

Renewable Energy Conversion Systems



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Dedication

**To my parents Muhammad Ramzan (late) and
Naziran BiBi for their support and love and to my
beloved wife Badar Un Nisa and my son M. Sarim Kamran
for their inspiration and love.**

Muhammad Kamran

**To my family, for their continuing unconditional love
and support throughout my life. I am also thankful to
my teachers who equipped with me the power of
knowledge. Last but not least, I am grateful to
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opportunity to work with him.**

Muhammad Rayyan Fazal

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Chapter 1

Fundamentals of renewable energy systems

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1.1 Introduction

1.1.1 Why renewables

Until the 19th century, the main concern of humans was to gather food for family members, and technological progress, as a result, remained limited. Energy and fuels played a vital role in the evolution of human civilization since humans learned to ignite the fire for the very first time. The primary energy source was wood until 1700 and then coal superseded it in the 1780s. A rapid transition can be seen in the past three centuries including steam engines, enhancement in oil extraction and refinement techniques, and coal-based power plants that dramatically altered this fuel usage pattern. Hence, it took just two centuries to shift towards fulfilling 80% of energy requirements through fossil fuels whereas it took thousands of years to switch from wood to coal. Until now, coal is playing a vital role in fulfilling energy demands. However, its use remained limited, i.e., electricity production, till the development of the techniques to convert it into chemicals [1]. Their practical implementations are yet to be validated for commercial use before considering it as a replacement for fossil fuels. Coal consumption is further reduced because of the recent developments in natural gas, and methane gas [2]. On the other hand, there are many types of fuels obtained through fossil fuels such as liquid gas, crude oil, gasoline, kerosene, diesel, etc. A large amount of chemicals is produced through crude oil. Furthermore, there is no additional requirement of chemical processes in using them as fuels hence byproducts are usually of a negligible amount. That's why crude oil remained the central point for technology development and policymaking in the last century.

Today, the dominating power in the world is technology. Hence, the demand to power various devices required for smooth and efficient operations

has been dramatically increased. The technology evolution and rapid population growth are pushing the countries to look for various sustainable alternative forms of energy to accommodate future needs. With industrialization and the increasing population, energy demands have been increased exponentially whereas the conventional energy sources are depleting at the same rate. As per estimations, 80% of the world's energy is taken from non-renewable resources i.e., oil, coal, and natural gas. These fossil fuels are of limited quantity and likely to get exhausted soon if this trend continues. As fossil fuels are unlikely to meet the demand of the exponentially growing population of the world. In the same way, the emissions like CO₂ are reaching dangerous thresholds due to excessive use of fossil fuels. This is now becoming a serious concern because of the increasing threat to the overall ecosystem. It is not only the greenhouse gases that are causing the problems but these fuels also left Sulphur, nitrogen, and carbon oxides that significantly degrade the environment. However, there are now rules and regulations strictly implemented by most of the countries to narrow down the potential hazards at large but yet the amount of fossil fuel usage in various applications around the globe has risen so high that it seems impossible to get complete rid of the pollutants. Another associated problem with fossil fuels is their non-uniform distribution worldwide. There exists a huge gap in the demand and supply of fossil fuels throughout the world. It makes some nations dependent upon others, and any sociopolitical conflicts or economic instabilities might result in massive energy-related problems. Therefore, there is a sheer need of getting rid of this huge dependency and look for alternative technologies superior in environmental factors as well as sustainable point of view.

This worldwide crisis can be best addressed utilizing 'renewable energy resources', referred to as systems having the ability to provide unlimited energy potential. There are plenty of these types available these days with their technologies matured and accepted worldwide. Research on reliability, efficiency, and consistency is still underway but yet these technologies are now widely implemented to produce energy. These renewable energy sources can be used to generate electricity or to meet the heating requirements with minor or low impact on the environment. Renewable energy resources like Solar (Photovoltaic Systems), Wind (Wind turbines), the heat of the earth core (Geothermal Energy), biomass (Bioenergy), and water (hydropower energy) have emerged as strong competitors of fossil fuels. Unlike fossil fuels, many renewables are unable to be used directly for energy production or producing chemical byproducts. Renewable resources such as solar, wind, and hydropower can act as sustainable sources and capable of fulfilling energy demands in different shapes. However, they cannot be used to generate any other form of fuel or chemicals. Still, they produce a sustainable form of energy as these resources are unlikely to be discontinued or politically affected. Sun will continue to shine for any reason and other resources are mainly dependent upon solar energy for their existence such as

wind and water. Therefore, using these technologies for energy production will not affect any kind of resources, unlike fossil fuel reservoirs that are likely to get exhausted for our future generations. There are many advantages of using these renewable energy resources as energy-producing alternatives:

- **Air Pollution:** Due to the increasing demand for fossil fuels, their transportation, industrial usage, and power production is polluting the air to a great extent. The use of charcoal and wood is contributing to poor air conditions and also causing millions of premature deaths, according to the world health organization. Instead of polluting the environment, renewables are also saving precious resources hence better for our health.
- **Greenhouse Gas Emission:** Renewable Energy has a great advantage in achieving better climatic conditions over non-renewable energy. As the emissions from fossil fuels have a devastating effect on the environment. The combustion of these fossil fuels adds to the greenhouse gas emissions hence promoting the global warming phenomenon. Renewables on the other hand have little to no emission at all even if the full life cycle of the project is considered.
- **Economics:** Renewable energy is never subjected to get affected because of the geopolitical crisis, or discontinuity of supply, or sudden price spikes found to be common in the case of fossil fuels.
- **Community's betterment:** Generating power from renewable resources is an emerging technology. Many countries are putting huge investments in the research and development sector for their practical implementation. This renewable energy in return generates revenue and is used for further development of this sector, hence proving a better alternative for the community's betterment.
- **Resilient infrastructure:** Renewable energy facilitates the development of the energy production setup at remote locations. Hence, making urban independent from national grids. Power systems are becoming more flexible, manageable, and resilient against catastrophic events with the help of renewable energy units.
- **Easy access:** Technology evolution is leading towards cheaper power generation through renewable resources. This in return is making it possible to use renewable resources for energy production especially for the people living in remote locations.
- **Secure and stable:** Greater energy demands and modern infrastructure requires the adoption of safe, secure, and stable strategies for energy production. Renewable resources are safe and secure hence offering more stability in return.

There is a wide range of applications using renewable energy in different forms. Worldwide, 26% of the electricity generation is through renewables but yet electricity represents just 17% of the world's energy needs. A major form of energy usage is cooling and heating that comprised nearly 50% of the total world's energy demand. Whereas nearly one-third of the total energy is