GEL Q430
UDK 330.4

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AN ECOLOGICAL-ECONOMIC CONVERGENCE: TRANSITION TO SUSTAINABLE ENERGY

Sustainable energy development is complex challenge, so only complex decisions and approaches could be possible to implement in the most efficient way. There is still open question – what is the optimal volume of new energy resources using to support sustainable development and environment safety for any state of the world. Article deals with the availability of convergence to serve for the more effective usage of analytic and system approaches for modeling ecological-economic spillovers in the case of transition to sustainable energy. The economic effects of sustainable energy transition are considered. The analysis of dynamic of energy consumption in the scale of different type of resources during 1820-2030 years depicted the situation of complicated analysis of "economy-energy-environment" linkage. It arises the agenda of necessity to implement complex approaches for modeling and forecasting of new energy systems development. Different types of models and techniques to analyze economy-energy systems are listed and compared.

Keywords: energy consumption; convergence; model; energy resources.

Introduction. Energy conservation and energy efficiency become a priority areas of energy policy in increasing number of countries, due to shortage of fuel and energy, increased anthropogenic impact on the environment, inadequate own stocks of resources and the increasing need for them. World economic standard of the previous century was the continuous and rapid growth in production and consumption, primarily due to the organic nature of energy – oil, natural gas and coal. Despite annual growth investments in R&D of renewable energy, it is likely that global energy demand will be satisfied mainly by traditional sources.

Minimizing adverse effects of the energy processes on the environment, along with providing energy security, the development of competitive energy market became bases of the energy policy of the European countries. Mitigating environmental impact of energy activities challenging, yet creates new opportunities.

WORLD ENERGY OUTLOOK 2012 FACTSHEET give some answers and challenges "How will global energy markets evolve to 2035?", some of them are following:

1) Taking all new developments and policies into account, the world is still failing to put the global energy system onto a more sustainable path.

2) Emerging economies drive global energy markets.

3) Energy subsidies are essential to the growth in renewable energy, especially in the power sector, as many renewable resources are still more expensive than conventional sources.

Status of new and renewable energy production is under consideration as on the level of scientists [1-4] but mainly on the level of policy makers (local and international policy) [5-7]. There is strong believe that increasing the part of the renewable energy resources will led states to the sustainable economic development. There are increasing number of literature, publications and releases that prove and provide evidence for positive economic effect of new energy era [3-4, 8]. However, all of them remark that the transferring to such energy usage is mostly expensive, and not so rapid and appropriate for every state [9-10]. More and more reports claim that developed countries can easily to change their system of energy consumption – that really increases their environment security, economic development. But for most developing states, countries under transition such new energy programme is no budget, and even happen not same spillovers are considered. There is evidence that some states become "greener" at the expense of other mostly less developed states.

The challenge is to find out that exact optimal point under which the defined exact portion of different energy sources be used and will led to equal, maximum positive effect for all states over the world – so it will be optimum for the Earth needs. Such the optimum energy resource consumption point that would provide the most economic development and the less ecological pollution – is not found yet, and studies devoted to such research are still in shortage.

The main aim of this paper is to consider possibilities of analytic and calculative approaches to be implemented for ecologic-economic spillovers modeling in the case of transition to sustainable energy, and for the search of optimum point mentioned latter.

An ecological-economic convergence. The idea of **convergence** in economics (also sometimes known as *the catch-up effect*) is the hypothesis that poorer economies' per capita incomes will tend to grow at faster rates than richer economies [11]. As a result, all economies should eventually converge in terms of per capita income. Similar concept could be implemented for the convergence of environmental standards. Same definition can be transferred on the ecological-economic contradiction: less-environmentally friendly economies per capita emissions will tend to grow at slower rates than richer economies. As a result: all economies should eventually converge in terms of "green economy" and energy consumption. But the opposite side of this coin*: race to bottom*.

The exact place where convergence principals appear – ecological problems of modern world have the economic approach in their basis. So without convergence of knowledge between economic theories, modeling approach and ecology it's fully impossible to calculate any environmental costs in their real complex scale (especially at the international level).

What we knew before? And what we know nowadays? Conception of the economic process treats the economy as an independent, self-regulating and self-sustaining system whose productivity and growth are not seriously constrained by the environment (Fig 1.). Expansionists treat the economy as an open, growing, independent system which, because of technological Innovation, lacks any fundamentally important connectedness to the 'environment' (which is therefore treated as infinite). Ecological economists argue that conventional economic development models are responsible for, or at least aggravate, the sustainability crisis [10].

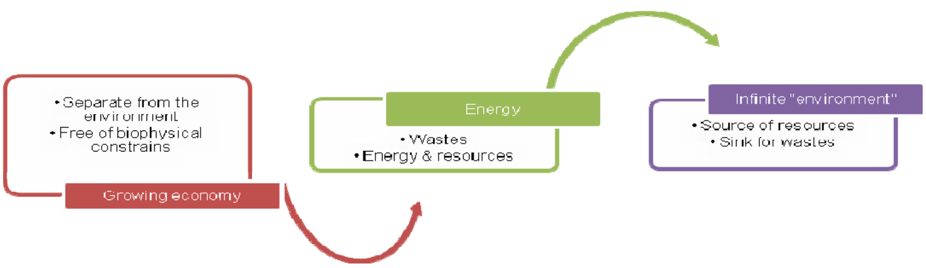

Fig. 1. Linkage "economy-energy-environment"
Source: authorial computation

The first step toward understanding this interpretation is to recognize that despite all our modern gadgetry, human beings remain ecological entities. Ecological economics sees the economy as an open, growing, wholly dependent subsystem of a materially-closed, non-growing, finite, ecosphere [10].

According to the environmental economics, an environmental resource deserves economic treatment only if it is 'relatively scarce' and is capable of generating utility to the individuals whereas. The ecological economics treats almost all the ecological resources as equally important in their analysis, irrespective of whether a resource is 'economically' scarce or not. The utility-based approach in the environmental economics is that the resources should be protected for improving the welfare of the individuals [12].

Economic mechanism of environmental regulation – complex multi-level relationships between entities themselves and with the parent bodies (Fig. 2).

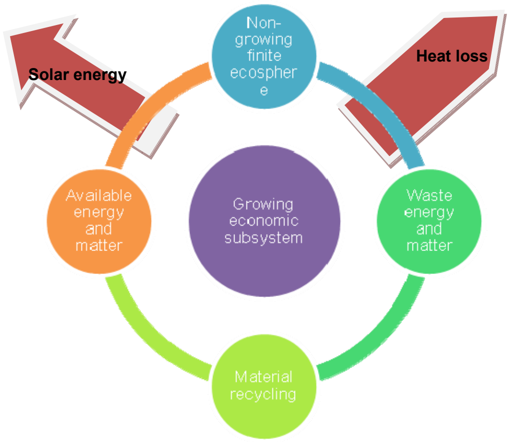

Fig. 2. The Ecological (Steady-State) Perspective
Source: authorial computation

The connecting arm of this relationship should become an environmental audit (EA) and economic-environmental modeling (EEM) – tools that include organizational and economic factors of environmental protection [9, 13, 14].

The application of such approaches to energy sector lets to consider and estimate in details the various energy-using activities within each demand sector, charting their volume and physical energy intensities over time [9, 15]. These approaches pay particular attention to maximizing energy efficiency through the use of best available technologies. So, we have solid provement to use only convergence approach for the assessment of energy balances, energy policies and its forecasting.

Transition to sustainable energy: dynamics and trends. Renewable energy has become quite topical, and it is gradually being realized that our energy future, if it is to be sustainable, lies in that direction [16].

Figure 3 and 4 show the development of energy consumption over time. How history is cycling?! We have moved from renewable energy (biomass, mostly wood) to fossil fuels (first coal, then oil, then the present move to natural gas), and appear to be moving back to a mix of renewable energy technologies [16].

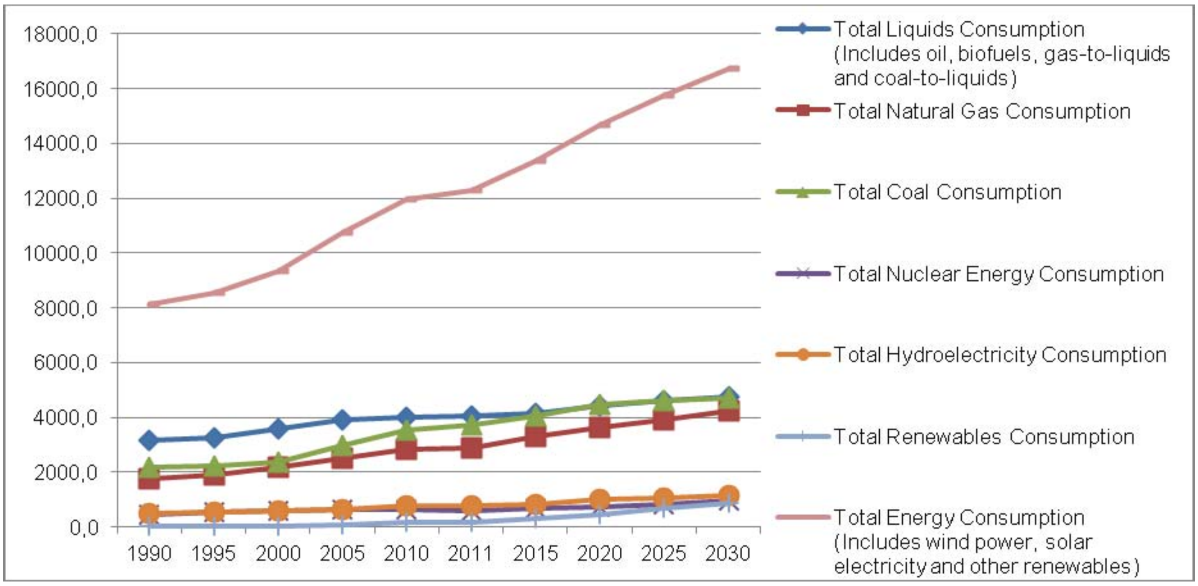

Fig. 3. World Consumption of Energy (1990-2030), million tonnes oil equivalent
Source: authorial computation on the base of date from BP Energy Outlook 2030: January 2013 (http://www.bp.com/energyoutlook2030)

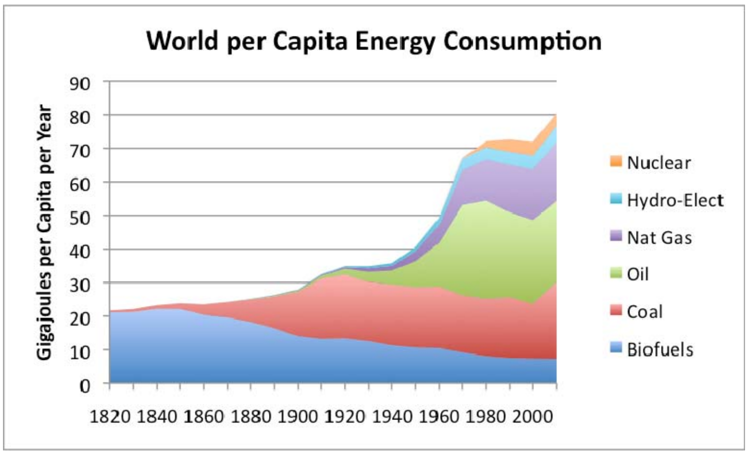

Fig. 4. Per capita world energy consumption, calculated by dividing world energy consumption by population estimates, based on Angus Maddison data.
Source: authorial computation on the base of date available at:
http://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/

Figure 4 demonstrates a small jump about the time of World War I and then a huge jerk of growth between World War II and 1970. There is also a new jump of growth in new millennium as a result of growing coal usage in Asia. Both charts show long-term changes in energy consumption, and together with some observations could be helpful to calculate impacts and spillovers. For example, if we look at the dynamic of CO_2 emissions over the world – there is straight increasing tendency, despite any transfer to new energy resources (fig. 5), so we can assume that the temp of changing energy sources is too slow to impact the environmental pollution. So the future steps should be directed on calculation and modeling appropriate optimum speed of sustainable energy transfer over the world to support sustainable ecological safety.

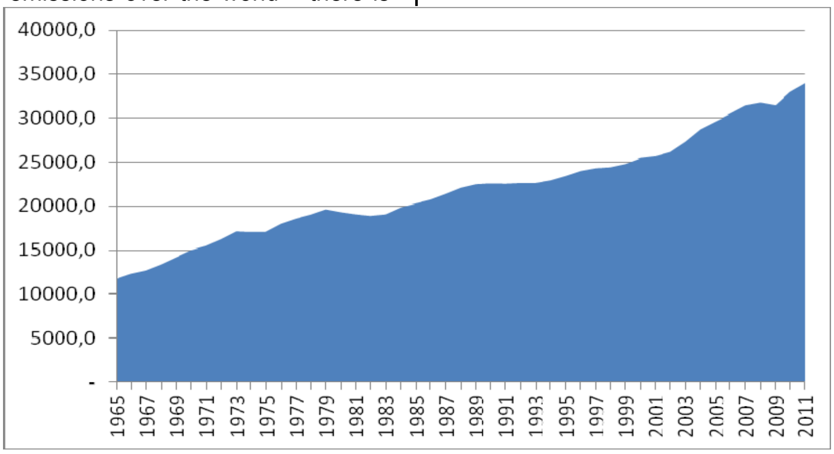

Fig. 5. World Carbon Dioxide Emissions (1965-2011), million tonnes carbon dioxide
Source: authorial computation on the base of date from BP Statistical Review of World Energy June 2012
(http://www.bp.com/statisticalreview)

Convergence of approaches: models, methods, calculation techniques. The main challenge for forecasting and modeling our energy future is in diversity of energy resources (known already and supposed to be discovered or implemented in technology), so the diversity of models could be in need for the approaching the aim (Fig. 6). However, the diversity does not led to the optimal decision on the level of the world needs. The challenge is in developing one complex converged model equally available for different implementations in any state.

However, ways to achieve the sustainable energy goals are often mutually contradictory. This makes the task of strategic planning of the energy sector complex, which requires finding acceptable compromises. High capital intensity of energy facilities and environmental risks that are inherent, the total inertia of energy, its social importance, coupled with predominantly low energy efficiency of industrial production necessitated the search for the optimal scenario. To determine the best combination of economic and energy sectors ***special economic and mathematical models*** are proposed to use [1, 18] (fig. 7).

The feasibility of using economic and mathematical models due to their possibility to determine relationships and dependencies between different elements of the system that otherwise would have remained not identified, determine the impact of external factors on the system, analysis of alternatives development. The complexity of real processes prevents their perfect expression in the model. Such simplification and limitation, possible inaccuracies on certain parameters, on the other hand – any unpredictable events of real life, of course, can reduce the reliability of the model. However, the use of models should rather be viewed not as a search for clear answers for decision-making, but as a way to study the processes that occur in the system. Often the information and experience gained during the construction and operation of the model is much more important than the direct results of model calculations. However, the optimum point is still not found.

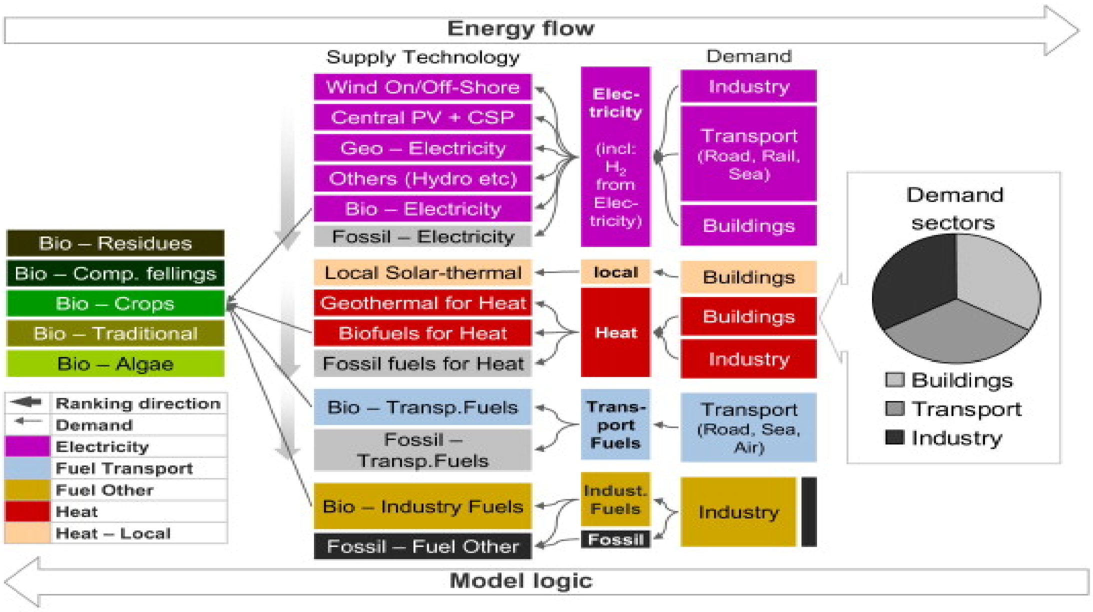

Fig. 6. Diversity of approaches and levels used to calculate energy demand and supply model.
Source: [17].

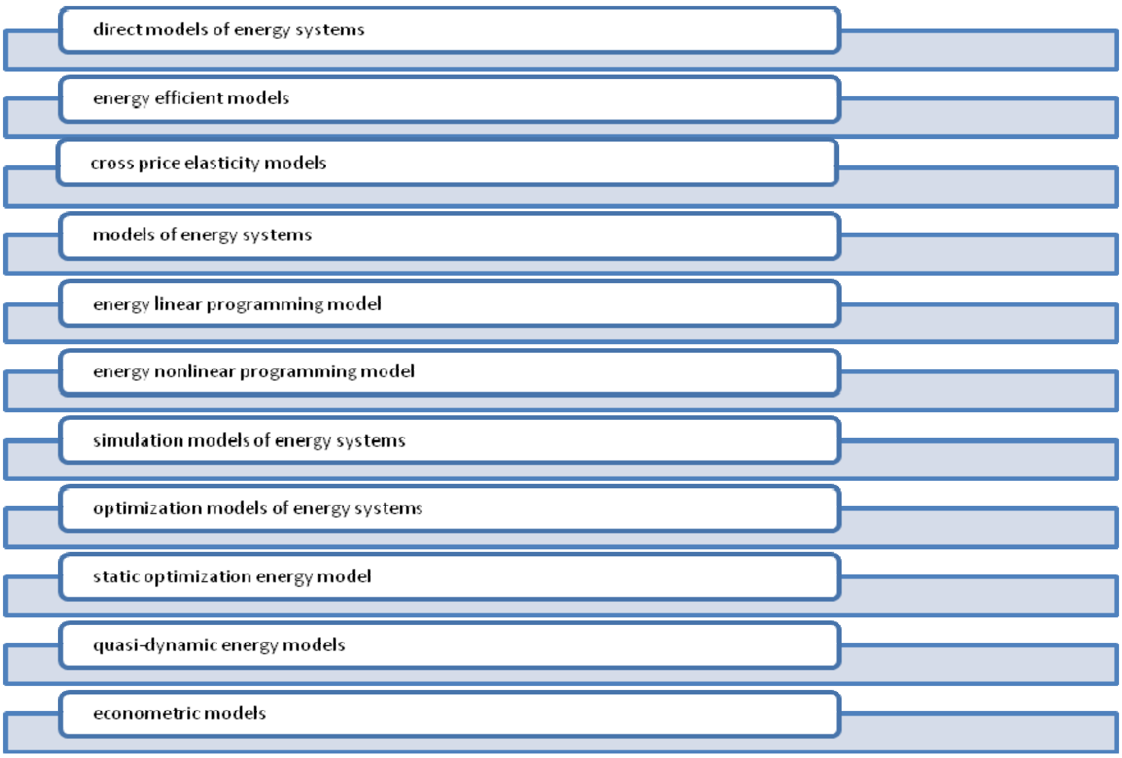

Fig. 7. Special economic and mathematical models for estimating and modeling of ecological-economic energy processes.
Source: authorial computation

Spectrum of economic-mathematical models in energy is quite broad [15, 18-19], and the term *energy modeling* is quite common:

➢ *models of energy systems* detail links within the energy sector, disaggregated range of energy, full set of processing technologies and energy consumption.

➢ typical *energy-economic model* considers the complete economy, resulting representation of the energy sector in somewhat simplistic way.

➢ based on expert values *cross price elasticity model* calculates the point of market equilibrium factors of production.

➢ *energy-efficient models* mainly are used for assess the impact of energy policy on the economy and vice versa.

➢ in *models of energy systems* all technologies describe a set of parameters – such as price, operating costs, operational lifetime and payback period, availability, performance, and others. In fact, the technology represents the process of energy product transformation.

➢ *energy linear programming model* is used as for the development of the production programs of individual energy complex, as for long-term planning of national power system. The inclusion in models only linear equations guarantees the existence of absolute optimum.

➢ the use of *nonlinear models* can be achieved by displaying a more complex relationship in a system, however, unlike linear optimization, the absolute optimum exists only under the condition that the objective function and constraints are convex.

➢ to determine the required capacity of the new energy facility sometimes conduct an analysis of energy during the peak of the system – *static optimization model*. This type of models examines the state of the system at a particular moment, ignoring changes in system time.

➢ in *quasi-dynamic models* the whole time horizon is divided into successive periods, not necessarily equal to each other, the solution of the optimization problem for the first period becomes the initial information for the second time period, and so far for all subsequent periods. In contrast, dynamic models have the function that covers the entire horizon, i.e. the optimization problem immediately works for the whole period. As a result, the initial information for quasi-dynamic model is the current state of the system, while working with a dynamic model requires a clear understanding of the possible future changes of the system.

Identification of this methodological approach (models sighted above) is as a *"bottom-up"* because the final decision is taken after the model analysis of economic processes at the micro level, in other words – technological changes at the level of final consumers of energy. This approach is used to determine the optimal strategy of providing energy services to national and international levels [18].

All the above models are parametric – they are mainly used for medium and long-term modeling of the energy system, the structure and parameters of which may change over time. Input data for these models is official statistics and expert opinions of the researchers. All these feature minimize the uniformity of such models' implementation.

Models of energy systems can be in their turn divided into partial equilibrium models and fixed demand models (fig. 8.)

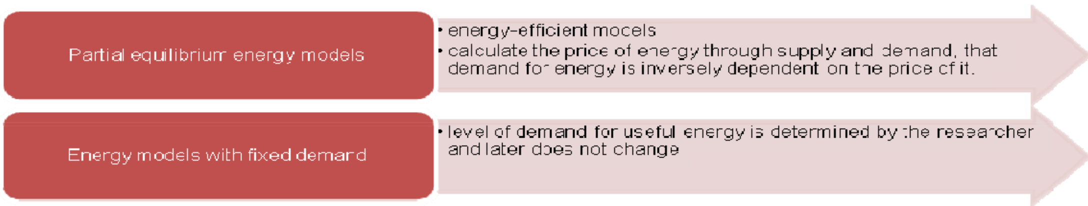

Fig.8. Types of models of energy systems.
Source: authorial computation on the base of [15, 18]

In preparing short-term forecasts often *econometric models* are used along with parametric. The basis of this approach is the assumption that existing in the past the trend average correlation has not changed over time. On the basis of statistical time series analysis statistical dependences and trends are established and retrospective adjustment statistics are assessed.

On the other hand, not always every energy model can be strictly categorized, and have the characteristics of different classes of models.

Conclusions. We came in the epoch of the end of technoutopia – we understand that further economic and production development will destroy general system of human being, if we will not develop environmentally benign technologies [20].

Statistic and expert estimations [17] prove that a fully renewable global energy system is possible: we can reach a 95% sustainably sourced energy supply by 2050. To achieve this goal we need to combine all known approaches and use their convergence effects: accelerated renewable energy supply from all possible sources. This requires a paradigm shift towards long-term, integrated strategies and will not be met with small, incremental changes [20]. We have to consider the efficiency and major advantages of renewable energy:

- Little or no pollution or greenhouse gases (i.e. environmental sustainability);
- Available now and forever (i.e. supply sustainability);
- No increasing fuel costs (price stability);
- Low concentrations available worldwide (unlike e.g. present oil concentration in the Middle East, thus improving supply security);
- Potential for development of indigenous energy industry, with associated jobs (since renewable energy needn't be on the scale of fossil energy technology, and thus the exclusive domain of countries with heavy manufacturing capability).

The challenges for this transition to a sustainable energy future include:

- The cost of renewable energy is generally higher than fossil fuels;
- Renewable energy comes in relatively low concentrations;
- A large capital investment required globally to make the transition;
- New infrastructure (e.g. transmission lines) is required
- Limited time to make the transition (see below)
- Insufficient global energy governance to effectively manage the transition.

Establish an integrated and closed system (indicators) of energy security should be based on the performance of the previous analysis of the processes that occur in the production, supply, distribution and consumption of energy in a country, as well as actual and potential threats to energy security. These threats should be considered in the context of reducing protection of vital interests of the people, businesses, municipalities and regions of the country as a whole at the moment and for the foreseeable future. These indicators can be both quantitative and qualitative characteristics of the definition for each indicator boundary change intervals within which it is believed that threats to energy security is minimal or zero. Only economic-modeling approach have enough tools to mix qualitative and quantative features of the energy process without any subjective approach. Today we have to consider the developing of a new model or a new mathematical algorithm that provide further application implementation. Thus, sustainable energy development is complex challenge, so only complex decisions and approaches could be possible to implement in the most efficient way.

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Received 13.05.13

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ЕКОЛОГО-ЕКОНОМІЧНА КОНВЕРГЕНЦІЯ: ПЕРЕХІД ДО СТІЙКОЇ ЕНЕРГЕТИКИ

Сталий енергетичний розвиток є складним завданням, так що тільки комплексні рішення і підходи можливо реалізувати найбільш ефективним чином. Залишається невирішеним питання, – яким має бути оптимальний обсяг використання нових і відомих енергоресурсів для забезпечення та підтримки сталого розвитку та екологічної безпеки для будь-якої держави світу. Стаття присвячена аналізу конвергенції в аспекті більш ефективного використання аналітичного та системного підходу для моделювання еколого-економічних зовнішніх ефектів при переході до стійкої енергетики. Розглядаються економічні наслідки такого переходу. Проводиться аналіз динаміки енергоспоживання в розрізі різних типів енергоресурсів за період 1820-2030 років. Результат підтвердив необхідність комплексного аналізу зв'язку "економіка – енергетика – довкілля". Вкрай актуальним бачиться необхідність впровадження комплексних підходів для моделювання та прогнозування розвитку нових енергетичних систем. Проведено порівняльний аналіз різних типів моделей і методів аналізу економіко-енергетичних систем.
Ключові слова: споживання енергії; конвергенція; моделі; енергоресурси.

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ЭКОЛОГО-ЭКОНОМИЧЕСКАЯ КОНВЕРГЕНЦИЯ: ПЕРЕХОД К УСТОЙЧИВОЙ ЭНЕРГЕТИКЕ

Устойчивое энергетическое развитие является сложной задачей, так что только комплексные решения и подходы возможно реализовать наиболее эффективным образом. Остается нерешенным вопрос, – каким должен быть оптимальный объем использования новых и известных энергоресурсов для обеспечения и поддержки устойчивого развития и экологической безопасности для любого государства мира. Статья посвящена анализу конвергенции в аспекте более эффективного использования аналитического и системного подхода для моделирования эколого-экономических внешних эффектов при переходе к устойчивой энергетике. Рассматриваются экономические последствия такого перехода. Проводится анализ динамики энергопотребления в разрезе различных типов энергоресурсов за период 1820-2030 годов. Результат подтвердил необходимость комплексного анализа связи "экономика – энергетика – окружающая среда". Крайне актуальным видится необходимость внедрения комплексных подходов для моделирования и прогнозирования развития новых энергетических систем. Проведен сравнительный анализ различных типов моделей и методов анализа экономико-энергетических систем.
Ключевые слова: Потребление энергии; конвергенция; модели; энергоресурсы.

JEL H 630
UDC 336.273.3:339.97

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COMPARATIVE ANALYSIS OF THE KEY FACTORS OF GROWTH OF STATE DEBT OF UKRAINE AND EU

Based on research results, economical-statistical model was developed aimed to exhibit the connection between the government debt and major economic factors, namely: gross capital formation, household consumption and credits granted to the residents. After the statistical data of European countries had been examined, the peculiarities of debt formation were elicited in each of them. As a result, the relation between the type of economy and factors of debt formation was outlined.

Keywords: Government debt; government borrowing; capital formation; consumption of the population; lending to the economy.

Introduction

In the world of total globalization the development of the international financial system is notable for a significant increase in external government debt in different countries that by estimations has exceeded 30 trillion dollars [1]. Government borrowing is now an integral part of the financial systems of most countries in the world, as well as an effective institution in the mechanism of macroeconomic regulation and a tool for implementation of an economic strategy of a country. However, the use of debt instruments for the purpose of overcoming nonrecurring deficit and social issues transfers the payment of the debt to a future period without considering the state budget potential.

In this context there is a need, on the one hand, to identify factors that lead to the external debt growth in different countries, while on the other hand, to clarify the