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A CRITICAL ANALYSIS OF THE PRIMARY ENERGY CONSUMPTION TRENDS FROM A SUSTAINABLE PERSPECTIVE

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Scopurile acestei lucrări sunt analiza tendinţelor de consum la nivel global în cazul surselor de energie primară şi identificarea măsurii concrete în care este încurajată la nivel european dezvoltarea resurselor regenerabile. Se prezintă o scurtă trecere în revistă a obiectivelor strategiei energetice a Uniunii Europene şi se descrie tabloul actual energetic al acesteia. Se efectuează o investigare matematică a tendinţelor evoluţiei de consum pentru sursele de energie primară până în anul 2020 şi se realizează o piramidă a importanţei diferitelor obiective asociate cu economia energetică, din punctul de vedere al implicării la nivel guvernamental.

The aims of this paper are to analyze the global consumption trends for primary energy sources and to identify the manner in which the development of renewables is actually encouraged at European level. The paper briefly describes the goals of the energy strategy of the European Union and renders its actual energy framework. The paper shows a mathematical investigation of the evolution patterns of the primary energy sources up to 2020 and realizes a pyramid of the importance of different objectives associated with the energy economics from the perspective of the governmental involvement.

Keywords: energy consumption, renewables, energy economics

1. Introduction

Energy is the most important issue on the agenda of the policy makers of the XXI century, as it represents a crucial element for human development. The world largely relies on fossil fuels – oil, coal, and gas – that are providing almost 85% of the current global energy demand. Given the energy - economic growth and welfare relationship and the impact on the environment, numerous strategies and studies aimed to find alternative scenarios to fossil fuels and recommend the switch to renewable sources of energy (RES). The concern for the elaboration of energy strategies has as starting point the first oil shock from the '70s. For instance, in 1973, The United States (USA) launched "*Project independence*" that aimed to decrease the American dependency on imported energy sources. Also concerns regarding the environment emerged, as the "*Environmental action plan – EAP1*" was launched by the European Community in the same year.

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However, given the fact that the security of energy supply is a critical key point of any national or regional strategy, there are still challenges to cope with [1,2]. For instance, in 1997, the European Union (EU) by its "*Action plan for renewable energies*" set a target of a 12% share of renewable energy in its overall mix by 2010 (doubling its 1997 levels) [3]. The production increased by 58%, but the share of renewable energy remained low, less than 7%, and is expected, in the best scenario, not to exceed 10% by 2010. In spite of the alarming meteorological events that were correlated with global warming induced by green house gases [4], especially CO_2 from fossil fuels use, the political agenda registered a real awareness and many declarations of intent, but no coherence needed to bring sustainability, security of supply and competitiveness [5].

2. Calculus

The analyses performed in this paper involved the collection of data from different reliable sources, their validation, given the fact that they were reported by various international, regional and national authorities in the domain, and data processing and interpretation. Therefore, the analysis involving the primary energy consumption data over the interval 1850-2000 were processed from studies of the EIA (*Energy Information Administration*) from USA and IIASA (*International Institute for Applied Systems Analysis*) – Laxenburg from Austria [6-8].

The measuring units expressing the quantities of fossil fuels involved tones of oil equivalent (toe), expressing, in heat units, approximately 10 million Kcal, that are equivalent with the burning of 1.5 tones of hard coal or 1110 m^3 of natural gas.

Based on the dynamics of the primary energy consumption over the period 1850-2000, the general tendency was assessed, and the forecast was performed for a period of 20 years. Three important groups of fuels were considered: oil & gas (O&G), coal (C) and sources with zero emissions (ZE) – RES and nuclear energy that are characterized by the non-emission of green house gases (GHG). By 1950 the considered renewables were the traditional ones, mainly wood, and after that year the modern ones (wind, solar, geothermal, hydro energy and biomass). Oil and gas were considered into the same group as there are perceived as "leaders" in the energy mix for the next period, with a shift towards gas, considered the "cleanest" fossil fuel.

After a careful mathematical analysis, the forecasts took into consideration the polynomial regression of 3^{rd} order for all the involved values, with the unity being equal with 10 years [9]. To verify the accuracy of the mathematical models many statistical tools are employed, and among these the coefficient of determination (R^2) was chosen [10]. R^2 reveals how closely the estimated values

of the trend line correspond with the actual data (a trend line is most reliable when its R^2 is near 1). The considered formula for R^2 is (1), where x_t are the actual data, x(t) are the estimated data, and n stands for the number of values.

$$R^2 = 1 - \frac{\sum_{t=1}^{n}(x_t - x(t))^2}{\sum_{t=1}^{n}(x_t)^2 - \frac{(\sum_{t=1}^{n} x_t)^2}{n}} \quad (1)$$

3. Results and discussion

3.1. Analysis of the current primary energy consumption mix

World energy demand grows continuously, with the central part played by the fossil fuels, which account for about 85% [11] of the actual global primary energy consumption. The current growth rate in global primary energy consumption is more than 2%/year [12], and at this rate it will double in the next 35 years leading to enormous quantities of energy.

As might be noticed in Table 1, global oil consumption has increased with about 1.5%/year since 1990, meaning that the consumption has increased with more than 20% in the last 14 years.

Table 1.

Global primary energy consumption rates for nonrenewable energy sources over the period 1990-2004. Data shown are based on calculations on [12].

Fuel type	Consumption in 1990, Mtoe	Consumption in 2004, Mtoe	Average growth, % *	Average growth rate, %/year
Oil	3144.5	3798.6	20.80	1.49
Gas	1793.5	2425.2	35.22	2.52
Coal	2233.7	2798.9	25.30	1.81
Nuclear energy	453.2	625.1	37.93	2.71
Total	**7624.9**	**9647.8**	**29.81**	**2.13**

$$* - \text{Average growth} = \frac{\text{Data from } 2004 - \text{Data from } 1990}{\text{Data from } 1990} \times 100$$

Natural gas, the cleanest fossil fuel, that produces the least quantity of CO_2/unit, has registered a significant increase, leading to a consumption boost of about 35%. Burning coal, the dirtiest fossil fuel, registered a maximum in 1996, followed by a sharp decrease in demand. But this decline stopped in 2001, being followed by a sharp increase in the last years, mainly due to China demand [13],

recording an average increase during 1990-2004 of more than 25%. Although the nuclear energy does not produce CO_2, the consumption remains low, this fact being attributed to the reticence of the governments to develop/use this type of energy due to related hazards.

At European level, the issues are somewhat different. The highest increase was registered for natural gas (60% increase in the period 1990-2004), followed by nuclear energy (28% in the same period) and RES (58% in the considered period) [14]. In spite of these spectacular changes in consumption, the actual total primary energy supply for the EU is mainly based on oil, as portrayed in Fig. 1.

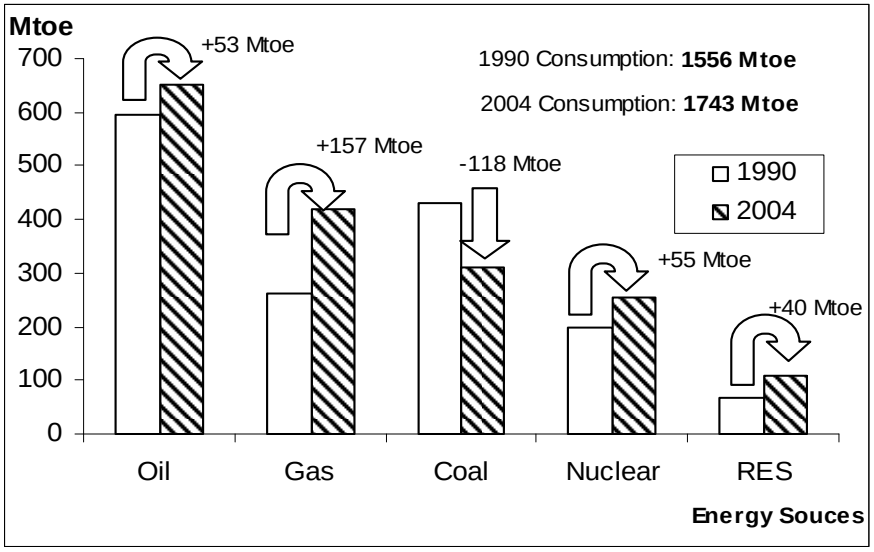

Fig. 1. EU(25) total primary energy consumption in 1990 and 2004. Data shown are based on calculations on [14].

Now, by the newly launched energy policy [15], the Commission of the European Communities aims 3 main ambitious goals, by 2020:

- improving energy efficiency by 20%;
- raising the share of RES in the energy mix to 20%;
- increasing the level of biofuels in transport fuel to 10%.

Another fact agreed at the European Council of 8-9 March 2007 from Brussels was the reduction of GHG by 20% by 2020, European Union assuming the pioneer role in the domain of reducing pollution and GHG emissions. Although the Commission has in view such ambitious objectives, the situation must be analyzed more realistically, by taking into consideration the interests of all involved countries, unless the Europeans will not surpass, once again, their

own assumed stakes. What is achievable at the national levels and what can be done to fight for sustainable development without affecting countries' competitiveness and security must become more important issues.

3.2. Primary energy consumption trends to 2020

In order to identify the evolution types and to choose the appropriate mathematical models that render best the dynamics of each group, several mathematical functions were considered and investigated by the author. Amid these, the polynomial regression of 3rd order was considered for all the involved groups – see equations (2) for C, (3) for O&G and (4) for ZE:

$$For\ C: \quad x(t) = 20.231 + 7.94787t - 0.5757t^2 + 0.0048t^3 \quad (2)$$

$$For\ O\&G: \quad x(t) = 13.712 - 10.843t + 1.841t^2 - 0.0597t^3 \quad (3)$$

$$For\ ZE: \quad x(t) = 66.058 + 2.8949t - 1.2653t^2 + 0.055t^3 \quad (4)$$

In order to verify the accuracy of the models, the R^2 values were computed using relationship (1) for all the mentioned groups and all were near 1, proving the validity of the identified evolutions in time:

$$\begin{aligned} &For\ C && R^2 = 0.91 \\ &For\ O\&G && R^2 = 0.98 \qquad 0 \le R^2 \le 1 \\ &For\ ZE && R^2 = 0.98 \end{aligned} \quad (5)$$

Following these determinations, the forecasts were performed up to 2020 and are shown in Fig. 2.

As might be noticed, in the 2020 the O&G group will still dominate the world, but with a more important part played by gas, due to its environmentally friendly character. ZE will sharply increase to almost 30% of the market, being boost by the investments in nuclear energy and RES. This increase will be done at the expense of a sharp decrease in coal consumption. However, this tendency might be limited by the new development of clean burning coal technologies.

The forecast was stopped at 2020, as in author's opinion the current conditions of producing and consuming energy will be valid to that point, given the lifespan of the actual investments in thermal energy facilities, refineries and so on. After 2020, several important technological changes will be in force – nuclear reactors of IV generation, H_2, fuel cells, etc –, or the prices for oil and gas would increase above a critical point boosting the RES to more than 50%.

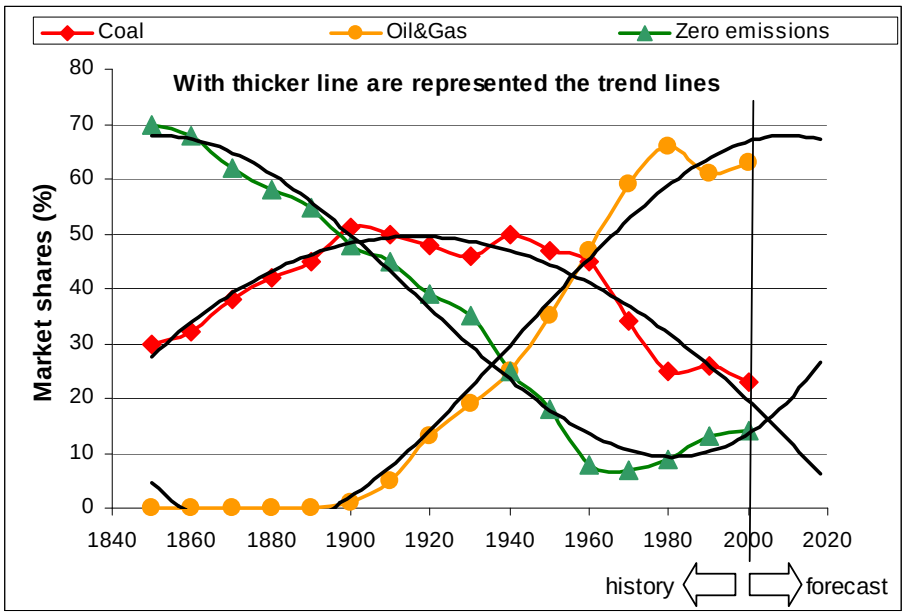

Fig. 2. The global fuels consumption patterns and their trends. Hystorical data are based on [6-8].

3.3. Managing sustainability and RES

Numerous summits, conferences, workshops were held in EU over the last years and were focused on the environmental impacts of energy. After hundreds of speeches and declarations of intent, the RES are accounting about 1% more than 10 years ago in the energy mix. Aside particular situations in developing modern renewables, the real investments in RES remain only window dressing.

Given these findings, it is clear that the future world will still rely on fossil fuels, in spite of the disclosed problems: release of toxic gases – CO_2, NO_x, SO_2 -, global warming, increased toxicity of soil, water and air, and so on. In author's opinion, the real investments in RES will start only when oil price will rise and maintain to 100 USD/barrel, this being the moment of considering the involved costs of modern technologies.

Security of supply always comes first in all energy strategies and the sustainable development is approached only in the last place. In author's opinion, in spite of the declared goals, the measures taken in the energy sector will be in direct correlation with their perceived importance in the political and business eyes. Therefore, it can be perceived as a pyramid with 4 levels, on the fist being placed the security issue, on the second the market concern that involves also job creation, and on the third the technological problem. Only on the last level of the pyramid are considered the environmental issues, this meaning that will be the last

to be tackled (see the Fig. 3). Moreover, the energy interests of rich and emerging countries are quite divergent, and hard choices are to be made between security of energy of a given nation and the global environment.

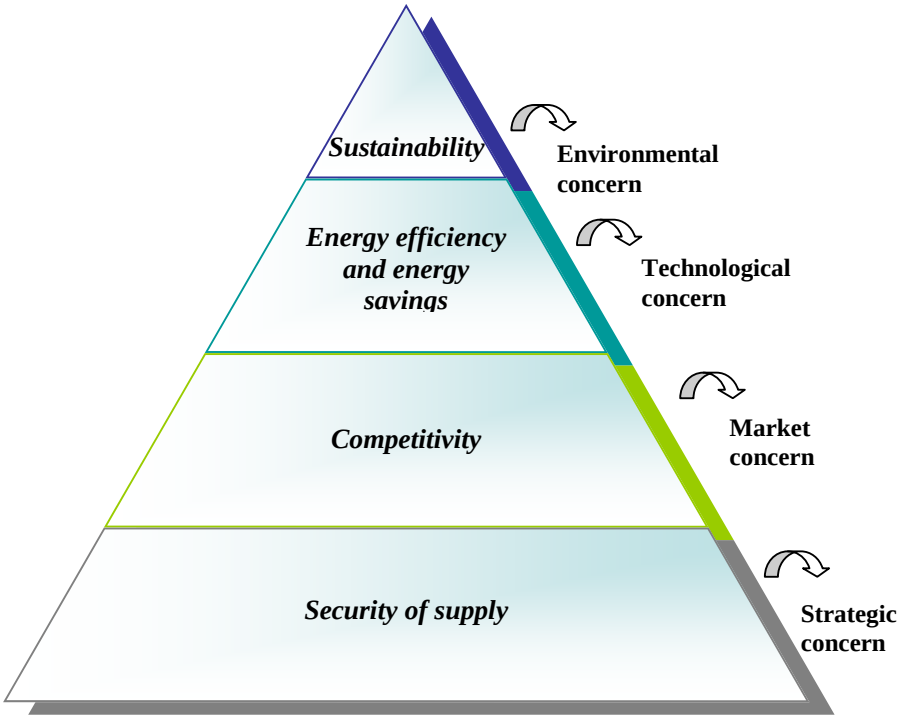

Fig. 3. The energy pyramid – the importance of different objectives associated with energy economics.

4. Conclusions

This paper presents an analysis of the current energy consumption patterns at global and European levels. Based on this analysis, a forecast to 2020 is represented and key conclusions are assessed. This paper shows that during time EU was engaged in ambitious programs focused on RES development and GHG emissions reduction, but failed to accomplish them.

The paper argues that this might be the problem also with the recently launched energy policy for Europe, given the fact that security of supply and competitiveness always come first, as suggested in the presented energy pyramid.

The interests of all member states must be balanced and what is achievable at the national levels must be initially tackled.

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