

### 25 Available energy

#### *Subject:*

In publications about the energy economy of a country by public authorities and universities one often finds so-called energy flow charts [1,2,3]. They indicate the energy balance of a national economy. The title may be something like: "Estimated U.S. Energy use in 2008". They show with which energy carriers the energy enters the system, i.e. the national economy, which part is transformed into which other energy forms and in which forms the energy leaves the system. For the outgoing flow the distinction is made between final, available or useful energy on one hand, and lost or rejected energy on the other.

#### *Deficiencies:*

The following impression arises: for the applications of the final user energy is needed in a certain form. Hence it has to be transformed, and by doing so part of it is lost. One tries to keep the transformation and transportation losses as low as possible, but for physical reasons a considerable loss is unavoidable. Only when arriving at its final destination, i.e. at the end user, the energy can be employed for what it is really needed.

This view does not exactly meet the point. This can be seen when considering that every energy loss is due to the production of entropy. This entropy must be eliminated, i.e. transferred to the environment. For that purpose energy is needed and this energy is lost. The flow of the lost energy  $P_L$  is proportional to the flow of the entropy  $I_S$  that has to be disposed of:

$$P_L = T_0 \cdot I_S$$

Here,  $T_0$  is the absolute temperature of the environment, i.e. of the system that absorbs the entropy.

From this consideration two conclusions can be drawn:

1. From a physical point of view the losses are not unavoidable. Any process can also be carried out in a reversible way. It may be impossible for technical or economical reasons, but it is not physics that forbids them. Even the "transformation" of the chemical energy of Carbon (+ Oxygen) into electric energy, where one usually holds the Carnot factor responsible for the low efficiency, can in principle be carried out reversibly, for example in a ideal fuel cell. Thus, in the energy flow chart, already the incoming energy could reasonably be called useful energy.
2. After arriving at the so called end user all the energy is eventually "used" to produce entropy, i.e. is wasted; all of the energy that has been sold to the user as available energy ends as lost energy. By the way: Also for the final user holds, that every process in which he is interested, can be carried out reversibly.

We do not claim that something is wrong with the flowcharts, neither that they are not useful. We only believe that they convey a false message. It is not correct, that only a fraction of the primary energy is "really" useful. After a series of steps all of the primary energy ends in entropy production, and the flowcharts mentioned above tell only half of the story.

*Origin:*

Why do energy flowcharts stop at a certain point? Why do they not show that all of the “usable energy” eventually ends up in the thermal depository? Because they are issued by institutions that have particular interests. For the energy industry the picture ends at the fare stage, the place where they ask for money. They are concerned with the losses before this point. They do not care about what the client is doing with the energy which they have sold him.

*Disposal:*

Above all, we clarify that the whole of the primary energy is used for entropy production. Since there are no physical limits to reduce the entropy production there is no physical limit for energy saving. We discuss the technical problems that arise, when trying to approach this goal. In this way students learn much Physics and also Chemistry.

[1] <https://str.llnl.gov/Sep09/simon.html>

[2] <http://www.energyliteracy.com/?p=310>

[3] <http://blog.everydayscientist.com/?p=1773>

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