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Review Article

Advance in Environmental Waste Management & Recycling

A Review of Different Renewable Energy Resources and Their Energy Efficiency Technologies

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Abstract

In recent years, the increasing prices of fossil fuels and concerns about the environmental consequences of greenhouse gas emissions have renewed the interest in the development of alternative energy resources. Renewable energy is now considered a more desirable source of fuel compared to nuclear power due to the absence of safety risk and disasters. Considering that the major component of greenhouse gases is carbon dioxide, there is a global concern about reducing carbon emissions to minimize the problem of climate change. In this regard, different policies could be applied to reducing carbon emissions, such as enhancing renewable energy deployment and encouraging technological innovations. Two possible solutions may be implemented to reduce carbon dioxide (CO2) emissions and hence to overcome the problem of climate change: replacing fossil fuels with renewable energy sources as much as possible and enhancing energy efficiency. In this paper, we discuss alternative technologies for enhancing renewable energy deployment and energy use efficiency keeping into consideration of climate conditions in Libya.

Keywords: Fossil Fuels, Environmental Consequences, Greenhouse Gas Emissions, Alternative Energy Resources. Renewable Energy, Nuclear Power, Safety Risk and Disasters, Greenhouse Gases, Carbon Dioxide, Global Concern, Problem of Climate Change, Reducing Carbon Emissions, Renewable Energy, Encouraging Technological Innovations, Replacing Fossil Fuels, Renewable Energy Sources, Alternative Technologies, Climate Conditions in Libya

Introduction

Energy consumption has rapidly increased since the 1950s. The reasons of energy consumption include economic development, rising population and technological developments. When fossil fuels are burned, they release large amounts of carbon dioxide, a greenhouse gas, into the air. Greenhouse gases trap heat in our atmosphere, causing global warming. There is a global concern about reducing carbon dioxide emissions. In this regard, different policies could be applied to reduce carbon emissions, such as enhancing renewable energy deployment and encouraging technological innovations. In addition, supporting mechanisms, such as renewable portfolio standards and tax policies, feed-in tariffs, are employed by governments to develop renewable energy generation along with implementing energy use efficiency for saving energy. There are following five major renewable energy sources:

- Hydropower
- Wind energy
- Solar energy from the sun Geothermal energy
- Bioenergy
- Geothermal energy from heat inside the earth.

Many countries have started to install facilities that use renewable energy sources for power generation. The importance of alternative energy sources comes together with climate change challenges associated with the excessive use of fossil fuels. There are three primary motivators that stimulate the growth of renewable energy technologies: energy security, economic impacts and carbon dioxide emission reduction. According to ***IEA 2019*** report world energy production amounted to **617 EJ in 2019** – a 2% increase from 2018. This increase was mostly driven by natural gas (+4%) and coal (+2%), though some renewables increased much more in relative terms (e.g. +14% for solar and +12% for wind). Hydro-electricity production stagnated at 15 EJ. The more recent

years of high fossil fuel energy use has led renewable technologies to become increasingly competitive on a cost basis with their alternatives in a number of countries and circumstances. According to IEA calculations, wind and solar are the most competitive type of renewable energy technology among the other options. Table 1 presents global direct primary energy consumption during year 2019 and Table 2 presents renewable electricity generation increase by technology, 2019 – 2020 and 2020 – 2021.

Table 1: Global Direct Primary Energy Consumption during Year 2019

Type of Energy	Energy Consumption (TWh – Tetra watthour)
Solar	724
Wind	1,430
Hydropower	4,222
Traditional Biofuels	11,111
Modern Biofuels	1,143
Other Renewables	652
Nuclear	2,796
Gas	39,292
Oil	53,620
Coal	43,849

TWh (tetrawatt hour) is a unit of energy used for expressing the amount of produced energy, electricity and heat. (1 TWh = 1,000 GWh)

Source: *World Energy Outlook, OECD Publishing 2019*

Table 2: Renewable Electricity Generation Increase by Technology, 2019 – 2020 and 2020 – 2021

Type of Renewable Energy	Year	Amount of Energy (TWh)	Year-on-year Percent Growth
Solar PV	2019 – 2020	153	23
	2020 - 2021	145	18
Wind	2019 – 2020	175	12
	2020 - 2021	275	17
Hydro	2019 – 2020	114	3
	2020 - 2021	140	3
Bioenergy	2019 – 2020	40	6
	2020 - 2021	72	10

Source: *World Energy Outlook, OECD Publishing 2021*

Hydro Power

Hydropower is the most widely-used renewable power source. Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river. Hydropower reservoirs often have multiple uses - providing drinking water, water for irrigation, flood and drought control, navigation services, as well as energy supply.

Hydropower currently is the largest source of renewable energy in the electricity sector. The infrastructure needed to create hydropower can also impact on ecosystems in adverse ways. Currently, hydropower development is difficult due to a large initial fixed investment cost and environmental concerns. Additionally, hydropower has caused problems for local residents associated with the need to relocate large populations, as well as the construction of dams is permanent with a sunk cost of utilities which cannot be removed. The environment is also influenced by hydropower construction because of large engineering works. On the other hand, hydropower is attractive due to a preexisting supply of water for agriculture, household and industrial use, and hydro power is clean and enables the storage of both water and energy. Also, the stored energy can be used for the application of both base-load and peak time power generation. For this reason, many consider small-scale hydro a more environmentally-friendly option, and especially suitable for communities in remote locations.

Table 3: Worldwide Hydroelectricity Consumption

Year	Consumption in (EJ, exajoules)
2000	26.52
2001	25.67
2002	25.98
2003	25.77
2004	27.49
2005	28.24
2006	29.13
2007	29.45
2008	30.96
2009	3072
2010	32.25
2011	34.69
2012	35.95
2013	37.17
2014	37.93
2015	37.60
2016	38.67
2017	38.99
2018	39.84
2019	40.15
2020	41.09
2021	40.26

1 EXAJOULE = 174 MILLION BARRELS OF OIL EQUIVALENT

Source: *World Energy Outlook, OECD Publishing 2021*

Solar Energy

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy.

Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels for a host of applications. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation.

Although not all countries are equally endowed with solar energy, a significant contribution to the energy mix from direct solar energy is possible for every country.

The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. Solar panels have a lifespan of roughly 30 years, and come in variety of shades depending on the type of material used in manufacturing.

Table 4: Worldwide Cumulative Installed Solar PV Capacity

Year	Nameplate Capacity in Mega Watts
2011	72.22
2012	101.75
2013	137.23
2014	175.62
2015	223.20

2016	295.23
2017	390.21
2018	483.02
2019	584.69
2020	710.28
2021	843.09

Source: *World Energy Outlook, OECD Publishing 2021*

Wind Energy

Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters. Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential

Table 5: New Wind Power Capacity in 2021 by Regiona

Region	Wind Power Capacity (Percent)
Asia-Pacific (APAC)	59%
Europe	19%
North America	14%
Latin America (LATAM)	6%
Africa & Middle East	2%

93.6 GW of new wind power capacity was added worldwide in 2021, only 18% lower than the 2020 record, bringing the total installed wind capacity of 837 GW, a growth of 12.4% compared to last year (IEA 2021).

Bio Energy

Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Most biomass is used in rural areas for cooking, lighting and space heating, generally by poorer populations in developing countries.

Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams. Energy created by burning biomass creates greenhouse gas emissions, but at lower levels than burning fossil fuels like coal, oil or gas. However, bioenergy should only be used in limited applications, given potential negative environmental impacts related to large-scale increases in forest and bioenergy plantations, and resulting deforestation and land-use change. Slow and reverse climate change: The top cause contributing to carbon dioxide emissions in the United States is electricity generation from fossil fuel power plants. Carbon dioxide and additional greenhouse gas emissions are leading contributors to climate change and global warming. Alternative energy sources have a much lower carbon footprint than natural gas, coal, and other fossil fuels. Switching to renewable energy sources to produce electricity will help the planet by slowing and reversing climate change.

Energy Efficiency Technologies

There are two main solutions to reducing CO2 emissions and to overcoming the climate change problem: replacing fossil fuels with renewable energy sources as much as possible and through enhancing energy efficiency. We discussed the state of the art methods for technical and economic feasibility of expanding the use renewable energy sources and the possibility of substitution in this review. In this part that follows, we discuss energy efficiency technologies. Energy efficiency for an electricity network could be considered in different stages, such as the power generation, transmission, distribution and consumption. The different technologies that are currently available include electric vehicles (EV), combined heat and power (CHP), virtual power plants (VPP) and smart grids, each of which are discussed below.

Electric Vehicles

Electric vehicles (EV, including the battery, fuel cell, and hybrid types) have the potential to be considered viable options for both electricity storage and power generation. Considering that the transportation sector is one of the main sources of emissions, improving fuel efficiency enables us to achieve the largest fuel savings and CO2 reduction in the short term. Thus, the increased usage of EVs and increasing their share of the vehicle fleet can play a key role in the long term [1, 2]. Forecasted an increased share of plug-in hybrid electric vehicles (PHEV) over the next two decades, with a total increase of up to 50% by 2050. "In long-term, smart grid technology may enable EVs to be used as distributed storage devices, feeding electricity stored in their batteries back to the sys-

tem when needed (vehicle to grid), to help provide peak-shaving capability"[3, 4]. Ford (1995) examined the impact of the large scale use of electric vehicles in southern California and concluded that Southern California Edison (a power company in the area) was able to accommodate a large number of EVs with their existing capacity, particularly if the charging system was managed by smart control.

Combined Heat and Power

Combined heat and power (CHP), is the use of heat and electric power together. It is expected to have a substantial gain in efficiency over each source separately. Most power distribution companies supply only electricity, not hot water or steam. CHP is an efficient use of fuel when a portion of the energy is discarded as waste heat. It captures some or CHP could transform a significant part of the waste heat into a positive economic value for industrial processes or heating in residual and commercial buildings. Hawkes and Leach (2007) examined cost effective operating strategies of three alternatives micro-CHP technologies (Sterling engine, gas engine and solid oxide fuel cell-based (SOFC) system) for residential application in the UK. They evaluated the economic and environmental attributes on the abovementioned technologies for heat-led, electricity-led and least-cost operating strategies. The results showed that the SOFC-based system had the maximum operating cost and the largest CO2 emission reduction following the least-cost operating strategy.

Virtual Power Plant (VPP)

A Virtual Power Plant (VPP) is a cluster of distributed energy resources, such as micro-CHP, wind turbines, and solar photovoltaic panels, which are controlled and managed by a central control unit. The term distributed energy resources (DER) can be used for fossil or renewable energy fuels. A DER system has been defined in order to overcome energy waste problems due to long distances and transmission losses. Therefore, DERs are generally located close to the distribution networks. The concept of VPP is used for DER integration. According to the Europe FENIX project, there are two types of VPPs, the Commercial VPP (CVPP) and the Technical VPP (TVPP) [5]. DERs can simultaneously be part of both a CVPP and a TVPP. A commercial VPP is defined as a portfolio that could be used by a DER to participate in electricity markets. CVPPs can represent a DER from any geographic place in an electricity network. A technical VPP enables operators to facilitate DER energy capacity and optimize the power balance in the system with the minimum cost [6, 7]. The share of distributed generation (DG) in an electricity network is increasing in importance and VPP is considered to be an emerging technology that enhances energy efficiency. Schulz et al. (2005) analyzed the technical and economic feasibility of operating a VPP with micro CHP units. They explained that, due to Germany's plan to abandon nuclear power plants until 2020, a part of the new capacity should be comprised of renewable energy sources and CHP utility, which are considered DG units. VPP is an alternative to the management of these units, as of the absence control needs provides an advantage for renewable energy technology. Based their findings, the power generated by an individual owner is too small to supply, with the amount of the power output needing to be 30 MW or higher based on existing regulation. A VPP operator can integrate a large number of DERs and provide 30 MW through aggregating 6,000 micro-CHP units, each with a power output of 5 kW.

Smart Meter

The most important objective for power generation companies in demand side management is to reduce peak demand during a certain period. In this regard, a smart meter is a device to record the consumption of electricity in hourly intervals and the information is monitored by both the utility and customer. A smart meter is able to have two way communication and intelligence management for home appliances. Examined the application of smart meters and customer choice control in order to show that a time-of-use (TOU) strategy can be beneficial for a utility company [8]. The results show that the TOU rate option could result in a 107 kWh energy savings for each customer per year. They calculated the annual savings on customers' electricity bills to be $77 with a cost savings of $134 per customer for the utility company. Applying smart meters could facilitate a significant change in the energy efficiency of electricity networks.

Economic Impacts

Renewable energy technologies could enable countries like Libya with good solar or wind resources to employ these energy sources to meet their domestic demand. Also, renewable energy technologies may even enable these countries to utilize renewable energy sources with long-term export potential. A main economic driver to the enhancement of renewable energy technologies is their job creation potential. The majority of jobs in renewable energy industries are located in China, Brazil, the United States and the European Union. Germany has been the front runner in Europe in terms of job creation in the renewable energy industry. It has sharply increased its power generation by renewable technologies since the beginning of this century, with a share of almost 15 percent of the total electricity production in 2008 investigated the gross and net effects of renewable energy policies in the European Union [9-11]. In particular, they analyzed the past, present and future effects of renewable energy policies on employment and the economy at the overall and member levels. They found that the current economic benefits of the renewable energy sectors can and should be increased in future by improving the existing policies, "in order to reach the agreed target of 20 percent renewable energies in Europe by 2020." They argued that increasing the share of renewable energy sources not only has minimal negative effects on the economy, but that it could also help the economy through job creation and increasing the GDP. From their point of view, the economic advantages of renewable energy could be even higher if external costs were included in calculations [12, 13].

Summary and Conclusion

1. The concerns about climate change have made renewable energy sources an important component of the world energy consumption portfolio.

2. Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and the transportation sector.
3. Two main solutions may be implemented to reduce CO2 emissions and to overcome the problem of climate change: replacing fossil fuels with renewable energy sources as much as possible and enhancing energy efficiency regardless of type.
4. Due to negative and irreversible externalities associated with conventional energy extraction and consumption, it is necessary to promote and develop renewable energy supply and consumption. The IEA forecasts positive developments in renewable energy sources. They act as substitutes for fossil fuels and reduce emissions. In the short term, some renewable technologies may not be comparable to conventional fuels in the scope of production costs and transmission, but they could be comparable if we consider their associated positive externalities, such as their environmental and social effects.
5. Transmission and distribution costs and technologies do not differ much among the conventional and renewable energy sources.
6. Libya has potential to develop its solar power energy due to available wide land and sunny climate throughout the year.

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