

Embodied Energy Model on Water Systems in Great Lakes Region

Weiwei Mo, Advisor: Qiong Zhang
Department of Civil and Environmental Engineering, Michigan Technological University

Introduction

Water supply and wastewater treatment consumes not only large quantities of electricity but also materials for pipelines and water/wastewater treatment utilities, which will bring potential environmental impacts. Previous researches mostly focus on direct energy consumption such as electricity in estimating embodied energy while neglecting indirect energy associated with materials consumption. (Wilkinson, 2000; Elliott et al., 2003; Scott et al. 2007).

The objective of this study is to develop a model for estimating both direct and indirect energy embodied in water for municipal, industrial and agriculture application with consideration of a full life cycle of water systems as shown in Figure 1.

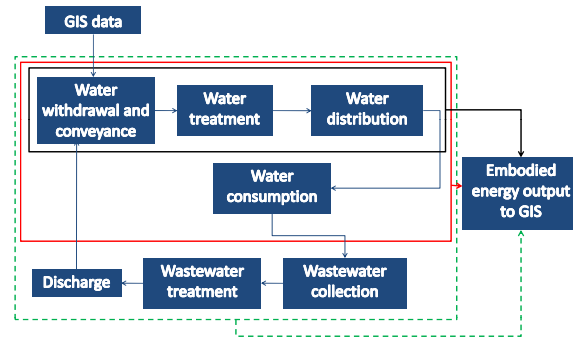


Figure 1 A Full life cycle of water systems and different phases of the study

Methodology

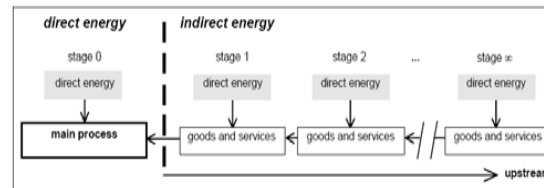
There are two main methods for calculating embodied energy.

- ❖ The first method, input-output analysis, is a top-down economic technique that uses sectoral monetary transactions data to account for the complex interdependence of industries. It is complete and comprehensive, but it may contain various errors due to the basis of national average data.
- ❖ The second method is process analysis within which energy input into the main process in a chosen system boundary are assessed in detail. Process analysis is specific and accurate. However, it's labor and time intensive.

Based on the advantages and disadvantages of both input-output analysis and process analysis, a hybrid analysis is used to calculate embodied energy in water systems.

Basic steps using hybrid analysis can be concluded like that:

1. Calculate the initial embodied energy for a water system using values derived from Input-Output matrix;



Source: after Boustead and Hancock, 1979, p. 79

2. Break the total embodied energy calculation into a number of energy paths using a threshold value;
3. Modify some of the energy paths for a certain water system using process analysis data such as specific product quantities and direct energy intensities for various sectors and products;
4. Calculate the new total embodied energy for the water system with the modified portion based on process analysis data.

Current status

- ❖ Goal: Calculating direct energy intensity of non-energy supply sectors.
- ❖ Matrix: the industry-by-industry direct requirements table derived from total requirements table after redefinition, 1997
- ❖ Target Sector: water, sewage and other systems
- ❖ Energy supply sectors: oil and gas extraction
coal mining
power generation and supply
natural gas distribution
petroleum refineries
- ❖ Equation:

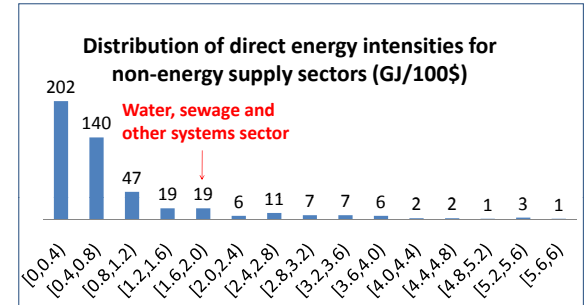
$$\varepsilon_n = \sum_{e=1}^E D_{en} \times \text{tariff}_e \times PEF_e$$

ε_n =the direct energy intensity of the target sector, n
E=the number of energy supply sectors, e
Den=the direct input of each energy supply sector into the target sector, n
Tariff_e=the national average energy tariffs
PEF_e=the primary energy factors

- ❖ Energy tariffs and primary energy factors

Energy Supply Sectors	Primary Energy Factor	Energy Tariff (GJ/\$)
oil and gas extraction	1.05	0.38267
coal mining	1.13	1.28561
power generation and supply	3.44	0.10207
natural gas distribution	1.05	0.74111
petroleum refineries	1.42	0.48885

Preliminary Results



Water, sewage and other systems sector is among the sectors with high direct energy intensities. Of all the 486 non-energy sectors, about 80% have lower direct energy intensity than water, sewage and other systems sector. Thus it's important to study the direct and total energy embodied in this sector and find out possible ways in saving energy in the water cycle.

References

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Scott, C. A., Varady, R. G., Browning-Aiken, A., and Sproule, T. W. (2007) Linking water and energy along the Arizona-Sonora Border, *Southwest Hydrology* 6(5) 26-31.
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