Students Scientific Conference

The facts behind the fiction

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Introduction

Today's world is a world of rapid development. Newer products and services occur in every moment so quickly we do not have time to get used to them. Nowadays, there are no households without a computer, television, smartphones or tablets. But one thing is for sure: these products require energy, and this fact shows the importance of energetics, since it deals with power generation, transport, distribution. Furthermore, a considerable per cent of a country's GDP comes from energetics, so it is undeniable, that this topic is an essential part of the economy. That is the reason why I chose this topic. In this thesis I will compare several ways of energy production from an economic viewpoint, but first, we have to be familiar with some basic knowledge on the topic.

The basic knowledge of energy production

First and foremost, it is not possible to get energy out of nothing. What is more, we cannot use most of the raw energy sources we have, so we must convert them into usable energy (for example, we convert chemical energy into kinetic energy (cars)).
We have to distinguish primary and secondary energy sources. The sources we consider primary are those that can be found in nature and which we have to convert to be able to use as energy. This includes: coal, oil, gas, uranium, wind, sun, water, geothermic- and biomass. After the conversion, these sources become secondary energy sources.

The primary energy has two groups: renewable and non-renewable energy. Wind, sun, water and biomass are renewable sources, whereas coal oil, nature gas and uranium are non-renewable. We could make electric energy from coal, gas, uranium, wind, sun, water and biomass. To convert energy we have to do several difficult processes. Nowadays there are some misbeliefs about this conversion.

Non-renewable sources except uranium are fossil energy sources, which means these give us energy as a result of a combustion process.

Features of energy sources

The coal is at the largest quantity of all available fossil energy sources. Most of it is in Russia, China, North-America and Europe. The certified supply of coal is 826 Gt, which will be enough for 122 years – assuming that today's average consumption of coal will not grow any further. A great benefit of coal is that it is shared out relatively evenly around the world, which makes it easily available. On the other hand, a main disadvantage of coal, compared to nature gas is that the coal's calorific value is lower (33.8GJ/t) and it's CO_2 emission is twice as big as that of natural gas.

Nature gas is the noblest of all fossil energy sources. Its calorific value is higher (max. 49.5GJ/t) and the CO_2 emission is lower than that of coal. The biggest drawback is its price, since it's shared out unevenly around the world. 52.4% of all natural gas can be found in only three countries; Russia, Iran and Qatar. The certified supply of natural gas is 185TNm3, which is enough for about 60 years.

The uranium is also a non-renewable energy source, but it is different from the previous energy sources. It stores energy in nuclear form. This has the largest benefit. From uranium we can make the cheapest electric energy and it can be found almost all over the world. It has strict security requirements and its social acceptance leaves much to be desired.

The solar power can be found in the greatest quantities. It produces energy without carbon, but due to the small density of energy it does not produce energy effectively and it depends on the weather. Furthermore, making a solar panel is very polluting. Despite these, solar energy is more and more popular nowadays, but it cannot be a competitive energy source without the support of the government.

Wind power is similar to solar power, since these are both environmentally friendly. The efficiency of wind power is greater than that of solar energy, but it cannot be so widespread, since it is only worth to build it where the annual average wind speed is at least 5m/s (18km/h). Hungary's annual average of wind speed fluctuates between 2-4m/s.

Hydro energy's efficiency is high, it is a carbonless energy and it uses kinetic energy of – for example – a river to produce energy. It is only possible to build them on big rivers which have greater level drops in their beds. Its main disadvantage is that it is requires a big intervention into nature and its productivity depends on environmental factors.

The biomass contains organic fuels and wastes. It is renewable if the pace of use does not exceed the pace of producing. Calorific value of this is similar to coal, but the CO_2 emission of biomass is a bit smaller. In spite of these, we consider it carbonless process, since we assume that the emissioned CO_2 is balanced by the quantity of O2 the used organism could have produced. The main advantage of this method is that it is available everywhere, but it is very space consuming and it uses economically valuable areas.

The change of the quantity of the produced energy

The task of electric energy systems is to always fulfil the consumer's needs. Of course, it does not mean that the whole world will be provided with energy 24/7 year round. What it means, is that there will not be a consumption limit if it can be avoided and it is affordable.

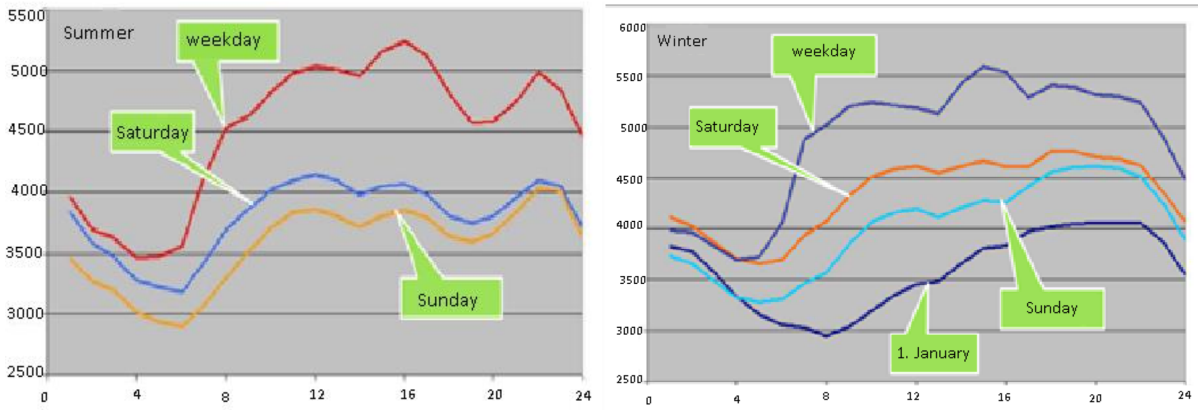
The electric power is a product. It cannot be stored in huge quantities (or at least, it does not worth it), therefore we have to produce it when it is needed. As we cannot control or limit the quantity of consumption, the producers have to adapt to the demands. Although each consumer's needs cannot be foreseen, their habits in regards to energy consumption are predictable.

Numerous consumer demands at the same time are called net consumer demand. To fulfil these demands we have to make available more power, because there are losses during the transport. These are called "network loss". The net consumer demand and the network loss together make the gross consumer demand. A Hungary-sized electric energy system exceeds the net consumer demand by 10%.

Short and long-term factors influence the power consumption. From an economic view we could explain long-term changes with constant economic growth, such as changes in industry structure and in consumer habits.

Beside the different economic development levels and industry construction of each country, the geographical and the climatic factors also influence the differences in the use of electric energy. In a shorter period of time the weather and the calendar (sunrise, sunset, weekdays, holidays) make the differences in the demand for electricity.

Figure 1: Daily consumption



Source: István Gács: Villamosenergia-termelés gazdasági értékelése

These line graphs show how consumption fluctuates in summer and in winter. We can see both seasons are similar and the lines reach the peak at late afternoon. In the morning starting work, work-related consumption and the traffic cause the increase. In the afternoon the consumption of households have a major function. The power stations have to follow these fluctuations. Therefore the regulation of power stations is important. The public utility power plants could be basic-, timetable holder and peak-load power plants.

The basic power stations have huge peak utilisation time span (over 5500 hours/year) and operate nearly permanently. These are usually modern, and work with high efficiency and use cheap fuel (e.g.: Hungary, Nuclear Power Plant “Paks”).

Timetable power stations follow the changes of electricity demands. These can change their performance flexibly. We never build new power stations as timetable plants. The previous stations become timetable station (e.g.: next to the Tisza and the Danube).

Peak-load power plants work just in time of peak consumption (1500-2000h/years). For this aim we usually build stations which have cheap costs and the lower efficiency (generally gas turbine power stations).

The power station’s expenses

After these basics, let us continue with the economic questions. These stations have long cycle time so inflation is important. During the construction time of a power station the inflation is not constant, so we have to take this into consideration when we are making an evaluation.

The inflation means the decreasing value of money. We could write it with this formula:

$$1\$_{n-1} = (1 + p_i)\$_n$$

where:

- p_i is the annual inflation rate
- n is the year
- $ is the currency

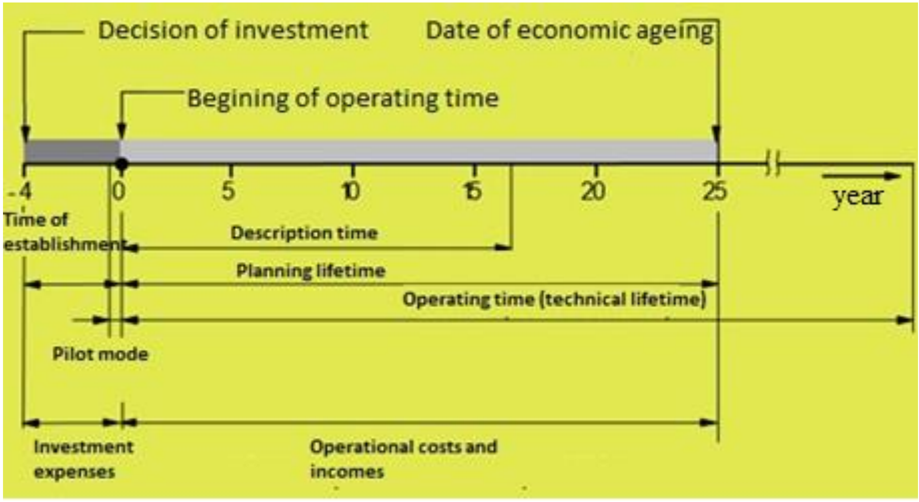
This means that 1 $ in this year is more valuable than 1 $ in the next year, because of the inflation.

The other important question is whether we have to count with a deposit or a borrowing rate. Between these two there are some major differences. Most of power stations are not built from their own capital or bank credit, but from the blend of these. In this way we use a “middle interest rate”, which was never listed by banks.

We distinguish inner and exterior expenses. The inner expenses are the costs of energy conversion inside the power station, whereas the exterior expenses are the expenses of the damages (which are caused by changes, losses) and loss prevention.

When we analyze power stations from an economic view, we have to take every cycle of their life into consideration. It is not only the operation time that is important, but the maintenance, the decommissioning costs should also be taken into account. After all these, the power station still has to make a profit.

Figure 2: A power station’s life cycles



Source: István Gács: Villamosenergia-termelés gazdasági értékelése

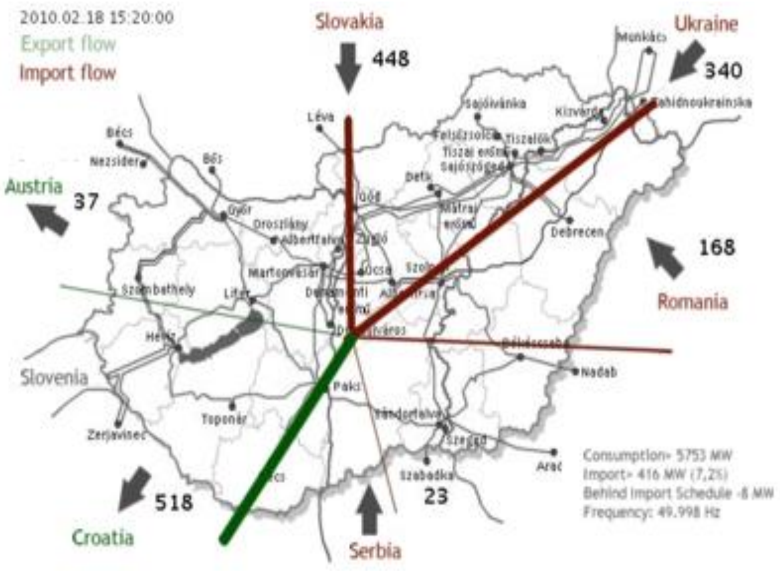
This figure shows that the expenses and incomes do not appear at the same time. Therefore it is important to distinguish the operating costs and establishment costs. The test operation is still in the establishment time period. In this time there are fuel costs too. This expense is in the establishment time until the official start-up and until it is paid by the investor. The investment costs can be paid by the investors own source or by bank credit. In both of these cases profit is the most important, but in the second case we have to pay back the interest too.

It is hard to estimate all the operating time and technical life. If there is a careful planning and operating, the technical lifetime may not be smaller than planned lifetime. The main expenses from the operating cost are the following: fuel, used materials, maintenance, wages, taxes and insurances. The costs of liquidation is also a part of the power station's lifetime. Usually this expense is low compared to the other costs of lifetime (except for nuclear power plants).

The sources of energy

Nowadays the power systems (e.g.: The Hungarian Electricity System) work in co-operation with each other. This means that we can also receive energy from neighboring systems. The following picture shows that we bought it from Ukraine, Slovakia, Romania and Serbia and sold it to Austria and Croatia in 2010.

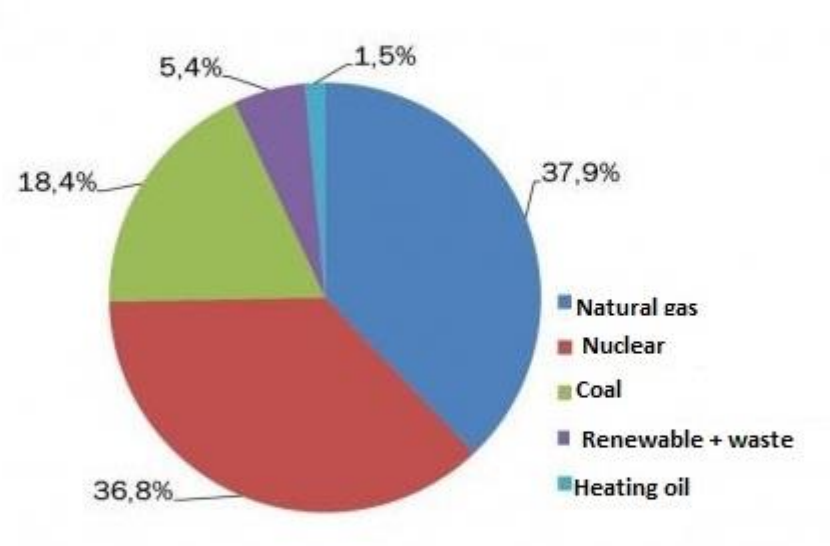
Figure 3: The exports and imports of electric energy



Source: Prof. Dr. Attila Aszódi: Villamos energia rendszerek, lecture notes, BME

The picture points out that the domestic producers and the import balance also take part collectively in the satisfaction of the domestic gross demand of electric energy. Hungary has been an importer for decades. That part of energy supply is significant (30%), compare with other countries it is a high value.

Figure 4: The production of electric energy in Hungary in 2011



Source: Prof. Dr. Attila Aszódi: Villamos energia rendszerek, lecture notes, BME

This pie chart shows that two thirds of energy production are from fossil energy source and one third is from nuclear energy source. Renewable and other sources are significantly low compared to the other sources.

What kind of methods can we use to produce energy in Hungary?

Since 1990 the coal mining in Hungary has been declining, numerous mines were judged to be making losses and then were closed, and so were the low efficacy steam power plant blocks. These are the current working power station integrations:

- Visonta (Bükkábrány) - Mátrai Erőmű Rt (lignite),
- Oroszlány (mine) - Vértesi Erőmű Zrt (brown coal), since 2010 under bankruptcy proceedings.

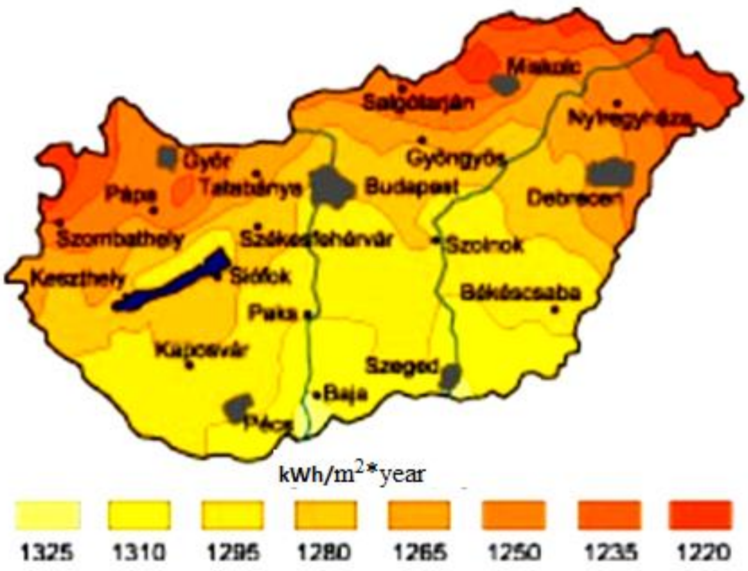
The consumption of coal is decreasing nowadays.

The exploitable black coal is 1986Mt (in Mecsek), brown coal is 2244Mt and lignite is 14324Mt. The question is whether we can reduce our dependency on coal importation so that we could use Hungarian coal in timetable steam power stations. The coal was suppressed as a primary energy source of heat energetics, since it has the highest CO_2 emission.

Gas production in Hungary decreases gradually as the supplies are running lower and lower. According to a forecast Hungarys production of natural gas has dropped since 2009 from 2,56 GNm3/year (~20 %) to 1 GNm3/year (<10 %). In other words, this means that over 90% of our gas supplies are imported, mainly from Russia. Through the Nabucco pipeline we could decrease this huge dependency on Russia.

Nowadays solar energy becomes more and more popular.

Figure 5: The solar radiation of Hungary



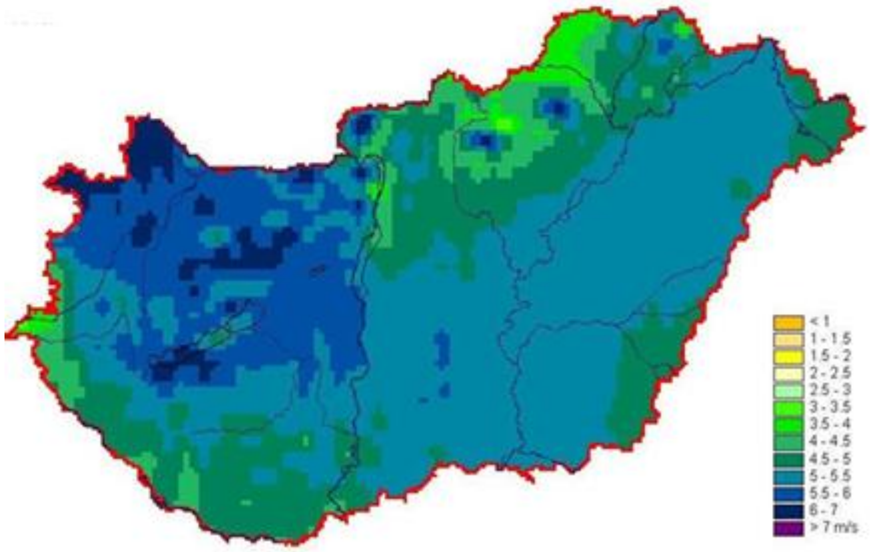
Source: Dr. Gyula Csom: Fenntartható fejlődés és atomenergia, lecture notes, BME

The exploitable potential of the solar radiation falling on Hungary – based on the solar energy map – fluctuates between 4.77 and 4.392 (GJ/m2year). Calculating with the average value the solar energy potential is four hundred times greater than Hungarys energy consumption in a year, but the energy production of the solar panels are highly influenced by the weather, seasonal distribution and other factors.

We use the heat of solar radiation converted by solar collectors to produce hot water and heat buildings, but we cannot use it to produce electric energy – simply because it is not cost-effective.

The water power potential in Hungary is non-significant, 16 PJ/year (~510 MWe), but 80% of this is made in Bős-Nagymaros. The Danube is barraged at Bős, which means fewer stream deposits can enter our homeland, which leads to the continuous deepening of the riverbed. The deeper the riverbed is, the lower the water-level will be on the Alföld and the Dunántúl.

Figure 6: Average wind speed in 75 metres of altitude



Source: Dr. Gyula Csom: Fenntartható fejlődés és atomenergia, lecture notes, BME

This picture shows Hungarys wind map at 75m altitude. Those territories which have their annual average wind speed over 5m/s are suitable for energy production. So, as you can see, only the North-Western areas of Hungary could be involved in this method of energy producing. To improve Hungarys potential in wind speed, pumped storage hydro power plants should be built. This means that with the energy that was produced with the wind turbine we deliver the water to a cistern and during the highest energy demand of the day we let it flow down. The flowing water turns a wheel, which wheel works like a wind turbine and produces electric energy.

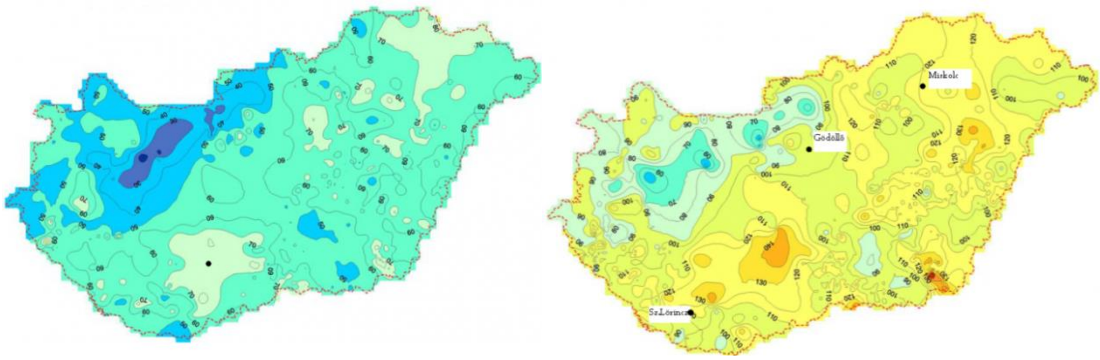
We distinguish three groups of biomass:

1) Primary: the organic material produced by the vegetal photosynthesis; the natural vegetation, the tillage and horticultural plants, the forest, the meadow and pasture, the plants which are living in the water;
2) Secondary: fauna, economic livestock, the wastes of animal husbandry
3) Tertiary: waste of industry which use degradable material

Potential of domestic biomass is 200-330 PJ/year, which is 18-30% of all energy consumption.

Our geothermal depots which can be found in 3 km of depth ~2500 km3 volume, contains 500EJ heated thermal water, but since the average temperature of our thermal waters (68°C) is low, we can only use 5-20PJ/year. 500 EJ heat content thermal water is contained, but the average temperature of our thermal waters (68 °C) is small, because of this the fraction of this, 5-20 PJ/year is exploitable.

Figure 7: The temperature of water at 1 km and 2 km of depth



Source: Dr. Gyula Csom: Fenntartható fejlődés és atomenergia, lecture notes, BME

The water that comes from ~1km depth is at 50-55°C temperature when it reaches the surface, therefore we can use it to warm water. Also, the water which comes from ~2km depth is much hotter. It can reach 80-85°C temperature, so it is useable for district heating (with the reinjection of the used water). The rising water's quality is not applicable, so we have to get rid of its contaminations (such as methane or salt) because of the deposition.

For electricity production, the water temperature has to be at least 130-150°C, but it is located at ~3-3,5 km depth, and it is very difficult and expensive to bring it to the surface, so in Hungary the geothermal energy is used only for heating.

What kind of basic power plant we should build?

Basic power plants add up to most of the produced energy. Characteristics of these different power plants show that not every power plant is suitable for the role of a basic power plant. Consumers provide a constant demand for energy and the producers must satisfy these demands regardless of the price of energy –, while on the other hand, price – after permanency – is one of the greatest viewpoint of consumers. Nowadays, the environment becomes more important, and the producers have to reduce the harmful emissions which adds additional costs. Their task is to find a method which produces power effectively and sustainably without harming the environment.

In the following, I will compare the basic power plants installation and maintenance costs (coal, nuclear, natural gas and biomass). The renewables are not mentioned in this paragraph.

In this table we see values per power plant:
Black which are constant (from International Energy Agency)
Red which are calculated

Type of power plant		Coal	Coal+CCS (Carbon capture and storage)	Nuclear	CCGT (Combined cycle gas turbine)	Biomass
r	%/year	6	6	6	6	6
n	year	35	35	60	25	25
$\boldsymbol{\alpha_l}$	1/year	0,069	0,069	0,062	0,078	0,078
i	.	1,2	1,2	1,25	1,1	1,15
α_{TMK}	1/year	0,025	0,025	0,03	0,035	0,045
α_e	1/year	0,01	0,01	0,012	0,008	0,01
α	1/year	0,118	0,118	0,1195	0,1255	0,1413
a	USD/kWh	2000	4000	5500	1200	4000
ε	%	9	11	6	5	10
r_{TMK}	-	1,06	1,06	1,06	1,04	1,08
$r_{ÜT}$	-	1,04	1,04	1,04	1,04	1,05
v_{vh}	-	0,97	0,97	0,96	0,98	0,97
τ_{cs}	h/year	7000	7000	7500	7000	7500
$k_{áll}$	USD/kWh	0,042	0,086	0,107	0,025	0,1
$k_{áll}$	HUF/kWh	11,634	23,822	29,639	6,925	27,7
$k_{áll}$	EUR/kWh	0,0382	0,0782	0,097	0,023	0,091
p_q	USD/GJ	3,6	3,6	0,6	14	4,2
$\dot{\eta}$	%	39	30	33	57	28
k_v	USD/kWh	0,033	0,043	0,0065	0,088	0,054
k_v	HUF/kWh	9,141	11,911	1,8	24,376	14,958
k_v	EUR/kWh	0,03	0,039	0,0059	0,08	0,049
k	USD/kWh	**0,075**	**0,129**	**0,1135**	**0,113**	**0,154**
k	HUF/kWh	**20,775**	**35,733**	**31,43**	**31,301**	**42,658**
k	EUR/kWh	**0,6825**	**0,117**	**0,103**	**0,103**	**0,14**

where the exchange rate in 26.03.2015 is:

1USD= 277HUF 1EUR=305HUF 1USD=0,91EUR

(based on exchange rate of the Hungarian National Bank)

To calculate this we have to use some symbols:

r: interest

n: operating time

α_l: establishment costs compare operating time

i: internal costs

α_{TMK}:: planned scheduled maintenance

α_e: other costs

α: combined cost factor

a: specific investment costs

ε: self-consumption

r_{TMK}:: maintenance reserve factor

$r_{ÜT}$: operational safety reserve factor

v_{vh}: variable deficit

τ_{cs}:: peak utilization time

$k_{áll}$: fix costs

p_q: fuel price (heat)

ή: efficiency/ year (%)

k_v: fuel price (material)

k: full costs

In the following calculations I used a coal power plants data.

This calculation is based on Prof. Dr. Attila Aszódi and István Gács's notes.

The expenses of the establishment could be calculated with the help of the interest and the operating time.

$$\alpha_l = \frac{r}{1-(1+r)^{-n}}$$

The coal power plant's value substituted into this formula:

$$\alpha_l = \frac{6}{1-(1+6)^{-35}} = 0{,}069$$

From which we could calculate the combined cost factor:

$$\alpha = \alpha_l * i + \alpha_{TMK} + \alpha_e$$

Substituting into this:

$$\alpha = 0{,}069 * 1{,}2 + 0{,}025 + 0{,}01 = 0{,}118$$

From these data we could calculate the constant costs of 1 kWh energy.

$$k_{áll} = \frac{\alpha * a * r_{TMK} * r_{ÜT}}{\tau_{cs} * (1-\varepsilon) * v_{vh}}$$

After the substituting:

$$k_{áll} = \frac{0{,}118 * 2000 * 1{,}06 * 1{,}04}{7000 * (1-0{,}09) * 0{,}97} = 0{,}042$$

After that we have to count with a changing factor. We get this from:

$$k_v = \frac{p_q}{\acute{\eta}}$$

After substituting:

$$k_v = \frac{\frac{3,6}{1000} * 3,6}{0,39} = 0,33$$

Finally from these we get the all of costs of 1kWh energy.

$$k = k_v + k_{áll}$$

$$k = 0,33 + 0,042 = 0,075$$

This is how we can calculate the costs of coal+CCS, nuclear, CCGT and biomass power plants.

As we can see, the cheapest way to produce energy is to use coal power stations. However, this method is the most polluting solution to make electric energy. The most expensive way is the biomass power plant.

Summary

Economically, the best solution is the coal power station. But we have to protect our environment so we have to reduce the emissions into a minimum level. In this case the best solution could be to use nuclear power plants. The social acceptance of using nuclear power plants is low, since it is dangerous.

In Hungary we use mainly nuclear power and natural gas. Nowadays a new nuclear power plant is under construction. It will not increase the amount of energy we produce, since the efficiency of previous stations will decrease slowly while the new stations will rise, so the amount of produced energy will not change.

Sources

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