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ECONOMIC GROWTH, SUSTAINABLE DEVELOPMENT AND ENERGY SECURITY INTERRELATIONS

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Abstract. Presented paper aims to indicate what types of interrelationships between energy usage patterns prevailing in particular country, economic growth and finally, sustainable development could be distinguished. The topic of paper, or, rather research area, is neither new nor original. Nevertheless, an array of approaches towards character of considered interrelationships can be encountered. Complicity of chosen issue, we reckon, lies in differences of perception of the following questions. Our findings consequently would depend on, at first, how we measure economic growth in short and long terms, the second, how we measure energy security, and, the third, how we benchmark progress towards sustainable development. Methods, which we consider as being applicable for measuring of selected interrelationships, comprise a separate part of scientific elaboration. Therefore we formulate a task to overview the most contemporary measurable perceptions of economic growth, perceptions of energy security facets affecting economic growth and consequent reaction of sustainable development to various scenarios of energy consumption and economic growth. Resulting conclusions about measurement of indicated phenomena and argumentations of their plausible interrelation would lead us to choice of methodological approaches of described interrelations' analysis.

Keywords: Economic growth, sustainable development, energy security, energy intensity, competitiveness.

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JEL Classifications: E21, E25, L1, N7

1. Variety of approaches towards energy security

Energy security in contemporary literature is being discussed from plethora of angles. After comparatively concise review of prevailing perceptions we will distinguish facets relevant for taking into account in the model, which would be devised for prediction of economic growth and sustainable development tendencies.

The most characteristic perception of energy security for early years of indicated decade can be represented by approach, according which energy security is seen as comprising constitute of sustainable development (Streimikiene e*t al.* 2007). The article authors assume that policy makers need a simple tool for "current and future effects of energy use on human health, society, air, soil and water". According to them, energy indicators for sustainable development (EISD) can be used. The further elaborations are based on 30 indicators used by United Nations Commission on sustainable development. Those indicators, as classic approach to sustainable development suggest, are attributed to a group of social, economic or en-

vironmental ones. For further analysis authors select EISD, which they think are important specifically for Baltic States energy sector development. Hence the following indicators are being tackled: Energy use per capita, Energy intensity of GDP, Energy supply efficiency, Energy intensity of industry, Energy intensity in agriculture, Energy intensity in commerce, Energy intensity in household, Energy intensity in transport, Energy mix, Renewable energy share, Net energy import dependency, CO2 emissions from energy sector per capita and unit of GDP (the scheme of core EISD indicators is presented in Figure 1).

SOCIAL		
Equity	**Health**	
Accessibility SOC1 Affordability SOC2 Disparities SOC 3	Safety SOC4	
ECONOMIC		
Use and production patterns	**Security**	
Overall use ECO1 Overall production ECO2 Supply efficiency ECO3 Production ECO4 and ECO5 End use ECO6-EC10 Diversification ECO11-ECO14	Imports ECO 15 Strategic fuel stocks ECO 16	
ENVIRONMENTAL		
Air	**Water**	**Land**
Climate change ENV1 Air quality ENV2-ENV3	Water quality ENV4	Soil quality ENV5 Forests ENV6 Solid waste ENV7-ENV9

Fig.1. Set of core EISD

Source: Streimikiene et al. (2007)

A result of research lies in providing linkages between indicators and policy actions. Critically evaluating adopted by authors approach, it can be concluded that there is not much attention paid to a concept of energy security. Scientists perceive problem of energy use as constituent of sustainable development problematic. No contentious elaborations on currently urgent concept of "energy security" are provided. It complies with EUROSTAT approach, in principle.

Recall that interrelation of economic growth and energy use indicators as presented in EUROSTAT Sustainable Development Indicators system is not emphasized. According EUROSTAT Sustainable Development Indicators' system, economic growth estimated by "growth rate of GDP per inhabitant" indicator is considered as a single and the most important indicator reflecting economic development of a country (it is found in Theme 1: Socio-economic development, in Level 1, what corresponds the highest level of abstraction). Role of energy in sustainable development processes is being reflected through the following multifaceted set of indicators. "Final energy consumption by sector" is found in Theme 2: Sustainable Consumption and Production, and reflects resource (in the case, specifically, electricity) productivity). Another reference to energy use is being made in the context of environmental sustainability. In Theme 6: Climate Change and Energy, Sub-theme "Energy" is being introduced. The following indicators are considered. Level 1, "Share of renewables in gross inland energy consumption", Level 2, "Energy dependency", Level 3 "Gross inland energy consumption by fuel", "Electricity generated from renewable sources", "Share of biofuels in fuel consumption of transport", "Combined heat and power generation", "Implicit tax rate on energy". Impression is that energy security currently has obtained much broader treatment (e.g. Tvaronavičienė 2012) than is reflected in EUROSTAT Sustainable Development Indicators' system. It means the discussion on multifaceted perceptions of energy security had not gained its momentum at year of the publication submission, i.e. year 2006.

Looking chronologically at evolution of energy security concept it is rather interesting to glance at introduction of some novel understandings of sustainable development. Classic and the mostly spread association with sustainable development research area triggers emerging of dimensions, mentioned in above cited paper, i.e. social, economic and environmental. Those aspects of development – more or less emphasized – inherently is embraced by the classic perception of sustainable development. Meanwhile, parallel to classic approach, obviously a lot of different understandings could be found. Not switching discussion towards research area of sustainable development but just for the sake of scientific interest, let us point out, that relating of energy, or energy security indicators to sustainable development indicators is relevant only in cases, when sustainable development perception coincides with classic one. Meanwhile, some perceptions of sustainable development do not directly

tackle energy issues at all (De Vries, Petersen 2009). These authors adopt different from classic conceptual framework of sustainable development evaluation, a hub of which is subjectively perceived quality of life. Paradoxically, those authors do not put especial emphasis on energy or energy security. That facet of reality is embedded in more general blokes of natural resources and technology (Figure 2).

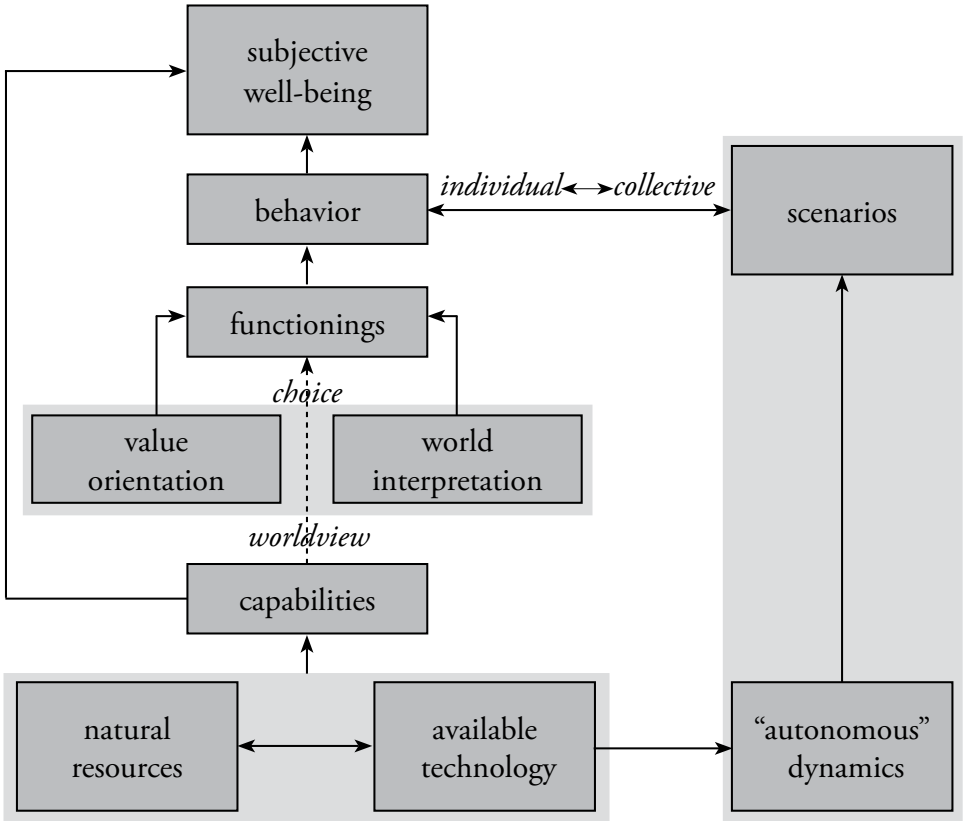

Fig.2. Conceptual framework for sustainability assessment

Source: De Vries, Petersen (2009)

Hence, to generalize, what seems to be classic approach towards energy and energy security (which meant that energy issues should be incorporated into sustainable development notion) appears to be not unanimously accepted. Here we enter into elaboration of energy security facets perceptions, which are analyzed as separate field and possibly, characterized by effects, which appears to be beyond boundaries set by research area of sustainable development.

An attempt of extending boundaries of renewable energy production impact estimation could be represented by e.g. research, in which concepts of substantive (classic) and procedural (extended) sustainability are being introduced; impact of renewable energy is being measured from prospect of local stakeholders (Del Río, Burguillo 2009) (Figure 3).

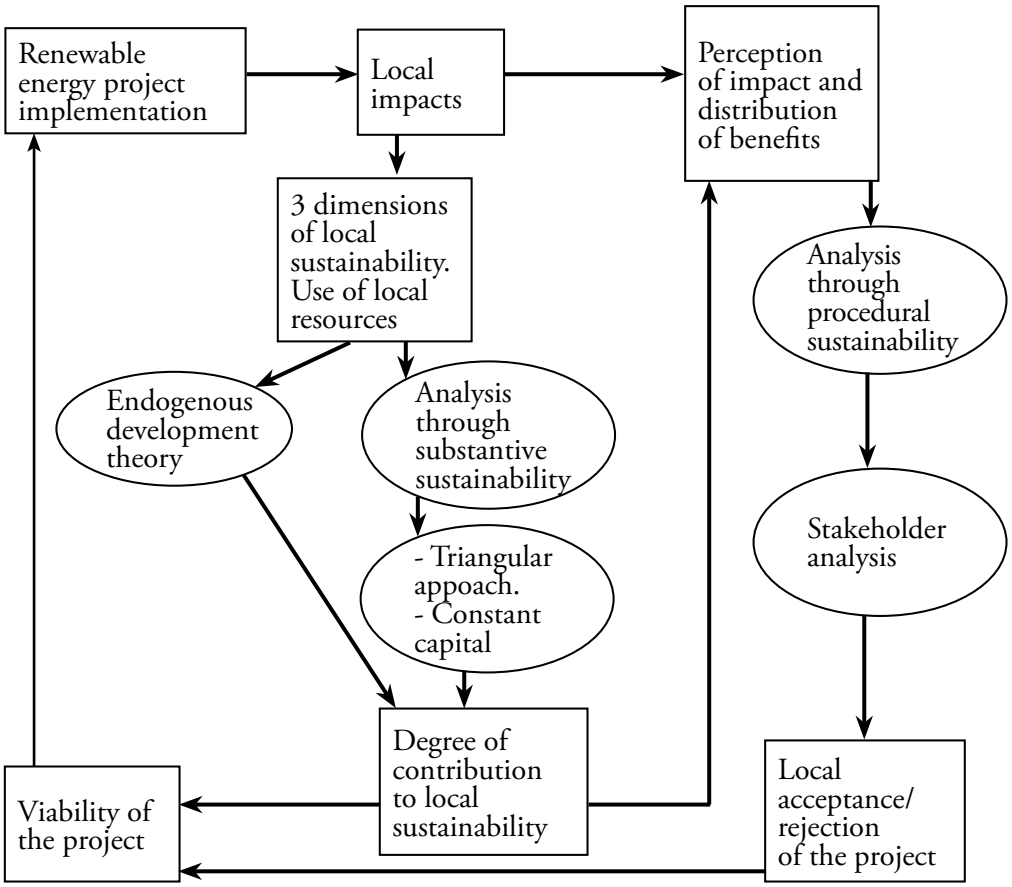

Fig.3. Theoretical framework

Source: Del Río, Burguillo (2008, 2009)

Another research, published at the same year (2009), similarly as one considered above, incorporates renewable energy (biofuels, specifically) into extended (we can call it "procedural") sustainable development framework. Authors adopt view of sustainable development elaborated by Sachs in his book "Caminhos para o desenvolvimento sustentável" (Garcez, de Souza Vianna 2009). Adopted approach suggests eight dimensions (instead of classic, or substantive, approach based on three conventional dimensions) of sustainable development: social, cultural, ecological, environmental, territorial, economic, and political on both national and international levels. Biofuels problematic addresses only social and environmental aspects of sustainability: 1) social sustainability—social inclusion of family farmers; regional development; food security; (2) environmental sustainability—influencing the carbon and energy balances of biodiesel; promoting sustainable agricultural practices; and a diversity of primary material (feedstock) (Garcez, de Souza Vianna 2009). Other attempts enrich the considered approaches (Gallego Carrera, Mack 2010; McNally *et al.* 2009, Bassi *et al.* 2009, Coccia 2010). E.g. in the later research energy security and sustainability are being observed through lenses of institutional capacity to react to changes caused by increase in production and population, therefore increase in demand of energy. If institutions are lacking that capacity to react, potential of conflict appears which threatens human security. "Power shed" may be needed, otherwise military forces might be employed (McNally *et al.* 2009). Nevertheless, stability rather than resilience solutions are of major importance. Peculiarly, the energy security is being related to institutional dimension of sustainable development. The context in which institutions are considered differs from rather conventional dimensions (Tvaronavičienė, Grybaitė 2012). In this case institutions are seen as factor able to mitigate effects of societal and economic pressures raised by increase in energy of demand, and, presumably conflicts by energy scarcity.

Hence, to generalize, above considered papers tackle renewable energy problematic and relate it with extended perception of sustainable development. It is

rather interesting to notice that both approaches put emphasis on non-economic dimension; while the first draws attention to stakeholders, the second points to social sustainability (through farmer employment; and farmers are stakeholders as well) and environmental sustainability (pollution). As it was already indicated, economic efficiently of renewable energy is not being estimated through cost-benefit lenses; even more – economic growth is not being considered by mentioned authors at all.

To elude impression that discussion on energy security after year 2007 lost its interest in interrelation of energy consumption and economic growth, let us glance at a paper, which "investigates the resource consumption of Japanese society since 1979 and its subsequent effects on the economic output of the nation and the environment" (Gasparatos, Gadda 2009). Main authors' ideas related to energy security could be rephrased in the following way. Despite energy consumption in main sectors of economy, such as industry, transport, agriculture stabilized, or even decrease, the energy consumption by households and service sector continue to increase. Japanese has not managed to embed into its economy presence of foreign oil markets but nevertheless, rely on export on energy and other resources intensive commodities. There is no unanimous agreement about causal relationship between energy consumption and economic growth. One group of scientists claim than energy consumption results in economic growth, while opponents reckon reverse causality is more plausible (Gasparatos, Gadda 2009).

To conclude, authors consider energy consumption as driving force or consequence of economic growth. Energy security emerges as precondition of economic development and, consequently, sustainable development. This study investigates the resource consumption of Japanese society since 1979 and its subsequent effects on the economic output of the nation and the environment. In order to quantify resource appropriation and trends in production and consumption, the concept of emergy synthesis is employed. Our results show a significant increase in the total amount of emergy consumed by 66.9% between 1979 and 2003 which comes hand in hand with an increase in the level of environmental stress by 93.7% (quantified as the environmental loading ratio). On the other hand the emergy required to produce 1 USD of economic output has been gradually decreasing which denotes an increase in the efficiency of the conversion of natural capital into economic output. What is most interesting though is the growing dependence of the Japanese economy on imported emergy, increasingly from developing nations, that severely affects the potential for unhindered economic growth (Gasparatos, Gadda 2009).

2. Energy security and sustainable development interrelation

From the above presented considerations we can draw a conclusion that increase of total amount of consumed energy coincides with GDP growth and environmental damage, despite energy required to produce one conventional unit of GDP decreases (later we will introduce a concept of energy intensity).

Another concept related to reaction of so called "state welfare" to increased usage of energy is being introduced. As scientists Blum and Legey claim, "energy security is defined, in this context, as the ability of an economy to provide sufficient, affordable and environmentally sustainable energy services so as to maintain a maximum welfare state, even when issues would press it otherwise. We introduce the notion of energy security gap to represent the economy's failure to show such ability (Blum, Legey 2012). The authors methodology is being reflected by a general approach which: (a) addresses the matter from the perspective of both demand and supply sides, with no spatial, temporal or sectorial constraints; (b) complies with any energy system (economic and physical) structure, regardless of either the energy security risk factors to which it is exposed or the mitigating measures it has available; (c) supports inter-economy and intertemporal benchmarking (Blum, Legey 2012). To put those ideas into other way, we can say that economic growth, which coincides with increased consumption of energetic resources cannot be reached "sustainably", i.e. without harm to environment.

Sensitivity of "welfare economy" or, if we rephrase authors, "susceptibility" to harm caused by increased energy consumption could be characterized by "resilience of economy". Blum and Legey define resilience as the ability of an economy to handle energy related effects. The more resilient the economy is, the smaller its energy security gap. In other words, the larger the resilience, the lower (higher) the impacts of disadvantageous (advantageous) energy related effects in the economy; conversely, the smaller the resilience, the higher (lower) their effects (Blum, Legey 2012).

According Blum and Legey (2012), we are in a position to define an indicator for an economy's energy resilience. But firstly it is necessary to proceed through some auxiliary definitions. Let:

A = [*ai*]

vector of all economic activities that are potential sources of relevant energy related issues;

qi, *pi*, *li* - quantity, price and quality of energy or energy related materials flowing through activity *ai*;

W - energy sensitive measure of welfare;

Δ*qi*, Δ*pi*, Δ*li* - deviations in *qi*, *pi* and *li*; and Δ*Wiq*, Δ*Wip*, Δ*Wil* deviations in *W* as a consequence of Δ*qi*, Δ*pi* and Δ*li*, and actions taken through implemented energy security mechanisms.

Blum and Lege (2012) define three ratios of change, which are elasticity-like measures of welfare variations arising from deviations in energy quantity, price and quality in each critical economic activity.

(1)

$$\varepsilon_i^q = \frac{\frac{\Delta W_i^q}{W}}{\frac{\Delta q_i}{q_i}}$$ (energy related) quantity–elasticity of welfare to deviations in activity a_i

(2)

$$\varepsilon_i^p = \frac{\frac{\Delta W_i^p}{W}}{\frac{\Delta p_i}{p_i}}$$ (energy related) price–elasticity of welfare to deviations in activity a_i, and

(3)

$$\varepsilon_i^l = \frac{\frac{\Delta W_i^l}{W}}{\frac{\Delta l_i}{l_i}}$$ (energy related) quality–elasticity of welfare to deviations in activity a_i.

Anyway, authors claim that despite their ability of those indicators to quantify to what extent an energy related issue impacts on the economy's welfare, the above measures do not reflect thoroughly the economy's energy resilience since it also depends on the nature of the welfare change. Two situations may occur (Blum, Legey 2012). (In one case, *the energy related issue causes a decrease in the economy's welfare* (in this case, the more energy inelastic the economy, the less it is burdened by the issue). In another case, *the energy related issue causes an increase in the economy's welfare* (in this case, the more energy elastic the economy, the more it will be able to take advantage of the issue).

Authors convince about two possible, diametrically opposite, directions of energy consumption impact on countries' welfare. On the other hand, the more complicated question relating to benchmarking of consumption, i.e. estimating and setting a limit, which would separate beneficial and detrimental level of energy consumption (supply) would remain unanswered. Hence, in the report of European commission it has been noticed the same blind alley of research projects performed under Framework Program on sustainable development. It was mentioned that scientists tend to focus on modelling for the prediction of economies sectors development and its impacts rather than monotoring progress towards specific sustainability objectives (DG for R&I, EC 2010).

3. Economic growth and energy consumption (supply): if the same goals are being tackled by countries of different development

In order to answer to a question of methodological character, if energy consumption (in case of sufficient supply, of course) enhances economic wealth (or growth – to look through narrower lenses) let us depict countries' economies functioning scheme. As Gasparados and Gadda indicate (Garparatos, Gadda 2009), the main assumption behind emergy synthesis is that real wealth depends on the amount of resources consumed within a system and as a result it makes use of a different valuation perspective to that of the traditional economic analysis that focuses on human wellbeing and utility. The authors (Garparatos, Gadda 2009) in Figure 4 present a simplified view of the input and output flows from a nation. The numerous emergy flows are aggregated into local renewable (R), local non-renewable (N, N1, N2, N0), imports (F, G, P2I) and export (N2, B, P1E) flows. These flows are then further combined into different indices that provide information on the metabolism of the system. Some of the most commonly used indices include the emergy yield ratio (EYR), the emergy investment ratio (EIR) and the environmental loading ratio (EYR).

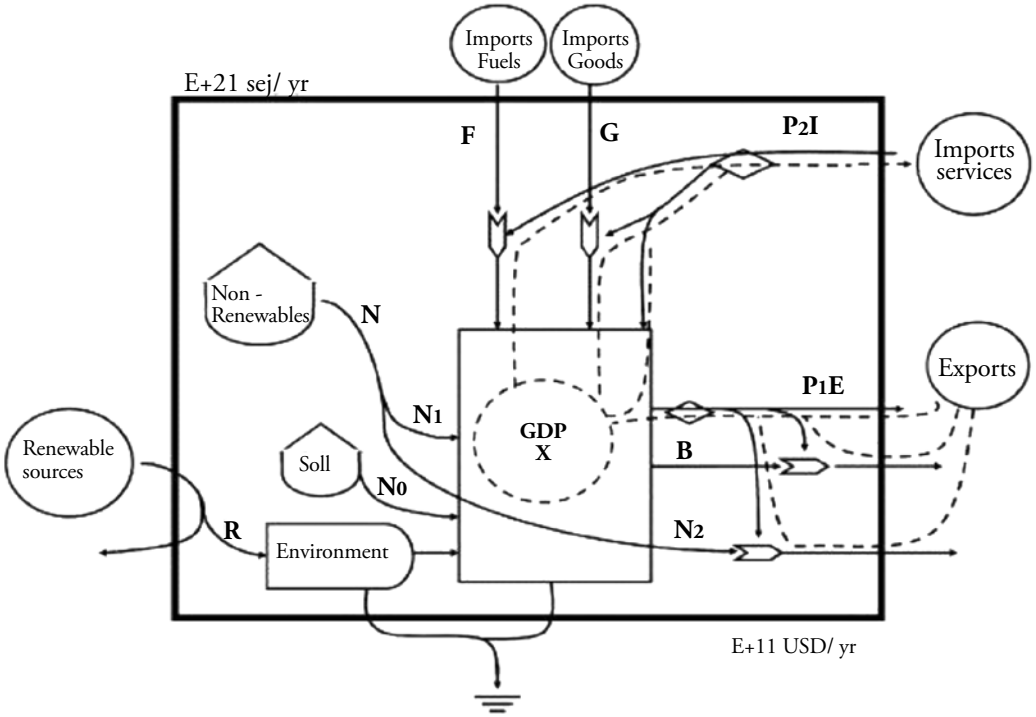

Fig.4. Emergy flow diagram

Source: Garparatos, Gadda (2009)

Analysis of interrelation of economic welfare (or growth) and energy security requires to shortcut an extensive list of indicators. Some suggest narrowing down the concept of energy security to the concept of energy supply continuity. This reduces the overlap between the policy goals of energy security, sustainability and economic efficiency. The narrower concept of energy supply continuity can be measured more precisely and reduces the double counting of potentially less important aspects, simply because they lie on the border between different concepts (Winzer 2012). We will see later that other authors argues for narrowed but still broader treatment of energy security, i.e. they argue that not only supply but demand as well plays very important role (the greater demand, the greater supply and the greater consumption in economy, what results in detrimental effect of restricted supply to sustainable economic development).

The argumentation could spin supporting sides into vicious circle unless context of argument is introduced. Here we need to admit that level of countries development play a crucial role in stepping into one or another position of arguing parties. E.g. scientists from less developed and energetically dependent country, Lithuania, (Augutis *et al.* 2012) suggests energy security indicator, which is a special index which gives numerical values to important issues for security of energy sector. In his paper, each indicator is described by presenting the title, comments, factual and threshold, pre-critical and critical state values. The integral characteristics of these indicators show the level of energy security and in order to identify it, a point system assessment scale is used. The methodology developed in this paper is applied for the assessment of the Lithuanian energy security level in different scenarios. At first, indicator groups are constructed and group weights are determined. The weights of indicators within each group are established in two ways: when all weights are equal and one indicator is dominating. Taking into consideration the assessment of indicators by points, their weights in groups and group weights, the Lithuanian energy security level was determined according to separate indicator blocks. The security level of each indicator and each indicator block, and total security level are presented as the results. The indicators that have the highest impact on the security level increase or decrease are determined as well (Augutis *et al.* 2012).

Environmental threats are not the significant in that particular context. Lithuania has undertaken the obligation from the EU to increase the share of renewable energy sources in the final balance up to 23% until

2020. So far a level of 13% has been achieved, thus the obligation is most likely to be met. The main sources used are biofuel and wind energy. A greater problem is posed by the EU directive on Pollution Standards which will come into force in 2016. Following this directive, the Lithuanian thermal power plants will no longer meet the requirements indicated therein and will have to be replaced or equipped with new technologies, reducing the CO2 to the required level (Augutis *et al.* 2012). Economical threats are more worrying since Lithuania (as e.g. Latvia) is dependent on a single energy supplier, that is Russia (Augutis *et al.* 2012; Karnitis 2011). According this approach, energy contributes to a virtuous cycle of human, economic and social improvements that are essential to sustainable development in developing countries (Figure 5).

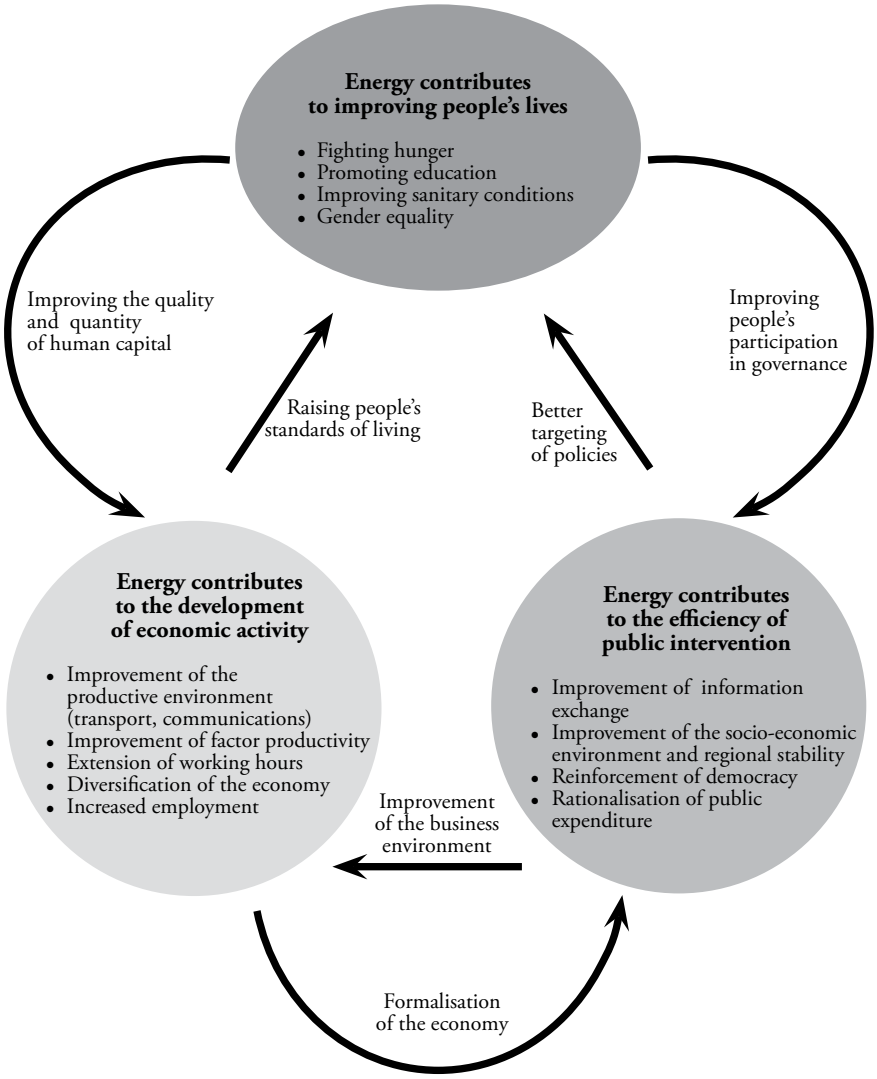

Fig.5. Links between energy and human, economic and social development

Source: Augutis *et al.* (2012)

Kaygusuzl (2012) representing more developed country, switches emphasis from energy supply issues towards economic development sustainability. He claims "people of today and tomorrow demands much greater levels of energy services". It also demands that these services be delivered in a manner that is more universally accessible, affordable, reliable, safe and environmental friendly. This will require fundamental changes in technologies, methods, infrastructure and people's behavior everywhere. The change needs to be so profound that government, business and social leaders need to use every instrument at their disposable as effectively and efficiently as possible. Energy development and use should be placed in a sustainable

development context to ensure that no dimensions, resources or policy tools are overlooked (Kaygusuzl 2012; Makštutis *et al.* 2012; Verbruggen 2006).

It has to be noticed that a numerous studies are devoted to energy consumption and environment pollution interrelation. In this article we do not tackle this particular relationship, but still it is worth to mention so called "Kuznec curve", which indicates an inverted *U* form relationship between energy consumption and state welfare growth; i.e. the curve indicates that at low level of economic development energy consumption stimulates economic growth but the effect tends to transform into opposite after country achieves higher level of development because of deteriorating impact of GHG gas emissions on environment.

4. Alternatives of sustainable economic growth measurement

So far we discussion in the area of economic growth, sustainable growth and energy security interrelation area was concentrated in energy security perception, economic and sustainable development implications caused by increased energy consumption. While measurement of sustainable development has long been an almost conventional area of scientific discussion (e.g. Korsakienė *et al.* 2011; Borsekova *et al.* 2012), measurement of economic growth was implied to be conventionally adopted: i.e. economic growth is measured by GDP or GNI growth rates or GDP or GNI per capita growth. A relatively new approach to sustainable economic growth was expressed by You (2011). Authors employ the structural vector auto regressions framework and the generalized impulse response function to study the long-term dynamic relation between China's energy consumption and sustainable economic growth. They claim that in addition to the conventional economic indicators (GDP growth rates), genuine savings rates are to be particularly examined to indicate sustainable economic development. They results show that the high elasticity of energy consumption dramatically undermines the capacity of China's sustainability in terms of reducing genuine savings rates. Their analysis finds that clean and renewable energy increase the country's genuine savings significantly. That is, renewable energy consumption promotes sustainable development for both natural and economic societies. However, increase in traditional solid energy consumption is more likely to benefit only the growth of GDP (You 2011; Feng *et al.* 2009; Zhang *et al.* 2012).

Besides introduction of savings rate into system of economic growth estimation, let us finish the current paper with additional observations related with energy intensive economies competitiveness in the long-run. To our minds, it is very important to take into account growing strand of scientific literature devoted to investigation of interrelationship between energy intensity and ability to export "dirty" or energy intensive products. "Clean" products are being seen as proxy for long-term competitiveness gained by international exports (Zuo 2011; Constantini, Mazzanti 2012).

Concluding remarks

In order to indicate interrelations between economic growth, sustainable development and energy security, we need to agree what presumptions lie under those categories'. By claiming what concept means what to us let to build rigid framework of scientific elaboration and formulate methodology of research.

Review of the most contemporary scientific literature on the topic has led us to the following insights.

The first, despite wide array of definitions of energy security concept, and numerous attempts to build complex indicators, nevertheless, a task of revealing interrelation between economic growth and energy consumption requires very concrete metrics. For less developed countries energy supply still remains a metric of the highest importance, which, consequently, stands for energy security.

The second, energy security (in our case supply or availability) can have rather controversial effect on sustainable development. The direction of impact can be positive either negative; positive impact can be tade-offed by negative, i.e. impact is context sensitive. We assume that for less developed countries increase in energy consumption stimulates economic growth and sustainable development. For more developed countries further increase in energy consumption can have detrimental effect because of increased environment deterioration. The final effect depends on economy income elasticity to energy price, which again can be related to country's development level.

The third, we agree that short-term and long-term economic growth had to be distinguished. Long-term growth measure net had to incorporate savings rate,

as some authors suggest.

Benchmarking of rational and acceptable energy consumption had to be attempted with respect to countries development level. Economic growth and export competitiveness cannot be achieved by encouraging energy intensities increases, especially in exporting industries.

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