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Inter-Relation Of Energy Efficiency And Gross Domestic Product With Special Reference To India

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Abstract:

Improving energy efficiency can be a powerful tool for achieving sustainable economic development and most important for reducing energy consumption and environmentalpollution on national as well as international level. Unfortunately, energy efficiency is difficult to conceptualize and there is no single commonly accepted definition. Because of that, measurement of achieved energy efficiency and its impact on national or internationaleconomy is very complicated.

Gross domestic product is often used to assess the financial effects of applied energy efficiency measures at the national and international levels. The growth in energyconsumption per capita leads to a similar growth in gross domestic product, but it isdesirable to provide for the reduction of these values.

The paper analyzes some standardindicators and the analysis has been applied to a very large sample ensuring reliability forconclusion purposes. National parameters for 128 countries in the world in 2011(2007) were analyzed. In addition to that, parameters were analyzed in the last year for global regionsand India.

Key words: *Energy Efficiency, Energy Consumption, Gross Domestic Product (GDP).*

1.Introduction

In the seventies of the last century, there was abrupt rise of energy raw materials prices and short stagnation in the volume of their use but some dozen years later, the prices became relatively stable again and the growing trends of consumption continued all over again. Ever since, these events have been causing war turmoil because energy requirements of the most developed and military the most powerful countries are very high and, as a rule, the deposits are outside their territories in under developed and military weak countries. There is fairly accurate correlation between overall economic progress of a country and its energy consumption growth.

Growth related economic indicators are true "driving force" for special care of energy. It can be said with certainty that the energy sector of a country occupied between 10 and 20% of the national product before the oil prices rise (which was reflected in the growth of prices for other energy carriers) in the seventies of the last century. Now- a-days, this is probably between 25% and 50%. The extent to which certain country is developed and has regulated economy affects financial proportion of energy in the national income.

There are no doubts that the introduction of energy efficiency measures should slow down this growth. Energy price in the last few decades has substantially grown in both relative and absolute sense. Almost all countries in the world design measures in the area of energy efficiency as well as in order to reduce the share of energy in the gross domestic product (GDP).

In the most recent literature dealing with energy economics, it is discussed more and more about the relation between economic growth and energy consumption [1-6]. International Energy Agency (IEA) 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, CO2/TPES, CO2/population,and CO2/GDP. This data base [1-20] has been used for analyses and calculations in this paper.

The paper deals with relations between energy and GDP and analyzes integration, co-integration and causality of the relationship between energy output and consumption by comparing data of six countries included in the Gulf Co-operation Council (GCC). The obtained results are slightly in favor of the hypothesis: since oil exporters enjoy cheap energy resources then, energy consumption is the source of GDP growth in these countries. Empirical results obtained in this paper can be, thus, compared with some

other groups of countries or with single countries. Among other things, this hypothesis has also been proved in this paper but on a much larger sample.

There is no doubt that for the assessment of effects generated by energy efficiency measures at the national level the most important is energy intensity and it will be dealt with in more details in this paper. This paper provides growthperspective ofprimary energy supply and energy intensity not only for the world regions but also for theIndia.

2.Energy Indicators

Energy consumption is defined in various ways and used with the indicator of energy intensity. The problem occurs relevant to the choice of measuring energy quantities since they differ depending on special requirements of the study and analysis or depend on the politics and expectations. Types of energy consumption generally involve the end use, useful energy, final energy, purchased energy (the most easily measured and most often used), net available energyand primary energy demand needed to provide final energy expressed for every sector. The basic factor which affects the source of energy consumption classification refers to available data, complexity of measurement, as well as measurement of potentials for reducing CO2 emissions,level of data break down.

Since unmistakable quantification of energy efficiency measurement does not exist,there is a trend of relying on energy indicators which are typically composed of quantified indices with an aim to express energy efficiency approximately. According to the synthesis of this idea [8], there are three resulting types of energy indicators which can be used for monitoring

energy efficiency such as: thermo-dynamical, physical, and economical.

In the absence of adequate ways for measuring energy efficiency trends, as we have already mentioned in the previous sections, the gross domestic product is used as the basis.

Indicators of energy efficiency provide the connection between the consumption of energy and certain relevant economic and physical indicators. They can be defined at various levels of aggregation in respect of energy requirements (energy-wide, sector, sub-sector, end users, technology, process, or particular equipment).

Economic energy indicators are often used when energy efficiency is measured at higher level of aggregation, for example, at the national level, because it is not possible to make the analysis otherwise. Economic indicators provide relations between energy consumption expressed in the energy unit of economic activities expressed in monetary

units. Never the less, numerous examples have shown and this paper also, that energy intensity should not be observed separately from other energy and economic parameters.

In this paper, the technical concept of energy efficiency is used:

- Energy efficiency is the ratio between the useful output of energy conversion machine and energy input. The useful output may be electric power, mechanical work, or heat. Energy conversion efficiency is not defined uniquely but instead, it depends on the usefulness of output. All or part of the heat produced from burning fuel may become rejected waste heat if, for example, work is the desired output from the thermodynamic cycle. Using this concept energy efficiency is:

$h=P_{out}/P_{in}$ (1)

where, *P*out is the energy output and *P*in the energy input.

When this technical definition is applied to national or regional levels, it implies total primary energy supply (TPES) as *P*in and total final energy consumption (TFC).

Now, primary and final energy should be defined.

- Primary energy is energy that has not been subjected to any conversion or transformation

process. Thus, primary energy does not include electricity or refined petroleum products.

- Final energy are forms and fuels as sold to or as used by final consumers (households, industries, commercial buildings, transport, *etc*.) oravailable to the consumer to be converted into useful energy (*e. g*., electricity at the walloutlet).

Final energy forms and fuels are generated involving various steps of conversion from primary energy to final.

The TFC is often found in national statistics for economic sectors, for example, industry, transport, and other sectors. Other sectors assumes: residential, commercial and public services, agriculture and forestry, fishing, and non-specified, and as a special item, there is non-energy use. Since primary energy supply is always an integral part of such national statistics, it is possible to define one indicator of energy efficiency by the relation between TFC and TPES.

National energy efficiency measurements and monitoring have become important components of energy strategy in many countries, especially energy deficient ones. With substantial increases oil prices in the world, many countries have recognized the need to understand whether energy is consumed effectively in their economies and to increase energy efficiency. To serve these purposes, appropriate energy efficiency indicators have

been developed and applied so that any efficiency changes that have taken place can be quantitatively expressed. These indicators are also used in cross-country comparisons to explain differences in energy performance between countries and for international benchmarking. We have already defined one of such indicators as the relation between TFC and TPES. But, there are many mutually independent factors affecting energy efficiency at national or regional levels and, it is not possible to assessenergy efficiency correctly only on the basis of one indicator.

When energy efficiency at the national or regional level is concerned, energy intensity indicator is frequently used. This indicator is based on the GDP, which should be defined:

- GDP is the total value of goods and services produced by the nation's economy beforededuction of depreciation charges and other allowances for capital consumption, labor, and property located in the country. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade.

The World Bank has recommended the methodology which should be used in all countries. Unfortunately, very often, due to political reasons, there are some deviations in methodologies for the calculation of GDP in some countries which later cause confusion when this indicator is used in practice.

Energy intensity connects energy efficiency and some other economic indicator. It can generally be defined as the ratio between energy consumption and the measure of demand for services (number of buildings, total floor space, number of employees, or value of GDP for

services, etc.). For the purpose of this paper, the energy intensity will imply the ratio betweenconsumed energy and relevant GDP. It is assumed that PRIMARY ENERGY is used in the creation of the GDP. Why primary energy? It is because this is the only way in which the GDP isconsistently associated with energy consumed for its creation. For the purpose of more realistic evaluation of national economies, this paper uses GDP in dollars for estimates derived from purchasing power parity calculations of GDP (ppp).

3.Energy Indicators For 128 Countries

Only data from 2007 will be analyzed as the most recent ones are not available. However, ad hoc checks have shown that in the last decade relative relations of data for some countries were very stable.

Figure 1 shows dependency of energy intensity from GDP (ppp) per capita for 128 countries in the world. Such a large sample covers around 95% of the world's population. All countries form the sample are grouped into those which import or export energy. There are 43exporting countries and 85 importing ones. Some 25% of population on the planet lives in energy exporting countries. The GDP(ppp) span per capita is enormous and moves from 657(Democratic Republic of the Congo) up to 65000 (Luxemburg). The span of energy intensity varies form 0.0563 (Hong Kong) to 1.1602 (Iraq)

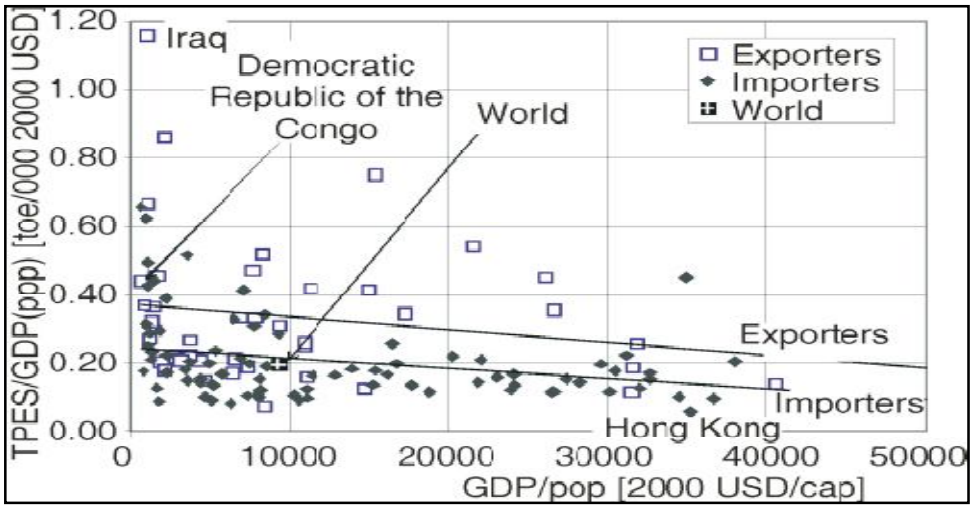

Figure 1: Energy intensity vs. GDP perpopulation for 128 countries

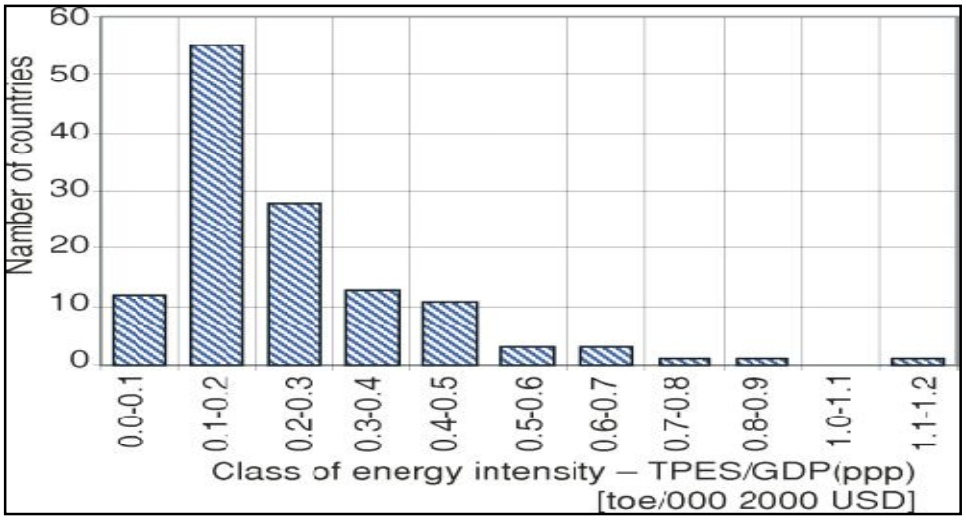

Figure 2: Number of countries distribution vs.class of energy intensity

Figure 2 shows classes of energy intensity and the number of countries in certain classes. There are few countries with exceptionally high energy intensity (Bahrain, Iraq, Jamaica, Kazakhstan, Nigeria, Tanzania, Trinidad and Tobago, Uzbekistan, and Zimbabwe). They are all energy exporting and three of them (Jamaica, Tanzania, and Zimbabwe) have low GDP per capita.

It should be emphasized that higher GDP(ppp) per capita is obvious for the same energy intensity in energy exporting countriesthan in energy importing ones. The strength of the energy sector is evident.

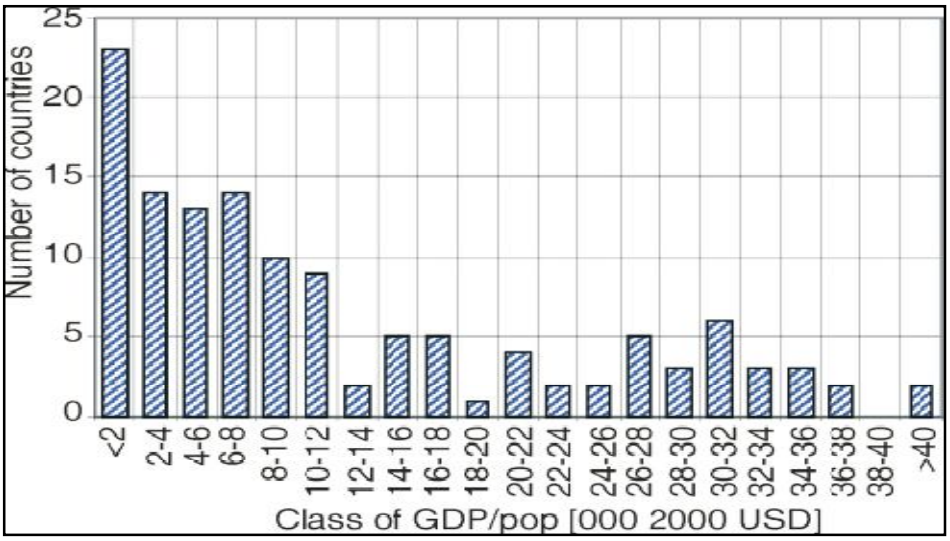

Figure 3: Number of countries distribution vs.class of energy intensity

Figure 3 presents distributions of the number of countries in the world *vs*. GDP(ppp) percapita. Unfortunately, dominant are countries with low GDP(ppp) per capita. Both distributions significantly diverge from normal Gaussian distribution which best describes great majority of occurrences in nature. Presented distributions correspond well to the Weibull distribution.

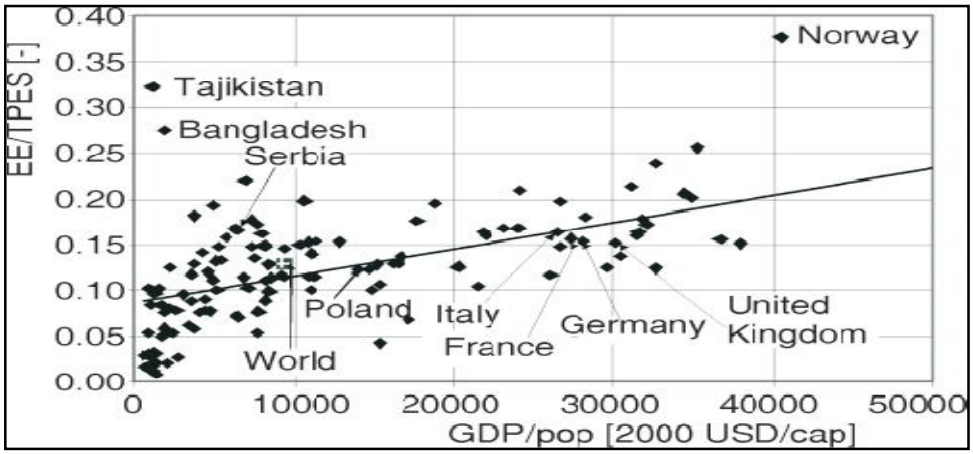

Figure 4: Ratio of electrical energy consumptionand TPES vs. GDP per capita

One indicator which is not often used is shown in fig. 4. This is the relation between electricity consumption against total primary energy supply. Unequivocally, it can be concluded from the figure that countries with higher GDP per capita use much more electricity than those with low GDP. The exceptions are Tajikistan and Bangladesh. The former generates almost all electrical energy from enormous available hydro potential and the latter uses own resources of natural gas for generating electricity. It is typical for both countries that they import part of the energy and economic activities there are at a very low level. Unfortunately, there are many countries in which the proportion of electricity consumption in total TPES is very small and they also have low GDP per capita. Those are poor countries with respect to all possible criteria. Five developed European countries (UK, Germany, France, Italy, and Poland) which have advanced electric energy systems but use different fuels for running them (France mostly uses nuclear power, Poland coal, Italy natural gas and coal, UK coal, natural gas, and nuclear power, and Germany coal and nuclear power), show very constant relation between indicators EE/TPES and GDP per capita. This also indicates without any doubts approximately the same level of energy efficiency in these countries. At the same time, this relation in India is much higher which can be attributed to the lower level of energy efficiency. In India, electricity is mostly generated from coal and hydro power.

The relation between TFC and TPES *vs.* GDP is the indicator of energy transformation efficiency at the national (or regional) level which involves all possible transformations up to final energy supply. Non-energy use of final energy is exempt from the analysis. The world average is 62.5%. Extremes refer to Nepal, Ethiopia, Trinidad and Tobago, and Singapore. Explanation can be found in energy systems of these countries. When

Nepal is concerned, it should be said that relatively smallproduction of electricity is achieved only from hydro power and other primary energy is directly used as final without any transformations. Similar situation is in Ethiopia where around 90% of electricity is produced from hydropower, and the rest from petroleum products.

These analyses explicitly point out to large dependence of national or regional energy system structure on basic energy indicators.

4.Discussion

The relation between overall primary energy consumption and the GDP, or energy – GDP ratio, is one of the most frequently used economic indicators for energy efficiency. This relation is the measure of the economy's energy intensity at the highest level of aggregation. Calculated at the annual level, energy-GDP ratio can show short term and long term trends. The decline of this ratio shows on the average reduced necessary energy for the generation of nationaloutput units. This comparison can provide satisfactory results only if single indicators are carefully determined in the same way. Therefore, we have precisely defined terms such as TPES,GDP, *etc*., at the beginning of the pa per. Also, for all our analyses, we have used the samesources which are more or less relied on International Energy Agency.

The elusive causative connection between the energy consumption and the GDP makes it difficult to create adequate energy saving policy. Empirical investigations of the relationship between energy and GDP have given mixed results of analyses in oil importing countries. This has raised questions regarding effects which occur due to the application of the energy saving policy on the economic development not only in developed countries but in developing countries as well. It is believed that this difference has occurred as a consequence of various methodologies and origins of data. Therefore, the agreement on the causality between the energy consumption and the GDP has failed [1].

Some authors have supposed that there is direct connection between energy consumption and the GDP and they have further proceeded with estimating their values by means of various methods [19, 20]. Other authors have used various methods for estimates in order to study both the direction and the amount of this sub-relation [8].

Methodologically, empirical conclusions related to the nature of the relation betweenenergy consumption and the GDP have shown that they change depending on econometricmethod used and on the way in which data have been collected. Standard

tests based on causality techniques have been widely used. However, such methods are criticized as yielding inconsistentresults. Instead, co-integration and error-correction models are being increasingly applied [1].

Indicators which reflect changes in energy intensity have been used for the last ten years to follow the progress of efficiency and to identify opportunities for improving this efficiency. Governments make documents routinely in order to present these trends and make comparisons with energy intensity in various countries and do not take into account specificities of these countries.

In other words, policy-makers are becoming increasingly concerned with the physical rather than with economic repercussions of energy use [2].

However, there are issues which concern interpretation of trends described by energy indicators as different trends appear in case of physical and in case of economic energy indicators.

5.Conclusion

The research about causality between energy consumption and GDP in developed countries is of a more recent date. By employing different methodologies, many authors have come to opposite results when the question concerns effects that can be accomplished in thecountries in transition. The investigation results in developed countries are not much more convincing than results obtained in the transition economies.

This paper has addressed the need to analyze energy intensity concurrently with other indicators of energy and economy. In the contrary, very unreliable conclusions can be made.

Also, it is necessary to use only verified data obtained by means of well-known methodologies. Such analysis can be very useful to the energy policy makers.

India is a candidate for becoming a permanent member of UN Security Council in the future and preparation for thisintegration requires stable economy. In that respect, it will be necessary to analyze the energy situation in India in correlation with economic indicators.

6.Nomenclature

- GDP – Gross Domestic Product, [USD]

- GDP(ppp) – GDP dollar estimates derived from purchasing power parity (ppp) calculations; purchasing powerparity (ppp) is a theory of long-term equilibrium exchange rates based on relative price levels of two countries, [USD]
- TPES – Total Primary Energy Supply (indigenous production + imports – exports–international marine bunkers ± stock changes), [ktoe]
- TFC – Total Final Consumption, [ktoe]

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