Emergy and water – findings from Cyprus' and Sweden's water balances

Elena Paschali and Erik Grönlund
Ecotechnology and Sustainable Building Engineering,
Mid Sweden University, Östersund, Sweden

Introduction

As an extension to a project of assessing the sustainability of water use in Cyprus (Paschali, 2019), data for Sweden has also been collected and processed. In figure 1 are presented the water balance for Sweden and Cyprus. The fundamental flows of water reaching Sweden and Cyprus described in the two diagrams include water entering as precipitation, inflow from neighbouring countries (where applied) and flowing out through evapotranspiration and outflow to the sea and neighbouring territories.

Emergy and Water

The energy available in water is in emergy accounting calculated in two ways. Firstly the physical energy – use of the gravity potential between the rain entering the system and the sea level where no more gravity energy is converted to movement energy or other energies, useful to humans or other subsystems of the ecosystem. Second the chemical energy – use of the chemical potential in the water. The possible chemical reactions with substances in the soil, in the photosynthesis processes in plants, as well as chemical reactions in industries and households. This energy, in traditional emergy accounting, is estimated by using the osmotic potential difference between rainwater and saltwater calculated by Gibbs free energy on Seawater (Odum, 1996). This is the difference reduction in the water when dissolved elements increase in the water on its way from the mountains to the plains and finally mounts in the sea. A lot of the osmotic potential is still there when rivers meet the seawater which is used up by the very productive estuary ecosystems.

In emergy accounting –emergy algebra (Odum, 1996) – a central choice needed to make, is if the emergy flow should be treated as a split or a coproduct. A split is …"…branches that split into two flows of the same type…", while coproducts (also called by-products) are "…branching transformations that produce flows of different types" (Odum, 1996).

The splits keep the same transformity for both branches, and the division of emergy follow the energy content and is diagrammed as pathways branching without associated energy transformations. Coproducts have different transformities for both branches, all branches carry "…the same emergy (the full amount coming in)" (Odum, 1996), and if"…the branches come together again, [they are]…not to be added because it is realized that the two sources are not independent." For coproducts, an energy transformation symbol is used (producer, consumer, interaction, miscellanous box).

Regarding water, it is clear that water streams are treated like splits, for surface water, groundwater, or water in pipes. It is also clear that when water goes into a chemical reaction, like in photosynthesis or industrial chemical reactions, water emergy is treated like coproducts. Then there is a grey zone, not yet fully sorted out, regarding the minerals dissolving in the water, or when suspended particles are carried by the water. This is, of course, even more significant in wastewater. In the grey zone, is also the water carrying heat content, e.g. in cooling applications and similar.

Emergy findings for the Swedish and Cypriot data.

Evapotranspiration in Cyprus in 2017, as we can see in the diagrams, is higher by almost 40% compared to Sweden. Most water flowing internally, in Sweden, is outflowing in the sea and some water

(1%) is outflowing into neighbouring territories. Whereas in Cyprus, most water flows internally and appears to remain, only some (31%) outflows in the sea.

***Figure 1**: Water balance flows of (A) Sweden and (B) Cyprus for the year 2017 based on Eurostat data.*

Discussion

Regarding the principal question of split or coproduct for dissolved substances in water, it seems like coproduct is a more suitable choice since it is a chemical reaction producing ions taking place.

The energy properties of water appear to change to some extent. Regarding suspended solids, the split approach seems more relevant, since no energy conversion appears to be involved. And as for heat content, the same can be said. In both Cyprus and Sweden the dominating accounting choice are splits, but also some coproduction (e.g. in soil reaction, photosynthesis and chemical reactions in industries). Cooling water split since the water itself is not changed, just its heat content. The same applies to desalination, water content split, but if the desalination plant is in focus, it is a coproduct process.

If the heat processes of conduction and convection, is regarded as involving no energy conversion it should be treated as a split. Heat energy seems to have a special position compared to other energy forms.
Regarding rivers, maybe it could be useful to think of like a similar approach to a heat exchanger device in the rivers, where the salinity increases more close to the seawater. This since the difference in sea salinity is very different for Sweden ie.- on the west coast, Kattegatt, salinity amounts for 3.5% whereas in the northern part of the Baltic Sea on the east coast it is only approximately 0.3%.

Conclusions

For emergy and water, there is no doubt that water streaming, whether surface or groundwater, should be treated as a split, while chemical reactions with water molecules involved are clearly of the coproduct type. Regarding the application of dissolved substances of different types, suspended solids, and also heat content and exchange in water, seem to be in a grey zone still.

References:

Odum, H. T. 1996. *Environmental accounting. Emergy and environmental decision making*. John Wiley & Sons, New York.

Paschali, E. 2019. Data problems in assessing country emergy flows – the examples of Cyprus and Sweden. Pages 49-50 in E. Grönlund (ed.): *Emergy Scandinavia 2019–Assessing both Nature and Society*. Proceedings from the 1st Scandinavian