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What is Energy?

How can it be applied, managed and saved wisely

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Giving Hope Foundation
EMPOWERING VULNERABLE COMMUNITIES

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Enormous amounts of energy are incorporated in every matter and in every item above 0 K = minus 273.15 °C.

- Energy is invisible, silent, odourless, kinetic and weightless.
- Only when a **difference** is involved, it can be noisy, shining, smell, heat and move.
- Energy comes in various kinds: mechanical, electromagnetic, chemical, etc.
- Energy does not get lost; it just splits into various appearances. Example: when energy is applied as heat to a pot, it splits into heating pot and contents, radiation to the ambient, convection, etc.


A CooKit in front of the solar furnace of Sorède, France

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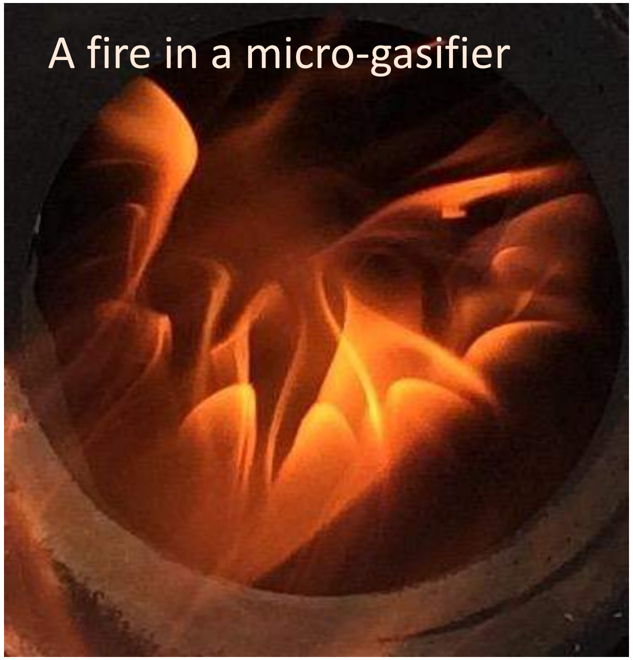
The SI-unit of energy is J (Joule)

1 Joule = 1 Watt-Second

3600J = 3.6kJ = 1 Wh

Examples:

- To heat 1 kg of water by 1°C, it takes 4186 Joule = 4.186 kJ (Kilojoule)
- To transform 1 kg of liquid water to steam it takes 2,257,000 J = 2,257 kJ = 2.257 MJ (Megajoule)
- A fire with (dry) wood delivers 15 MJ
- A fire with charcoal delivers 30 MJ



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Energy losses

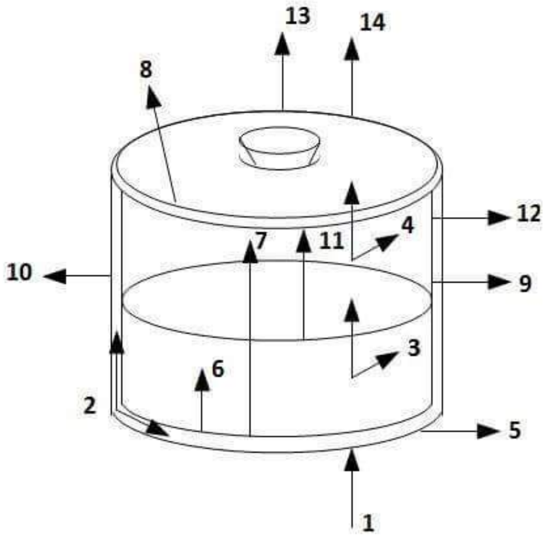
Since energy does not get lost, what does the term “energy losses” mean?

Energy which is not useful anymore is considered as loss.

Heat energy is normally transported and “lost” by

- conduction
- convection
- radiation

but also by other influences.



Heat energy movements in a cooking pot during the cooking process. Image courtesy by Ing. Verónica Frías, Mexico.

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Example No. 1 of energy losses (Fire)

Dry wood has a LCV (lower calorific value) of 15 MJ per kg.
How to calculate the losses once fresh cut wood is burnt?

Sample calculation of energy losses, imagining a pile of 2 kg wood with 50% moisture content. The LCV of 1 kg of dry wood (1 x 15 MJ) is	15000 kJ
Heating the contained water from 20°C to 100°C (1 kg * 80° * 4.186 kJ)	-335 kJ
Transformation of 1 kg water to vapour (1 kg * 2,257 kJ)	-2257 kJ
Heating water vapour from 100°C to 400°C (3 * 210 kJ)	-630 kJ
Energy to convert wood to char (1 MJ per kg dry wood)	-1000 kJ
Result (calorific value, energy “delivered”)	10778 kJ
Total "losses”: **28.15% wasted,** just because the wood is not dry.	**4222** kJ

Information thanks to Christa Roth "Micro-gasification", GIZ-HERA, Vol. 1.0, Jan. 2011

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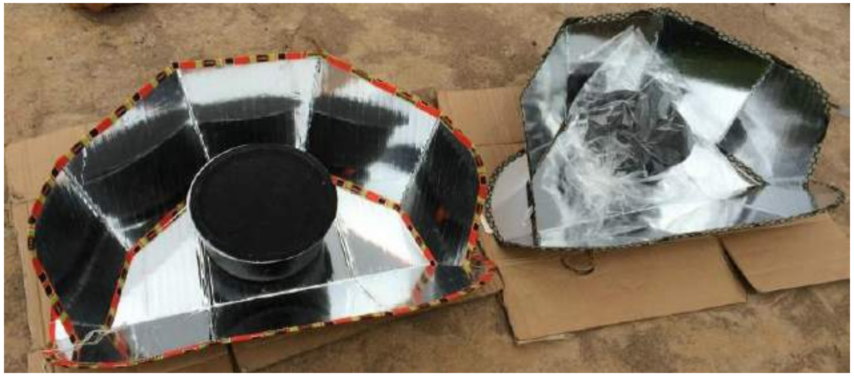
Example No. 2 of energy losses (Solar thermal)

Solar thermal cooking is much more complicated. Although the solar irradiance is roughly 1000 Watt per m^2 at clear sky, only 700 Watt can be converted to thermal energy (heat).

1. The sun rays hit the reflector and are re-directed to the pot. Losses are created by the focussation efficiency and the reflectivity coefficient (min. 25%).
2. The sun rays transit a glass or plastic heat trap cover. The losses are determined by the transmissivity coefficient and the refraction losses of the cover (5-25%). This step is valid for solar box and panel cookers only.
3. Only a certain percentage of the received energy is converted to heat, depending on the absorptivity coefficient. (Dull black pot: about 5% losses).
4. A part of the heat is emitted, determined by the emissivity coefficient, which is normally equal to the absorptivity according to Kirchhoff's law.
5. The pot is heated according to the specific heat capacity of the pot material.
6. Finally, the heat is directed from the pot to the contents, where losses by vaporisation can occur.

Example No. 3 of energy losses (Solar thermal, continued)

Solar panel cookers (left) need a plastic bag or similar device to avoid losses by convection and radiation to the ambient. The same is valid for box cookers (right), but they must be tightly sealed against losses of hot air. Also, their cooking compartments must be insulated towards the outer corpus.



Example No. 4 of energy losses (Solar thermal, continued)

Parabolic solar cookers have a larger surface. Hence, they are able to reflect many solar rays to the pot. Due to the high power concentration, only small ones need a heat trap of glass or plastic.

Parabolic cookers are generally more expensive than panel or box cookers due to

1. higher efforts on precise design
2. better materials
3. larger amounts of materials

Example No. 5 of energy losses (Solar thermal, continued)

Just during the last few years, vacuum tubes are conquering the solar cooker market. The heat is best trapped by the vacuum. The shown tube has a capacity of 4 litres.

Those tubes are manufactured in China by large numbers but are expensive at the retailer in your country, since the Chinese are shipping them in container loads only. Hence, just a few rich companies can afford the import and dictate the prices, which are usually outrageous.

The vacuum tubes are vulnerable to thermal and mechanical shocks. They are made of glass. Treat it like glass!

Example No. 6 of energy losses (Fireless cookers)

Fireless cookers were invented in England five centuries ago. They are also known as thermos baskets, hay boxes, etc.
In contrary to the before mentioned vacuum tubes or the air-insulated Jar-in-Jar, the pot needs to be heated for a few minutes **before** it is put into the fireless cooker.
Once a good insulation of cotton, blanket waste or similar material is considered, the food inside the inserted pot can cook for many hours.

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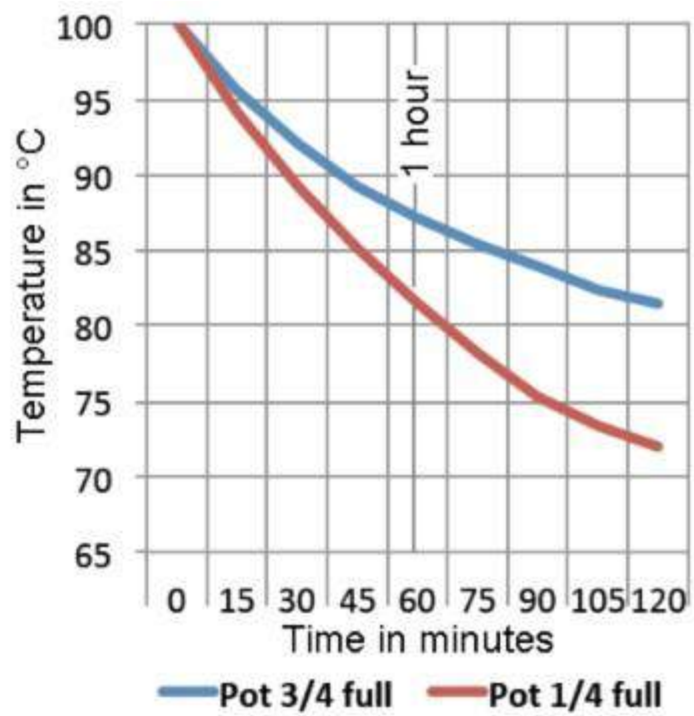
Example No. 6 of energy losses (Fireless cookers, cont'd.)

Since the energy is put into the food by mass (Watt per kg * specific heat capacity), but the losses occur by surface area (Watt per m^2), **it is advised to fill the pot up to minimum ¾ of its capacity.**
Anyhow, if you just prepare some rice which needs only 40 minutes to cook ready to consume, a smaller amount of food will also lead to sufficient results.



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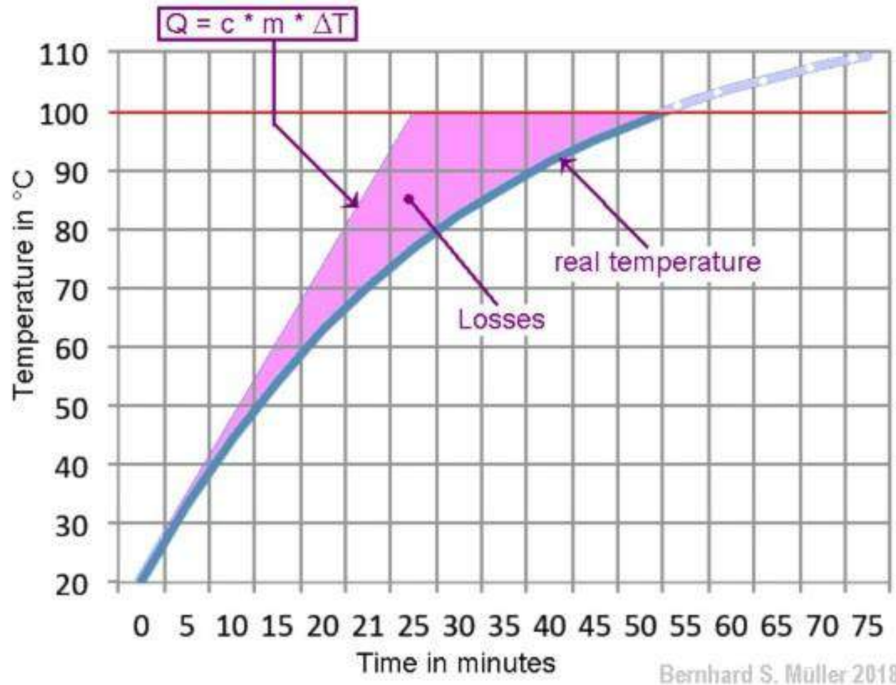
Example No. 7 of energy losses (General)

The difference makes the difference. The higher the temperature difference between the pot and the ambient, the more losses occur.

The basic formula is
Specific Heat Capacity * Mass * Temperature Difference.

100° is the boiling point for water at sea level.

In some cases, c (specific heat capacity) is explained as C_P



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Obtained temperatures

- **With more energy, higher temperatures can be obtained.**
- **With higher temperatures, more mass can be heated in shorter time.**

Doubtless, fuel which burns, delivers higher temperatures. But it is dirtier, expensive, needs to be transported, is a health risk, etc.

Frying and roasting need 170°C and can be done with parabolic cookers or vacuum tubes only.
Box cookers solve all cooking tasks including baking up to 160°C, but not frying and roasting.
Even with simple panel cookers, a cake can be baked at 140°, to get a light brown crust. Esther Nattabi demonstrates this in a perfect manner.

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Safe biomass fuel energy by intelligent designed stoves

A clean burning flame saves enormous amounts of biomass, such as wood, farming residues, briquettes or pellets. This is obtained by feeding warm additional air to the flame to reach a complete combustion of the emitted toxic carbon monoxide (CO) and the particulate matter (PM).

A stove that reaches these tasks is the new developed **Baba Moto** which is produced in Kenya and Uganda in series already. Another wise construction is the gasifier, which burns batch loads of biomass fuel, also by secondary air. The fuel needs to have uniform size.
A further advantage of a gasifier is the production of pure charcoal which can be used as a soil amendment or for cooking purposes.

Safe fire energy by other design features

Sunken pots or pot skirts boost the heat transfer, thus saving fuel. Once the flames (or the hot gas) leave the zone underneath the pot, they radiate and convect their heat to the environment. A pot skirt directs the hot air to the lower sides of the pot, providing additional heat (picture right).

Very clever is the sunken pot design on the picture left. A stove like this one can be produced for less than US$ 3. Some of them have been handed over to the people of the Ugandan town Kyabiiri with tools and the hope that they continue themselves with the production.

Save fire energy by other design features, continued.

There are ceramic and metal cookers available. Which one is the best? In general, the two rules apply:

- Ceramic coated stoves, e.g. Lorena, KCJ, Kuni Mbili or similar, are designed for longer cooking periods; usually longer than 1 ½ hours, since the clay mantle takes also a part of the energy but it retains it after a while.
- Steel stoves reflect the energy of the fire back and do not absorb the heat. Hence, they are better for cooking sessions of up to 1 ½ hours.

Be wise! Choose the right stove! Even if it is more expensive, you'll save on the long run. Your environment, your family, your health and your wallet will thank you.