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1 RENEWABLE Energy - Background

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1.1 Introduction

The term energy can be generally defined as the amount of force or power when applied can move one object from one position to another, or it defines the capacity of a system to do the work. The energy can have many forms such as kinetic, potential, electromagnetic, nuclear, sound, light or photo-energy, and gravitational. The most important characteristic of energy is the possibility to convert one of its forms to another. This can be done naturally (e.g. chemical reactions) or artificially through man-made energy technologies (e.g. hydropower generators). In the later energy conversions, the energy technologies convert a naturally available form of energy to a specific desired form such as electricity or heat.

Energy is one of the most important needs of humans in daily lives and has been for decades, perhaps millenniums. Once the things we cannot do without energy is considered, energy becomes of great importance and is becoming increasingly vital as technology advances progressively. Since

fossil fuels are utilized for the production of energy and they are not endless, due precautions must be taken in order to prevent future problems for countries and earth. These issues present the major challenges in the worldwide energy as summarized in Fig. 1.1.

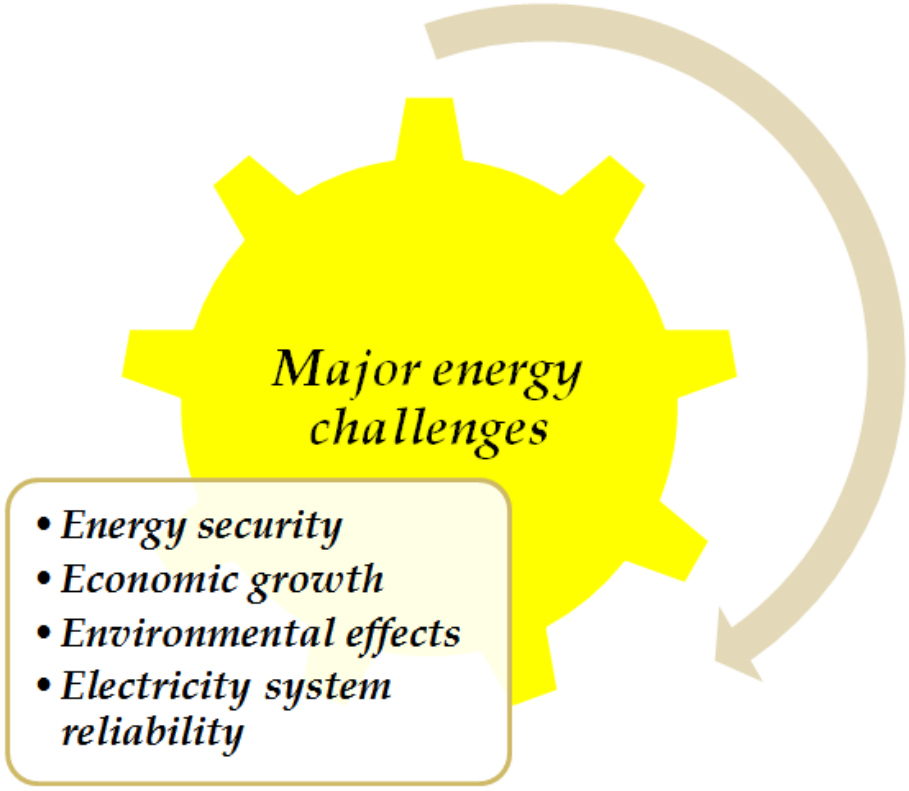


Fig. 1.1: Major energy challenges

The energy security refers to the availability of energy resources for the future while the economic growth refers to the accommodation the energy needs in developing countries. The environmental effect refers to the impacts associated with the artificial energy conversion processes on the environment. The electricity system reliability refers to the integrality of the electric energy infrastructure and its capability to provide continuous electric power with sufficient quality.

As time goes by, world population is increasing; therefore the need for consumption of energy is growing day by day. Consequently, environmental

pollution and the greenhouse effect are harming our atmosphere, threatening the health of humans as well as the natural habitat.

Fossil fuels not being endless and harming the environment have not prevented countries from stopping to use them for energy; in fact, they are still utilized to provide the majority of the world's energy source. However, it is visible that more and more countries around the globe are focusing on renewable energy, reforming their policies and legislations in order to reduce environmental harm, and search for alternative energy sources.

In 2012 a sum of 244 billion dollars was invested in renewable energy across the world totaling almost 19% of the global energy need coming from renewable energy. Although some developing countries have not shown progress in adopting renewable energy in the past, (e.g. Turkey 2.33% in 2011) more and more nations are increasing their renewable energy source use (Özkale et. al., 2017)[1].

In 2015, employment in the renewable energy sector (not including large-scale hydropower) increased to an estimated 8.1 million jobs and the leading employers were USA, Brazil, China and India (Global Status Report, 2016)[2]. Moreover, different areas around the world are blessed with various types of natural resources, thus the North African countries are mainly gifted with rich hydrocarbon resources apart from Morocco and Tunisia. Preferring to implement renewable energy is driven by concerns for the environment, developing energy security, and the European intention to build far-reaching across borders solar power plants and wind parks in order to establish an intercontinental connection to transfer electricity from North Africa to Europe. In 2009 a group of German companies (Desertec Industrial Initiative) offered a $400 billion investment to install solar power plants in North Africa and connect them with the European grid through submarine cables. Europe and some Mediterranean countries aim to turn North Africa into a renewable energy producer and be able to supply to trade with

[1] Özkale, C., Celik, C., Turkmen, A. and Cakmaz, E. (2017). Decision analysis application intended for selection of a power plant running on renewable energy sources. *Renewable and Sustainable Energy Reviews*, 70, pp.1011-1021.

[2] Global Status Report. (2016). Available at: http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf

neighboring European countries. Therefore, it is significantly important to determine if the renewable energy project makes economic sense. There are different calculations such as *simple payback, net present value, annual energy savings,* and *SWOT analysis* for deciding whether renewable energy makes economic sense or not. In order to deploy renewable energy, firstly the countries 'overall infrastructures should be analyzed to see the availability of natural resources and whether it is possible to produce and export to other countries as intended. This action refers to *assessment of renewable resources*.

1.2 Renewable Energy Resources and Sources

The term energy *resources* refer to the naturally available forms of energy while the energy *sources* refer to the output forms of energy from the man-made *energy technologies*. Generally, the energy technologies are the man-made devices, equipment, and systems used to *capture*, *convert*, *store*, and *transport* energy from the energy resources. Alternative or renewable energy sources include traditional renewable energy technologies (such as wind turbines) as well as innovative new technologies, such as hydrogen internal combustion engines, and hydrogen-based fuel cells. This chapter is briefly defines some important types of alternative energy sources.

Various types of renewable resources such as *hydrothermal, geothermal, solar, wind, marine,* and *biogenic energies* are available and they give the possibility to produce consistent power. The landscape and weather conditions allow North Africa to produce a significant quantity of 0.25 TWh/km^2 yearly. In addition, with the appropriate technology a vast amount of fresh water could be generated which could be distributable to neighboring countries in need of water. Wind energy is also a strong resource in the area as Egypt having the best potential of output, followed by Morocco. Table 1.1 illustrates the top 15 countries by their total wind energy installations. It is clear that the 2015 worldwide growth rate of 17.2% is pretty high and indicates a powerful trend towards the use of renewable energy.

Table 1.1: Top 15 Countries by total wind installations[3]

Position	Country	Total Capacity 2015 (MW)	Added Capacity (MW)	Growth Rate 2015 (%)
1	**China**	**148,000**	**32,970**	**29.0**
2	**USA**	**74,347**	**8598**	**13.1**
3	**Germany**	**45,192**	**4919**	**11.7**
4	**India**	**24,759**	**2294**	**10.2**
5	**Spain**	**22,987**	**0**	**0.0**
6	**UK**	**13,614**	**1174**	**9.4**
7	**Canada**	**11,205**	**1511**	**15.6**
8	**France**	**10,293**	**997**	**10.7**
9	**Italy**	**8958**	**295**	**3.4**
10	**Brazil**	**8715**	**2754**	**46.2**
11	**Sweden**	**6025**	**615**	**11.1**
12	**Poland**	**5100**	**1266**	**33.0**
13	**Portugal**	**5079**	**126**	**2.5**
14	**Denmark**	**5064**	**217**	**3.7**
15	**Turkey**	**4718**	**955**	**25.4**
Rest of the World		**40,800**	**5000**	**14.0**
		Totals		**Average**
		434,856	**63,690**	**17.2**

[3] Igliński, B., Iglińska, A., Koziński, G., Skrzatek, M. and Buczkowski, R. (2016). Wind energy in Poland – History, current state, surveys, Renewable Energy Sources Act, SWOT analysis. *Renewable and Sustainable Energy Reviews*, 64, pp.19-33.

Fig. 1.2 illustrates the main energy conversion process in various non-renewable and renewable energy sources. As shown in the figure, the renewable energy resources are classified into two categories based on their prime cause; solar-driven and non-solar driven. The final output of these energy conversions is the electric energy. Each of the shown energy conversions is performed by a relevant set of energy conversion alternatives. For a specific energy conversion process, many technologies are available, each of which is characterized by specific efficiency, control capabilities, reliability, and fixed as well as running costs.

Fig. 1.3 provides further insight on various generic technologies responsible in various energy conversion processes. For more details about the technological characteristics of various energy technologies the readers may refer to many references such as references[4,5,6,7,8].

[4] Wood, Allen J., and Bruce F. Wollenberg. *Power generation, operation, and control*. John Wiley & Sons, 2012.

[5] M. EL-Shimy. Dynamic Security of Interconnected Electric Power Systems - Volume 2: Dynamics and stability of conventional and renewable energy systems. Lap Lambert Academic Publishing / Omniscriptum Gmbh & Company Kg; Germany; ISBN: 978-3-659-80714-5; Nov. 2015.

[6] M. EL-Shimy, "Probable Power Production in Optimally Matched Wind Power Systems. International journal of Sustainable Energy Technologies and Assessments (SETA). 2, (2013) 55–66.

[7] M. EL-Shimy, T. Abdo, "PV Technologies: History, Technological Advances, and Characterization', In Sohail Anwar (ed.) Encyclopedia of Energy Engineering and Technology – Volume III, Taylor & Francis - CRC Press, 2015.

[8] Goswami, D. Yogi, and Frank Kreith, eds. Energy Efficiency and Renewable Energy Handbook. CRC Press, 2015.

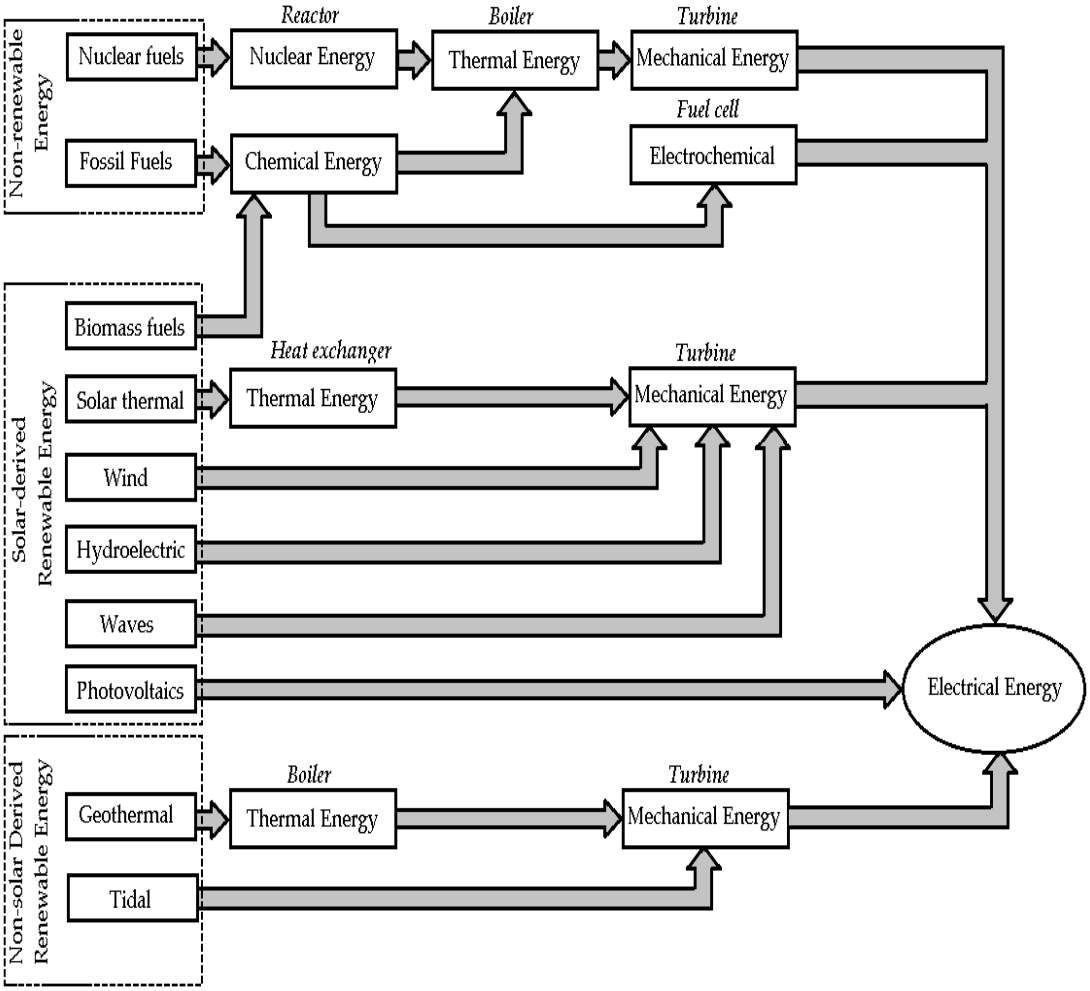
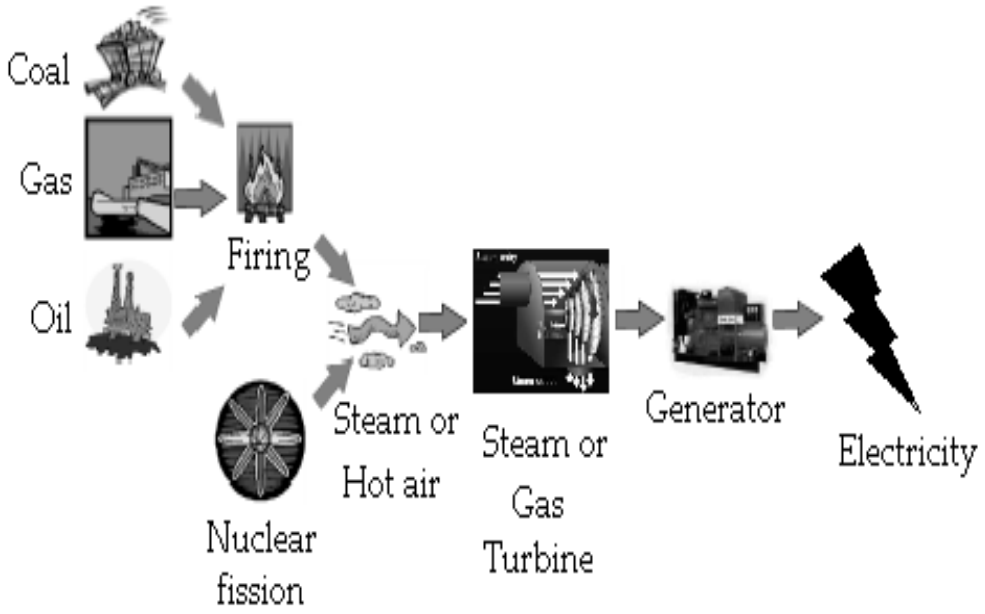


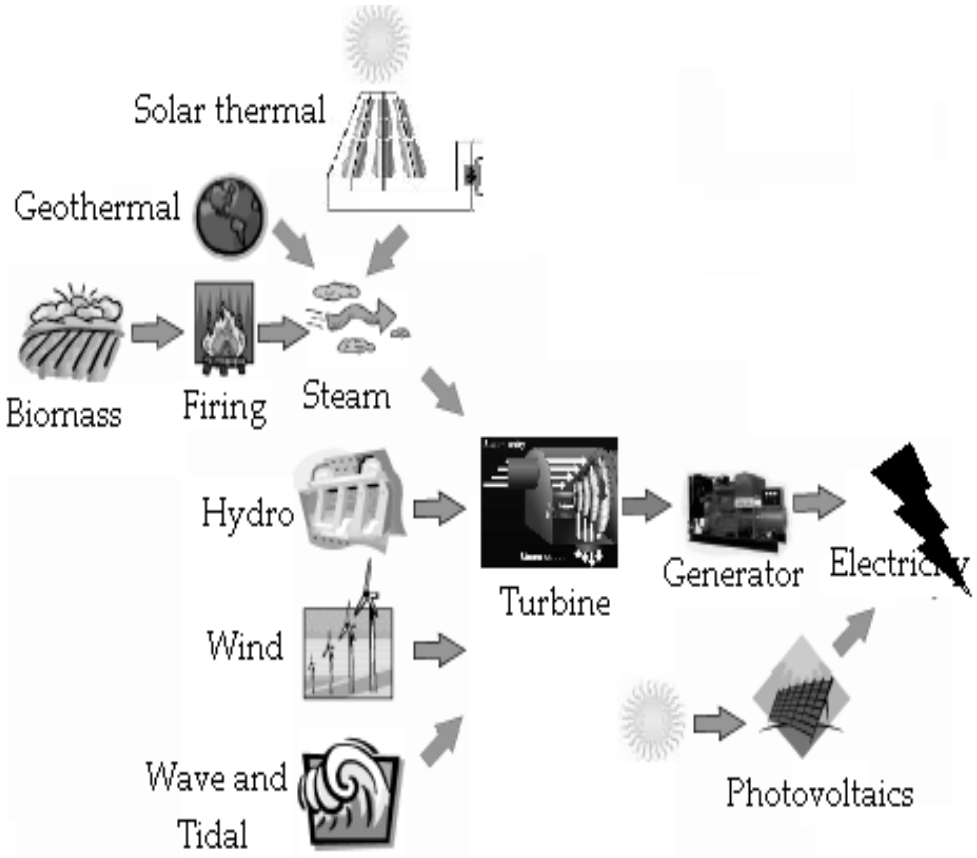
Fig. 1.2: Energy conversion processes in various energy sources

In the simplest manner, *hydropower* generators are producing energy from the flow of water. Through this method, electricity could be created as shown in Fig. 1.2 and 1.3. Compared to other renewable energies, hydropower has a longer history, therefore the overall quantity of hydro energy are most commonly applied amongst nations. If we look at countries producing hydropower, China come first place, followed by Brazil and Canada. Estimations for the future of hydro energy reveal exceeding 6000 TWh when we reach 2050 and in the year 2012 world hydrothermal capability was 3700 TWh (Aydin, 2014)[9].

[9] Aydin, G. (2014). Modeling of energy consumption based on economic and demographic factors: The case of Turkey with projections. *Renewable and Sustainable Energy Reviews*, 35, pp.382-389.



(a)



(b)

Fig. 1.3: Generic energy technologies. (a) Non-renewable; (b) Renewable

A *geothermal* resource needs liquid, high temperature and permeable matter to be able to produce electricity. In this respect; traditional hydrothermal resources comprise all these 3 matters habitually (energy.gov)[10].

Solar power is the energy obtained from the sun and it is converted into thermal or electrical energy. Solar energy is known to be the cleanest and most abundant renewable energy source (Kalogirou, 2014)[11]. USA has some of the richest solar resources in the world. Modern technology can channel this energy for different uses, such as generating electricity, providing light, having a comfortable interior environment, and heating water for the use of domestic, commercial, or industrial areas (SEIA, 2017)[12].

Historically, the *wind* as an energy source has been used by people for a long time. Together with the sun, wind has also been utilized during the drying process of agricultural crops. In addition, wind energy has been a key method of geographical exploration through energy for sailing ships and also windmills were used for grain grinning, watering or drying fields. The wind energy sector is growing to be more and more significant for the world economy as the declined price of fossil fuels did not affect the wind energy sector negatively. It also leads the way in the environmentally-friendly methods to generate power across the globe with 16.4 % in 2014 and a 0.8% rise to reach 17.2% in 2015. Visible in Table 1.1, Turkey, Brazil, China and Poland showed high growth rates, and China leads the way in the production of wind power (Igliński et al., 2015)[13].

The vast oceans across the Earth offer huge, however, nearly unexploited, *marine sources* of alternative renewable energy since the currents of the

[10] Energy.gov. (2017). *Hydrothermal Resources | Department of Energy*. [online] Available at: https://energy.gov/eere/geothermal/hydrothermal-resources [Accessed 25 Mar. 2017]
[11] Kalogirou, S. (2014). *Solar Energy Engineering: Processes and Systems*. 2nd ed. Ozford: Elsevier, p.1.
[12] www. seia.org
[13] Iglinski, B., Buczkowski, R., Cichosz,, M., Iglinska, A. and Plaskacz-Dziuba, M. (2015). SWOT analysis of the renewable energy sector in Poland. Case study of Wielkopolskie region. *Journal of Power Technologies*, 95(2), pp.143-157.

ocean, never-ending *waves* could play in important role in the future energy mix (Wilden, 2017)[14]. The ocean is able to generate 2 kinds of energy; thermal energy through the heat from the Sun, and mechanical energy coming from waves, tides and the currents (renewableenergyworld.com, 2017)[15].

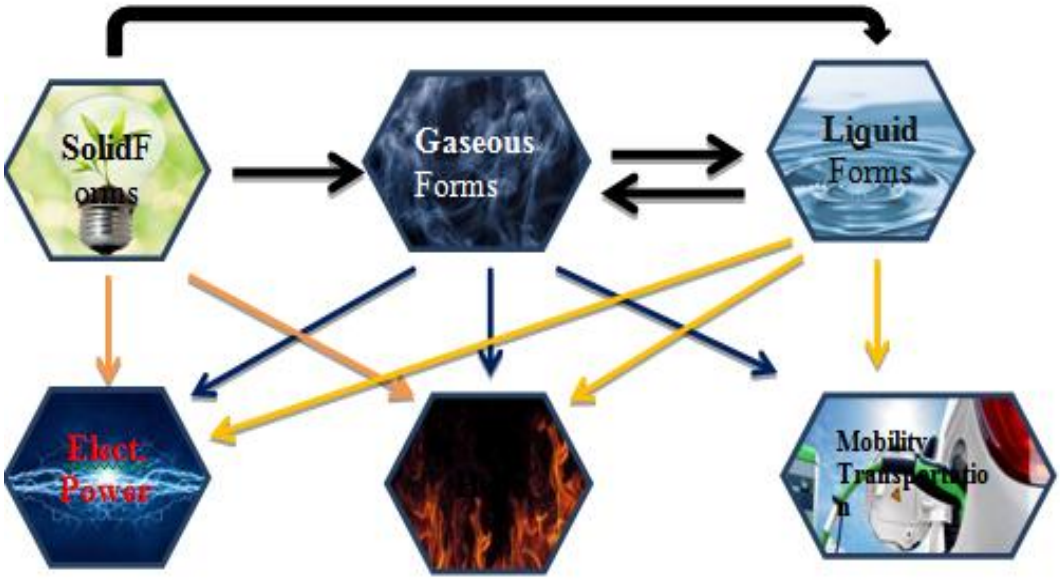


Fig. 1.4: Bioenergy generation processes – 3 types and 3 uses. Source: Worlen, C. (2012)[16]

Biogenic energy is utilized by biogas from waste such as municipal bio-solids, sewage and agricultural residues visible in Fig. 1.4. This is also referred to as Waste-to-Energy meaning achieving energy from biomass or bio-waste (IEA Bioenergy, 2012)[17]. In other words, biogenic energy converts low value biomass waste into a renewable fuel for generating

[14] Wilden, R. (2017). *Marine Energy | Oxford Energy*. [online] Energy.ox.ac.uk. Available at: http://www.energy.ox.ac.uk/wordpress/marine/ [Accessed 25 Mar . 2017].
[15] Renewableenergyworld.com. (2017). *Ocean Energy*. [online] Available at: http://www.renewableenergyworld.com/ocean-energy/tech.html [Accessed 25 Mar. 2017].
[16] Worlen, C. (2012). *Biowaste to Energy – Examples from Germany*. [online] Deutsch-Kolumbianische Industrie- ind Hendelskammer. Available at: http://www.ahk-colombia.com/uploads/media/Presentacion_experto_Woerlen.pdf [Accessed 2 Apr. 2017]
[17] IEA Bioenergy, (2012). *Energy recovery from renewable content of waste: incentives and methodology for analysing biogenic content of mixed waste*. Task 36. [online] Milano: RSE S. p. A.

electrical power using supercritical water oxidation technology (biogenic energy, 2017)[18]. The advantages of using biogenic energy are:

1. Reduction of greenhouse gases and nitrogen oxide significantly
2. Diversion of waste from landfills
3. Creation of zero air emissions
4. Protection of natural resources
5. Energy cost savings
6. Waste management and opportunities for reduction
7. Opportunities for local economic development

1.3 Renewable Energy around the World

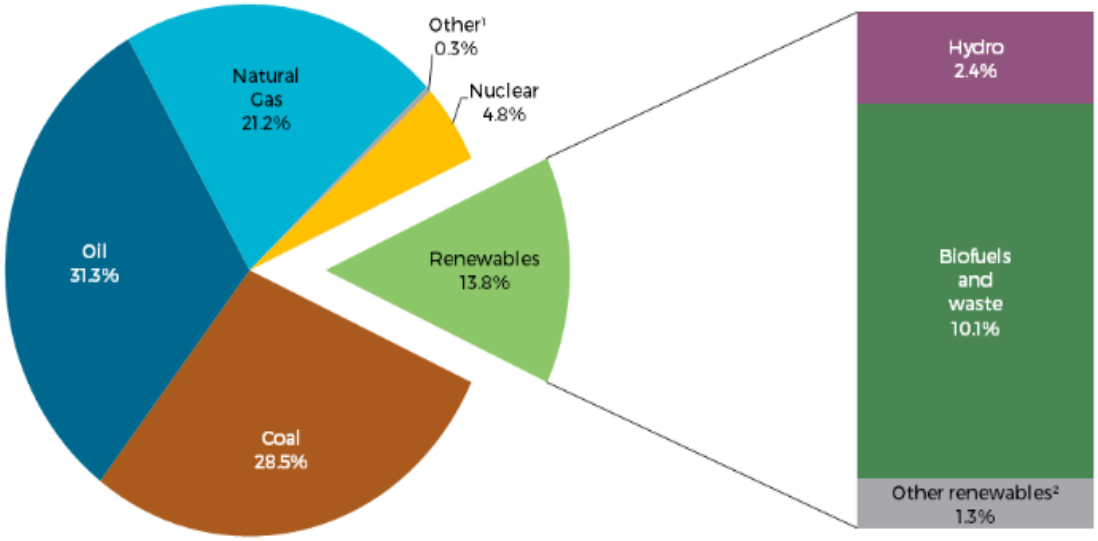
The natural resources being used to create energy and electricity for nations around the globe are not endless and could come to a point where it is not enough to supply the demand of people. Parallel to this, the world production of renewable energy increased by 2.9% between 2013 and 2014. So if the world energy supply consists of 13.700 Million Tones of Oil Equivalent (Mtoe) (Figure 2), renewable energy represents 13.8% of the Total Primary Energy Supply with 1.894 Mtoe (Iea.org, 2016)[19]. This is a significant amount considering the energy demand of the world population is predicted to reach 599 Exajoule[20] (EJ) by 2020 and 657 EJ in 2025 (Igliński

[18] www.biogenic.energy/

[19] Iea.org. (2016). *July: Renewable energy continuing to increase market share*. [online] Available at: https://www.iea.org/newsroom/news/2016/july/renewable-energy-continuing-to-increase-market-share.html [Accessed 1 Apr. 2017].

[20] Exajoule: The SI prefix "exa" represents a factor of 10^{18}. Therefore, it can be written as 1 **exajoule** = 10^{18} joules. The joule (symbol J, called newton meter, watt second, or coulomb volt) is the (system of units) SI unit of work and energy.

et al., 2016)[21]. Along with the growth of overall demand, since the 1990`s producing energy through renewable energy has increased around 2.2% on average, which is greater than the 1.9% growth rate of the total primary energy supply (Fig. 1.5).



Source: Iea.org, (2016)

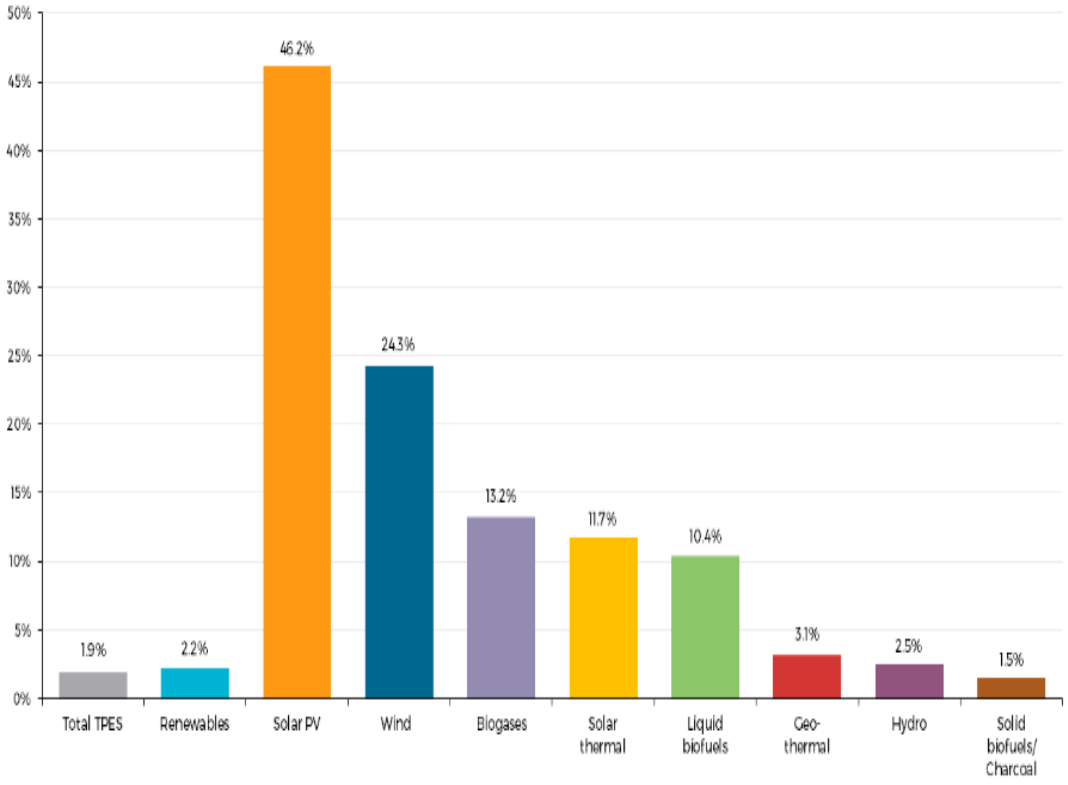
Fig. 1.5: Overall Primary Energy Supplies for 2014 Fuel Shares Around the Globe

Nonetheless, amongst several renewable energy supplies, the growth rate for solar photovoltaic and wind power has been 46.2% for the former and 24.3% for the latter, mainly the OECD area and China. At the same time, hydro and solid biofuel continue to be the most utilized type of renewable energy with a growth rate of 2.5% and 1.5% annually respectively.

As shown in Fig. 1.6 to 1.8, the non-OECD regions consume approximately 75% of all the renewable energies where utilizing biomass

[21] Igliński, B., Iglińska, A., Koziński, G., Skrzatek, M. and Buczkowski, R. (2016). Wind energy in Poland – History, current state, surveys, Renewable Energy Sources Act, SWOT analysis. *Renewable and Sustainable Energy Reviews*, 64, pp.19-33.

sources such as wood by the general public. Accordingly, almost 50% of the total energy used in Africa come from renewable energies; however, this amount is the quarter of the energy consumed in Asia (China excluded) and Non-OECD Americas. Conversely, in the Organization for Economic Co-operation and Development (OECD) region, the portion of renewable energies in the overall consumption is only 9.4% which is very low compared to Africa (Iea.org, 2016).

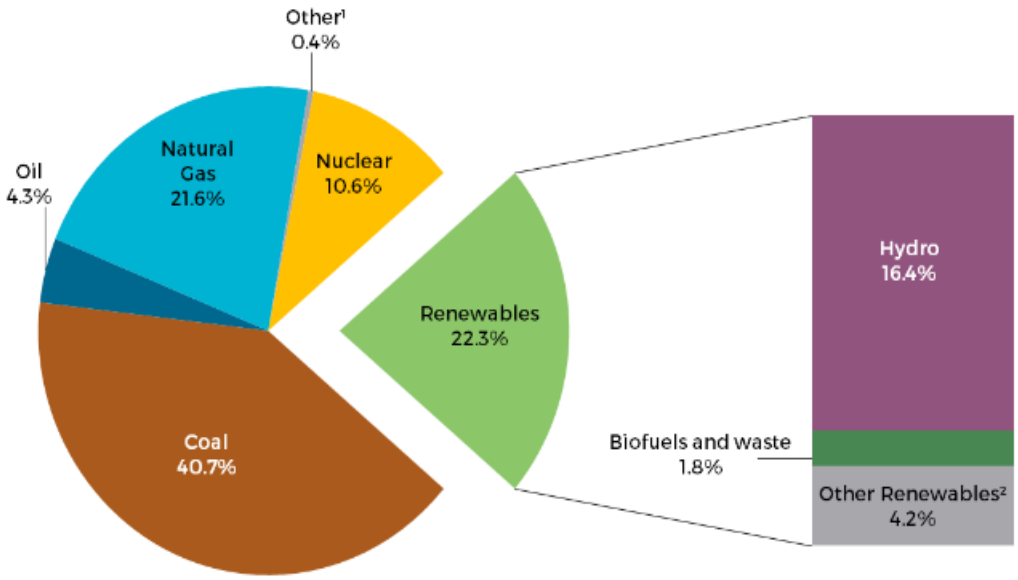


Source: Iea.org, (2016)

Fig. 1.6: Yearly growth Rates of the Global Renewable Energy Supply from 1990 to 2014

Hydroelectricity supplies an important proportion of renewable electricity, over 73%, representing more than 16% of world's electricity production. Moreover, a steady fresh increase lies within solar, wind, geothermal, and tidal renewable energies which accounts for above 4% of the

total electricity generation in 2014 and nearly 19% of total renewable energies. After the 1990s renewable electricity production around the world had increased by 3.6% averagely on a yearly basis, a little higher than the overall electricity production growth rate of 2.9%.

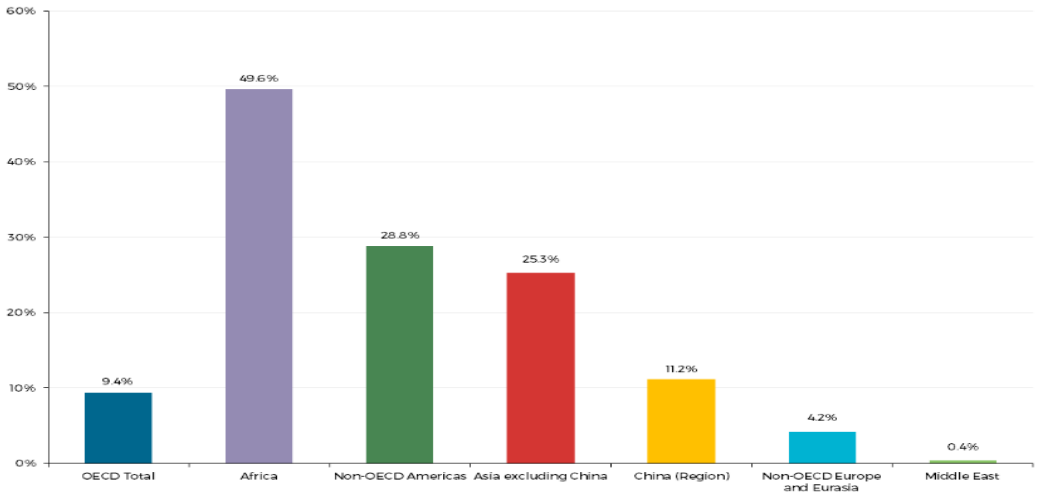


Source:Iea.org, (2016)

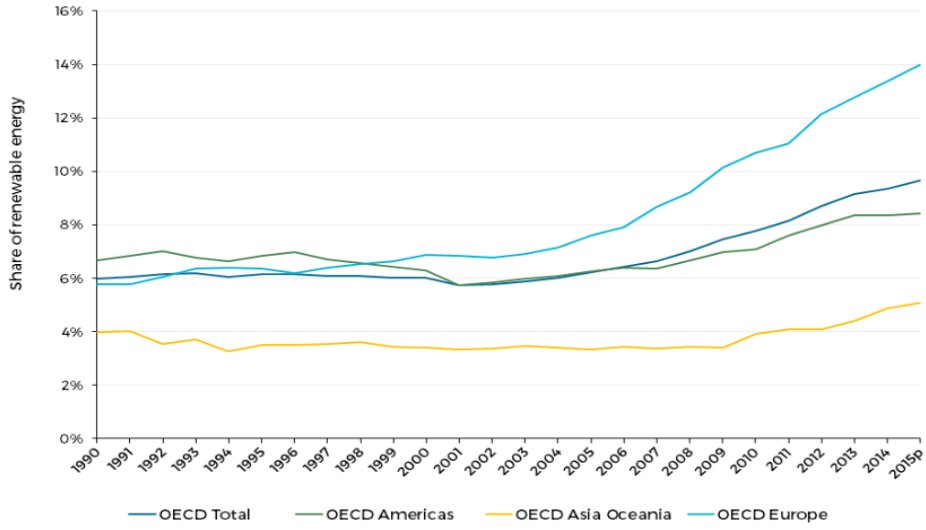
Fig. 1.7: Fuel Shares in Global Electricity Generation in 2014

As illustrated in Fig. 1.8, Africa shows the most growth compared to other areas around the world. Conversely, the least deployment of renewables and growth over the years appears to be in the Middle East. This could be because of the vast natural resources of oil/gas, or lack of technology, or governments' unwillingness to invest in such area. As shown in Fig. 1.7, renewable energy is the second biggest source of worldwide electricity production, accounting for over 22% of the world's generation in 2014 taking second place after coal (over 40%), and

just before has (over 21%), followed by nuclear (over 10%) and oil (over 4%).



(a)



(b)

Fig. 1.8: OCED countries: (a) Yearly Growth Rates of Electricity Generation from 1990 to 2015; (b) Shares of Renewable Electricity Generation between 1990 and 2015 Source: Iea.org, (2016)

In *Africa*, the economic development of the whole Continent revealed a decline in 2017, amongst global shifts, a loss of momentum compared to the previous year. This is surprising since economic development for the past 5 years has increased before 2017. Even though countries` performances are imbalanced, Africa still faces serious challenges such as dropping commodity prices, increased electricity prices, energy shortage and affordability; and for a high amount of regions, insecurity, political uncertainty and widespread corruption.

Although various regions have succeeded in strengthening their electricity infrastructure, this came with a consequence of increased high tariffs; however, many countries are still experiencing an electricity crisis; and overall deficiency in the industry prolongs to threaten Africa`s both economic and social development, and competitiveness (World Energy Council, 2017)[22].

So as to improve last year's decline of development, "*New Deal for energy in Africa*" with the aim to resolve the continents enormous energy shortage and stop energy poorness by 2025, the African Development Bank has formed solid international and regional partnerships including all the necessary stakeholders which resulted in a fresh, cooperative and coordinated important primary actions. Around the African continent for the 2017 agenda, countries such as Morocco, Democratic Republic of Congo (DRC), Tanzania, Kenya, South Africa, Ethiopia, Algeria and Egypt plans considerable growth regarding the renewable energy impact, enlarged power production in remote communities and help rural parts get connected and generate power, all aiming to revolutionize the Renewable Energy evolution for the Continent. A fresh start African *Renewable Energy Initiative* has been initiated at the Paris Climate Conference with the goal of deploying no less than 10 GW of extra renewable energy capacity until the year 2020, and help deployments for the ultimate intention of generating a minimum of 300 GW by 2030 (World Energy Council, 2017).

[22] Exposing the New Energy Realities. (2017). [online] Wales: World Energy Council 2017, pp.1-40. Available at: http://file:///C:/Users/user/Pictures/1.-World-Energy-Issues-Monitor-2017-Full-Report.pdf [Accessed 1 Apr. 2017].

The next chapter will provide the main tools for techno-economic modeling, and analysis for the assessment of the economic performance of various renewable energy projects.

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