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Renewable Energy And Sustainable Development: A Crucial Review

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Abstract: Long-term potential efforts for sustainable development are necessary to solve the environmental problems we confront today. Renewable energy sources are among the most cost-effective and efficient options available. That is why there is an intimate connection between renewable energy and sustainable development. Anticipated patterns of future energy usage and associated environmental repercussions (focussing on acid precipitation, stratospheric ozone depletion and the greenhouse e€ ect) are fully explored in this study. Also, potential answers to present environmental concerns are identified along with renewable energy technology. The relations between renewable energy and sustainable development are described using practical instances, and an illustrative example is offered. Throughout the article numerous topics relating to renewable energy, environment and sustainable development are reviewed from both current and future perspectives.

1. Introduction

Renewable energy comes from sources like wind, solar, hydropower, geothermal energy, biomass, and hydropower. Previously, these sources were referred to as "alternative energy sources." The world is running out of usable energy from fossil fuels (oil, gas, coal, natural gas, and nuclear power) at the start of the twenty-first century, while renewable energies (wind and solar) are yet too underdeveloped to provide a complete and adaptable alternative. Since fossil fuels are limited resources and most projections indicate that proven oil reserves won't be enough to supply global demand by at least the middle of the 21st century, society is moving toward a dependence on renewable energy today. All of this creates a sort of paradox because 200 years ago, all energy was sustainable and renewable in and of itself. For example, people used water or wind to power water mills or to propel ships through the oceans. The widespread use of fossil fuels, which in turn caused significant pollution, prepared the way for the transition to renewable energy,

sustainable development, and ultimately the digitization of the energy industry. These developments were all influenced by the first Industrial Revolution.

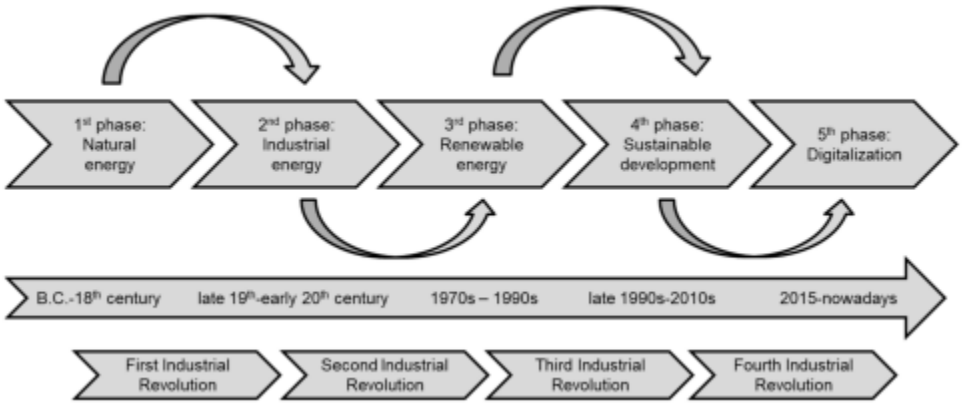

Figure 1. Development of the energy sector prior and beyond the first to the fourth Industrial Revolutions.

More than 70% of new electricity generating capacity in the United States is expected to begin commercial operation in 2021 as renewable energy, according to the Energy Information Administration (EIA). Solar energy accounts for the largest share of new capacity at 39%, followed by wind energy at 31%. Large hydroelectric facilities provide the lion's share of this electricity (about 6% of total electricity generation). Because of its negligible impact on the environment, some experts classify nuclear power as a renewable resource. Roughly 10% of the world's electricity comes from nuclear power, per the International Atomic Energy Agency. Around 16.3 percent, or about 16 billion kilowatt-hours (kWh), of the world's total electricity was generated by the largest hydropower plant in 2015.

This was the second largest proportion of worldwide electricity generation, behind only nuclear power. Renewable energy sources are gradually replacing fossil fuels because decarbonization of the energy sector is possible. The term "renewable energy" refers to power that is generated by using resources that are naturally renewed over time. The World Bank reports that greenhouse gas emissions, the main cause of global warming and climate change, can be avoided when power is generated using renewable energy sources. About 20% of the gross final energy consumption in the European Union's 27 member states comes from renewable sources (18 percent of which is hydropower). Wind energy is the use of natural wind to create power, and this can be done by installing even relatively modest wind turbines on commercial premises.

More than 1.3 million MW of electricity generation capacity in 41 states and 2 territories is provided by wind power, according to the National Renewable Energy Laboratory (NREL).

Energy is the convertible currency of technology. Without energy the whole fabric of society as we know it would crumble; the e□ect of a 24-h cut in electricity supplies to a city shows how totally dependent we are on that particularly useful form of energy. Computers and lifts cease to function, hospitals sink to a care and maintenance level and the lights go out. As populations grow, many faster than the average 2%, the need for

more and more energy is exacerbated. Enhanced lifestyle and energy demand rise together and the wealthy industrialized economies which contain 25% of the world's population consume 75% of the world's energy supply.

Problems with energy supply and use are related not only to global warming, but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and emission of radioactive substances. These issues must be taken into consideration simultaneously if humanity is to achieve a bright energy future with minimal environmental impacts. Much evidence exists, which suggests that the future will be negatively impacted if humans keep degrading the environment. Other environmental considerations have been given increasing attention by energy industries and the public. The concept that consumers share responsibility for pollution and its cost has been increasingly accepted.

The main objective of this paper is to discuss the environmental problems such as acid precipitation, stratospheric ozone depletion, and greenhouse e□ect and the anticipated patterns of future energy use and consequent environmental impacts and to identify some solutions to the current environmental problems, focussing on renewable energy sources and technologies and the linkage between renewable energy and sustainable development.

2. Environmental problems

The threat and reality of environmental degradation have grown during the last 20 years. Growing evidence of environmental issues is the result of a number of factors, as human activity's impact on the environment has greatly increased due to the sheer growth in global population, consumerism, industrial activity, etc. Most environmental research and legal controls throughout the 1970s focused on common pollutants including SO_2, NOx, particulates, and CO. The control of micro- or hazardous air pollutants, which are typically toxic chemicals and dangerous in small quantities, as well as that of globally significant pollutants like CO_2, has recently come under increased attention. In addition to improvements in environmental research, changes in industrial structures and processes have brought up new environmental issues. For instance, significant changes in the transportation of industrial items by road and individual automobile travel have increased road traffic, which has changed the focus on the causes and effects of NOx and volatile organic compound (VOC) emissions.

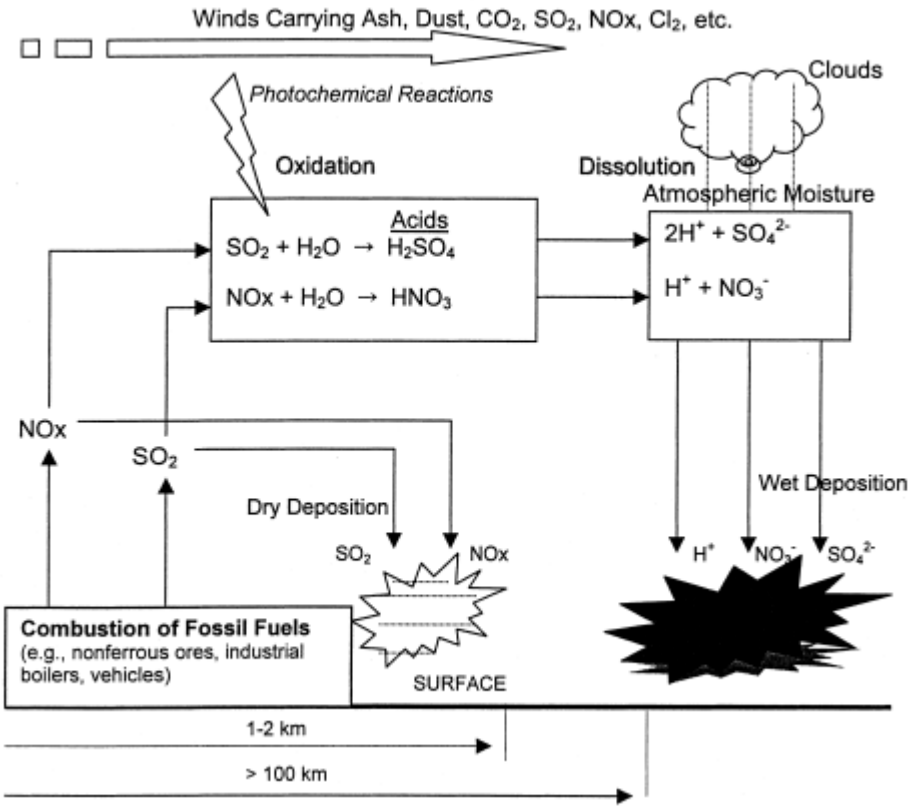

Fig. 2. A schematic representation of the formation, distribution, and impact of acid precipitation.

Environmental problems span a continuously growing range of pollutants, hazards and ecosystem degradation over ever wider areas. The major areas of environmental problems may be classified as follows:

- Major environmental accidents
- Water pollution
- Maritime pollution
- Land use and siting impact
- Radiation and radioactivity
- Solid waste disposal
- Hazardous air pollutants
- Ambient air quality
- Acid rain
- Stratospheric ozone depletion, and
- Global climate change (greenhouse e□ect).

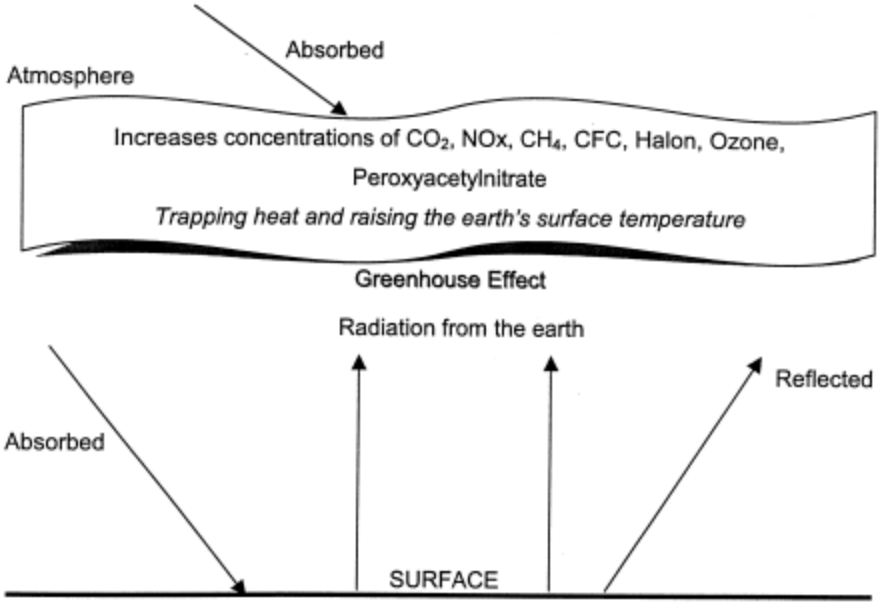

Fig. 3. A schematic representation of greenhouse e□ect.

3. Sustainable development

A secure supply of energy resources is generally agreed to be a necessary but not su□cient requirement for development within a society. Furthermore, sustainable development demands a sustainable supply of energy resources that, in the long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts. Supplies of such energy resources as fossil fuels (coal, oil, and natural gas) and uranium are generally acknowledged to be finite; other energy sources such as sunlight, wind and falling water are generally considered renewable and therefore sustainable over the relatively long term. Wastes (convertible to useful energy forms through, for example, waste-to-energy incineration facilities) and biomass fuels are also usually viewed as sustainable energy sources. In general, the implications of these statements are numerous, and depend on how sustainable is defined. Environmental concerns are an important factor in sustainable development. For a variety of reasons, activities which continually degrade the environment are not sustainable over time, e.g., the cumulative impact on the environment of such activities often leads over time to a variety of health, ecological and other problems. A large portion of the environmental impact in a society is associated with its utilization of energy resources. Ideally, a society seeking sustainable development utilizes only energy resources which cause no environmental impact (e.g., which release no emissions to the environment). However, since all energy resources lead to some environmental impact, it is reasonable to suggest that some (not all) of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts can be in part overcome through increased energy e□ciency. Clearly, a strong relation exists between energy e□ciency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with increased energy e□ciency. While not all renewable energy

resources are inherently clean, there is such a diversity of choices that a shift to renewables carried out in the context of sustainable development could provide a far cleaner system than would be feasible by tightening controls on conventional energy. Furthermore, being by nature sitespecific, they favor a power system decentralization and locally applicable solutions more or less independent of the national network. It enables citizens to perceive positive and negative externalities of energy consumption. Consequently, the small scale of the equipment often makes the time required from initial design to operation short, providing greater adaptability in responding to unpredictable growth and/or changes in energy demand.

2.1 Sustainable Development and Electric Power

In order to meet future energy challenges, the most important types of renewable energy sources with great potential are solar, wind, hydro, and biomass. Renewable energy sources should ensure sustainable development of a country due to the exhaustive share of fossil fuels, rising fossil fuel prices worldwide, and reduced environmental impacts. The use of nuclear energy for electricity generation is a means of reducing resource requirements to a more sustainable level. The extent to which these technologies have been industrialized and commercialized is important. The number of materials used to produce electricity measured by the amount of fossil fuel-producing technology that consumes, and the extent to which the technology has been industrialized, is inevitable, because the industrial size and speed of development of that technology is larger in developed countries than developing countries. Figure 4 shows the total electricity generation trends in the selected OECD countries.

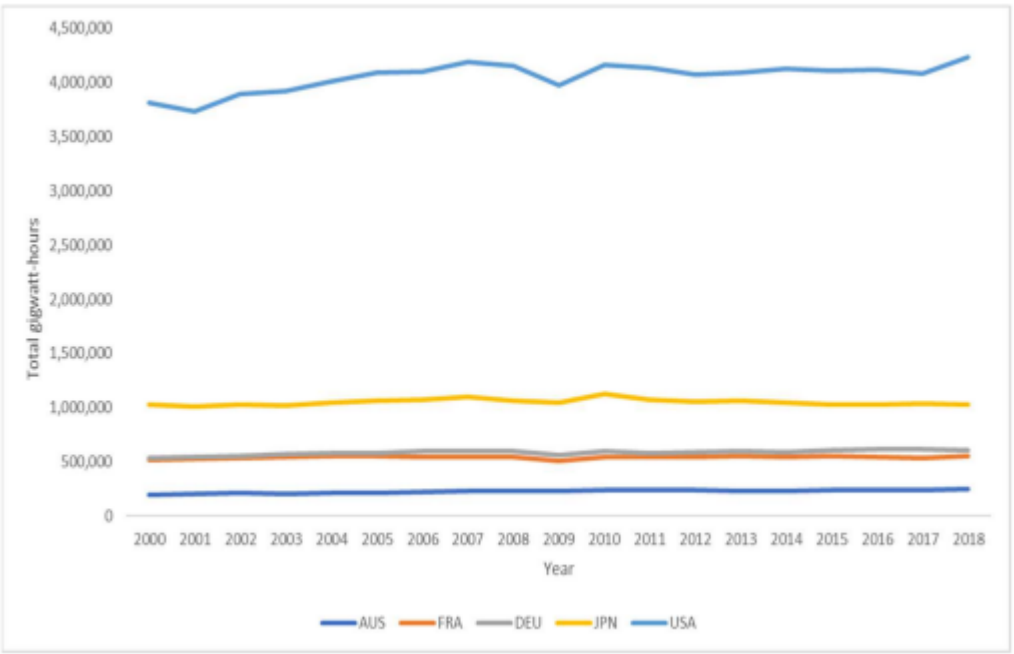

Figure 4. Total electricity generation in selected OECD countries (2000–2018).

Access to modern energy has profound benefits, but the goal of ensuring access can only be achieved if it is affordable. One can, for example, assess the decisions in the electricity sector by comparing geothermal and coal as the two main power generation technologies and developing technologies such as wind and solar. The relative affordability of the power supply options is important for the costs they impose on the system as a whole. Given the rapidly growing global demand for electricity and sustainable development, the need to consider energy policy in terms of its impact on energy security, energy efficiency, and environmental sustainability offers the opportunity to grow the economy faster and create more reliable and affordable options for the energy supply. Another case is the creation of united electric power markets (for example, the common electricity market of the Eurasian Economic Union consisting of Russia and several post-Soviet countries). Preserving and developing cross-border power lines and determining clear market rules for their use might help to ensure mutually beneficial economic development of the countries of the common economic space. The capacity for electricity generation, which meets the supply of electricity with demand, is of crucial importance. It is obvious that the situation in developing countries is in many ways more difficult than in developed countries. However, they can have advantages in trying to restructure their energy sector and they can build on cleaner and more efficient technologies. A significant proportion of the population may have difficulty obtaining basic energy services due to resource scarcity. Despite the growing recognition of nuclear power as a key component of contributing to sustainable development, there is a growing awareness that nuclear energy has a crucial role to play if the United Nations Sustainable Development Goals (SDGs) are to be achieved. The competitive position of nuclear energy is robust due to its low operating costs, high reliability, low operating and maintenance costs, and high efficiency.

2.2 Importance of renewable energy resources and technologies for sustainable development

The exploitation of renewable energy resources and technologies is a key component of sustainable development. There are three significant reasons for it as follows.

- They have much less environmental impact compared to other sources of energy since there is no any energy sources with zero environmental impact. There are a variety of choices available in practice that a shift to renewables could provide a far cleaner energy system than would be feasible by tightening controls on conventional energy.
- Renewable energy resources can not be depleted unlike fossil fuel and uranium resources. If used wisely in appropriate and e□cient applications, they can provide a reliable and sustainable supply energy almost indefinitely. In contrast, fossil fuel and uranium resources are finite and can be diminished by extraction and consumption.
- They favor power system decentralization and locally applicable solutions more or less independent of the national network, thus enhancing the ¯exibility of the system and the economic power supply to

3. Critical Factors Influencing Renewable Energy Generation

In general, renewable energies can be generated locally with systems, devices, and locations using panels, government buildings, geothermal heat pumps, biomass, or combined heat and power. Using renewable energy, such as solar and wind, to generate electricity can produce electricity without emitting carbon dioxide, but electricity depends on cost-effective technologies that can improve or reduce the cost of peak sources of kilowatthours per kWh. In addition, other promising technologies for producing renewable energy tend to emerge—for example, the ones offering the prospects of harnessing energy from tides and waves. Solar thermal technologies, in particular heat storage, have great potential in sunny climates. Although government support for the use of wind and solar technologies are in the same league, their prices per kilowatt-hour are in the same league, increasing the cost of fossil-fuel technologies and the possible CO_2 emissions they generate. The cost of generating electricity from shore wind has dropped by 23% since 2010 and the cost of solar power (PV) has fallen by 73% over the same period. Another reason for the continuing fall in prices is renewable energy tariffs. The impact of falling tariffs affects two key players: electricity producers and plant builders. Along the value chain, equipment manufacturers face oversupply problems, as many countries recently withdrew support for solar photovoltaic generation.

3.1 Renewable energy resources and technologies

Since the oil crises in the early 1970 s, there has been active worldwide research and development in the field of renewable energy resources and systems. During this time, energy conversion systems that were based on renewable energy technologies appeared to be most attractive because of facts such as the projected high cost of oil and the cost e□ectiveness estimates and easy implementation of renewable energy systems. Furthermore, in more recent times, it has been realized that renewable energy sources and systems can have a beneficial impact on the following essential technical, environmental, economic, and political issues of the world.

- Major environmental problems (e.g., acid rain, stratospheric ozone depletion, greenhouse e□ect)
- Environmental degradation
- Depletion of the world's nonrenewable energy sources
- Increasing energy use in developing countries

As pointed out by Hartley, renewable energy technologies produce marketable energy by converting natural phenomena into useful energy forms. These technologies use the energy inherent in sunlight and its direct and indirect impacts on the Earth (photons, wind, falling water, heating e□ects, and plant growth), gravitational forces (the tides), and the heat of the Earth's core (geothermal) as the resources from which they produce energy. These resources represent a massive energy potential which dwarfs that of equivalent fossil resources. Therefore, the magnitude of these is not a key constraint on energy production. However, they are

generally di□use and not fully accessible, some are intermittent, and all have distinct regional variabilities. Such aspects of their nature give rise to di□cult, but solvable, technical, institutional, and economical challenges inherent in development and use of renewable energy resources. Despite having such di□culties and challenges, the research and development on renewable energy resources and technologies has been expanded during the past two decades because of the facts listed above. Nowadays, significant progress is made by:

- Improving the collection and conversion e□ciencies
- Lowering the initial and maintenance costs
- Increasing the reliability and applicability
- Understanding the phenomena of renewable energy systems.

Table 1 gives the renewable energy technologies as a mix of several old concepts (e.g., hydropower, geothermal, biomass) and new technologies (e.g., solar, ocean thermal). Renewable energy technologies become important as environmental concerns increase, utility (hydro) costs climb and labor costs escalate. The uncertain global economy is an additional factor. The situation may be turned around with an increase in research and development in the Hi-Tech fields, some of which are closely associated with renewable energy technologies. This may lead to innovative products and job creation that are supported by the governments. The progress in other technologies, especially in Hi-Tech has induced some innovative ideas in renewable energy system designs. The ubiquitous computer has provided means for optimizing system performance, costs/benefits and environmental impacts even before the engineer was o□ the drawing board! The operating and financial attributes of renewable energy technologies, which include modularity and flexibility, low operating costs (suggesting relative cost certainty), are considerably di□erent than those for traditional, fossil based technologies, whose attributes include large capital investments, long implementation lead times, and operating cost uncertainties, regarding future fuel costs. The overall benefits of renewable energy technologies are often not well understood and consequently they are often evaluated to be not as cost e□ective as traditional technologies. In order to assess comprehensively renewable energy technologies, however, some of their benefits that are often not considered must be accounted for. Renewable energy technologies, in general, are sometimes seen as direct substitutes for existing technologies so that their benefits and costs are conceived in terms of assessment methods developed for the existing technologies. For example, solar and other renewable energy technologies can provide small incremental capacity additions to the existing energy systems with short lead times. Such power generation units usually provide more flexibility in incremental supply than large, long lead-time units such as nuclear power stations.

Table:1 Maturity of renewable energy technologies

Proven capability	Transition phase	Future potential
Hydropower	Wind	Advanced Turbines
Geothermal	Geothermal	Geothermal
Hydrothermal	Hydrothermal	Hot dry rock
		Geopressure
		Magma
Biomass	Biofuels	Biofuels
Direct combustion	Ethanol from corn	Methane
Gasification	Municipal wastes	
Passive solar	Active solar	Solar thermal
Buildings	Buildings	Advanced electricity
	Process heat	High-temperature processes
	Solar Thermal	
	Thermal/gas hybrid	
Photovoltaics	Photovoltaics	Photovoltaics
Small remote	Remote power	Utility power
Specialty products	Diesel hybrids	
		Ocean Thermal

3.2 Legal and Policy Boost Factors for Renewable Energy Project Development

There are many success stories that list the use of legal and policy factors for boosting renewable energy projects that justify continued state involvement in a dynamic energy market. For example, between 2001 and 2017, the cumulative wind capacity worldwide increased by more than 539,000 megawatts (23,900 MW), more than 22-fold. This fast-growing sector has created jobs, made power grids more resilient, expanded access to energy in developing countries, and helped reduce energy costs. The use of renewable energies, in particular solar and wind energy, needs the wide support of the population.

However, without government support for the use of wind and solar technologies, their costs will be in the same league as the increased cost of fossil-fuel technologies per kilowatthour, and it is more likely that CO_2 emissions will be added to electricity generation by these technologies. Wind turbines have developed rapidly in recent decades, and solar photovoltaic technologies are becoming increasingly efficient, improving the prospects of harnessing energy from tides and waves. Solar thermal technologies, in particular heat storage, have great potential in sunny climates. Some people are opposed to wind turbines, but they look to the horizon, where they are solid, and wind energy prices are falling, proving that a valuable resource can be denied. Currently, 29 U.S. states have set standards for renewable energy—policies that require a certain percentage of energy to come from renewable sources—and more than 100 cities have at least 70% renewable energy, whereas others have committed to reaching 100%.

In 2020, states, cities, utilities, and businesses started to announce and pursue decarbonization plans after the onset of the global pandemic and recession. Direct incentives for the development of green infrastructure and stimulus measures adopted in response to COVID-19 and the demand for clean energy in the United States have proven resilient, with renewable storage systems recording declining costs and increasing capacity and utilization factors. New policy initiatives have revised customs policy and made purchasing and production

obligations mandatory. Expressions of interest invited the installation of photovoltaic production capacity and the associated guaranteed purchase of up to 20 GW. Tenders are set for solar, wind, and hybrid systems, and existing projects are invited. Facilitating research and development of renewable energy technologies in national laboratories for policy testing, standardization, and certification has been announced by the authorities.

Renewable Energy Impact at the Utility Side and the Benefits for the System In order to expand the paper's focus on renewables' interconnection as a benefit for customers and markets, the impact on the utility side and the benefits for the system should also be mentioned. Renewable energy technologies use resources in the environment to generate electricity. Unlike conventional fossil fuel power plants, renewable energy power plants are not "disposable" or "generative" (so called because they depend on variable resources such as solar and wind, which change over the course of a day). On a centralized supply scale, a renewable power plant is comparable to a fossil fuel power plant producing several hundred megawatts of electricity. Wind, geothermal, solar, water, and other renewable technologies are the most popular energy sources in the world today. Renewables will become an increasingly important source of energy in the near future, as we use these resources to generate useful energy.

In order to develop sound policies, policymakers need to understand the relative environmental impact of alternative energy sources, including the impact of these technologies compared to fossil fuel technologies and ways to improve energy efficiency. Energy storage improves the efficiency of the electricity grid by increasing the capacity of existing resources, thus offsetting the need to build new, polluting peak power plants. Through more flexibility in the grid, energy storage systems can help integrate solar, wind, and decentralized energy resources. Energy storage is a critical hub for our power grid, adding demand-side resources and system efficiency values to resources such as wind, solar, hydro, nuclear, and fossil fuels. Moreover, energy storage saves the energy grid cost of operation and money for electricity consumers who install energy storage in their homes and businesses. Since renewable energy sources are connected to the grid, capacity issues arise, but energy storage is the main problem with long-standing systems.

Conclusion

Renewable energy resources and their utilization are intimately related to sustainable development. For societies to attain or try to attain sustainable development, much e□ort should be devoted to discovering sustainable energy resources in terms of renewables.

All in all, it appears that the role of renewable energy in the sustainable development of the electrical power sector is far from underestimated. It includes the protection of the environment, the improvement of the sources used for the generation of electric power, and the creation of new business opportunities for companies and individuals (in the framework of the sharing economy and peer-to-peer (P2P) energy

networks) who are becoming the prosumers (both producers and consumers of the electric energy). One can see that renewable energy sources offer many direct and indirect economic benefits at both the micro and macro level.

The term “renewable” is applied to energy resources and technologies that have the common feature of not being exhaustible and being refillable. Renewable resources include solar energy, wind, falling water, geothermal energy, plant materials, biomass, waves, ocean currents, temperature differences, ocean energy, and tides. Renewable energy technologies have an environmental impact because they are preferable to conventional sources, can replace fossil fuels, and have considerable potential for reducing greenhouse gas emissions. Replacing the burning of harmful fossil fuels with renewable energy can help mitigate problems such as air and water pollution, excessive water and land use, habitat loss for wildlife, harm to public health, and global warming. Moreover, most people realize that solar and wind energy are low-carbon energy sources, and bioenergy and carbon capture and storage play an indispensable role in scenarios in which countries reduce their carbon emissions. Renewable technologies are considered to constitute clean energy sources by the general public because optimal use of renewable technologies reduces environmental impact, produces minimal secondary waste, and is sustainable based on current and future economic and social needs. Countries around the world are promoting energy security and economic growth, and studying and using renewable energy sources to solve environmental challenges posed by climate change. Renewable energy technologies are increasingly being used in countries with a higher per capita GDP and higher energy security. However, risks associated with their generation, storage, and deployment should also be calculated and taken into account. The recent gas crisis in Europe happened largely due to the ill-executed decarbonization strategy, when seasonal changes and downfalls in the renewable energy generation, as well as the lack of the backup by traditional fossil fuel generation facilities, left many European countries unprepared.

In addition, environmental concerns should be addressed. The following concluding remarks can be drawn from this study:

- There are a number of environmental problems that we face today. These problems span a continuously growing range of pollutants, hazards and ecosystem degradation over ever wider areas. The most significant ones are acid precipitation, stratospheric ozone depletion, and global climate change.
- Potentially the most important environmental problem relating to energy utilization is the greenhouse e□ect. Increasing atmospheric concentrations of greenhouse gases are increasing the manner in which these gases trap heat radiated from the Earth's surface, thereby raising the surface temperature of the Earth and as a consequence risen sea levels.

- Recently, a variety of potential solutions to the current environmental problems associated with the harmful pollutant emissions has evolved. However, renewable energy appears to be one of the most important solutions.
- In order to attain the energy, economic and environmental bene®ts that renewable energy sources o□er, an integrated set of activities such as R&D, technology assessment, standards development and technology transfer should be conducted as required.

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