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ENERGY AND SOCIETY

Abstract: Energy is and will remain the most critical parameter for every society's development and well-being, its struggle to alleviate poverty and increase democracy and freedom of choice among its citizens, and its efforts to understand society's impact on the environment and climate change. As society's size and complexity increase, so does its technological and industrial infrastructure which itself demands more energy and higher energy efficiency. In this paper three areas will be discussed: (1) Emerging world-wide facts relating to energy consumption and mix of the available energy resources, which is gradually shifting towards renewable energy sources; (2) Global changes in the electricity sector mainly due to new developments in decarbonization, digitization of the electrical energy system, and decentralization of energy consumers and producers; and (3) Progress in efforts to escape poverty through provision of modern forms of energy especially affordable electricity.

Key words: *energy, energy consumption, energy mix, electricity, society, energy poverty, climate change*

1. EMERGING WORLD-WIDE FACTS RELATING TO ENERGY

Energy is and will remain the most critical parameter of every county's development, a challenge in its struggle to alleviate world poverty, and a crucial factor in understanding human intervention in the environment and climate change. Two factors that exemplify the profound impact of energy on society are (i) the increase in world population and (ii) the climate change and its consequences [1].

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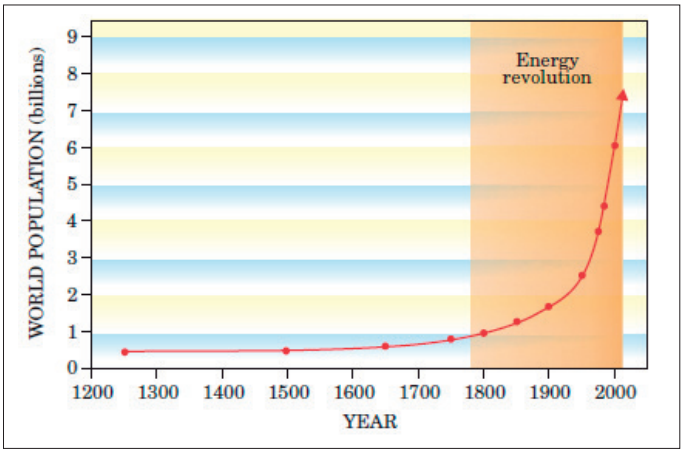

Fig. 1. World population growth since the 13th century and its precipitous increase in the energy revolution [2].

Figure 1 shows [2] the increase in world population between 1250 and ~2000; clearly the energy revolution since 1800 is primarily responsible for the enormous increase in world population from ~ 1 billion in 1800 to ~ 8 billion in ~2000.

Regarding climate change, it is becoming the challenge of the 21rst century. Clearly, humanity cannot face this challenge without addressing the impact on climate change of energy production and use. Many studies and reports (see, for instance, Refs. [3, 4] make it abundantly clear that Negative Emission Technologies (NET), i. e, technologies to remove many hundreds of Gt of CO_2 per year from the environment, will NOT be possible and urgent mitigation measures are needed at the source, foremost in the combustion industry (capture and utilization of CO_2 at the source) and possibly new techniques of breaking up the CO_2 molecule.

1. 1. THE TOTAL WORLD ENERGY CONSUMPTION GROWS AND THE WORLD-ENERGY MIX CHANGES

The growth of the total world energy consumption between 1965 and 2035 is shown in Figure 2a and the changes in the world energy mix in the same time period is shown in Figure 2b [5]. It is clearly seen from these figures that the use of oil and coal is and will be decreasing and the use that natural gas is and will be increasing, Also the use of oil, coal and natural gas in the next decades will continue to dominate energy consumption, *and herewith lays the problem and the challenge.*

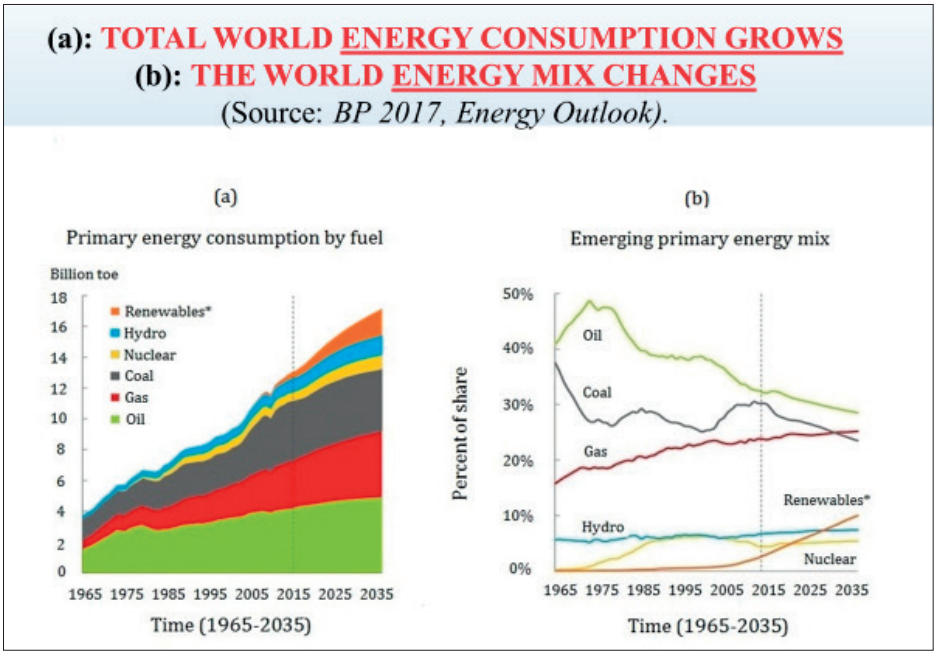

Fig. 2. (a) Trends in primary energy consumption by fuel between 1965 and 2035; (b) Emerging primary energy mix (per cent of share) vs time (1965–2035) [5].

Clearly, there is a gradual shift in the energy fuel mix toward the Renewable Energy Sources (RES), which will be increasing in the years ahead. *Irrespective of these changes, however, in the global energy mix, in the coming decades, the fossil fuels oil and coal, will continue to prevail and will therefore continue to exacerbate climate change.*

1. 2. THE GLOBAL ENERGY LANDSCAPE IS BEING CHANGING

— Digitization and modern telecommunications ensure consumer access to and participation in the market.

— Electricity storage (e. g, at hydro, batteries, fuel cells) enhances the system's operational flexibility and reduces the need for fossil fuels.

— Natural gas (NG) is offered to cover system's reliability until (stochastic) RES are further developed. The NG is emerging as an energy source with greater use for electricity generation and for transport partly because its burning generates lower percentages of GHGs compared to other fossil fuels.

— Electricity and NG markets will be affected by the challenges in the transport sector such as vehicle electrification, vehicle re-engineering, alternative fuel development, and transport infrastructure.

1. 3. THE CHALLENGES ARE BIG

These include:

— Security of energy sources, stable supply and affordable prices.

— Transition to "Clean Energy" (low–carbon or no carbon at all).

— New ways to access existing sources of energy, for instance shale gas. There are vast deposits of shale, but shale is too dense for gas to flow freely. Horizontal drilling and hydraulic fracturing are used to extract gas from shales, especially in the USA.

— New energy sources, even new carriers of energy besides electricity.

— While global action is not sufficient to limit global average temperature rise below 2°C, four energy policies can help keep the < 2°C target alive:

— Adopt specific energy conservation and energy efficiency measures.

— Limit construction and use of least-efficient coal-fired power plants.

— Phase-out subsidies to fossil-fuel consumption.

— Minimize methane emissions from upstream oil and gas production, especially, in shale-gas production. In the following Figure (Fig. 3) [6], methane in groundwater at concentrations high enough to be flammable can occur naturally is clearly seen. Such high quantities of methane are normally related to the thousands of natural gas wells drilled in shale-gas extraction. The picture with the flaming tap water was taken [6] in Granville Summit, Pennsylvania, in March 2012. It exemplifies the risk of this technology and the concerns of society. Besides methane escape, there are concerns about

Fig. 3. Methane in ground water at high enough concentrations to be flammable can be related to natural gas wells [6].

the enormous quantities of water needed in drilling, possible flows of chemicals under pressure used in drilling polluting surrounding aquifers, and small size but large numbers of earthquakes induced by fluid injection [7].

1. 4. GLOBAL ELECTRICITY AND ITS RECENT TRANSFORMATION

Electricity is the most important energy carrier today.

Over the last 50 years electricity consumption increased by a factor of ~ 4.5. The demand for electricity will continue to grow in the future. By the year 2050, it may globally reach 30 TW, that is twice its present level.

The local autonomous electricity generation and distribution systems have been transformed into national and supranational interconnected systems. Electrical systems are gradually being characterized by scattered RES units, decentralized small systems, and scattered production and consumption. Production, storage, and consumer/electricity providers, constitute the upcoming model of evolving new electrical systems.

It has long been known that countries with high electricity consumption, such as the USA, offer their citizens a high degree of freedom of choice. And that the GDP of a country correlates with its electricity consumption (Figure 4 [8]).

2. ENERGY AND POVERTY

— Energy is a major factor of social well being and the key for poverty eradication; Peoples' poverty is essentially energy poverty.

— The challenge of any society is its moral responsibility to make modern forms of energy, especially electricity, accessible to and affordable by *all its citizens*.

— The role of energy as a prerequisite of poverty eradication and higher standard of living is gradually being widely recognized [1].

— Yet, energy poverty is hard to define and even harder to measure.

— Some have defined it in terms of access to modern energy services (affordable and reliable electricity and clean household facilities.

— Others have defined energy poverty as 1kWh per person per day.

— The IEA suggested 250 kWh per household per year for rural and twice that amount for urban households.

— Based on such definitions of energy poverty in terms of electrical energy consumption, 1.3–1.6 billion people in the world have no access to electricity and some 2.4–3.0 billion rely on traditional use of biomass for cooking and heating and have incomes less than $2 per day.

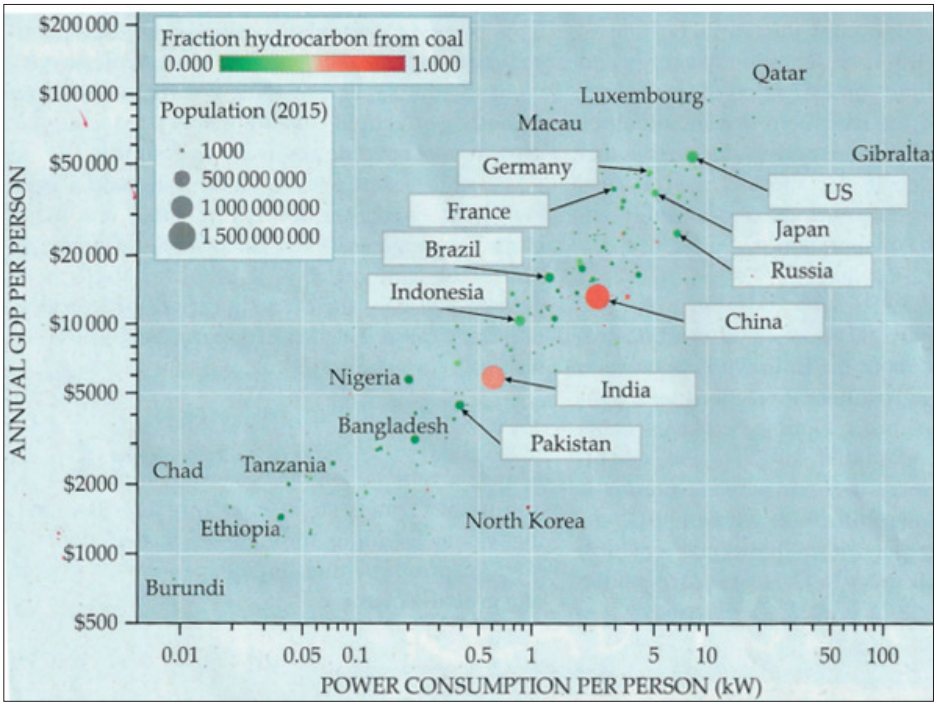

Fig. 4. Relation between the annual GDP per person and the consumption of electrical power per person for various countries [8].

— Despite progress being made, if present trends continue, by the year 2030 some 1.4 billion people will lack access to electricity and more than 2.6 billion will still rely on traditional biomass fuels.

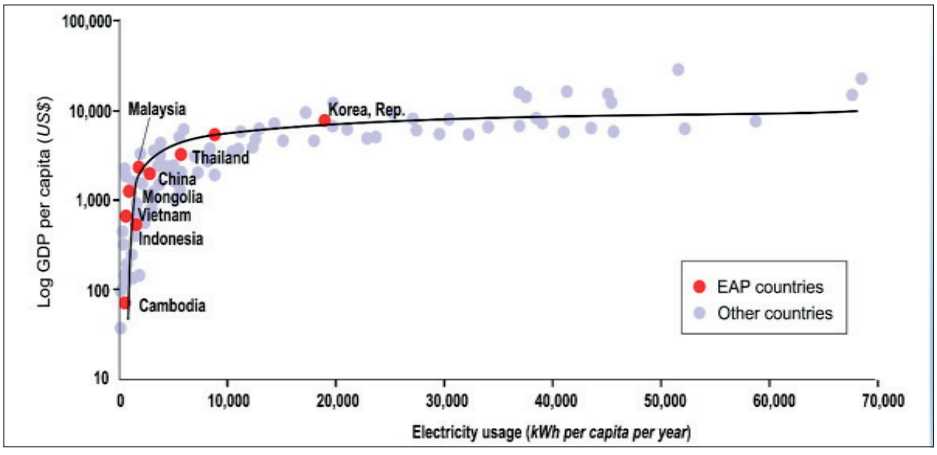

Fig. 5. Log GDP per capita vs. Electricity usage [9].

Let us consider the low-electricity consumption data in Figure 5 where the GDP per capita of various countries is plotted as a function of energy usage; more specifically, the data below ~2,000 kWh per person per year. Let us accept a Poverty Level for energy consumption, 365 kWh per person per year. If the poverty level is raised to 1000 kWh per person per year, the GDP would substantially increase above the poverty level. Reducing, on the other hand, by 2000 kWh the amount of energy consumed by the EU citizens above 20,000 kWh per person per year would hardly impact their standards of living; actually, any such change would be within the spread of their incomes.

The Earth Institute claims that at levels of electricity usage of 2000 kWh per person per year, access to modern needs becomes possible. Regrettably, however, the IEA envisages the poverty level rising slowly and reaching 800 kWh per household per year by 2030; by comparison, the average annual household consumption in the 27 EU countries in 2008 was ~18,000 kWh.

3. THE ENERGY SITUATION IN GREECE

In Greece:

— The use of lignite is decreasing, the use of NG and RES is increasing, and the use of imported oil continues at a high level.

— High levels of exhaust emissions continue, mainly due to the high use of imported fossil fuels in road transport.

— Among the primary energy sources, only the RES, Lignite, and Energy Conservation constitute Greece's domestic energy sources. In the future, any discovery and exploitation of significant indigenous NG deposits or Oil fields will be crucial for the country's development.

— The energy sector of Greece will adapt to the framework of the European Union Policy.

3. 1. ELEMENTS OF THE LONG-RANGE PLANNING OF GREECE

As to the long-range planning of Greece, the Energy Committee of the Academy of Athens suggested that Greece should:

(i) Take advantage of the technological advantages that lead to a low-CO_2-energy mix at a competitive cost.

(ii) Proceed immediately with the necessary infrastructure and investment in energy storage technologies, smart grids, and digitization.

(iii) Make effective use of the energy sector to:

— Protect the environment and reduce climate change;

— Extend the provision of NG across the country and promote the use of NG and LNG in transport;

— Reduce road transport, produce and use biofuels, and use renewable electricity for transport including railways;

— Moderate the price of electricity by improving efficiency.

4. THE ENERGY COMMITTEE OF THE ACADEMY OF ATHENS: ITS MISSION AND WORK

— Through its Energy Committee, the Academy of Athens is helping Greece with its Energy Needs and Resources.

— The Academy's Energy Committee was established in 2005 to play a consultative role in the energy issues of Greece.

— Since then, the Committee has provided broad and sound information to the Greek citizens, and independent and scientifically based advice to the State, on Greece's energy sources, needs and long-range prospects.

— The Committee achieves its purpose through studies by Greek and foreign experts of specific energy issues, via Symposia, Workshops, Working

Table 1. Symposia/Workshops/Working Groups/Year/Topics.

The Academy of Athens: Helping Greece with its Energy Needs and Resources	
Symposium/Workshop/ Working Group, Year	**Topic**
Symposium, 2006	Energy Conservation
Symposium, 2008	Energy and the Environment
Working Group, 2009	Nuclear Power and the Energy Needs of Greece
Symposium, 2010	Materials for Energy Applications
Working Group, 2011	Electricity Generation in Greece: Fossil Fuels, Renewable Energy Sources and Prospects of Energy Supply
AA/EASAC Workshop, 2011	Concentrating Solar Power
Symposium, 2012	Greek Hydrocarbons: From Research to Exploitation
Symposium, 2013	Renewable Energy Sources: Prerequisites for Mass Penetration in Power Generation
Symposium, 2014	Waste Management and Energy Exploitation in Greece
Symposium, 2015	Energy and Development Planning in Greece
Symposium, 2016	Energy and Transport in Greece: Requirements and measures for clean and sustainable energy in transport
Working Group, 2018	Energy Perspectives of Greece in 2030 with Horizon in 2050
Symposium, 2018	Hydrocarbon Research in the Eastern Mediterranean: Prospects and Challenges
Symposium, 2019	Energy Research in Greece

Groups, Lectures, Press Releases and Books of Proceedings of the Symposia, Workshops and Working Groups, which are distributed widely and (usually) free of charge.

Table 1 lists the Symposia/Workshops/Working Groups, the year they were held, and the topic they dealt with.

It is hoped that these findings and recommendations for Greece, made by the Energy Committee of the Academy of Athens, can similarly help other countries in the region.

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