Nuclear Power Development Example

Since the dawn of humanity, energy has been the driving force towards survival, continuation of society, as well as development. All sectors of modern economy are highly dependent on energy sources. The constantly expanding human needs require every day a greater amount of energy supplies. Nutritional needs, medicine, transportation, manufacture and construction are just a sample of sectors admitting huge energy requirements.

Historical data has shown, that since the very early stages of production and development, the energy source being used to cover power requirements has been the burning of hydrocarbons. Later on and until today, along with the technology development and the steady research in the field of technology, other energy sources have been assessed, such as oil, gas, coal. Today we are glad to refer to the fact, that steps have been made towards the improvement of efficiency of solar, wind and biomass power. However, still nowadays, about 80% of the total energy consumption derived from the hydrocarbon combustion. The consequences of this choice are severe and the unfortunate fact is that they are not yet fully known and predictable. Global warming leading to the dangerous phenomenon of climate change on Earth, as well as, the dominant presence of the Greenhouse effect, are raising significant sustainability issues.

Finite sources of energy are already in a critical point. USA, which used to have under its occupation enormously reach resources, at the moment is importing more than 2/3 of its oil consumption. UK has already exhausted the North Sea oil and gas only after 40 years of its opening. According to studies carried out in 2010, the total mass of global oil from proved sources has been measured as 188,8 million tonnes, meaning a sufficiency for 46.2 years from that time. Natural gas showed a similar picture, being able to cover the needs in that rate for 58.6 years.1

The Second World War raised the awareness of the scientific community towards a new and incredibly powerful energy source, the nuclear energy. However, accidents, hazards related to radioactivity and security concerns in the link of nuclear weapons proliferation paused the development in the sector. Unfortunately, the fear of an accident was proven by Chernobyl, which led many countries to abandon their plants. Additionally, the severe earthquake and tsunami in Japan in 2011 has given rise to concerns about a potential nuclear incident.

Nowadays, the discussion about nuclear energy arises and is a really controversial issue in the scientific community, as well as in the political and socioeconomic sector. The nuclear option is a challenge for the effective regulation of decommissioning costs, radioactive waste management, security measures, as well as for the probably most important factor, which is the adaption and integration into society of the new era of energy. The world's perspective is to discuss the development of innovative, safe and efficient reactors, to examine and to promote security measures, by taking lessons from history towards a sustainable future.

The objectives of the present report are to make a thorough analysis of the use of nuclear energy as an alternative energy proposal and to evaluate existing reactors, in combination with their use of fuel mixtures. It is also intended to drive a survey about the socioeconomic footprint of the potential use of nuclear energy, to investigate and to examine finally the sustainability of the matter. The aim of the study is to evaluate the environmental, social and economic impact of the upcoming energy source. The major question to be answered: how clean is nuclear energy?

LITERATURE REVIEW

Power generation has always been the motivating force towards investigation and development in the field of energy. At the same time, various energy production processes are causing rising sea levels and air pollution, which is one of the largest sources of global warming and environmental hazards. The energy choices and decisions that have to be taken at this pivotal moment, will significantly affect the world for the decades to come. Right now the world is facing the turn from the coalcentered energy production to the natural gas one. However natural gas as a source of energy generation has two main drawbacks. The first one is the dependence of the community on a nonrenewable source, thus the near future cannot be ensured. The second major drawback of the reliance on natural gas is that this is not a green solution. The extensive use of natural gas as an energy production source rises many sustainability concerns, proving that is not an adequate solution. Our energy choices now, have direct impacts on our health, our environment and our economy. In order to assure a prospect future is necessary to promote a sustainable way of energy production.

Sustainability

Definition

Over the last years, the scientific community has tried to reach a complete definition of the term sustainability. Various definitions have been assigned and later shaken down, since they did not picture the real target. The most appropriate at this moment has been given by Cambridge dictionary, which defines sustainability, as the quality of causing little or no damage to the environment and therefore able to continue for a long time.2 It refers to a continuous development and growth, without significant deterioration of the environment and depletion of natural resources on which human well-being depends. This definition measures income as flow of goods and services that an economy can generate indefinitely without reducing its natural productive capacity.

Sustainability is also defined by three main pillars: economic, social and environmental.

Economic development is the most controversial, since people tend to disagree on whether a solution is economically sound, in extension it will promote and not affect business, employability and efficacy. Sustainable economic development encouraged and fosters incentives to promote green solutions in any scale of industry.

Social development refers to the protection of the society from pollution and hazardous business related activities. Human exposure to heavy chemical and toxic substances is also in issue to be tackled. One of the preliminary targets of the sustainable social development is the maintenance of access to basic resources without compromising the quality of life.

Environmental protection and development refers to the reduction of power consumption. If the world keeps steady the rates of energy consumption, it is foreseen that in the next fifty years we will not be able to feed our needs of energy. Therefore, legislation has been issued for industries, in order to regulate pollution and to keep carbon emissions in low levels.

Fig. 1Three pillars of Sustainability

Energy and climate change

Climate change is a phenomenon that the scientific community has to tackle in order to assure a sustainable future for the next generations. Climate change is defined as the effect caused by a major concentration of greenhouse gases, liberated to the atmosphere through the combustion of fossil fuels, causing significant carbon dioxide emissions. The direct consequence of climate change is widely known as global warming. Global warming, or the anomalous increase of Earth's temperature, is a threat for regional ecosystems, world's economy and human populations.

According to scientific reports for the United States Environmental Protection Agency, the combustion of fossil fuels e.g. coal and oil is increasing the concentration of greenhouse gases significantly. Carbon dioxide emissions caused by burning of these substances contribute to an overall of 80% of total global CO2 emissions. Another

significant factor of greenhouse gas emissions is the agricultural sector, contributing with 15% annually to the total emissions.3 From the statistical data regarding the temperature rise NASA provided the following chart, that shows the undianbal increase in Earth's temperatures, due to CO2 emissions.

Fig.2Increasing Global Temperature, chart

According to the Stern Review, regarding the economic impact of climate change, following suggestions have been stated: the mitigation of the consequences of the phenomenon would cost 1% of global GDP per annum by 2050. On the other hand, it will cost about 5% of global GDP per annum if we keep ignoring the matter.

Assessing a brief flashback in UK's historical data regarding energy resources, following data can be extracted: until 1950 UK's economy and industry has been entirely dependent on coal. Since 1970 oil and gas from the North Sea have been the main resources for energy generation. Some attempts towards the turn into nuclear energy have taken place from 1990 giving very positive feedback, since plants fuelled by imported Uranium fed up to 15% of UK's total energy consumption, saving at least 12% of carbon emissions for the corresponding energy supply from fossil fuels plants.

Nuclear Power Development

Nuclear energy is predicted to dominate in the field of energy in the decades coming and up to 2050. Especially in the industrialized countries of the OECD, nuclear energy generation will contribute as the primary supply, since the already high requirements in electricity are predicted to rise during the next generations. The constantly increasing demand and supply rates of energy are enforcing the development in the sector.

According to the latest data collection of IAEA, in 2016 there have been declared 448 operational nuclear power reactors, producing a total net installed capacity of 391 GW(e). At the end of 2016, a total of 61 units have been under construction, with an estimated capacity of 61 GW(e). With a total amount of operational reactors connected to grid, electricity production from operational nuclear reactors increased about 2%, reaching 2476

TWh. The energy production in terms of electricity for the nuclear active countries can be observed in the chart below.

Fig. 3Nuclear power production by country

At this stage, it is necessary to comment the electricity production. According to IAEA statistical data, the total electricity production at the end of 2016 grew by 2,6%, while the stated growth of nuclear energy was only 2,1%. Despite the availability of infrastructure for the generation of electricity from alternative sources, coal has been the dominant source for energy production. Although the share of renewable sources showed an increase in the total power generation, it was not sufficient to overcome the increasing demand of energy supply.

Fig. 4 Age distribution of reactors

The world energy demand is expected to increase by 18% until 2030 and by nearly 40% by 2050. Considering the current technology being used in nuclear power supply, the world nuclear electrical generating capacity is projected to increase to 554 GW(e) and to 874 GW(e) by 2050. This estimation represents a 200% increase in the nuclear power plants capacity by 2050.

Taking into account the existing reactors, that are active for more than 30 years, it is inevident that they are going to retire very soon. It is assumed that since nuclear energy is still in the background of the total energy supply, they can be given a life extension, until the scientific community will be able to provide a complete solution to replace them by reactors with greater capacity, highly sustainable and low risk state.

Nuclear Challenge

To prevent dangerous and irreversible global warming and in coherence with sustainability concerns, the European Union has set a target to be implemented by the 2030 climate and energy framework. The framework includes binding targets to reduce greenhouse gas emissions in the EU by at least 40% below 1990 levels by 2030,

which is an acknowledged EU commitment under the Paris Agreement. In terms of rising global temperature this translates into an allowable increase of plus two degrees compared to the pre-industrial conditions. Such an increase is considered to be acceptable from a climate change point of view, but still implies a reduction of 50% - 80% CO2 emissions by 2050.

The relationship between CO2 emissions, population (N), production per capita (GDP/N), energy intensity of the economy (E/GDP) and carbon content of energy (C/E) can be provided by the Kaya equation, deriving from the principle of Jancovici (2003)

$CO2 = N \times (GDP/N) \times (E/GDP) \times (C/E)$

According to the UN Department of Economis and Social Affairs the population (N) is projected to grow by a factor of 1,5. Analyzing the equation the product of the three remaining factors (GDP/N, E/GDP, C/E) has to be reduced by a factor of three.4

Taking into account the Pricewaterhouse Coopers (PwC) report 2015 regarding the projection of GDP per capita, it is estimated to grow by a factor of 12%. Taking into consideration the most conservative value, 1% is going to get used for the Kaya identity, instead of the average factor of 1,5% in order to avoid the exaggeration of the principle. 5

The energy intensity level is projected to decrease by 1,8% annually. This translates into an overall reduction of the term by a factor of 2.5%

Summing up the abovementioned statistical data, the European Union committee came to the result, that an approximate reduction of CO2 emmisions by a factor of two, is necessary to lead to the desired target. The nearly carbonfree energy generation requirement makes the big challenge for the promotion of nuclear power as the primary source for energy generation.