SYDE 532 Assignment 1

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Problem 3.5: Conceptual—System Boundaries

For your chosen energy context, develop three system envelopes, of different size or scope, which could be used to assess the *invested* energy, as discussed in Example 3.5. For each of these three systems, you should show an explicit diagram or a detailed list showing what is / is not contained in the system, and the predominant invested and output energy flows.

Do *not* attempt to actually calculate EROEI numbers. Rather, please discuss the pros and cons of each of your systems, where the pros and cons should relate to how complete the system model is, what is omitted, and the feasibility or practicality of comp uting EROEI based on such a system.

System chosen: **hydrogen**

System 1: Hydrogen Electrolysis

Invested energy: water, electricity

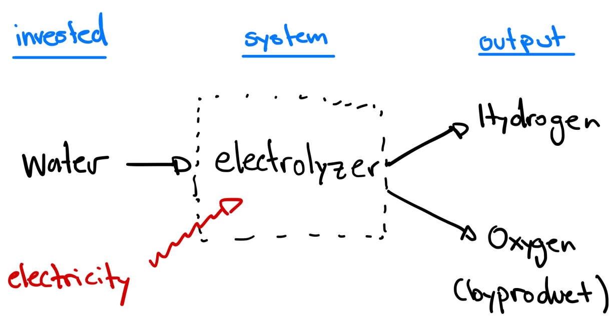
Contained:

- Energy: electricity
- Material: water, hydrogen, oxygen

Assessment

- Efficiency (output/input)

Figure 1: Hydrogen Electrolysis System Diagram



Overall, this system envelope is limited to the electrolysis process of obtaining hydrogen from water. The limited scope of the system is excellent for computing the system efficiency (including losses) and EROEI. The limited scope also means that information regarding the environmental impact (i.e. obtaining water and electricity) as well as anything beyond hydrogen generation is not present.

System 2: Hydrogen storage

Invested energy

- Water for electrolysis.
- Electricity for the electrolysis process.
- Energy for compression and storage of hydrogen.

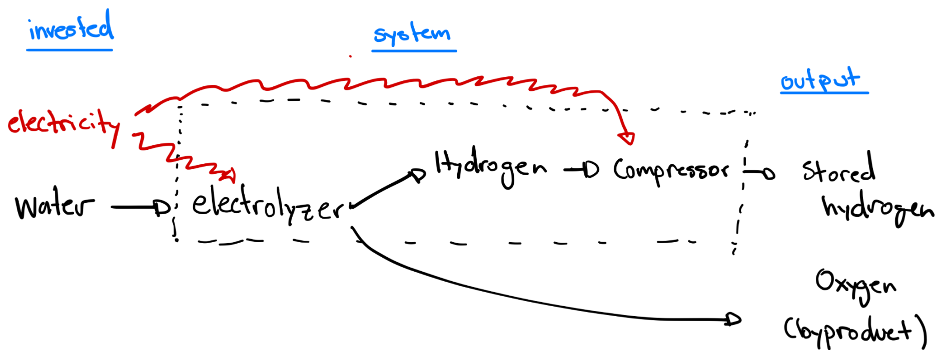
Contained

- Energy: Electricity.
- Material: Water, Hydrogen, Storage infrastructure.

Assessment:

- Energy losses in compression and storage.
- Transportation energy efficiency.

Figure 2: Hydrogen Storage System Diagram



This system envelope includes a more complete hydrogen generation process as it also includes the hydrogen transportation and storage elements. This may result in a more accurate EROEI as energy is required to transport and store hydrogen. This system still lacks information regarding the source of energy as well as its usage.

System 3: Electric grid with hydrogen component

Invested energy: Renewable and non-renewable sources for electricity production.

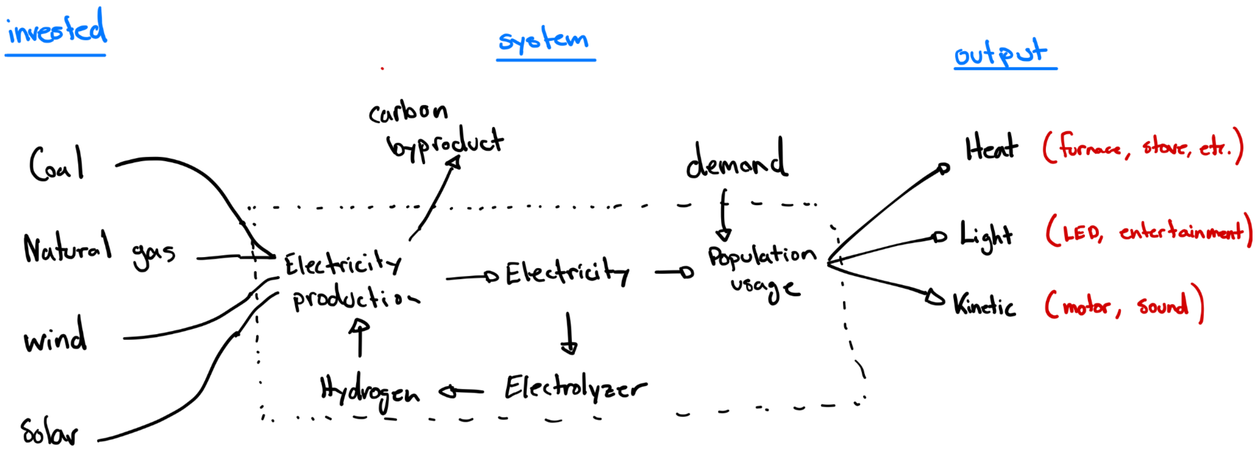
Contained

- Electricity production methods
- Demand / response
- Electricity consumption

Assessment

- Cleanliness of electricity sources.
- Energy waste and grid efficiency.
- Social accessibility to electricity.

Figure 3: Electricity Grid with Hydrogen System Diagram



This system is a more holistic view of how hydrogen plays a role in the electricity grid. It includes the possible sources of electricity used for hydrogen production as well as the electricity grid. These boundaries may make it difficult to calculate EROEI considering the number of different input and output sources as well as the impact of customer demand on the system. However, this system includes higher level impacts such as the byproduct of the electricity being produced as well as the ability for hydrogen to maintain grid stability during off peak hours.

Problem 3.9: Numerical/Computational—Efficiency

(a) If we had just mixed the two reservoirs the final temperature would have been (400 + 300)/2. Why is the final temperature now different?

The final temperature is different due to the dynamic boundary. The change in temperature of the mix is influenced by the temperature difference. Since the heat flow changes as the temperature changes, the final equilibrium temperature will not be the average of the two.

(b) What would the expected efficiency have been,for infinite reservoirs at temperatures TH = 400, TC = 300?

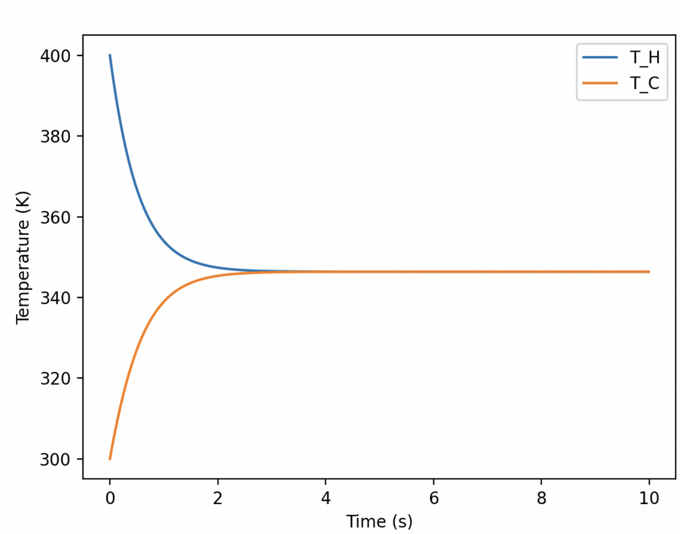
$$Expected\ efficiency\ = 1\ -\ \frac{Wc}{Wh} = 1 - \frac{300}{400} = 0.25$$

(c) What is the actual efficiency in your simulation, computed as

$$Actual\ efficiency\ =\ \frac{\int W}{\int Q}\ =\ 0.13$$

Where $\frac{\int W}{\int Q}$ is the total work divided by the total heat flow, calculated with a time step of 0.1.

Figure 4: Computational simulation of reservoirs using Euler's formula.



Problem 3.10: Reading—Energy Returned on Invested Example 3.5 discussed the concept of EROEI (energy returned on energy invested). Read4 Chapter 3—Net Energy (EROEI) in Searching for a Miracle [5]. Comment briefly on the challenges of net energy evaluation and the challenges associated with ambiguities of where to assert system boundaries.

Energy evaluation is a complicated topic that changes depending on the scope and complexity of the system. One challenge of this type of system is the changing nature of technologies. Processes such as energy generation and conversion become more efficient and potentially expensive over time, making the concept of evaluating the EROEI a nonlinear and dynamic system. Further, choosing the boundary of the chosen system can change the complexity and also introduce errors in assessment. For example, choosing a narrow boundary when assessing Natural Gas as a resource may have a clear calculation for production efficiency. However, it may not include impacts to the electrical grid and social accessibility. For example, Natural Gas can be generated at any time to help meet electricity demand which can make the grid more resilient, cheaper, and more accessible. On the contrary, a broad boundary can increase complexity and introduce errors. Drawing the line becomes a decision based on the goal of the evaluation and resources available.

It is also important to note that it is sometimes difficult to define unambiguous boundaries. Given the complex nature of energy systems, if boundaries are not well-defined, EROEI may be calculated inconsistently depending on interpretation.

Finally, EROEI focuses solely on energy inputs and outputs. In reality, systems can include non-energy inputs and outputs such as objects, events, people, and more. It is difficult to account for the indirect resources used for each non-energy input or output. For example, water can be interpreted as a chemical energy when converted into Hydrogen but also has kinetic energy (that is harnessed in other contexts). It is challenging to assert system boundaries that only consider energy inputs and outputs. Overall, EROEI is a useful tool to understand the efficiency of energy systems, but system boundaries must be well-thought out to ensure consistent and accurate calculations.