

ASPIRATIONS FOR SUSTAINABILITY AND GLOBAL ENERGY DEVELOPMENT TRENDS

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Abstract. Global economic development and continuous growth of the world population are the major factors which cause growth of energy consumption and increasing volumes of greenhouse gas emissions. Attempts to achieve sustainable energy development are still not enough successful. Scientific community and international organizations are concerned with consequences of global warming: increasing temperature in various regions of the planet, significant and harmful effects on health and environment, growing number of extreme storm events and large wildfires, rising sea levels, changes in landscapes. Increasing efforts of governments and politicians should be directed to reduction of greenhouse gas emissions from fossil fuels combustion by increasing energy efficiency and by deployment of renewable energy sources. The paper focuses on efforts of world community directed to sustainable global energy development, implementation of new energy policies and provides an overview of energy consumption trends in the world by 2035.

Keywords: sustainable development, global warming, energy efficiency, energy policy, energy strategy

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1. Introduction

Consumption of various energy sources is very important to development of the national economy in each country and to the global economic development. Energy provides an essential ingredient for almost all human activities. Development of industrial production, transportation, activities in agriculture, mineral extraction, food production and storage, space and water heating, lighting, air conditioning, rendering of various services, etc. require corresponding consumption of energy sources. Modern energy services are engine of economic and social development, serve as one of major driving forces of sustainable development (Grybaitė 2011, Stańczyk 2011; Dudzevičiūtė 2012, Lankauskienė, Tvaronavičienė

2012; Vosylius *et al.* 2013; Vasiliūnaitė 2014).

During last four decades global economy was growing on average by 3% per year. Total population increased from 3.8 billion in 1971 to 7 billion in 2011, i.e. was growing on average by 1.6% per year. These two factors, including fast industrialization of developing countries, caused rapid growth of primary energy consumption. Total world primary energy over the period 1971-2011 was growing on average by 2.2% per year and in 2011 it amounted to 13.1 billion toe. Consumption of coal was increasing over this period on average by 2.4%, oil demand was growing on average by 1.2% and consumption of natural gas was growing on average by 2.9%. Contribution of fossil fuels into the global primary energy

mix decreased only slightly – from 86.6% in 1971 to 81.6% in 2011.

Debate is lasting for decades about the potential problems for the future generations due to dwindling reserves of the traditional fossil fuels, dramatic consequences of wasteful energy consumption, threatening growth of greenhouse gas emissions, a great their influence on climate change and global warming (Lapinskienė *et al.* 2014; Mačiulis, Tvaronavičienė 2013; Tvaronavičienė 2012; Vosylius *et al.* 2013; Vasiliūnaitė 2014). During the last few decades there has been growing consensus that human activities, and in particular greenhouse gas emissions from fossil fuel combustion, cause problems of the global warming.

Over the past century the average planet's temperature has increased by more than half a degree Celsius and all predictions are that the global warming will continue. Scientific community is concerned with consequences of this warming: significant and harmful effects on health and environment, growing number of extreme storm events and large wildfires, rising sea levels, etc. As a result of common efforts of scientists, various international organizations, governments, politicians and public, the concept of sustainable development was formulated in 1987 and the United Nations Framework Convention on Climate Change was signed by over 150 countries at Rio de Janeiro in 1992. Ambitious sustainability goals for Member States are formulated in the EU directives and communications, national strategies, and other documents. However, close dialog between industrialized and developing countries and common efforts of world community are still required. The aim of this paper is to discuss aspirations of sustainable global energy development and trends of primary energy consumption in the world, to set out some findings from analysis of foreseen energy demand scenarios. The paper also focuses on efforts directed to implementation of new energy policies.

2. Aspirations for sustainable energy development

The modern economy is closely linked to the energy that role is to ensure energy security and create favourable conditions for the economic well-being (Tvaronavičienė 2012, Miškinis *et al.* 2013; Vosylius *et al.* 2013; Dudzevičiūtė 2013; Tvaronavičienė 2014; Vasiliūnaitė 2014). Long-term energy policy

of individual countries is based on modelling of potential future scenarios over the medium and long term period, as well on a comprehensive insight into development of the possible political, technological and environmental factors. The most important feature of the current energy systems is that the fossil fuels still dominate in the world energy balance and dependence on energy imports is increasing in many countries. Permanent growth of energy demand is stipulated by industrial development, mechanization and automation of processes in all sectors of the economy, growing population and increasing their mobility, the desire to ensure better working conditions and greater living comfort and other factors. However, there are still large differences in energy supply, as well as in economic-social conditions and quality of life between industrialized and developing countries. World Energy Congress, held in 2013, 13-17 October, Daegu, Korea, stated that 1.3 billion people in the world lack access to electricity and 2.7 billion have no access to modern and healthy forms of cooking (World Energy Insight 2013; Otto 2013).

Debate is lasting for several decades on various levels about the energy status, the potential problems for the future generations and consequences of growing greenhouse gas emissions on climate change. In 1968, the Club of Rome has brought together efforts of thirty experienced scientists, prominent politicians and businessmen to set out the global economic trends and to assess the potential risks. Using a special method of dynamic modelling (Forester 1971), changes in the global population, the necessary quantity of food products, the consumption of natural resources, as well as in the volume of industrial production and the extent of environmental pollution were analysed. Based on the evaluation of these factors, trends and interrelationships between them, very pessimistic future of the world was predicted a few decades ago – in a case global population, use of natural resources and industrial production are increasing in the same pace, environmental pollution at the beginning of the twenty-first century can achieve catastrophic level and ecological crisis can be inevitable (Meadows *et al.* 1972). The most important findings from these forecasts were as follows: it is necessary to review priorities of the social development and to abandon reckless economic growth as the sole and most important priority; it is necessary to pay more attention and resources for regulation and control of the use of main natural resources and

environmental pollution.

Results presented in the Club of Rome studies, despite criticism of many experts, have stimulated very active discussions of scientists, writers, and various organizations and public on the rational scenarios of future world development. In 1987, a special report of the World Commission on Environment and Development was presented at the General Assembly of United Nations. The concept of sustainable development was formulated in this report – “humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (Our common future 1987).

In 1992, principles of sustainable development were formulated and adopted internationally in the Declaration at Rio de Janeiro United Nations World Summit. In addition the sustainable development action programme Agenda 21 was adopted (Agenda 21). In 2002, the sustainable development action programme was corrected at the World Summit in Johannesburg, and specific commitments to priority areas were approved. All states were required to develop and begin to implement national strategies for sustainable development. In 2003, Lithuanian Government approved National Strategy for Sustainable Development (National Strategy for Sustainable Development 2003). On 9 June 2006, the European Council adopted a revised EU Sustainable Development Strategy and imposed an obligation to Member States to update existing national sustainable development strategies and to ensure their consistency. In 2009, Lithuanian Government approved an updated National Strategy for Sustainable Development with ambitious objective – “to achieve, by 2020, the average development level of EU countries of 2003 according to the indicators of economic and social development as well as to the efficiency in consumption of resources, and to stay within the EU permissible limits with respect to the indicators of environmental pollution adhering to the requirements of international conventions to minimize environmental pollution and impact on the global climate change” (National Strategy for Sustainable Development 2009).

In 2009, the Netherlands Environmental Assessment Agency produced a report and presented an analysis of the energy consumption trends and global environmental problems. The focus of the report is given on energy supply and climate change, agriculture and

biodiversity loss (Growing within Limits 2009). Insights are provided on measures that create conditions for sustainable development and a great potential for increase of energy efficiency and for more efficient food supply system is shown in the report. The implementation of the Challenge Scenario in the energy sector is recommended by increasing energy efficiency and deployment of renewable energy resources, by implementing carbon capture and storage technologies, reducing deforestation and non-CO₂ emissions. An essential condition for future actions – the reduction of global emissions can be achieved only by common efforts of developed and developing countries.

The stabilization of climate change is one of the priorities in the EU energy policy. In 2000, the European Commission established the First European Climate Change Programme with an objective to identify the most environmentally effective and most cost-effective policies and measures that can be taken to cut greenhouse gas emissions. The Second European Climate Change Programme was launched in 2005 with the aspiration to explore new cost-effective options for reduction of greenhouse gas emissions (European Climate Change Programme 2005). The next step in the EU energy policy was approval of the climate and energy package with an ambitious plan to improve energy efficiency by 20%, to reduce greenhouse gas emissions in the EU by 20% from the 1990 level and to achieve a mandatory target of a 20% share of renewable energies in the gross final energy consumption by 2020 (The climate and energy targets for 2020). In the recent documents new ambitious objectives are foreseen: continued progress towards a low-carbon economy, increase of energy security, reduction of dependence on energy import, reduction of the EU domestic greenhouse gas emissions by 40% below the 1990 level by 2030 (2030 framework for climate and energy policies) and by 80-95% by 2050 compared to the 1990 level (Roadmap for moving to a low-carbon economy in 2050). Ambitious sustainability goals for the Member States are formulated in the EU directives and communications, national strategies, and other documents.

3. Current trends in the world energy

World economy has increased over the last four decades by 3.3 times. Overall global economic growth was slowing down: over the decade 1971-1980 a rate of economic growth was equal on average to

3.8% per year, in 1980-1990 decreased to 3.0%, in 1990-2000 – to 2.8%, in 2000-2011 – to 2.6% per year. However, as shown in Figure 1, the overall global economic slowdown has led to this tendency due to slower economic growth in industrialized countries belonging to Organization for Economic Cooperation and Development (OECD). Due to the global economic crisis the GDP in these countries over the period 2000-2011 was increasing on average by 1.6% per year. Meanwhile, in developing countries economic growth over the last three decades was increasing: over the decade 1980-1990 a rate of economic growth was equal on average to 2.4% per year; in 1990-2000 the GDP was increasing on average by 3.1% per year, and in 2000-2011 by 6.1% per year. The GDP in China over the period 2000-2011 was growing on average by 9.9% per year, and the

GDP growth index has increased over this period by 2.8 times, while global economic growth index during this period was equal to 32%, and in the United States – only 19%.

Role of developing countries in the global economy is becoming stronger – a share of GDP they created in 2005 U.S. dollars, using estimates of Purchasing Power Parity, increased from 34.6% in 2000 to 46.1% in 2011. Economic growth in the Asian region, and particularly in China, is even faster. The share of the China economy in the global economic structure has increased from 7.4% in 2000 to 14.6% in 2011. The role of the United States economy during this period decreased significantly – from 23.1% in 2000 to 18.8% in 2011 (Figure 1).

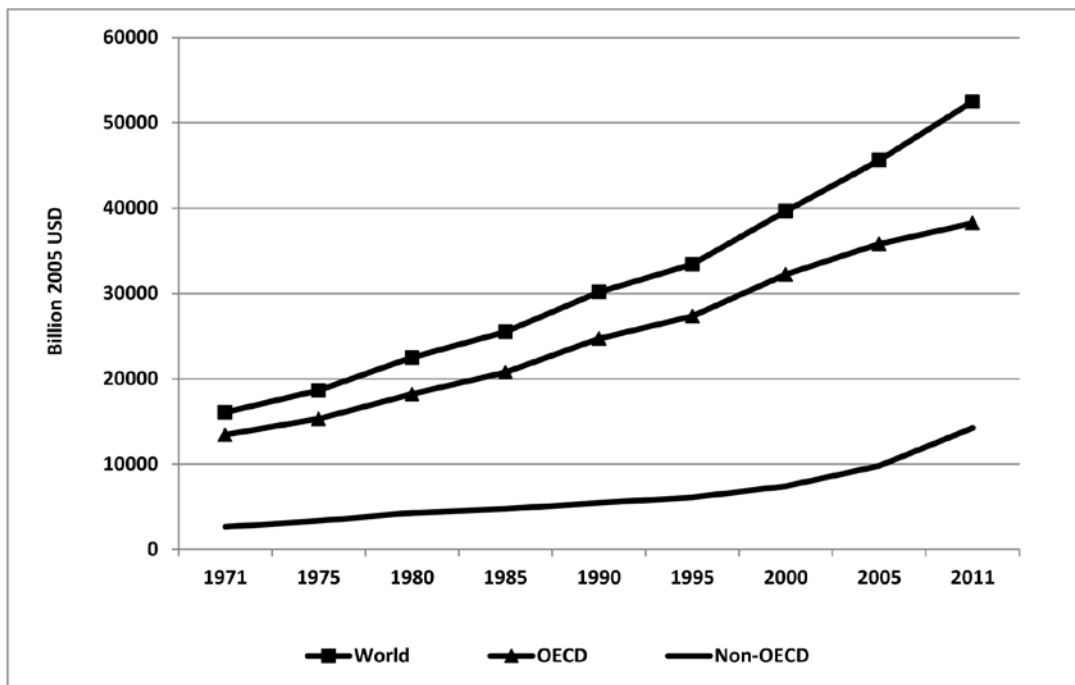


Fig.1. Trends of the World economic growth

Source: International Energy Agency 2012, 2013a, 2013b

In spite of all the fears and many prompts to change trends of energy consumption as well as considerable efforts to substitute fossil fuels by renewable energy sources, the total world energy consumption, including use of oil and oil products, natural gas and coal, is still increasing. Total consumption of primary energy in the world was growing over the period 1971-1980 on average by 3.0%, in 1980-1990 by 2.0%, in 1990-2000 by 1.4%, and in 2000-2011 on average by 2.4% per year. As shown in Figure 2, the rapid

economic growth in developing countries over the period 1990-2000 has led not only to the growth of energy consumption in these countries, but also to the overall growing trend of energy demand in the world. Primary energy consumption in China has been growing extremely fast – on average by 8.6% per year. In 2009, due to the economic crisis, which was painful for most countries, the total consumption of primary energy in the world was by 1% less than in 2008. In 2011, the total primary energy con-

sumption in industrialized countries was the same as in 2000 – 5.3 billion toe. Meanwhile, primary energy consumption in developing countries increased by 66.1% – from 4.4 billion toe in 2000 to 7.4 billion toe in 2011. Primary energy consumption in China in 2009 was for the first time higher than in the

United States. In 2011, primary energy consumption in China was 2.7 billion toe and over the eleven years period has increased by 2.5 times. The total primary energy consumption in the world has increased over the period 2000-2011 by 29.8%.

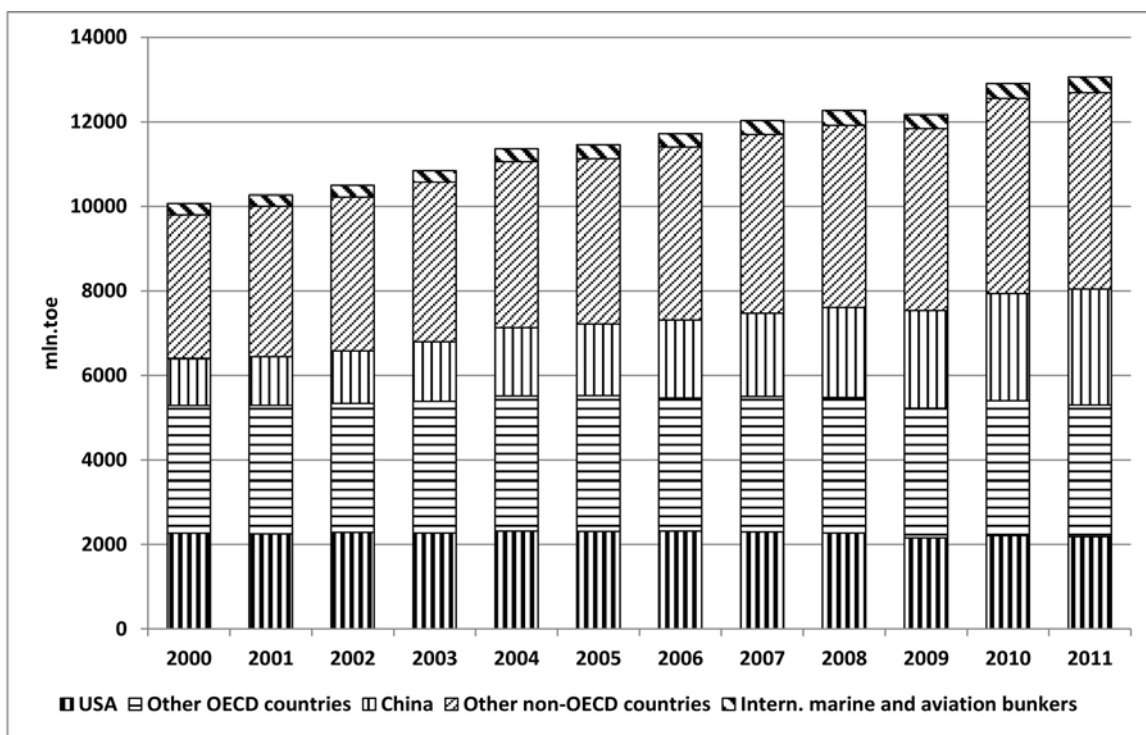


Fig.2. Trends of the world primary energy consumption

Source: International Energy Agency 2006, 2009, 2012, 2013a, 2013b

Various forms of energy, and in particular petroleum products used for transport of goods and passengers as well as electricity widely penetrated to all human activities, has been and remain one of the most important and essential component of humanity needs to ensure the progress and improve the living conditions. Over the period 2000-2011 coal demand was increasing very rapidly (4.4% per annum) and total

consumption of this fuel rose from 2.4 billion toe in 2000 to 3.8 billion toe in 2011. However, oil and oil products are still dominating in the global primary energy mix with 4.1 billion toe in 2011. Natural gas consumption during this period increased by 34.4%, and the share of this fuel in the global primary energy consumption increased to 21.3% in 2012.

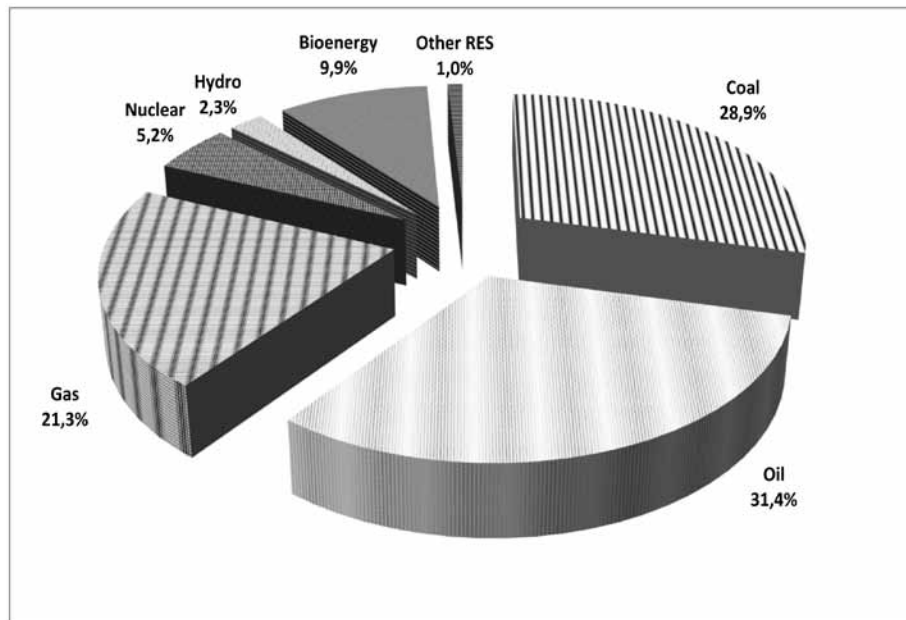


Fig.3. Structure of the World primary energy consumption in 2011

Source: International Energy Agency 2013c

Nuclear fuel in absolute terms was almost the same over this period, and its share in the primary world's energy mix decreased to 5.2%. Consumption of renewable energy sources in 2011 was 32.7% higher than in 2000, but their share in the primary energy mix in 2011 accounted for only 13.2% (Figure 3).

4. World energy development scenarios

World energy demand development is influenced by many factors, which can lead to different trends in the energy demand growth as well as different ways giving opportunity to meet them. In 2013, experienced experts of the International Energy Agency produced a comprehensive study on the world energy development trends by 2035. The three global scenarios are analysed in the energy outlook: 1) Current Policies Scenario, 2) New Policies Scenario, and 3) 450 Scenario. New Policies Scenario can be considered as the basic scenario. It is based on the assumption that the right combination of energy policies and the current and future technologies can weaken the links between the economic growth, energy demand and energy-related greenhouse gas emissions.

The selection of these scenarios was stipulated at a large extent by two major findings from long-term scientific research on climate change: 1) it is necessary to stabilize the average global temperature increase so that, compared to data in the pre-industrial

period, it does not exceed 2°C, 2) the strategic objective can be achieved only if greenhouse gas concentration in the atmosphere as measured by a number of carbon molecules per million molecules does not exceed the 450. On the other hand, in recent years a lot of discussions continue on the influence of factors that can affect climate change: whether it is necessary to ensure that temperature rises less than 2°C; what is the real impact of greenhouse gas emissions on climate change; whether the solar influence on climate change is assessed correctly; what could be the effects of climate change on a global society and individual lifestyles, ecosystems and water resources?

As one can see from Figure 4, the continued growth of global energy demand is foreseen in all three scenarios – the Current Policies Scenario predicts that by 2035 primary energy demand in the world will increase by 44%, in a case of the New Policies Scenario energy demand will increase by 33%, and in the 450 Scenario primary energy demand will increase by 14% compare with the 2011 level. Energy demand growth in the world will be stipulated by the global economic and population growth – it is foreseen that GDP will grow on average by 3.6% per year until 2035 and will increase over this period by 2.3 times, while population in the world will increase up to 8.7 billion.

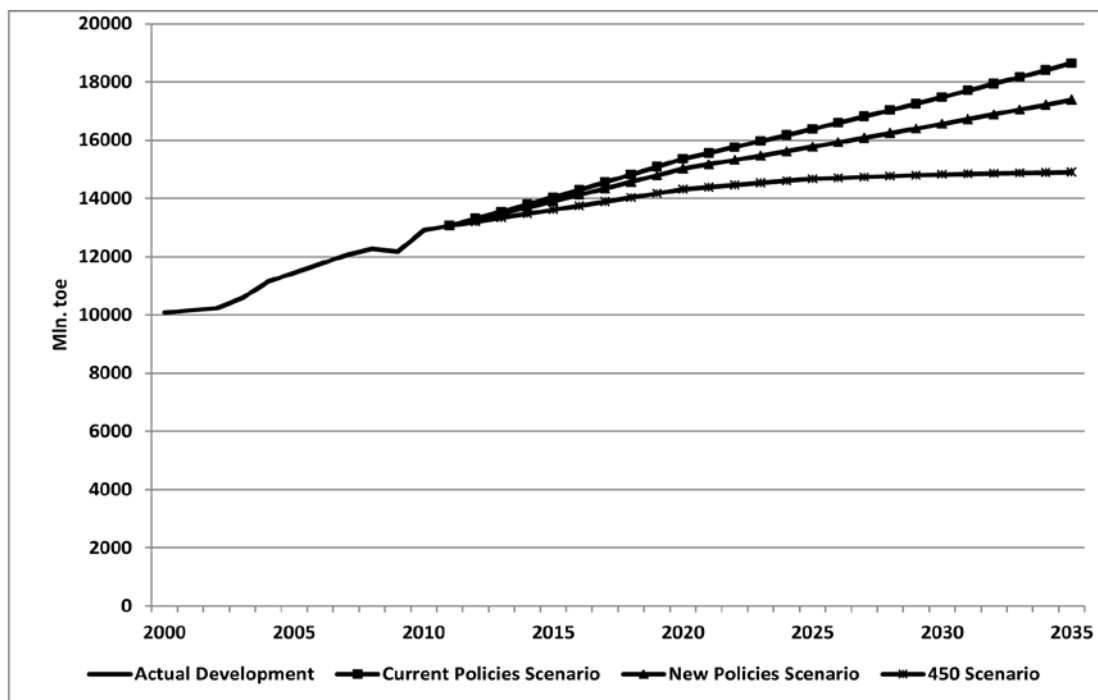


Fig.4. Forecast of the world primary energy demand

Source: International Energy Agency 2013c

Significant changes in the global energy mix could be stipulated by very different growth rates of fossil fuels and renewable energy sources. As one can see from Table 1, consumption of coal, oil and natural gas by 2035 in the Current Policies Scenario will increase by 40% and in the New Policies Scenario by 24% compare with the 2011 level. In a case when assumptions of the 450 Scenario are realized, consumption of fossil fuels would increase only by 4% up to 2020, but then demand of these fuels will start to decline. In 2035 total consumption of coal, oil and natural gas will decrease by 11% compare with the 2011 level. And vice versa, consumption of renewable energy sources will increase in 2035 by 2.3 times in the 450 Scenario, by 77% in the New Policies Scenario and by 58% in the Current Policies Scenario compare with the 2011

level. The share of renewable energy sources in the world's primary energy mix will increase from 13.2% in 2011 to 26% in 2035 in the 450 Scenario, to 18% in the New Policies Scenario and only to 15% in the Current Policies Scenario. Growth of nuclear fuel consumption is foreseen in all scenarios – in the Current Policies Scenario consumption of this fuel will increase over the period 2011-2035 by 51%, in a case of the New Policies Scenario by 66%, and in the 450 Scenario by 2.3 times. When preparing scenarios of the future world's energy development, preliminary assessment of potential impact of an accident at the Fukushima Daiichi nuclear power plant on nuclear power development was done. However, currently the scope and a pace of nuclear power development remain uncertain.

Table 1. Forecast of the world primary energy demand, mln. toe

	<i>Actual development</i>		<i>Current Policies Scenario</i>		<i>New Policies Scenario</i>		<i>450 Scenario</i>	
	<i>2000</i>	<i>2011</i>	<i>2020</i>	<i>2035</i>	<i>2020</i>	<i>2035</i>	<i>2020</i>	<i>2035</i>
Coal	2357	3773	4843	5435	4202	4428	3715	2533
Oil	3664	4108	4546	5094	4470	4661	4264	3577
Natural gas	2073	2787	3335	4369	3273	4119	3148	3357
Nuclear	676	674	866	1020	886	1119	924	1521
Hydro	225	300	379	471	392	501	401	550
Bioenergy	1016	1300	1472	1729	1493	1847	1522	2205
Other renewables	60	127	278	528	309	711	342	1164
Total	10071	13070	15359	18646	15025	17387	14316	14908

Source: International Energy Agency 2013c

Policy actions directed to stabilisation of the energy demand growth and diversification of energy supply from new sources (including unconventional oil and gas) will be critical in the medium and long-term period (Tvaronavičienė 2012; Miškinis *et al.* 2013; Vosylius *et al.* 2013; Dudzevičiūtė 2013; Vasiliūnaitė 2014; Tvaronavičienė 2014). Global energy demand can grow significantly due to increasing consumption of petroleum products in the transport sector of developing countries (Tvaronavičienė *et al.* 2013; Dudzevičiūtė 2013). It is predicted that, despite the significant increase in energy efficiency of vehicles, rapid growth in the number of cars can lead to growth of energy demand. No doubt alternative technologies in the transport sector, including cars with low fuel consumption, electric cars, etc., will become economically viable. However, the longer period is required seeking to penetrate market by feasible alternative technologies.

It is likely that energy demand growth will cause crucial increase of greenhouse gas emissions and will contribute to climate changes of global scale (Dudzevičiūtė 2013; Miškinis *et al.* 2013; Lapinskienė *et al.* 2014). In a case when current energy consumption trends continue, global emissions of greenhouse gas will rise by 2035 to 43.1 Gt or by 38% compare with the 2011 level. The implementation of energy trends foreseen in the New Policies Scenario would increase greenhouse gas emissions to 37.2 Gt or by 19%. Such increase of these emissions will cause in the long-term dangerous rise of global average temperature. To stabilize climate change additional energy saving measures must be implemented, electricity generation at coal-fired power plants should be limited, continued support for deployment of renewable energy sources should be foreseen

and other measures incorporated in the 450 Scenario must be implemented. In a case assumptions of the 450 Scenario are realized, volume of greenhouse gas emissions will decrease by 2035 to 21.6 Gt or by 69% compare with the 2011 level.

The recent energy outlook (BP 2014) of the world's energy development by 2035, produced by experts of the famous oil and gas production company BP, predicts the growth of energy demand, primary energy mix and volumes of greenhouse gases emissions, which are similar to prediction of experts from the International Energy Agency foreseen in the New Policies Scenario. The World Energy Council has warned participants of the 22nd World Energy Congress about the prevailing myths that hinder governments, the energy industry and civil society to create a sustainable energy future (World Energy Council Statement 2013) and presented position on expected changes:

- *Energy demand growth in the world will slow down or energy demand will remain the same.* In reality energy demand will further grow and will increase by two times till 2050, this increase will be caused mainly by economic growth in developing countries;
- *Peak of oil extraction is inevitable owing to limited global oil reserves.* In reality oil shortage is still not felt. Extraction of oil from existing fields is improved, new fields are discovered, new technologies allow extraction of unconventional oil and gas;
- *Growing energy demand could be met with the new clean energy sources.* Despite significantly faster relative growth of contribution from renewable energy sources, which will reach by 2050 from 20% to 30% in the global primary energy mix, volume of fossil fuels consumption in 2050 will amount to 10-16 billion toe;

- *Overall emissions of greenhouse gas could be reduced till 2050 by 50%*. Even in the best case volume of greenhouse gas emissions in the world in 2050 can be by almost two times higher compare with the internationally agreed target, corresponding to 450 ppm;
- *Current business and market models are appropriate*. Current market and business models are not able to cope with the problems posed by the increasing share of renewable energy sources in the global primary energy mix, deployment of distributed systems and the growing flow of information;
- *Current programmes will provide a universal access to energy in the next 10-15 years*. Universal access to energy is still far from reality. When implementing the current measures, about 530-880 million people in the world will live without electricity in 2050.

Position of the World Energy Council presented in the official statement demonstrates concern for the future of the global energy development and calls for effective actions to transform energy systems in the world, otherwise there may be a risk for aspirations of energy security, energy supply at reasonable price and environmental sustainability.

Conclusions

Energy is a central aspect of social, economic, and environmental development. Therefore sustainable energy development can guarantee access to clean and reliable energy at affordable prices, will contribute to mitigation of climate change, to increase of energy security and to poverty reduction.

Global energy demand growth in the medium and long-term period could be stipulated by economic and population growth in developing countries. Based on comprehensive analysis in a study prepared by energy experts of the International Energy Agency, three scenarios of global energy demand growth are foreseen: a) in a case the current energy consumption trends will continue, primary energy demand in the world by 2035 will increase by 44% compare with the 2011 level; b) in a case new energy policy provisions will be implemented rates of energy demand growth will be moderate – about 1.2% per year over the period 2011-2035; c) only essential transformation of the world's energy systems can ensure a slow (approximately 0,5% per year) growth of energy demand, substantial increase of the role of renewable energy sources and stabilization of the average global temperature increase so that, compared to data of the

pre-industrial period, it does not exceed 2°C.

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