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CONCEPTS OF SUSTAINABLE ENERGY

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ABSTRACT

Thanks to technological advancements, the profitably useable fossil energy deposits are increasing, and their exploitation requires more and more energy investment. In developed countries, the efficiency increase driven by competition decreases the per unit energy need, however, this effect cannot compensate for the increasing energy demand of the world. The use of renewable energy resources in not only vital for the three pillars of sustainability but for supply security, too, even though their competitiveness is still lower than that of fossil energy resources. The exploitation of renewable energy resources involves higher investment costs and lower maintenance costs per unit. Due to extra costs deriving from long transportation routes, lower maintenance costs are not necessarily true for conditionally renewable energy resources. This significantly influences environmental sustainability, too. The exploitation of solar and wind energy are the fields where considerable improvement can be expected due to the increasing efficiency and low maintenance costs. However, these favourable effects can also be achieved by other energetic investments; therefore an objective comparison of options is required. The analysis of the retail price structure of electricity reveals that electricity prices primarily depend on the energy resources used and the technology; however, final prices are to an even greater extent influenced by tax and fee elements.
Keywords: Renewable energy sources, sustainability, energy prices, competitiveness, energy efficiency, technological development, energy structure

INTRODUCTION

Our current macroeconomic model ignores humanity's eternal dependency on nature; it does not take the limited resources (limited carrying capacity) of Earth into consideration (*Vida*, 2007). Instead, the model is built on increasing material consumption, it generates excessive demand for natural resources, it wastes them, it creates problems to be solved, and besides these, it requires constant population growth and the generation of consumer needs (*Gyulai*, 2013). This led to a disturbance in the balance of consumption and environment, as presented in the study "A fogyasztás zsákutcája" ("The dead-end of consumption") by *Náray-Szabó* (2003). The higher demand generated by the increased consumption also revealed the limited availability of energy resources, thus highlighting the key importance of energy security and supply security.

MATERIALS AND METHODS

The study examines the competitiveness of renewable energy resources in electricity production from the points of view of sustainability and energy security. The review is based on statistical data from several international organizations (Eurostat, Energy Information Administration and World Nuclear Association) and Hungarian scientific studies. The economic analysis of the investment side deals with the per unit cost of electricity generation and the risks derived from cost structures. The environmental approach of the study examines the per unit GHG emissions of production by evaluation and comparative analysis of the data available, then the possible alternatives of the emission savings are presented.

RESULTS AND DISCUSSION

By today the symptoms of the overturning of the natural balance and the problems and their consequences caused by environmental externalities appear in the list of the ten most important global challenges compiled by Nobel Prize winner Professor Richard E. Smalley. On the top of the list there are *power-supply, water-supply, food-supply* and the *protection of the natural environment* and in the tenth place there is the *stoppage of overpopulation* is (*Dinya*, 2010). Referring to the list Dinya mentions and emphasizes several times it can be stated that the exponential challenges are interlocked and appear in a complex way strengthening each other. Among them there are numerous cause and effect relationships, direct and indirect interference also can be discovered. For example, due to the population- and the consumption growth occurring increasingly - more energy can be used and as a result of this environmental problems have global effects, too. The population growth keeps on enhancing the problems of the food supply, meanwhile the environmental pollution caused by extreme weather increases the unpredictability of food production. A consequence of soil degradation and the desertification of further areas must be involved in agricultural use, which is also leading to the deterioration of the environmental values. Facing the complicated economic, social, environmental correlation of the system that produce effects on each other, the challenges need simultaneous and collective solutions. The summary of this whole multifactorial coherent problem-system can be described by the sustainability concept, to which the complete response of ecological economics and the ideology of sustainable development can be given. Nowadays the three-dimensional theory is generally accepted defined and improved by the Brundtland Commissions which interprets sustainable development as a synchronous harmony of ecological, social and economic factors (*Szlávik*, 2013). *Csete* (2008) considers that the implementation of this question as well as the most important stepping stone is the energy issue that could be the answer given to the climate change. With regard to that fact energy is provided for the economic foundation and therefore the base of the production, there is every reason to believe that without the rationalization of our energy utilization and the usage of the renewable energy sources the sustainability cannot be achieved (*Dinica*, 2006). *Pálvölgyi's* (2000) conclusion also supports this theory when he determines that the combustion of different types of fuel are responsible for the climate change in 50-60% due to the emission of greenhouse (GHG) gases.

The power-supply question is of overriding importance not only from the sustainability side but also from the point of view of security policy. . As most of the developed countries need energy import (in the EU Denmark is the only exception for this) from the point of view of security policy the reduction of energy dependence is also important, which may affect the country's sovereignty. The maintenance of the power-supply and the security of supply can primarily mean the insurance of the uninterrupted availability of the energy sources and services. This complex economic-trading-technical system can be considered within an economic, societal, political, military, technical, technological system summarized in a geopolitical-strategic acting issue which the national energy strategy and energy politics give the respond to. This relative stability must be adapted to our ever changing, ambiguous World. This relative stability must be adapted to the changing circumstances and also against its root causes of the change, for example to the economic and political interests, technological innovations, energy poverty, environmental and climate protection or its summary can be interpreted as a suit correspondence to the previously mentioned requirements of sustainability (*Katona*, 2013).

Energy supply security is threatened by several factors. Among others the following factors can be considered as a risk: the decreasing stock of fossil energy sources, the unstable political, economic situation of the countries possessing energy resources, natural catastrophes, anthropogenic effects caused by the more and more extreme weather conditions (*CKKE*, 2010). Firstly, it was the crude oil crisis in 1973 and the news on the decreasing sources of fossil energy. They drew the attention to the terminating stocks of fossil energy sources as the risk of primary importance. This also highlighted the importance of the diversification of the utilized energy sources and their purchasing routes.

Today, with the non-conventional crude oil and natural gas production, the risk of the depletion of stocks permanently seems to be passing away. But the revolution of the shale oil and shale gas leads to decreasing prices in the United States, with the expansion of the production it could become net energy exporter. This can redraw the Worlds' geopolitics and as the *Figure 1* shows, due to the increasing supply appearing at low prices owing to the industrial investments, developments become more risky. With the lower operating costs working production units and technologies have the competitive advantage, while further environmental anxieties arise as a consequence of the spread of new technologies (*Genté*, 2013; *Flues and Simon*, 2013).

The question has arised whether the global competition for the natural resources that shares the world could be available for sustainablility at all. Or instead of the competition the solidarity and the cooperation would be necessary that is not typical of this economic system.

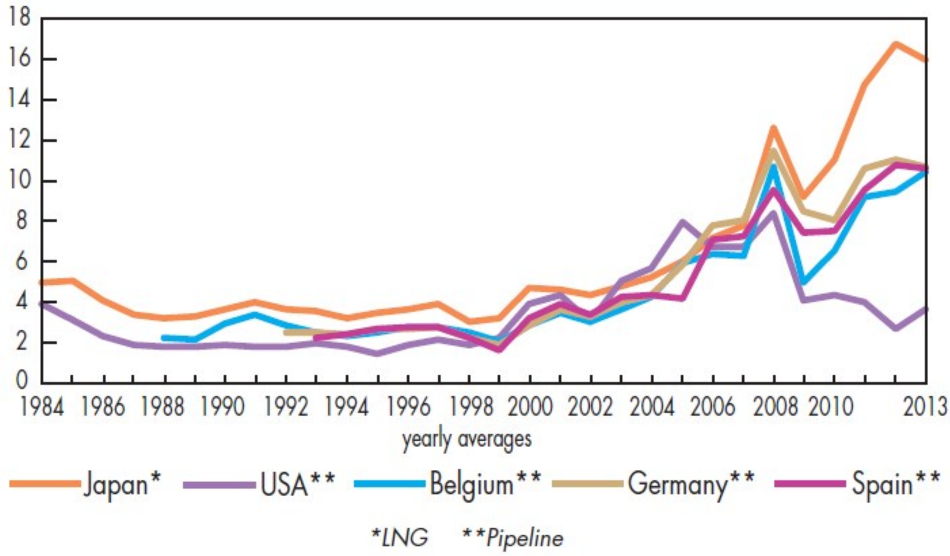
As for the terminating fossil energy resources and the unsustainability Schultz states that the problem is not the size of the stock of the fossil energy. The main problem is „before all fossil fuel would be used up the mankind would destroy the economy due to the environmental damages" (*Schultz*, 2005).

Creating the energy structure

Creating the sustainable energy mix and power plant structure is an economical, energy and environmental matter which is determined by energy politics through the energy strategy, based on the resources of the given country. Besides supply

Figure 1.

Natural gas import prices in USD/MBtu



Source: International Energy Agency: Key World Energy Statistics 2014

security, compliance with international and (for EU member states) Community commitments is another important factor. For electricity production this primarily means the reduction of harmful emissions, which among others, can be achieved by the wider use of renewable energy resources. Spreading renewable energy resources cannot only offer a solution to energy supply security issues but has several positive economic effects, too (e.g. creates jobs).

According to the prognosis of the International Energy Agency, the use of coal as an energy resource will be taken over by gas and renewable energy resources. In 2035, the proportion of renewable energy resources will be 3 times higher than the level of 2010, with different energy resource repartition in each economy (*Putzer*, 2013). Since 2011 there has been a decline in global investments in renewable energy resources, with the greatest decrease observed in the European Union. In 2013, China, the largest coal user took over the leading role from the EU with an investment of 56 billion USD, while in the EU the renewable energy sector, which is considered to be the most recession-proof, already takes up 1% of the GDP in the EU. Out of the global investments of 215 billion USD in 2013, solar energy took up 53%, wind energy 37.2%, and biomass 6.04% (with 2.34% biofuel) (*FS-UNEP*, 2014*; REN21*, 2014).

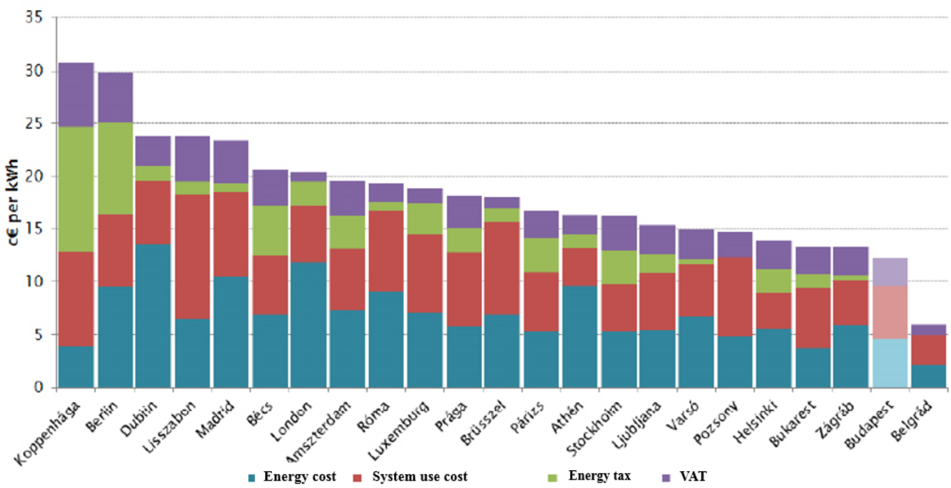
Governments around the world have begun to quantify the environmental costs by developing various financial instruments, subventions that are granted to those who generate or purchase renewable energy. Despite the globally increasing subventions, renewable energy resources are in a competitive disadvantage: in 2010 subventions for fossil fuels totalled 409 billion USD, while subventions for renewable energy resources totalled only 64 billion USD (*Dupcsák and Marselek*, 2013).

The retail price of electricity

Due to the fact that energy is one of the bases of production, the price of fuels and electricity is a determining factor in economic competitiveness. This is the primary reason for preferring certain energy sources when creating the energy mix. Due to the competition, there are no considerable differences in industrial electricity prices in EU member states, however, retail prices differ significantly. As shown in *Figure 2*, each component of retail prices shows considerable variance with taxes and other costs over energy prices being significant, too. Fiscal policies (taxes and fees) play a major role in forming prices. As shown in the example of Denmark, the energy fee does not considerably influence the retail price, other fees and taxes have a more significant impact. Hungary is the only EU member state with no energy tax implemented.

Figure 2

Household cosumers electricity tariff items in euro (eurocents/kWh) January 2015.



Source: MEKH, 2015

In countries with relatively higher consumer price levels, higher electricity retail prices are considered cheaper on purchasing power parity while with relatively lower consumer price levels, prices on purchasing power parity are higher. In countries with higher net income, there is an opportunity to create higher retail prices in order to rationalize consumption. Besides that, in accordance with the needs of the society, certain cost elements imposed on electricity retail prices can be increased, with the collected money used to subsidise the use of renewable energy resources.

The Levelized Cost of Electricity (LCOE)

Besides the environmental considerations viewed from the investment side it can be said that difference can be experienced not only due to the type of the energy source in the value of specific investment's cost. Over the primary commodities depending on the type of the utilization and the conversion, also there is a perceptible difference in its technological level and the plant size in the specific investment's cost and in the cost of the produced electricity power.

As a financial tool, LCOE is very valuable for the comparison of various generation options. LCOE is often cited as a convenient summary measure of the overall competiveness of different generating technologies. It represents the per-kilowatthour cost (in real dollars) and cost structure of building and operating a generating plant over an assumed financial life and duty cycle. As the *Table 1* represents, key inputs calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. Owing to the LCOE the investors can get accurate picture of the cost structure of the power generation, which involve numerous factors during investment decisions. The importance of the factors varies among technologies and regional characteristics, that is why the different generating technologies contain different risk during the cost recovery period. The factors such as project utilization rate, existing resource mix, capacity value, policy-related factors, portfolio diversification, marginal unit of new capacity determine the success of the project. To the same technology the different legal regulations and economic environment may produce very different financial results by countries, but in this case the same proportion remains between the values of productions. A relatively low LCOE means that electricity is being produced at a low cost, with higher likely returns for the investor. LCOE estimates may or may not include the environmental costs associated with energy production (*Namovicz*, 2013).

The different cost proportion of the power generation technologies also contain different risks or potentials in the future. The effects of inflation on future plant maintenance must be considered, and the price of fuel for the plant must be estimated for decades into the future. As those costs rise, they are passed on to the rate-payer. A renewable energy plant is initially more expensive to build but it has very low maintenance costs and there is no fuel cost in a life-time of 20-30 year with the exception of that based on the various biomass sources. In case of biomass from the point of view of greenhouse (GHG) gas emission and profitability, the transport distance has decisive importance due to low energy density.

Due to the component prices for photovoltaic systems fell drastically over the last years. Also this can be mentioned according to the onshore wind. According to sectoral forecasts, the efficiency of photovoltaic and wind power generation technologies will prove to be the best. Therefore, these renewable technologies can be a match for fossil energy sources in the future (*EIA*, 2014*; Lazard*, 2014*; DECC*, 2013*; Fraunhofer ISE*, 2013).

Table 1

Estimated levelized cost of electricity (LCOE)
for new generation resources, 2020,
(U.S. Average Levelized Costs (2013 $/MWh)
for Plants Entering Service in 2020)

Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (incl. fuel)	Transmission Investment	Total System LCOE
Dispatchable Technologies						
Conventional Coal	85	60,40	4,2	29,40	1,2	95,1
Advanced Coal	85	76,9	6,9	30,7	1,2	115,7
Advanced Coal with CCS	85	97,3	9,8	36,1	1,2	144,4
Natural Gas-fired						
Conventional Combined Cycle	87	14,4	1,7	57,8	1,2	75,2
Advanced Combined Cycle	87	15,9	2	53,6	1,2	72,6
Advanced CC with CCS	87	30,1	4,2	64,7	1,2	100,2
Conventional Combustion Turbine	30	40,7	2,8	94,6	3,5	141,5
Advanced Combustion Turbine	30	27,8	2,7	79,6	3,5	113,5
Advanced Nuclear	90	70,1	11,8	12,2	1,1	95,2
Geothermal	92	34,1	12,3	0	1,4	47,8
Biomass	83	47,1	14,5	37,6	1,2	100,5
Non-dispatchable Technologies						
Wind	36	57,7	12,8	0	3,1	73,6
Wind - Offshore	38	168,6	22,5	0	5,8	196,9
Solar PV	25	109,8	11,4	0	4,1	125,3
Solar Thermal	20	191,6	42,1	0	6	239,7
Hydroelectric	54	70,7	3,9	7	2	83,5

Source: *EIA* (2015).

The matter of technological development and efficiency

In sustainable development the goal is to achieve economic growth with the least possible environmental pollution which includes the greatest possible reduction of greenhouse gas (GHG) emission. The desired reduction of emission can be achieved in different ways, even by the simultaneous use of several instruments. Different alternatives compete for the investments. *Benkő and Pitrik* (2011) define the basic types of efficiency-increasing investments which also have positive effects on the use of renewable energy resources, rational energy use, energy savings and supply security. They also mention the decreasing of the unfavourable effects of current facilities thus making them "greener". For the most efficient possible use of resources it is advisable to examine the economical and environmental sustainability of investments and to choose the most efficient solutions, which does not necessarily mean the creation of modern, renewable electricity sources.

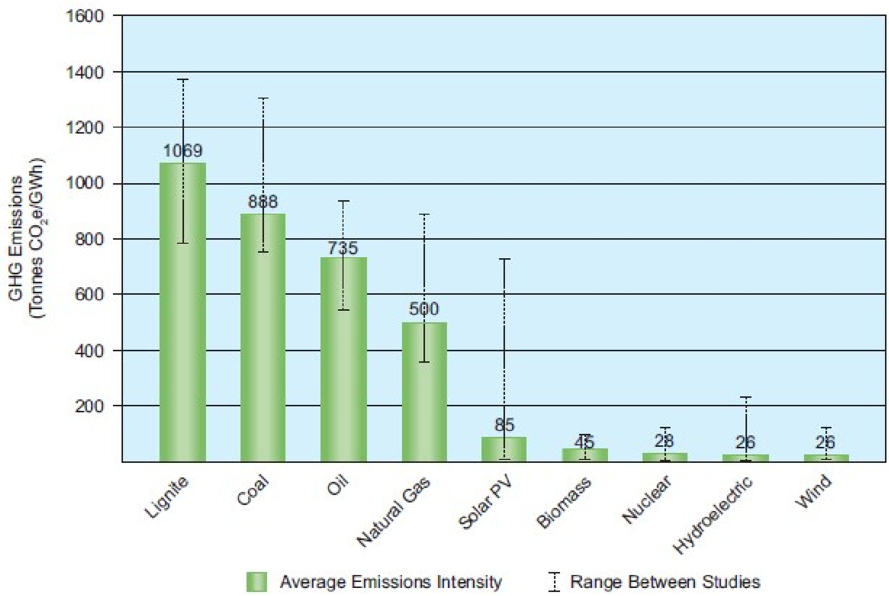
Relative carbon dioxide or GHG emissions are widely accepted indexes of energy efficiency. The emission of carbon dioxide and other greenhouse gases can be examined in several ways. It can be broken down to the emission of economic sectors, it can be connected to efficiency (related to relative economic performance or as per capita emission), and can also be characterised as one of the efficiency factors of electricity production. The energy use per unit of GDP on purchasing power parity is constantly decreasing in OECD countries. In the USA, energy intensity decreased to the 40% of the 1950 value by 2010 (*EIA*, 2013*; Eurostat*, 2014). The global value is primarily deteriorated by the high-proportion coal use of China where GDP-related carbon dioxide emission is more than twice of the USA values (*UNSD*, 2013). This can only be partly explained by technological developments, the favourable values in developed countries can also be attributed to the relocation of pollution-intensive industries. The average 2.5% growth of global primer energy consumption in the last 10 years can primarily be attributed to India and China (*BP*, 2014). The dispersion of use can be demonstrated by the fact that while in 2003 the per capita energy consumption in the USA was 4.1 times higher than the global average as opposed to the 2.2x, 0.33x and 0.11x relative values of the EU, China and India, respectively, now the per capita energy consumption in China exceeds the global average (*Ekéné Zamárdi and Baros*, 2004*; Zsoldos*, 2013).

The reduction of harmful substance emission and the related costs depend on the economical and technological level of each country. Economic competition facilitates this process, which is also supported by the words of Shrivastava as cited by *Kerekes* (2014): "Companies may profit from cutting down costs by increasing ecological efficiency, they may tap green markets and gain other advantages … they may improve their image". *Porter and Van Der Linde* (cited by *Kerekes*, 2014) share the same opinion: "the ecological effect turns into resource efficiency which may result in competitive advantage." Due to technological differences, the cost of emission reduction differs considerably in developed and developing countries. Reducing the carbon dioxide emission by 1 ton costs 300 to 500 USD in developed countries while only 10 to 15 USD in developing countries (*Nagy*, 2006). This raises the question whether it would be more effective to support the technological developments in developing countries rather than subsidizing EU investments. To address this issue, the United Nations Framework – Convention on Climate Change, Green Climate Fund; UNFCCC – GCF) was created which spends 100 billion USD on these projects in the following years (*Fenton*, 2014*; Lattanzio*, 2011).

GHG emission is one of the major elements of environmental costs. Results aggregated by World Nuclear Association (WNA) from various literature sources also support that emissions from renewable energy resources are significantly lower than that of their fossil counterparts (*Figure 3*). It must be noted, however, that there is a considerable dispersion among the results of the individual studies. It is interesting that emissions from conditionally renewable biomass is lower than that of the renewable solar energy, despite the fact that exploiting biomass energy involves the production of raw materials and the transportation of products of low energy density.

Figure 3

Lifecycle GHG Emissions Intensity of Electricity Generation Methods



Source: *WNA* (2011)

The achievements from technological developments driven by competition have complex effects that may have adverse influences on sustainability. Thanks to the innovations, not only renewable energy resources become more and more competitive but also less-accessible conventional and unconventional fossil energy deposits can be exploited profitably. It must be noted, however, that despite the improvements in technological efficiency, more and more energy must be invested in order to recover one energy unit. The "Energy Return on Energy Invested" (EROEI) index shows how much energy can be acquired from a particular energy resource by expending 1 unit of energy. A report by Worldwatch Institute also confirms that despite technological developments, the average EROEI value of petroleum is globally decreasing, having been 100:1 in 1900 and being only 20:1 at present times. According to data of the USA petroleum industry, the return of energy invested decreased from 24:1 to 11:1 between 1954 and 2007 (*Zencey*, 2013).
At present times, developments make it possible to decrease the external effects of use of fossil energy resources. This helps maintain the competitiveness of traditional electricity producing capacities, making them alternatives of renewable energy investments. Examples of these new technologies are cogeneration systems

and carbon capture and sequestration (CCS) systems which are recommended by IPCC as well (*Pápay*, 2011; *Valaska*, 2011). There are several carbon capture methods (*Buzea*, 2013) which can also be associated with carbon emission trading (*Horánszky*, 2012). Studies in this field were conducted in Hungary as well, concluding that our country has favourable conditions for storage capacities (*Szunyog*, 2012). Although this technology appears to be quite promising, it is currently in early developmental stages and does not have widespread commercial application. Therefore, the lifecycle GHG emissions cannot be accurately estimated and have not been included in the WNA report. CCS systems significantly decrease harmful emissions, however, due to the energy used for carbon capture the electricity production of power plants decreases as well.

For certain energy production and energy efficiency technologies, calculating the additional costs of relative primer energy savings provides us with a more accurate overview from the points of view of environmental sustainability and comparability of investments. These calculations can compare not only electricity producing technologies but also investments in energy efficiency (adding heat insulation, replacing doors and windows) where there is considerable energy efficiency potential to be exploited. Besides that, an accurate overview of the general situation can be produced, with the possibility to compare it with the technological level of other countries or industries.

CONCLUSIONS

Due to the large number of factors, the per unit investment costs and harmful emissions of fossil and renewable energy resources show a great variety between countries and regions, even within the same technology. When planning an investment, in addition to the economic sustainability, the environmental sustainability of the project should also be examined using eligibility criteria. This would particularly be important for conditionally renewable biomass where transportation costs and energy investments substantially influence the energy balance and harmful emissions. Thanks to technological innovations, a considerable increase in competitiveness can primarily be expected on the market of renewable energy resources. Until then, besides strict regulation, currently competitive, technologically sound investments of the same environmental effects (e.g. modernization of transmission systems in order to increase efficiency by decreasing losses) may be preferred. This way, the consequences of the "rebound effect" can be minimized, too. Fast technological advancements offer a take-off point for the companies in the industry, by giving them an opportunity to increase their market share.

The retail price of electricity affects competitiveness, too; low retail prices are favourable for consumers while higher prices help increase effectiveness and promote a more rational use. Retail prices of electricity are influenced by other fee elements than by the actual production costs to a greater extent.

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