Second Regional Conference
Industrial Energy and Environmental Protection
in South-East Europe
Zlatibor, Serbia 2010

TAKSONOMIC AND TERMINOLOGIC INOVATION OF TERMS RELATED TO ENERGY EFFICIENCY

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INTRODUCTION

An increase in energy efficiency is certainly the best way for climate changes mitigation. The investments in energy efficiency are more payable than the investments in building new plants. In a life cycle of a product and services, investments in energy efficiency have even less carbon print, than renewable energy sources. All the facts point to the necessity to increase energy efficiency. But many energy efficient improvements do not reduce greenhouse gasses emission, and the greenhouse effect still grows. The main goal of this paper is to show, through certain analysis, where should be taken action in order to reduce greenhouse gasses emission, by increasing energy efficiency. In that case, it should be necessary to suggest different classification of energy efficiency notions and introduce some new terms.

1. WHAT IS ENERGY EFFICIENCY

The unique definition of energy efficiency does not exist. Even the IPPC directive [32] which requires the energy efficiency of a plant, does not give its definition. In a wide term, under energy efficiency is considered the process of using less energy to perform the same function. This, increased energy efficiency releases certain amount of energy on the market, which can be used to satisfies the needs of further consumers and it can be considered as the new energy resource, so the energy gained this way is popularly called *negajoule* [2]. However, if literature is analyzed, three groups of energy efficiency definitions can be sighted. First group defines energy efficiency as the ratio between energy left the technical system (for conversion in the form of useful energy) and energy put into the system. Second group defines energy efficiency as the ratio between the function of the system and energy enter the system. In that case, the dimension is equal to the ratio between the measure of the service and input energy. Third group of definitions put the question what is the real function of the system that uses the energy.

In the first group can be found definitions like: energy conversion efficiency is the ratio between the useful output of an energy conversion machine and the input, in energy terms (the useful output may be electric power, mechanical work, or heat) [11]; the amount of energy extracted from a system divided by the amount of energy put into the system in order to recover the energy [14]; a measure of energy produced, compared to energy consumed [20]; indication of how efficient energy is converted from one to another [21]; cutting down on waste energy (a good example is an energy efficient light bulb which produces the same amount of light as a conventional bulb but uses up to 75% less energy to do so) [28]. The authors of Energy Management Handbook [3] use the energy efficiency term generally, as the process of more rational energy use. But they also use terms as a boiler efficiency, an engine efficiency, a system efficiency (larger number of energy sources and larger number of energy consumers) or, in general, mechanical equipment efficiency (the ratio between output and input energy). They make a difference between gross and net efficiency. Net efficiency relates to basic device, and gross efficiency also includes energy consumption of auxiliary plants. Another term that is also in use is combustion efficiency, which is not the same as the heat engine efficiency, because only the losses in the process of combustion are being observed, but not the other losses. But, it is clear, under efficiency is considered the efficiency of technical system.

In the second group are definitions connected to insuring some technical system, for example, using less energy to accomplish the same task, such as heating or lighting a building [12]; using less energy to perform the same function [13]; methods and technology that can reduce the amount of electricity or fuel used to do some work, such as keeping a house warm using less energy [15]; the term that refers to how effectively energy is being used for a given purpose, for example, providing a similar (or better) level of service with less energy consumption on a per unit basis is considered an improvement in energy efficiency [18]; the ratio of the useful output of services from an article of industrial equipment to the energy use by such an article, for example vehicle miles travelled per gallon of fuel (mpg) [22]; reducing the amount of energy used for a given service or level of end-use service – energy efficiency improvements are predominantly achieved through using technologically more advanced equipment [23]; energy efficiency involves promoting all behaviours, working methods and production techniques that consume less energy for the same rate of production [24]; energy efficiency is the practice of reducing the amount of energy used without reducing the end-use benefits enabled by that energy – it can be categorized in a number of ways including end-use efficiency and end-to-end efficiency [25]; refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, without affecting the services provided [27]; energy efficiency refers to the activity or product that can be produced with a given amount of energy, for example, the number of tons of steel that can be melted with a megawatt hour of electricity [29]; refers to products or systems using less energy to do the same or better job than conventional products or systems – energy efficiency saves energy, saves money on utility bills and helps protect the environment by reducing the demand for electricity [16]; reducing energy or demand requirements without reducing the end-use benefits [19].

In the second group can also be inserted BAT document for energy efficiency [4]. According to this BAT, defining of energy efficiency is complicated task. It is not possible to present it in a way to satisfy all interested parts. Although this term is in use, it still has not been clearly defined. And when it is defined, it depends on concept of observing. It is possible to define it in a frame of certain subsystems, but the problems occur when complex industrial plant is being observed. The question is does it refer to primary or secondary energy. Energy efficiency should be differed on macro level (for example the state) and micro level (for example industrial plant). In accordance with IPPC directive, energy efficiency refers to industrial plant, not the product; life cycle of the product is not considered. The term energy service also belongs in this group of definitions. It is useful energy extraction of energy from a power plant, for example mechanical work, transportation, heating and cooling, ventilation, lightning, processing of data, telecommunication, television etc. [31].

According to the Energy saving directive [9] BAT defines energy efficiency as the ratio between energy outputs and inputs. BAT defines energy efficiency as the amount of used energy per unit of product or per unit of raw material (this ratio is also called as specific energy consumption, or energy intensity factor) [4]. The difference should be made between energy efficiency of the location and energy efficiency of the plant, because energy efficiency of the location is not energy efficiency summary of all plants on that location. Energy efficiency should be made for certain period of time. It has to be longer period of time – months, a year [4].

Third group of definitions rarely appear in literature; they do not relate only on technical devices that perform conversion of energy or support certain service, but also on human behaviour. Not only specific loses of energy in space are observed, but also how much and how often people use heating or cooling, weather to save the energy, or for the medical reasons, they heat confined space more intensively [17].

When is spoken about energy use efficiency, literature shows two more terms „efficacy“ and „effectiveness“. In the Handbook [3] the term „efficacy“ is used only in connection with the light and defines the ratio of lumen per vat of used energy of lightning devices. It means that unlike the definition that appears on old energy devices, where efficiency (as the ratio between output and input energy) is dimensionless number, this way of efficiency is dimensional number and has a certain name. The energy effectiveness factor is defined as a dimensionless ratio that enables the effectiveness of the conversion of energy form the depletable resource potential form to the final use form to be expected [16].

There are few more terms that can be found in literature, that describe effectiveness of energy use – the most used term is energy intensity. Energy intensity is the amount of energy use per unit of activity. Examples of activity measures in households, floor spaces, passenger – kilometres, tone – kilometres, physical units of production, or gain [30]. The difference between efficiency and energy intensity is obvious – one is simply the inverse of the other.

BAT [4] also introduces terms such as energy intensity factor and energy efficiency index. These terms introduced for benchmarking between some plant and the referent plant of the same production type. Energy intensity factor is defined as the ratio of distinction between energy put into the system and extracted energy and produced product (dimension, for example GJ/t). Energy efficiency index is ratio between energy intensity of the referent plant and given plant.

The conclusion: there is no unique definition of energy efficiency term. In general, this term is used to describe the process of achieving the goals by reducing energy use. Some authors define it as the ratio between energy extracted from the technical system in the form of useful energy, and energy put into the system. The others define it as the ratio between gains achieved by energy usage (heated confined space, the distance crossed by car). In both cases energy efficiency is related to engineering approach and methods – just in one found case was spoken about energy efficiency in a function of human behaviour.

2. REBOUND EFFECT

One of the explanations why, even after the measures for reduction of energy consumption are taken, energy consumption is not being reduced, lies in the appearance of so called *Rebound effect* [1]. The rebound effect can be defined as the difference between the projected and actual savings of energy due to increased efficiency. It can also be defined as a tendency to spend more energy, caused by improvements in energy efficiency that results in lower utility bills. Rebound effect can be calculated as:

$$RE = \frac{\text{expected savings} - \text{actual savings}}{\text{expected savings}} \text{ x } 100$$

Rebound effect can be observed in time frames (short, medium and long term), as well as within system boundaries (household, firm, sector, national economy). Rebound effect can be direct, indirect and macroeconomic.

Direct effect: the consumer chooses to use more of the resource instead of realizing the energy cost savings. For example, a person who has a more efficient home heater will choose to heat the home more, or a person who drives a more efficient car will choose to drive more.

Indirect effect: a person will choose to spend the money saved, by buying other goods which use the same energy resource. For example, a person who saves the money due to a more efficient air conditioner will use the savings to buy more electronic goods.

Macroeconomic: decreased demand for a resource leads to a lower resource price, making new uses economically viable. For example, production of energy efficient, but socially unnecessary goods, such as solar garden lights. Although these devices are energy efficient, their usage do not comprehend in total energy savings, because a lot of energy is spent for manufacturing these products, and without them on the market, a person would use conventional lights instead, and would spend energy for unnecessary lightning. Spending energy on manufacturing, leads to emission of greenhouse gasses in the atmosphere, so instead of reduction of greenhouse gasses emission and energy savings, energy use increases, as well as the emission of CO_2 in the atmosphere. This is the most difficult aspect of the rebound effect to predict and measure.

Actual measures of the rebound effect can be related between 0% and 100%. The measure of the rebound effect shows the size of actual savings of energy due to increased efficiency.

Rebound effect appears when a person or a firm invests money, saved due to increased energy efficiency in some other activity which leads to increased energy consumption. For example, the plant which saved money due to energy efficiency improvement, will invest the saved money in building a new plant, which will result in increased energy use and increased CO_2 emission. Under the certain circumstances, rebound effect can turn an increase in efficiency into an increase in demand, which results in increased CO_2 emission. However, this has only happened in very special cases, such as in some developing countries or in new markets, such as the coal market in the mid 1800s, or the electricity market in the early 1900s. Today, for mature markets, it is generally accepted the existence of the rebound effect, but it is limited. Rebound effect depends on many variables, such as specific resource, the specific device, how developed the resource market and overall economy are.

Table 1. The ratio between certain device and rebound effect

DEVICE	SIZE OF REBOUND EFFECT (%)
Electric equipment	0% - 40%
Home appliances	0%
Space heating/cooling	0% - 50%
Automobiles	10% - 30%

Knowledge of the size of the rebound effect is necessary to assess the realistic contribution of energy efficiency. The rebound effect is a complex topic that cannot be ignored. The studies show that the key factor that influences on the size of rebound effect is consumers' awareness and socio–cultural factors. It is important to know, that beside technological development, energy efficiency and the size of rebound effect are influenced by many different factors, such as: public relations, economic development, tradition, culture, and social norms.

3. THE SUGGESTION FOR TAKSONOMY NOVELATION

The essence of taxonomy that is suggested is monitoring of energy flow from entering the production system through three systems (Fig. 1):

1. energy system,
2. process system and
3. management system.

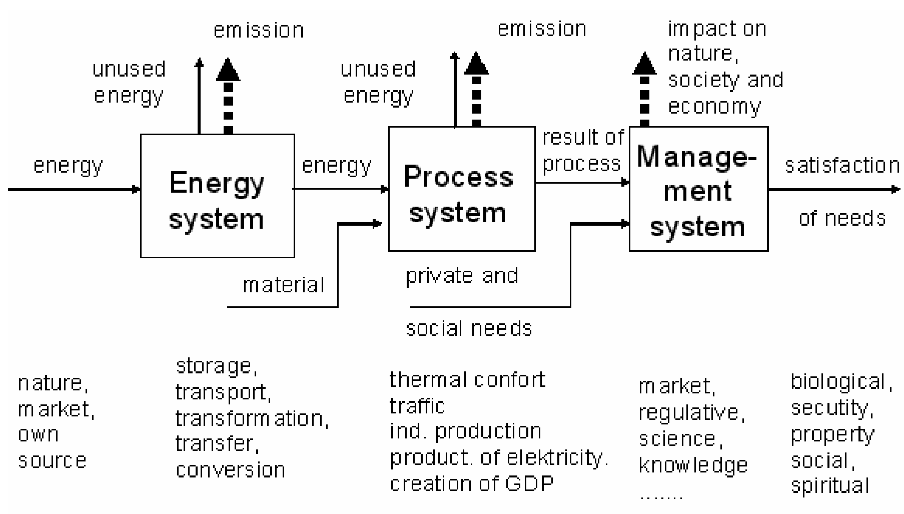


Fig. 1. Taxonomy of energy use process

Energy system is technical system where energy is entry and exit. On the entry is the energy from the nature (primary) or from the market (secondary) – depends on management system type, and on the exit is useful energy (secondary energy for the market, or the form of energy needed for process system functioning). In energy system, one or more energy processes can be accomplished, out of five: (i) storage (keeping the energy carrier for a while), (ii) transport (energy carrier transition from one to another location), (iii) transformation (the change of potential of certain energy form), (iv) transfer (from one energy carrier to another) and (v) conversion (energy transition from one form to another) [8].

Process system is also a technical system, where different processes are being accomplished (industrial manufacturing, traffic, creating a thermal comfort in confined spaces), where the entry is energy with all parameters needed, and the exit is preformed function (product – processed material, archived temperature in confined space etc.). The energy that leaves the process system is unusefull energy, which means that it stays embodied in the product.

Management system is the system which uses the results of process system. Its functioning is based on market regulation (incentives and disincentives), moral, culture, science development, etc. The exit from this system is satisfaction of private and social needs. The most common needs classification, by Maslow, can be expressed as: physiological, safety, property, social and spiritual ([5], [6]). This system also leads energy and process systems. It means that energy and process systems are subsystems of management system. It is clear that first two systems are techno–economical systems, while the third system is social, business system. First two systems have environmental impact, and their effects on the environment are regulated through environmental protection techniques. At the same time, management system has the influence on the nature, society and economy and these effects are regulated through sustainable development approach.

3.1. Suggested terms

Suggested terms are relying on practice. Within technical system frame, often used term is device efficiency (boiler, furnace) and it is accepted here. It is dimensionless number and it shows the ratio between useful output energy and energy put in energy system. For observed cases, this term is in concrete:

- inhabitation: the ratio between the energy delivered to a dwelling and the amount of energy which enters the boiler house or individual furnace; it is rated around 0,8,
- transportation: would be the engine efficiency of the car engine; it is rated around 0,4, but the data of the car engine efficiency is not used in practice,
- industry: the ratio between amount of energy which is delivered to process system and the amount of energy gained on the market; it can be rated around 0,8,
- production of electricity: the ratio between useful energy released from the boiler in a form of overheated steam under pressure and fossil fuel energy and energy spent through secondary devices (coal delivery, ventilation); it can be rated around 0,85, and it is also not used in practice (because, by chance, the output product of the process system has energy dimension),
- the state: the ratio between secondary forms of energy which energy sector delivers to industry sector, agriculture, inhabitation and other sectors and the amount of primary energy – it can be corrected with the amount of import/export of energy; it is rated around 0,6.

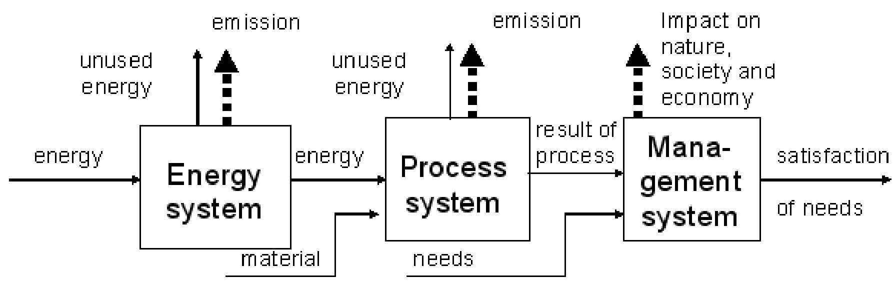
Within the process system frame, the most often used indicators are indicators that show the amount of spent energy per unit of product or function. So:

- inhabitation: energy spent per unit of dwelling area, which has been heated for a year (for example 100 kWh/m^2 a);
- transportation: energy spent per unit of the road, also includes engine efficiency;
- industry: energy spent for processing per tone of product, for example 40 MJ/t;
- electricity production: specific consumption of fossil fuels (t/MWh of produced electric energy);

- the state: energy spent per unit of GDP[1] (for example in B&H in 2008. 0,78 teo/000 (2000.)$[2].

Within the management system frame, efficiency measures are related to what needs and in which intensity are satisfied. Because, the goal is not to heat a certain area of the dwelling, but to create comfort for certain number of people. The goal is not to achieve low specific energy consumption in a vehicle, but to transfer someone or something to achieve certain goal etc. It is clear that the larger effect of energy use is if more people live in the certain area of the dwelling, if the vehicle is more filled up and needed road to cross is shorter. Indicators of management system effects are (Fig.2):

- inhabitation: average dwelling area per person (for example 4 inhabitants on $100m^2$)
- transportation: number of passengers per vehicle and per km of road
- industry: achieved price of product on the market
- Electricity production: large number of welfare development measurements and life quality measurements
- the state: wanted GDP or HDI[3].



RESI-DING	Efficiency of heating system	Specific heat losses	Area per tenant	Energy consumption per capita
TRA-FFIC	Efficiency of engine	Specific energy losses	Driving mode, filling in vehicles	Energy consumption per capita
INDUS-TRY	Efficiency of industrial energy plant	Specific energy losses	Price of product	Energy consumption per profit
STATE	Efficiency of primary energy use	Specific use of energy per sectors	Value of production	Energy consumption per GDP or HDI

Fig. 2. Used indicators of efficiency of energy use in some sectors

Now, the efficiency of energy usage terms can be imported, as is suggested in this paper, by monitoring the energy flow and entry and exits in energy, process and management systems (Fig. 3):

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[1] GDP – Gross domestic Product

[2] tonne of equivalent oil fuel by 1000US$ price from year 2000

[3] HDI - Human Development Index

- on the energy system level: efficiency of conversion of devices energy: the ratio between useful output and energy put in energy system
- on the level of energy and process system together: energy efficiency: the ratio between output and input energy results within the energy system and
- on the level of all three systems (energy, process and management): energy effectiveness – the ratio between the size of satisfied needs or social goals and the amount of energy that entered the technical system.

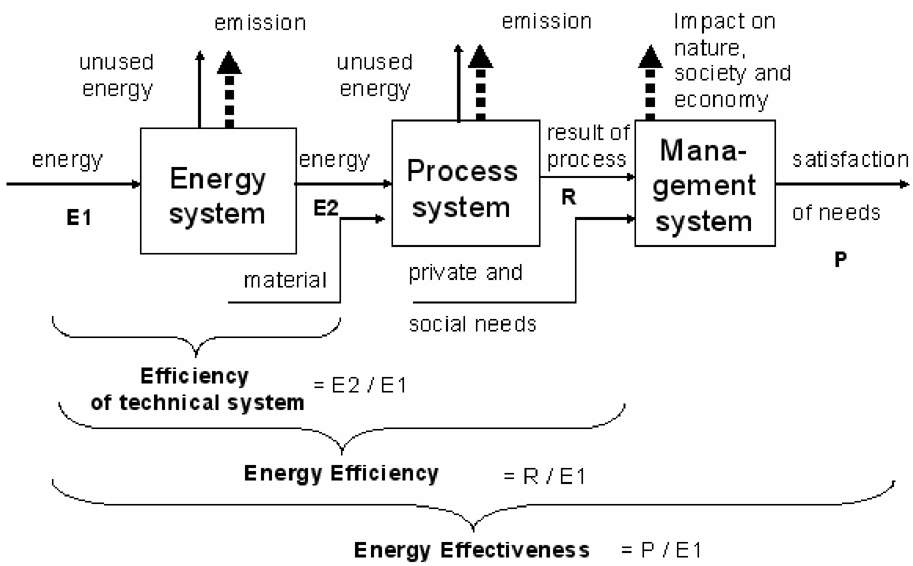

Fig.. 3. Definitions of efficiency of energy use

It is also clear how every measure can be calculated. Energy efficiency is equal the ratio between conversion device efficiency and specific energy consumption (for example inhabitation), or is equal with reversed value of specific energy consumption, if this consumption is related to both systems – energy and process (for example transportation).

Energy effectiveness is equal with a product of energy efficiency and needs satisfaction indicators which are under the influence of the quality of process system functioning. It is easy to show that the biggest probability for rational energy use lays in the management system. It is also easy to prove that rationality of energy usage grows, if the vehicle is more filed up and if the distance between dwelling and work is shorter. The effectiveness is also bigger if the state regulates the market by increasing manufacturing value, which results in slower growth of social product than energy consumption. Energy efficiency is measure of engineering energy savings and energy effectiveness is measure of social energy management system.

3.2. Notes

Efficiency of energy system device does not include only main device efficiency (for example boiler), but it also includes secondary devices efficiency (ventilators, filters), which means that it represents net efficiency value. It also represents average annual value which depends on ratio between energy consumption perimeter and working or optimal point.

It is not always possible to divide energy and process system. For example, in rotational incinerator energy operations are happening at the same time. In that case, energy is transported only to rotational incinerator, and rotational incinerator itself, with boiler, is considered as a process system (efficiency is 100%, or close to 100%).

There are cases where energy from energy system branches out into more process systems. In that case energy efficiency of every process system is calculated separately, but it is also possible to calculate their energy efficiency in common, which is not equal with the summary of optimal energy efficiency values of every single process system.

Although is said that the energy that leaves process system is useless, there are some cases when the part of that energy can be used. But it depends on a process system. For example co-generation of energy is energy process of transformation fossil fuel energy into the heat energy in a form of steam. In a process part electric energy is produced (this product is, by chance, in a form of energy). This, unused energy can be used to heat confined spaces or water, which increases energy efficiency of a process system. In that case specific energy consumption in a process system is distinction ratio between energy that entered and energy extracted from the system and produced amount of energy. Energy efficiency of electric energy production is defined as the ratio between en imported and energy extracted from the process system.

The main goal of importing this taxonomy is to show the size of potential for energy consumption rationalization. It is not very difficult to establish that the less potential for energy consumption rationalization is on the level of energy systems, a bit larger on the level of process systems and the largest on the level of management systems. Without intensive action on the level of management systems, sustainable reduction of energy consumption is not possible.

CONCLUSION

The main goal of this paper is to establish certain taxonomy and terminology in the field of energy efficiency and to show the right path for action, that would enlarge energy consumption rationality. Energy consumption is being spotted through flows of energy, materials and activity – from nature (or market) to the place where the needs are satisfied through three systems, called (i) energy, (ii) process and (iii) management. In energy system, energy converts from one form to another, which is necessary for process development. In the process system energy is used to perform certain process. The exit from this system is product or service, and energy leaves the system in a form of unuseful energy, or is materialized in the product. In management system, the way and intensity of human needs satisfaction are regulated. In accordance with this division, certain terms, related to energy use are imported. Efficiency of energy system is expressed through technical device efficiency (furnace, engine), efficiency of energy and process system together – energy efficiency, and efficiency of all three systems together – the term energy effectiveness is imported. Energy efficiency represents measure of development efficiency and technique usage, and energy effectiveness represents efficacy of the whole society in energy consumption. In this paper, the model is illustrated through four examples: inhabitancy, traffic, industrial production and energy consumption in the state or territorial community.

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