Fossil fuel conversion to solar power

Fossil fuels

The table below presents the heat combustion of some of the most common fuels:

Table 1. Fuel heat combustion rates (Islam, 2014)

Fuel	Heat combustion [MJ/kg]
Gasoline	47,0
Diesel	45,0
Propane	49,9
Butane	49,2
Coal (Lignite)	15,0
Coal (Anthracite)	21,0

To convert the values displayed on the table to kWh, energy unit commonly used for electricity, it is necessary to think from the basic unit of W [Watt], i.e.:

$$1\ Watt\ [W] = \frac{1\ Joule\ [J]}{1\ second\ [s]}$$

$$\text{So}\quad 1\ Watt\ hour\ \ [Wh] = \frac{1\ Joule\ [J]}{1\ second\ [s]} * 1h$$

In each hour there’s 3600 seconds:

$$1\ Watt\ hour\ \ [Wh] = \frac{1\ Joule\ [J]}{1\ second\ [s]} * 3600\ [s] = 3600\ J$$

Converting using metric units:

$$1\ kWatt\ hour\ \ [kWh] = 3,6\ Mj$$

Thereby table 1 can be converted as:

Table 2. Fuel heat combustion rates in kWh/kg (data based on table 1)

Fuel	Heat combustion [kWh/kg]
Gasoline	13,1
Diesel	12,5
Propane	13,9
Butane	13,7
Coal (Lignite)	4,2
Coal (Anthracite)	5,8

Once gasoline and diesel are normally accounted in liters one more conversion is needed for these fuels.

In accordance with Brownstein (2015) gasoline’s density ranges between 0,7 – 0,75 kg/l, as diesel’s density is about 0,85 kg/l. Thereby:

Table 3. Fuel heat combustion rates in kWh/l (data based on table 2)

Fuel	Heat combustion [kWh/l]
Gasoline	9,1 (using the minimum density value)
Diesel	10,6

Solar panels

Roughly, the total energy output of a solar panel can be calculated as:

$$E = A * \varepsilon * h * pr$$

Equation 3. Energy output from solar cell (Photovoltaic softwares, 2019)

Where:

E = Energy (kWh)
A = Total solar panel Area (m2)
ε = solar panel efficiency = (default value for 2019 = 16%)
h = Annual mean time of solar radiation on the tilted panels (shadings not included)
pr = Performance ratio including coefficient for losses, weak radiation, temperature losses, etc. (ranges between 0.5 and 0.9)

Comparison between fossil fuels and solar power in electricity production

What is the volume of diesel needed to produce 1 MWh of electricity?

Approximately the electricity produced by a diesel generator can be calculated as:

$$E \ [kWh] = Heat\ combustion[\frac{kWh}{l}] * volume\ [l] * efficiency$$

Where the efficiency to produce electricity of a diesel generator falls between 30% and 55% (Adefarati et al., 2019), the volume (capacity) is calculated in liters and the value of heat combustion can be seen in table 3.

For this specific example the following default values are going to be used:

- Heath efficiency = 10,6 [kWh/l]
- ε = 42,5%

Answer:

To produce 1 MWh (1000 kWh) the volume needed would be:

$$Volume = \frac{Energy}{Heat\ combustion * effiency} \approx \frac{1000}{10{,}6 * 0{,}425} \approx 222\ liters$$

What is the solar panel area needed to produce 1 MWh of electricity?

For this example the following default values are going to be used:

- ε = 0,16 (Extance, 2019)
- h = 1850 hours / year (SMHI, 2013)
- pr = 0,5

Note: For the following calculation the annual mean time of solar radiation on tilted panels (h) does not include any shading effect.

Answer:

To produce 1 MWh (1000 kWh) the solar panel area needed would be:

$$A = \frac{E}{\varepsilon * h * pr} \approx \frac{1000}{0,16 * 1850 * 0,5} \approx 6,8\ m^2$$

In sum to produce the same 1MWh of electricity one would need 6,8 m^2 of solar panel area and 222 liters of diesel.

References

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