Parthenope University of Naples

Paper Title

"*A multi-criteria framework for assessing urban socio-ecological systems: The emergy nexus of the urban economy and environment*"

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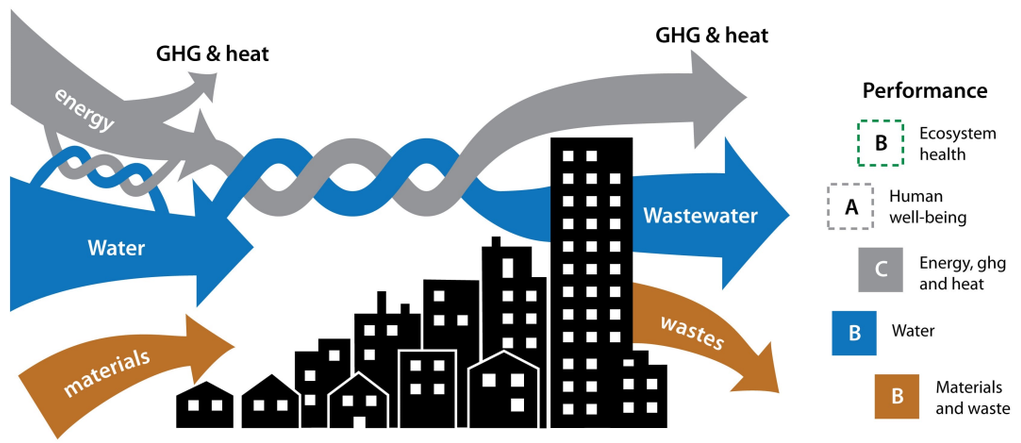
Research questions

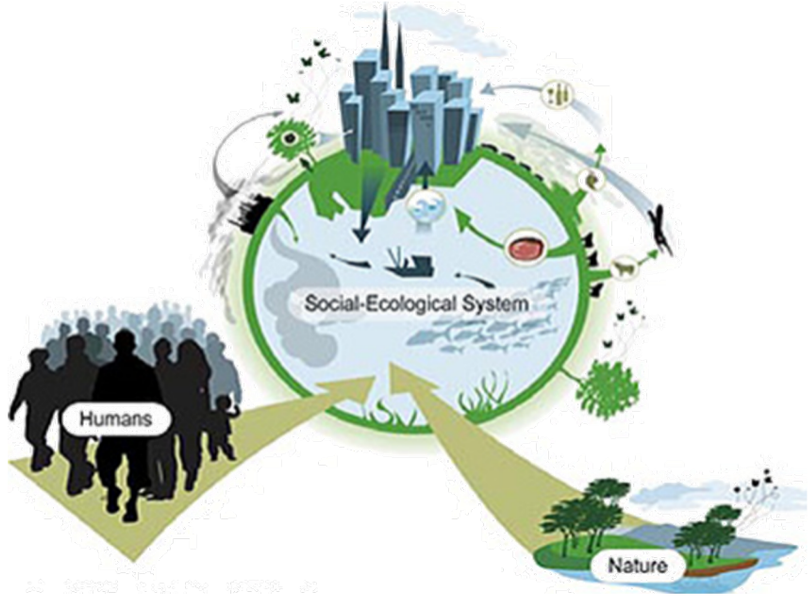
Towards sustainable cities

1. How to explore the urban metabolism of cities using an input-output model?

2. How to develop a multicriteria framework to assess the environmental performance and sustainability of urban systems?



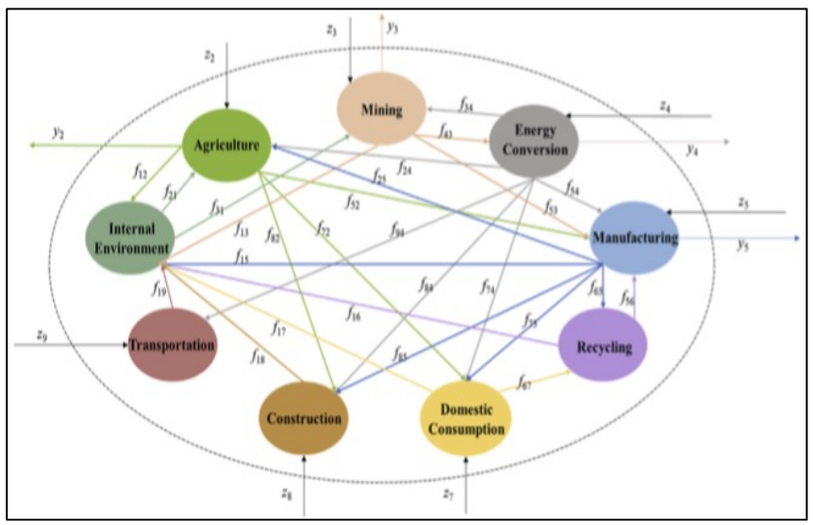
Scientific Background



1. The social and ecological impacts generated by urbanization require the integrated management of cities based on a sustainable supply of resources for the long-term management of human economy.

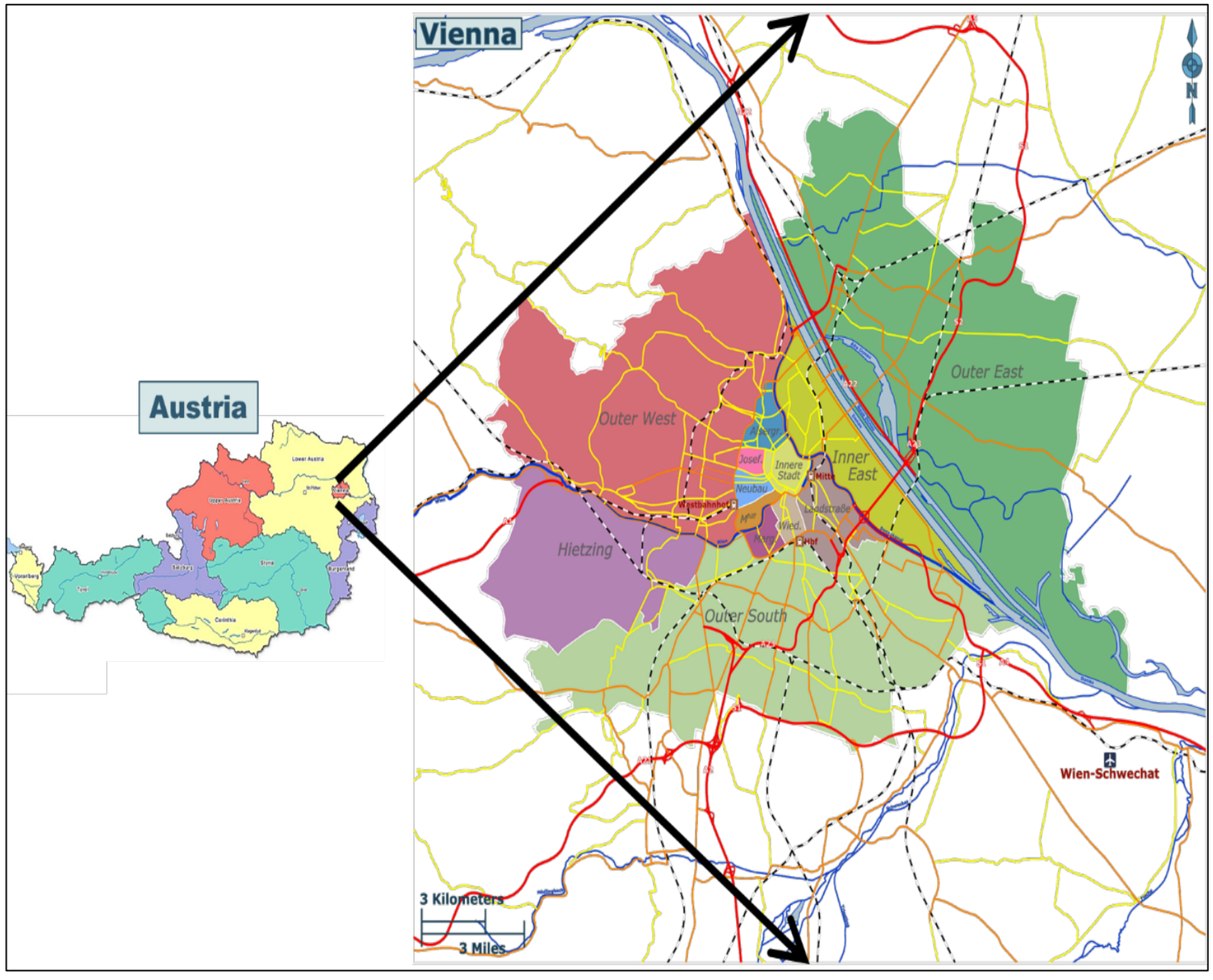
2. This perspective is based on network models to study internal metabolic processes in urban socio-ecological systems, complementing traditional “black box” urban models.

“black box” urban model



Network model

The case study of the Municipality of Vienna (Austria)



- Vienna region has the smallest area among other regions (414.9 km^2).
- Vienna region hosts a population of about 1.9 million (2020).
- This region generates about one quarter of the national GDP, about 96 billion euros.

Methods

HYBRID INPUT-OUTPUT

Analyze interdependence of energy and non-energy industries in urban economy.

MATRIX INVERSION

An extension of hybrid input-output analysis to estimate transformity values.

REFLEXIVE METHOD

Analysis of entire supply chain of each product to estimate transformity values.

Regional monetary and energy IO tables

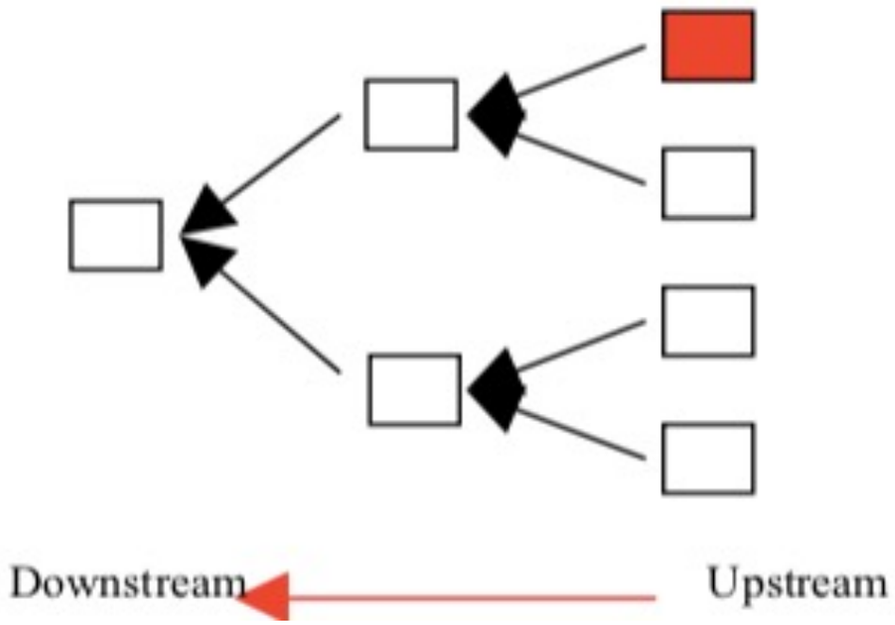


Fig.1. Supply-side approach

- The national monetary use and supply data was regionalized using supply-side and location quotient approaches (measure of industrial concentration)

- Commodity-by-industry approach was applied to build regional monetary input-output table.

Regional monetary and energy IO tables

	Commodity	Industry	Final Demand	Total Use
Commodity		Use Matrix	Final uses	Commodity outputs
Industry	Make Matrix			Industry outputs
Energy losses / Value Added		Energy losses / Value Added		
Imports	Imports			
Total supply	Commodity outputs	Industry outputs		

Fig. 2. Commodity-by-industry accounting framework

- Regional shares of energy products were obtained using supply-side and location quotient approaches. These regional shares were then applied to disaggregate energy balance data.

- Commodity-by-industry approach was used to build energy input-output table of Vienna Region.

Development of emergy input-output model

Table 1 Limitations and extensions.

Methods \ Limitations	Negative transformities	Non-unique solution of transformities
Matrix Inversion	Problem	Ok
Reflexive Method	Ok	Problem
Matrix + Reflexive	Ok	Ok

- The matrix method was integrated with reflexive method to overcome limitations in computing transformity values.

- Regional monetary and energy input-output tables were multiplied by their respective transformity values and summed up to build the emergy input output table.

Hybrid-unit emergy input-output model

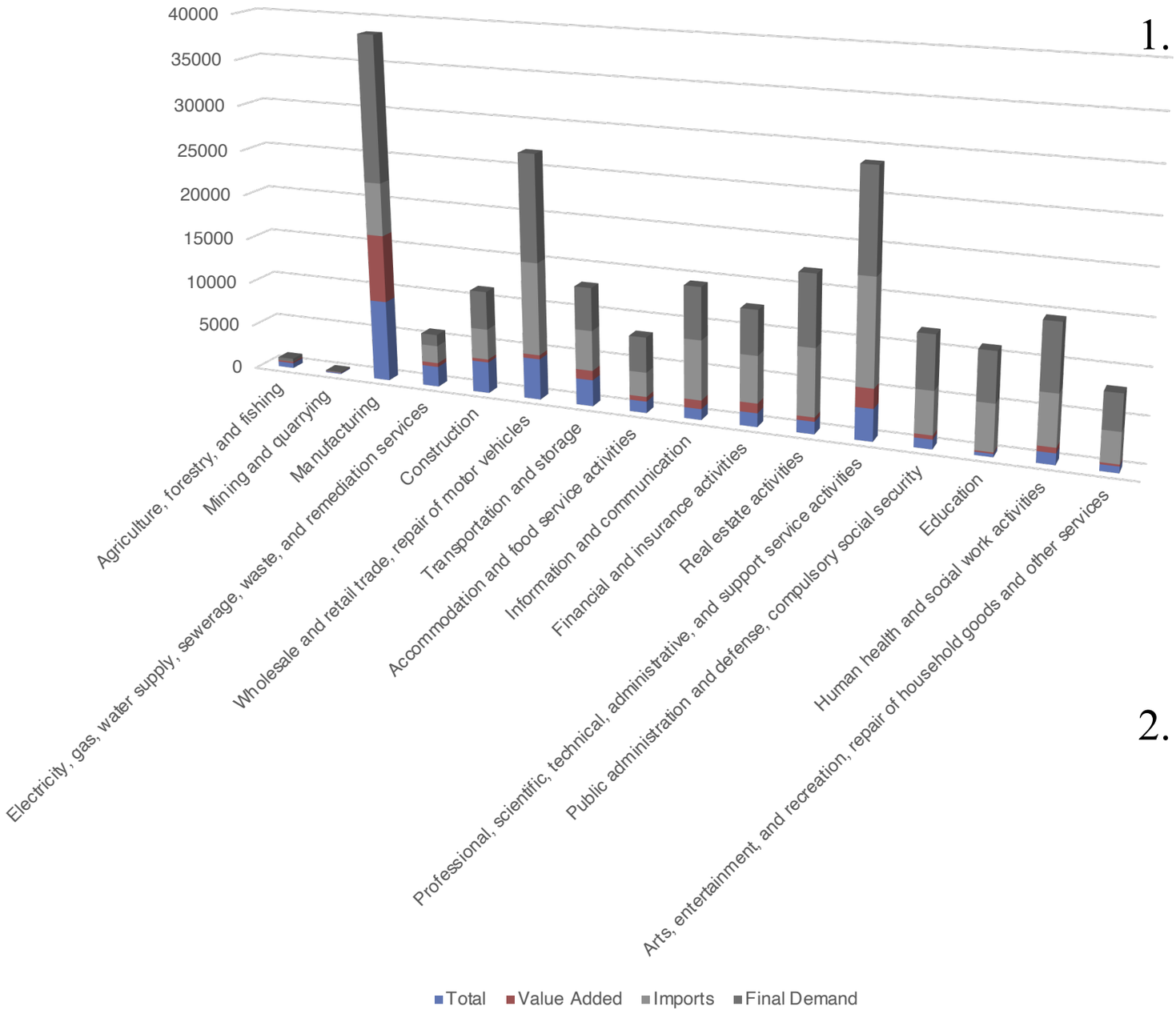
Table 2 Hybrid-unit emergy input-output model

H-EIO	Consuming sectors	Final Consumers	Total Use
Producing sector	Intermediate use	Final use	Industry outputs
Imports	Imports		
Value added	Value added		

Data in grey area are in emergy units (seJ) and data in white area are in monetary units (€)

- The emergy input-output table was combined with the monetary input-output table based on hybrid-unit input-output approach to build hybrid-unit emergy IO model.
- This model allows to assess the total emergy exchanged between the urban economy and the environment.

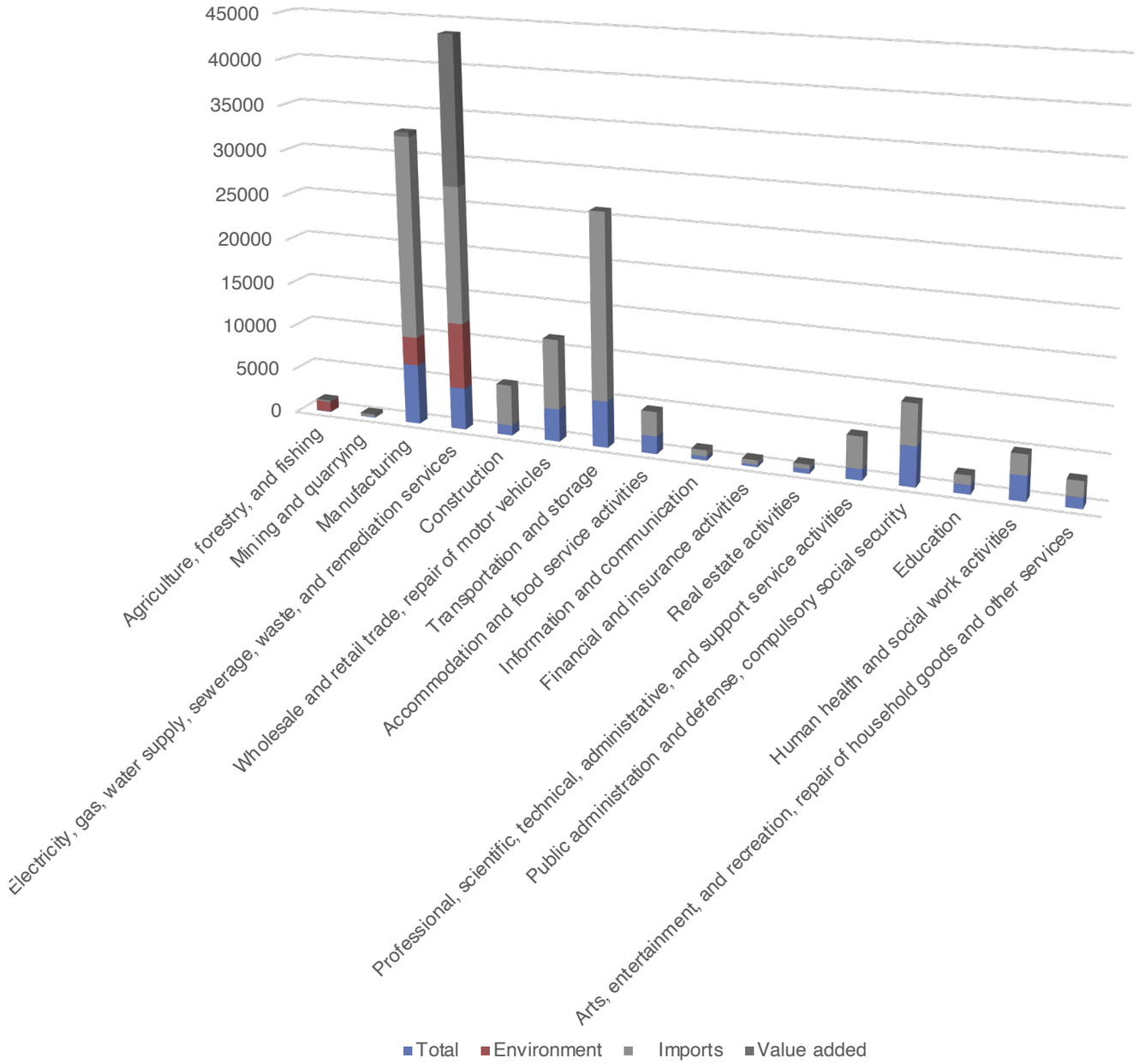
Results: Monetary consumption



1. "Mining and quarrying", and "agriculture, forestry, and fishing" are the weakest sectors in the urban economy

2. Those two sectors and "manufacturing" have shown dependence on imported products, with manufacturing been dependent on 33% of imported products

Results: Energy consumption

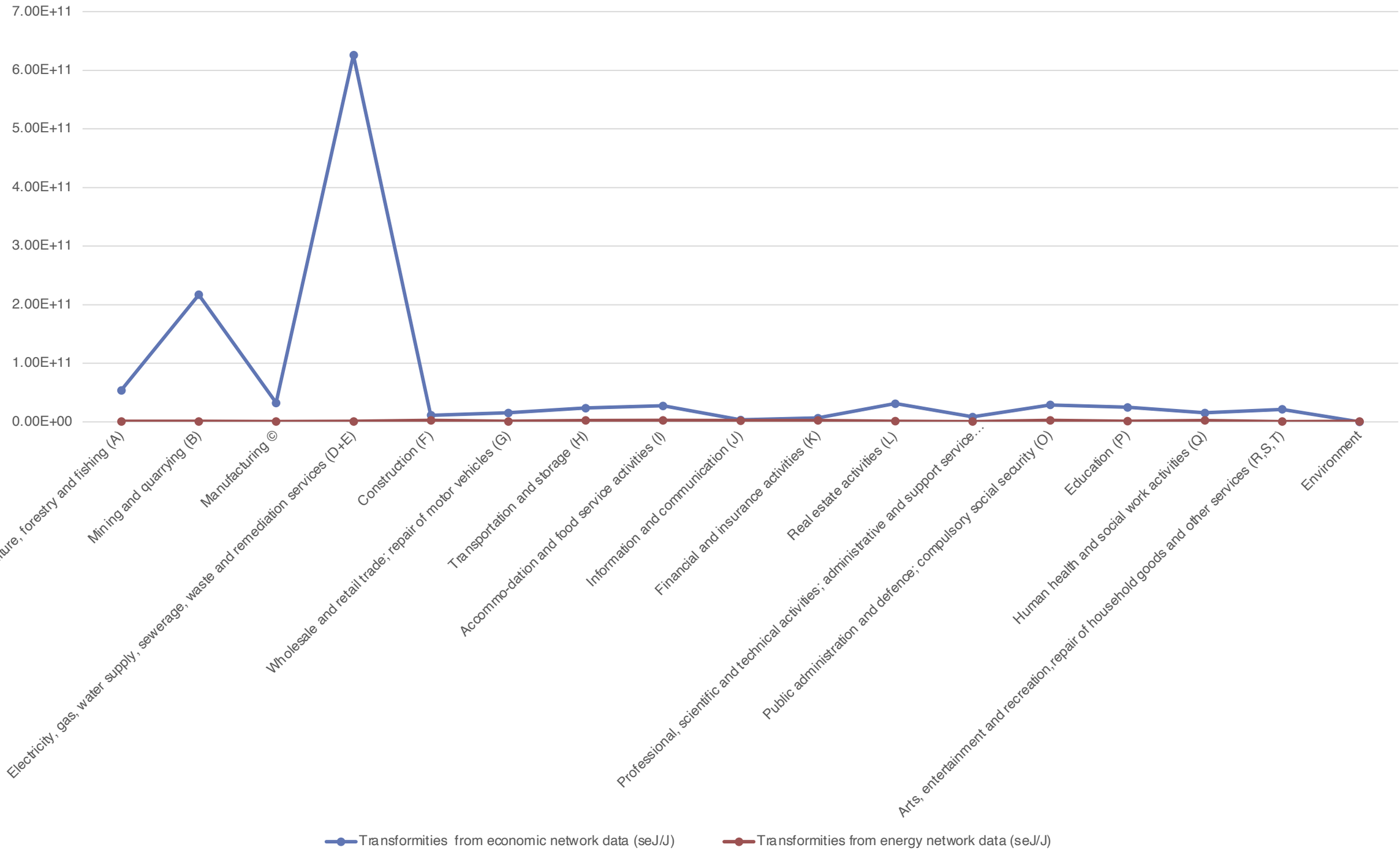


1. Renewable energy inputs are mostly used in the upstream industry, namely “agriculture, forestry, and fishing, “manufacturing” and “electricity, gas, water supply, sewerage, waste, and remediation services”.

2. “Construction” and “transportation and storage” sectors are the highest energy importers, 80% and 79% respectively

3. “Electricity, gas, water supply, sewerage, waste, and remediation services” and “manufacturing” sectors have the largest outputs: 43650.02 TJ and 32834.60TJ,

Results: Transformities



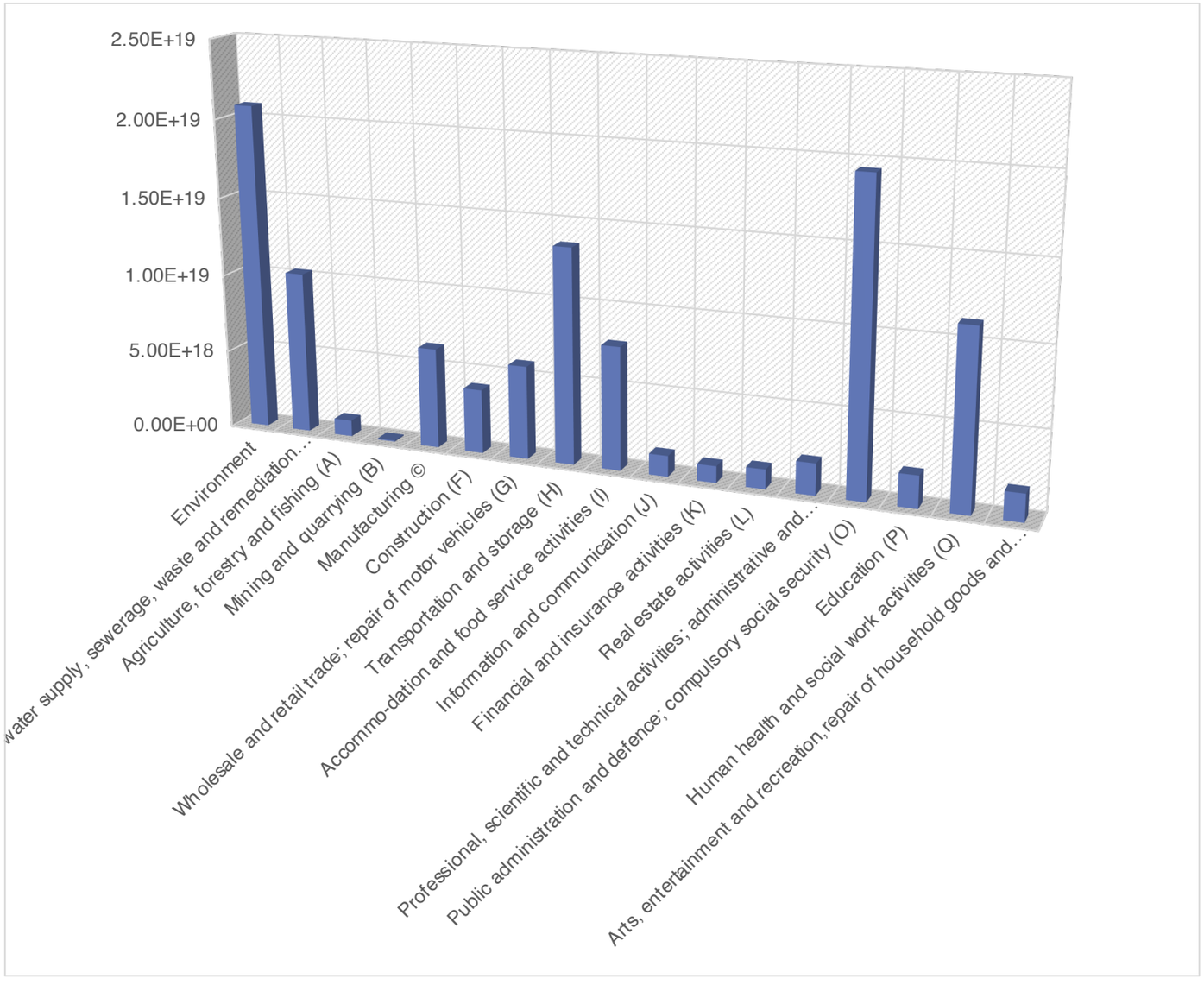
Results: Transformities

The transformities based on “energy network data” of “construction”, “accommodation and food service activities” and “public administration and defence, social security” were were 4.1 times that of the “manufacturing” sector (6.44E+08 seJ/J).

The “information and communication” and “financial and insurance activities” are characterized by the high transformities based on “energy network data”, and accounted for 50% and 33% of transformities based on “economic network data”.

The transformities based on “economic network data of “electricity, gas, water supply, sewerage, waste, and remediation services”, “mining and quarrying”, “agriculture, forestry, and fishing”, and “manufacturing” sectors were 95, 33, 8 and 5 times that of the sector with the lowest magnitude, namely “financial and insurance activities”.

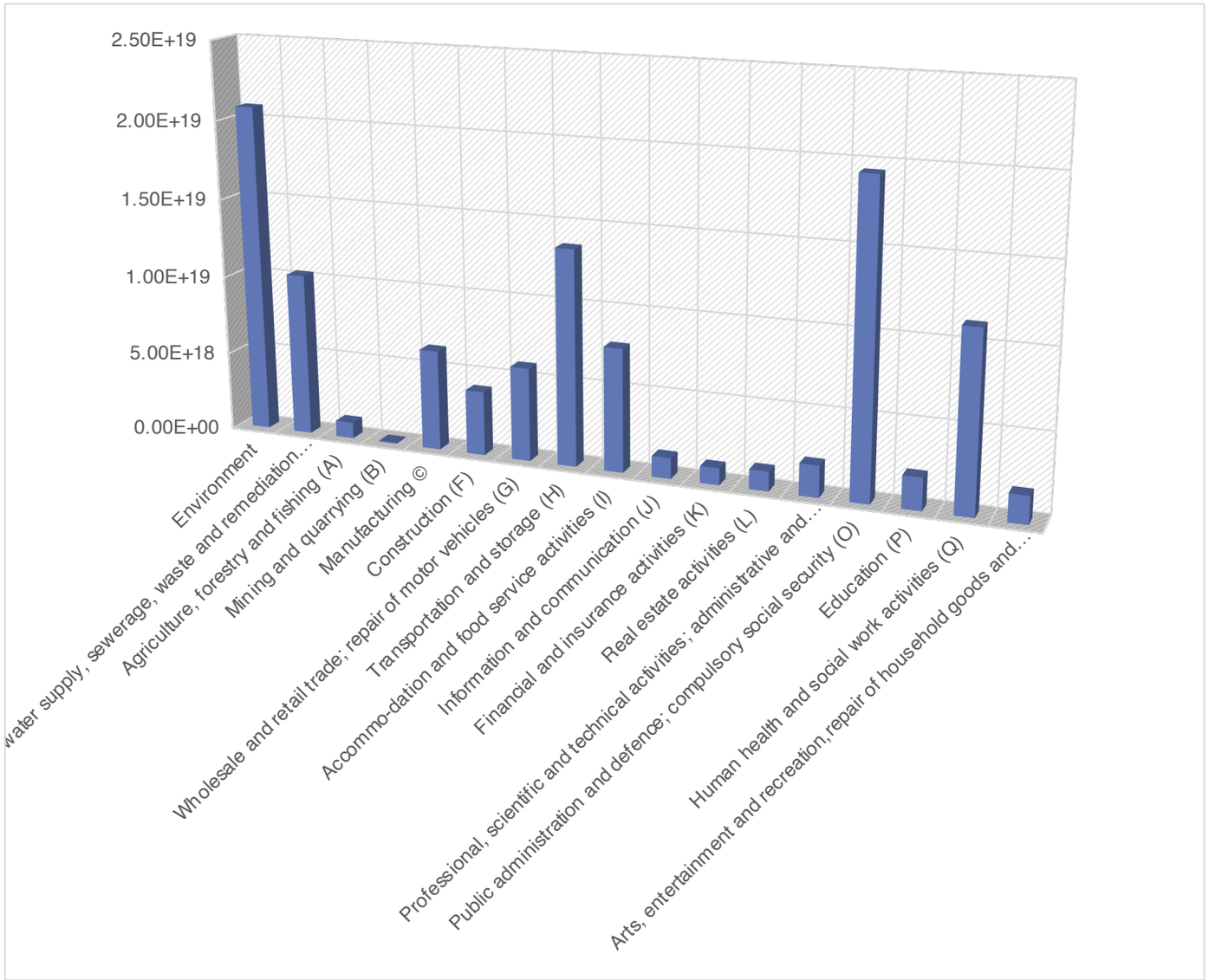
Results: Total emergy consumption



1. "Renewable energy" sector is supported by a large emergy consumption, confirming the importance of renewable energy in the context of Vienna's regional economy.

2. The lowest emergy use of the "mining and quarrying" sector shows that this sector is not prioritized by the Vienna's government focused on improving circular economy strategies and renewable energy production.

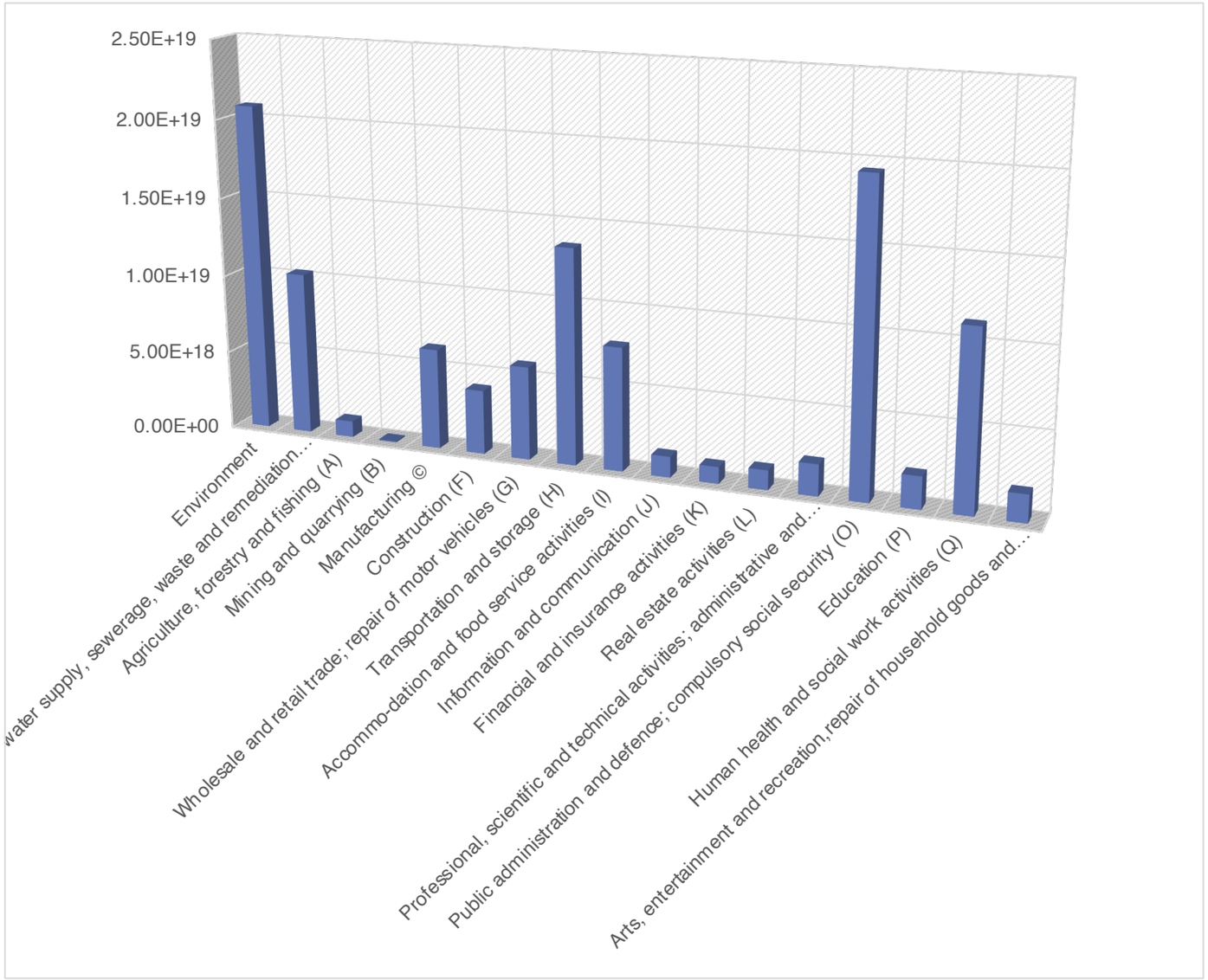
Results: Total emergy consumption



3. “Agriculture, forestry, and fishing” uses only slightly more emergy compared to “mining and quarrying” sector (1.03E+18 seJ), indicating that this sector is similar in terms of investments to “mining and quarrying” sector.

4. The second highest emergy use of “Electricity, gas, water supply, sewerage, waste, and remediation services” reflect the large power plants located in Vienna Region.

Results: Total emergy consumption



5. Among the tertiary sectors, “public administration and defence, social security”, “transportation and storage”, and “human health and social work activities” are characterized by a high emergy support, confirming a strong policy commitment to provide high quality social services oriented towards smart cities and urban sustainability in line with the Urban Development Plan STEP, 2025.

Conclusion: Recommendations

Future strategies should consider applying supply-side and demand-side interventions to continue improving the share of renewable energies while promoting and supporting sectors with low emergy consumption (i.e., organic agriculture, mining and quarrying, transportation and storage).

The investments into “agriculture, forestry, and fishing” sector should be prioritized due to the role of this sector in renewable energy production and its position in supply chain: acceptance of renewable energy from the source(i. e. bringing raw materials into the system), and its transfer in the production and supply of agricultural products (i.e., farm products) to all other sectors.

The sectors with the high transformities based on “economic network data” should substitute an expensive machinery and raw materials (i.e., crude oil, steel) with the cost-effective solutions (i.e., solar energy, fuelwood) and to increase the reuse and recycle of materials (i.e., use of animal waste to produce biogas and renewable diesel to satisfy “energy “and “transportation” demands, respectively), etc.

Conclusion: Limitations

Limitations

The outputs-inputs matrix Z constructed from economic network data does not have a zero ‘eigenvalue’ due to regionalization method employed instead of the survey or partial survey methods.

The other limitation was an unavailability of region-specific monetary data for construction of regionalized version of national monetary input-output table.

Conclusion: Future scope

Model can be particularly useful in other hybrid-unit input-output applications such as detailed and complete energy, material consumption and GHG emissions accounting based on ‘full life-cycle perspective’.

This approach can be complemented with environmentally extended input-output analysis (EE-IOA) to obtain more reliable findings on sectors responsible for high consumption and emissions within city boundaries.

The future research should focus on integration of our model with ecological network analysis to study the relationship between of system’s internal processes and system-level resource metabolism.

Thank you for your kind attention!