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INCREASING ENERGY EFFICIENCY: BENEDICTION OR MALEDICTION

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Abstract: During this decade we have to face some problems such as global climate changes, increasing energy consumption of developing countries, new trends in energy sectors. Not only the governments, but the companies aim to enhance the energy efficiency. Usually improvements in energy efficiency lead to reduced energy consumption and it have a positive impact on economic growth. But in special cases it can happen that increasing energy efficiency results in the enhance of energy consumption.

Keywords: energy efficiency, rebound effect, energy consumption, Jevons-paradox.

1. INTRODUCTION

General target of the politicians is the emission reduction and slowing the exploitation of non-renewable energy sources. The main tool to reach these goals is increasing of the economy's energy efficiency. The retrenchment with non-renewable energy sources (for example fossil fuels) is really reasonable and it can be explained from many sides. From the environmental side the resource scarcity, which means that the reachable resources is restricted by the technology; from the economic side the target is to enhance the cost efficiency, reduce the dependence on imported energy and increasing of the energy safety.

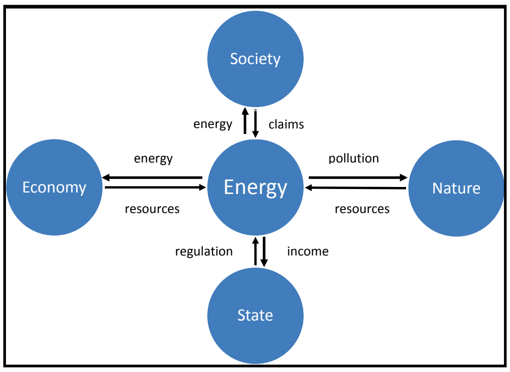
The first theories of resource scarcity were created by T. Malthus and D. Ricardo (Zilahy, 2000). Malthus has deal with economic analysis of population: according to him the rising of population is exponential, the produced food increase as arithmetic series. "Population, when unchecked, increases in a geometrical ratio. Subsistence only increases in an arithmetical ratio." (Samuelson et al. 2008).

The absolute and relative form of the scarcity emerged later in the work of J. Mill, W. Jevons and A. Marshall (Zilahy 2000). W. Jevons proved firstly the existence of rebound effect (take back effect or offseting behavior) in "The Coal Question" book published in 1865. "The reduction of the consumption of coal, per ton of iron, to less than one third of its former amount, has been followed … by a tenfold increase in total consumption, not to speak of the indirect effect of cheap iron in accelerating other coal consuming branches of industry." According to Saunders H. already the neoclassical growth theories predict that the clean developments in the productivity of labor, capital, material enhance the total energy consumption. For example the technological changes are the main cause of these productivity improvements (Sorrell 2009).

The energy economy stems from the resource economy and it exists from 1973. Actually this is the economy of fuel markets and it includes every conception in connection with analysis of energy sources (Evans et al. 2009). Many studies demonstrated the positive and strong correlation between the economic growth and energy consumption (Sorrell et al. 2007, Jin et al. 2009, Tsani 2010, Warr et al. 2010). Although it is not clear, which factor is the dependant or independent one. According to Cleveland "the correlation between aggregate energy consumption and GDP in both industrialised and developing countries is undeniable. While industrial countries appear to have partly decoupled growth in energy consumption (measured in kWh heat content) from growth in GDP in recent years, the close correlation reappears when energy consumption is weighted by the quality of different fuel types." When the shift towards higher quality forms of energy is taken into account, energy use and the level of economic activity appear to be tightly coupled, despite ongoing improvements in energy efficiency (Sorrell, 2007 Technical Report 5. pp.8). According to the neoclassical and endogen development economies theories the increasing energy use affect just a little the economic growth (because the energy costs is a little part of total costs).

Contrarily the opinion of the ecological economists is the cause of economic growth in the last two century was the accessibility to energy inputs, which represent a higher level of technology (Sorrel 2009). Nowadays not only it is discussed that the energy efficiency can contribute to the reducing of energy consumption, but the energy efficiency has a positive effect on economic growth (Madlener et al. 2009).

According to the newest theories (H. Herring) the main objective has to be not the energy efficiency but the energy saving. The energy saving means the lowest level of energy consumption. According to H. Herring in the future there will be the revolution of four production factor (work, capital, energy, material): in the industrialized countries there is a shift towards the dematerialized economy. It means the main cause of the economic growth is not the increasing demand for energy and other resource. We can save our planet if we emphasize the restrictions and conservations, not the energy efficiency and consumption (Herring 2006). But in fact the consumers make concrete steps towards the energy savings if they get real economic benefit (Vajda 2001 pp.50).



Picture 1: The modells of interactions
Source: Vajda Gy. 2001 pp.66

2. CLARIFY OF BASIC ENERGETIC DEFINITIONS, WITH SPECIAL REGARD TO THE REBOUND EFFECT

D. Khazzoom called attention to the direct rebound effect in 1980; afterwards, the topic has got into the focus of many researches – especially in Anglo-Saxon areas (S. Sorrell, H. Herring, C. Saunders). He was the first to give a plausible explanation to why measures associated with developing energy intensity at macro-economic level have not resulted in the intended decrease in energy consumption (Barker et al. 2008). Before embarking on explaining the rebound effect, I hold it necessary to clarify the subject of energy, energy intensity, energy efficiency, technical and market potential.

Energy means, in economy and physics, working capacity which is the extractable work from a given system in a given environment. Physical energy is not the actual working capacity; it is rather an abstract quantity that relates working capacity to mathematically well-defined reference state, a vacuum. In physics, energy remains, however in the economy the quantity called energy does not remain, it "runs out" (Kádár et al 2010). The quantity called energy in the economy is called exergy by the technical and scientific literature. This quantity gives the maximum extractable energy in the given environment which is described physically by temperature, air-pressure and chemical potential. Exergy means the working capacity of a system in an environment described with constant conditions. This is the usable energy and this is what we have to manage.

The Final Energy Consumption (F) means the energies used for energy and non-energy purposes by customers. The end energy users include manufacturers (industry), transport, households and the population (buildings) and other energy users according to the statistics. In statistical statements and comparisons we may relate the end energy consumed to the total value of domestic production (GDP), which is called end energy intensity.

$$\varepsilon_F = \frac{F}{GDP}$$

Or to the number of population (L), which is called end energy consumption per capita:

$$f = \frac{F}{L}$$

By the Primary Energy Supply (G) both domestic and imported sources can be found among the primary energy-consumption. Traditionally, we regard exhaustible energy resources as primary energy, more specifically combustible (fossil) energies (coal, petroleum, natural gas) and nuclear energy. We either relate the consumed primary energy to the total value of domestic production, which is primary energy intensity:

$$\varepsilon_G = \frac{G}{GDP}$$

Or to the number of population, which is the primary energy consumption per capita:

$$g = \frac{G}{L}$$

Energy conversion, transport and distribution entail losses. Those losses altogether mean the loss of the energy supply system:

$$L=L_{con}+L_{trp}+L_{lo}$$

This loss causes the difference between primary energy and end energy:

$$L=G-F$$

and the efficiency of energy supply can be interpreted by means of this energy loss:

$${}_F = \frac{F}{G}$$

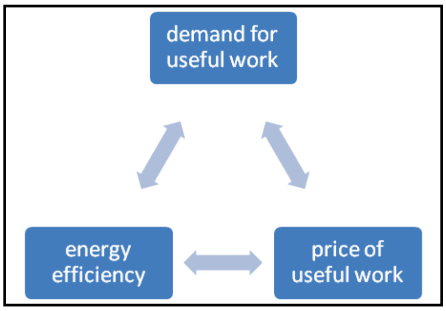
(Hungarian Academy of Sciences, 2010 pp.12)

Energy efficiency is actually the rate of useful outputs and energy inputs in the system. The system can be a building, an industrial process, a company, a sector or a whole economy. In each case the index-number of energy efficiency depends on how the inputs and outputs were determined (Sorrell 2009). Energy efficiency can be interpreted in many ways. “Technical efficiency is the ratio of useful energy consumption and primary energy consumption: it shows how much useful energy we can get with the consumption of a unit of primary energy in the case of a given energy conversion” (Hungarian Academy of Sciences, 2008 pp. 73). Economic efficiency means the economic yield of energy investment, the value of the indicator has no limit in principle (Vajda 2001 pp.54).

By engineering potential we mean the maximum amount of energy we can save by way of a technological innovation (Zilahy 2000, Madlener et al. 2009). Market potential is a narrower category, it is the potential energy saving actually achieved in practice. It shows what is viable on the market from the technical and financial side (Zilahy 2000).

According to S. Sorrell „the rebound effect is an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency". Even the smallest increase in the demand for energy services reduces the energy savings resulting from the growth of energy efficiency (Sorrell et al. 2009 pp.1356). For example, a customer who buys a more economical car (more efficient, less petrol consumption) decides to use it more frequently because of the lower operating costs per kilometre. Another typical example is related to the household sector: the heating temperature will increase as a result of the reduction of heating costs per m2 (e.g. the thermal insulation of a house), or even the heating period will be longer.

York suggests that the rebound effect is a kind of ecological paradox. The increasing energy efficiency often entails the increased load on the environment, at least at national level. The paradox of the paperless office: developing a substitute for a natural resource may enhance the consumption of the mentioned resource (York 2008).



Picture 2: Appearance of endogeneity in energetic
Source: Sorrel 2007 pp.37 – own construction

The picture above indicates that an energy efficiency measure reduces the real price of useful work and thus it increases demand. At the same time however, the increased demand may have a motivational effect on energy efficiency. We call this phenomenon endogeneity, that is, the relevant factors partly determine each other (they reinforce the effect of one another) (UKERC 2007. Technical Report 2, summary).

3. PUBLICATION OF REBOUND EFFECT IN THE INTERNATIONAL AND HUNGARIAN ECONOMIC LITERATURE

The first European Union strategy mentioning the existence of the rebound effect is the Energy 2020. "It is necessary to address the paradox whereby demand for more energy-intensive or new products outstrips gains in energy efficiency" (Energy 2020 pp. 6). In accordance with this recognition the European Union set a 20% energy saving as a strategic goal (it is worth mentioning that it is about energy saving instead of energy efficiency).

Vajda Gy. was the first in Hungary to mention it in his book written in 2001: "improving the efficiency is the permanent responsibility of technical development, although its result can be noticed slowly. Although there are technical advancements bringing about an immense reduction in the specific energy consumption, it is exactly the rapid spread of the utilisation of these procedures that offset savings. A good example is the massive expansion of information technology equipment: notwithstanding the several percent decrease in the energy consumption of modern personal computers every year, their sales growth exceeds this percentage by many times and they appear in every household" (Vajda 2001 pp.51).

4. THE CLASSIFICATION OF THE REBOUND EFFECT

Two types of the rebound effect are known: direct and indirect. According to the former one any efficiency improvement in energy supply reduces its price, which leads to the increase of demand for that service. The indirect rebound effect comes from the substitutability of goods: the price decrease of energy leads to the rearrangement among the groups of goods consumed by a consumer. E. g.: the thermal insulation of a house leads to the reduction of heating costs; the savings achieved this way will be spent on holiday by a given family which, in turn, will enhance the consumption of kerosene or other fuel.

Economy size rebound effect = DRE + IRE

where:

DRE: direct rebound effect
IRE: indirect rebound effect

The economy-wide rebound effect is the sum of direct and indirect rebound effect. It means "the percentage of the expected energy savings caused by the energy efficiency improvement" (Sorrell 2009, pp.1457). If the rebound effect is more than 100 percent, it is called backfire (Madlener et al. 2009).

Some authors (A. B. Lovins, L. Schipper, M. J. Grubb) question the rebound effect: those surveys explain the growth of energy consumption with the rise of the level of welfare and the increasing consumption, furthermore with the fact that the expenditures associated with energy constitute a small part of the total cost (Evans et al. 2009); while other explanations suggest that certain market barriers hinder the price-decreasing mechanism of the energy efficiency measures (Barker et al. 2008). It is essential when measuring the rebound effect that additional consumption originating from income growth is screened out.

5. FACILITIES OF MEASURE – THE DIRECT REBOUND EFFECT

There are two possibilities of measuring the rebound effect: the first is a simple estimation by which we examine how much the demand for energy supply was before and after the energy efficiency innovation. The methodological elaboration of these measurements is very soft because they try to draw conclusions only from a before and after comparison. The other method of estimation is associated with the econometric analysis of secondary statistical data. In this case the data can be varied: panel data, cross-sectional and time series data; furthermore, different levels of aggregation of data can be in use (economic sector, region, country). Depending on the availability of data the estimate of the rebound effect can be calculated from the elasticity of the followings:

$\eta_\varepsilon(E)$: elasticity of the demand for energy (E) associated with energy efficiency (ε)

$\eta_\varepsilon(S)$: elasticity of the demand for "useful work" (S) associated with energy efficiency (ε) ($S=\varepsilon E$).

Energy saving resulting from efficiency growth can only be equal to technical saving if the demand for energy supply remains unchanged, i.e. $\eta_\varepsilon(S)=0$. In this case x% of energy saving results in x% reduction in energy consumption ($\eta_\varepsilon(E)=-1$). Rebound effect occurs if $\eta_\varepsilon(S)>0$ and $0>\eta_\varepsilon(E)>-1$, while "backfire" effect occurs if $\eta_\varepsilon(S)>1$ and $\eta_\varepsilon(E)>0$ (Sorrell et al. 2009). That is, the rebound effect being 20% means that 20% of the potential energy saving has been lost.

Rebound effect may occur due to substitution, income and price effect. The essence of the income effect is that price-decrease occurring as a result of energy efficiency increases the demand for the given good, thus excluding potential energy-saving. According to the substitution effect the growth of consumption occurs because of the decrease of the relative price of the good. The essence of the price effect is that while at the beginning the given energy-input is used in small quantity in production, the price reduction due to the energy efficiency growth has lead to the substitution of other production factors with energy inputs (Madlener et al. 2009). That is, the rebound effect can be examined from the point of view of both manufacturers and customers. While in the former case the effect can be divided into the mentioned substitution and production effects, in the latter case substitution and income effects can be distinguished (Sorrell 2007).

6. SIZE OF REBOUND EFFECT

Dinya, L. asserts that "the purest energy is what is not necessary to be produced – that is, what we can save (the so called negajoule). According to some calculations the energy-saving potential is 20-25% in the developed countries, in the less developed ones – also in Hungary – it is 30-35%" (Dinya, 2010. pp. 4).

It is indispensable to know accurately and to forecast the degree of the rebound effect for elaborating the appropriate national strategies. The most important question is whether the degree of the rebound effect is such high that it against the arguments in favour of energy efficiency (Madlener et al. 2009). Two standpoints can be observed among the energy economists: according to one group energy consumption is higher if there is no improvement in energy efficiency (main representatives are L. Brookes és H. Saunders). In the opinion of the other group (main representative is L. Schipper) energy consumption is lower in the lack of the increase of energy efficiency (Herring 2008). Next I try to present the size of the rebound effect in different sectors.

Table 1: Size of direct rebound effect

Direct rebound effect (long term)	**< 10-30% (others 5-50%, (Binswanger 2001))**
household heating, cooling	< 10-60%
household water heating	< 10-40%
lighting	< 0-2%
household devices	< 20%
public transport	< 10-30%

Source: Own construction

7. SUMMARY

Reducing emission, the dependence on fossil fuels, enhancing the diversity of energy resources is an important objective of governmental policies one method of which is improving energy efficiency. Nowadays it has become particularly important to make decision makers accept the rebound effect since currently the governmental energy efficiency measures only take technical energy saving into account, they assume that the degree of the rebound effect is zero.

The strongest objective of the European and Hungarian energy policy is improving energy saving that is related to the end energy use, i.e. energy users (Utilisation of renewable energy, 2010). The European Commission has recently published its strategic document "Energy 2020" in which it set a goal of a 20% energy efficiency improvement till 2020, as well as the separation of economic growth and the related energy consumption (Europe 2020). Commitment to enhancing energy efficiency appears in both the National Climate Change Strategy and the New Széchenyi Plan, although specific target numbers are not included in the document. Knowing the degree of the rebound effect one can establish how much energy efficiency improvement is necessary for the saving of a certain amount of energy.

In spite of the increasingly intensive research activity, the evidences relating to the existence of the rebound effect are scattered, which is predominantly the consequence of the lack of data. The existing results are limited to the following sectors: transport (passenger and air traffic), households (e.g. researches concerning heating and the use of electronic device), industry and trade (Barker et al. 2008, Sorrell et al. 2009). Few surveys analyse the presence of the effect in the case of groups of different social status in the society (Wadud et al. 2009). That is, the main objective of the surveys is to identify and clarify those factors triggering rebound effect that cause changes in energy consumption due to the improvement of energy efficiency (Evans et al. 2009). The main question, according to the energy economists (Jevons, Brookes, Khazzoom, Saunders), is that measures alone aiming at increasing energy efficiency will no lead to energy saving.

S. Sorrel in his paper published in 2007 calls for a better structuring of researches done on the field of energy, that is he calls for the application of Evidence-Based Policy and Practice (EBPP) which means the integration of the best available evidences derived from experiences, opinions, expertise and systematic research. In his view, the efficiency of the surveys in the field of energy economics would be greatly enhanced by the delimitation of the research questions of the given topic, systematic and profound review of the literature, application of explicit criteria in setting up categories, transparency, appropriate summarisation and synthetisation of the results, and its wider public dissemination (Sorrell 2007). The application of these basic principles in measuring the rebound effect as well would lead to the smaller dispersion of the results and their better adoption by the decision makers.

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