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Introduction

In a broad sense, *energy conversion* is the capacity to promote changes and/or actions (heating, motion, etc.), and *biomass* includes all kinds of materials that were directly or indirectly derived not too long ago from contemporary photosynthesis reactions, such as vegetal matter and its derivatives: wood fuel, wood-derived fuels, fuel crops, agricultural and agro-industrial by-products, and animal by-products. *Bioenergy* is the word used for energy associated to biomass, and *biofuel* is the bioenergy carrier, transporting solar energy stored as chemical energy. Biofuels can be considered a renewable source of energy as long as they are based on sustainable biomass production **[1]**.

Worldwide, there is a growing interest in the use of solid, liquid and gaseous biofuels for energy purposes. There are various reasons for this, such as:

- political benefits (for instance, the reduction of the dependency on imported oil);
- employment creation – biomass fuels create up to 20 times more employment than coal and oil; and
- environmental benefits such as mitigation of greenhouse gas emissions, reduction of acid rain and soil improvements.

Figure 1.1 *Many countries have abundant resources of unused biomass readily available*

Figure 1.2 *Wood-stove commonly used in Cambodia*

Large amounts of wood and other solid biomass residues remain unused so far and could potentially be made available for use as a source of energy. In addition to this, wood and other biomass energy crops could be grown. There is, for instance, a policy debate on whether trees should be used to sequester carbon or to replace fossil fuels. Trees and other forms of biomass can act as carbon sinks but at the end of their growing life there must be plans for using the biomass as a source of fuel to offset fossil energies or as very long-lived timber products.* Otherwise, the many years of paying to sequester and protect the carbon in trees will simply be lost as they decay and/or burn uncontrollably.

Solid biofuels could provide a significant part of the energy demand if appropriate technologies were introduced. For this reason, many countries around the world have become involved in modern applications of wood and biomass to energy technologies. These are not only research or pilot projects; there are actual investment projects that exploit wood and other biomass fuels to generate heat and/or electricity for use by industries, utilities, communities and single households through more efficient, convenient and modern technologies. These projects prove that biomass energy can be a technically efficient, economically viable, and environmentally sustainable fuel option in the environment in which it operates.

* This does not apply to primary forests where preserving biodiversity is of major importance.

1.1 Current status of bioenergy

Table 1.1 illustrates that the current share of bioenergy in various regions in the world is still very limited. The contribution of biomass in industrialized countries is estimated at only 4 per cent.

In developing countries, around 22 per cent of the energy used originates from biomass, but the majority of it is used non-commercially in traditional applications (such as cooking stoves). These traditional cooking stoves are often characterized by low efficiencies and high release of toxic organic compounds. With 1.3 million deaths globally each year due to pneumonia, chronic respiratory disease and lung cancer, indoor smoke in high-mortality developing countries is responsible for an estimated 3.7 per cent of the overall disease burden, making it the most lethal killer after malnutrition, unsafe sex and lack of safe water and sanitation **[2]**. In a country like Nepal, traditional biomass fuels cover over 90 per cent of the primary energy input.

Table 1.1 *Primary energy consumption by energy source and region in 2006, PJ/year*

	Modern biomass	Traditional biomass	Other renewables	Conventional energy	Total primary energy	Modern biomass as % of primary energy
World	**16,611**	**33,432**	**13,776**	**409,479**	**473,319**	**3.5%**
OECD	**8442**	**42**	**6783**	**222,369**	**237,636**	**3.6%**
OECD North America	4158	–	3276	112,959	120,393	3.5%
US and Canada	*3801*	–	*2898*	*106,281*	*112,980*	*3.4%*
Mexico	*357*	–	*399*	*6678*	*7392*	*4.8%*
OECD Pacific	882	42	798	36,561	38,283	2.4%
OECD Asia	*504*	*42*	*525*	*31,374*	*32,445*	*1.6%*
OECD Oceania	*378*	–	*252*	*5208*	*5838*	*6.5%*
OECD Europe	3402	–	2688	72,828	78,939	4.3%
OECD Europe – EU	*3129*	–	*1785*	*69,384*	*74,298*	*4.2%*
Transition economies	**693**	**–**	**1176**	**44,688**	**46,536**	**1.5%**
Russia	273	–	672	26,901	27,867	1.0%
Developing countries	**7434**	**33,432**	**5817**	**136,269**	**182,994**	**4.1%**
China	315	8988	1323	49,602	60,144	0.5%
East Asia	1092	3633	1197	20,202	26,145	4.2%
Indonesia	*126*	*1680*	*357*	*5418*	*7560*	*1.7%*
South Asia	1302	9828	504	18,627	30,261	4.3%
India	*1092*	*8043*	*357*	*15,582*	*25,074*	*4.4%*
Latin America	2394	1239	2373	15,834	21,840	11.0%
Brazil	*1680*	*357*	*1176*	*5502*	*8736*	*19.2%*
Middle East	21	63	105	19,341	19,551	0.1%
Africa	2310	9702	315	12,726	25,074	9.2%

Note: OECD = Organisation for Economic Co-operation and Development.
Source: Interpolated from data in **[3]**, other renewables includes solar, wind, hydro, geothermal, wave and ocean energy; conventional energy includes coal, oil, gas and nuclear energy.

Many countries around the globe have developed a growing interest in the use of biomass as an energy source, and therefore various technological developments in this field are ongoing. Although major technological developments have already been achieved, most bioenergy technologies are not yet commercially feasible without political support. In order to achieve wider application of modern bioenergy technologies, individual countries have set varying targets and implemented promotional policies. As a result of increased support for bioenergy technologies, major progress has been made. Chapter 10 provides an overview of approaches and progress made in selected countries.

1.2 Combustion as main bioenergy technology

Biomass combustion is the main technology route for bioenergy, responsible for over 90 per cent of the global contribution to bioenergy. The selection and design of any biomass combustion system is mainly determined by the characteristics of the fuel to be used, local environmental legislation, the costs and performance of the equipment necessary or available as well as the energy and capacity needed (heat, electricity). Furthermore, the fuel characteristics can be influenced in order to fulfil the technological and ecological requirements of a given combustion technology. The most suitable technology package therefore can vary from case to case but generally, due to *economy of scale* effects concerning the complexity of the fuel-feeding system, the combustion technology and the flue gas cleaning system, large-scale systems use low-quality fuels (with inhomogeneous fuel characteristics concerning, e.g., moisture content, particle size, and ash-melting behaviour), and high-quality fuels are necessary for small-scale systems.

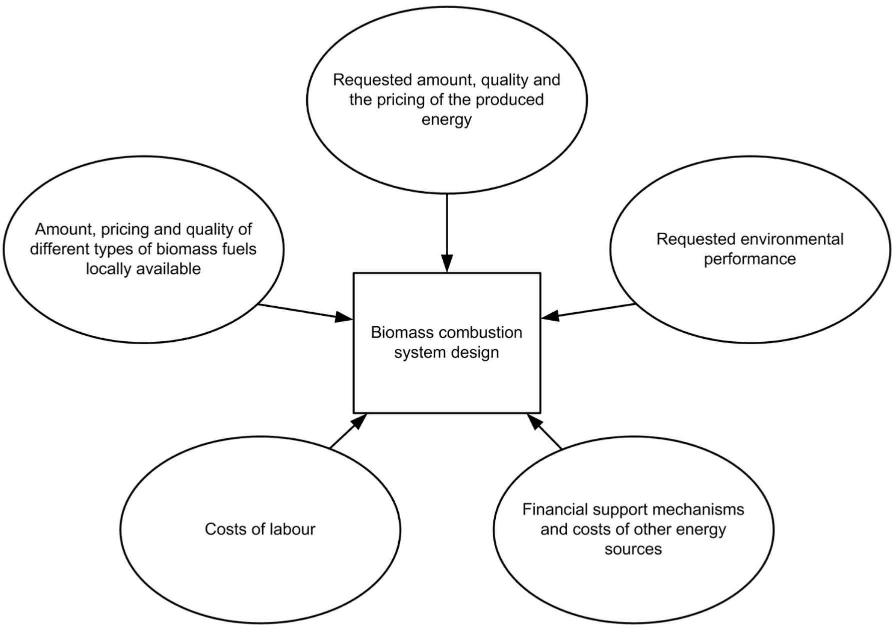

Figure 1.3 *Influencing parameters for the optimal design of biomass combustion systems*

Biomass combustion technologies show, especially for large-scale applications, similarities to waste combustion systems, but especially when chemically untreated (natural) biomass fuels are utilized, the necessary flue gas cleaning technologies are less complex and therefore cheaper. Furthermore, old combustion technologies have proven unable to handle inhomogeneous biomass fuels, and problems concerning emissions and fail-safety have occurred. New fuel preparation, combustion and flue gas cleaning technologies have been developed and introduced that are more efficient, cleaner and more cost-effective than previous systems and can be utilized for multifuel feed. This opens up new opportunities for biomass combustion applications under conditions that were previously too expensive or inadequate, increases the competitiveness of these systems, and raises plant availability. In this respect, knowledge exchange through the IEA, the EU and other international organizations as well as the creation of conducive market mechanisms and legislation are essential for a more widespread introduction of biomass energy systems.

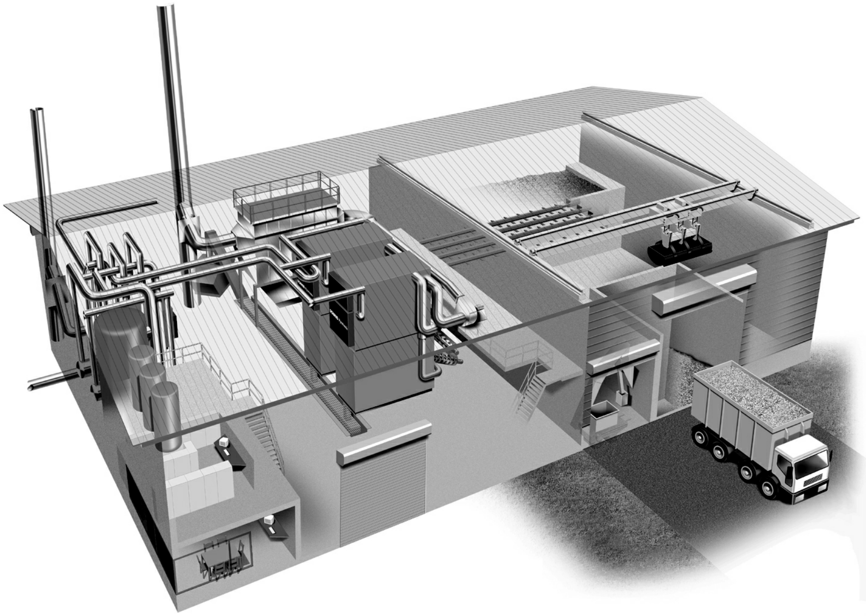

Figure 1.4 *Wood-fired heating plant used for district heating in Wilderswil, Switzerland*

Note: Thermal capacity 6.4MW_{th} on woodchips + 3MW_{th} back-up on fuel oil.

Source: Courtesy of Schmid AG, Switzerland

1.3 This handbook

This handbook describes the current state of biomass combustion technologies for both domestic and industrial use. It is a thorough update of the first edition of the handbook with the same title. The book was carefully compiled through the collaborative work of members of the IEA Bioenergy Agreement, Task 32 'Biomass Combustion and Cofiring', using available literature sources, national information and experiences as well as suggestions and comments from equipment suppliers. As technological developments in the field of biomass combustion occur very rapidly and are often difficult to keep track of, this handbook is not to be regarded as complete. Nevertheless, it represents a comprehensive overview of important issues and topics concerning biomass combustion, and the reader may especially benefit from the large number of international experts in this field who participated as authors.

In Chapter 2, the basic principles of combustion are explained and the various biomass fuels are characterized regarding their physical and chemical parameters and their influence on the combustion process.

Chapter 3 provides information on possible biomass fuel pre-treatment options and fuel-feeding technologies.

Chapter 4 describes currently available biomass combustion technologies for domestic space heating.

Chapter 5 describes the biomass combustion technologies currently applied or under development for industrial utilization of biomass fuels. Moreover, technological possibilities to increase the efficiency of biomass combustion plants are discussed, and technological and economic standards regarding the proper dimensioning of biomass combustion systems are given.

Chapter 6 covers the various technologies for power production based on biomass combustion.

In Chapter 7, various concepts for biomass co-firing technologies and applications are explained and discussed. Typical technical problems are explained and guidelines for co-firing presented.

Inorganic components in biomass have direct influence on the eventual formation of slag deposits, corrosion of boiler components, aerosol formation and utilization options for the ashes formed. Chapter 8 is dedicated to ash characteristics and the behaviour of ash in biomass combustion systems.

Chapter 9 is devoted to environmental aspects of biomass combustion. It provides overviews of average gaseous and solid emissions from combustion installations and describes possible primary and secondary measures for emission reduction. Furthermore, biomass ashes are characterized and possible treatments and utilizations are pointed out. Finally, this chapter offers an overview of the various environmental regulations in 19 European countries regarding emissions limits for biomass combustion facilities.

Chapter 10 provides an overview of trends and policies with regard to the implementation of biomass combustion systems.

Finally, Chapter 11 supplies an overview of needs and ongoing activities concerning research and development in the field of biomass combustion.

1.4 References

1 UN FOOD AND AGRICULTURE ORGANIZATION (FAO) (1997) Bioenergy Terminology and Bioenergy Database, Wood Energy Programme, Wood and Non-Wood Products Utilization Branch (FOPW)/FAO (ed.), Rome, Italy
2 WORLD HEALTH ORGANIZATION, see www.who.int
3 IEA (2004) *World Energy Outlook*, IEA