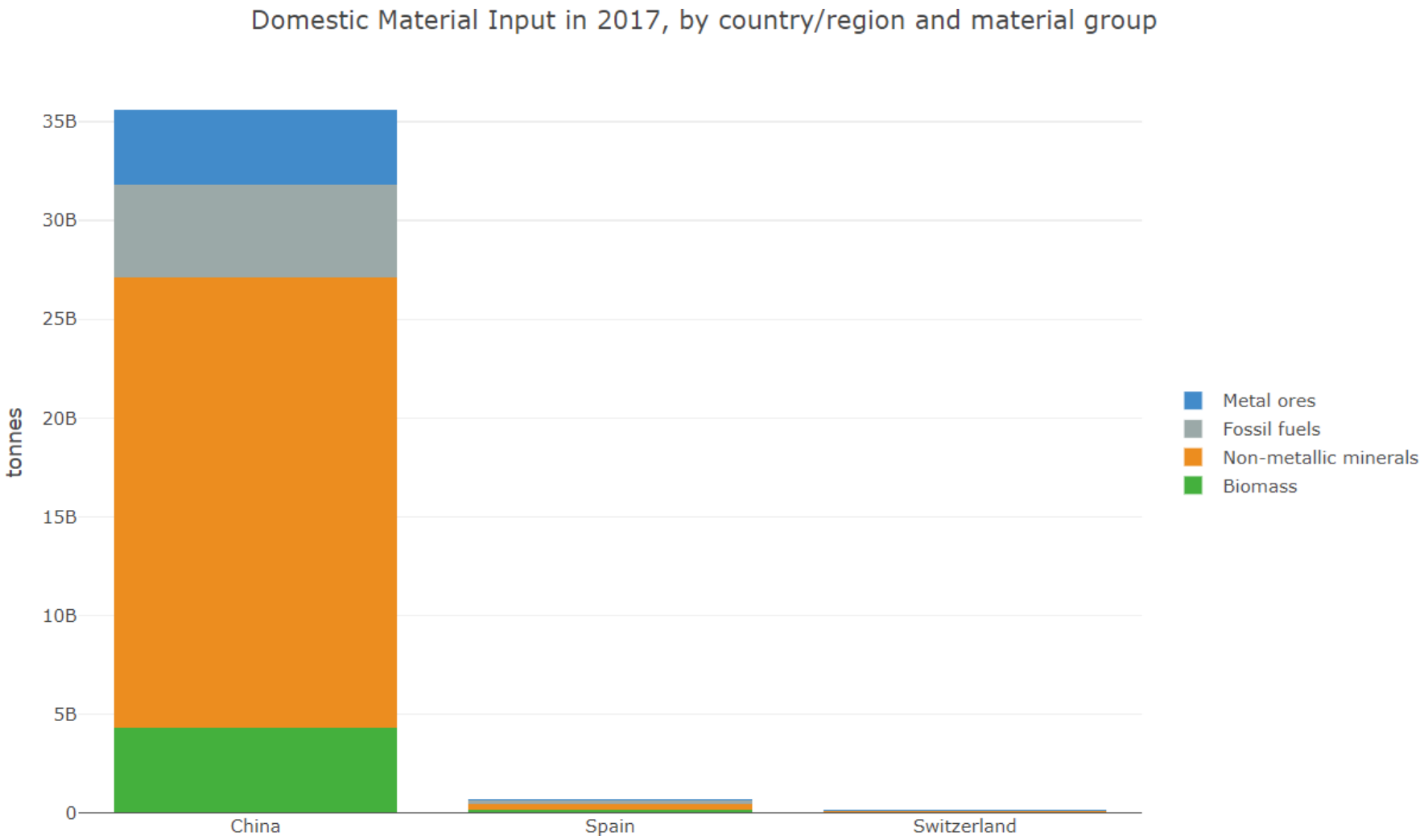
Basic flow types

- Domestic extraction (DE)
- Domestic processed output (DPO)
- Imports (IMP)
- Exports (EXP)

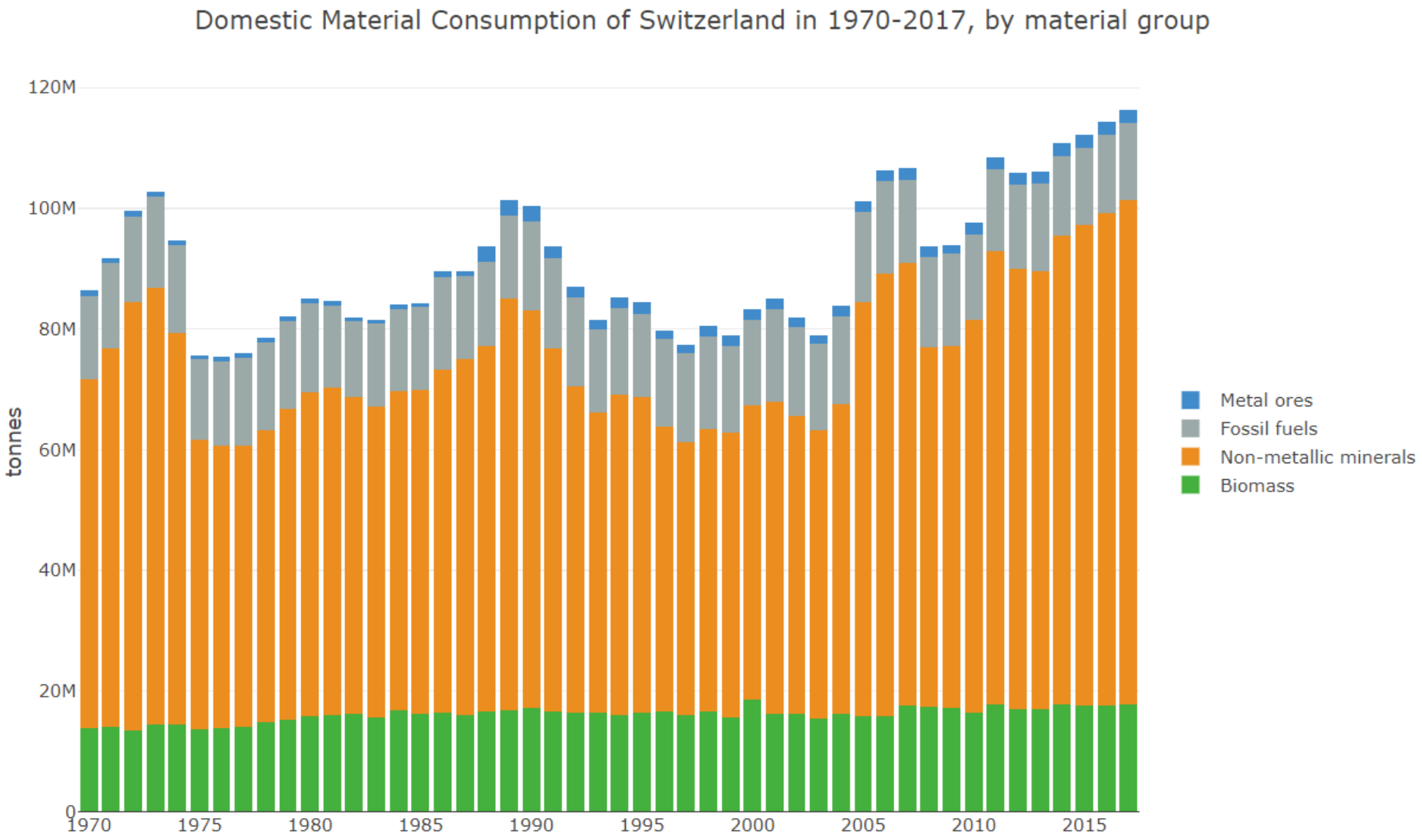
Flows types are basis for indicators

- Domestic material input (DMI) = DE + IMP
- Domestic material consumption (DMC) = DE + IMP – EXP
- Physical trade balance (PTB) = IMP – EXP
- Net additions to stock = DMI – DPO – EXP

MFA (Eurostat): indicators DMI

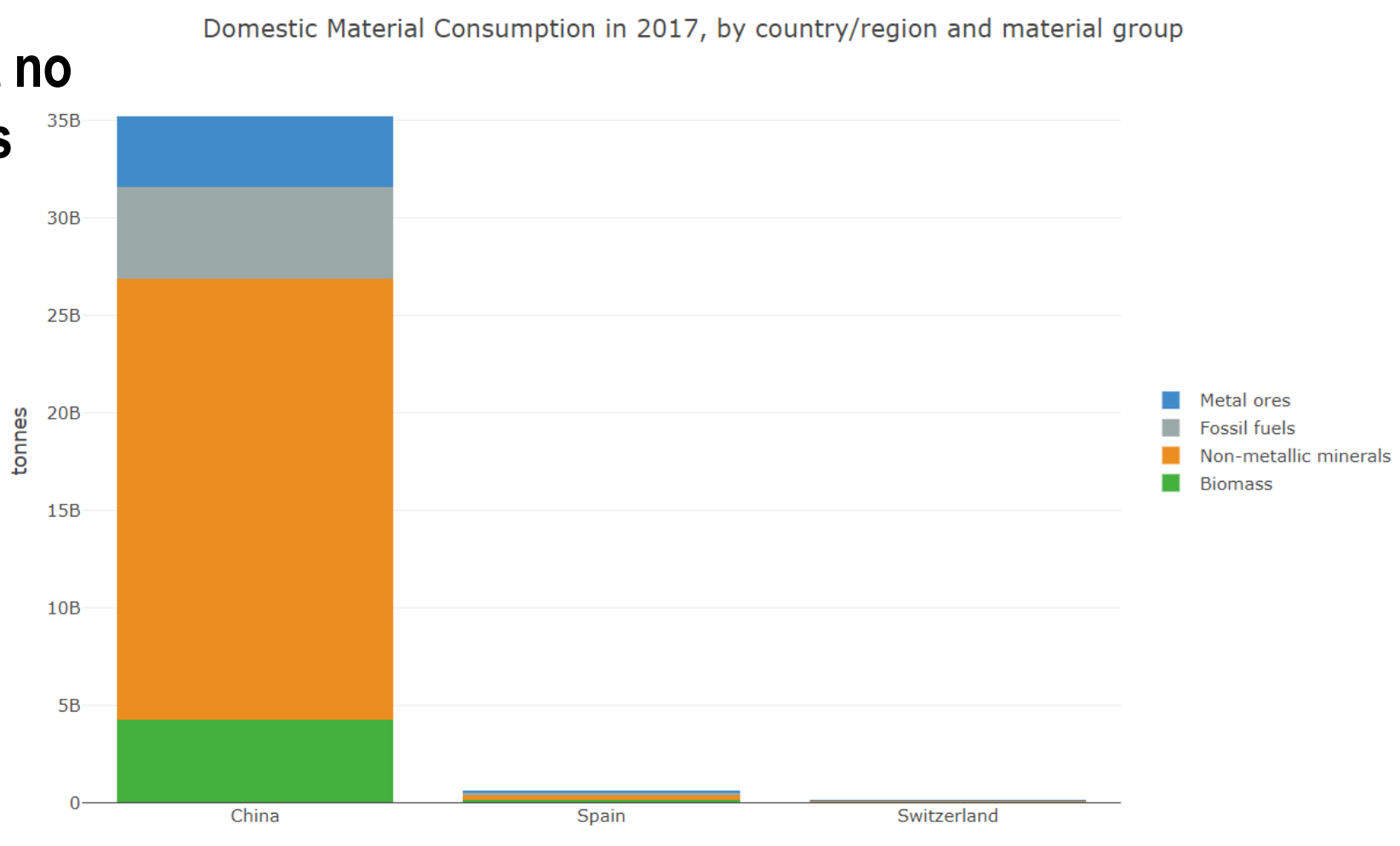


Domestic material consumption in CH



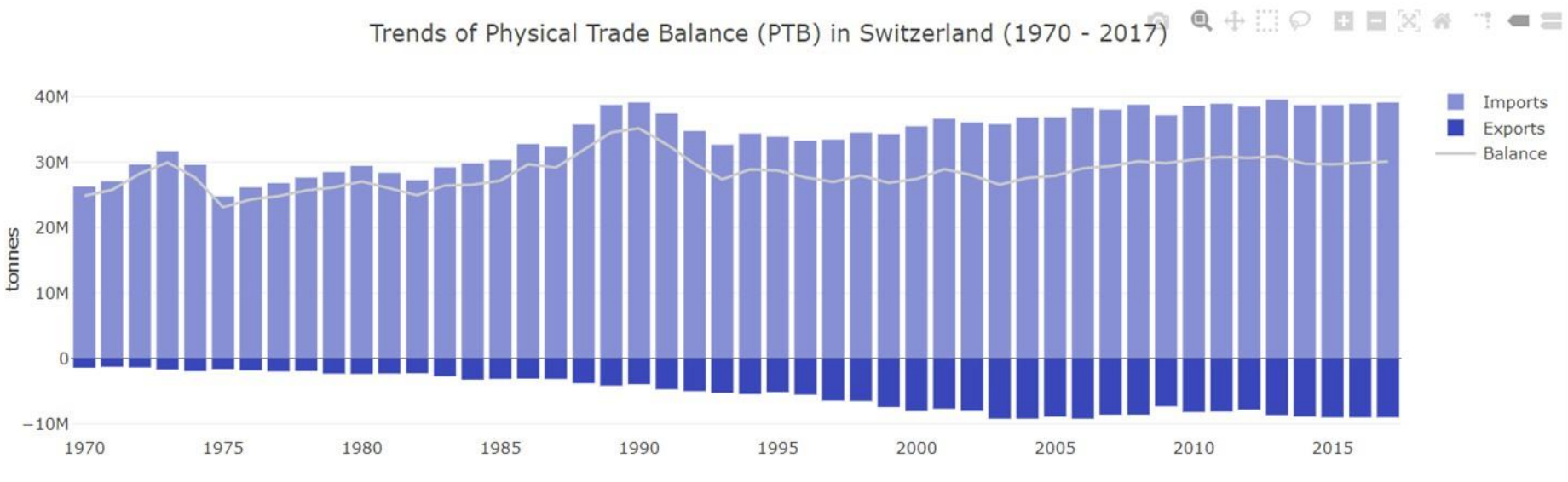
Domestic material consumption

Almost no imports



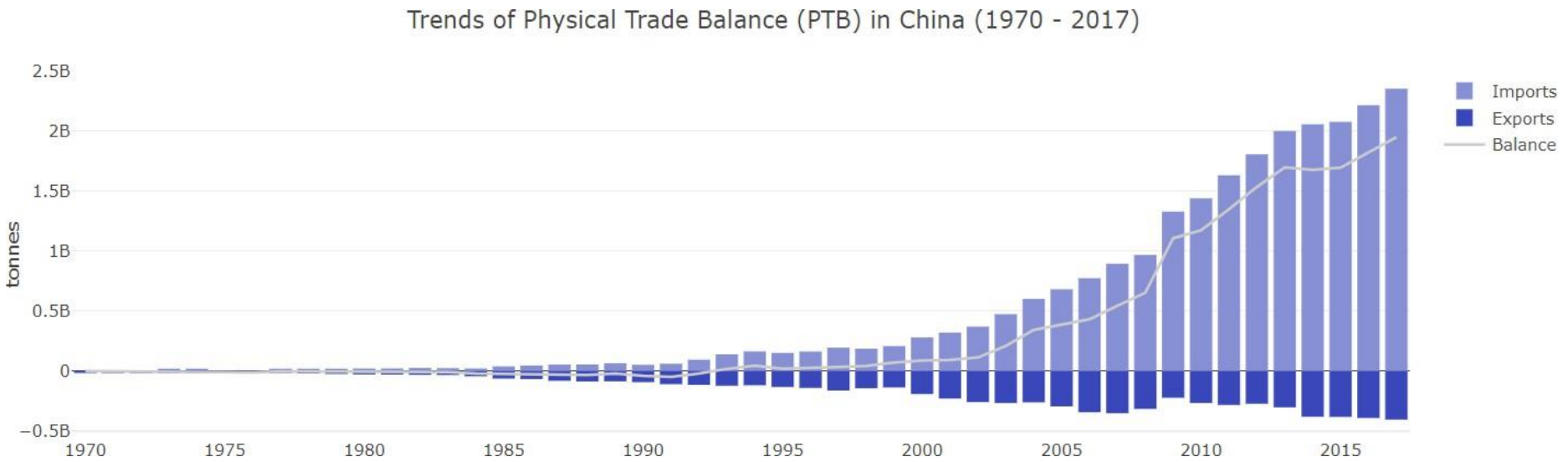
PTB in CH

Is a country a physical net-importer or net-exporter of raw materials?



PTB in China

Is a country a physical net-importer or net-exporter of raw materials?



MFA (Eurostat): additional "monetary" indicators

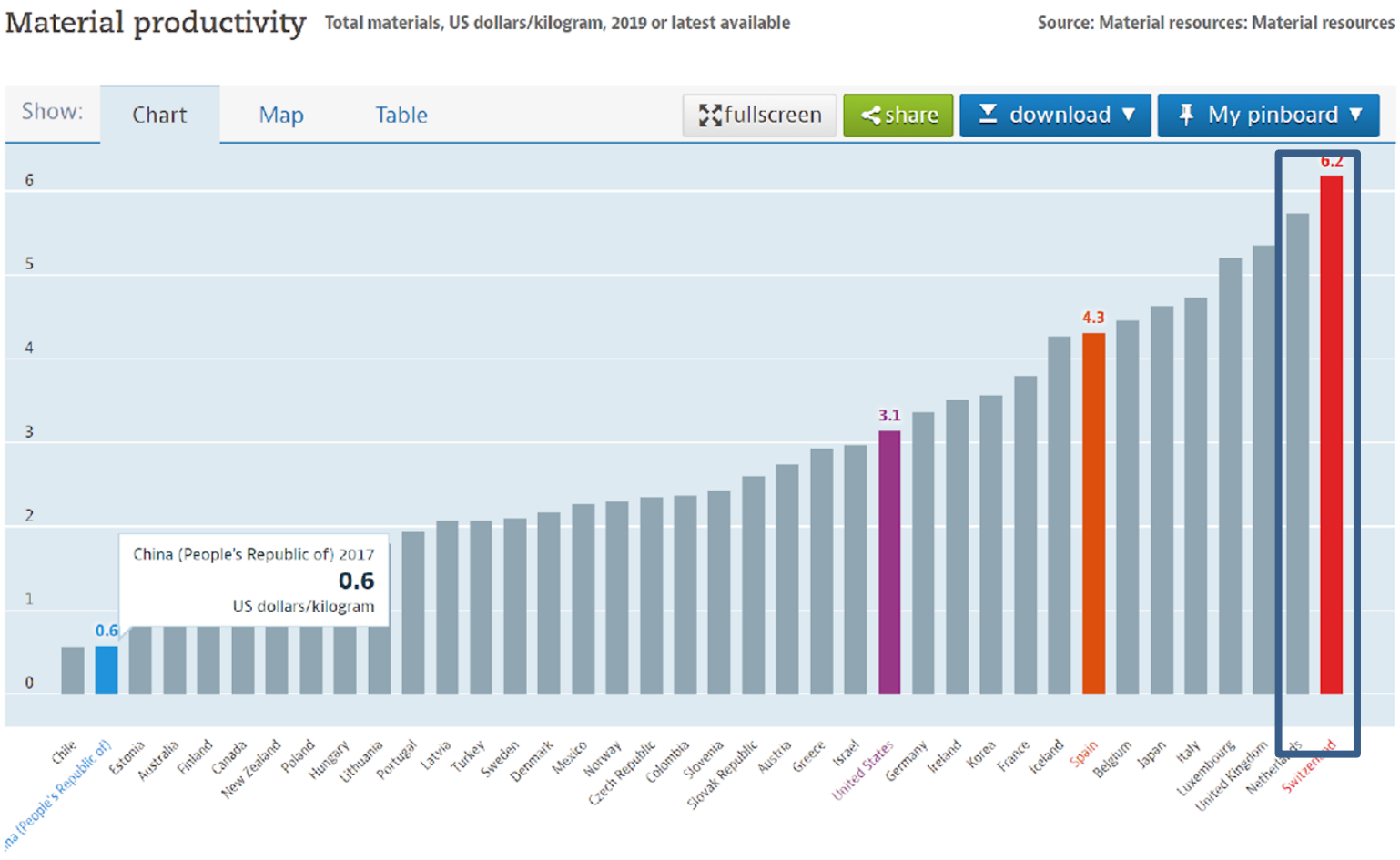
Material productivity = GDP [€ of added value] **/ DMC** [t of material input]

- **Material productivity:** measure of economic output (goods or services) per unit of material input.
- Increase in material productivity = decoupling material use and economic performance.

Material intensity = DMC [t of material input] **/ GDP** [€ of added value]

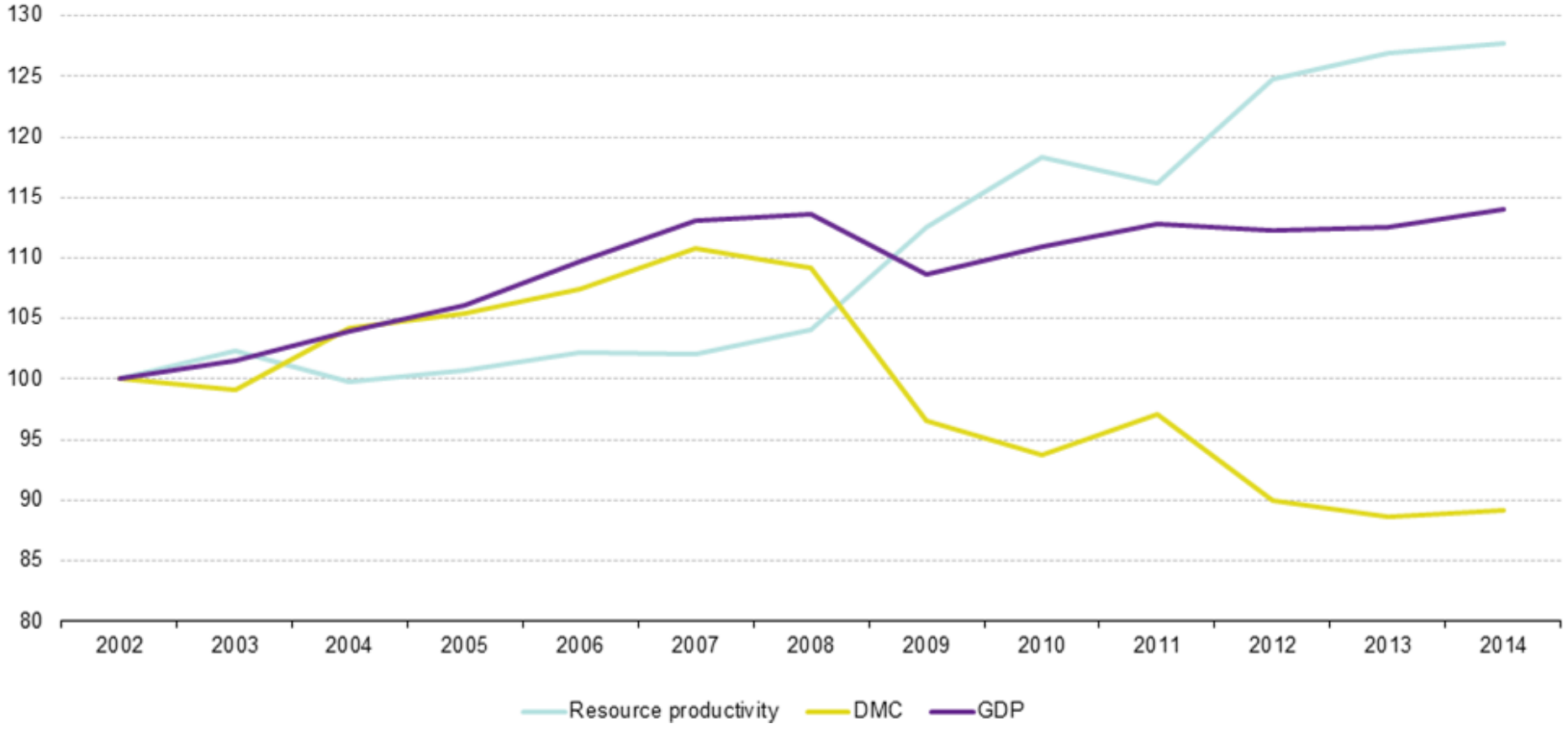
- **Material intensity:** measure of material input used per economic output (good or service)
- Decrease in material intensity = more efficient material use.

Material productivity OECD-37



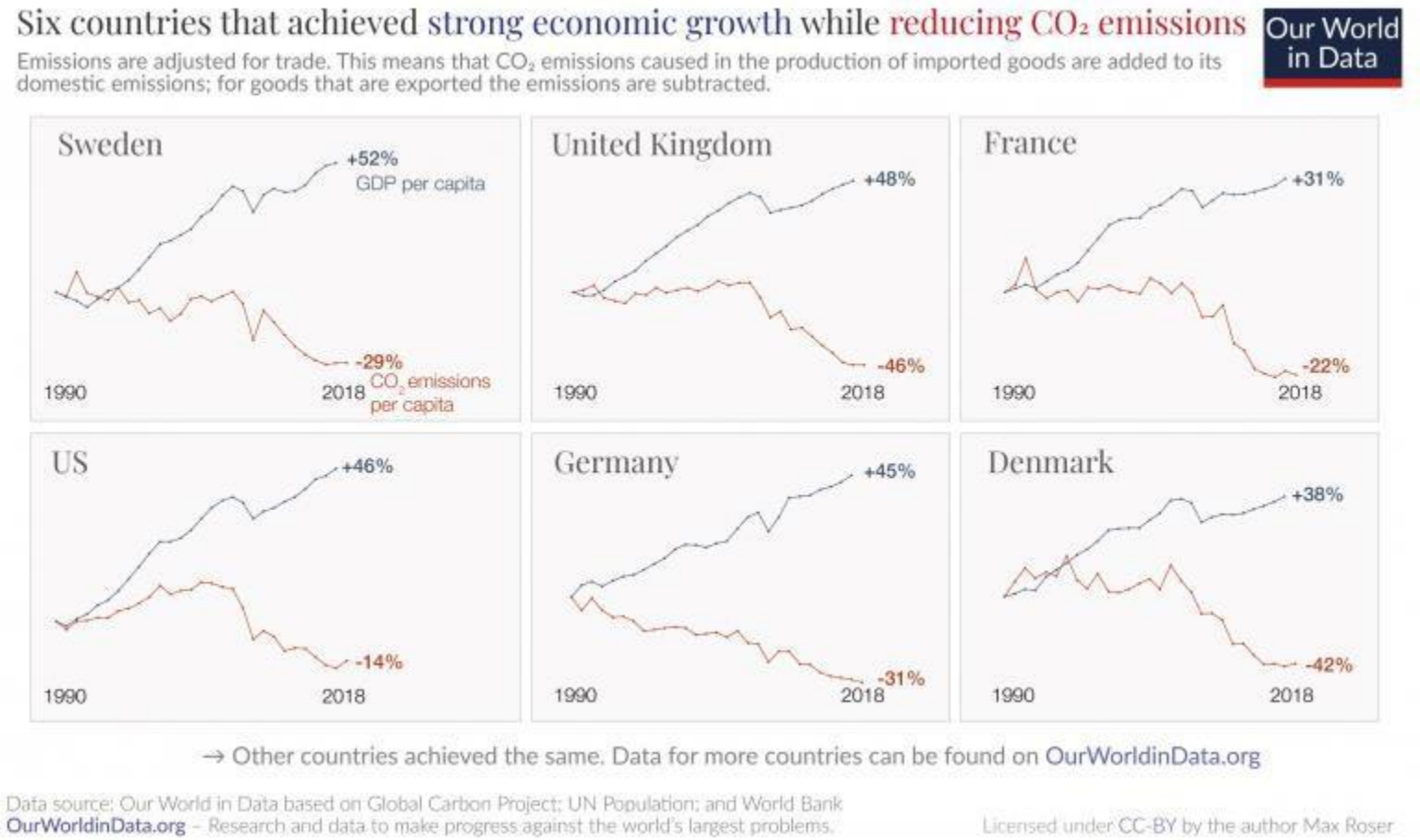
Why?

Let's talk about decoupling (absolute, relative, sufficient)



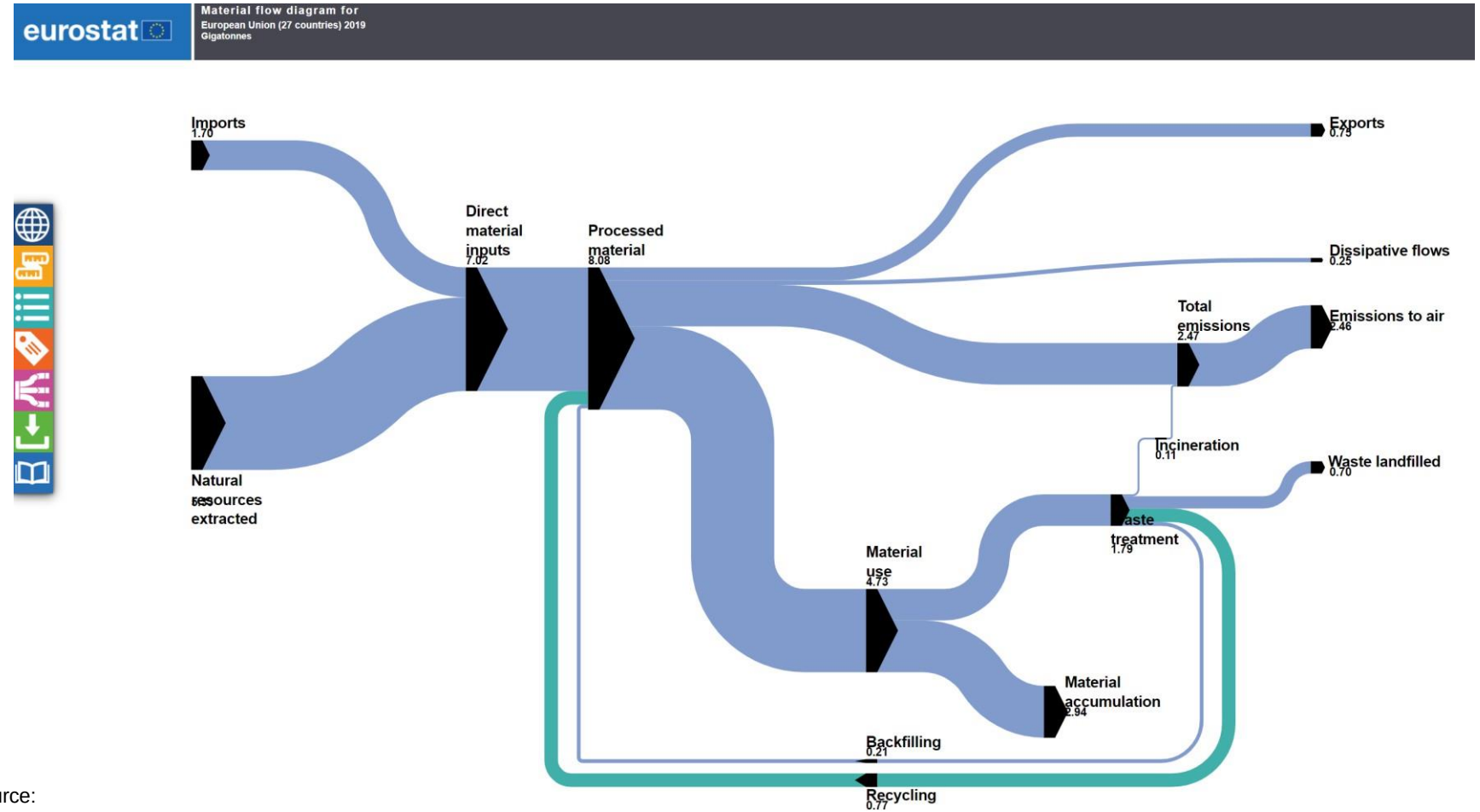
https://data.oecd.org/materials/material-productivity.htm#indicator-chart

Let's talk about decoupling (absolute, relative, sufficient)



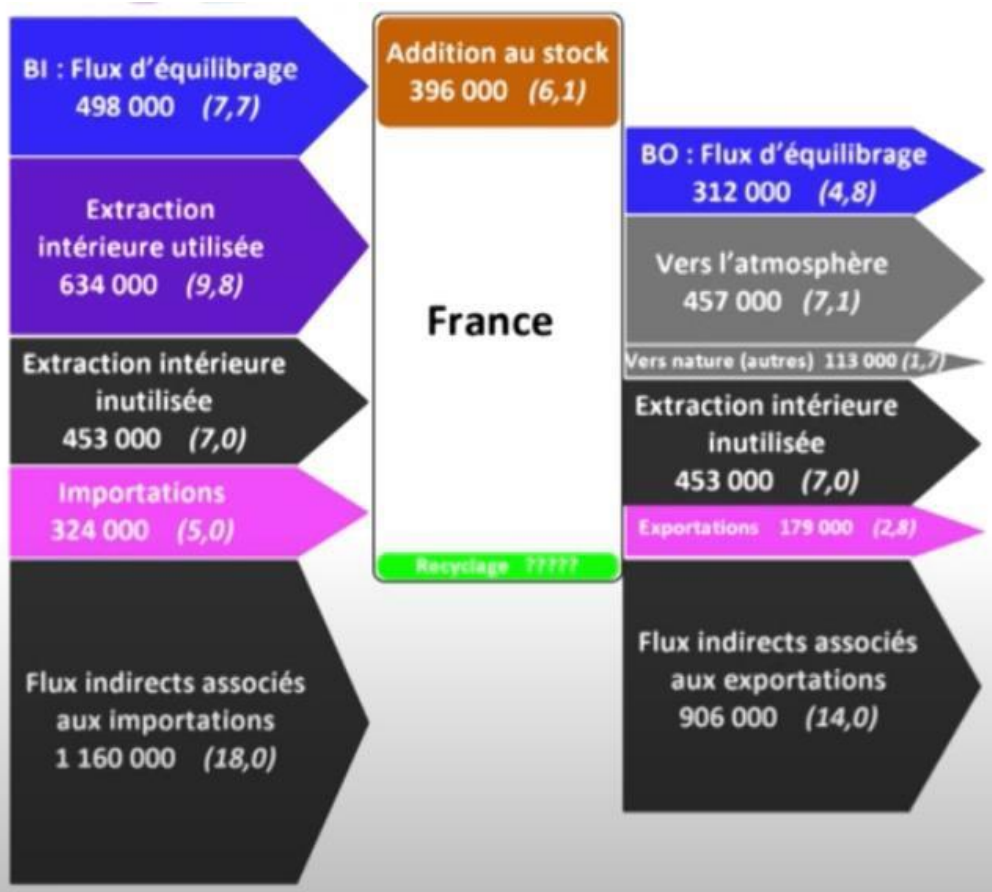
https://ourworldindata.org/carbon-price

Circular Economy at a EU level



Source: https://ec.europa.eu/eurostat/cache/sankey/circular_economy/sankey.html?geos=EU27&year=2019&unit=G_T&materials=TOTAL&highlight=0&nodeDisagg=0101100100&flowDisagg=false&translateX=200&translateY=70&scale=0.6&language=EN&xyz=89&material=TOTAL

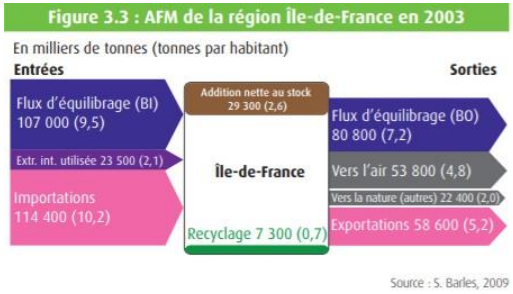
EW-MFA: Use at a territorial level (French case study)

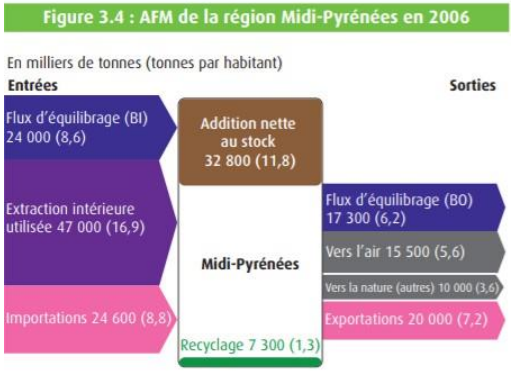


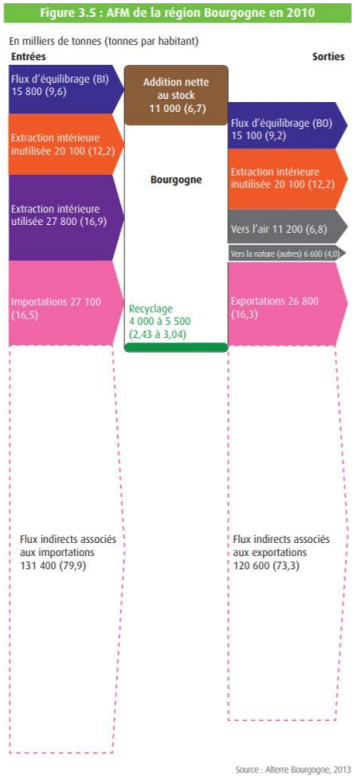
Bilan de matières brutes, France, 2010, milliers de tonnes *(tonnes par habitant)*

Source: https://www.youtube.com/watch?v=W1Fgqh1xlaM&list=PLeU78T5dtVW6wH7xsbDc2KdU3QmnlT8RC

EW-MFA: Use at a territorial level (French case study)







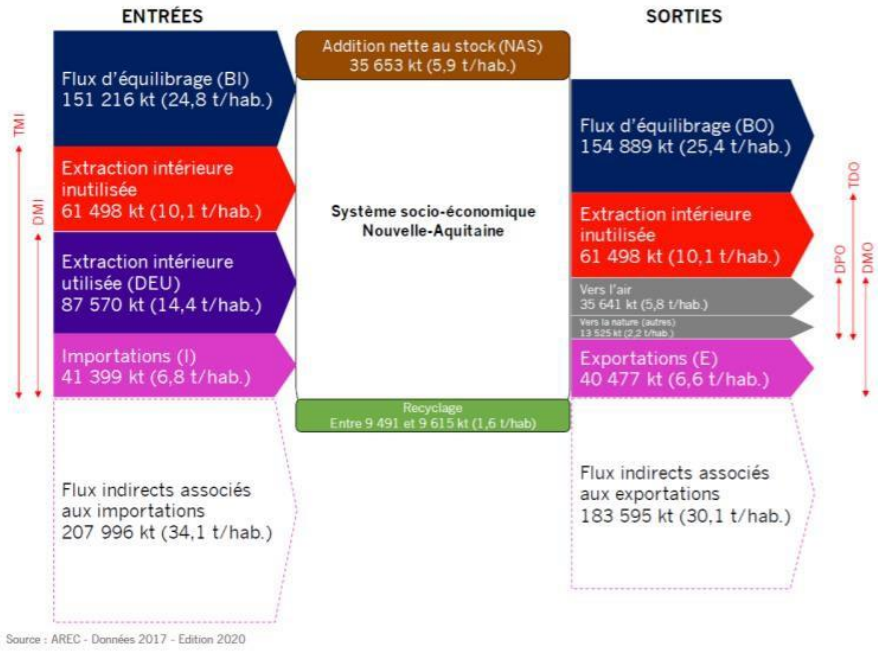
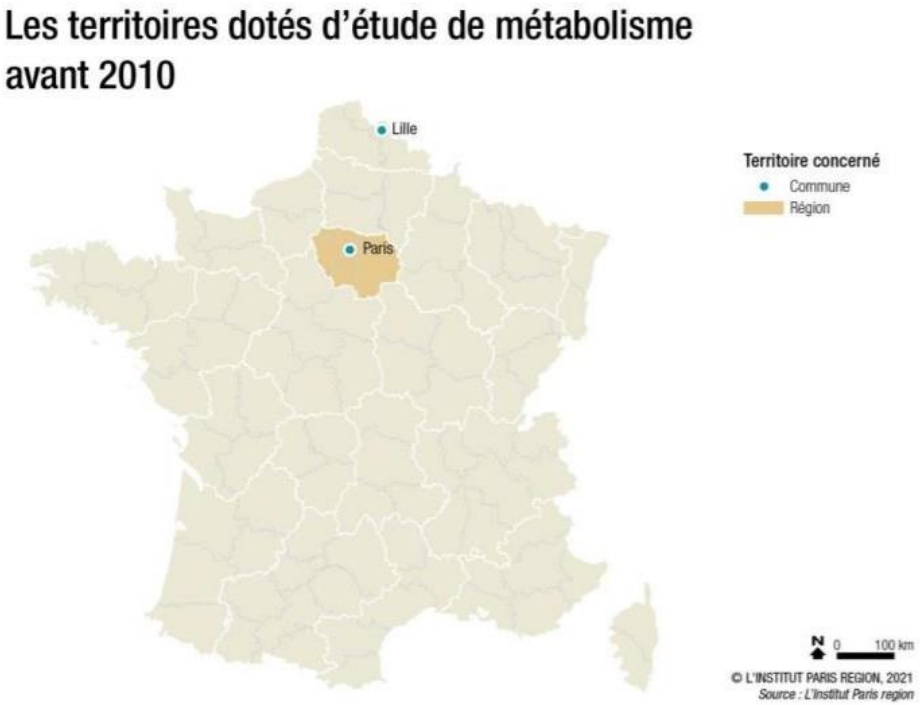
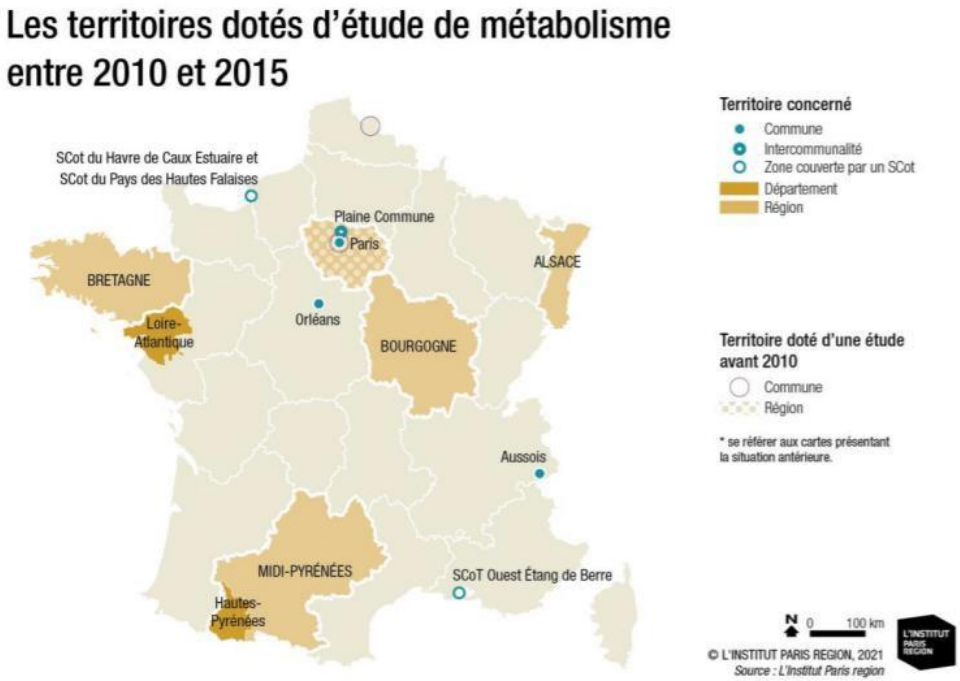


Figure 6. Schéma de principe et principaux indicateurs de l'analyse de flux de matières de la Nouvelle-Aquitaine en 2017. Sources : « Analyse de flux de matières de la Nouvelle-Aquitaine ». Les synthèses de l'AREC - ORDEC Edition 2020 – année 2017.

Source: https://www.ecologie.gouv.fr/sites/default/files/EIT%20-%20comptabilite%20des%20flux%20de%20matieres.pdf / https://www.institutparisregion.fr/fileadmin/NewEtudes/000pack2/Etude_2625/EtudesMetabolisme_Recensement_VF.pdf

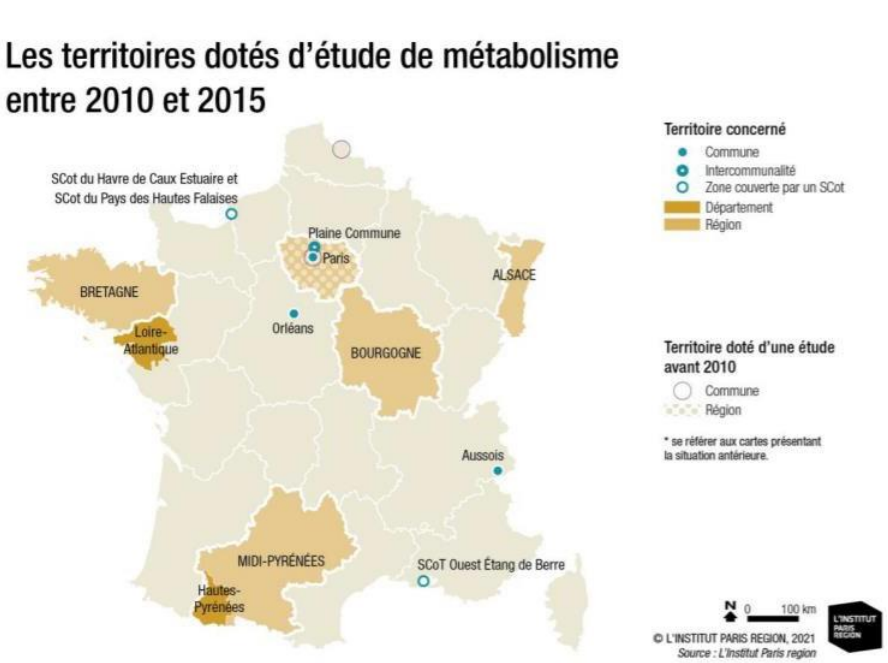
EW-MFA: Use at a territorial level (French case study)

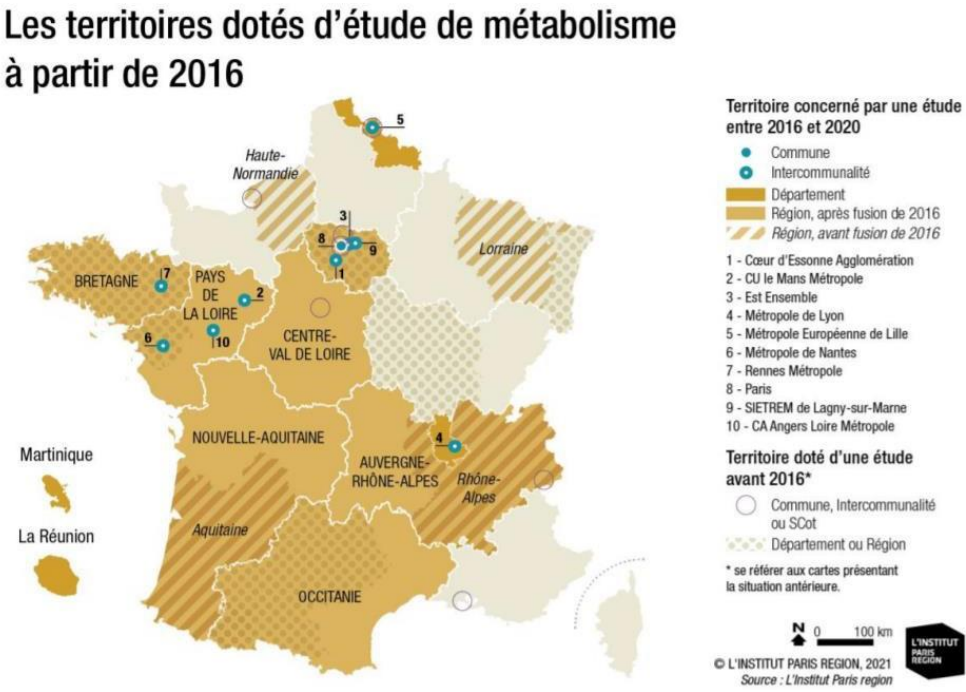




Source:https://www.institutparisregion.fr/fileadmin/NewEtudes/000pack2/Etude_2625/EtudesMetabolisme_Recensement_VF.pdf

EW-MFA: Use at a territorial level (French case study)





Carte n°3 : Etudes de métabolisme territorial en France métropolitaine en 2020

Source:https://www.institutparisregion.fr/fileadmin/NewEtudes/000pack2/Etude_2625/EtudesMetabolisme_Recensement_VF.pdf

EW-MFA: advantages vs. disadvantages

Advantages

- Trend representation within countries
- Identification of proportions and hotpots
- Comparative analysis across countries/regions
- Development of physical indicators which can be set in relation to economic indicators
- Monitoring and assessment of overarching policy goals (e.g. SDGs)
- Circular Economy monitoring

Disadvantages

- Black-box approach
- Difficulties in explaining trends
- Difficulties in deriving causalities
- None of the indicators show the full picture

EW-MFA: source

- **Eurostat**
  https://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity
- **International Resource Panel (IRP)**
  https://www.resourcepanel.org/global-material-flows-database
- **OECD Statistics**
  https://stats.oecd.org/
- **World Resource Institute**
  http://www.wri.org/
- **WU Vienna / CSIRO**
  http://www.materialflows.net/
- **Material flows of Switzerland**
  https://www.bfs.admin.ch

Method 2:
Material Flow Analysis

Baccini/Brunner/ Rechberger method

Steps of MFA

Step I: System definition
Problem definition, definition of system boundaries, selection of processes and flows of materials/substances (qualitative model)

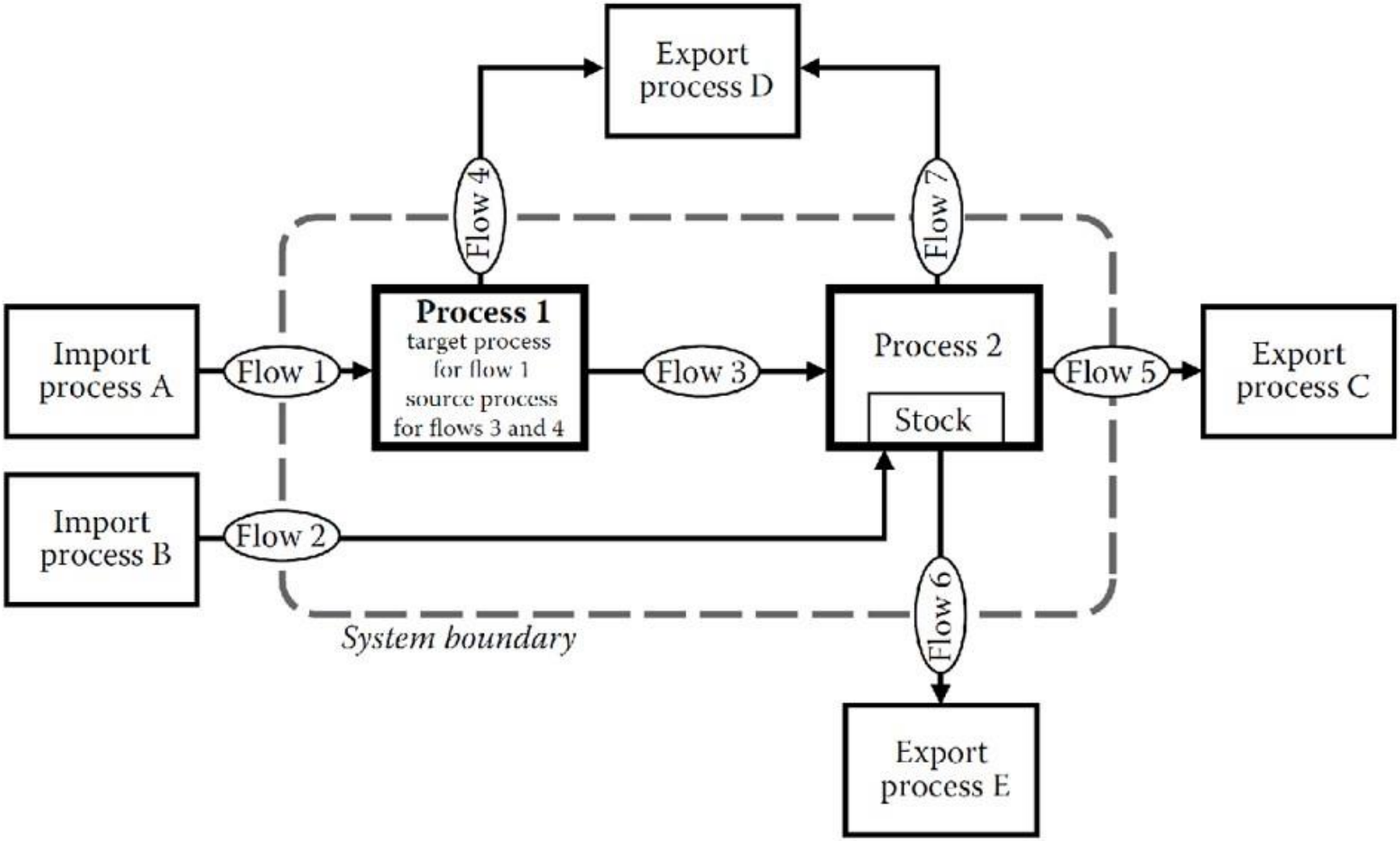
Step II: Measurement
Data collection of flows and stocks of materials/substances and characterization of uncertainties (measurements, literature data, estimations)

Step III: Calculation
Calculation of unknown quantities by balancing of materials based on the principle of mass conservation (MFA software)

Step IV: Illustration and interpretation
Sources, stocks, flows and sinks

Step V: Recommendations
How can the system be optimized?

Steps of MFA



Brunner & Rechberger, 2016

Definitions: MFA system

MFA system: comprises a set of material flows, stocks, and processes within a defined boundary.

- **System boundary** is defined in space and time.
- **Temporal boundary:** time period over which the material balance is calculated (e.g. 1 hour for waste incineration process, 1000 years for landfills, 1 year for a city).
- **Spatial boundary:** geographical area (e.g. municipality, region, city)
  or virtual limits (e.g. private households, company).

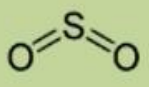
Definitions: MFA system

Materials: substances and goods.

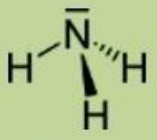
Chemical elements

e.g.

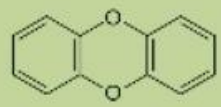
Chemical compounds



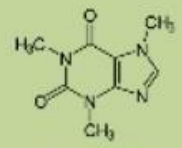
Sulfur dioxide



Ammonia



Dibenzodioxin



Caffeine

Goods

Substance

Material

Goods

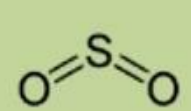
Definitions: MFA system

Substances: chemical elements (e.g. carbon, iron) or a chemical compound (e.g. carbon dioxide) composed of uniform units.

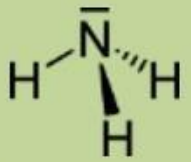
Chemical elements

e.g.

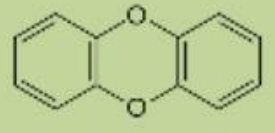
Chemical compounds



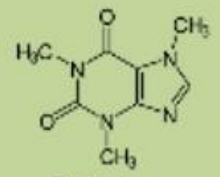
Sulfur dioxide



Ammonia



Dibenzodioxin



Caffeine

Substance

Definitions: MFA system

Goods: substances or mixtures of substances with positive (e.g. car, fuel) or negative (e.g. waste, sewage sludge) economic values.

Goods

Goods

Definitions: process

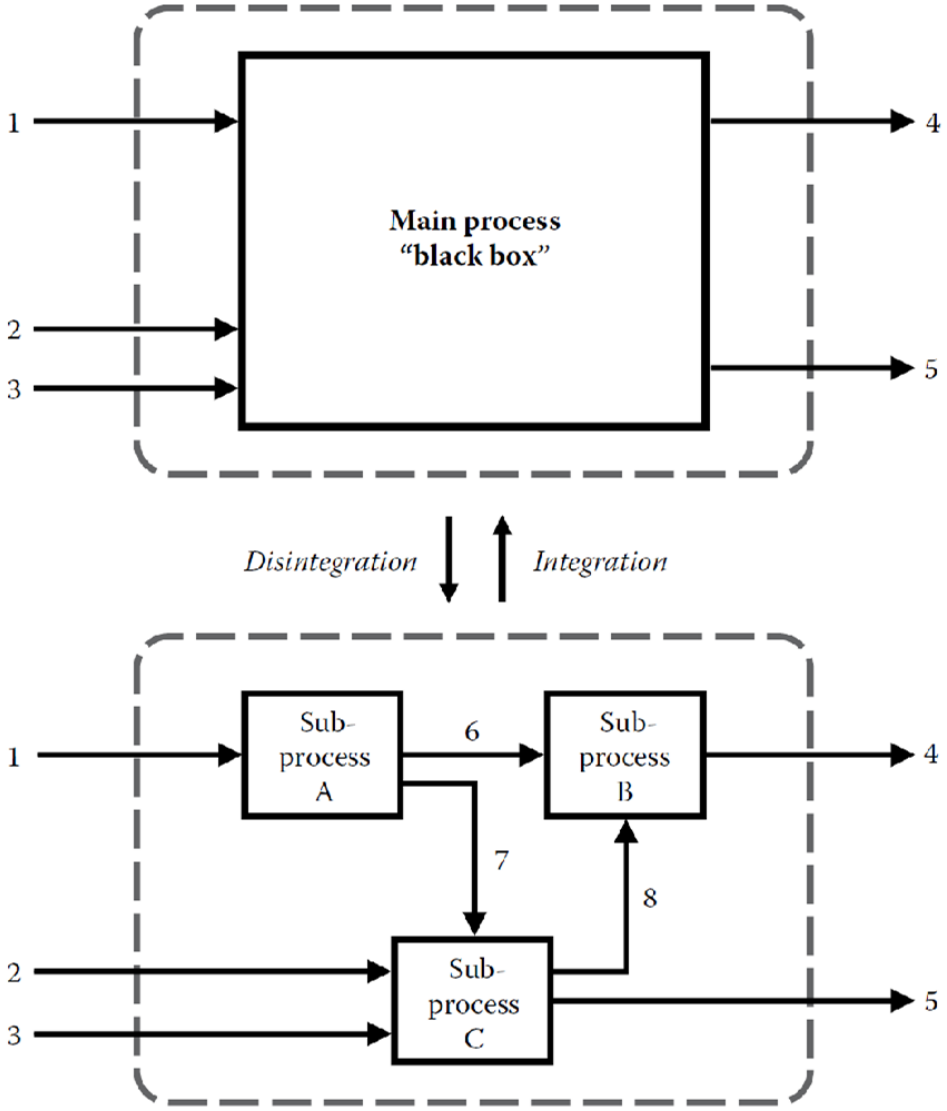
Process: any kind of transformation, transport or storage of a material that is characterized by input and output flows.

- Waste incineration process
- Wastewater treatment plant
- Energy production process
- Recycling process
- Human physiological process
- Landfill
- Gas tank farm





Subdividing black box into subprocesses



???

Can you give some examples of subprocesses

Water use

Brunner & Rechberger, 2016

Definitions: stocks

Stocks: material reservoirs or material quantity within a process.

- Stocks can stay constant, increase or decrease in size.
- Accumulation/depletion of stock: difference between process inputs and outputs between two time steps.

Definitions: geogenic and anthropogenic stocks

Geogenic stocks

- Surface and ground water
- Quarries (e.g. granit, limestone)
- Metal ores
- Oil and gas fields
- etc.

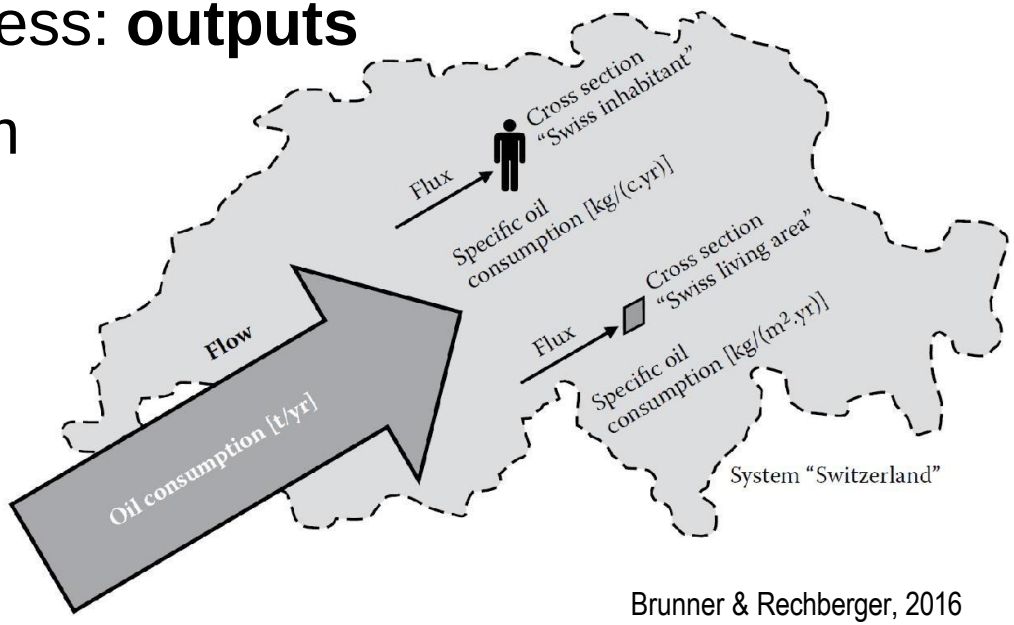
Anthropogenic stocks

- Concrete and steel in buildings
- Copper wires in buildings and goods
- Urban mines (e.g. landfills)
- etc.

Definitions: flows

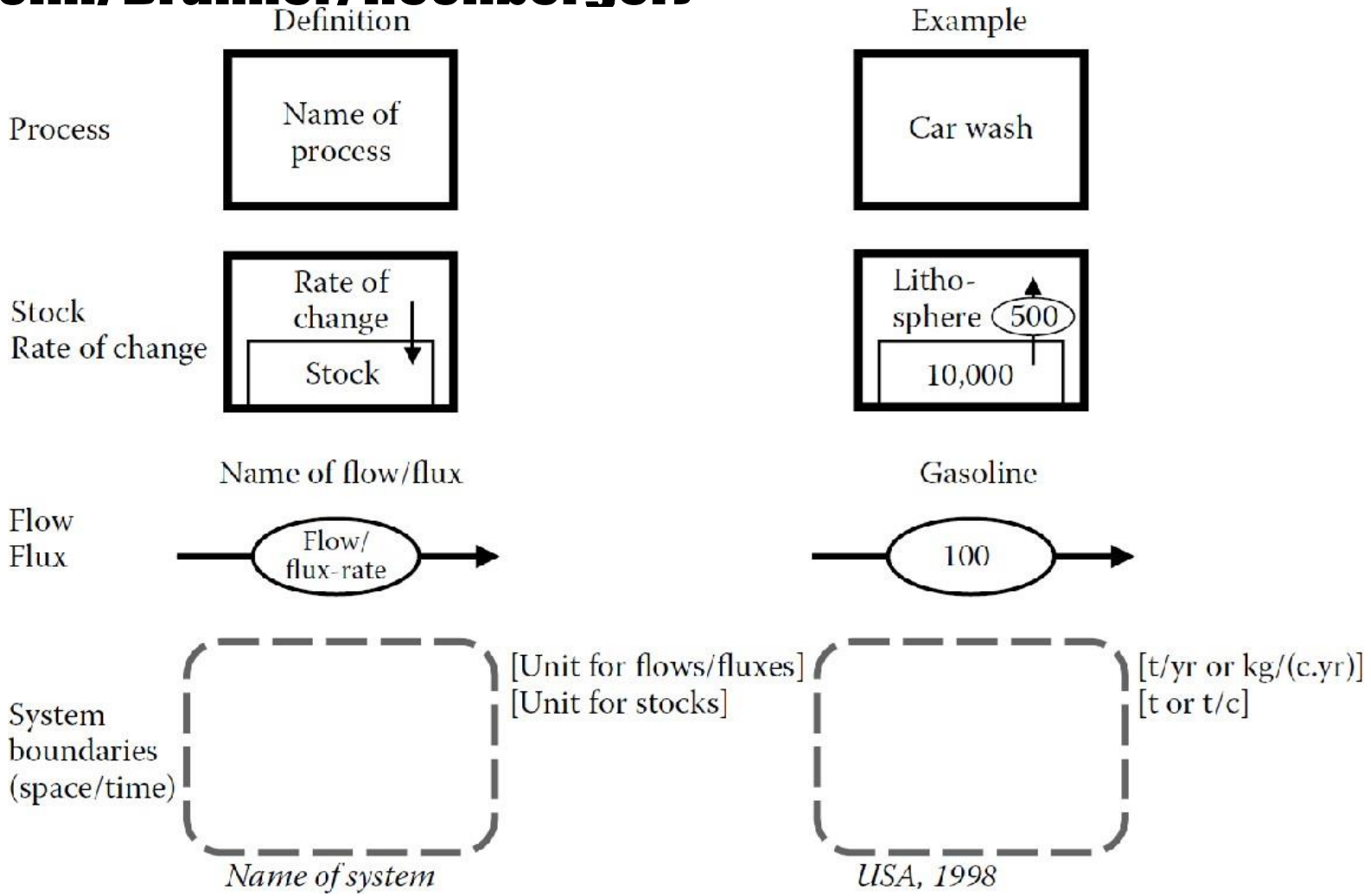
Flows: materials flowing from one process to another.

- **Flows:** ratio of mass per time (e.g. t/y)
- **Fluxes:** flow per cross section (e.g. person, private household, area)
- Flows/fluxes entering a process: **inputs**
- Flows/fluxes exiting a process: **outputs**
- Flows/fluxes across system boundaries: **imports and exports**

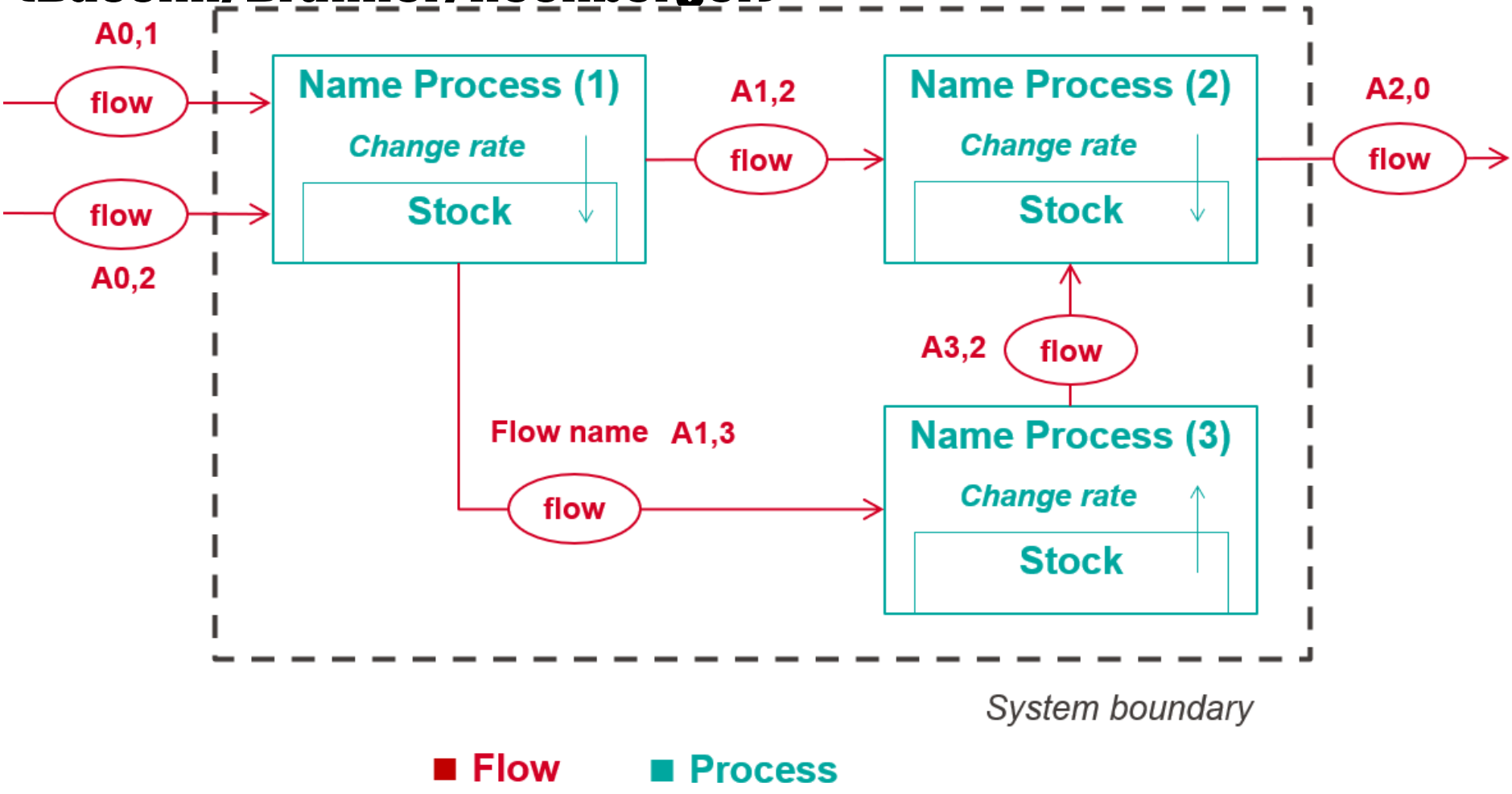


Brunner & Rechberger, 2016

Symbols used in MFA diagrams (Baccini/Brunner/Rechberger)



Symbols used in MFA diagrams (Baccini/Brunner/Rechberger)



Time in MFA

- **Steady state**: constant flows and stocks

  $dM_{stock}/dt = 0$ and $M_{stock}(0) = M_{stock}(t)$

- **Quasi stationary**: constant flows and linear (de)growth of stocks: $dM_{stock}/dt = c$ and

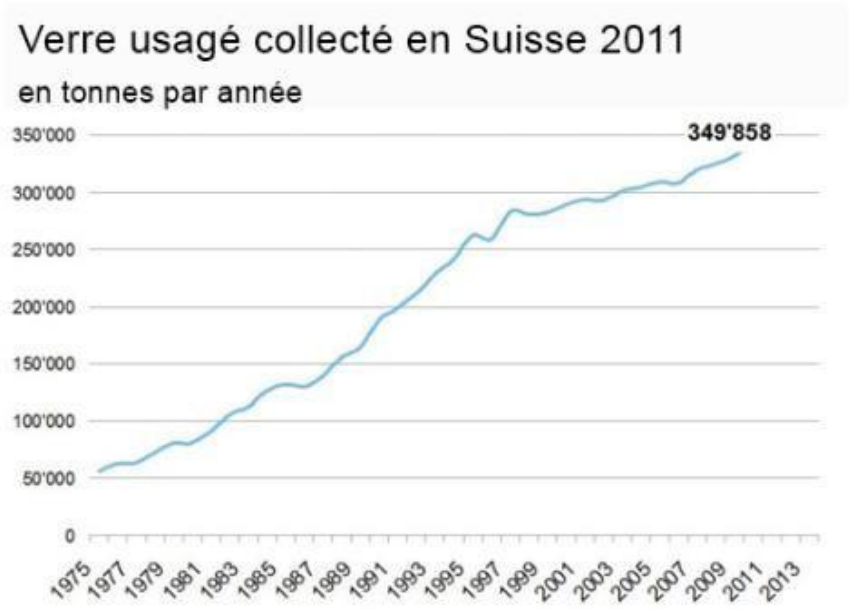
  $M_{stock}(0) \neq M_{stock}(t)$

- **Time dependent**: parameters external to the model are function of time (e.g. extraction or disposal costs).

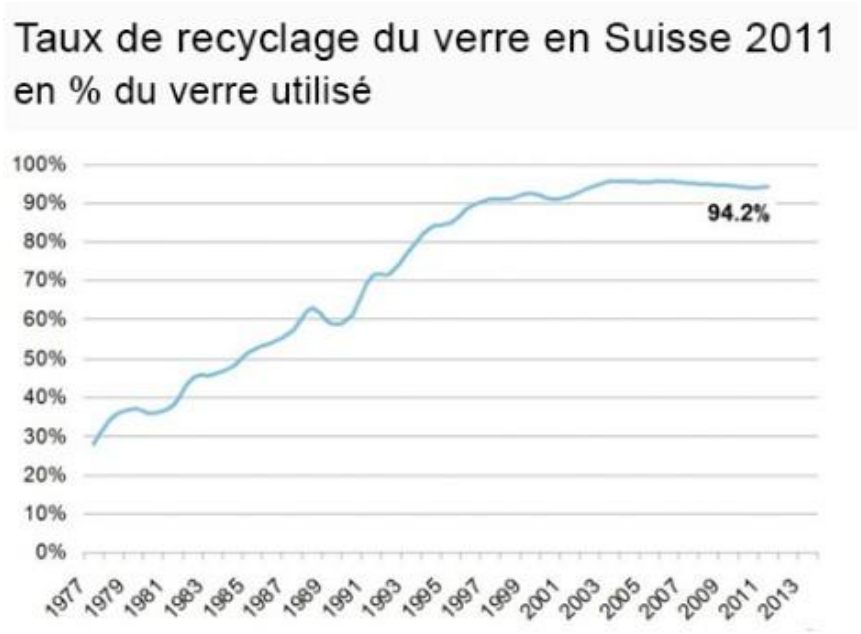
- **Dynamic**: System state at t is a function of the state a t-1.

Example – Recycling glass

vetroswiss
... pour un recyclage efficace du verre ...



Evolution du verre usagé collecté dans toute la Suisse (Source : www.vetrorecycling.ch)



Evolution du taux de recyclage du verre en Suisse (Source : www.vetrorecycling.ch)

Example – Recycling glass

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How can the system be optimized?

Example – Recycling glass

Formulate a precise question.
What problem should be tackled with the material flow analysis?

Define the system in space and time.
Determining the spatial and temporal boundary for material flow modelling.

Characterize the material balance system.
Which processes and material flows are relevant to the question formulated and have to be taken into account in the model?

Select material flow indicators.
Which material flow indicators are relevant for answering the question?

Example – Recycling glass

- **Research question for glass bottle management in CH:**

  How does glass recycling change the system?

  a. How much glass needs to be imported?

  b. How much energy can be saved?

- **System boundary:** Switzerland, 1 year

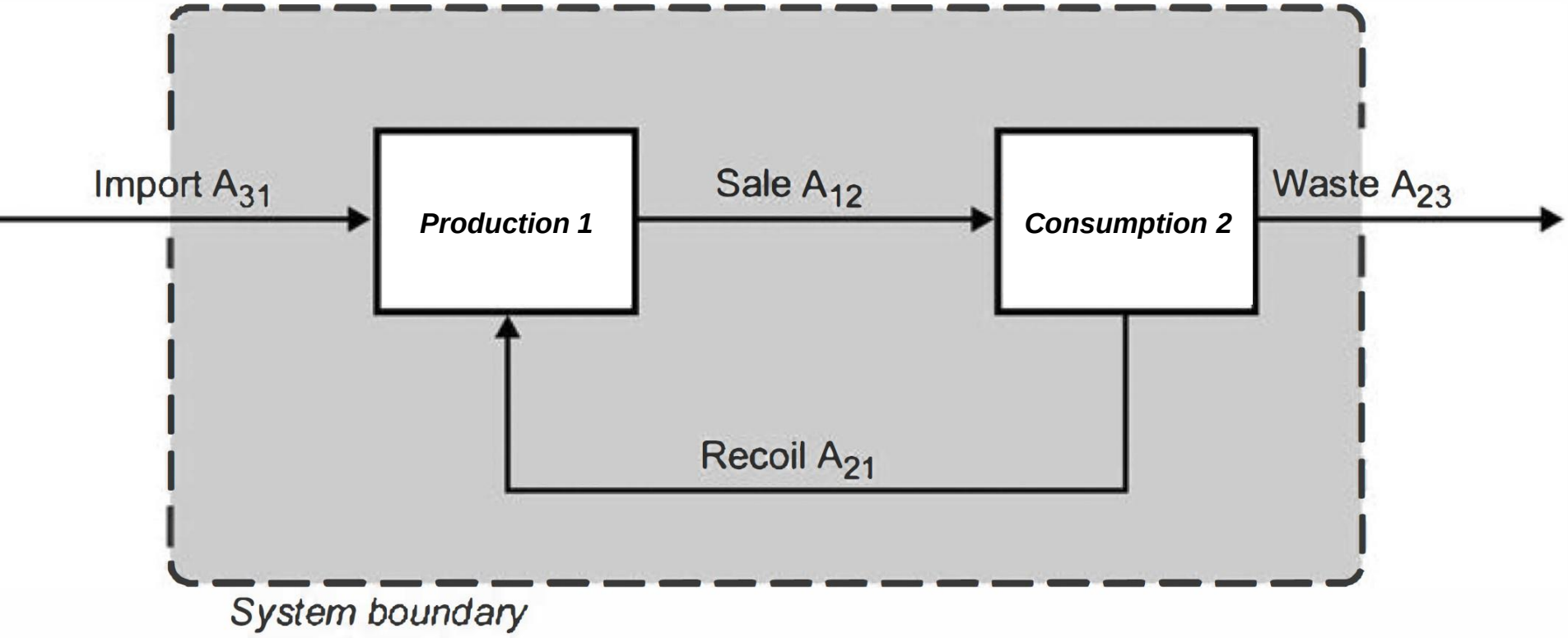
  Unit for flows/fluxes: kg/c,yr

  Unit for stocks: kg/c

- **Processes:** glass production, glass consumption
- **Material flows/fluxes:** glass, waste glass
- **Indicators:** glass import rate, energy use

Example – Recycling glass

Material flow/flux: glass, waste glass



Simplified material system for glass bottle management in Switzerland.

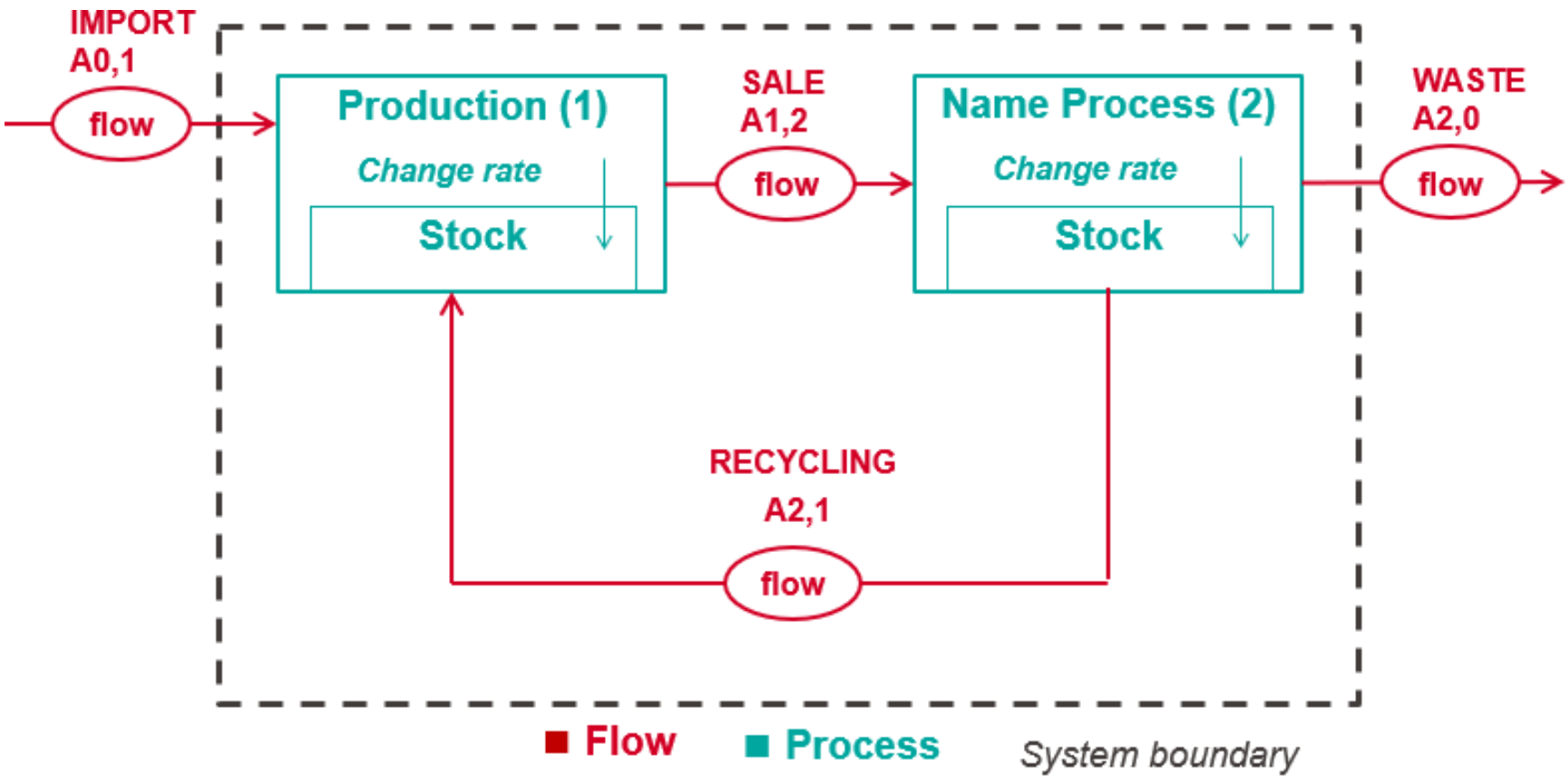
Baccini & Brunner, 2012

Example – Recycling glass

Procedure for mathematical system definition:

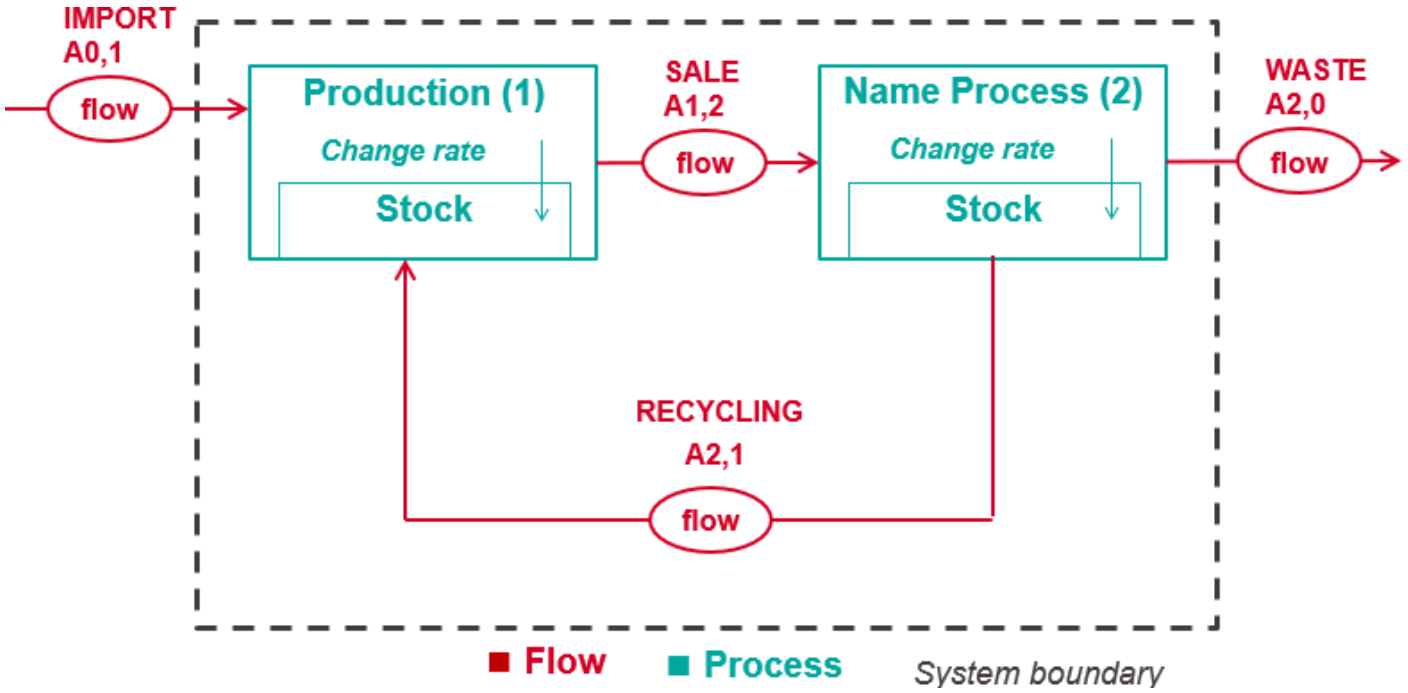
- Define the system unknowns.
- Setup the system of equations.
- Complete the system of equations with specific relationships.
- Solve the system of equations.
- Analyze the results and check for errors.

Example – Recycling glass



General case: 8 system unknowns (stocks, stock changes, flows)
Steady state: 6 system unknowns (stocks, flows)

Example – Recycling glass



General case

$$\frac{dM^{(1)}}{dt} = A_{21} + A_{31} - A_{12}$$

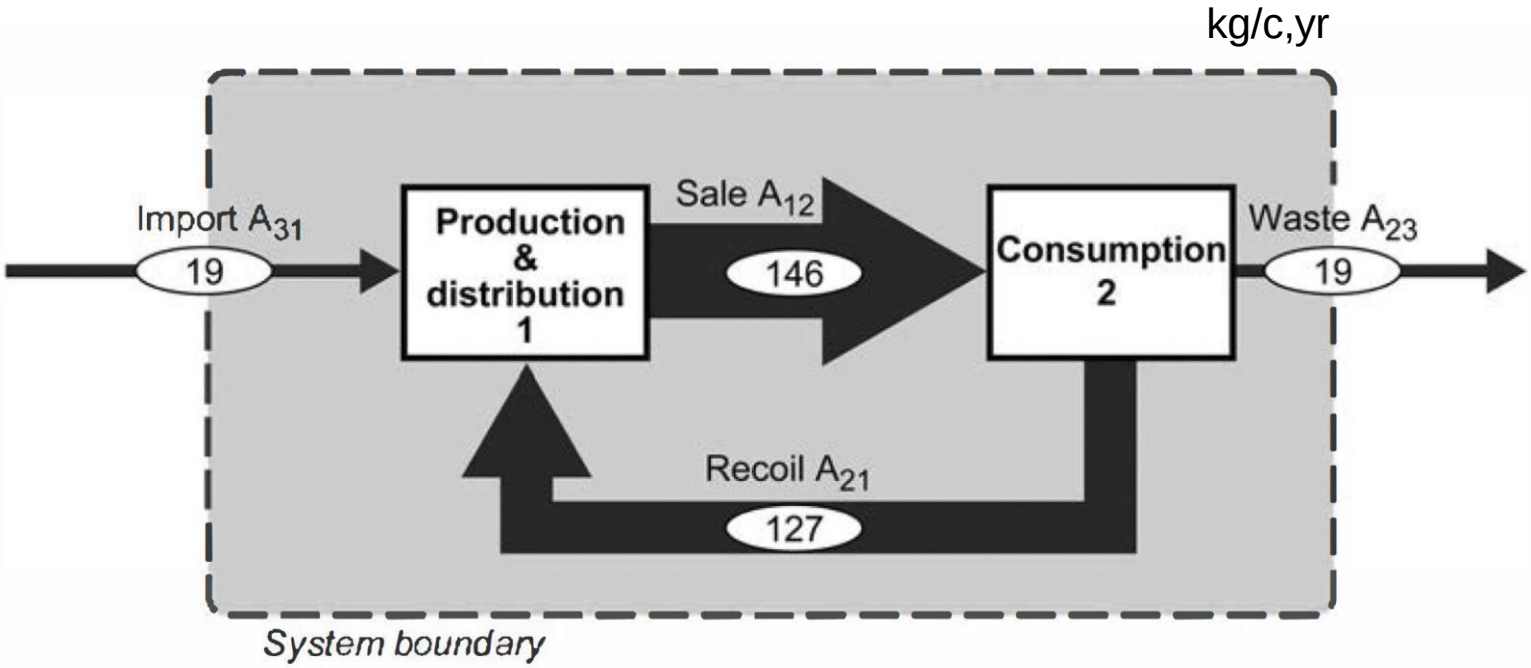
$$\frac{dM^{(2)}}{dt} = A_{12} - A_{21} - A_{23}$$

Steady state

$$\frac{dM^{(1)}}{dt} = 0$$

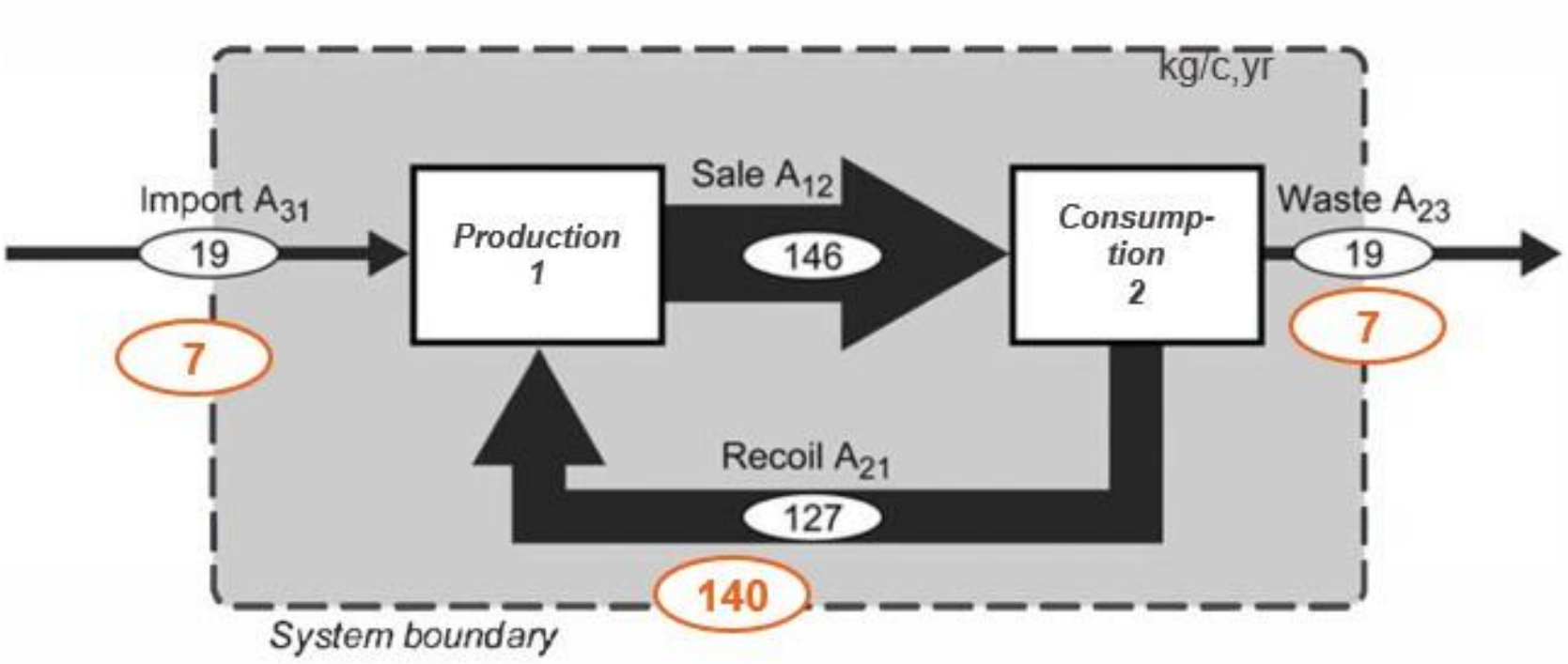
$$\frac{dM^{(2)}}{dt} = 0$$

Example – Recycling glass



Simplified material system for glass bottle management in Switzerland.

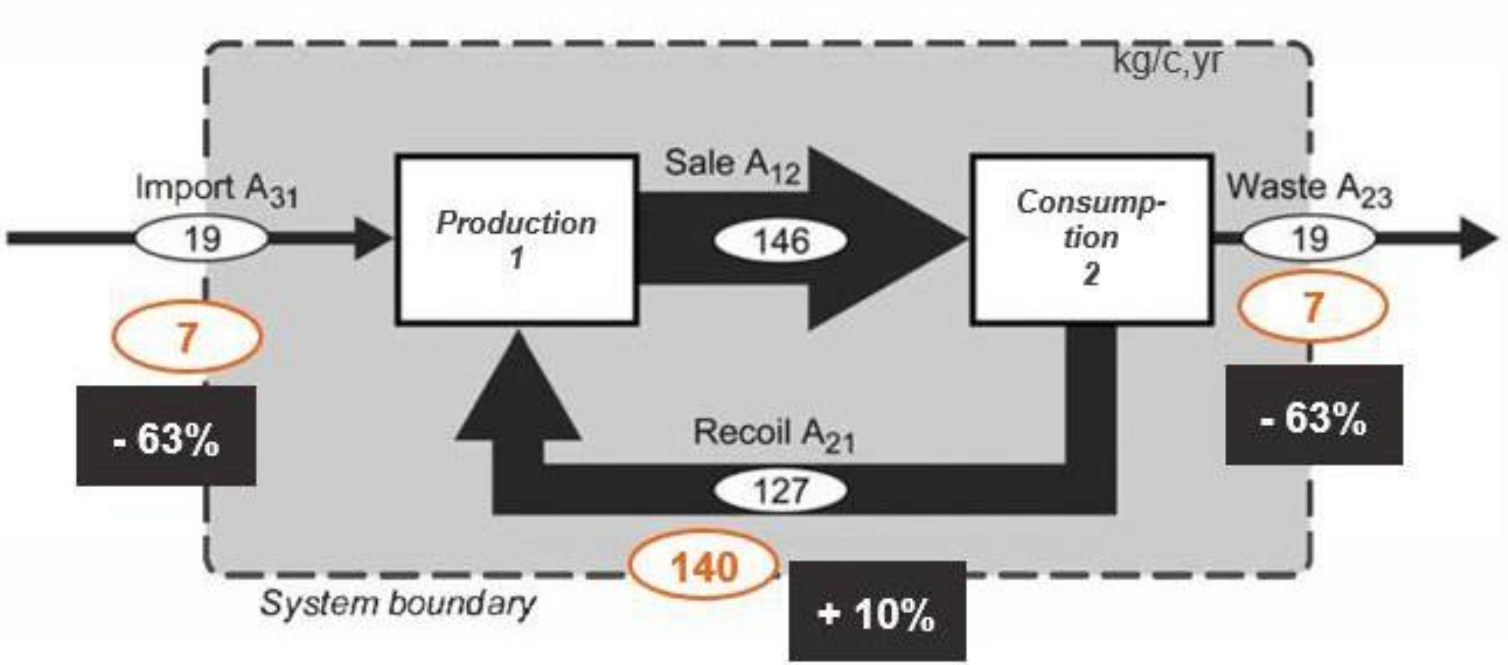
Example – Recycling glass



What if recycling rate increases by 10%

assuming that glass imports and exports stay constant

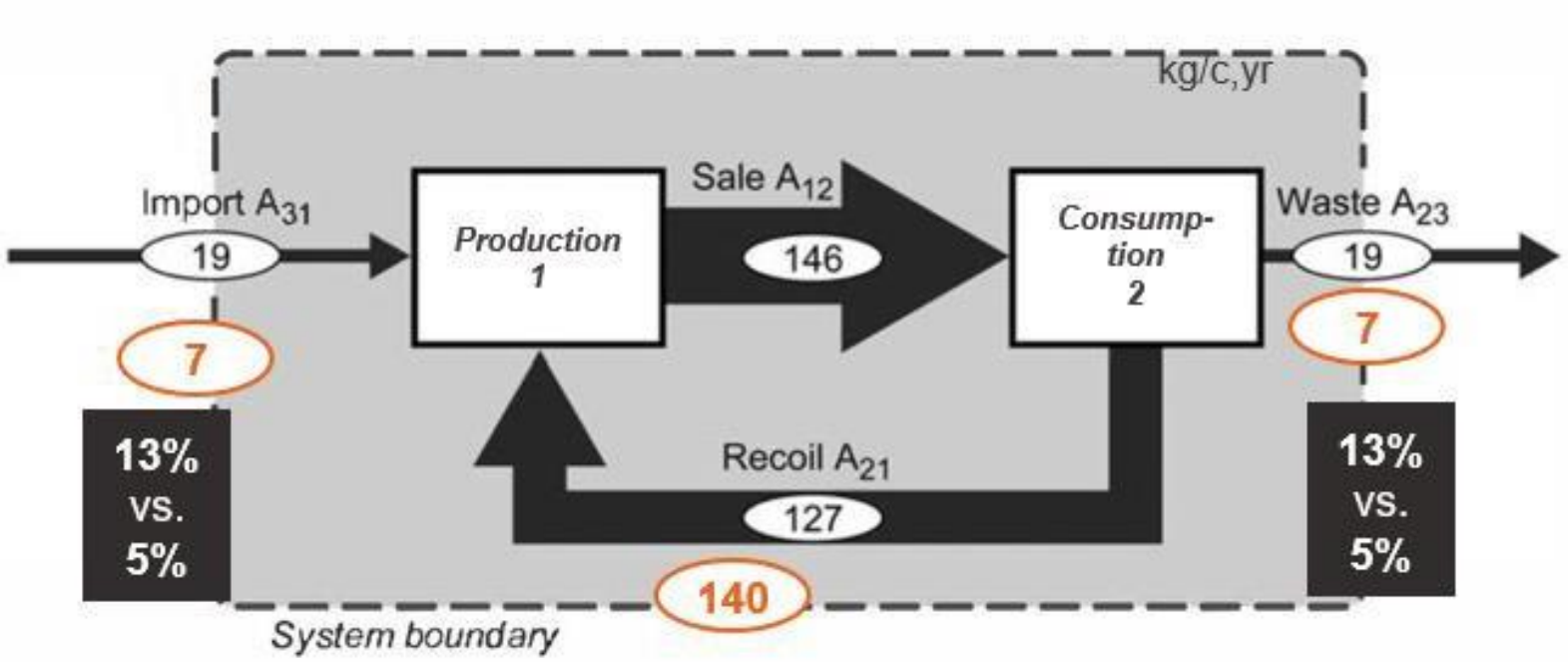
Example – Recycling glass



How to check the results?

a. Compare with statistical data
b. Compare with literature data
c. Get feedback from field experts

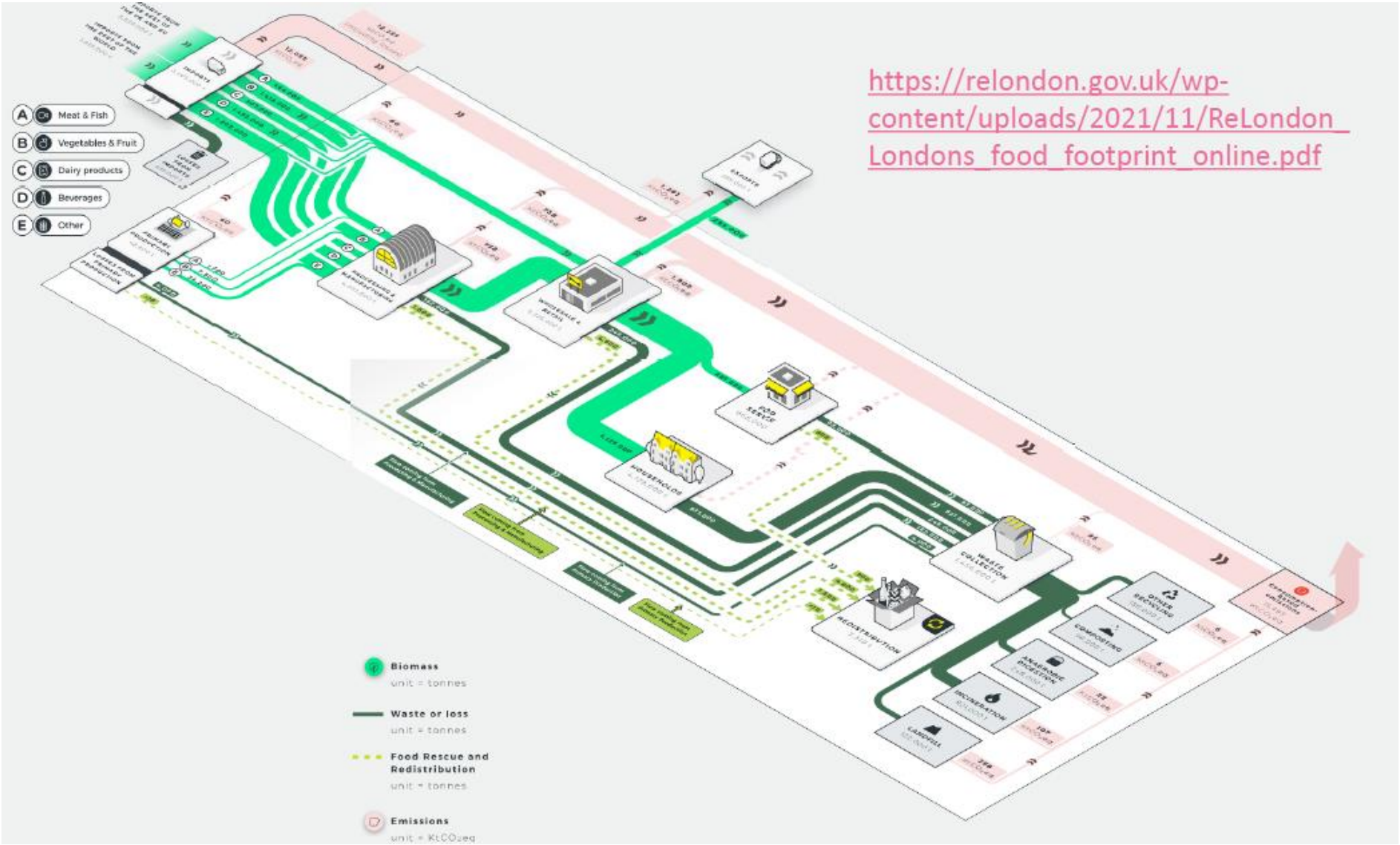
Example – Recycling glass



Indicators (as defined earlier)

a. Import rate

Example – Biomass flows



https://relondon.gov.uk/wp-content/uploads/2021/11/ReLondon_Londons_food_footprint_online.pdf

Course organisation

Aim of the course (I)

- Analyser un produit ou nu service avec l'ACV
- Calculer les impacts environnementaux d'un produit
- Anticiper les évolutions réglementaires en environnement
- Optimiser les performances environnementales des produits
- Critiquer une étude existante
- Elaborer des stratégies holistiques pour boucler les flux de matière
- Critiquer les stratégies et plans environnementaux des villes et pays
- Analyser les flux de ressources et de déchets

Aim of the course (II)

- Planifier des actions et les mener à bien de façon à faire un usage optimal du temps et des ressources à disposition.
- Recevoir du feedback (une critique) et y répondre de manière appropriée.
- Ecrire un rapport scientifique ou technique.
- Utiliser les outils informatiques courants ainsi que ceux spécifiques à leur discipline.
- Etre responsable des impacts environnementaux de ses actions et décisions.