ABOUT THE SERBIAN ENERGY EFFICIENCY PROBLEMS

by

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This paper analyzes energy efficiency in Serbia. The analysis has been done on the basis of energy intensity indicators for Serbia and neighboring countries, and some other countries and regions. It relates to the period of some ten years and it is directed to the consideration of required interventions regarding the change of the National Energy Efficiency Policy. Regardless of constant attempts to improve and increase energy efficiency and to expand utilization of renewable energy sources, it seems that accomplished results are still very modest. The analysis of several energy indicators and their changes in the midterm period confirms this statement.

Key words: *energy intensity, energy efficiency, energy consumption*

Introduction

In the most recent literature dealing with energy economics, it is discussed more and more about the relation between economic growth and energy consumption [1-12]. International Energy Agency (IEA) (www.iea.org) has been gathering and statistically processing data which affect energy sector at the national level. The Agency has energy data for numerous countries at the annual level. The IEA synthesizes gathered data into following indicators: TPES/population (toe/capita), TPES/GDP, TPES/GDP (ppp), EE consumption/ population, CO_2/TPES, CO_2/population, CO_2/GDP. This database has been used for analyses and calculations in this paper.

The availability of all forms of energy at affordable prices is an encouragement for both economic and social development of a society. At the same time, the energy sector is accountable for approximately 75% of total emissions of greenhouse gases (GHG) thus causing the main reason of climate change. As a result of correlative development of international concerns because of climate change and safety of energy supply, the last decade is faced with the growing awareness of politicians and wide public about issues associated with energy and the creation of a new energy pattern directed towards *energy efficiency*. Energy efficiency typically refers to energy consumption and it is not easily achievable because there are various stakeholders *i. e.*, participants at the energy efficiency market are different, and they should be encouraged to accept energy efficiency as a way of doing business and finally as a way of living. This requires a change in a way people think. Since a more efficient use of energy is undoubtedly

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of general interest, in particular with reference to the fight against climate changes, there is a need for interventions in the energy efficiency policy in order to remove barriers for achieving and improving efficiency. The instruments of energy efficiency policy for promoting energy efficiency should not only stimulate the market for higher efficiency but also to achieve cleaner environment, higher standard of living, more competitive industry and safer energy supply. In addition, they should be complied with actual market needs and adaptable to variable market requirements and aimed at the best way to implement objectives.

In spite of excellent energy policies all over the world headed by the European Union (EU), which is an indisputable leader in energy efficiency and in the fight against climate change, there are no remarkable results in the reduction of energy consumption [13, 14]. Therefore, the fulfillment of energy efficiency requires new innovative approaches whose main characteristic is their *changeability* [14]. This means that energy policy should be adaptable and innovative and its making, evaluation and implementation should be continuous. This paper is a result of detailed and long time analysis of reasons for relatively small shifts in the area of energy efficiency and scanty utilization of renewable energy sources in Serbia and in neighboring countries. This analysis has explicitly shown that the main reasons are inadequate and slow institutional organizing and application of state instruments aimed at own strategies implementation. Unfortunately, even some developed countries have not fully reached their strategic objectives in this area. For this reason, the energy efficiency is in this paper observed primarily as a continuous and adaptable process which should in the best way present available technical solutions to those who should utilize these solutions.

Serbian energy system

Serbia shares borders with Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, the Former Yugoslav Republic of Macedonia and Romania. Serbia's terrain ranges from rich, fertile plains of the northern Vojvodina region, limestone ranges and basins in the east to geological old mountains and hills in the central, southeast and southwest parts [12].

The climate of Serbia varies from moderate continental climate in the northern Pannonia lowlands along the rivers Sava and Danube and in the foothill zone inland of the country, to alpine climate in the high mountain regions.

Out of the total land area of Serbia about 5.6 million ha are suitable for agriculture of which only 57,000 ha are irrigated. Forests cover approximately 30% of the Serbia's territory.

Energy balance

Total consumption of primary energy in Serbia was 14.448 Mtoe in 2009, out of which domestic production accounted for 60%, and imports for 40%. Domestic production of primary energy includes exploitation and the use of domestic resources of coal, crude oil, natural gas and renewable energy sources (hydro-potential, fuel wood, and bio-diesel). The energy balance of Serbia is given in tab. 1.

Table 1. Participation of energy types in TPES in Serbia (2009) (in megatons of oil equivalent [Mtoe] on a net calorific value basis) [6]

Energy	[Mtoe]	[%]
Coal and peat	8.019	55.5
Crude oil	2.985	20.7
Oil products	0.958	6.6
Gas	1.395	9.7
Nuclear	0	0.0
Hydro	0.881	6.1
Geothermal, solar, *etc.*	0.046	0.3
Combustible renewables and wastes	0.287	2.0
Electricity	–0.123	–0.9
Heat	0	0.0
Total	14.448	100

Energy structure

The energy sector of Serbia consists of the following:

(1) Oil sector within which the following is performed:
- domestic exploitation of crude oil (annual production of approximately 0.6 Mt of crude oil),
- import, export and transport of crude oil and oil derivates,
- processing of crude oil in two refineries (annual production of approximately 4.0 Mt of oil derivatives), and
- oil derivatives distribution and trade.

Oil transport is performed predominantly trough the trunk oil pipeline (JANAF) from Omišalj in Croatia to oil refineries in Pančevo and Novi Sad in Serbia. Total installed petroleum refineries capacity is 7.8 Mt per year (4.8 Mt in Pančevo and 3 Mt in Novi Sad), while their current operating capacities are reduced to 6.6 Mt.

(2) Natural gas sector within which the following is performed:
- domestic exploitation of natural gas (annual production of approximately 0.3 million m^3 of natural gas) and
- import, transport and distribution to natural gas consumers.

(3) Coal sector which consists of:
- three open pit mines in three mining basins: Kolubara, Kostolac and Kosovo-Metohia basins (the latter temporarily not operating as part of the energy system of Serbia) and
- underground mines.

Over 95% of the total coal production from open pit mines is used for power production.

(4) Power sector consists of:
- electricity production in power plants with installed power of 7,120 MW (3,936 MW in lignite-operated thermal power plants, 2,831 MW in hydropower plants and 353 MW in heavy fuel oil or natural gas thermal power plants-district heating companies),
- power transmission systems with 10,200 km of 400, 220 and 110 kV power lines and about 15.8 GVA installed in the transformer stations, and
- power distribution systems.

(5) District heating system existing in 50 cities of Serbia consists of decentralized heat sources with installed power of about 6,000 MJ/s and appropriate distribution networks. The systems are used for heating residential and office space of about 450,000 flat equivalents.

(6) Industrial energy system includes heating sources with 6,300 MJ/s installed in several hundred industrial companies of Serbia. They are used for the production of industrial steam and heat for the production process purposes and for heating premises. In about 30 industrial companies, there are power plants which enable combined production of thermal energy and power (with a capacity of about 250 MW), the largest number of which has not been operational for a long time.

Basic characteristic of all parts of mentioned energy system is significant obsolescence of technology and low energy efficiency, as well as currently disturbing and in the long term unacceptable technological condition from the standpoint of environmental protection.

Energy sources of Serbia

The volume and structure of energy reserves and resources of Serbia are very unfavorable. The reserves of quality energy products, such as oil and natural gas, are small (less than 1% in total balance sheet reserves of Serbia), while the remaining 99% of energy reserves consist of various types of coal, predominantly low-quality lignite, with the share of over 92% in the total balance sheet reserves. Lignite is extracted from two open pit mines in Kolubara and Kostolac with yearly production of 35 Mt of lignite. Hard and brown coals are produced in underground mines with annual production of 0.6 Mt.

Domestic production of crude oil and gas is small and covers only 15% of energy demand (more than 80% of oil and gas are imported).

The most important renewable energy resource of Serbia is hydro energy estimated at around 17,000 GWh annually. 10,000 GWh of hydro potential has been used so far. Some 7,000 GWh of hydropower potential in Serbia is still unused, which represents about 7.5% of the total final energy consumption in 2009. Furthermore, there is room for the construction of individual medium size hydro power plants (HPP) with power over 10 MW and annual production of about 5,200 GWh. At about 900 potential locations on Serbian rivers, including small rivers, possibilities have been determined for the construction of small hydropower plants (of up to 10 MW), with possible production of about 1,800 GWh/year.

The energy potential of biomass is very significant and amounts to over 3 Mtoe per year (the potential of small hydro power plants is about 0.4 Mtoe). The energy potential of existing geothermal energy in Serbia is nearly 0.2 Mtoe in the province of Vojvodina, the Sava Basin, Mačva, the Danube basin and in wider region of Central Serbia, as well as in existing spas.

The Energy sector development strategy of the Republic of Serbia by 2015

This document defines five basic priorities:

(1) continuous technological modernization of existing energy facilities/systems /sources, in the following sectors: oil, natural gas and coal including strip mining and underground mining, power sector with production facilities-thermal power plants, hydropower plants and thermal power plants-district heating companies and transmission system, *i. e.* distribution system, and thermal energy sector-district heating companies and industrial power plants;
(2) economical use of quality energy products and energy increase in the energy efficiency in the production, distribution and utilization of energy by end consumers of energy-related services;
(3) use of renewable energy sources and new, more energy efficient and environmentally acceptable energy technologies and installations/equipment for energy utilization;
(4) extraordinary/urgent investments in new power sources, with new gas technologies; and
(5) long term development and regional strategic priority of constructing new energy infrastructure facilities and electric and thermal power sources within energy sectors of Serbia, as well as capital-intensive energy infrastructure, within the frameworks of regional and Pan European infrastructure systems connected with our systems.

According to the Energy Law and the Strategy, the Ministry of Mining and Energy prepared Program for Implementation of Energy Sector Development Strategy for the Period from 2007 to 2012 which was adopted by the Serbian Government in January 2007. This Program is a Decree defining conditions, method and time schedule of the Strategy implementation for the following energy items:

– coal sector (underground and open pit mines),
– oil sector (domestic exploitation, refineries and transport),
– gas sector,
– electric power sector (hydropower plants, thermal power plants, distribution and transmission),
– district heating system,

– industrial energy sector,
– energy efficiency in final energy consumption sectors (industry, transport, buildings), Energy Efficiency Fund, and
– environmental protection in energy sector.

There are also several other strategies which have already been prepared or which are in the process of preparation and they will be of further relevance for the energy sector (Strategy for Sustainable Development, National Strategy for Sustainable Use of Natural Resources and Goods, Strategy for Introducing Cleaner Production).

Despite the fact that the period for the implementation of these documents has not yet expired, it can be said that the results are very poor. This fact and the reasons for poor results will be discussed below.

Energy efficiency indicators

Energy efficiency should be understood as a set of organized activities which are undertaken within the boundaries of a defined energy system with an aim to reduce the consumption of input energy, harmful gases emissions and energy costs at the unchanged degree of provided services or the creation of new value in the production process within the defined system [15]. The very definition indicates also the complexity of a problem arising from the need to connect *people, procedures and technologies* in order to accomplish consistent and continuous improvements in energy efficiency.

However, the energy efficiency today is predominantly the matter of *technology* and not of *knowledge*. New technologies are very often not critical and very aggressively imposed to users without essential proofs of their efficiency in relation to formerly used technologies. Mainly, only unconvincing marketing explanations are given which do not provide sufficient knowledge for someone who is supposed to apply this new technology. It is obvious that new technologies have been made by improving old ones and thus it is not reasonable to reject old technologies without detail analysis.

Because of its complexity, there are no doubts that energy efficiency is difficult to measure. There are six indicators which are most frequently used and also employed in various situations. These are [14]:

(1) ***Energy intensity*** – The relation between energy consumption (measured in energy units: toe, Joule) and activity indicator measured by monetary units (gross domestic product, added value). Energy intensity is the only indicator which can be used for the assessment of energy efficiency at the high aggregation level at which it is not possible to characterize an activity by means of technical or physical indicators, *i. e.*, at the level of the whole national economy or the sector.

(2) ***Specific consumption*** – It connects energy consumption with activity indicator which is measured by physical units (tones of steel, number of vehicles, *etc.*) or with an energy consumption unit (vehicle, dwelling unit, *etc.*). As a matter of fact, it is more used in industrial plants, in buildings or in transport when the efficiency of certain machines or objects or devices is measured.

(3) ***Energy efficiency index*** – provides overall assessment of trends in the energy efficiency sector. It is calculated by means of weighted average of sub-sector indicators (towards end users, manner of transportation, *etc.*). The reduction implies the improvement of energy efficiency. Such an index is more relevant for understanding the reality of changes in energy efficiency than the energy intensity indicator. Some of the years in the period which has been analyzed are taken as the base ones (100%).

(4) ***Diffusion indicator*** – There are three types of these indicators: 1) market penetration of renewable energy sources (number of sold biomass boilers, percentage of fuel wood boilers for heating, *etc.*); 2) market penetration of efficient technologies (number of sold energy saving electric bulbs, percentage of electrical appliances with the A grade, *etc.*); 3) diffusion of energy efficient practice (number of passengers using public transport, non-motor transport, percentage of goods transported by railway, combined passenger–railway transport, percentage of efficient processes in industry, *etc.*). Diffusion indicators have been introduced in order to supplement existing energy efficiency indicators because they can easily be tracked. Their aim is to improve interpretation of trends which have been noticed relevant to energy efficiency indicators.

(5) ***Adjusted energy efficiency indicators*** – refer to differences which exist among countries relevant to climate, economic structures or technologies. The comparison of energy efficiency performance in different countries is important only when it is based on such indicators. External factors which can affect the consumption of energy include: a) weather conditions; b) degree of load; c) operating hours of public buildings; d) degree of utilization of installed equipment; e) level of production; f) added value, including GDP changes; g) planned utilization of installations and vehicles; h) relationship with other departments, *etc.* Some of these factors are important for the correction of aggregate indicators whereas the others will be used only for individual plants in which energy efficiency measures have been made.

(6) ***Target indicators*** – are aimed at providing referent values which will show possible improvements of desired energy efficiency or possibilities for energy efficiency in a certain country. In a way, they show similar resulting values but they are determined at the macro levels assuming careful interpretation of differences. Their aim is to define the distance to the average of three best countries; this indicates the benefits that can be generated.

Even at the first sight it is clear that it is not possible to use all listed indicators successfully in all situations and that they have been defined in order to satisfy certain practical requirements in a better way. Figure 1 shows the IEA energy efficiency indicator pyramid covering as many aggregation levels as possible, actively pushing the attainable level further down by developing new indicators for lower aggregation levels and gathering additional data. Data availability decreases the number of countries for which indicators can be developed to ever smaller sub-sectors of IEA member countries at lower aggregation levels. These data provides the indicators that give the most insight into the underlying drivers that determine energy trends over time and explain differences between countries. All initiatives agree on the limitations of high level indicators and indicate a preference for physical indicators as being closer to the actual drivers of energy consumption than those based on monetary units. The IEA uses historical trend analysis to assess the impacts of past developments in energy efficiency and compare the results

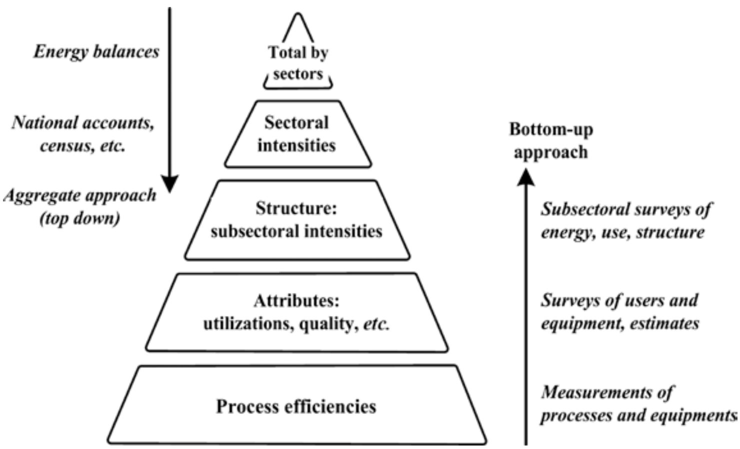


Figure 1. The energy efficiency indicator pyramid

across countries. The IEA also uses benchmarking against best practice to determine where the largest improvement potentials exist in industry [14].

In addition to listed indicators, it is possible to define some other ones which are needed in different analyses and in particular, when indicators of different countries and regions are compared.

This paper deals with the analysis of indicators which refer to the whole country and the offered analysis is aimed at the comparison of these energy indicators among the countries and regions. The tab. 2 gives key indicators for Serbia and 8 neighboring countries, for Denmark, for the EU 27 and for the World. It is logical to compare Serbia and neighboring counties since they have considerable similarities both relevant to energy systems and to energy carriers which they use. In addition, the table shows data for Denmark, not a large European country with an exceptionally high GDP per capita, extremely high technologies in the area of energy efficiency and in particular, in the area of renewable energy sources. Also, Denmark is the only EU 27 country which exports energy. Key indicators are also given for EU 27, to which Serbia is striving, as well as for the World to which it belongs. The IEA database has been used for this purpose. Data for Montenegro are incomplete as they do not exist in the above mentioned database and we have not used other databases on purpose as we wanted to avoid frequent mutual inconsistencies.

Table 2. Key indicators for Serbia, neighboring countries, EU 27 and the world

Country[1] or region	Land area	Population	GDP	GDP (ppp)[2]	TPES	Electricity consumption[4]	CO_2 emissions[5]
	[km^2]	[million]	[US$ 2000]	[US$ 2000]	[Mtoe]	[TWh]	[Mt of CO_2]
Serbia (112)	88,361[3]	7.32	9.00	33.13	14.45	30.96	46.26
Croatia (126)	56,594	4.43	28.35	63.14	8.7	16.44	19.77
Bosnia and Herzegovina (127)	51,197	3.77	8.14	33.13	5.95	10.8	19.09
Albania (143)	28,748	3.16	5.88	18.16	1.72	5.58	2.7
Macedonia FYRM (148)	25,713	2.04	4.41	14.95	2.78	7.08	8.34
Montenegro (160)	13,812	0.67					
Hungary (110)	93,028	10.02	56.40	147.51	24.86	37.82	48.16
Romania (82)	238,391	21.48	56.00	199.91	34.41	48.69	78.36
Bulgaria (105)	110,879	7.59	19.29	74.84	17.48	33.38	42.21
Denmark (133)	38,394	5.52	167.73	161.21	18.61	34.5	46.78
EU 27	4,324,782	500.37	9481.59	12007.61	1655.79	3037.15	3576.79
World	148,940,000	6760.75	39674.41	64244.43	12149.85	18451.5	28999.35

(1) Figure in brackets means order of the country by land area starting form the biggest (out of 236 countries. The largest country is Russia -11.5%, and the smallest one is Vatican City - 0.0000003%).
(2) GDP is on a purchasing power parity (ppp) basis divided by population as of year 2009.
(3) UN area figure includes Kosovo, which has an area of 10,887 km^2 and has declared independence. The area of Serbia without Kosovo is 77,474 km^2.
(4) Gross production + imports – exports – losses.
(5) Emissions from fuel combustion only.

Table 3 shows compound indicators for the same countries and regions, excluding Montenegro as already explained.

With reference to other countries and regions, it can be concluded that in Serbia:

- population density is on the average relevant to our neighbors, much lover than in Denmark, higher than in the EU 27 and much lower than in the world,
- the consumption TPES per capita is on the average relevant to our neighbors, much lover than in Denmark and the EU 27 and approximately identical with the world,
- the consumption TPES/GDP (ppp) is unfortunately the highest and even higher than in the world,
- the physical indicator of electrical energy consumption per capita is among the highest in the neighborhood but much lower than in Denmark and the EU 27. Since economic activities in Serbia are still very poor, the high consumption of electrical energy implies that it is used irrationally and for non-industrial purposes and that it does not contribute to the increase of the GDP; and
- unfortunately, CO_2 emissions per TPES consumption are among the highest and very high per capita taking into considerations the population density in Serbia and in other countries.

Table 3. Compound indicators for Serbia, neighboring countries, EU 27 and the world

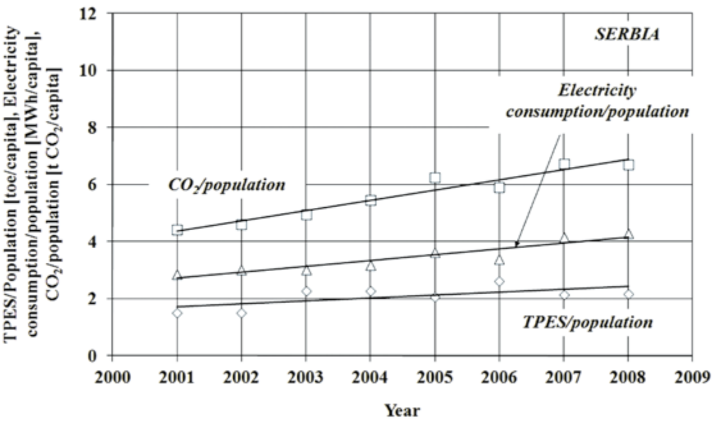
Country or region		TPES/pop.	TPES/GDP (ppp)	Electricity cons./pop.	CO_2/TPES	CO_2/pop.	CO_2/GDP (ppp)	GDP/ population	GDP(ppp)/ population
	[population/km^2]	[toe/capita]	[toe/10^3 2000 US$]	[kWh/cap.]	[tCO_2/toe]	[tCO_2/cap.]	[kgCO_2/ 2000 US$]	[US$2000/ cap.]	[US$2000 (ppp)/cap.]
Serbia (112)	83	1.97	0.44	4,230	3.20	6.32	1.40	1,230	4,526
Croatia (126)	78	1.96	0.14	3,711	2.27	4.46	0.31	6,400	14,253
Bosnia and Herzegovina (127)	74	1.58	0.18	2,865	3.21	5.06	0.58	2,159	8,788
Albania (143)	110	0.54	0.09	1,766	1.57	0.85	0.15	1,861	5,747
Macedonia, FYRM (148)	79	1.36	0.19	3,471	3.00	4.09	0.56	2,162	7,328
Hungary (110)	108	2.48	0.17	3,774	1.94	4.81	0.33	5,629	14,722
Romania (82)	90	1.60	0.17	2,267	2.28	3.65	0.39	2,607	9,307
Bulgaria (105)	68	2.30	0.23	4,398	2.41	5.56	0.56	2,542	9,860
Denmark (133)	144	3.37	0.12	6,250	2.51	8.47	0.29	30,386	29,205
EU 27	116	3.31	0.14	6,070	2.16	7.15	0.30	18,949	23,997
World	45	1.80	0.19	2,729	2.39	4.29	0.45	5,868	9,503

We are going to show below the change of the following physical indicators during time: 1) total primary energy supply (TPES) per capita, 2) electricity consumption per capita, and 3) CO_2 emissions per capita. These indicators will be examined for Serbia and Denmark. On the basis of their trends, we are going to assess the degree of energy efficiency development at the national level. These indicators are not given for other countries exclusively for the lack of space herein. These indicators for both Serbia and Denmark are shown in figs. 2 and 3. Denmark has been chosen because it is the world's leader in development and utilization of energy efficient technologies and renewables, and because it is a country slightly smaller than Serbia but economically by far ahead of Serbia.

The presented trends in the change of energy indicators in the previous period are without large oscillations in Denmark and with a falling trend. In Serbia, it is quite the opposite. Oscillations are much more pronounced but at the same time, all three mentioned indicators have growing trends.

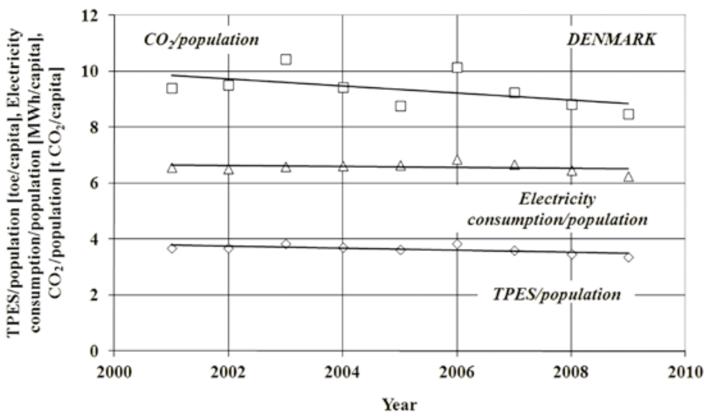
There is the growth of TPES consumption per capita in the conditions of mild decrease of population and very apparent economic stagnation which shows the absence of positive effects of energy efficiency measures.

If this is accompanied by the growth of CO_2 emissions then, this is yet another confirmation of the poor energy efficiency and also of the absence of the corresponding use of technologies for renewable energy sources. The growth of electrical energy consumption per capita can be explained in the same way. Taking into account the present economic stagnation, it can be concluded that the increased energy consumption is not used for the purpose of the GDP growth but only for the purpose of raising the standard of living.



Basic social and economic characteristics:
- mild fall of population
- slowdown of economic growth
- considerable growth of primary energy consumption per capita
- considerable growth of electrical energy per capita
- considerable growth of carbon dioxide emissions per capita
- GDP(ppp) population = = 4,526 US$ (2000) in 2009

Figure 2. Some energy indicators in Serbia from 2001 to 2009



Basic social and economic characteristics:
- very mild growth of population
- stable economic development
- stagnation in the consumption of primary energy per capita
- stagnation of electrical energy consumption per capita
- considerable fall of carbon dioxide emissions per capita
- GDP (ppp)/population = =30,386 US$ (2000) in 2009

Figure 3. Some energy indicators in Denmark from 2001 to 2009

In the previous illustration of comparing Denmark and Serbia, it can be seen that the situation in Denmark is completely different. There is a constant fall of TPES consumption and CO_2 emissions and the stagnation in the consumption of electrical energy. And, above all, the GDP per capita in Denmark is several times higher than in Serbia.

Based on the above facts, it can be concluded that the energy efficiency in Serbia is at a very low level. Although there are numerous studies and papers which indicate potentials and propose measures for the increase of energy efficiency, the large scale result has failed to occur. It is quite likely that a roadway to energy efficiency increase is through the essential change in the energy efficiency policy and in the introduction of elements of control and management in the process of its implementation.

The evaluation of energy efficiency policy effects: monitoring & verification (M&V)

As the first step in the preparation of the energy efficiency program, it will be necessary to determine how policy instruments (or the package of instruments) are expected to influence the improvement of energy efficiency. On the basis of clearly explained assumptions, the instruments of energy efficiency policy will be created, that is, well devised means for cost-effective improvement of energy efficiency market performance. The participants in the preparation of the energy efficiency program should predict in the way which is as precise as possible the effects of energy efficiency policy instruments before they are going to be implemented. This is discussed as the policy evaluation *ex-ante* or the policy's evaluation beforehand during which the impacts (social, technological and financial) of policy instruments will be predicted. The expected impact and cost-effectiveness of instruments will be evaluated and compared with the usual operating scenario in which no instruments are applied. The evaluation *ex-ante* involves the assessment of expected impact in the sense of energy saving, as well as the cost-effectiveness of policy instruments. However, those who are preparing the energy efficiency program do not have sufficient experience and knowledge to confirm whether the evaluation has been good and therefore, the preparation of such a program should be public, *i. e.*, all stakeholders and interested parties and market participant who can contribute in the overall understanding of planned instruments effects should be involved. As opposed to the *ex-ante* evaluation, the *ex-post* evaluation is used after some time has elapsed after the use of an instrument in order to assess the effects of its application and respond to two crucial questions:

- How much has the instrument contributed to the fulfillment of the policy's objectives (the instrument's efficiency)?
  - The instrument's efficiency is measured as its net effect with reference to the objective of the energy efficiency policy. The net effect is equal to the difference between the amount of energy which is used before and after the utilization of the instrument and it is determined in line with the previously determined baseline.
  - Has the instrument been cost-effective, *i. e.*, could the objectives have been fulfilled in a cheaper way?
- The cost-effectiveness is a ratio between additional costs which the application of an instrument imposed on the end user, the society as a whole or the government and its net impacts. The government's costs are related to the implementation of the energy efficiency policy, administration, implementation of regulations, monitoring and assessment, subsidies and tax relieves. In other words, the instrument's cost-effectiveness is evaluated in order to determine how well the public money has been used to achieve socially beneficial objectives. The costs for end users are determined on the basis of the energy price,

secondary investments and operating costs, as well as the costs for maintaining energy efficient measure.

However, the instruments of energy efficiency policy can have other effects as well, and it is necessary to raise the third question:

– What has the application of the energy efficiency policy's instrument also affected?

The most frequently mentioned side effects of the energy efficiency policy are benefits for the environment and opening of new jobs which are positive effects with respect to environmental, social and economic stability and progress. Sometimes, however, negative effects are also possible. For example, the compact fluorescent bulbs use much less energy and have longer lifetime and in the world's fight against climate changes they are starting to fully replace the "old" incandescent light bulbs. But, they also bring some other hazards, such as a small amount of highly toxic mercury they contain. The policy makers have to be aware of these relations and often compromises have to be done − in this case, the compromise is between efficiency and health risk.

The answers to these questions refer to the *ex-post* evaluation. This goes beyond the evaluation of finally achieved energy savings and tries to reveal the factors of success and failure enhancing in that way our knowledge about results achieved at the market. The enhanced knowledge enables the improvement of the effectiveness of the energy efficiency policy's instrument and redefining of the energy efficiency policy. This requires both qualitative and quantitative assessments and it is desirable that they are supported by empirical data about the policy performance. The most important is the cause − impact relationship supplemented by indicators which measure the existence of the cause − impact relationship and then, the relationship between the success and failure factors (qualitative) with other instruments of the energy efficiency policy (other instruments can enhance or mitigate the effect of analyzed instruments). In the evaluation, empirical data are also very important as they are additional and often the only indicators of certain instruments impacts.

The evaluations *ex-ante* and *ex-post* should be supported by quantitative data, *i. e.*, by data about the improvements of energy efficiency which have actually been realized by the implementation of policy instruments and energy efficiency improvement projects. For these purposes, monitoring and verification (M&V) of energy savings are used. M&V are essentially the part of any energy efficiency policy – as they include the overall improvement of energy efficiency and assess the impact of individual measures. M&V procedures include two major methodological approaches: top-down and bottom-up. Both approaches must be combined in order to evaluate appropriately and as exact as possible the success of the national energy efficiency policy and to evaluate the impact of energy efficiency improvement measures

The top-down calculation method means that a starting point for the calculation of energy savings is national or large aggregate sectoral energy savings. This is a purely statistical approach which is often called an energy efficiency indicator because it indicates accomplishments.

The top-down methodology is based on the collection of extensive data sets for not only energy consumption but also for various factors influencing it, and on the calculation and monitoring of energy efficiency indicators. The main advantage of using the top-down methods is their simplicity, lower costs and reliance on the existing systems or energy statistics, which is required for the development of the country's energy balance. On the other hand, these indicators do not consider individual energy efficiency measures and their impact and they do not show cause and effect relationships between measures and their resulting energy savings. Determining such indicators requires huge amount of data (it is necessary to have not only energy statistics, but also the whole set of macro and micro economic data that are influencing energy consumption in all sectors of end users), and data availability and reliability are often questionable in practice, and sometimes it is necessary that these data are determined and assessed by experts. Nevertheless, the energy efficiency indicators make an inevitable part of the energy efficiency evaluation (both *ex-ante* and *ex-post*) as they are the only means to make a starting point for own performance against the performance of others, to reveal the potentials and determine policy objectives, to measure the success, *i. e.*, failure, of the energy efficiency policy instruments and to track down the progress made in achieving defined objectives.

The bottom-up method means that energy consumption is reduced as a result of the implementation of specific energy efficiency improvement measure and it is measured in kilowatt-hours [kWh] and Joules [J] or in tons of oil equivalent [toe] which is added to energy savings results by applying other specific energy efficiency improvement measures in order to obtain an overall impact of the implementation of the defined energy efficiency policy. Thus, the bottom-up M&V methods are oriented towards the evaluation of individual energy efficiency projects and they are rarely used for the evaluation of overall energy efficiency policy impacts.

M&V approach is directed to the fact that the absence of energy use can be only determined by comparing measurements of energy use which has been made before (baseline) and after (post-retrofit) the implementation of energy efficiency measure or which can be expressed in a simple equation:

$$\textit{Energy saving} = \textit{Baseline energy use} - \textit{Post-retrofit energy use} \pm \textit{Adjustments} \tag{1}$$

The baseline conditions can be changed after the energy efficiency measures are installed and the "adjustment" (can be positive or negative) in eq. (1) in order to reduce the energy use in two periods (before and after) under the same conditions, sometimes significantly complicate the procedure. The conditions which determine the energy use are weather conditions, load, throughput of the plant and equipment which are required for necessary operations. These factors must be taken into account and analysed after measures are undertaken and adjustments are made in order to ensure correct comparisons of the state pre- and post-retrofit. This kind of M&V scheme (which is often called *ex-post*) can be very expensive but it guarantees the detections of real savings. The costs are related to actual measurements, *i. e.*, to the measurement equipment. To avoid large costs, only the largest or unpredictable measures should be analysed in this way.

Individual energy efficiency projects might also be evaluated using well reasoned estimations of impacts of individual energy efficiency improvement measures. This approach (often called *ex-ante*) means that the introduction of a certain type of energy efficiency measures provides a certain amount of energy savings prior to its actual realization. This approach has significantly lower costs and it is especially appropriate for measures which can be repeated and for which it is possible to make reasonable estimate through an agreement. There are also some "hybrid" solutions that combine *ex-ante* and *ex-post* approaches in the bottom-up M&V. This hybrid approach is often called *parameterized ex-ante* method. It is applied in measures for which energy savings are known but they may differ depending on a number of restricted factors (for example, availability factor or the number of working hours). The results of this approach can be more accurate than the results obtained by using the pure *ex-ante* methodology and the costs of M&V are not much higher.

The success of the national energy efficiency policy has to be constantly monitored and its impact evaluated. Findings obtained during evaluation will be used to make changes in the energy efficiency policies and for their higher effectiveness. Regardless of the importance of the evaluation of the energy efficiency policy, it is often neglected. The energy efficiency programs are often adopted by governments and parliaments and afterwards they are not interested in achieved results. Therefore, it is very difficult to set up a completely operable system for the evaluation of energy efficiency as it requires the change in the structure and practice of main stakeholders participating in the preparation of the energy efficiency policy. Additionally, such an evaluation should be supported by M&V procedures which require comprehensive data collection and the system's analysis in order to determine energy efficiency indicators that will quantify the effects of the energy efficiency policy.

The key for making an effective energy efficiency policy

For the energy efficiency policy to be successful, it should be the result of learning and knowledge both theoretical and practical. The closed loop is the most appropriate description for the policy making (fig. 4) which consists of the following stages:

(1) Policy design:
- Policy definition − objectives, tasks, approaches for different target groups, legal and regulatory frameworks,
- Policy instruments development − incentives, penalties, standards, technical and financial support,

(2) Policy implementation − institutional framework, stakeholders, human resources, capacities and capability development, supporting infrastructure (ICT), and

(3) Policy evaluation: monitoring of achieved results through energy statistics and energy efficiency indicators, qualitative and quantitative value of impacts of the policy instruments.

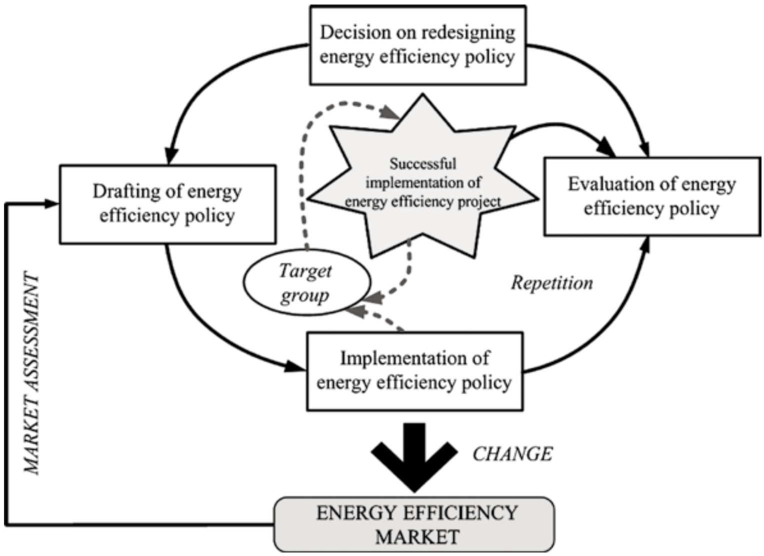


Figure 4. Changeability of energy efficiency policy

The energy efficiency policy is in its essence the program of market transformation which implies strategic interventions that cause permanent changes in the structure or function of markets for all energy efficient products/services/practices.

It is based on the following key pillars:
- the program of energy efficiency policy measures which will remove market barriers identified in the stages of development of individual energy efficiency projects,
- the policy interventions adaptable to market conditions which ensure sustainability of energy efficiency improvements by repeating successfully implemented energy efficiency projects,

– the policy instruments which should enable all market players (the government, the private sector, consumers, equipment producers, service sector, financial institutions, *etc.*) to find their own interest in the improvement of energy efficiency, and
– the improvements of energy efficiency which are the result of supply and demand interactions based on competitive market forces.

Therefore, before we start with the preparation of a draft energy efficiency program, it is necessary to perform a market assessment. The market assessment will reveal its maturity which is extremely important since different measures have different effects and they are appropriate for different markets, *i. e.*, for markets with various maturity levels. This means that some measures can stimulate market introduction, whereas other measures can accelerate commercialization or increase the overall demand for energy efficient products and services. The market analysis is required in order to identify market forces that have to be strengthened by incentives, *i. e.*, weakened by penalties. The measures should be carefully devised in order to overcome identified market barriers.

Conclusions

It is obvious that the preparation and drafting of an energy efficiency program is not one time job. It is a continuous process that should create conditions for the energy efficiency market to make suitable decisions. Therefore, approaches to markets as complex systems of supply and demand interactions should be changed and this change should be directed towards efficiency, environmental benefits and social wellbeing. However, there are some barriers which prevent functioning of the energy efficiency market in the best way and based on these barriers it will be necessary to make a choice of energy efficiency policy instruments. These instruments should be flexible so that they can respond to market requirements and enable the accomplishment of objectives in the best possible way, *i. e.*, with the lowest costs for the society. Because of the fast changing market conditions, energy efficiency programs can no longer be documents which remain unchanged for several years. The evaluation of the energy efficiency policy should become common. Future research work to support energy efficiency policy making should be exactly directed towards the elaboration of methodology that will be able to qualitatively and quantitatively evaluate effectiveness and cost-effectiveness of energy efficiency policy instruments and enable the selection of the best program for energy efficiency measures in dependence of current development stage of the energy efficiency market.

The evaluation procedures will advance and deepen our knowledge on success or failure factors of the energy efficiency policy. The analysis of the current situation shows that energy efficiency policies world-wide fail in accomplishing desired objectives in terms of energy consumption reduction. The main reason lies in the lack of understanding and focus on capacities for the implementation of the energy efficiency policy which are totally undeveloped, insufficient and inappropriate for ambitious objectives that have to be achieved. It is necessary to understand that the energy efficiency policy will not be implemented by itself and that capacities and capabilities are required in all social structures. The situation can be improved if we accept the system of energy management both in public services and in private sector. Additionally, with the positive pressure from civil society organisations and media, the understanding of energy and climate change issues will improve, gradually changing the society's mindset towards higher efficiency.

The national energy policy should be relied on the following:

- ultimate and continuous promotion of energy efficiency in all energy sectors,
- full use of renewable energy sources and reduced consumption of imported fossil fuels,

- development of service providers sector in order to achieve previous objectives (production of insulation materials, boilers for the use of biomass, small plants for the production of biogas, solar collectors, *etc.*), and
- modification of economic and financial mechanisms aimed at the implementation of previous objectives.

Perhaps it may seem to someone that such conditions for the national energy efficiency policy have already been said, but this paper primarily insists on the control of the implementation of energy efficiency policy measures.

Acronyms

GDP – gross domestic product, [US$]
GDP (ppp) – GDP dollar estimates derived from purchasing power parity (ppp) calculations. Purchasing power parity (ppp) is a theory of long-term equilibrium exchange rates based on relative price levels of two countries, [US$]
TPES – total primary energy supply, [ktoe] (indigenous production + imports – exports – international marine bunkers ± stock changes)

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