Water-Energy-Carbon Nexus of the EU27 and China



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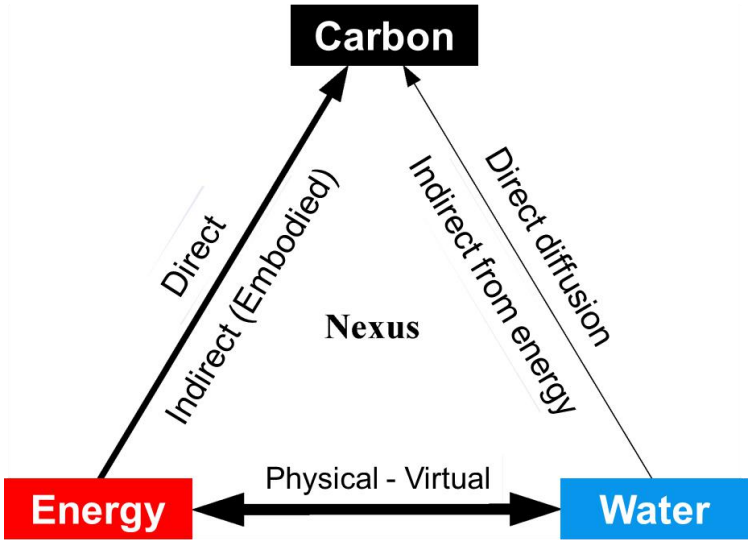
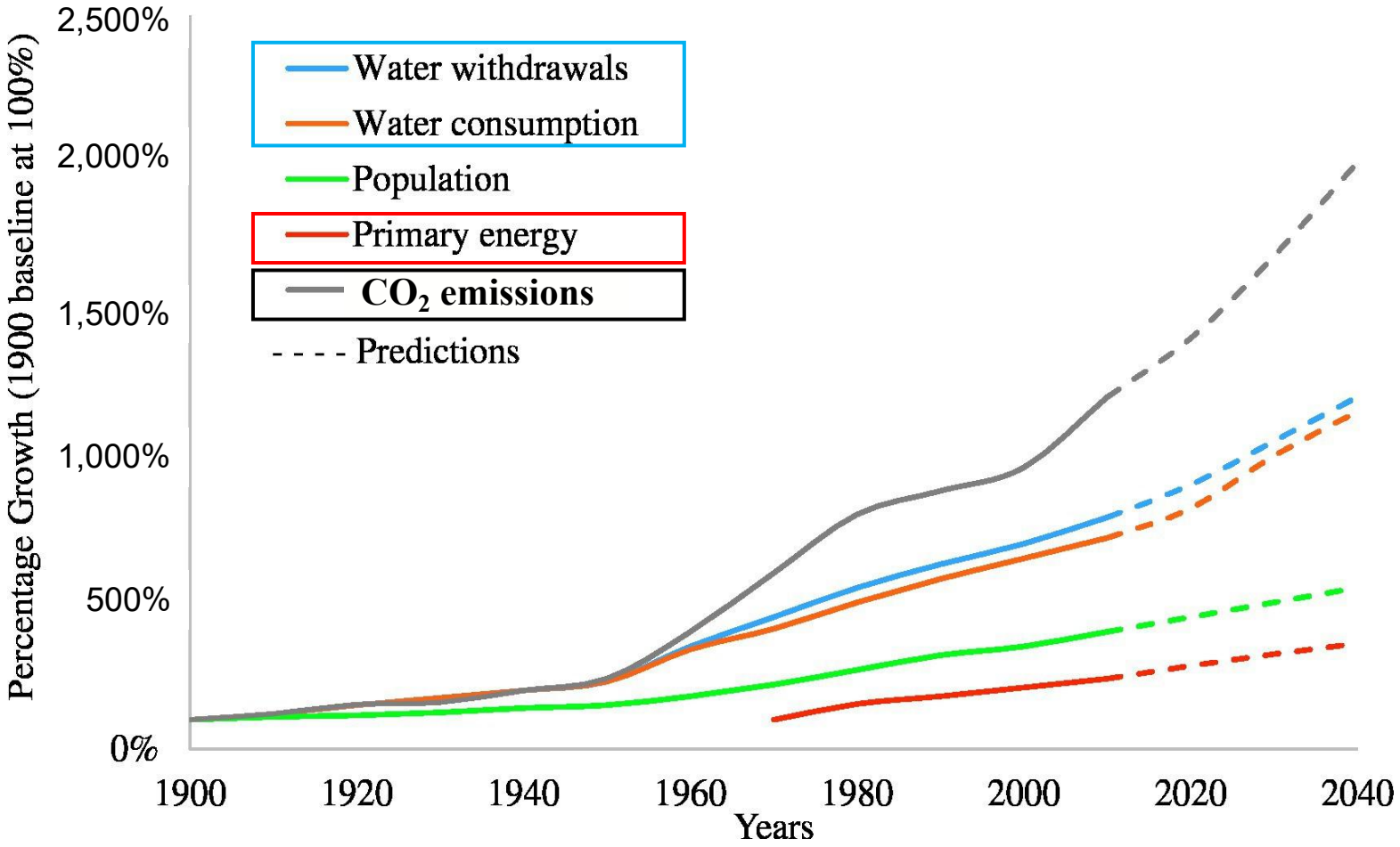
Outline

- Background
- Water-Energy-CO_2 (WEC) Nexus
- Research gaps and aims
- Methods
- Results
- Implications
- Conclusions



Background

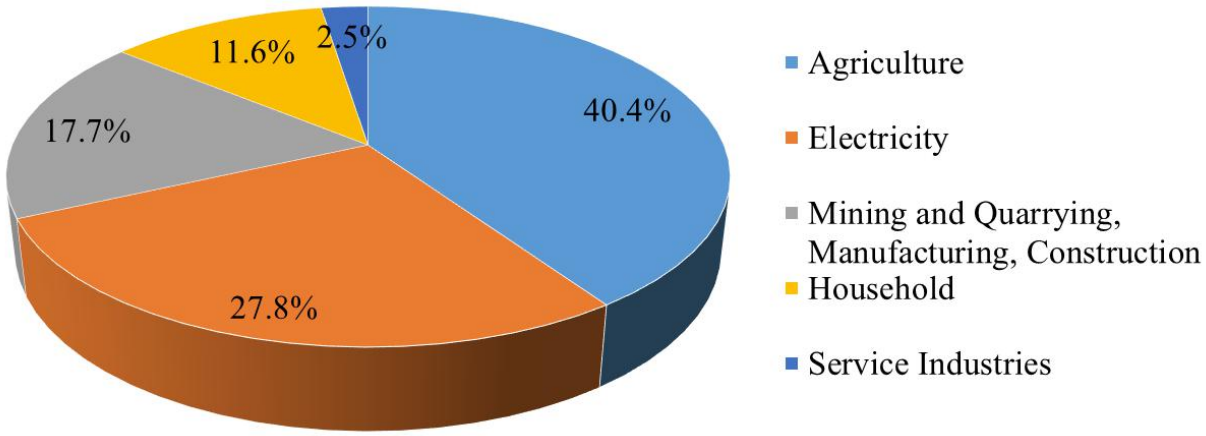


Water, population, primary energy and CO_2 emission percentage growth rate from 1900 to 2040.

Shahzad, M.W., Burhan, M., Ang, L., Ng, K.C., 2017. Energy-water-environment nexus underpinning future desalination sustainability. Desalination, 413, 52-64.

The EU

Water stress: **over 100 M** in Europe. An overall decrease in renewable water resources per capita by **24%** across Europe.



Water use of EU-28 by economic sectors

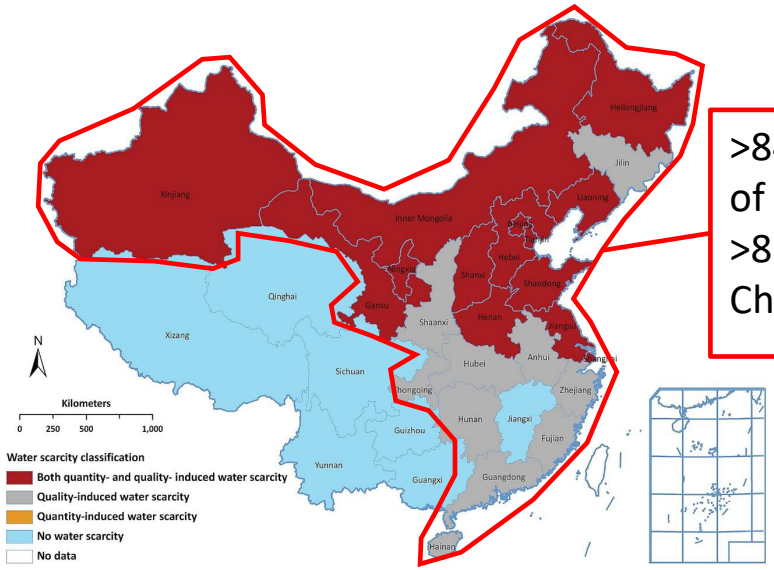
EU consumed **1,561 Mtoe** (Mt of oil equivalent) of primary energy consumption in 2017, which accounted for **11.05%** of worldwide.

It was still **5.3% higher** in 2017 than the target.

80% of GHG emissions in the EU comes from energy generation and consumption.

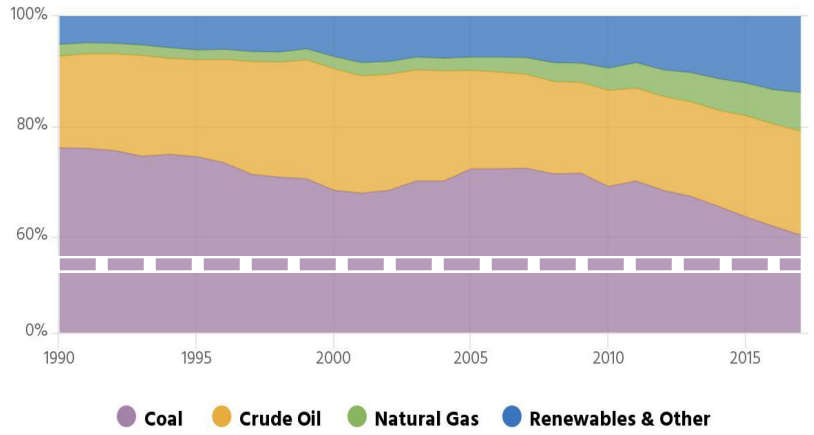
Wang, X.C., Klemeš, J.J., Long, X., Zhang, P., Varbanov, P.S., Fan, W., Dong, X. and Wang, Y., 2020. Measuring the environmental performance of the EU27 from the Water-Energy-Carbon nexus perspective. Journal of Cleaner Production, p.121832.

China



>84% Population of China
>85% GDP of China

- **Water scarcity**
- **Uneven water distribution**
- Despite the considerable progress, China is still leading the energy consumption list
- The biggest carbon emitter



Zeng, Z., J. Liu, and H. H. G. Savenije, 2013. A simple approach to assess water scarcity integrating water quantity and quality, Ecol. Indic., 34, 441–449.
<https://chinapower.csis.org/energy-footprint/>, <https://yearbook.enerdata.net/total-energy/>, accessed 6 Sep. 2019

Potential in China

If average building lifetime can be extended from 23 y to 50 y in China in 2011, we can save:

5.8 Gt

Equivalent to the national water withdrawal in Belgium

127.1 Mt_{ce}

Equivalent to the national energy consumption in Mexico

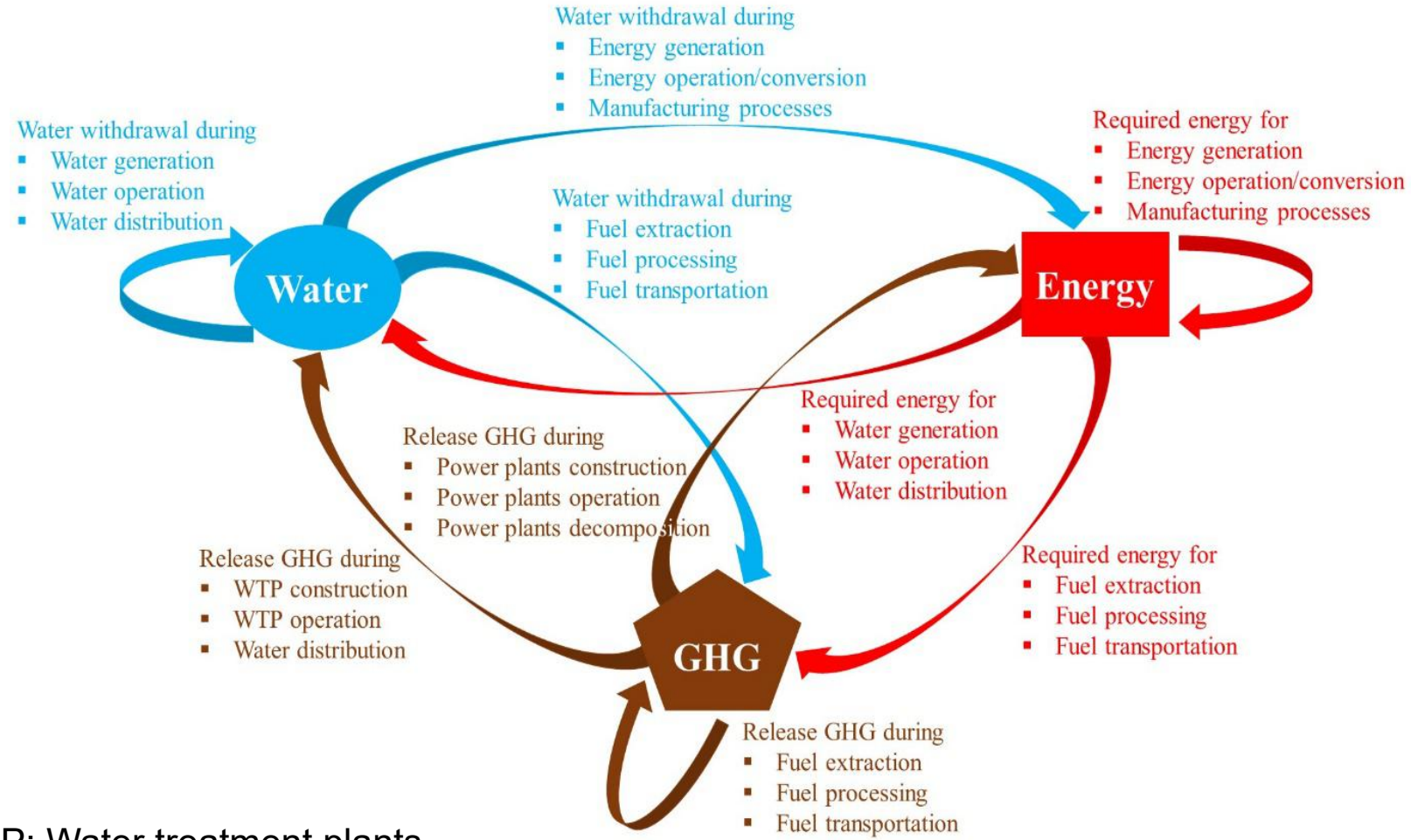
426.0 Mt

Equivalent to the national carbon emissions in Italy

Cai, W., Wan, L., Jiang, Y., Wang, C., Lin, L., 2015. Short-lived buildings in China: Impacts on water, energy, and carbon emissions. Environmental Science & Technology, 49(24), 13921-13928.

Literature Review and Research Gaps

Water-Energy-GHG Nexus



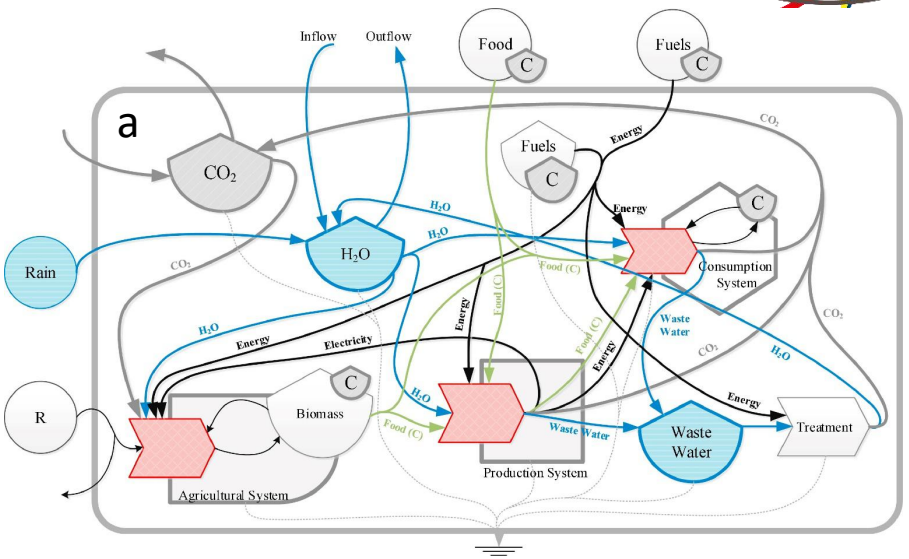
WTP: Water treatment plants

Wang, X.C., Klemeš, J.J., Wang, Y., Dong, X., Wei, H., Xu, Z., Varbanov, P.S. Water-Energy-Carbon Nexus Analysis of China: An Environmental Input-Output Model-Based Approach. Applied Energy, 261, p.114431.

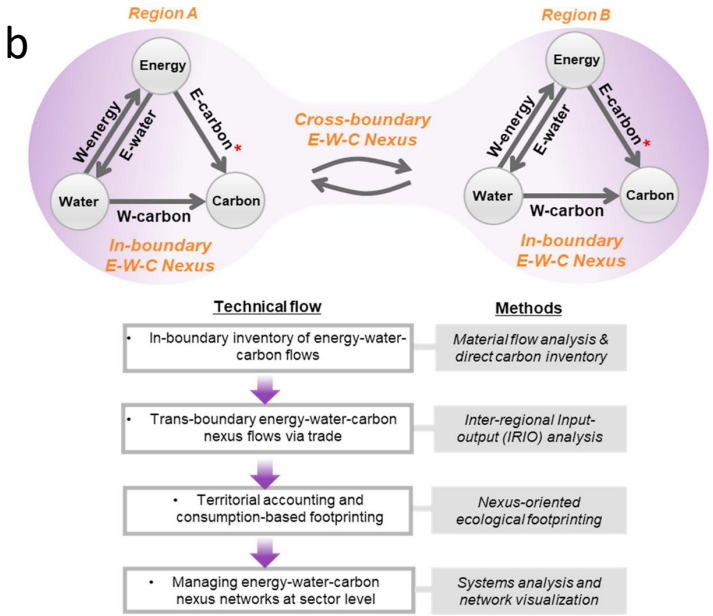
Literature Review and Research Gaps

Water-Energy-Carbon Emissions Nexus in:

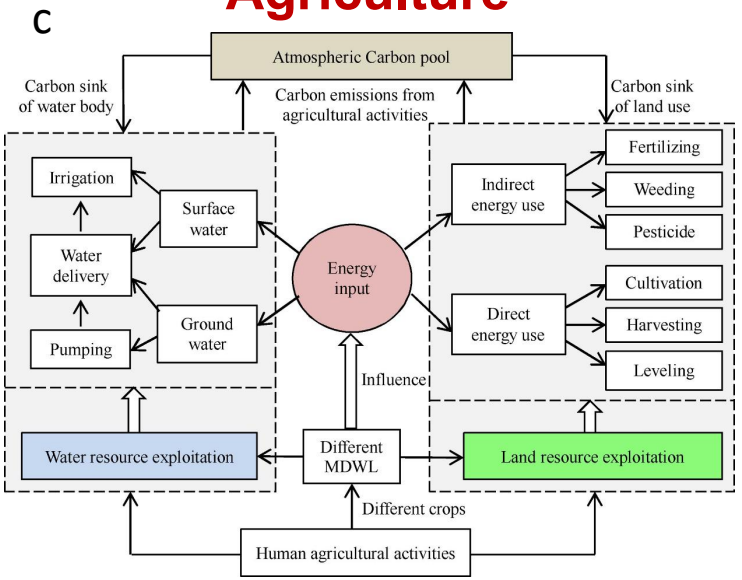
Urban



Inter-regional



Agriculture



a. Meng, F., Liu, G., Liang, S., Su, M., Yang, Z., 2019. Critical review of the energy-water-carbon nexus in cities. Energy, 171, 1017-1032.
b. Chen, S., Tan, Y., Liu, Z., 2019. Direct and embodied energy-water-carbon nexus at an inter-regional scale. Applied Energy, 251, p.113401.
c. Zhao, R., Liu, Y., Tian, M., Ding, M., Cao, L., Zhang, Z., Chuai, X., Xiao, L., Yao, L., 2018. Impacts of water and land resources exploitation on agricultural carbon emissions: The water-land-energy-carbon nexus. Land use policy, 72, 480-492.

Research Opportunities

Previous studies:

- Individual sector
- City scale
- Supply chain is ignored

Research gaps：

- WEC of Multi-countries need more in-depth study
- Embodied WEC coefficients of country level need more analysis
- Environmental performance assessment is needed
- Broader systems are necessary to be taken into consideration

Aims

WEC nexus/characteristics of **EU27**:

- Embodied water and energy consumption of **different countries**
- Embodied carbon emissions of **different countries**

WEC nexus/characteristics of **China**:

- Embodied water and energy consumption of **different sectors**
- Embodied carbon emissions of **different sectors**

For example, **Embodied Water Consumption**, a measure of the amount of water affected by the creation of a material, is the sum of all the water embodied in generating the product or providing the service itself.
Total water consumption, the sum of the direct and indirect water/energy input within one specific region or sector.

Environmental Input-Output (EIO) Model

EIO was originally developed from the economic input-output model.

		Intermediate demand	Final demand	Total output
		1, 2, …, n		
Intermediate input	1	X_{ii}	F_i	X_i
	2			
	…			
	n			
Value-added		V_j		
Total input		X_j		
Energy input	1	E_{ki}		
	2			
	…			
	n			
Water input		W_j		
Carbon emissions		C_i		

X_{ij} : flow from country/sector *i* to country/sector *j*

F_i : final demands of country/sector *i*

V_j : added value of country/sector *j*

X_i : total output of country/sector *i*

X_j : total input of country/sector *j*

E_{kj}: the amount of energy (type k) that directly consumed by country/sector j

W_j : national//sectoral (j) direct water consumption

C_j : direct carbon emissions of country/sector j.

Water Consumption

Embodied water consumption

Diagonal matrix

$$W^{em} = C^{w}(I - C)^{-1} F^{diag}$$

Matrix of direct water consumption coefficients with c_j^w

Matrix of direct consumption coefficients with c_{ij}

Direct water consumption coefficient

$$c_j^w = W_j / X_j, (j = 1, 2, 3, \ldots, n)$$

$$c_{ij} = X_{ij} / X_j, (i = 1, 2, 3, \ldots, m;\ j = 1, 2, 3, \ldots, n)$$

Direct consumption coefficients

Energy Consumption

Embodied energy consumption

Diagonal matrix

$$E^{em} = C^{e}(I - C)^{-1} F^{diag}$$

Matrix of direct energy consumption coefficients with c_j^w

Matrix of direct consumption coefficients with c_{ij}

Direct energy consumption coefficient

$$c_{kj}^{e} = E_{kj}/X_j, (k = 1, 2, 3, \dots, m;\ j = 1, 2, 3, \dots, n)$$

$$c_{ij} = X_{ij}/X_j, (i = 1, 2, 3, \dots, m;\ j = 1, 2, 3, \dots, n)$$

Direct consumption coefficients

Carbon Emissions

Embodied carbon emissions

Diagonal matrix

$$C^{em} = C^{c}(I - C)^{-1} F^{diag}$$

Direct carbon emissions with element c_j^c

Matrix of direct consumption coefficients with c_{ij}

Direct carbon emission coefficient

Direct carbon emission, country j

$$c_j^c = C_j / X_j \ (\mathrm{j} = 1, 2, 3, \ldots, \mathrm{n})$$

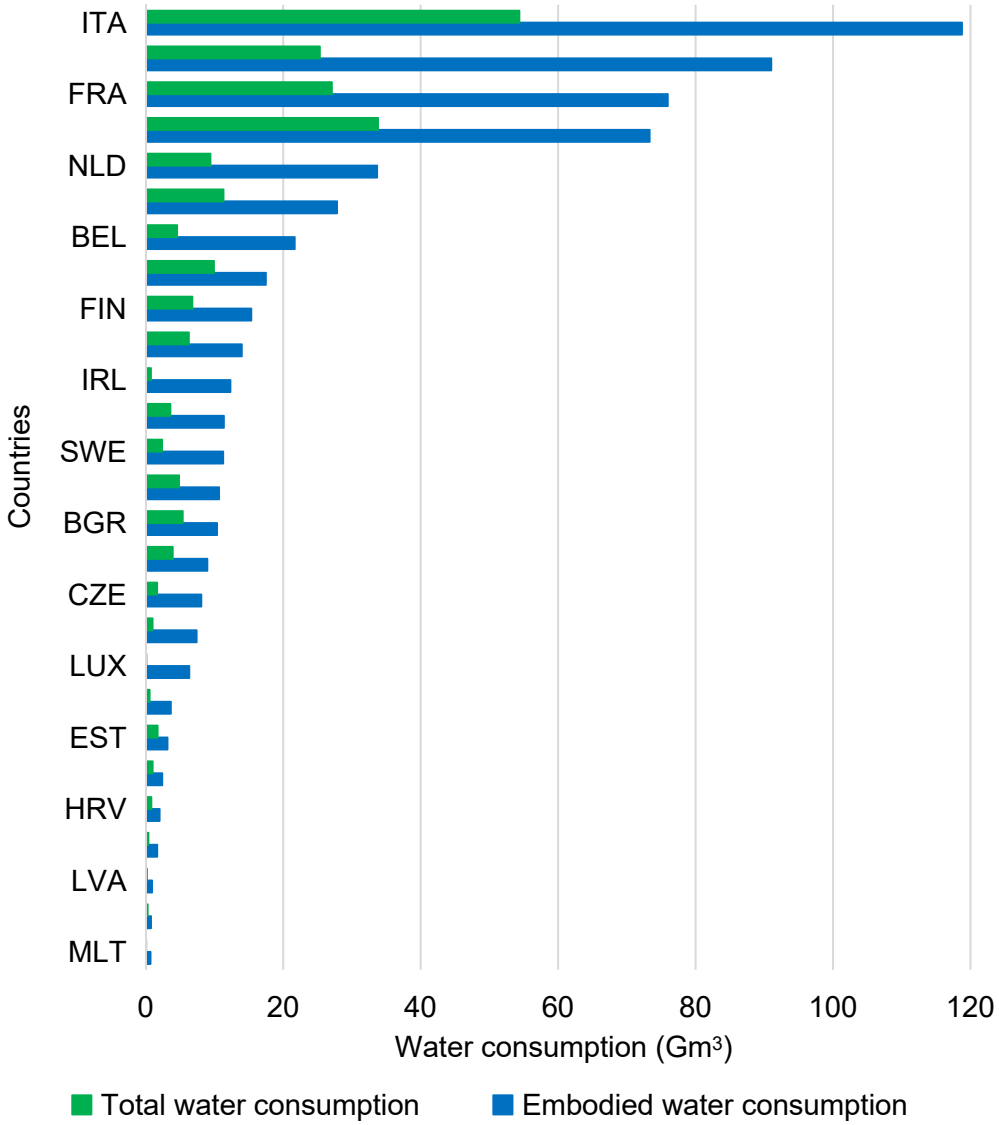
$$C_j = \sum_{k=1}^{m} A_{kj} \times J_k \times EF_k \times \frac{44}{12}, (j = 1, 2, 3, \ldots, n)$$

Consumption amount of energy type k by country j

Net calorific value

Emission factors

Results – Water Consumption of the EU27

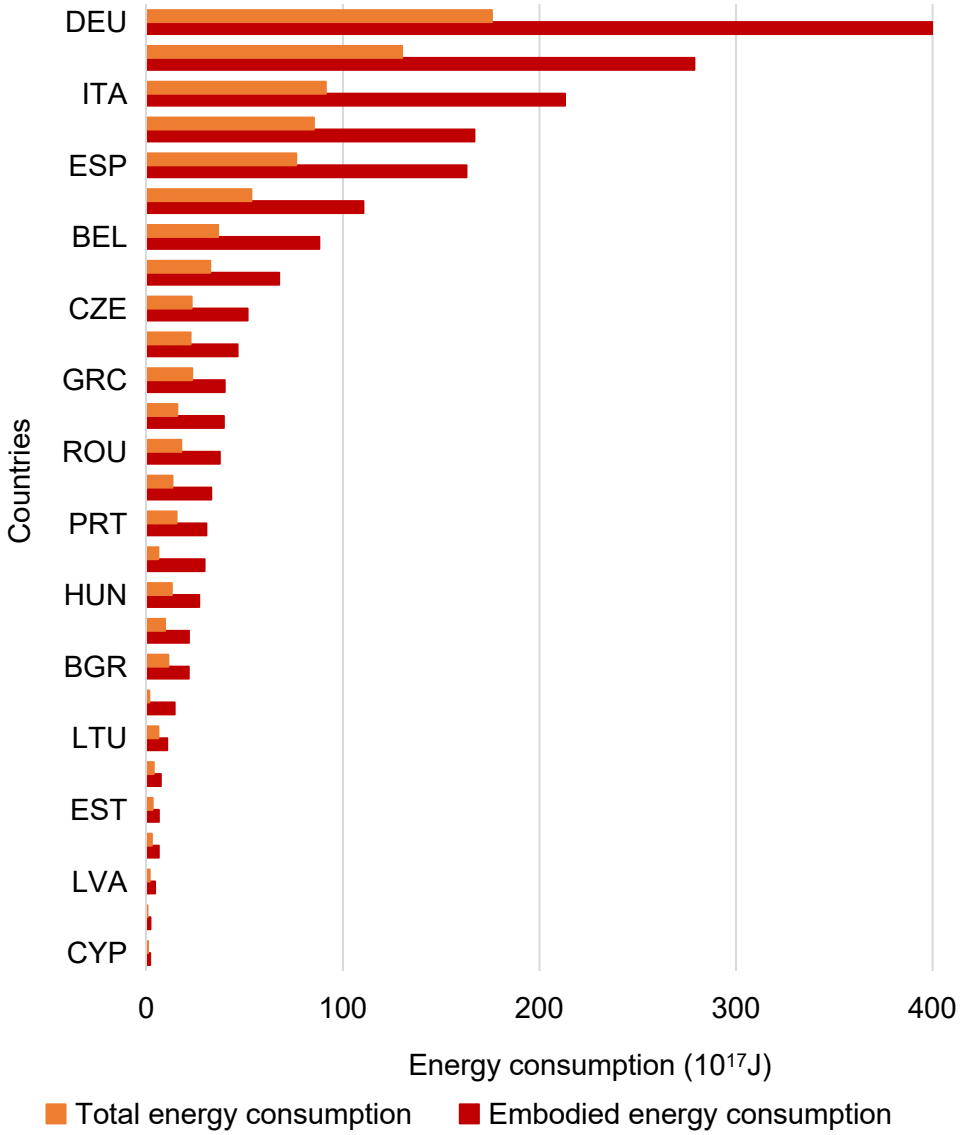


- The embodied water consumptions more than the total water consumption, which means these countries import a huge amount of embodied water during international trade.

- Italy, Germany, France and Spain are the top countries in the list. They also have the biggest difference value, which means they extremely rely on import

Wang, X.C., Klemes, J.J., Varbanov, P.S., 2019. Water-Energy-Carbon Nexus Analysis of the EU27 and China. Chemical Engineering Transactions, 81

Results – Energy Consumption of the EU27



- The embodied energy consumptions more than the total energy consumption, which means these countries import massive of embodied energy during international trade.

- Germany, France, Italy and Netherlands are the top countries in the list. They have very highly developed industries and with higher renewable energy utilisation, for example, 19.5 % of the electricity in France is from renewable energy

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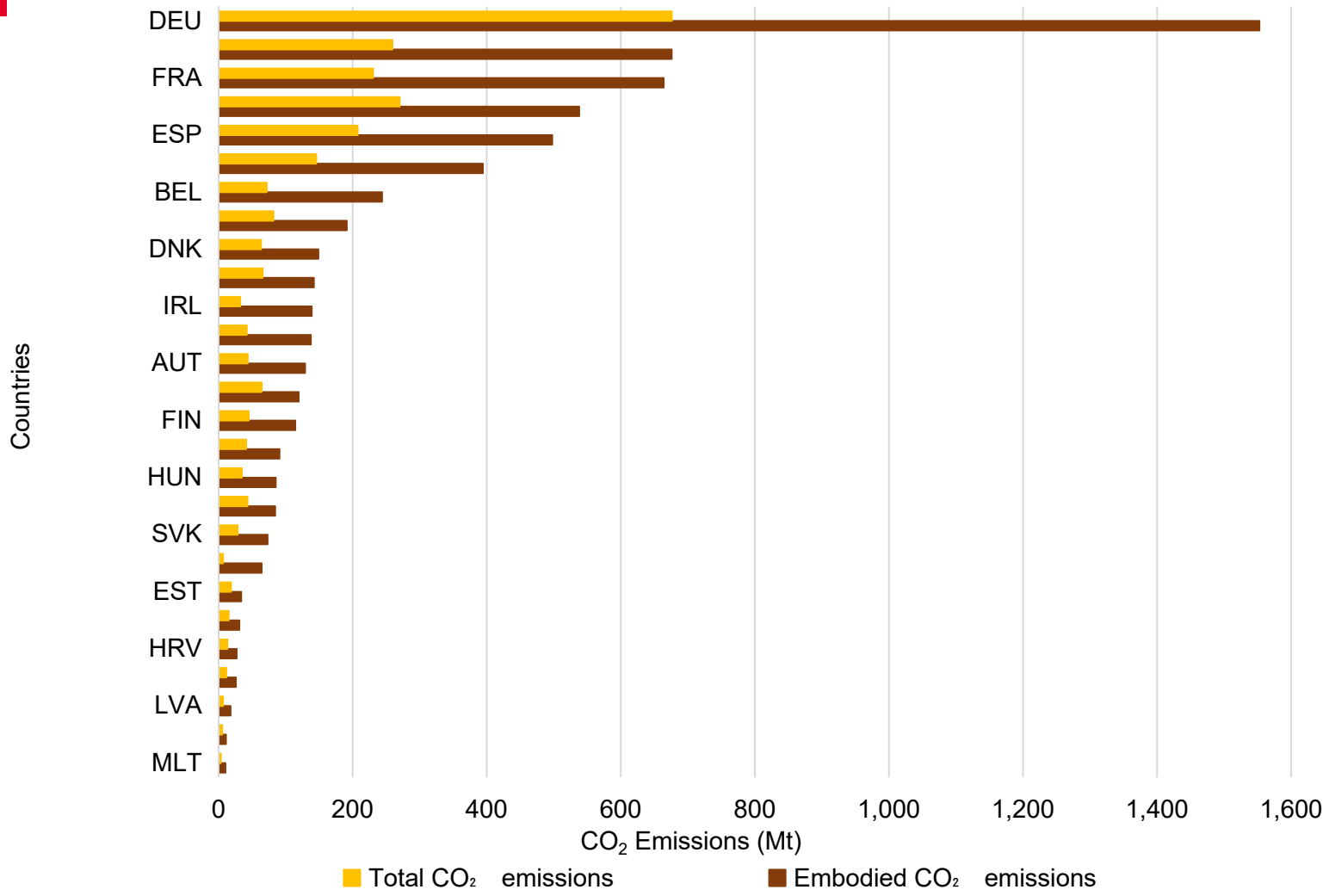
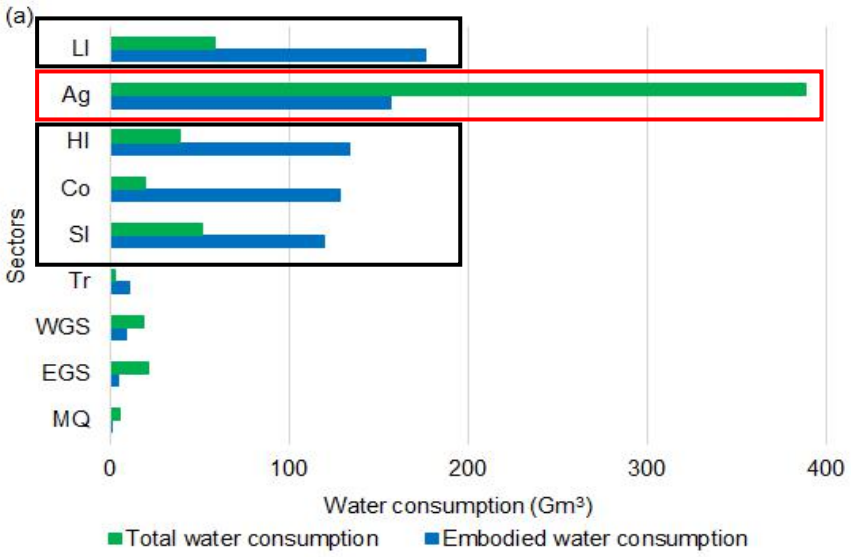
Results – Carbon Emissions of the EU27

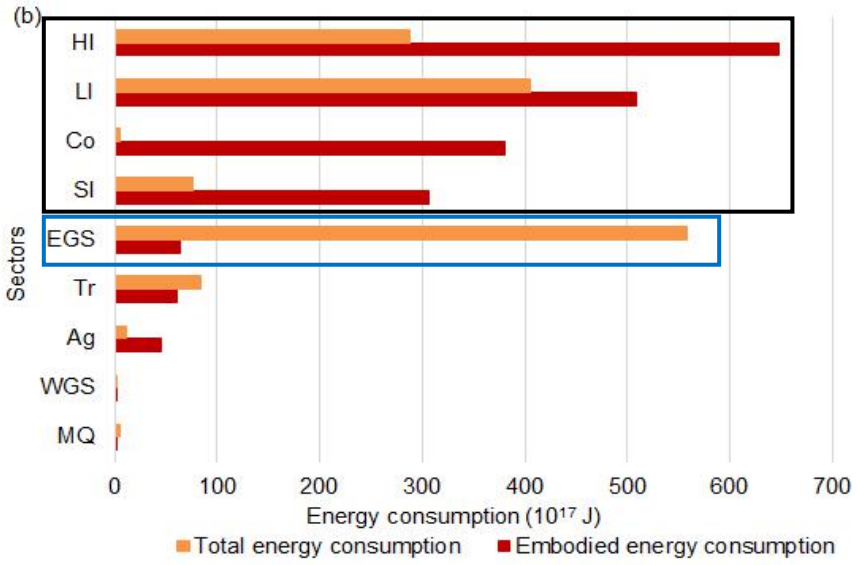


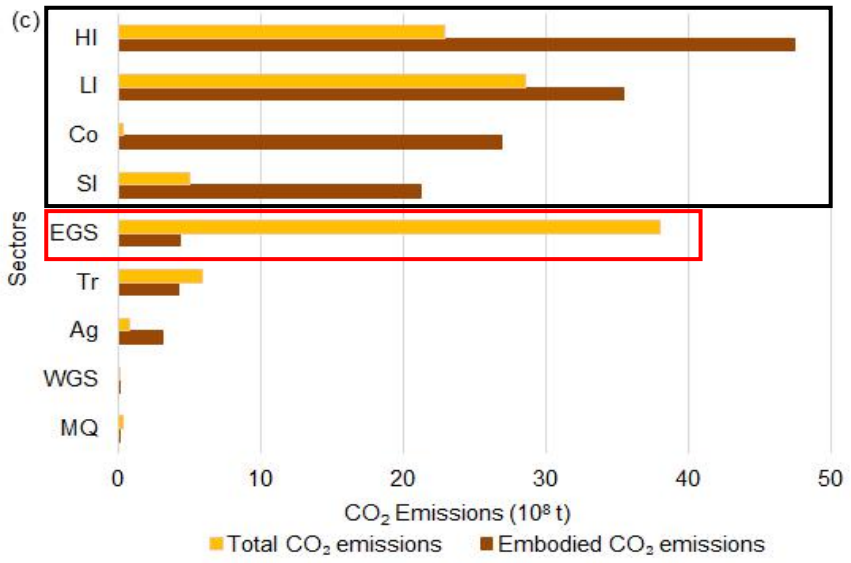
- These countries transfer big environment pressure to the upstream countries during international trade, benefiting from import in terms of environmental footprints.

Wang, X.C., Klemes, J.J., Varbanov, P.S., 2019. Water-Energy-Carbon Nexus Analysis of the EU27 and China. Chemical Engineering Transactions, 81

Results – WEC Nexus of China







Ag	Agriculture
HI	Heavy industry
LI	Light industry
MQ	Mining and quarrying
EGS	Energy generation and supply
WGS	Water generation and supply
Co	Construction
Tr	Transportation
SI	Service industries

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Implications

Countries/sectors that more rely on upstream countries/sectors:

- Can benefit from transferring environmental pressure to upstream countries/sectors during interregional/ intersectoral trade.
- The environmental performance more rely on the upstream countries/sectors from the supply chain perspective.
- Should strengthen cooperation with upstream countries/sectors, improving resources (intermediate products) utilisation efficiency, reducing emissions of upstream countries.

On the contrary:

- should more focus on improving efficiency within country/sector.

Conclusions

The WEC nexus of the EU27 and China have been analysed in this study.

- Most EU27 countries highly depend on import goods and services from the global chain.
- **EU27 import a huge amount of embodied water and embodied energy, as well as transfer a huge amount of embodied CO_2 emissions to the upstream countries/sectors**.
- **Heavy industry, light industry, construction and service industry of China are embodied- water-, energy-, CO_2- intensive sectors**.

Acknowledgement

- This research has been supported by the project "**Sustainable Process Integration Laboratory – SPIL**", project No. CZ.02.1.01/0.0/0.0/15_003/0000456 funded by EU "CZ Operational Programme Research, Development and Education".

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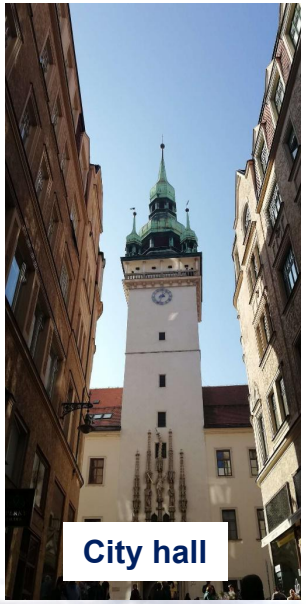
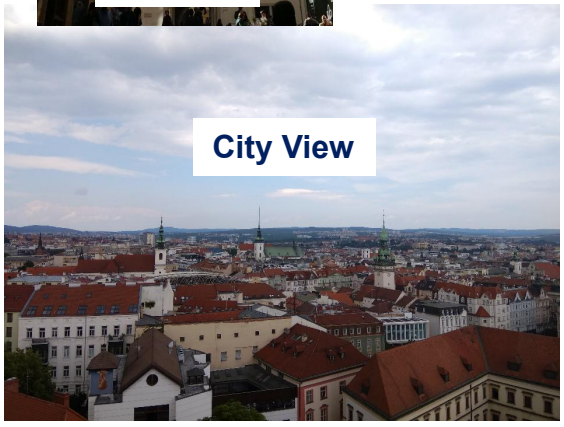

City hall


Villa Tugendhat


Moravian Karst

1st public building in the world to use Thomas Edison's electric lamps


City View


Mahen Theatre


Medlánky

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Prof Arpad Palotas
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Thank you for your attention.

Comments welcome.