EMEE Ex. 07

Energy goods as a subject of exchange on the market

Objective: *1) What is the goods in the electricity market?*
2) How to find out values to Energy Balance of ES?

1. **Basic information**

Under market conditions, the product is exchanged between at least two parties, between the supplier and the consumer – fig. 07.01.



Fig. 07.01

In a market economy, the parties meet in the market – Fig. 07.02.

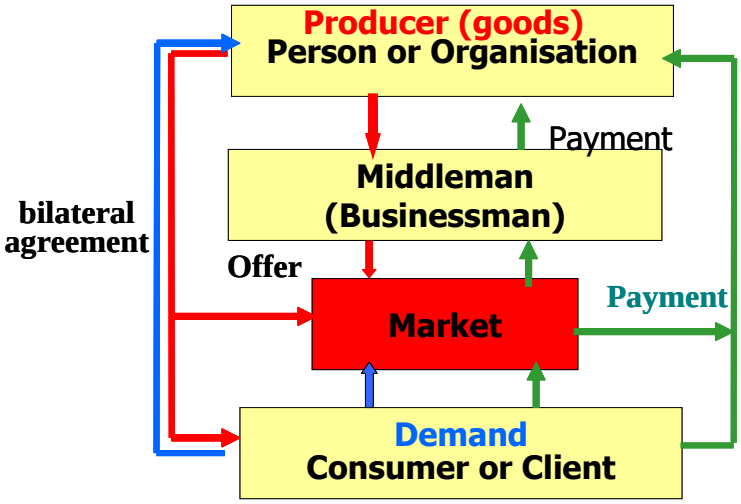


Fig. 07.02

The same method of exchange has been introduced in the relationship between customers and suppliers in the system of supply and consumption of electricity.
The primary thing in market relations is always the demand for a certain type of product - goods.
That there is someone who wants to get such a product. In this case, demand basically has only 4 options to secure the required goods:

1. Do it yourself
2. I forcibly take it from someone who owns it
3. Ask for it from the owner

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4. Offer the owner to exchange it for something (consideration - money, service, etc.)
Therefore, most of the production shift is likely to take place through a demand-supplier exchange process that takes place in a market environment in a place called a market.
The exchange process is a basic activity between supply and demand for a particular product, which can be realized if:

- ***There are at least two customer-supplier parties***
- ***Each party has something to exchange that is valuable to the other***
- ***Each of these parties is able to communicate and pass on these values***
- ***Each party is free to decide whether to join the shift***
- ***Each party believes that it is appropriate or desirable to negotiate an exchange with the other party - i.e. that it is advantageous for it.***

Whether the exchange will take place depends on whether the parties agree on the terms. Once an agreement is reached, an agreement or transaction has taken place.
Part of every transaction is the fulfillment of certain conditions without which it could not take place. The basic conditions of the transaction are:

- ***There is subject of the change – goods,***
- ***There must be to determine value of change goods,***
- ***Consideration for exchanged goods – price.***
- ***Time of change realisation.***
- ***Change way of single values between the parties.***
- ***Cancellation way of conditions in case of non-compliance with them.***

There therefore clear that without subject change existence:

1. ***goods,***
2. ***possibility to measure the value of change goods- quantification (accountability),***

the shift process cannot be performed. It is not possible to agree on a consideration for one commodity unit (c.j.) measured unit = **unit of measure – per unit (p.u.).** The countable unit of the goods is then exchanged. The countable unit of goods can be their:

- ***number = number of units (n.u.),***
- ***weight = mass unit (m.u.)***
- ***value = volume unit (v.u.)***
- ***square = square unit (s.u.)***

A demander requesting a certain number of commodity units expects them to be able to ***fulfilled the requirements*** (functions) he expects from them by using them, i.e. they will have ***useful value***. The evaluation measure of the fulfillment of the product's function is its quality.

Problem:

What is the subject of change in the power market and especially electricity and energy in general?

A good exchange on the power market an electricity market as well, (electricity, energy = ability to change), which ***is energy = goods*** with the energy potential to do work. Physically, this means in electricity that if we have a certain voltage difference, it is compensated by the passage of current, which performs the work. To determine the exchanged quantity, it is necessary to measure these (***V -voltage, I - curent***) parameters in a certain period of time, because the basic physical relationships (in SI units) is always apply during energy supply:

Force:

$$F = mass \bullet acleration = m.a \quad \left[kg.m/s^2 = N\right]$$

Work:

$$W = force \bullet length = F.l \quad \left[N.m = kgm^2/s^2 = J\right]$$

Power:

$$P = \frac{work}{time} = \frac{W}{t} \quad \left[J/s = kgm^2/s^3 = W\right]$$

Work is therefore acting power for specified time:

$$W = P.t \quad \left[J = Ws\right]$$

That is, we must measure the power level of energy goods exchanged over a period of time, or know the amount of work contained in one unit of energy delivered goods.

Goods units in ES therefore is work [Ws=J]

So they do not buy energy, but the ability of the product to do the work or provide warmth.

Specifically for electricity, the ***electrical work of*** W_E is measured with an electric meter, which can also be constructed on the mechanical principle - Thomson electric meter (Kelvin scales) - (mechanical equivalent) –Fig. 07.03.

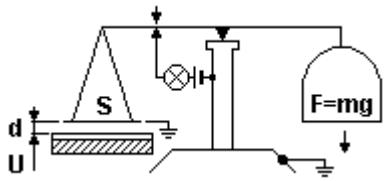


Fig. 07.03

Electricity voltage is possible to measure with non electric values:

$$V = \sqrt{\frac{2F_g d^2}{\varepsilon_o S}} \quad \left[V\right]$$

Where:

F_g – gravity force,
d – distance,
ε_0 - vacuum permittivity; ε_0 = 8,854.10-12 $A^2kg^{-1}m^{-3}s^4$
S – surface.

One volt is the voltage which causes one watt of thermal power on the conductor through which one ampere flows - Joule losses - the resistance of the conductor is then one ohm (V [V (volt)] = P_E [m^2 • kg / s^3] / I [A] = [V = (m^2 • kg) / (s^3.A]]

Each work, heat, electricity, can be determined by the mechanical equivalent.

It is easier to find out the work by measuring electrical quantities based on the Joule-Lenz law expressing work in the electrostatic field - Fig. 07.04

$\mathbf{W_E = V.I.t = R.I^2.t = (V^2/R).t}$ [J]

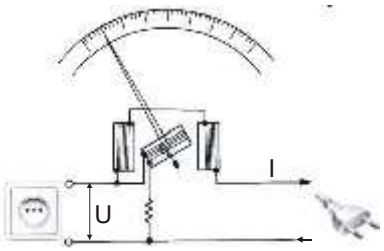


Fig. 07.04

Goods in power systems

The goods (product), which is sell or buy on the energy market, are energy values of Final Energy Sources ***FES***. It is possibility to make work by using them or to make heat. On the market we can find power goods which are selling in power units (electricity, heat), mass units or value units. But, only possibility of these goods to make work is useable value. There fore we should have to buy only in energy value of the power goods (*Joul, Watt second)*.

J=Ws

This ability of energy (***E***) we can show on the next example of three basic power transformations:

- potential (***PE***),
- kinetic (***KE***),
- internal (***U***),

which can be transform one to the other by the work (**W=A (germane Arbait)**) and heat (***Q***).

Work definition by potential energy (PE),*:*

Then the work, which is carry out by the level changing of mass m [kg] from level h_1 to h_2, is equal the ***PE*** changing of the mass:

$$W[J] = \int_{h_1}^{h_2} F.dx = \int_{h_1}^{h_2} m.g.dx = m.g.(h_1 - h_2) = m\Delta pe = \Delta PE$$

g = gravity acceleration [9,81 m/s^2]
Δpe = changing per 1 kg

Work definition by kinetic energy (PE

Kinetic energy is connected with the velocity $\vec{v}$ [m/s], which the mass (point) has. Work made by kinetic power change on defined trajectory is equal the mass velocity change:

$$W[J] = \int F.dx = \int m.a.dx = \int_{v_1}^{v_2} m.\vec{v}d\vec{v} = m\left(\frac{v_2^2 - v_1^2}{2}\right) = m\Delta ke = \Delta KE$$

Work definition by internal energy (U),:

The internal energy is connected with molecular activity of the mass of the body which is representing by the temperature t [ºC]. The value of ***U*** can be expressed by the heat which is necessary to change the temperature of the body. The change depends on the body material representing by the specific heat capacity c [J/kg.°C]:

$$Q[J] = mC\Delta t = m\Delta u = \Delta U$$

Example:
How much the body temperature will change, if the body mass is m = 1 kg, and the body fall down 10 times from the level of 100 m to the ground. The heat capacity of the body is C= 3000 [J/kg.°C].

Solution:

Under the energy saving law it must be follows:

$$\Delta PE = \Delta KE = \Delta U[J]$$

$$m.g.h = m.\frac{v^2}{2} = m.C.\Delta t = 1000\left[J/kg\right]$$

$$\Delta t = \frac{1000}{3000} = 0{,}33\left[^{o}C\right]$$

Energy units
In history, as well as in present, the power goods are selling not only in energy units, but in mass or volume units as well. The energy units in use were derived from measurements units of the relevant territory. In England, USA (mile, pound etc.), is used very often **FPS** measurement (foot, pound, second). There fore we often meet the power units on weight or volume base. We have to know the recalculation into **SI** system (international system of units) in order we should be able to make the power balances.
In enclosed tables the recalculation among the units are shown.

Weight units:

To: / From:	kg	t	lt	st	lb
	multiply by:				
kilogram (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
tonne (t)	1000	1	0.984	1.1023	2204.6
long ton (lt)	1016	1.016	1	1.120	2240.0
short ton (st)	907.2	0.9072	0.893	1	2000.0
pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Volume units:

To: / From:	gal U.S.	gal U.K.	bbl	ft^3	l	m^3
	multiply by:					
U.S. Gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. Gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0045
Barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
Cubic foot (ft^3)	7.48	6.229	0.1781	1	28.3	0.0283
Litre (l)	0.2642	0.220	0.0063	0.0353	1	0.001
Cubic metre (m^3)	264.2	220.0	6.289	35.3147	1000.0	1

Power units:

Explanation of power units:

BTU (British thermal unit), very often used power unit, and it is heat quantity which is need to increase the temperature of one pound of water between 60 a 61 degree of Fahrenheit under the atmospheric pressure. Actually, it is ***Q*** definition, as it the power unit calorie was (Q heat which is need to heat 1kg water over °C.

toe (Ton of Oil Equivalent) is equal power carry out from one tone of oil.

In the market condition, there is necessary to express the price of goods, in order to we can able to cross offer with demand. Therefore is very suitable for as to express the price of power goods on the same units – power units, but no on the weight or volume units.

There is no problem in electric and heat systems, because the measurement is obviously make by power output or heat during definite time.

To: / From:	TJ	Gcal	Mtoe	MBtu	GWh
	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

Electricity:

$P(t) = U.I$ [W]

where: U [V] …voltage

I [A] …..current

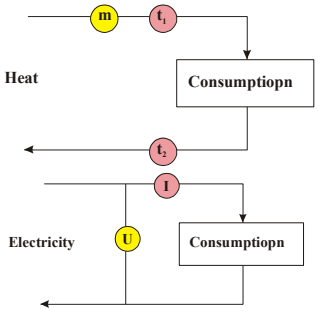
Heat:

$Q(t) = c \cdot m \cdot (t_1 - t_2)$

where: m [kg] …. mass

c [J/(kg.degree)]

t [temperature]



But, as regards the fuels, we usually make business under measurement of weight or volume units. We should be interested in the work which can be done by these products. Therefore we can be able to evaluate the power density inside these measured units. It is problem because there is impossible to evaluate the power density directly. In addition to this, the power density of gaseous fuels depends on the thermodynamic conditions (temperature, pressure). Thus we have to evaluate the power density under definite thermodynamic condition (normal conditions, index "n"), we can evaluate, by the burning of them – transformation of chemical power to heat). This can be done in measurement equipment which is called calorimeter, where a fuel is burned and cooled back from temperature t_2 to t_1.

Problem of chemical power transformation inside fuels to heat

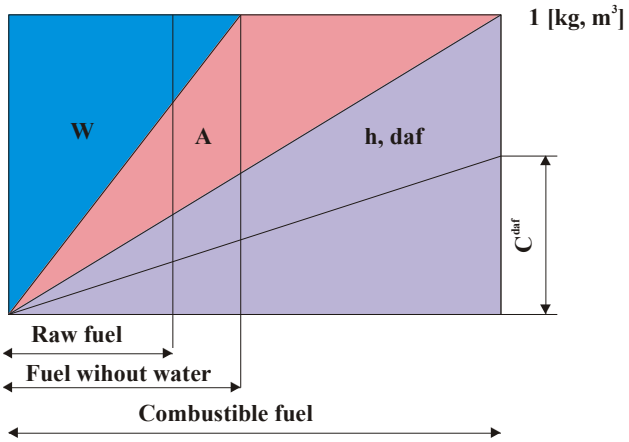
There is sometimes problem, what part of the power density we can put to the power balances.

All fuels, which have chemical power inside them (in one unit – 1kg, m^3), consist of components from which the power can be realised by chemical exothermic reaction (**h, daf** - combustible parts, dry ash free), components which haven't chemical reactivity (non combustible parts – **A** - ash) and water (**W**) – see picture.

Ash is in burning process only heated; water is, by heat, change to steam. The combustible part of the fuel consists mainly from carbon-hydrogen elements (atoms, molecules). The volume of carbon in **daf** is representing in picture by $\boldsymbol{C^{daf}}$ curve.

Therefore, if we in the calorimeter cool the temperature t_2 back to initial temperature t_1, we obtain just the all power density which is inside the fuel. If we didn't returned back the heat for water evaporation and ash heating (going out from combustion chamber unused), the useable power density is lower. We recognize two power densities inside the fuels:

- ***combustion heat, gross heating value, high heating value, (Q_{daf})***
- ***low heating value, caloricity, heating value, (Q_i)***



Pic.26: Fuels structure

The chemical reaction with power realising (exothermic) describes on the left side reactance parts and on the right side we write products. The number of atoms on left side is equal to right side. The mass on the left and right side have to be same. This description is called steicheiometric equals.

The main steicheiometric equals of solid fuels are:

$$2H_2 + O_2 \rightarrow 2H_2O + 285{,}7\ kJ/mol = 120580\ kJ/kg$$
$$C + O_2 \rightarrow CO_2 + 393{,}5\ kJ/mol = 33910\ kJ/kg$$
$$S + O_2 \rightarrow SO_2 + 29{,}6\ kJ/mol = 10470\ kJ/kg$$

The main steicheiometric equals of gaseous fuels are::

$$CH_4 + 2 \cdot O_2 \rightarrow CO_2 + 2H_2O + 1\,041{,}2\ kJ/mol$$
$$H_2S + 1{,}5 \cdot O_2 \rightarrow SO_2 + H_2O + 603{,}3\ kJ/mol$$
$$CO + 0{,}5 \cdot O_2 \rightarrow CO_2 + 393{,}5\ kJ/mol$$

The dependence between low heating value and high heating value can be expressed:

$$Q_i = Q_{daf} - 2{,}441 \cdot (W + 8{,}94 \cdot H) \quad [MJ/kg]$$
$$Q_i = Q_{daf} - 2441 \cdot m_{H_2O} \quad [kJ/kg, kJ/m_N^3]$$

Where: - 2500 is approximate heat value to evaporate 1 kg water,
- m_{H2O} is total mass of water.
..- 8,94 coefficient for recalculation hydrogen to water

Example 1:

From the parts analyse of the fuel was ensured follow data:

Combustible parts – h = 0,61 kg/kg
Water value – W = 0,21 kg/kg
Ash value - A = 0,18 kg/kg

Components of combustible parts in kg/kg are:
C^{daf} = 0,695, H_2^{daf} = 0,04, S^{daf} = 0,045, O_2^{daf} = 0,14, N_2^{daf} = 0,08

Allocate:
1) Parts content of the fuel
2) The change of parts content when the fuel is dry to W´= 0,08 kg/kg

Solution:

Ad 1) From the triangle similarity in picture follows equals for the computation of parts content of the fuel:

$C = (1-W-A).C^{daf} = (1-0,21-0,18).0,695=0,424$ kg/kg
$H_2 = (1-W-A).H_2^{daf} = (1-0,21-0,18).0,040=0,024$ kg/kg
$S = (1-W-A).S^{daf} = (1-0,21-0,18).0,045=0,027$ kg/kg
$O_2 = (1-W-A).O_2^{daf} = (1-0,21-0,18).0,140=0,085$ kg/kg
$N_2 = (1-W-A).N_2^{daf} = (1-0,21-0,18).0,080=0,050$ kg/kg

Computation verification:

$$H = C + H_2 + S + O_2 + N_2 = 0,61 \text{ kg/kg}$$

Ad 2) From the picture is known that by the draying the ach-combustible parts ratio is unchanging:

$$h' + A' + W' = h + A + W$$

therefore we can write equation:

$$h' = 1- A' - W' = 1 -0,21 - 0,08 = 0,71 \text{ kg/kg}$$

The percentage composition of the fuel we can calculate as in the previous example:

$C' = (1-W-A).C^{daf} = (1-0,21-0,08).0,695=0,493$ kg/kg
$H'_2 = (1-W-A).H_2^{daf} = (1-0,21-0,08).0,040=0,029$ kg/kg
$S' = (1-W-A).S^{daf} = (1-0,21-0,08).0,045=0,032$ kg/kg
$O'_2 = (1-W-A).O_2^{daf} = (1-0,21-0,08).0,140=0,099$ kg/kg
$N_2 = (1-W-A).O_2^{daf} = (1-0,21-0,08).0,080=0,057$ kg/kg

Computation verification:

$$h' = C' + H'_2 + S' + O'_2 + N'_2 = 0,71 \text{ kg/kg}$$

Example 2:

Calculate power density (high heat value) of 1 kg of combustion part of black coal with the combustion components 73 % C, 4 % H, 0,6 % S.

Solution:

High heat value of the fuel we can calculate from steicheiometric equals:

$$Q_{daf} = 0{,}73 \cdot \frac{393{,}5}{M_i^C} + 0{,}04 \cdot \frac{285{,}7}{M_i^H} + 0{,}006 \cdot \frac{29{,}6}{M_i^S} =$$

$$= 0{,}73 \cdot \frac{393{,}5}{12} + 0{,}04 \cdot \frac{285{,}7}{2{,}016} + 0{,}006 \cdot \frac{29{,}6}{16} =$$

$$= 0{,}73 \cdot 32{,}79 + 0{,}04 \cdot 141{,}72 + 0{,}006 \cdot 1{,}85 = 29{,}62 \ \ MJ/kg$$

where:

M_i^C , M_i^H , M_i^S - molar massses of single combustible parts [*kJ*/kmol].

Problem of gaseous fuels

We already can calculate or measure the power density of the gaseous fuels, but it is necessary to evaluate in which outstanding conditions the fuel is deliver to costumers because the power density is changing due to ***general gal low***.

$$\frac{p_1 v_1}{T_1} = \frac{p_2 v_2}{T_2} = konst = r$$

It means the measured value (v) of gas will depend on the pressure (p) and temperature (t). The power density measure under normal condition temperature t_n= 15°C and pressure p_n=0,1 MPa is usually differ.

Example 3:

Calculate power the work or heat which can be carry out by landfill gas of high heat value 10,5 kWh/m^3, measured in normal condition., if the measured volume was 5000 m^3. The gas meter is situated on outside and see level is 220 m and gas pressure is 2 kPa

Solution:

The barometric pressure of 220 m see level is 99,5 kPa.
The average outside temperature value is 10°C.

Correction coefficient: $\boldsymbol{k = \frac{T_v}{T_p} * \frac{p_G + p_b}{p_n} = \frac{288{,}15}{273{,}10 + 10} * \frac{2{,}0 + 99{,}5}{101{,}325} = 1{,}0134\ [-]}$

Where: T is Kelvin temperature t + 273,15

Q = V_G. k . Q_{daf} = 5000 . 1,0134 . 10,50 ´= 50 203 kWh