2050 Action Plan for Romania for the Optimization of Resource Use at National Level by a Multiscale Approach using the Extended Thermodynamic Indicators

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Background

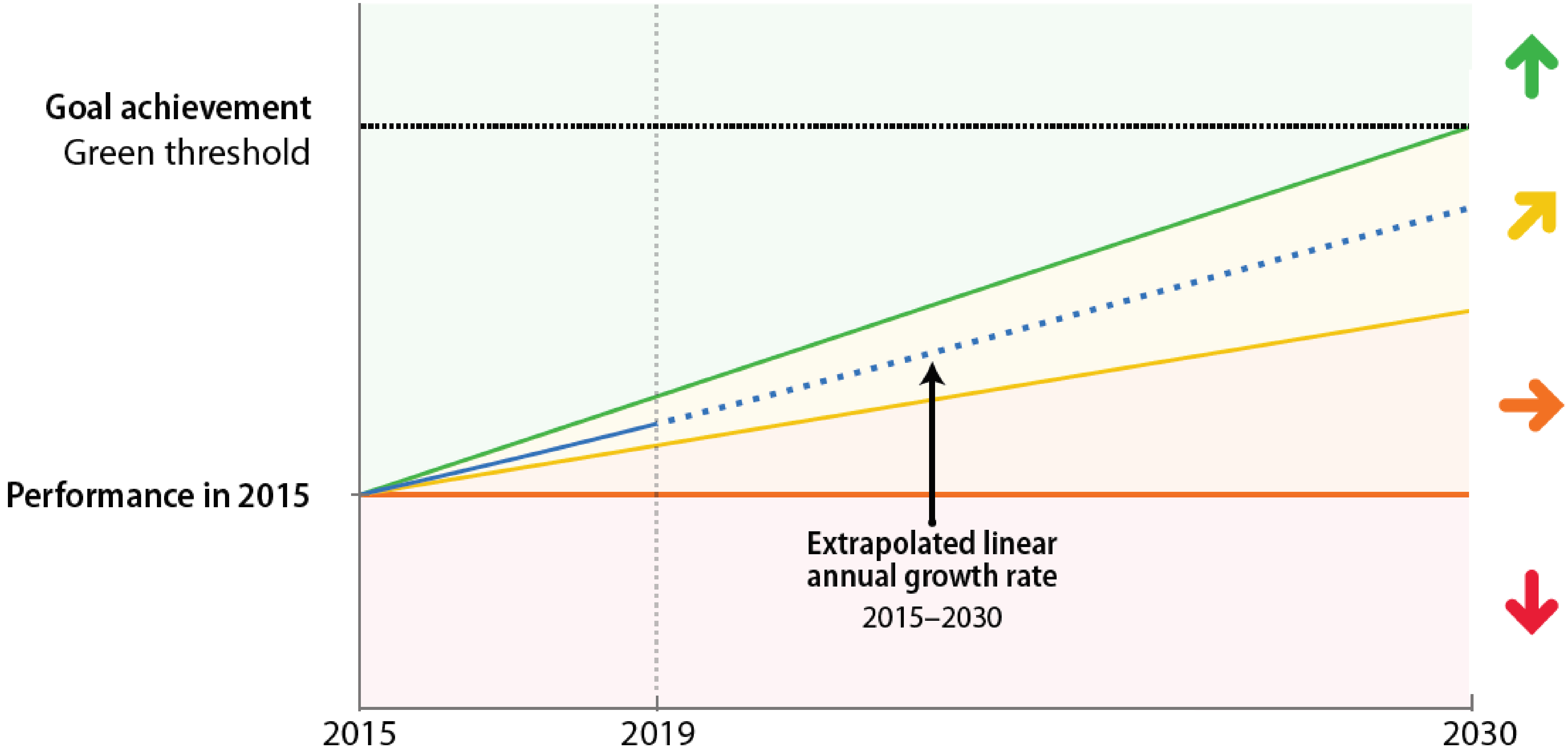
As it is widely known, in 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development. In this document, the heads of UN member states have committed their countries as follows: “*Until [..] 2030, to end poverty and hunger everywhere; to combat inequalities within and among countries; to build peaceful, just and inclusive societies; to protect human rights and promote gender equality and the empowerment of women and girls, and to ensure the lasting protection of the planet and its natural resources. [..] also to create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, considering different levels of national development and capacities*.”

17 Sustainable Development Goals - SDGs were defined, and each Goal includes clearly defined targets and indicators. As an example, for SDG 7 – Affordable and clean energy the targets and indicators are presented in the next slide.

Targets and Indicators for SDG 7

- **7.1. By 2030, ensure universal access to affordable, reliable and modern energy services**
- **Indicator 7.1.1:** Percentage of population with access to electricity
- **Indicator 7.1.2:** Proportion of population with primary reliance on clean fuels and technology
- **7.2. By 2030, increase substantially the share of renewable energy in the global energy mix**
- **Indicator 7.2.1:** Renewable energy share in the total final energy consumption
- **7.3. By 2030, double the global rate of improvement in energy efficiency**
- **Indicator 7.3.1:** Energy intensity measured in terms of primary energy and GDP
- **7.a. By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology**
- **Indicator 7.a.1:** Mobilized amount of investment per year starting in 2020 accountable towards the $100 billion commitment
- **7.b. By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programs of support**
- **Indicator 7.b.1:** Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services

The evaluation process of achievements of SDGs



Project ROMANA – Extended Exergy Accounting

The Extended Exergy Accounting method (EEA in the following) is based on a series of assumptions that concern the control volume used for the analysis: since it is necessary to exactly quantify the mass- and energy streams flowing in- and out of a given economic system, the most proper „control volume" to use is at the Country level.

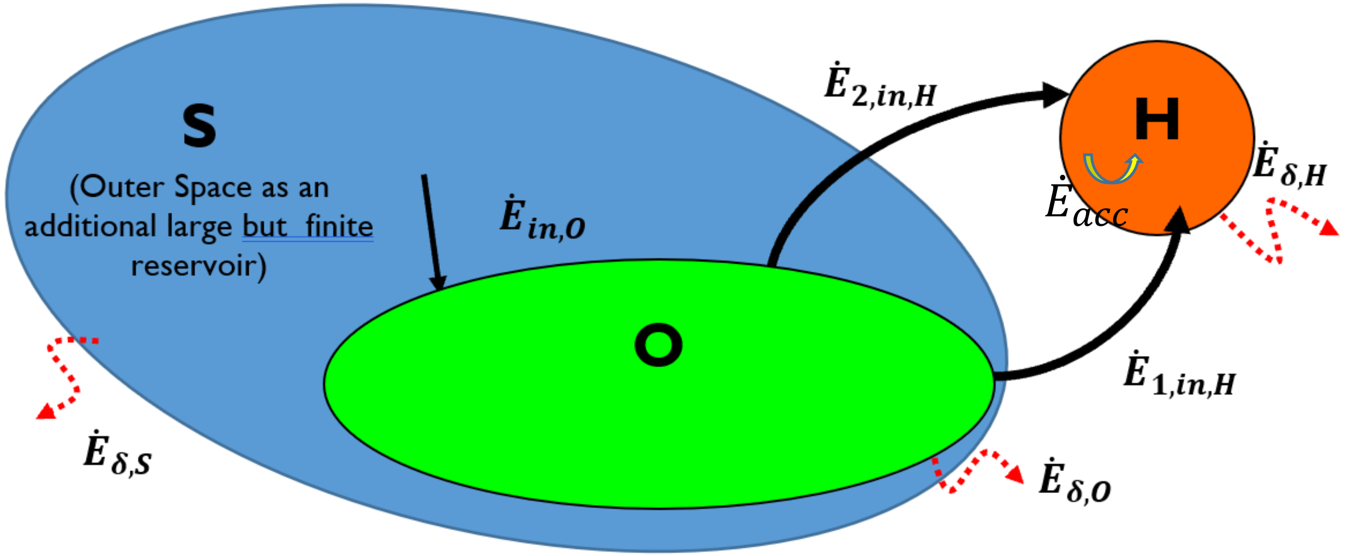


Figure 1a – Schematic representation of the Mass- and Energy budgets of a human society (expressed in Exergy Flows, W)

Legend: S=Outer space; O=Biosphere (here, Planet Earth); H=Human society; $E_{in,O}$=Exergy inflow into Earth from Outer space; $E_{1,in,H}$=Renewable exergy inflow into Society from Biosphere; $E_{2,in,H}$=Non-renewable exergy inflow into Society from Biosphere; E_d=Exergy destruction

Project ROMANA – Extended Exergy Accounting

Thus, every EEA analysis ought to begin by considering the material, energetic and economic budget of the entire Country. This does not mean that EEA is only valid at macro-levels: on the contrary, its most convenient applications are at intermediate and low (highly disaggregated) levels, down to a single production line.

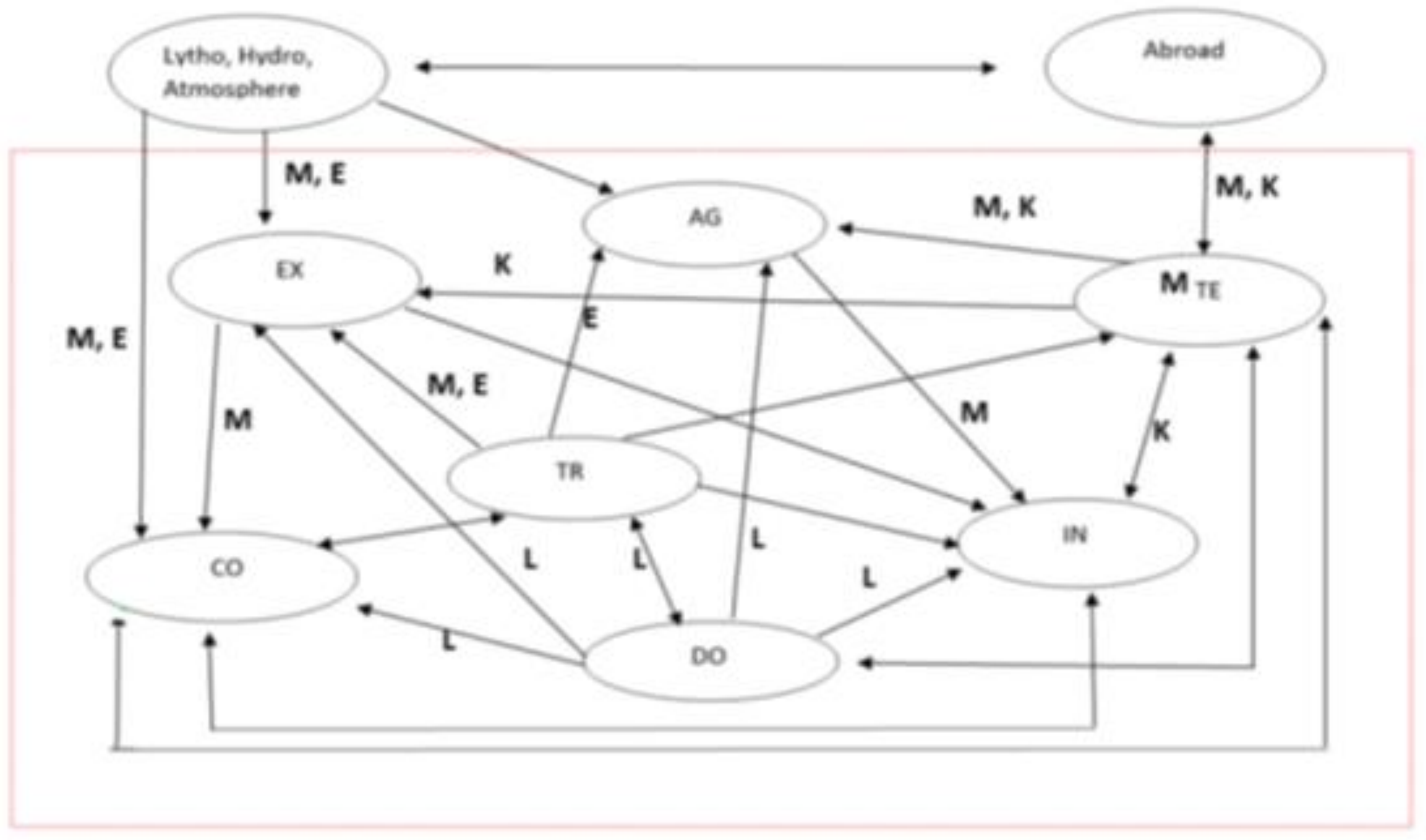
But the theory requires that two conversion operators be calculated at the Country level, and they require the acquisition of two econometric parameters that contain global economic, social and exergetic data.

Figure 1b – Schematic representation of the Exergy flows at the Country level

Legend: in blue the immaterial inputs; in red the material imputs; in purple the internal fluxes; in green the import/exports

Project ROMANA – Extended Exergy Accounting

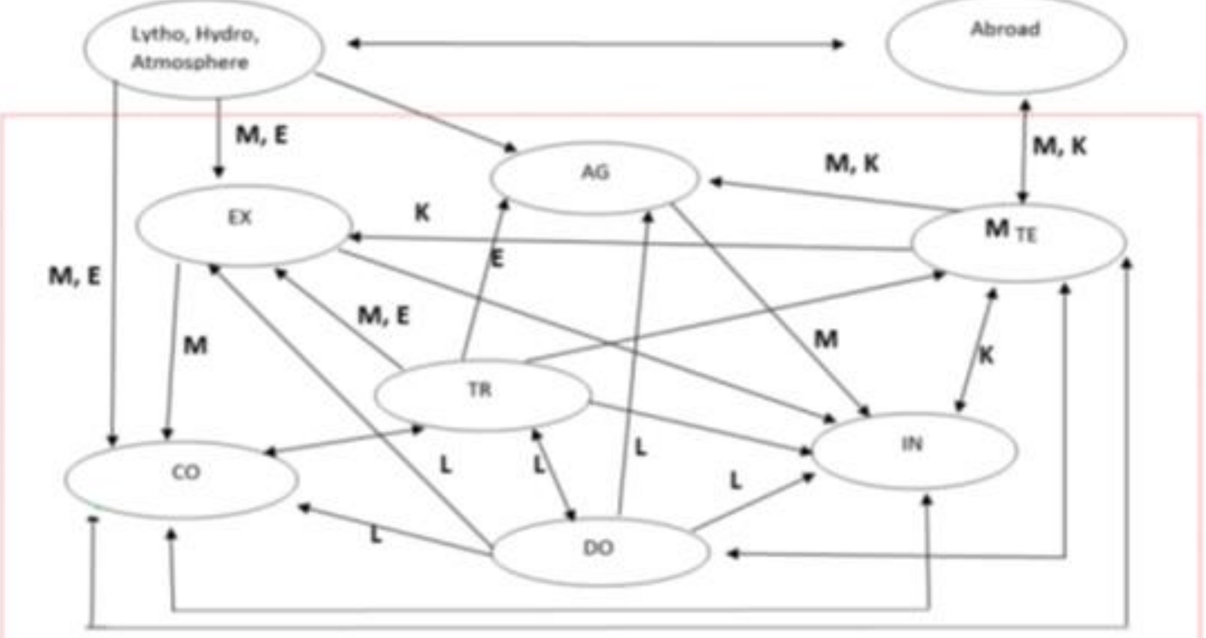
An EEA analysis is based on a model that represents the Country as consisting of 7 Productive Sectors, Extraction, Conversion, Industry, Transportation, Agriculture, Tertiary and Domestic, interacting among themselves and with two additional "external" Sectors named Abroad (import/export) and Environment. Once the material, energy and monetary budgets are quantified, all fluxes are converted to their primary exergy resource equivalent.



Schematic representation of the representation of societal Sectors in EEA
Legenda: M=Material streams; E=Immaterial streams; K=Capital flows; L=labour flows (the above representation is schematic: in the interest of clarity, not all flows have been included)

Extended Exergy Accounting of Romania

Based on properly disaggregated data obtained from several sources (National Institute of Statistics, Governmental, World Bank and Industrial reports), two econometric coefficients have been calculated and two primary-resource equivalents fotr the Labour and Capital externalities have been calculated:



Legenda: M=Material streams; E=Immaterial streams; K=Capital flows; L=labour flows

α=(total exergy consumption by inhabitants)/(total exergy inflow)

β=(M2 monetary indicator)/total wages)

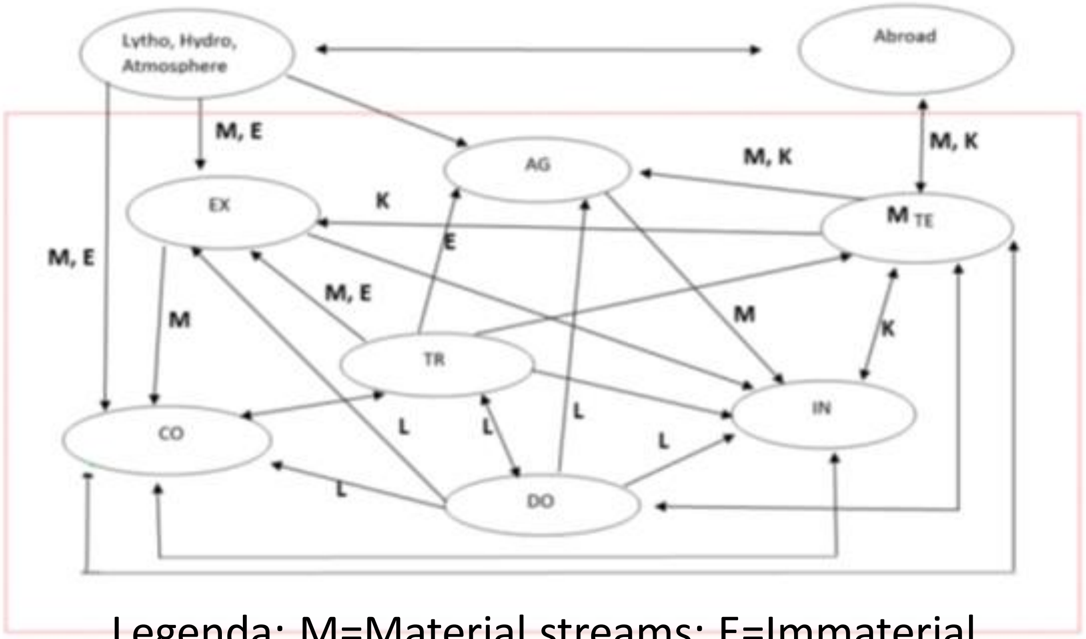
Extended Exergy Accounting of Romania

The values for a and b were then used to calculate the equivalent primary exergy “embodied” in one single worlhour and in one monetary unit:

$$ee_L = \frac{\alpha \dot{E}_{in}}{N_{Workers} whr_{worker}} \quad \text{[MJ/workhour]}$$

$$ee_K = \frac{\alpha \beta \dot{E}_{in}}{M2} \quad \text{[MJ/€]}$$

The numerical values are consistent with those previously calculated for other Countries:



Legenda: M=Material streams; E=Immaterial streams; K=Capital flows; L=labour flows

α=0.0121

β=1.35

ee_L=139 MJ/wkhr

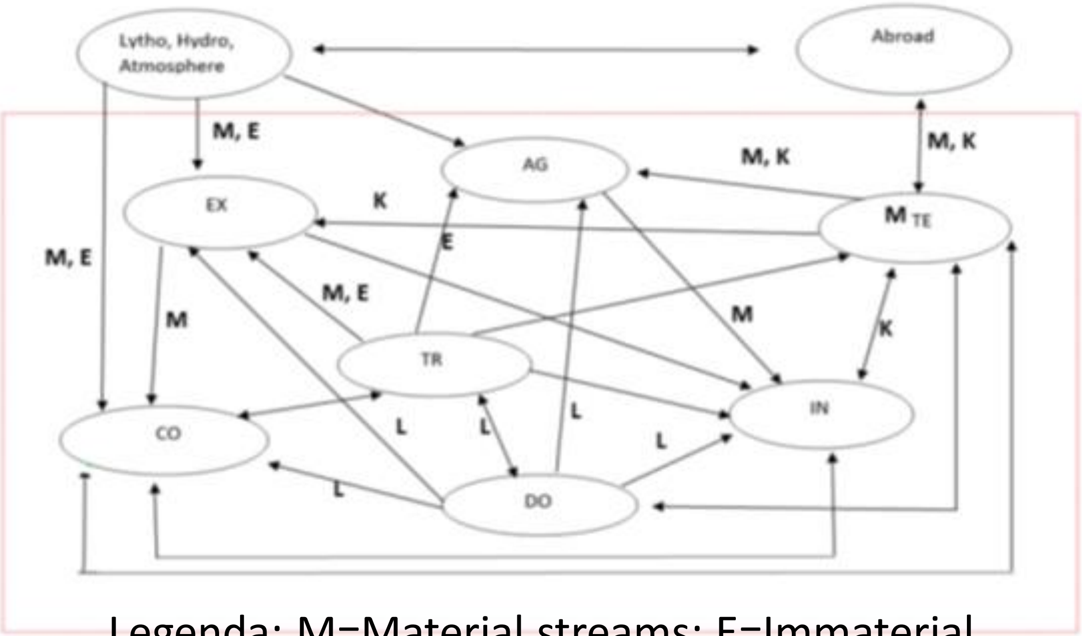
ee_K=14.8 MJ/€

Extended Exergy Accounting of Romania

The above values have a well-defined physical meaning and their values provide some insight into the operation of the Romanian system:

- Approximately 1.2% of the total incoming exergy inflow is consumed by human activities;

- The financial capital circulating in Romania is about 35% of the total wages;



Legenda: M=Material streams; E=Immaterial streams; K=Capital flows; L=labour flows

- Every workhour generated in any activity in Romania consumes 139 MJ of primary exergy equivalent;
- Every € (approx. 5 Lei) circulating in Romania consumes 14.8 MJ of primary exergy equivalent.

1 – The concept of “Sustainability”

Bruntland definition (UN report “Our Common Future”, 1987):
“Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.”

This definition is widely quoted by media and policymakers, but has been criticized by scientists for being too vague and difficult to quantify. In fact, the problem we are addressing here is the difficulty of concocting a Sustainability Indicator that can be easily , reproducibly and accurately quantified.

The concept is though clear: a society is on a “sustainable track” if it thrives on renewable primary resources and if its impact on the environment is such that it can be compensated by proper remediation actions.

At the current state of affairs, the above requirements are nowhere satisfied: humans are still using fossil resources, mine metals and other materials and do not compensate for their anthropic CO_2 generation.

A Sustainability Indicator should therefore provide a measure of how far we are from “complete sustainability”: in other words, it ought to measure the “degree of unsustainability” of a society.

2 – Some currently used Sustainability Indicators

A list of SI can be compiled by consulting several sources, like IEA, EU etc.: they may be classified in 3 classes.

A - Environmental Sustainability Indicators

1. Carbon footprint:

Measures the total greenhouse gas emissions associated with a product, organization, or individual.

2. Energy use:

Tracks the use of energy from various sources, such as renewable and nonrenewable.

3. Water use:

Quantifies the amount of water consumed, considering both direct and indirect usage.

4. Biodiversity loss:

Monitors the decline in the variety and abundance of species in a given area.

5. Waste generation:

Measures the amount of solid, liquid, or hazardous waste produced and disposed of.

6. Air quality:

Examines pollutants in the air, such as particulate matter, nitrogen dioxide, and ozone levels.

7. Land use change:

Tracks changes in land cover and land use patterns, especially related to urbanization and deforestation.

8. Ecoefficiency:

Evaluates the efficiency of resource use in producing goods and services.

B - Social Sustainability Indicators

1. Poverty rate:

Measures the percentage of the population living below the poverty line.

2. Education access:

Examines the availability and accessibility of education opportunities for all.

3. Health indicators:

Includes metrics like life expectancy, disease prevalence, and access to healthcare.

4. Gender equality:

Assesses equality between men and women in various aspects, including employment, education, and representation.

5. Community wellbeing:

Measures the overall health and vitality of communities, including factors like social cohesion and cultural wellbeing.

6. Labor conditions:

Evaluates working conditions, workers' rights, and fair wages.

7. Human rights:

Monitors adherence to fundamental human rights principles.

C - Economic Sustainability Indicators

1. Gross Domestic Product (GDP):

The total value of goods and services produced by a country, often used as a measure of economic health.

2. Income distribution:

Examines how wealth and income are distributed among a population.

3. Unemployment rate:

The percentage of the labor force that is unemployed and actively seeking employment.

4. Resource efficiency:

Measures how efficiently resources are used in economic activities.

5. Innovation and technology adoption:

Tracks the integration of sustainable technologies and innovations into economic processes.

6. Corporate social responsibility (CSR) performance:

Assesses how businesses contribute to social and environmental goals beyond profit.

7. Financial stability:

Examines the stability of financial systems and institutions.

3 – Merits of Sustainability Indicators

A general agreement on the definition and application modes of a set of properly defined Sustainability Indicators would offer several advantages to policymakers, energy-, infrastructure- and social planners:

1) it would allow for informed decision making at all levels;
2) it would make possible to monitor the situation of a single industry, of a city, of a region, of a Country, regardless of its geolocalization;
3) it would make comparisons possible, and guide towards adjustment of the enforced policies;
4) it would provide a quantitative tool to evaluate future scenarios.

4 – Limits of existing Sustainability Indicators

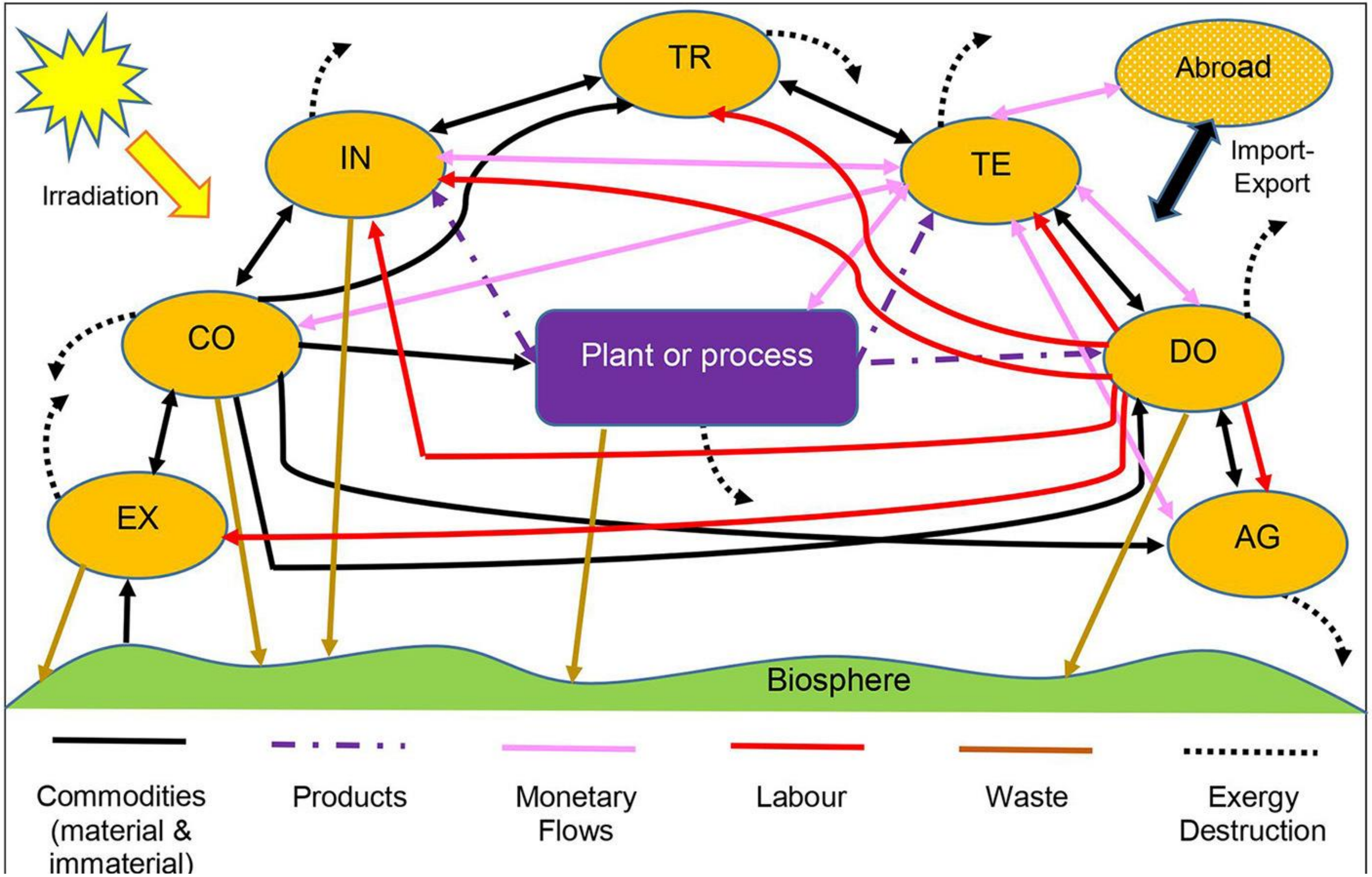
Sustainability Indicators clearly play a crucial role in assessing and promoting sustainable practices, but there is a general agreement that there are certain limitations and challenges associated with their use.

Several “problem lists” exist, not all unbiased. We include here a critical list compiled from publicly available documents.

1. Simplification and Selectivity:
SI often simplify complex issues to make them measurable, and this affects their accuracy and their ability to capture the full complexity of sustainability challenges.
2. Interconnectedness and Tradeoffs:
SI may not adequately account for the interconnected nature of environmental, social, and economic systems. Improving one aspect of sustainability in isolation may result in tradeoffs or unintended consequences in other areas.
3. Cultural and Contextual Variability:
What is considered sustainable can vary across cultures and contexts. Indicators that are suitable for one region or community may not be applicable or relevant elsewhere.
4. Temporal Considerations:
SI often focus on short to medium term outcomes, while long term effects may be overlooked. But some sustainability challenges, such as climate change, have long time horizons, making it difficult to assess progress accurately.
5. Data Availability and Quality:
In many cases, reliable and comprehensive data for SI may be lacking. The quality of available data can vary, leading to uncertainties and potential inaccuracies in assessments.

6. Subjectivity and Stakeholder Perspectives:
Different stakeholders may have varying perspectives on what should be prioritized in sustainability. The selection of indicators may be influenced by the values and interests of particular groups, leading to potential bias.
7. Complexity of Social Indicators:
The definition and quantification of Social SI can be challenging due to the complexity of social systems and the subjective nature of many social factors.
8. Dynamic Nature of Sustainability Challenges:
Sustainability challenges are dynamic, and the significance of certain issues may change over time.
9. Lack of Standardization:
There is often a lack of standardized metrics and methodologies for measuring sustainability, making it difficult to compare results across different entities and regions.

5 - A novel, resource-based Sustainability Indicator



How EEA represents a process interacting with the 7 Sectors of a society and with the Biosphere

The theory of EEA is somewhat specialistic and it is well-detailed in several publications and applications: here, we provide only some of the main points of its paradigm:

1) the control system is always an entire Country, for which the mass- and energy flows are known (ores, produce, fuels, products, imports and exports);
2) from an analysis of the total primary energy input, its eXergy value is calculated;
3) from an analysis of the final energy use, the eXergy consumption pro-capite is calculated;
4) the pro-capite exergy consumption is assumed as the “exergy equivalent” of the workhour;
5) the exergy equivalent of capital I calculated on the basis of the available monetary indicators;
6) for each material or energy flow, a “primary exergy cost” is calculated from the exergy flowchart of the process augmented by the equivalent exergy of capital, labour and environmental remediation: this cost is expressed in kJ/unit of product;
7) this is true of immaterial commodities as well: their “equivalent cost” is given by the sum of their equivalent capital and labour exergy plus the exergy required for environmental remediation;
8) the procedure is repeated iteratively for all societal sectors;
8) the result is the global primary exergy consumption of the society, and it is called its Exergy Footprint.

Notes:

a) once the EEA has been performed at a Country level, it can be scaled down to every sub-sector or entity (e.g., city) to compute the Exergy Footprint of any commodity: this is the “cost” in kJ of primary resources embodied into a unit of that commodity;

b) EEA is geographically and temporally localized, since it applies to a certain Country in a certain interval of time;

c) its results are independent of GDP, Health Index, etc. Correlations are possible;

d) the higher the Exergy Footprint of an item, the less sustainable it is. This applies at all scales and makes it possible to compare the same process localized in different Countries, or different production lines with the same product in the same Country, etc.

e) The accuracy of EEA depends on the availability of sufficiently disaggregated data.

Conclusions

Within the efforts dedicated to the implementation of the UN Sustainable Development Agenda 2030 and with extension until 2050, there is a strong need for developing science evidence-based tools tailored to the realities of the Black Sea region, in order to facilitate detailed analyses and optimization of economical, social and geo-political processes.

In this context, the proposed Action Plan based on the results of the ROMANA project is a possible path that has to be taken into consideration in developing National Strategies and Action Plans.

Thank you for your support!