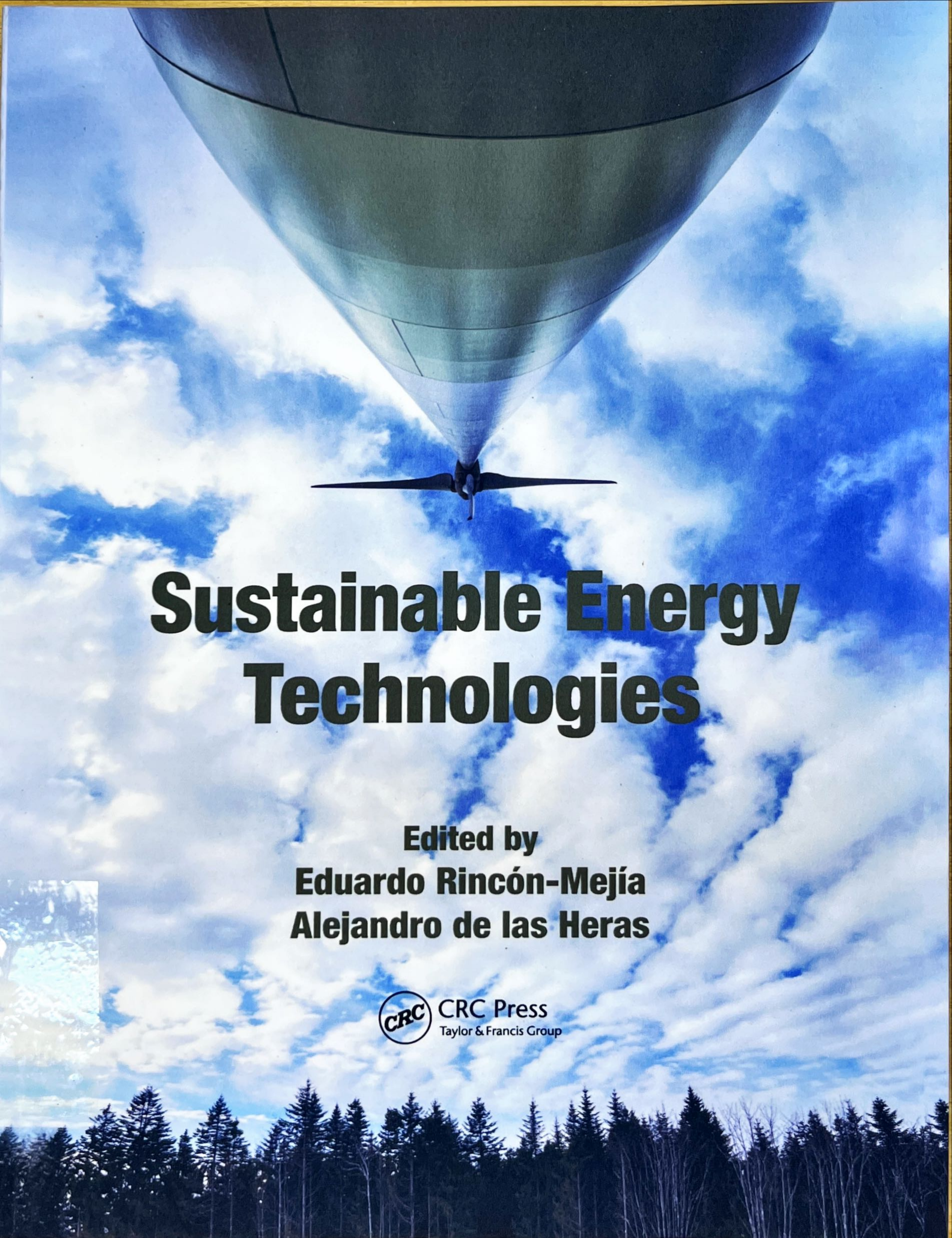

Sustainable Energy Technologies

Edited by

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CRC Press
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Preface

WHAT 'SUSTAINABILITY' MIGHT MEAN

American President Theodore Roosevelt said "We have become great because of the lavish use of our resources. But the time has come to inquire seriously what will happen when our forests are gone, when the coal, the iron, the oil, and the gas are exhausted, when the soils have still further impoverished and washed into the streams, polluting the rivers, denuding the fields and obstructing navigation. These issues are not just about the next century or generation." "The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased, and not impaired, in value" (1910).

This far-sighted comment warrants reevaluation of our culture. Sustainable development has now become a household word, but the term "development" hides phenomena such as the concentration and accumulation of capital, the ruthless destruction of nature, and the alienation of individuals (Latouche, 2009). Economics must rethink the idea that consumption of unlimited resources is the ultimate goal in life, as Georgescu-Roegen did, linking economy and thermodynamics. In the real world, all processes obey the laws of physics and biology (Bejan & Llorente, 2010).

In practice, a sustainable energy system should have the following features:

1. Energy reserves should last for as long as man exists on the planet.
2. The Hartwick rule (1977) should apply to exhaustible reserves. For example, fossil natural gas can be sustainable only if it is entirely dedicated to producing devices that tap much more renewable energy than is consumed in the production of that device and if pollution is offset.
3. Waste materials should all be treated as resources in recycling processes.
4. Working efficiencies should approximate thermodynamic limits.
5. The system should be resilient and dominated by maximally diverse modular and decentralized applications.
6. Energy should be used sparingly by all.
7. All subsystems should have very high energy return on energy invested.
8. Energy and matter transportation and conduction should be minimal thanks to local use of resources.
9. Profitability must consider both monetary and environmental numeraires on equal terms.
10. Sustainability can only be attained if ecosystems are restored.

These principles are embodied in the applications shown in this book.

BOOK OVERVIEW

This book begins with a reminder in Renné's Foreword of the 2015 Paris Agreements to further reduce carbon dioxide in the atmosphere. A few months after the Paris Agreements, news came that the price of electricity from renewable energy sources was, for the first time, lower than the nuclear MWh price.

In Chapter 1, Rincón-Mejía and colleagues link current carbon dioxide levels to the global mix of energy technologies. They caution against dead-end engineering ideas that could further imbalance the atmosphere. They also make the essential distinction between renewable and sustainable energy technologies, thereby questioning nonwaste agro-fuels. Finally, they show the momentous surge of sustainable energy sources in the worldwide market.

Chapter 2, by de las Heras, and colleagues, explains that fusion in the Sun and radioactive decay in Earth's crust and mantle are safe and easy to use while artificial fission poses intractable technical issues. Further, Sani's firsthand experience in nuclear power plants points to the intricate relationships of the oil and nuclear industries with regional and global military interests.

The lack of transparency of nuclear power resonates with citizen concern and involvement, in Chapter 3 by Leon-Grossmann; firsthand experience in California shows to the world that in one of the most democratic areas of the world, corporations and highly regarded politicians vie for power at the expense of the environment and democracy, two pillars of sustainability.

Having stated the current bias in the supply side of energy and the human flaws in energy systems, engineering takes over with a theoretical viewpoint on technology evolution: dos Santos and colleagues very didactically expound the intricacies and extremely wide field of application of the Constructal physical law in Chapter 4. This theory pinpoints many practical applications in sustainable energy systems.

In Chapter 5, Walker addresses one of the main challenges in the energy transition toward sustainability, namely the integration of more intermittent renewable energy to grids feeding cities and buildings. Although energy storage is the main solution, adaptations of sustainable energy sources are also needed, such as photovoltaic solar distribution over larger areas or different orientations than south-facing arrays, to even out the effects of partly cloudy days and morning and evening peak demand times. Hardware standards and load forecasting methods are also enhancing operation in grids coupling conventional and sustainable energy sources during the energy transition.

Changes in the global energy subsystems in the last four decades are described by Ruiz-Hernández in Chapter 6. The most salient feature of the global systems is the rise of renewable sources, and the resistance of the International Energy Agency to acknowledge this fact. Solar energy in particular has a potential for *direct* thermal and photovoltaic applications that bolster their efficiency and, consequently, their economic competitiveness. Ruiz-Hernández draws on the experience of Spanish top-of-the-line facilities to explore upcoming developments in solar concentrating thermal and electric applications.

Fundamental physics, mathematical tools, and the economic aspects of energy balance are used by González in Chapter 7 to show that technology has solved one of the key issues in tropical energetics: sustainable cooling in the face of high humidity. These results also point to the possibility of sustainable energy independence in islands around the world, and coastal areas, the most endangered areas in relation to global warming and sea level rise.

Taking advantage of a warming atmosphere, absorption thermodynamic cycles now allow for heat, cold or electricity applications, depending on the needs of the end user, as demonstrated by Lecuona-Neumann and colleagues in Chapter 8. These applications totally supersede systems that use ozone-depleting substances.

Weber takes over cooling and heating applications in Chapter 9. He shows the efficiency of hybridized solar and heat-pump systems. In these systems, the sun is the energy source, and heat is stored underground. These applications have large potentials in temperate and cold climes, where seasonal soil-air temperature gradients are elevated.

The field of solar energy storage applications is further explored by Solé and colleagues in Chapter 10, with a focus on recent developments in thermochemical materials. The full spectrum of solar energy storage is covered in that chapter.

Solar energy storage and the chemistry thereof are approached from another angle by Cabrera-Lara in Chapter 11. There, solar photocatalysis is used for hydrogen production, the energy carrier used for storage. The role of semiconductor catalysts and photoelectrochemical cells is elucidated, and key parameters are highlighted.

Dispatchability (i.e., use on demand) is fundamental in the competition of renewable energy systems against fossil fuels. Sattler and colleagues in Chapter 12 also deal with the conversion of solar energy into solar fuels at higher, more efficient, temperatures, using solid oxide and molten carbonate electrolyses. The focus is on concentrating solar power thermochemical H_2O and CO_2 transformation.

Sustainable electrochemical energy storage can also take place in supercapacitors, whose use in addition to current storage batteries is developing fast. Fierro and colleagues in Chapter 13 explain the fundamentals and applications of tannins, some cheap, inexpensive, non-toxic and renewable compounds as precursors of supercapacitor carbon electrodes.

Transportability is another key parameter in sustainable energy carriers. Hydrogen in particular lends itself to fuel cell applications, as shown by Reyes-Rodríguez and colleagues in Chapter 14. Fuel cell thermodynamics, components, and perspectives are dealt with in that chapter.

Transportability is of the essence in aeronautical applications. Iturbe and colleagues in Chapter 15 demonstrate the potential of sustainable biofuels in jet propulsion turbines and the solutions to the higher viscosities of biofuels. Sprays and droplet-size distribution in ultrasonic actuated fuel injection are treated in detail.

Global society is highly dependent on air travel, but for billions of people, gathering cooking fuel is still a highly energy-demanding activity, especially since wood fuel is becoming sparse due to deforestation. As shown by Lecuona-Neumann and colleagues in Chapter 16, solar cooking is a powerful alternative to combustion in most kitchens of the world and a climate-change mitigator. Concentrating solar cookers are now being hybridized with thermal or electrical solar energy storage, for enhanced nighttime and cloudy-day dispatchability.

Both large-scale and small autonomous systems are likely to require windpower in their energy mix: windpower is one of the lower-cost energy sources and has been harnessed for centuries, a sure indicator of the robustness of even less-efficient applications. Rincón-Mejía in Chapter 17 gives account of the principles of windpower and the most viable, up-to-date, applications.

Offshore windpower is but one of the sustainable energy sources that can be drawn from marine environments. Magar in Chapter 18 shows how tides and their interaction with the sea floor generate strong tidal currents, close by the sea shores, owing to Venturi effects. Numerical tidal resource assessment, based on computational fluid dynamics and technology developments in the last 20 years, is explicated.

Any discussion of current energy supply mixes should probably include Brazil, perhaps the foremost user of renewable energy sources: by 2015, an approximate 44% of the energy mix was obtained from renewable sources. Several of these however are not sustainable: wood fuel, vegetal coal, sugar cane ethanol, and hydroelectricity have large environmental and social footprints. Korys and Latawiec in Chapter 19 cover the environmental and social implications of large-scale hydropower dams, with implications of any such future projects in the world. They also discuss small-scale and run-of-river alternatives to making hydropower more sustainable.

Sustainable energy systems will not be complete if they do not tap the vast stores of energy in the billions of extant human bodies and the huge amounts of biowaste that they generate, as explained by Islas-Espinoza and de las Heras in Chapter 20. Starting with fundamentals of bioenergy, they go on to highlight the main application branches, human power, and waste-based biomethane. Hybrid applications are also illustrated.

The importance of biomethane can hardly be overestimated. Challenges remain, but Aydin and colleagues in Chapter 21 highlight solutions. They cover the complex biological essentials of the topic, key control parameters, and pathways to enhanced biomethane generation, including control of carbon dioxide and hydrogen sulfide.

As to fundamentals of human bodily energy, they are provided by Aguilar Becerril and colleagues in Chapter 22. These include (an)aerobic biochemical pathways of energy generation, which interestingly show the hybrid character of human energetics. Food energy substrates are covered, as is the essential concept of energy recovery via sleep and rehydration. Ergometric, spirometric, and anaerobic aspects of performance are covered, using as a model athletic performance.

As increasing numbers of humans settle in cities, and emerging economies grow, the already huge energy demand from homes is bound to soar. Energy generation is not a solution. The Net Zero Energy concept in building design has emerged as an alternative. Morillón Gálvez and Ceballos

Ochoa in Chapter 23 develop an energy balance account of a bioclimatic and photovoltaic Net Zero Energy architectural design in three of the world's bioclimates.

REFERENCES

Bejan, A. and Llorente, S. (2010). The constructual law of design and evolution in nature. *Philosophical Transactions of the Royal Society B, 365*, 1335–1347.

Hartwick, J. M. (1977). Intergenerational Equity and the Investing of Rents from Exhaustible Resources. *Review of Economic Studies, 67*, 973–974.

Latouche, S. (2009). *Farewell to Growth*. Cambridge, UK: Polity Press.

Roosevelt, T., 26th President of the US (1910). Speech before the Colorado Livestock Association, Denver, Colorado, August 19, 1910. Retrieved from quotationspage.com/quote/41325.html.