SVENSKA ARALSJÖSÄLLSKAPET

Swedish Aral Sea Society

Quantification of sustainability

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Measuring resource flows

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2023-05-17

Lecture 13 in the distant mode Master Course
Sustainable Development and Sustainability Science
presented by the Swedish Aral Sea Society in cooperation with Karakalpak State University and other Uzbek universities

Part 1

- **The 17 UN Sustainability Goals**
- **How can sustainability in principle be quantified, possibilities and limitations?**
- **How is sustainability followed up today?**
- **Ecological sustainability as a platform for human activity, as well as social and economic sustainability**

UN 2015

SUSTAINABLE DEVELOPMENT GOALS

2030


1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS


1
NO
POVERTY


2
ZERO
HUNGER

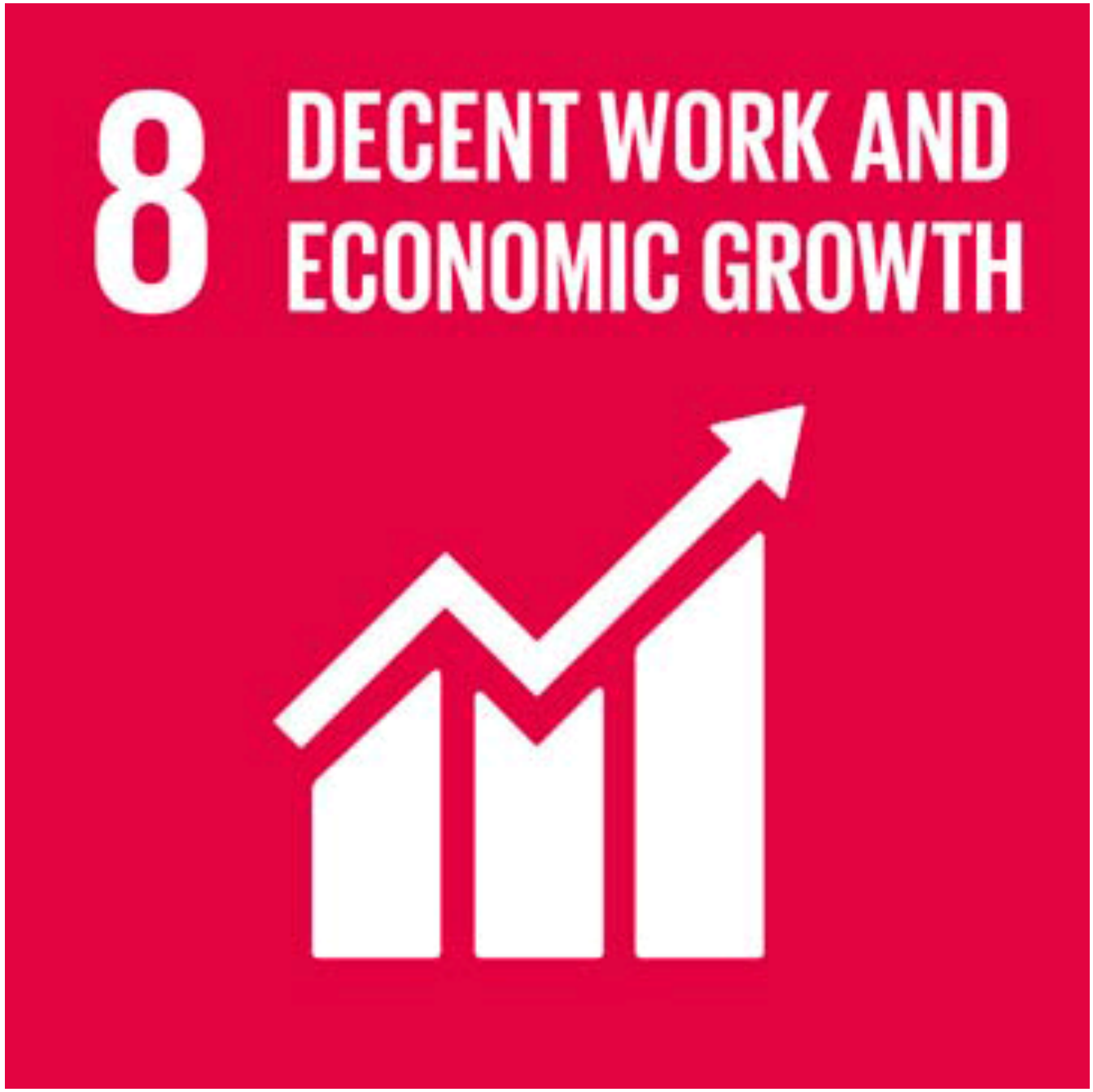

3
GOOD HEALTH
AND WELL-BEING


4
QUALITY
EDUCATION


5
GENDER
EQUALITY


6
CLEAN WATER
AND SANITATION


7
AFFORDABLE AND
CLEAN ENERGY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DECENT WORK AND
ECONOMIC GROWTH


9
INDUSTRY, INNOVATION
AND INFRASTRUCTURE


10
REDUCED
INEQUALITIES


11
SUSTAINABLE CITIES
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RESPONSIBLE
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14
LIFE
BELOW WATER


15
LIFE
ON LAND


16
PEACE AND JUSTICE
STRONG INSTITUTIONS


17
PARTNERSHIPS
FOR THE GOALS

Not only Climate – ”New” Global Threats

UN Report May 2019: Nature’s Dangerous Decline ‘Unprecedented’; Species Extinction Rates ‘Accelerating’

Current global response insufficient; Transformative changes’ needed to restore and protect nature; Opposition from vested interests can be overcome for public good; Most comprehensive assessment of its kind; 1,000,000 species threatened with extinction

https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

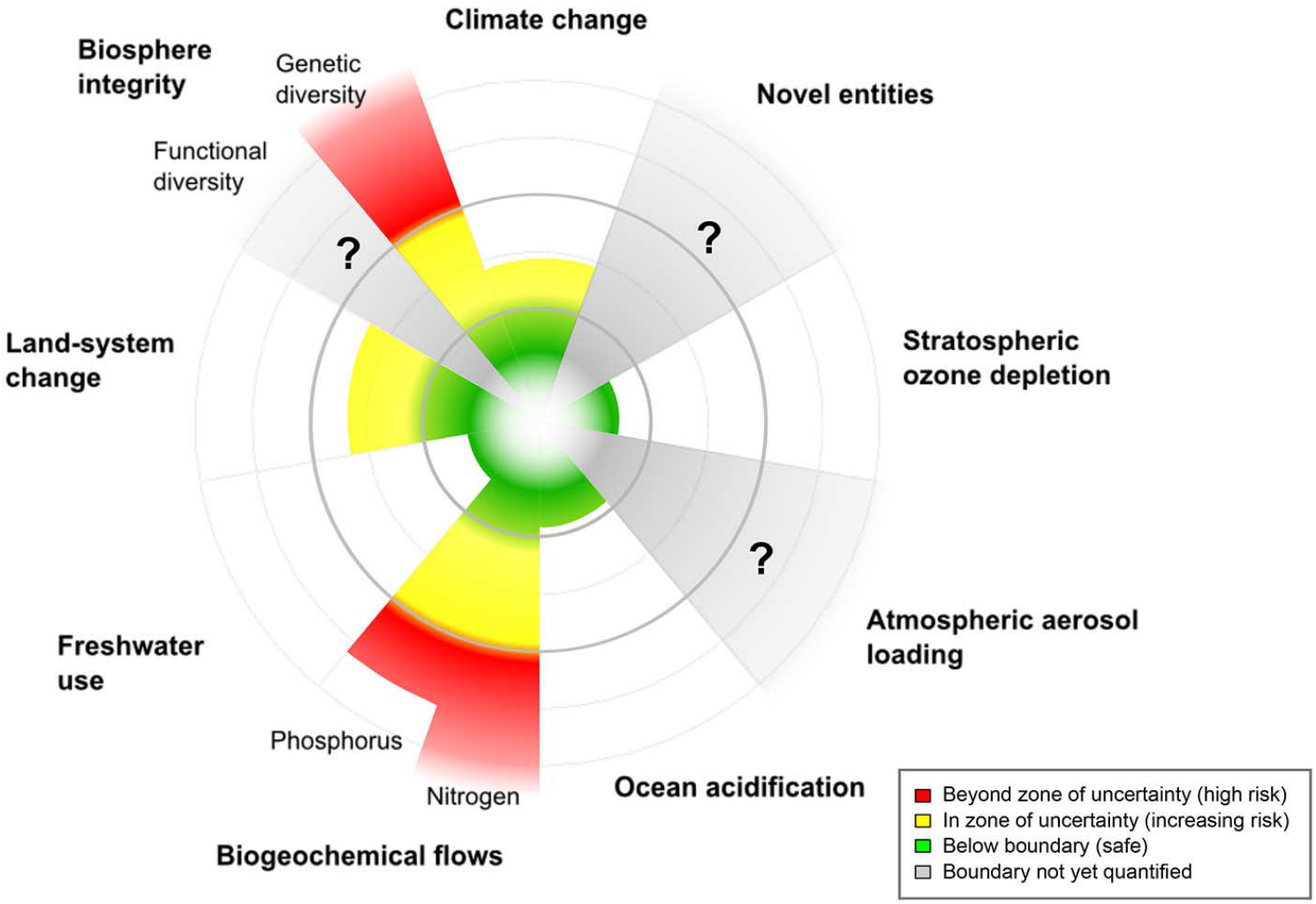
60 Per cent of all Vertebrates Extinct since 1970 - ”A New Global Deal for Nature and People Urgently Needed”

https://www.wwf.ch/sites/default/files/doc-2018-10/LPR2018_Full%20Report%20Pages_22.10.2018_0.pdf

How can sustainability in principle be quantified, possibilities and limitations?

A well-known approach

The Planetary Boundaries



Source: Steffen et al. (2015

Limitations of the Planetary Boundary Concept

The Planetary Boundary Concept focuses on emissions from the Human Activity System and does not consider primary resource supply and manmade stocks that have been built up in cities and other infrastructure. Thus, a comprehensive approach requires that both inflows to, outflows from and stocks being built up are considered in discussions of human physical resource use

Some sustainability issues on the agenda

Resource supply challenges (economic challenges)

- Food Supply
- Water Supply
- (Sustainable) Energy Supply
- Goods and Services Supply

Ecologic challenges

- Climate change
- Biodiversity
- Waste and wastewater management
- Toxicity (biochemical interference)
- Plastics

Social Challenges

- Income distribution
- Gender challenges
- Education

Challenges with considerable connection to engineering

Broad sustaina-bility oriented challenges

How do we measure?

How is sustainability followed up today?

Follow-up of sustainability-current approaches

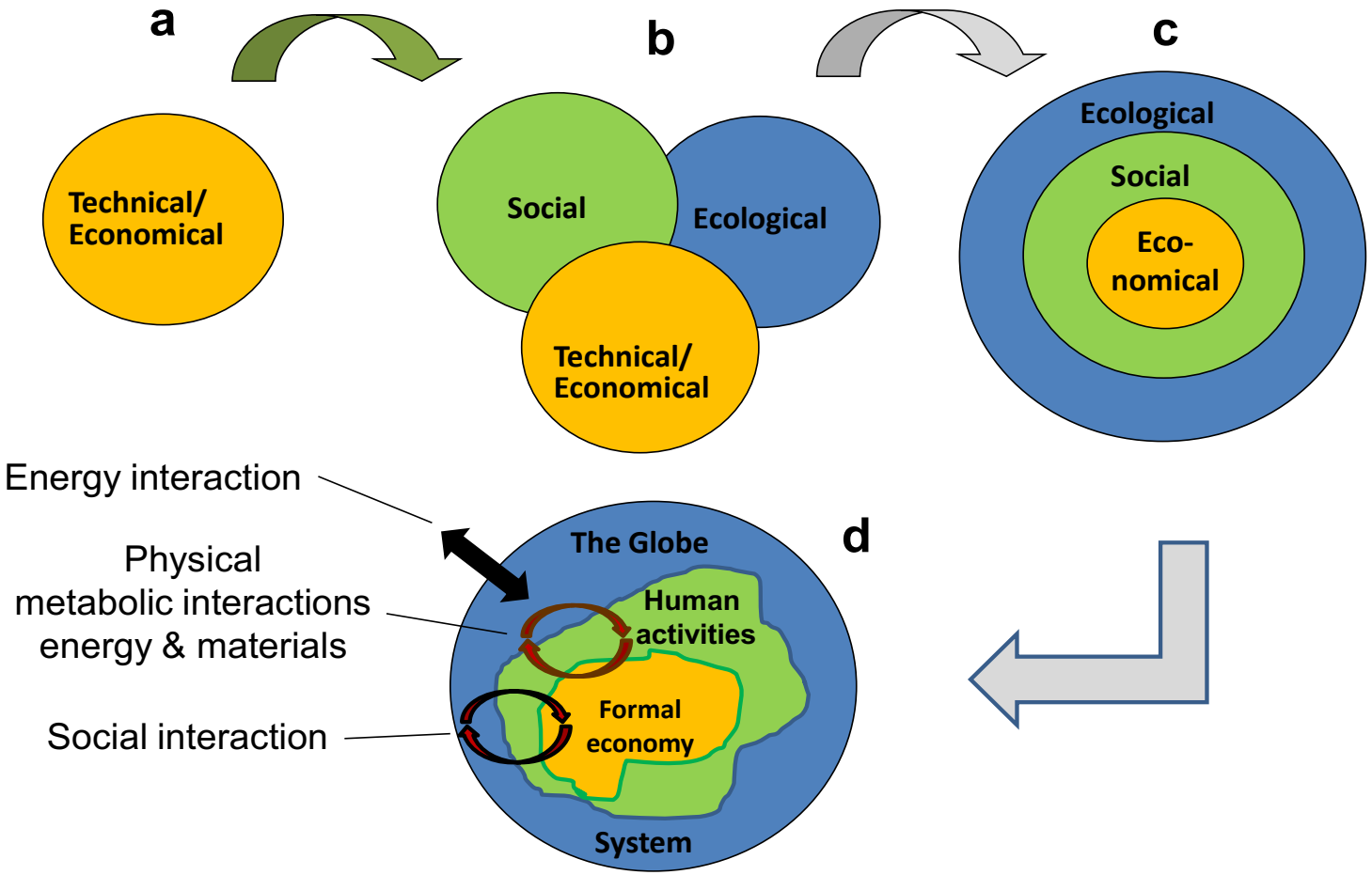
- **Countries typically have established national sustainable development goals and make national (annual) reports to the UN on how the actual national performance is developing. More and more, countries start to follow-up against the UN SD goals for 2030.**

- **There is still very much to do at other administrative levels (than the national), such as provincial, municipal, corporate and family/individual level in order to support and verify the national follow-up procedures. Methods, standards and reporting varies a lot from country to country.**

- **Still, financial accounts dominate the discussion, since economic development is still the main focus in essentially all countries on earth**

Ecological sustainability as a platform for human activity, as well as social and economic sustainability

Sustainable Development – A thought Path



cf. Frostell, 2013

Life on Earth Rests on Ecosystem Functionality!

Lecture break discussion question

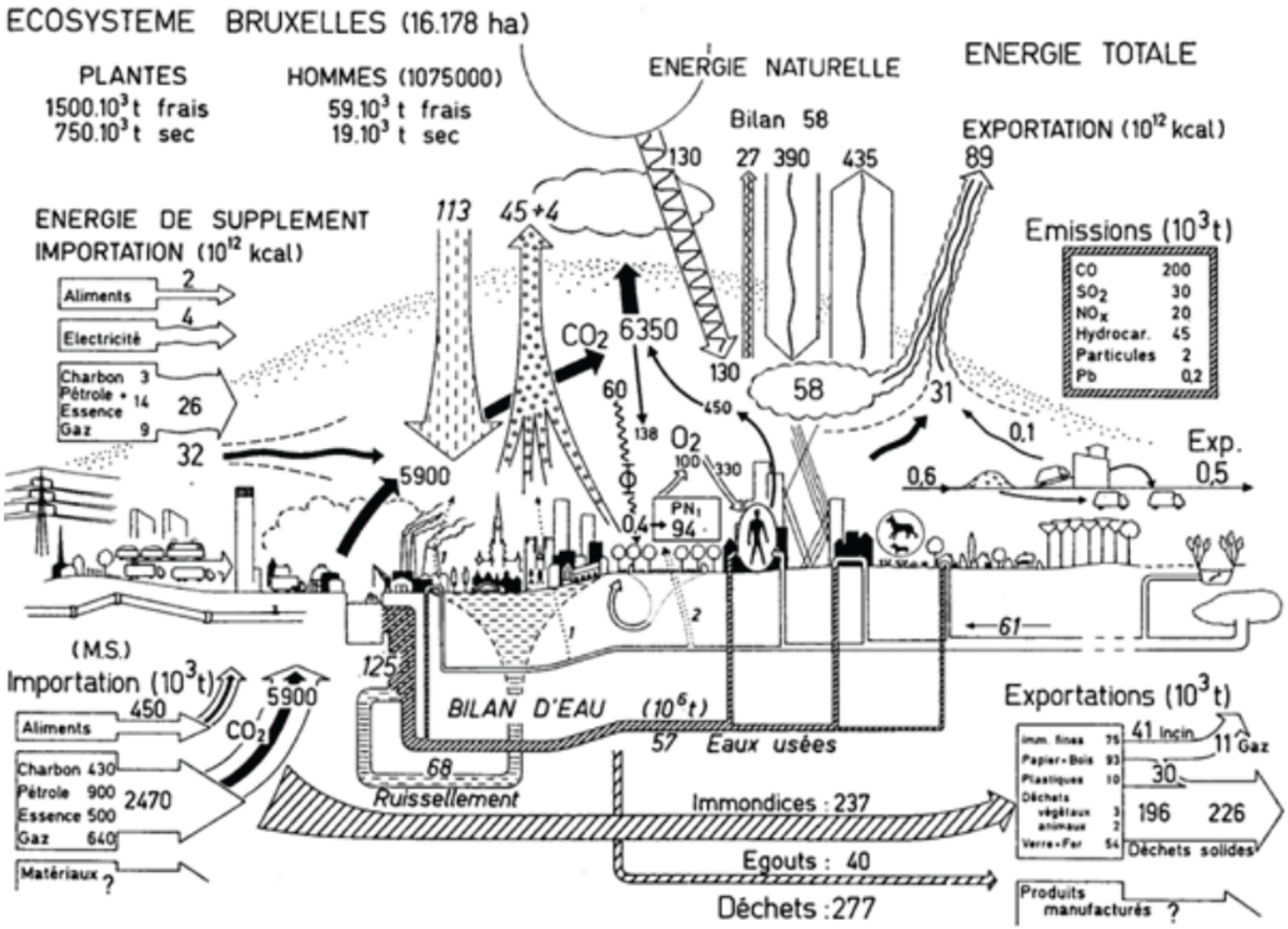
How is progress towards and deviation from sustainability being reported in Uzbekistan and Karakalpakstan?

Which are the three most important sustainability oriented parameters to monitor in Uzbektistan in your opinion?

Part 2

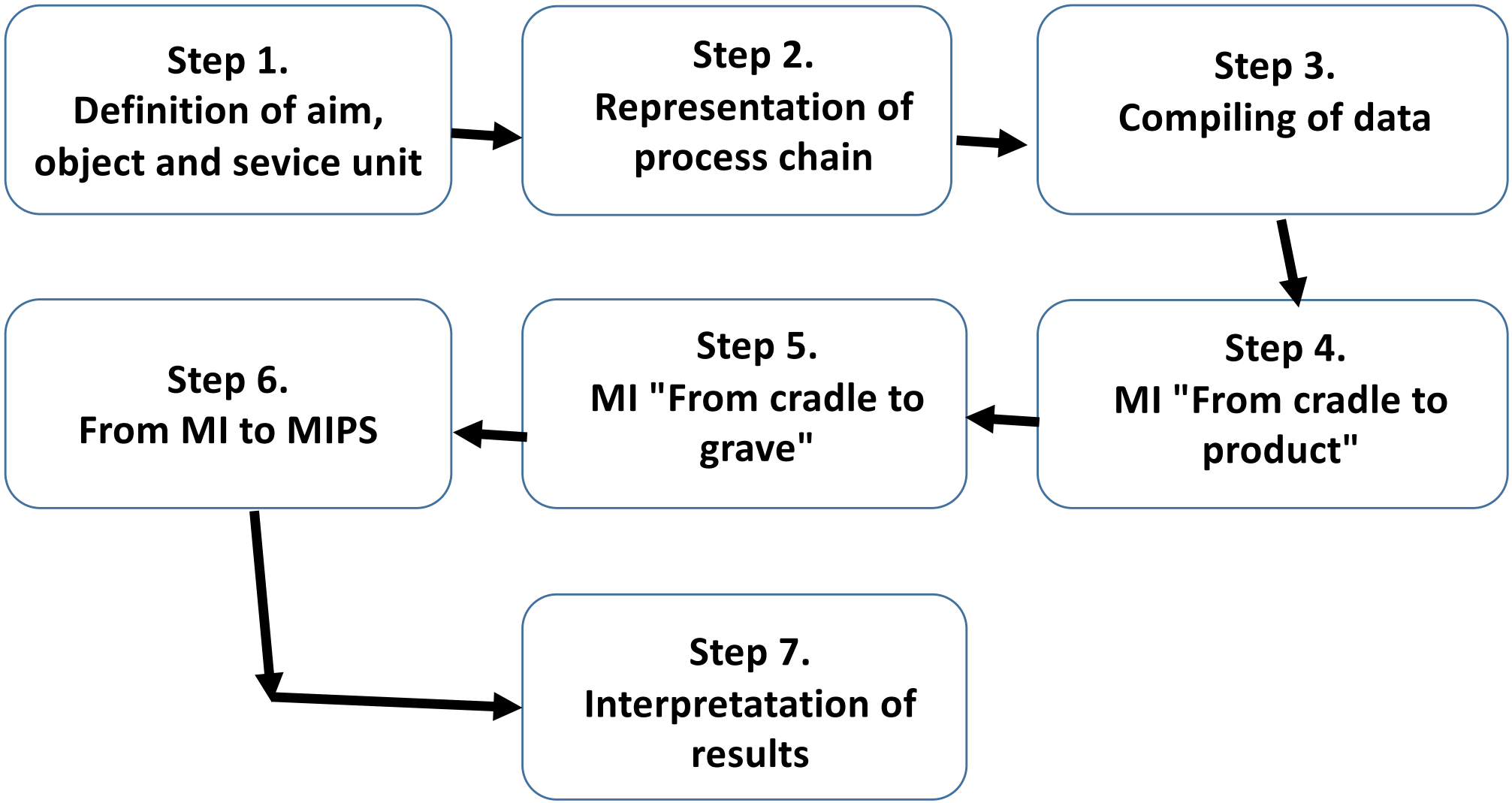
- **Physical resource flows and stocks as a key set of parameters to follow up for ecologic sustainability**
- **Initial approaches to quantify ecologic, social and economic sustainability**
- **A future outlook - A critical discussion of approaches applied so far**

Early attempt to a metabolic approach



Source: Duvigneaud and Denaeyer-De Smet 1977. ***The urban metabolism of Brussels, Belgium in the early 1970s.***

MIPS - Material Input Per unit of Service - principle



Source: Wuppertal Institute

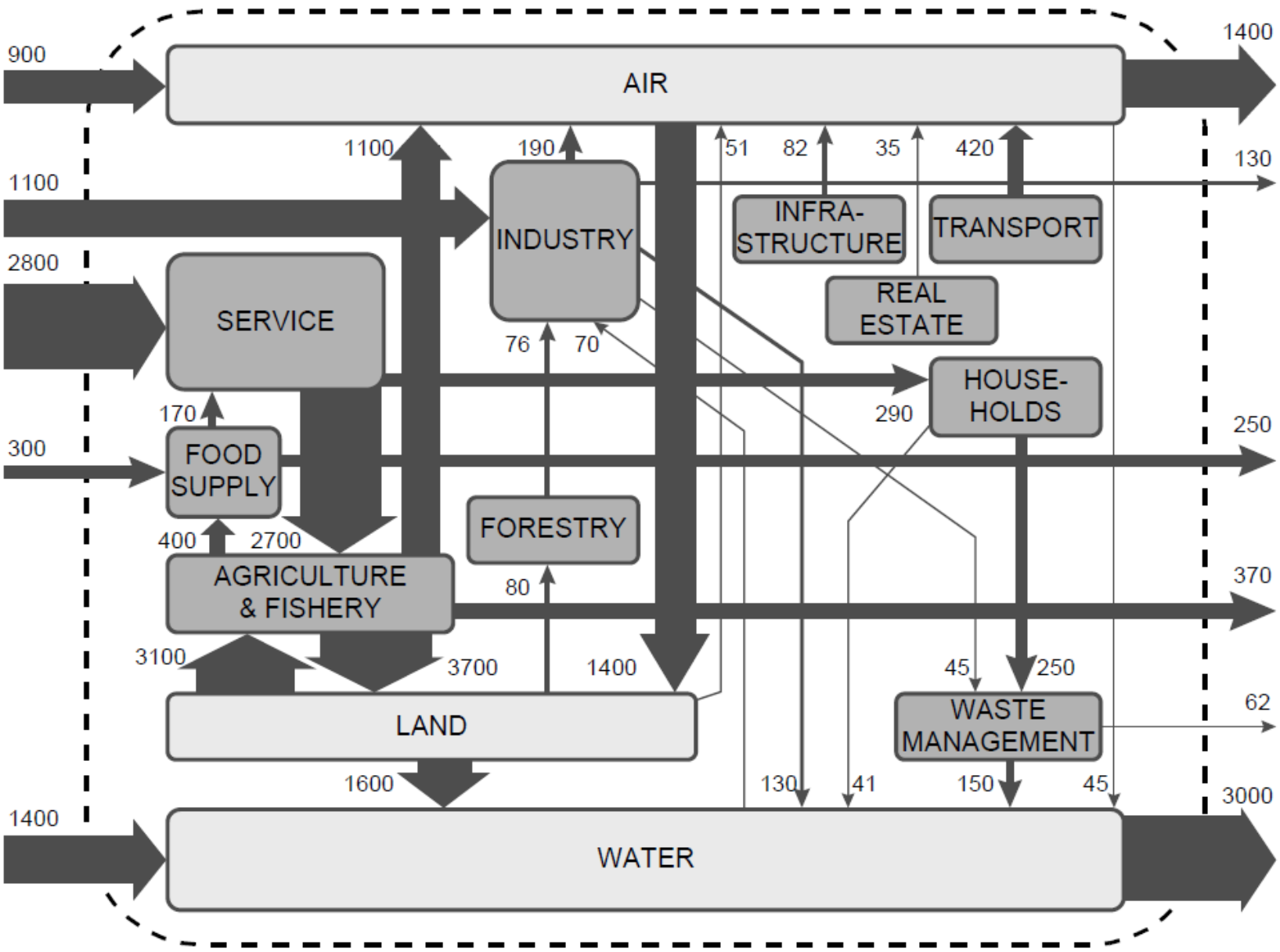
MIPS - Material Input Per unit of Service - example

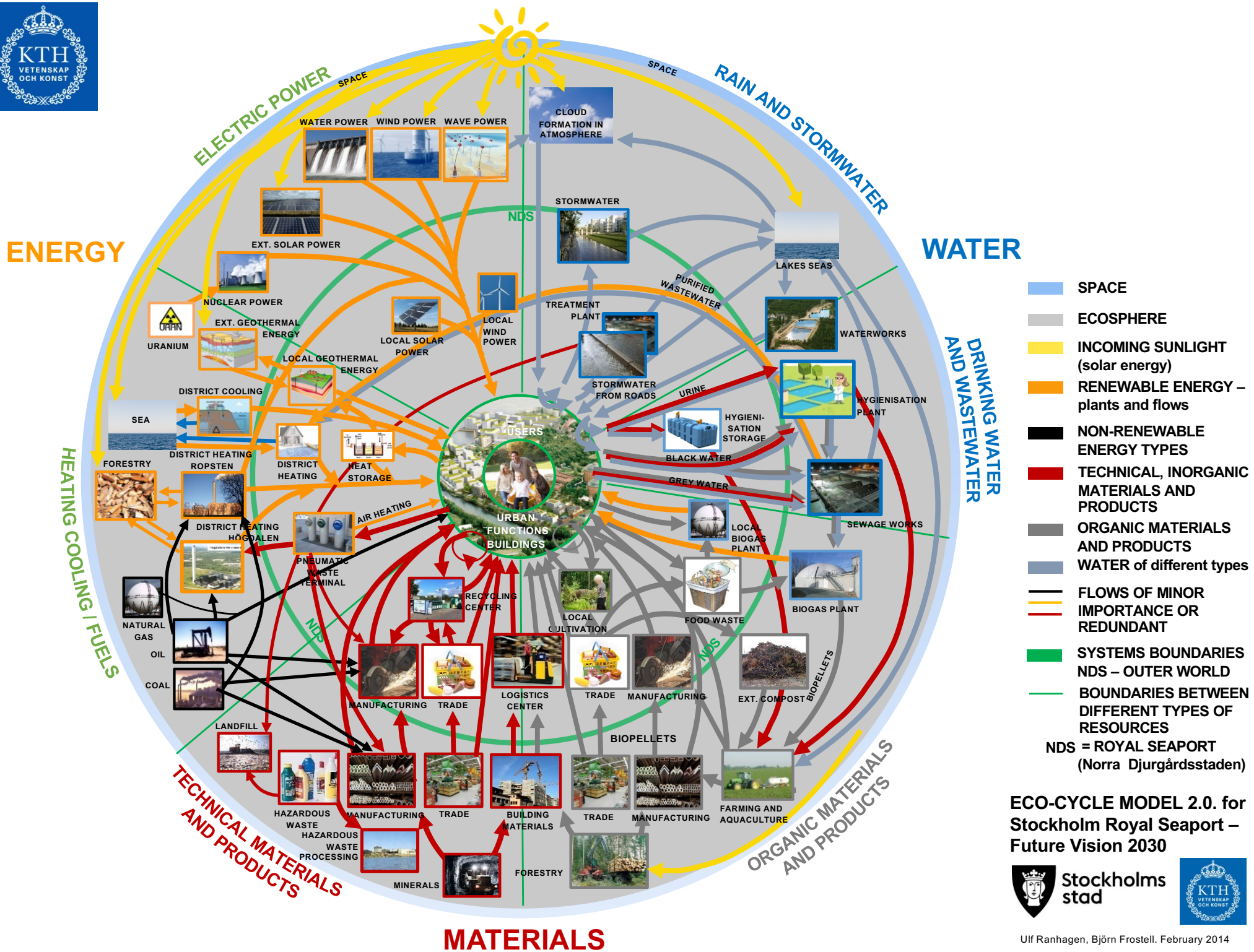
MI factors for electric power are, for example:

	Abiotic Resources [t/MWh]	Biotic Resources [t/MWh]	Water [t/MWh]	Air [t/MWh]	Earth movements [t/MWh]
Electric power (public supply, FRG)	4.7	–	83.1	0.6	–
Electric power (industrial generation, FRG)	2.67	–	37.9	0.64	–
Electric power (European OECD-countries)	1.58	–	63.8	0.425	–

Source: Ritthof, Rohn and Liedtke (2002);
https://epub.wupperinst.org/frontdoor/deliver/index/docId/1577/file/WS27e.pdf

Material flow accounts for municipalities
The ComBox Model





- SPACE
- ECOSPHERE
- INCOMING SUNLIGHT (solar energy)
- RENEWABLE ENERGY – plants and flows
- NON-RENEWABLE ENERGY TYPES
- TECHNICAL, INORGANIC MATERIALS AND PRODUCTS
- ORGANIC MATERIALS AND PRODUCTS
- WATER of different types
- FLOWS OF MINOR IMPORTANCE OR REDUNDANT
- SYSTEMS BOUNDARIES
- NDS – OUTER WORLD
- BOUNDARIES BETWEEN DIFFERENT TYPES OF RESOURCES

NDS = ROYAL SEAPORT (Norra Djurgårdsstaden)

ECO-CYCLE MODEL 2.0. for Stockholm Royal Seaport – Future Vision 2030

Stockholms stad

Ulf Ranhagen, Björn Frostell. February 2014

Environmental Systems Analysis (ESA)

Important tools

Scenario Development and Evaluation

SEA - Strategic Environmental Assessment

EIA - Environmental Impact Assessment

LCA - Life Cycle Assessment

LCC - Life Cycle Costing

CBA - Cost/Benefit Analysis

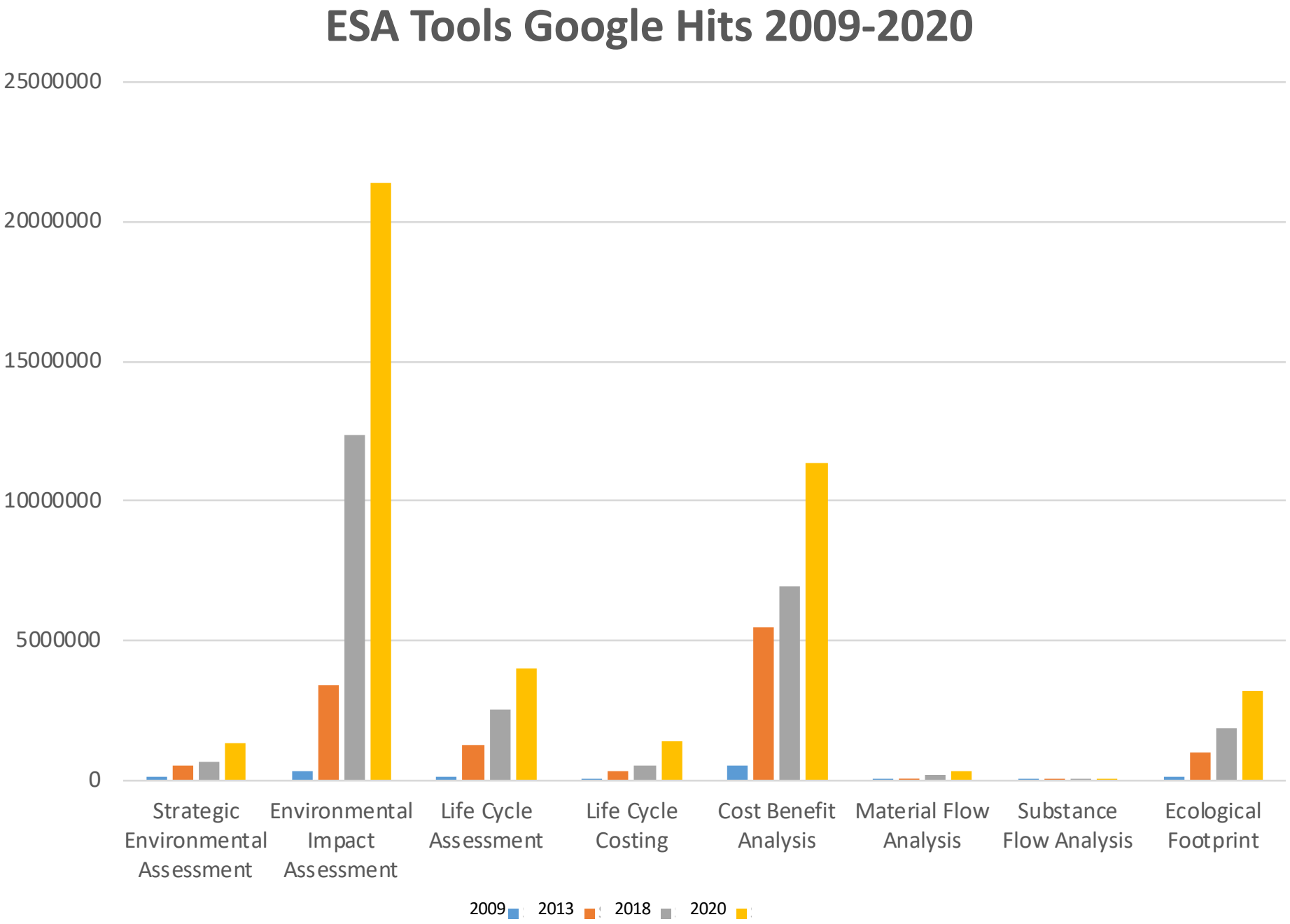
MFA - Material Flow Analysis

SFA - Substance Flow Analysis

PIOTs – Physical Input-Output Tables

EF – (Ecological) footprints

ISA – Integrated Sustainability Assessment


ESA Tools Google Hits 2009-2020
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20000000
15000000
10000000
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Strategic Environmental Assessment
Environmental Impact Assessment
Life Cycle Assessment
Life Cycle Costing
Cost Benefit Analysis
Material Flow Analysis
Substance Flow Analysis
Ecological Footprint
2009
2013
2018
2020

Scenario Methodology

Methodology

A body of methods, rules, and postulates employed by a discipline: a particular procedure or set of procedures

(Merriam-Webster OnLine Search)

A body of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry; a set of working methods

(The free dictionary by Farlex)

Scenario Methodology

A body of methods, rules, and postulates used to discuss and explore possible futures

Strategic Environmental Assessment

Scope

All plans and programmes which are prepared for a number of sectors and which set a framework for future development….*text*… and are likely to have significant effects on the environment, and should as a rule be made subject to systematic environmental assessment (DIRECTIVE 2001/42/EC)

Areas

…plans and programmes which are prepared for **agriculture, forestry, fisheries, energy, industry, transport, waste management, telecommunications, tourism, town and county planning or land use**

More reading: (1) Therivel & Paridario (2013) The Practice of strategic environmental assessment
(2) DIRECTIVE 2001/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL , https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0042&from=EN

Environmental Impact Assessment

EU Directive

- The EIA Directive (85/337/EEC) is in force since 1985 and applies to a wide range of defined **public and private projects**
- The EIA Directive of 1985 has been **amended five times**, in 1997, in 2003, 2009, 2011 and 2014

Scope

Mandatory EIA: all projects listed in Annex I are considered as having significant effects on the environment and require an EIA (e.g. long-distance railway lines, motorways and express roads, airports with a basic runway length ≥ 2100 m, installations for the disposal of hazardous waste, installations for the disposal of non-hazardous waste > 100 tonnes/day, waste water treatment plants > 150.000 p.e.)

More reading: http://ec.europa.eu/environment/eia/pdf/EIA_Directive_informal.pdf

Life Cycle Costing

Conventional approach

The conventional LCC methodology can be described as a financial assessment of the following types of internal costs (cost categories):

- Investment costs, which include purchase price and, where applicable, other associated costs, such as installation, commissioning and initial training of users;
- Operating costs, including consumption of energy, consumables and/or other resources needed for the manufacturing of the product;
- Maintenance costs, including any service charges and spare parts that have to be periodically replaced;
- End-of-life costs, such as decommissioning and disposal.

Social benefit-cost analysis

Definition

Social benefit-cost analysis is a process of identifying, measuring and comparing the social benefits and costs of an investment project or program

”There are few, if any, activities of government that are not amenable to appraisal and evaluation by means of social benefit-cost analysis.”

Material Flow Analysis

Terminology

Material Flow Analysis or Material Flow Accounting or Material Flux Analysis (MFA)

• refers to **accounts in physical units** comprising the extraction, production, transformation, consumption, recycling and disposal of flow of materials

• Based on the principle of material balances

• MFA covers approaches such as:
  – Substance Flow Analysis (SFA)
  – Bulk Material Flow Accounting (b-MFA)
  – Material Input Per Unit of Service (MIPS) - a function oriented variant of MFA

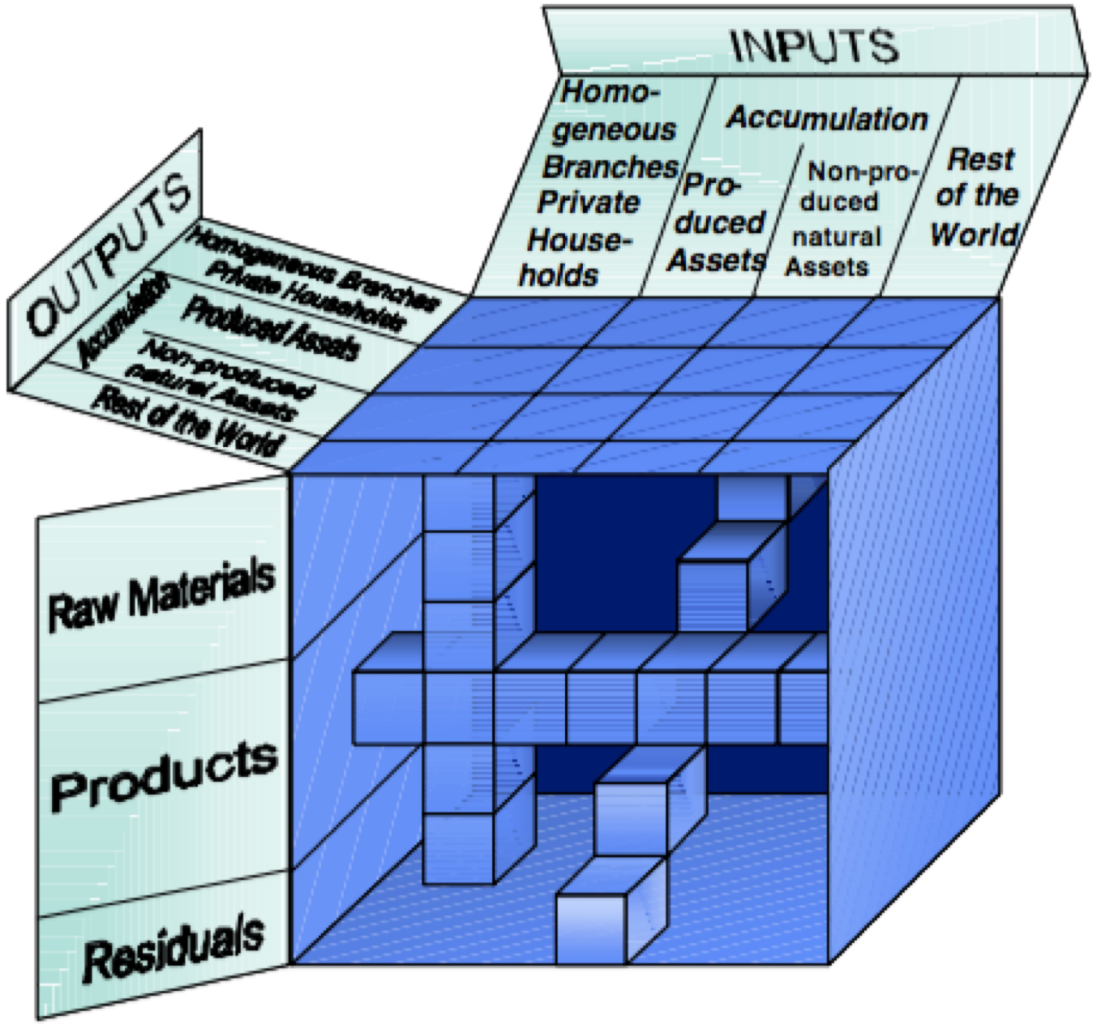
• for assessing the anthropogenic metabolism of regions in the early 1980s (Baccini and Brunner, 1991)

  – connect and interrelate soil, water and air with the anthroposphere in a holistic manner

Physical Input-Output Tables (PIOTs)

- PIOTs describe the flows of material and energy within the economic system and between the economic system and the natural environment;
- PIOTs are founded on the law of the physical conservation of matter and energy (first principle of thermodynamics);
- PIOTS form an important part of the so called MEFIS (Material and Energy Flow Information System). MEFIS is a databank in which all material and energy flows are integrated in one common system;
- MEFIS will allow to take better care of the relation of the flows among one another (e.g. combustion of energy carriers and the resulting emissions) and to get results that are more precise;
- The MEFIS-cube (see next figure) contains three different kinds of PIOTS. They are (i) Input-Tables, (ii) Output-Tables and (iii) (iii) Input-Output-Tables), which show the material-flows between the branches.

PIOTs – MEFIS* Illustration example



*MEFIS = Material and Energy Flow Information System

The Ecological Footprint

- The ecological footprint is a very pedagogic and illustrative indicator of ecologic sustainability. It is calculated as the land area needed to provide current social products and services in a sustainable way (with the best available technology; Wackernagel and Rees, 1996)

- The EF calculated is compared with the available land area and if the latter is smaller than the EF, the current situation is unsustainable

- According to the EF indicator , the world grand EF is larger than the available productive land area on earth (appr 30 % larger) and increasing each year

- The EF methodology has been criticized as being non-scientific and thus not a reliable indicator (cf. e.g. van den Bergh and Verbruggen 1999, Ayres 2000)

Recent alternative footprint approaches

Energy Footprint

1. According to the EF methodology
2. According to LCI methodology
3. Other approaches

Carbon Footprint

GFN (2018) The Carbon Footprint, (www.footprintnetwork.org/en/index.php/GFN/

The Water Footprint

Hoekstra A.Y. & Hung P.Q., 2005. Globalization of water resources: international virtual water flows in relation to crop trade. *Global Environmental Change* (15), pp. 45-56.

Hoekstra A.Y. (2008). Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. *Ecological Economics*, 68, 1963-1974.

EMA
Environmental Management Accounting

EMA combines physical (A) and financial (B) data in a company and calculates its total environmental cost. The physical data includes material and energy input, material flows, products, waste and emissions. Financial data includes expenditures, costs, earnings, and savings related to the company activities.

Reference: Cleaner Production - Technologies and Tools for Resource Efficient Production, pp. 150-152.

EMA – part A - physical flow estimates

The physical flow estimates are based on the mass balance of (i) the entire process and (ii) mass balances for the most important subprocesses according to the general formula for a continuous production process without accumulation term (as thoroughly discussed in lesson 7 part 2 on Cleaner Production):

Emissions = Input – Output

EMA – Financial estimates

Step B1: List all environmentally relevant facilities in the company

Step B2: Find the depreciation for these

Step B3: Find number of hours of work and its costs at these facilities

Step B4: Fill in all data in prepared excel sheets

Quantification of sustainability - an outlook

- **Recent work to quantify sustainability increasingly takes a metabolic approach, seeing human activities in the global economy as a very large organism metabolizing materials and energy. This is reflected in words such as circular economy, eco-cycles, ecologic approach, life cycle thinking and systems thinking**

- **It is important to understand that present-day (financial) economy not has been able to adequatly address sustainability. This should be ascribed to its narrow focus on humans and human activities and neglecting a broader approach and broader system boundaries**

- **There is a fantastic task for students to change this…!**

One way of quantifying sustainability

Björn hugging a 400 year (?) old Scots Pine tree on his Hälsingland farm, circumference appr. 4 metres, March 2021

Thank you!

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