

CHAPTER

1

INTRODUCTION TO SUSTAINABLE ENERGY

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1.1 INTRODUCTION

This book gathers contribution of studies and research works related to the different aspects of energy sustainability. From the lab scale study to the ready-to-use application, covering both levels of products as well as processes, this book provides latest findings and innovations that revolve around the theme of energy sustainability. In this introduction chapter, it is good for readers to have a glimpse on the concept of sustainability before narrowing into its relevancy in various aspects of energy application.

In general, sustainability is a guiding principle that ensures the needs of the present are met without compromising the ability of future generations to meet their own needs (Brundtland Commission, 1987). It is structured around three fundamental pillars (see Figure 1.1): Environmental, social, and economic sustainability, often referred to as the “triple bottom line” (Elkington, 1997). The environmental pillar focuses on protecting ecosystems, reducing carbon emissions, and promoting responsible resource management to maintain biodiversity and combat climate change (Rockström et al., 2009). The social pillar emphasises human well-being, equity, and social justice by addressing issues such as poverty, education, healthcare, and labour rights (United Nations [UN], 2015). The economic pillar ensures that financial and

industrial growth is achieved in a way that does not deplete natural resources or create social disparities (Purvis et al., 2019). These three dimensions are deeply interconnected—economic development depends on environmental sustainability, and social stability is crucial for long-term economic growth. Achieving true sustainability requires a holistic approach that integrates policies and practices balancing all three pillars to create a resilient and equitable future for all.

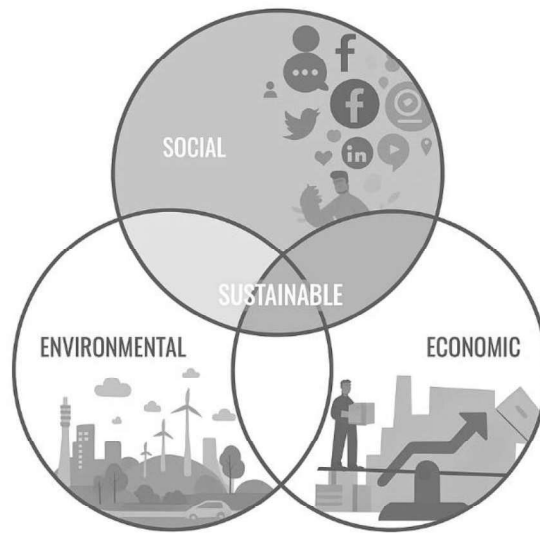


Figure 1.1 Three pillars of sustainability

1.2 WHAT IS SUSTAINABLE ENERGY

Sustainable energy refers to energy sources and technologies that meet present energy needs without compromising the ability of future generations to meet their own needs. It is a fundamental component of sustainability, aiming to provide reliable, affordable, and clean energy while minimising environmental and social impacts (Owusu & Asumadu-Sarkodie, 2016). Sustainable energy is often associated with renewable energy sources, such as solar, wind, hydro, and geothermal power, but also includes energy efficiency measures and innovations that reduce waste and improve energy conservation (UN, 2021).

1.2.1 Characteristics of Sustainable Energy

Sustainable energy is defined by several key characteristics that ensure long-term energy availability while minimising negative environmental and social impacts:

(1) **Renewability**

Sustainable energy sources, such as solar, wind, hydro, and geothermal, are naturally replenished and will not run out over time, unlike finite fossil fuels. This ensures a continuous and reliable supply of energy for future generations while reducing dependence on depleting resources (Ellabban et al., 2014).

(2) **Low Environmental Impact**

Renewable energy significantly reduces greenhouse gas (GHG) emissions compared to fossil fuels, helping to mitigate climate change. Additionally, it minimises air and water pollution, which can lead to improved public health and reduced damage to ecosystems. Hydropower, wind, and solar energy, for example, generate electricity without producing harmful emissions (Intergovernmental Panel on Climate Change [IPCC], 2018).

(3) **Energy Efficiency**

Enhancing energy efficiency through modern technologies, such as smart grids, energy storage systems, and advanced building insulation, maximises energy use while minimising waste. Efficient energy systems reduce overall consumption and lower operational costs, making sustainable energy both environmentally and economically viable (International Energy Agency [IEA], 2022).

(4) **Economic and Social Benefits**

The transition to sustainable energy fosters job creation in sectors like solar panel manufacturing, wind farm construction, and energy efficiency services. It also enhances energy security by reducing reliance on imported fossil fuels, stabilizing energy prices, and providing affordable energy access to underserved communities, improving overall quality of life (International Renewable Energy Agency [IRENA], 2019).