

Chapter 2

Biomass and Waste as Sustainable Resources

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Abstract Biomass, as the main contributor to renewable energy in the world (about 13% of total energy consumption), is a versatile energy source—it can be stored and converted in practically any form of energy carrier and also into biochemicals and biomaterials from which, once they have been used, the energy content can be recovered to generate electricity, heat, or transport fuels. It covers a broad range of products, including traditional use of wood for cooking and heating, industrial process heat, co-firing of biomass in coal-based power plants, biogas and biofuels. Moreover, the possibility to use residues and waste as a biomass feedstock enables the production of huge quantities of energy and environmental benefits all over the world, without any fertile land use or any competition with food or feed. Since residues and wastes are part of the short carbon cycle, their use for energy purposes has a minimal extra GHG emission.

2.1 Introduction

Biomass for energy is the main contributor to renewable energy around the world, with almost 13% of total energy consumption in 2006 [1] deriving from biomass. Biomass is in fact a term that covers a broad range of often very different products, although all are of organic origin. Many of these products can be used as a source of energy, either for electricity or heat production, or as a feedstock for biofuels production.

It is important to distinguish between ‘traditional’ and ‘modern’ use of biomass. Traditional use of biomass such as dung, charcoal and firewood for cooking and

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heating—mostly in open stoves—is still common practice for many people in developing countries. For ‘modern’ uses of biomass, a multitude of feedstock-to-end-use routes are feasible and indeed in use today. Modern biomass is used on a large scale for heating, power generation (e.g. co-firing in large-scale coal-based power plants or combined heat and power plants) and biogas and biofuels production. It is expected that in the future biomass could also provide an attractive feedstock for the chemical industry and that use of biogenic fibres will increase.

It has been estimated that bioenergy (based on biomass and waste) could sustainably contribute between a quarter and a third of global primary energy supply in 2050 [1] with:

- a large contribution to global primary energy supply;
- significant reductions in greenhouse gas emissions, and potentially other environmental benefits;
- improvements in energy security and trade balances, by substituting imported fossil fuels with domestic biomass;
- opportunities for economic and social development in rural communities;
- scope for using wastes and residues, reducing waste management and disposal problems, and making better use of resources.

Investment in bioenergy is strategic in order to achieve a sustainable global energy policy. The fossil fuel-based energy economy will continue for some time, while it is phased out by sustainable alternatives. In the meantime the negative impact of fossil fuels to the environment can be reduced by combining them with biomass. It is the only renewable source that can replace fossil fuels in all energy markets—in the production of heat, electricity, and fuels for transport.

Technologies for producing heat and power from biomass are already well-developed and fully commercialised. A wide range of additional conversion technologies are under development, offering prospects of improved efficiencies, lower costs and improved environmental performance.

However, expansion of bioenergy also poses some challenges. Several issues have to be taken into account and better analysed: the productivity of food and biomass feedstocks, the potential competition for land and for raw material with other biomass uses in order to produce biomass sustainably avoiding negative effects on food security and overuse of water resources, logistics and infrastructure issues, technological innovation to more efficient and cleaner conversion of a wide range of feedstocks.

Establishing national and global policies to foster sustainable markets for bioenergy is needed, taking into account both the risks of uncontrolled bioenergy production and deployment, and the opportunities arising from future RTD efforts.

2.2 Biomass: an Unlimited Resource

During photosynthesis, plants use solar energy, CO₂, minerals and water to produce primarily carbohydrates (Eq. 2.1) and oxygen, and by further biosynthesis, a

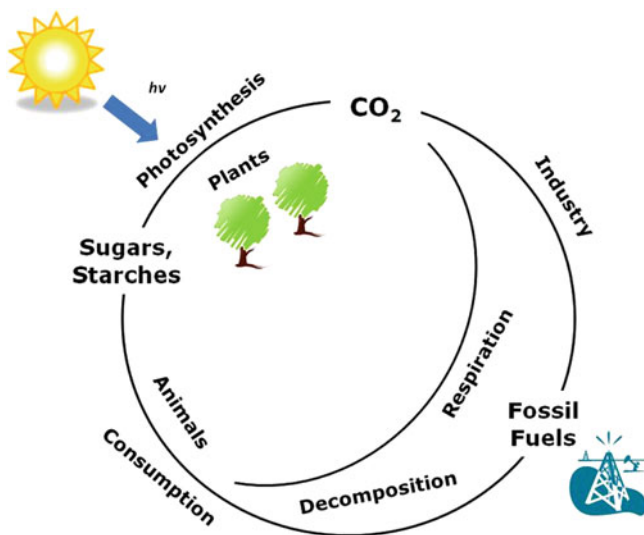
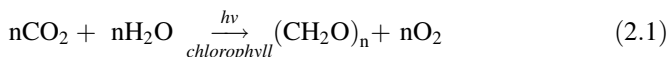


Fig. 2.1 The carbon cycle

large number of less oxygenated compounds including lignin, triglycerides, terpenes, proteins, etc. The composition depends on the type of the plant:



On average, the capture efficiency of incident solar radiation in biomass is 1% or less, but it can be as high as 15%, depending on the type of plant. The carbon (e.g. CO₂) and mineral (K, N, P) cycle is closed after decomposition of biomass or waste products, if disposed on land or after processing, consumption and degradation/combustion (Fig. 2.1). Consequently, the life cycle of biomass as renewable feedstock has a neutral effect on CO₂ emission.

Based on this fact, biomass is considered an intrinsically safe and clean material, with unlimited availability and high potential to be used as a renewable resource for the production of energy and alternative fuels, new materials in technical applications, and organic materials and chemicals.

At present, forestry and agricultural residues and municipal waste are the main feedstocks for the generation of electricity and heat from biomass. In addition, a very small share of sugar, grain, and vegetable oil crops are used as feedstock for the production of liquid biofuels. According to a recent IEA Bioenergy report, renewables accounted for a share of 13% of total energy consumption in 2006 [1]. Of this figure, 10% points are combustible renewables and waste (approximately 1.2 Gtoe), with the remainder provided by hydropower (2.2% points), geothermal (0.4% points) and solar/wind/other (0.2% points) (Fig. 2.2) [2].

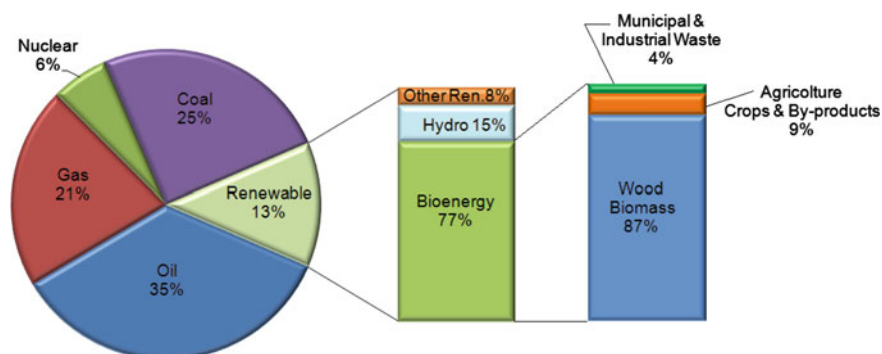


Fig. 2.2 Share of bioenergy in world primary energy mix. *Source* IEA Bioenergy, 2009. Bioenergy—A sustainable and reliable energy source. A review of status and prospects. Main report. IEA Bio energy: ExCo: 2009.06

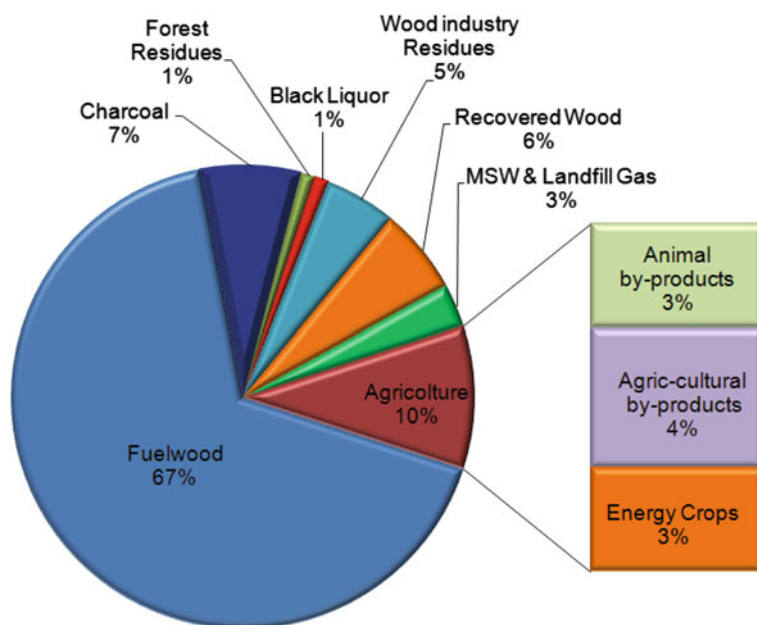


Fig. 2.3 Share of the biomass sources in the primary bioenergy mix. *Source* IEA Bioenergy, 2009. Bioenergy—A sustainable and reliable energy source. A review of status and prospects. Main report. IEA Bioenergy: ExCo: 2009.06

Around the world there are major differences in the use of biomass.

The predominant use of biomass today consists of fuel wood used in non-commercial applications, in simple inefficient stoves for domestic heating and cooking in developing countries, where biomass contributes some 22% to the total

primary energy mix. This traditional use of biomass is expected to grow with increasing world population, but there is significant scope to improve its efficiency and environmental performance, and thereby help reduce biomass consumption and related impacts (see Fig. 2.3).

In industrialized (OECD) countries bioenergy on average only represents about 3% of the mix, but is used for electricity, heating and increasingly for transport fuels. Among the industrialized countries large differences can be observed: in 2006 Finland and Sweden, for example, had respective shares of 20% and 18.5% (due to a large feedstock of black liquor, by-product from paper pulp production, which is used to produce industrial heat) while for Ireland and the UK these figures were 1.3 and 1.5% respectively [3].

2.2.1 Bioenergy in Europe

According to the *EU Directive 2001/77/EC*,¹ “biomass” is the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

The categories of biomass are defined as:

- Conventional crops for non-food use: starch crops (maize, wheat, corn, and barley), oil crops (rape seed, sunflower) and sugar crops (sugar beet, sweet sorghum...);
- Dedicated crops: short rotation forestry (willow, poplar) and herbaceous (grasses);
- Forestry by-products: logging residues, thinnings, etc;
- Agricultural by-products: straw, animal manure, etc;
- Industrial by-products: residues from food, and wood based industries;
- Biomass Waste: demolition wood waste, sewage sludge and organic fraction of municipal solid waste.

In the EU, around 5% of final energy consumption is from bioenergy. The projections made for the Renewable Energy Road Map² (January 2007) suggested that the use of biomass can be expected to double, to contribute around half of the total effort for reaching the 20% renewable energy target in 2020. The growing production and use of biomass for energy purposes already gives rise to international trade, and this market is bound to expand in the future. Most of the increased trade is expected to be in the form of pellets, a type of solid biomass, generally consisting of processing residues from forest based industries.³ Considering *solid*

¹ Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market, September 2001.

² COM(2006)848.

³ The European Biomass Association estimates that by 2020 up to 80 million tons of pellets could be used in the EU (33 Mtoe) http://www.aebiom.org/IMG/pdf/Pellet_Roadmap_final.pdf

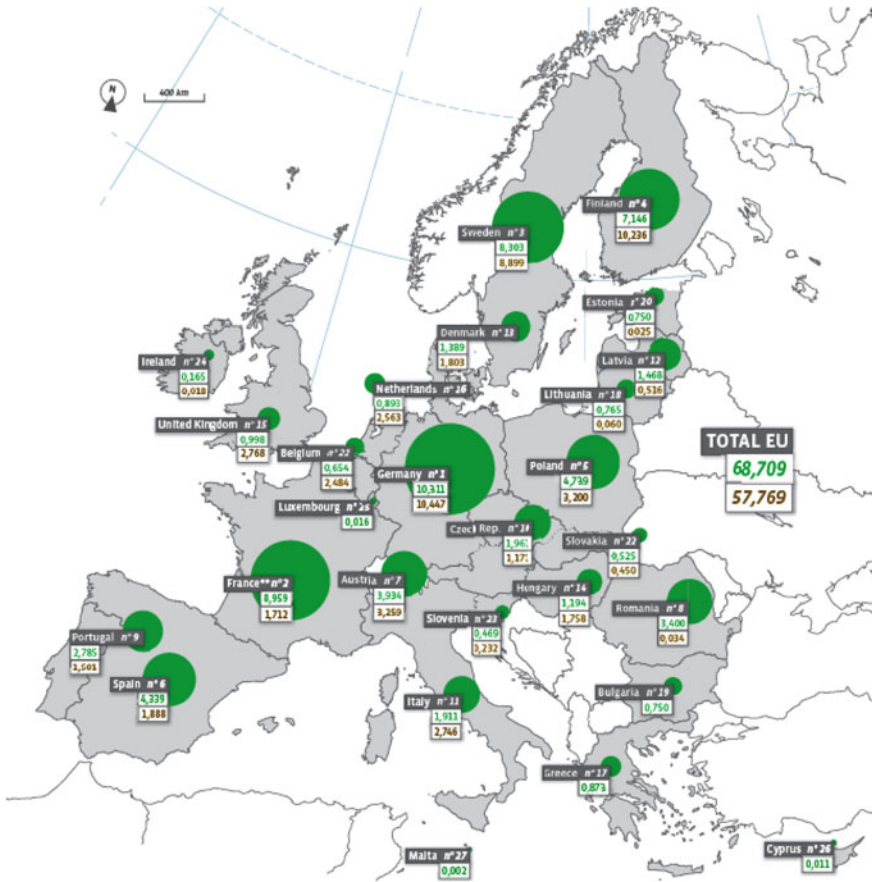


Fig. 2.4 68,7: Primary energy production from solid biomass in the EU, 2008 (Mtoe). 57,7: Gross electricity production from solid biomass in EU, 2008 (TWh) Source EurObserv'ER 2009

biomass, made up of wood and its waste, primary energy consumption in 2008 has been about 68.7 Mtoe, with an electricity output of 57.8 TWh. Figure 2.4 shows the distribution in European Countries.

Cogeneration plants, which convert solid biomass energy into both heat and electricity, provide 62.6% of Europe's production and it is primarily through the development of cogeneration plants that solid biomass electricity production has increased in recent years. Gross heat production from solid biomass in 2008 was 5.2 Mtoe; this amount only refers to heat sold via community heating networks. The statistics do not include industrial heat production used on site for heating factory premises, heat produced for domestic heating appliances, collectives, or industrial operations not linked to a network [4].

Considering *biofuels*, in the European Union, use for transport reached 12 Mtoe during 2009, with the incorporation rate in the overall transport fuel of 4%. In Europe

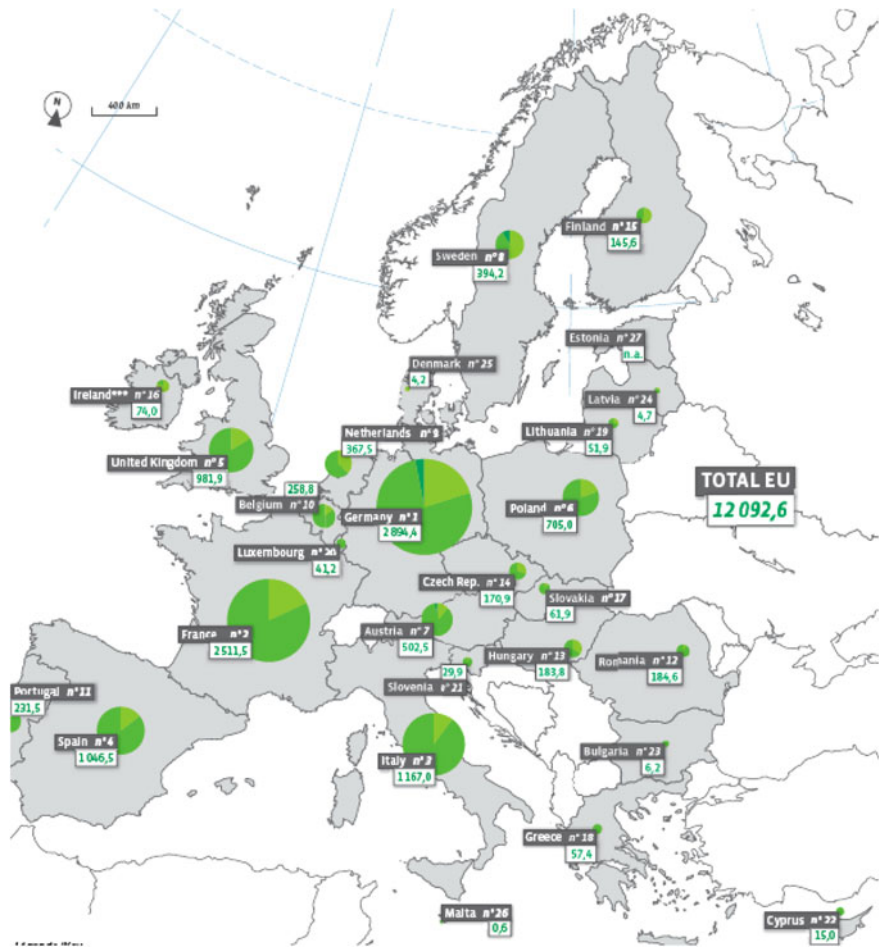


Fig. 2.5 Biofuels consumption for transport in the EU in 2009 (ktoe) with respective shares of the sectors biodiesel (largest), bioethanol and others (smallest). *Source* EurObserv'ER 2009

the biofuel most used in transport is biodiesel (9 million tons in 2009), which accounts for 79.5% of the total energy content, as opposed to 19.3% from bioethanol (3.6 million litres in 2009). The share of vegetable oil fuel is becoming negligible (0.9%) and for the moment the share of biogas in transport is specific to one country, Sweden (0.3%). Figure 2.5 shows the distribution in European Countries [5].

2.2.2 Global Biomass Potential

There is significant potential to expand biomass use by tapping the large volumes of unused residues and wastes. The use of conventional crops for energy use can also be expanded, with careful consideration of land availability and food demand.

Table 2.1 Overview of the global potential of bioenergy supply over the long-term for a number of categories. *Source 2 –IEA RETD Bioenergy [2]*

Biomass category	Technical potential in 2050 (EJ/yr)
Energy crop production on surplus agricultural land	0–700
Energy crop production on marginal land	<60–100
Agricultural residues	15–70
Forest residues	30–150
Dung	5–55
Organic wastes	5–50+
<i>Total</i>	<50 to > 1,100

For comparison, current global primary energy consumption is about 500 EJ/yr

Note also that bioenergy from macro- and micro-algae is not included owing to its early stage of development

In the medium term, lignocellulosic crops (both herbaceous and woody) could be produced on marginal, degraded and surplus agricultural lands and provide the bulk of the biomass resource. In the longer term, aquatic biomass (algae) could also make a significant contribution.

There is an intense debate about future biomass potentials, especially in the light of sustainability requirements. This is clearly illustrated in Table 2.1, which provides an overview of the global potential of land-based bioenergy supply over the long-term. The potentials shown here are the estimated technical potentials for a number of biomass categories, and the result of a synthesis of several global assessments.

Estimates of global biomass potentials vary widely, depending on the assumptions adopted (regarding agricultural yield improvements and trends in food demand, for example), modelling approaches and how sustainability is taken into account. According to IEA Bioenergy 2009, biomass potentials are likely to be sufficient to allow biomass to play a significant role in the global energy supply system even if stringent sustainability requirements are to be met. There are, however, major uncertainties concerning multiple issues and effects such as water availability, soil quality and impact on protected areas.

The global potential of biomass for energy which could be grown without degrading biodiversity, soils, and water resources depends on agricultural and forest developments and is estimated between 250 and 500 EJ/yr. This potential is comprised of residues from agriculture and forestry (~100 EJ), surplus forest production (~80 EJ), energy crops (~190 EJ) and additional crops due to extra yield increases (~140 EJ). Bioenergy potential, by 2050, with growing population and demand, could contribute between 25% and up to 33% of global energy supply. Figure 2.6 summarizes the situation and explains the terms [2].

Drivers for increased bioenergy use (e.g. policy targets for renewables) can lead to increased demand for biomass, leading to competition for land currently used for food production, and possibly (indirectly) causing sensitive areas to be converted into production. This will require intervention by policy makers, in the form of regulation of bioenergy chains and/or regulation of land use, to ensure sustainable demand and production. Development of appropriate policy requires an

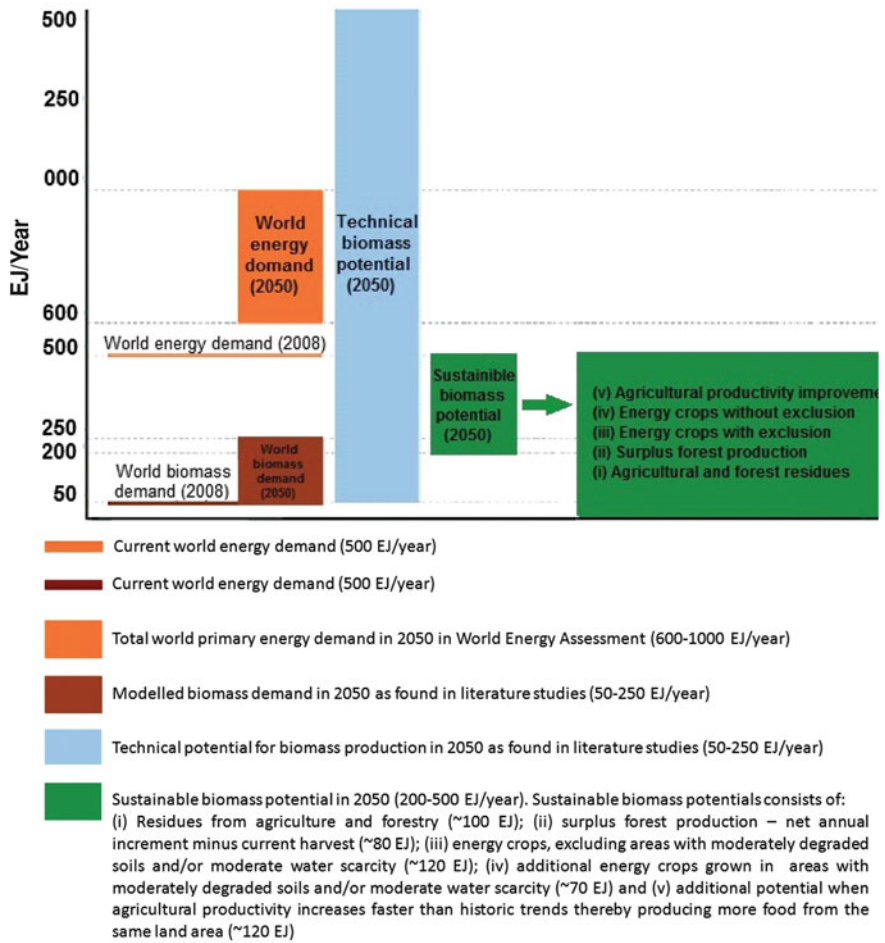


Fig. 2.6 Technical and sustainable biomass supply potentials and expected demand for biomass (primary energy) based on global energy models and expected total world primary energy demand in 2050. *Source* IEA Bioenergy, 2009. Bioenergy—A sustainable and reliable energy source. A review of status and prospects. Main report. IEA Bioenergy: ExCo: 2009.06

understanding of the complex issues involved and international cooperation on measures to promote global sustainable biomass production systems and practices. To achieve the bioenergy potential targets in the longer term, government policies, and industrial efforts need to be directed at increasing biomass yield levels and modernising agriculture in regions such as Africa, the Far East and Latin America, directly increasing global food production and thus the resources available for biomass. This can be achieved by technology development, and by the diffusion of best sustainable agricultural practices. The sustainable use of residues and wastes for bioenergy, which present limited or zero environmental risks, needs to be encouraged and promoted globally [1].

2.3 Waste and Residues: Refuse as Resource

Waste represents an enormous loss of resources both in the form of materials and energy, and imposes economic and environmental costs on society for its collection, treatment and disposal. Indeed, the amount of waste can be seen as an indicator of the material efficiency of society. Excessive quantities of waste result from:

- inefficient production processes;
- low durability of goods;
- unsustainable consumption patterns.

The impact of waste on the environment, resources and human health depends on its quantity and nature. Environmental pressures from the generation and management of waste include: leaching of heavy metals and other toxic compounds from landfills; use of land for landfills; emission of greenhouse gases from landfills and treatment of organic and inorganic waste; air pollution and toxic by-products from incinerators; air and water pollution and secondary waste streams from recycling plants; increased transport with heavy lorries, and so on.

Using organic waste from households and industry (e.g. municipal solid waste of biological origin, black liquor from the pulp and paper industry, etc.) and residues from forestry and agriculture as feedstock minimizes the risk of land use change, and ensures an effective reduction of greenhouse gas emissions.

In addition, the cost of these feedstocks is typically low. Increasing the exploitation of the waste and residues streams that are potentially available should therefore have a high priority in the quest for better use of biomass for bioenergy.

2.3.1 Waste in Europe

There is a limited availability of up-to-date, systematic and consistent data from all over the world; this lack of comparable data for many countries does not allow comprehensive, completely reliable assessment of waste-related issues. The *Sixth Environment Action Programme* (2002–2012)⁴ sets out the EU's key environmental objectives. The programme targets a significant, overall reduction in the volumes of waste generated through waste prevention initiatives and a significant reduction in the quantity of waste going to disposal. It further encourages reuse and aims to reduce the level of hazard, giving preference to recovery and

⁴ The 6th EAP sets out the framework for environmental policy-making in the EU for the period 2002–2012 and outlines actions that need to be taken to achieve them. <http://ec.europa.eu/environment/newprg/intro.htm>

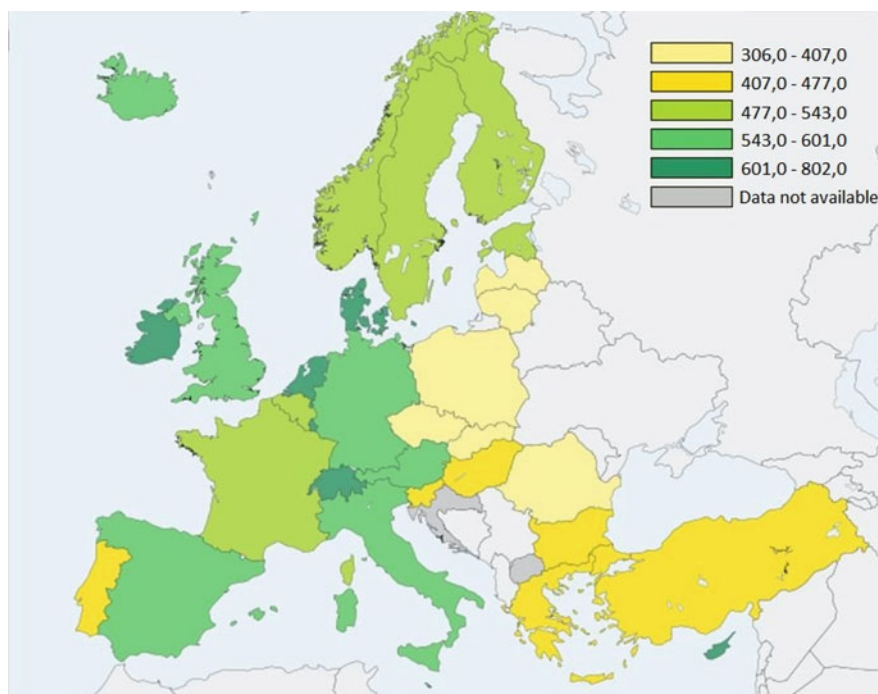


Fig. 2.7 Municipal waste generated in the EU27, kg per capita, 2010. *Source* Eurostat

especially recycling, making waste disposal as safe as possible, and ensuring that waste for disposal is treated as close as possible to its source.

By 2020, at least 50% of waste materials such as paper, glass, metals and plastic from households and possibly from other origins must be recycled or prepared for reuse. The minimum target set for construction and demolition waste is 70% by 2020. In the EU-27,⁵ 524 kg of municipal solid waste was generated per person in 2008: 40% of this waste was landfilled, 20% incinerated, 23% recycled and 17% composted. Figure 2.7 shows the data from Eurostat in 2010.

In 2008, the generation of *municipal solid waste* was estimated to amount to about 290 million tonnes in the EU-27 by 2010 with a further increase to 336 million tonnes by 2020. More than 80% of this waste is generated in the EU-15.⁶ Waste generation per inhabitant has been on the increase for years and the projections show that this will continue till 2020 [6].

⁵ EU-27: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

⁶ EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

Landfilling municipal solid waste has been the predominant option in the EU-27 Member States for several years. In 1995, 62% of municipal solid waste was landfilled on average and in 2008 this had fallen to 40%.

Thirteen countries had either no incineration or incinerated less than 10% of their municipal solid waste in 2007. Eight EU-15 Member States incinerated more than 20% of municipal solid waste. The figures from Eurostat do not indicate whether incineration takes place with or without energy recovery. According to published data, 22% of municipal solid waste generated in 2007 has been recycled and 17% composted [3]. The amount of *biodegradable waste* generated totalled 87.9 million tonnes. Around 67% of this waste was from municipal sources and the remaining 33% was from the food industry and services. 37% of biodegradable waste was recovered but the picture varied across the EU [7].

In Europe the volume of *municipal solid waste* (MSW) treated by *incineration* and used for producing energy is 48.8 million tons for 2006 (the most recent available figure). This treatment produces energy in the form of heat and electricity, but only a portion of the energy recovered from such waste may be considered to be renewable energy: that one related to the organic fraction of the waste. The European Commission has defined a clear hierarchy in waste management. Member States are asked to take appropriate measures to promote: firstly, the prevention or reduction of waste production; secondly, the exploitation of waste recycling, re-use and recovery; thirdly, the use of waste as a source of energy, as is discussed in Sect. 1.3.2 and shown in Fig. 1.7. Therefore incineration remains the last possible means for treating or processing waste before resorting to its storage. According to the Eurostat figures, landfill or storage of MSW is still the predominant treatment method in Europe (41%), followed by recycling and composting (40%) and incineration (19%).

Primary energy production by combustion of municipal solid waste (related to renewable the part) is estimated at 6.1 Mtoe, with corresponding renewable electricity production at almost 14 TWh in 2007. Figure 2.8 shows the distribution in European Countries.

The two forms of energy recovery, electricity and heat, are not used equally across Europe. Countries of Northern Europe recover energy from waste treatment more easily in the form of heat through cogeneration, which is aided by the fact that there are numerous district heating systems in these countries. On the other hand, due to the lack of outlets for heat, countries from Southern Europe prefer to recover energy in the form of electricity [8].

The net greenhouse gas emissions from the management of municipal solid waste are projected to decline from around 55 million tonnes CO₂-equivalents per year in the late 1980s to 10 million tonnes CO₂-equivalents by 2020. In 2005, the greenhouse gas emissions from waste management (including wastewater treatment) represented 2.6% of the total greenhouse gas emissions in the EU-15.

The net greenhouse gas emissions are the sum of the direct emissions (from landfill sites, incineration plants, recycling operations and collection of waste) and indirect emissions. Indirect emissions arise from the energy and secondary materials produced when incinerating and recycling waste replace energy production from

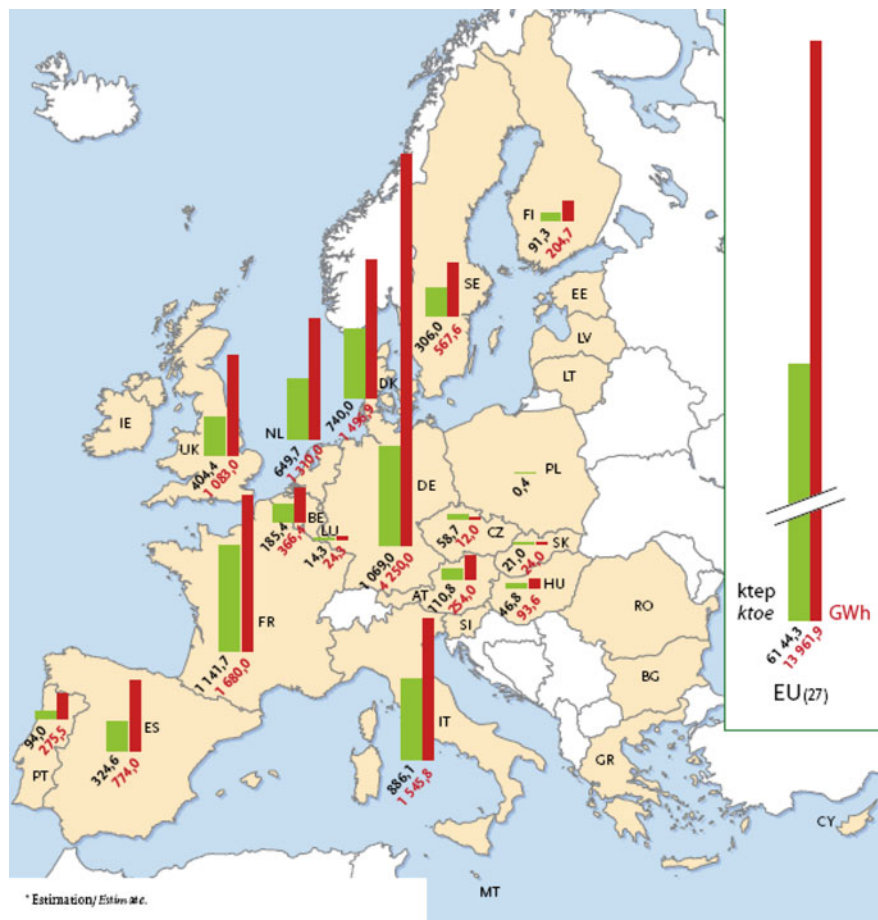


Fig. 2.8 6,144: Primary energy production from renewable municipal solid waste in the EU, 2007 (ktep). 13,962: Gross electricity production from renewable municipal solid waste in the EU, 2007 (GWh). *Source* EurObserv'ER 2009

fossil fuels and the use of raw materials for plastics, paper, metals etc. Indirect emissions also include a minor contribution from landfills, namely the avoided CO₂-emissions when methane is recovered in landfills and used as an energy source, substituting traditional (mostly fossil-fuel based) energy production [6].

2.4 Biomass and Waste Conversion Technologies

The possibility to use residues and waste as a biomass feedstock enables the production of huge quantities of energy and environmental benefits. The availability of biomass feedstock from residues and waste is very large all over the

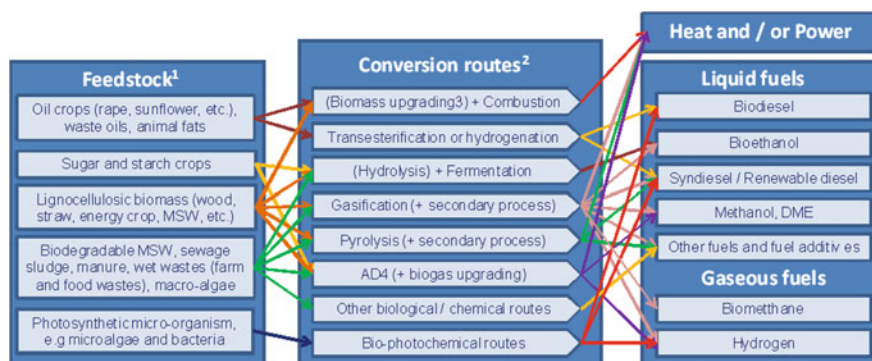


Fig. 2.9 Schematic view of the wide variety of bioenergy routes..Source Source: IEA Bioenergy, 2009. Bioenergy—A sustainable and reliable energy source. A review of status and prospects. Main report. IEA Bioenergy: ExCo: 2009.06

world and does not make use of fertile land and incurs minimal competition with food or feed production. Moreover, because the residues and waste are part of the short carbon cycle, the use of residues and wastes for energy purposes generates minimal extra GHG emission, with generally very low feedstock costs.

The global potential of this type of biomass has been estimated to 40–170 EJ per year, with a mean estimate of 100 EJ. Competing applications and consumption changes may push the net availability for energy applications to the lower end of the range. For comparison, current global primary energy demand is about 500 EJ, and current bioenergy production is about 40 EJ (see Fig. 2.2) [2].

There are many bioenergy routes which can be used to convert raw biomass feedstock into a final energy product (see Fig. 2.9). Several conversion technologies have been developed that are adapted to the different physical nature and chemical composition of the feedstock, and to the energy service required (heat, power, transport fuel).

The production of heat by direct combustion of biomass is the leading bioenergy application throughout the world, and is often cost-competitive with fossil fuel alternatives. For a more energy efficient use of the biomass resource, modern, large-scale heat applications are often combined with electricity production in combined heat and power (CHP) systems.

Different technologies exist or are being developed to produce electricity from biomass. *Co-combustion* (also called co-firing) in coal-based power plants is the most cost-effective use of biomass for power generation. Dedicated biomass combustion plants, including MSW combustion plants, are also in successful commercial operation, and many are industrial or district heating CHP facilities. For sludges, liquids and wet organic materials, *anaerobic digestion* is currently the best-suited option for producing electricity and/or heat from biomass, although its economic case relies heavily on the availability of low cost feedstock.

All these technologies are well established and commercially available. There are only few examples of commercial *gasification* plants, and the deployment of

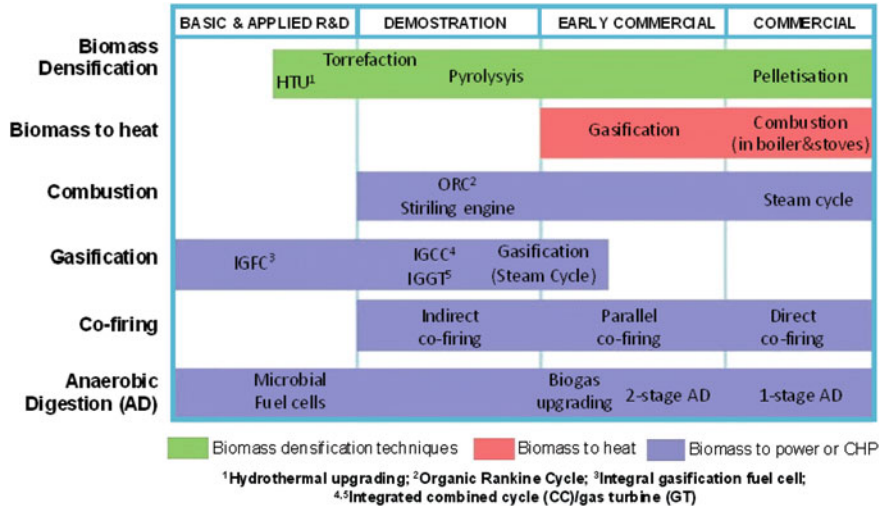


Fig. 2.10 Development status of the main technologies to upgrade biomass and/or to convert it into heat and/or power. *Source* IEA Bioenergy, 2009. Bioenergy—A sustainable and reliable energy source. A review of status and prospects. Main report. IEA Bioenergy: ExCo: 2009.06

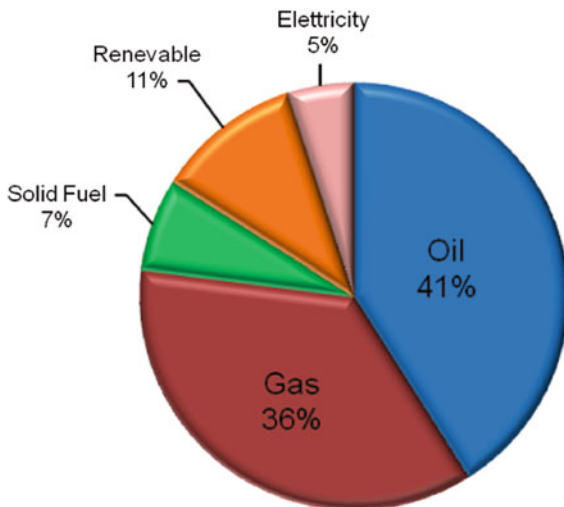
this technology is affected by its complexity and cost. In the longer term, if reliable and cost-effective operation can be more widely demonstrated, gasification promises greater efficiency, better economics at both small and large-scale and lower emissions compared with other biomass-based power generation options. Other technologies (such as *Organic Rankine Cycle* and *Stirling engines*) are currently in the demonstration stage and could prove economically viable in a range of small-scale applications, especially for CHP (see Fig. 2.10).

Although waste and residues feedstock are low-cost, the conversion techniques often are not, especially the ones in development. In the coming decades a lot of research and development is still needed to bring the conversion technologies to maturity and optimize the feedstock logistics to reduce the overall costs of bioenergy and make it more competitive with fossil fuels [1]. This will be discussed in the following section.

2.5 Competitive Costs for Bioenergy

One of the main barriers for biomass use for power generation, CHP and biofuels is the cost of applications, which generally are more expensive than their fossil alternatives. Bioenergy can significantly contribute to environmental and social objectives, such as waste treatment and rural development. Current bioenergy routes that generate heat and electricity from the sustainable use of residues and wastes should be strongly stimulated. Government support and regulations are in

Fig. 2.11 Primary energy supply, 2009. *Source* Elaboration by ENEA of MSE data, 2009



place in many countries to promote biomass use for electricity and heat generation and biofuels, and overcome the additional costs.

However, the literature is not clear about the cost of these government policies, the ranges given are quite large. For example, costs of biofuel policies were recently analysed by the OECD (2008). They conclude that the current biofuel support policies in the US, EU and Canada will cost taxpayers and consumers about US\$ 25 billion on average for the 2013–2017 period (at an assumed oil price of US\$ 90–100 per barrel). In another analysis it has been estimated that the costs of biofuels are relatively low, between 12.5–33.7 Euro/GJ of final energy. Heat production with biomass results in costs of about €45/GJ of final energy, and power generation costs about €11–120/GJ of final energy. According to this study low-cost options in biofuels are biodiesel and ethanol from sugar cane, low-cost options for power generation are co-firing of pellets in coal-fired power stations, and biogas from cheap agricultural residues and manure.

Further development of bioenergy technologies is needed mainly to improve the efficiency, reliability and sustainability of bioenergy chains. In the heat sector, improvement would lead to cleaner, more reliable systems linked to higher quality fuel supplies. In the electricity sector, the development of smaller and more cost-effective electricity or CHP systems could better match local resource availability. In the transport sector, improvements could lead to higher quality and more sustainable biofuels. Ultimately, bioenergy production may increasingly occur in bio-refineries where transport biofuels, power, heat, chemicals and other marketable products could all be co-produced from a mix of biomass feedstocks.

According to IEA Bioenergy (2009), costs of US\$ 3–4/GJ for primary biomass are seen as a threshold to compete with current fossil fuel prices. Use of more expensive biomass requires stringent policies (e.g. regulations) or financial

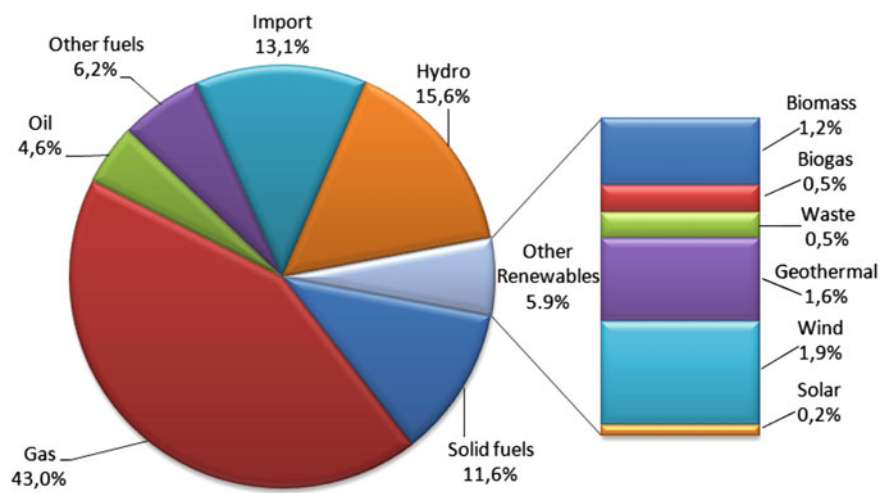


Fig. 2.12 Italian electricity consumption, 2009. *Source* Elaboration by ENEA of TERNA data, 2009

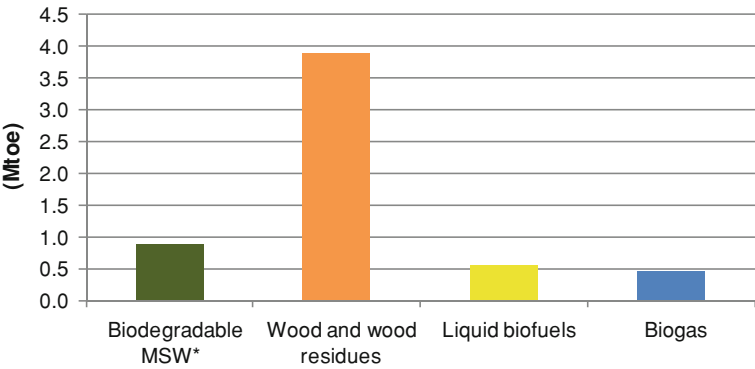


Fig. 2.13 Energy production from biomass in Italy, 2008 (Mtoe). *Source* ENEA—Energy and environment report 2008 [10]. *According to Eurostat the biodegradable amount is 50% of MSW

incentives. This cost level threshold (and therefore the biomass volume that can compete with fossil fuels) increases with higher fossil fuel prices [2].

2.6 Case Study: Energy Potential of Selected Biomass Types in Italy

The primary energy supply for Italy in 2009 was 180 Mtoe, The specific distribution is shown in Fig. 2.11, where renewable sources reached 11% of the total amount. Bioenergy production has been in use for a long time in Italy, although

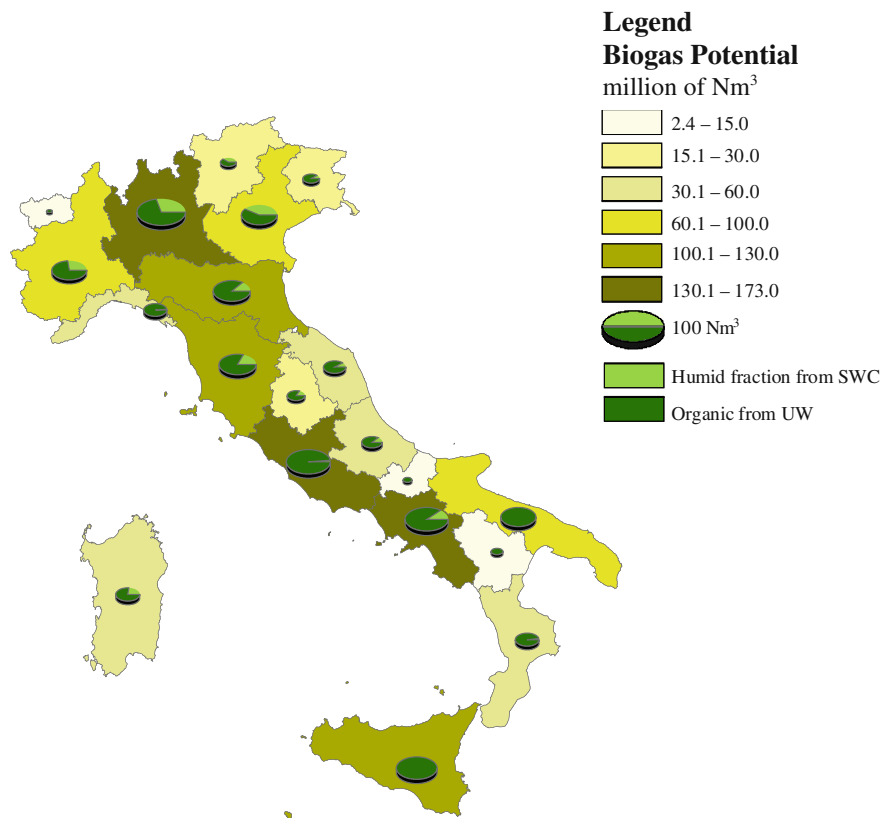


Fig. 2.14 Biogas potential from OFMSW and relative contribution of the humid fraction from separate waste collection (SWC) and residual organic fraction in the undifferentiated waste (UW) per region in 2006. *Source* ENEA-Atlante Nazionale delle Biomasse, 2009

presently, considering biomass, biogas and also the biodegradable amount of MSW (50% of MSW according to Eurostat), it contributes just 2.2% to the final national electricity consumption (see Fig. 2.12).

In general the main end uses of biomass for energy production are domestic heating, heat for industrial processes, biofuels (biodiesel and bioethanol in a small quantity), and finally electric power production in centralized plants from various feedstock such as woody biomass, agricultural and agro-industrial residues, municipal solid waste, biogas from liquid manure, organic fraction of municipal solid waste (OFMSW), dedicated crops (maize, sorghum). The amount of electricity produced from bioenergy (7.6 TWh in 2009) equals 41%

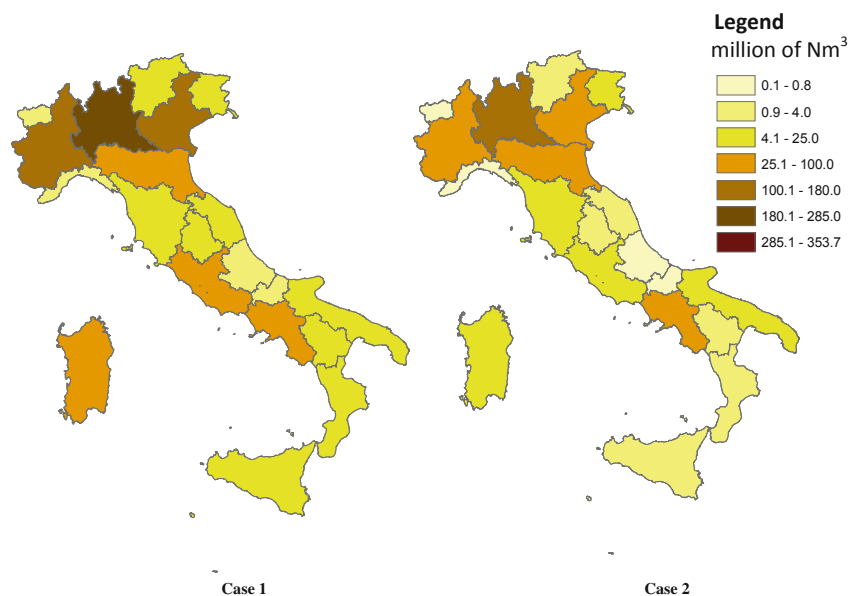


Fig. 2.15 Case 1: over 100 animals; Case 2: over 250 animals. Biogas potential from animal manure of cows and buffalos per region. *Source* ENEA-Atlante Nazionale delle Biomasse, 2009

of the target set for 2020 by the National Renewable Energy Action Plan (18.7 TWh) [9].

The biomass commonly used in Italy for heat and/or electric power production are mainly residue materials, residues and effluents from different sources, although agricultural-forestry dedicated crops (fast-growing poplars, maize and other annual crops for biogas production etc.) are also used. Nevertheless, a significant development of crops for energy production raises the issue of possible competition with food production, requiring a detailed evaluation of each bio-energy chain (see Fig. 2.13) [10].

Considering solid biomass, Italian consumption of primary energy in 2008 was about 1.9 Mtoe, with an electricity output of 2.7 TWh. Energy production by combustion of renewable municipal solid waste is estimated at 886 ktoe, with renewable electricity production at almost 1.5 TWh in 2007. Considering biofuels, the Italian use for transport reached 1.1 Mtoe during 2009, with 3% incorporation rate in overall transport fuel.

The following paragraphs provide a summary of the estimates of biogas potential that could be produced in Italy by some biomass typologies, taking into account only that one with the organic content, as the organic fraction of municipal solid waste and the animal manure. These estimates were derived from information provided by the

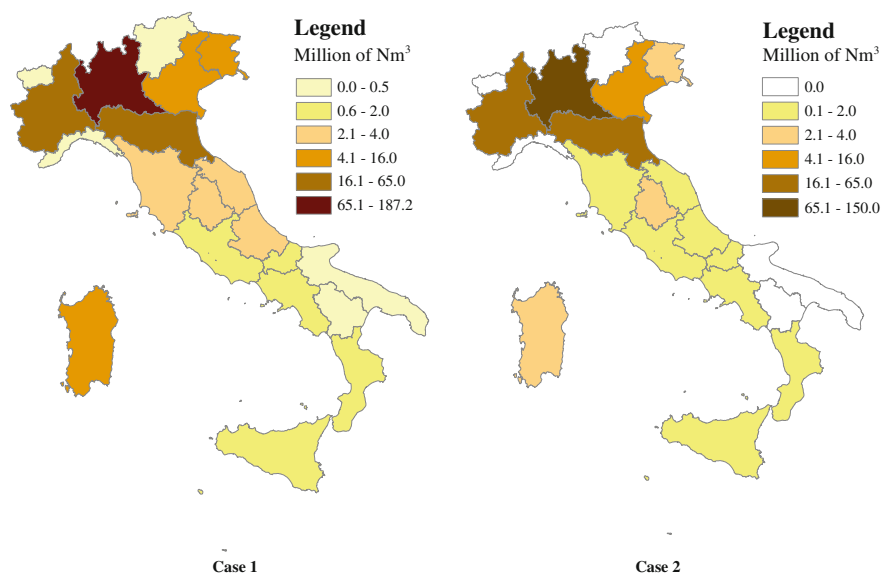


Fig. 2.16 Case 1: all the farms; Case 2: over 2,000 animals. Biogas potential from animal manure of swine per region. Source: ENEA-Atlante Nazionale delle Biomasse, 2009

National biomass Atlas,⁷ implemented by ENEA,⁸ Italian national agency for new technologies, energy and sustainable economic development.

2.6.1 Energy Potential of Organic Fraction of Municipal Solid Waste in Italy

In Italy the target of increasing separate waste collection to 60% in 2011 (Law December 27 2006, n. 296), and at the same time reducing the landfill of biodegradable waste (Dlgs. 36/2003), asks for urgent strategic choices in the management of the organic fraction of municipal solid waste (OFMSW). Currently the management of this fraction in Italy is mainly focused on material recovery through composting and production of fertilizer. The functioning plants (220 in 2007) are mainly located in northern Italy (66%); their frequent overfill hinders separate waste collection in some municipalities, while forcing others to take the

⁷ Census of energy potential of different types of biomass through the implementation of an interactive software platform, operating in GIS, taking into account logistical, geographical and technical economic aspects which concern the energy from biomass. <http://www.atlantebiomasse.enea.it/>

⁸ www.enea.it

organic fraction to plants often located at great distances, with negative effects on costs and the environment. Energy production from biogas based on anaerobic digestion of OFMSW is currently a very promising option for a sustainable management of this type of waste.

According to a recent estimate by ENEA contained in the *National biomass Atlas*, Italy has a huge energy potential that could derive from the anaerobic digestion of the organic fraction in municipal waste [11].

This energy potential was about 1.330 millions Nm^3 of biogas in 2006 [12], considering not only the organic fraction of municipal solid waste from separate waste collection, but also the residual fraction from undifferentiated waste, to be potentially recovered or otherwise destined to be landfilled.

The areas with higher potential are the Lombardia, Lazio and Campania regions (see Fig. 2.14) and which, in relation to a higher number of residents, show the highest production of MSW.

The Lombardia Region has the highest potential from the humid fraction, followed by the Veneto and Piemonte regions, in relation to the highest levels of separate waste collection in Italy (more than 40%). The increase of separate waste collection envisaged by law will imply for the following years: an increase in the humid fraction collected, a higher relative potential linked to the production of a purer biogas (due to the use of pre-selected material with a higher quality), and the production of a digestate with better qualities for agricultural purposes.

The biogas potential showed in this study by ENEA is a gross potential, since its estimate does not take into account either the amount of OFMSW treated in existing composting plants or the residual organic fraction of the undifferentiated waste, stabilized in mechanical–biological treatment plants.

2.6.2 Energy Potential of Animal Manure in Italy

In recent years increasing awareness that anaerobic digesters can help control waste odor and disposal has stimulated renewed interest in the technology. The application of anaerobic digesters in the treatment of wastewater and animal manure has become commonplace, being a very promising option for a sustainable management of this type of residues.

Energy potential has been estimated looking to the farm sector, for cow and swine.

According to a recent estimate by ENEA contained in the *National Biomass Atlas*, Italy has a huge energy potential that could derive from the anaerobic digestion of animal manure [11].

The biogas potential from anaerobic digestion of manure from cows and buffalos, calculated in the *National Biomass Atlas*, is about 1,480 millions of Nm^3 in 2006. The areas with the highest potential (more than 100 million of Nm^3) are Lombardia, Piemonte, Veneto and Emilia Romagna regions. The biogas potential has been calculated taking into account two different cases: the first one considering all the

farms with over 100 animals, and the second one considering all the farms with over 250 animals. Figure 2.15 shows the difference between the two cases. The selected feedstock can include only animal manures as a single input, or also agricultural crops, food residues, sewage sludge, municipal solid waste, etc., as a mixture of more feedstock types, in the so termed co-digestion process.

The biogas potential from anaerobic digestion of manure from swine, calculated in the *National Biomass Atlas*, is about 345 millions of Nm^3 in 2008. The areas with the highest potential (more than 100 million of Nm^3) are the Lombardia, Piemonte, and Emilia Romagna regions.

As before, the biogas potential has been calculated taking into account two different cases: the first one considering all the farms, and the second one considering all the farms with over 2,000 animals. The Fig. 2.16 shows the difference between the two cases. The threshold of 2,000 animals represents the minimum condition to realize a feasible anaerobic digestion plant integrated with the CHP unit [12].

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