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01-02: Introduction to herbaceous biomass

The rise of agricultural practices around 10,000 years ago was one of the most important stepping stones in the development of the human civilization. The adoption of agriculture resulted in the production of sufficient quantities of high-carbohydrate crops (wheat, rice potatoes, etc), which allowed for sedentary settlements to appear and for rapid population increases, the production of fiber crops (e.g. flax, cotton) that allowed greater living comforts or animal feed, which allowed for the upkeep of animals in confined spaces.

The link of agriculture and its non-woody products (or by-products) with the production of energy is however a more recent development. Wood, mostly from forests or from agriculture, was - and in some sense, still remains – the prefered solid biomass fuel for humanity. Non-woody solid fuels for energy production were much more rare and used only when wood resources were unavailable. Liquid biofuels from agricultural products were historically used in some specialized applications (e.g. plant or animal oils in lamps) and it is worth noting that some of the first diesel engines were designed to burn plant oils. During the Second World War, difficulties in securing oil for the war effort and the economy resulted in several initiatives that promoted the production of liquid biofuels from various agricultural products. However, after the war, cheap oil from the Middle East displaced such efforts and energy from agricultural biomass became again something found mostly in undeveloped countries.

In more recent years and as a results of repeated energy crises in the 1970s as well as of policies that attempt to mitigate the perceived anthropogenic causes of climate change, interest in all forms of renewable energy has soared. Herbaceous biomass is considered as especially important since it can be used not only for the direct production of electricity or heat, but also for the production of liquid biofuels – which, at least until electrical or hydrogen-fueled cars are commerciallized, is the one of the few options for a carbon neutral transport sector.

On the other hand, the introduction of herbaceous biomass resources in the energy system has raised severe concerns regarding the overall sustainability of such practices. For example, the use of agricultural-derived biomass for the production of biofuels has raised in several cases the issue of ”food vs fuel” and is one of the most controversial aspects of renewable energy today.

The purpose of this Chapter is to provide a first introduction in herbaceous biomass resources. The following major topics are introduced:

- What are the major types of herbaceous biomass resources, their key properties and their intended end-uses?
- What do studies foresee as the expected role of herbaceous biomass in the energy sector of the coming years?

- What are the key points to consider when examining the sustainability of energy-production from herbaceous biomass?

Different aspects of key issues to be considered by a system planner focusing on herbaceous biomass resources are covered in more detail by the other chapters of Row 2 of the BISYPLAN Handbook. Thus, the question of how to estimate or what parameters to consider in the evaluation of the available or potential herbaceous biomass resources in an area is handled in Chapter 02-02. Chapter 03-02 focuses on the issue of herbaceous biomass supply chains, Chapter 04-02 is providing insight on the properties of herbaceous biomass and the conversion technologies available for them, while Chapter 05-02 focuses on the economics of herbaceous biomass.

01-02-01: Introduction to types, key properties and end-uses of herbaceous biomass

01-02-01a: Definition of herbaceous biomass

The European Standard EN 14961-1 (Solid biofuels — Fuel specifications and classes Part 1: General requirements) distinguishes four categories of solid biofuels (woody, herbaceous, fruit and blends/mixtures) and provides the following definition for herbaceous biomass:

"Herbaceous biomass is from plants that have a non-woody stem and which die back at the end of the growing season. It includes grains or seeds crops from food processing industry and their by-products such as cereal straw."

According to their origin and the parts of the plant used, EN 14961-1 provides a detailed classification of herbaceous biomass, such as that seen in Table 01-02 1.

2.1.1 Cereal crops	2.1.1.1 Whole plant
	2.1.1.2 Straw parts
	2.1.1.3 Grains or seeds
	2.1.1.4 Husks or shells
	2.1.1.5 Blends and mixtures
2.1.2 Grasses	2.1.2.1 Whole plant
	2.1.2.2 Straw parts
	2.1.2.3 Seeds
	2.1.2.4 Shells
	2.1.2.5 Blends and mixtures

2.1.3 Oil seed crops	2.1.3.1 Whole plant
	2.1.3.2 Stalks and leaves
	2.1.3.3 Seeds
	2.1.3.4 Husks or shells
	2.1.3.5 Blends and mixtures
2.1.4 Root crops	2.1.4.1 Whole plant
	2.1.4.2 Stalks and leaves
	2.1.4.3 Root
	2.1.4.4 Blends and mixtures
2.1.5 Legume crops	2.1.5.1 Whole plant
	2.1.5.2 Stalks and leaves
	2.1.5.3 Fruit
	2.1.5.4 Pods
	2.1.5.5 Blends and mixtures
2.1.6 Flowers	2.1.6.1 Whole plant
	2.1.6.2 Stalks and leaves
	2.1.6.3 Seeds
	2.1.6.4 Blends and mixtures
2.1.7 Segregated herbaceous biomass from gardens, parks, roadside maintenance, vineyards, and fruit orchards	
2.1.8 Blends and mixtures	

Table 01-02 1: Classification of herbaceous biomass from agriculture and horticulture according to EN 14961-1. A similar classification exists for the by-products and residues of the herbaceous processing industry.

01-02-01b: Main sources of herbaceous biomass

One can easily understand that, from the definition and the above table, herbaceous biomass covers a wide range of materials that are associated mostly with agriculture, horticulture and various processing industries.

A more limited classification of the potential sources, but better suited to the purposes of the Handbook, is the categorization of herbaceous biomass to the following three categories:

Energy crops. These are plants and grasses grown by farmers specifically for use in the bioenergy sector. Currently, the most common application is the cultivation of oil and/or starch seed crops, the seeds of which are used for the production of liquid biofuels (biodiesel and bioethanol). Wheat and maize ethanol, as well as rapeseed and sunflower biodiesel are the best known examples of energy carriers produced from herbaceous biomass raw materials. The practice is also known as the production of *1st generation biofuels*. The idea behind the cultivation of such crops is that it is relatively easy to produce a liquid biofuel from a seed rich in oil/starch. On the other hand, such feedstock can also be used for the production of food, and therefore is seen in a negative light when it comes to sustainability.

Other types of herbaceous energy crops are characterized as “lingo-cellulosic” – the oil/starch content is minimal but they are rich in cellulose, hemicellulose and lignin and can be used directly for heat and/or power production or for the production of *2nd generation biofuels* – a more difficult process compared to 1st generation biofuels but one that raises less concerns over sustainability issues.

More information on the types of energy crops can be found in section 02-02-02a.

Residues, mostly agricultural residues. These are the on-field by-products of the production of food, fibre or feed crops. Straw from cereals and rice, maize residues, stalks and leaves from oil seed crops are included in the category.

Agricultural residues are used in some cases as solid biofuels for the production of heat and/or power. They can also be used as feedstock for the production of *2nd generation biofuels* – with the same difficulties as the lingo-cellulosic energy crops. In some cases, they have alternative uses, such as animal feed, which may limit their use in the bioenergy sector.

More information on agricultural residues can be found in 02-02-01.

Agro-industrial residues. These are the by-products or residues from processing industries, mostly from the food and fibber sector. Strictly speaking, some of these materials may not be categorized as “herbaceous biomass” according to EN 14961-1 but rather as “fruit biomass”.

Generally, agro-industrial residues exhibit good combustion properties and are widely utilized as heating fuels for the needs of the industry that produces them or in households. Other uses can also be considered. They differ from the other two categories not only in terms of properties but also because they can be collected at a specific point instead of a wide field. More information on these residues is available on section 02-02-03.

The same crop may provide biomass as an energy crop in whole or in part or only as a residue, with the main product being used for other purposes. Figure 01-01 1 illustrates a typical example in the case for corn, but the same can be said for wheat, rice and other crops.

Figure 01-02 1: Different possibilities of using biomass from maize: bioethanol from corn grain, a 1st generation biofuel (top left, source: http://www.makebiofuel.co.uk), maize residues left on the field after harvesting of grain, a potential fuel for thermal processes or feedstock for 2nd generation biofuels (top right, source: http://www.angusbeefbulletin.com/), harvesting of the whole maize plant to be used as substrate for biogas production (bottom, source: Ralph Orlowski/Getty Images Europe).

01-02-01c: Herbaceous biomass: tradable forms

Both energy crops and agricultural residues are produced in the field and need to be harvested/extracted from there, before being used in an energy plant. Depending on whether it is a residue or a main product, herbaceous biomass is harvested either as the whole plant or as part of the plant (e.g. direct harvesting of seeds, harvesting of remaining standing plant or harvesting of materials lying on the ground). With the exception of grain harvesting, which is identical to the harvesting practice for food production, herbaceous biomass in the fuel chain is typically found in one of the following three forms: chopped, baled or pellets.

A **chopped** material can be achieved by harvesting the residue or the crop with appropriate machinery, such as a forage harvester. More information can be found in section 03-02-01a. Due to the low density of the material, it is not commonly used in bioenergy systems, with the main exception of harvesting silage for biogas production.

Bales are currently the most common form of herbaceous biomass in bioenergy applications. They are produced with the use of appropriate equipment and come in a variety of sizes and dimensions – for bioenergy systems, the most common form are large square bales with dimensions of 120 x 130 x 240 cm and a density around 150 kg/m^3. Baled herbaceous biomass is usually somewhat denser compared to the chopped material; its main advantage though is the ease of handling during several steps of the supply chain – some can even be performed with little manual labour. More information on how to produce bales can be found in section 03-02-01b.

Pellets are small, cylindrical pieces of densified biomass with typical diameters in the range of 6 – 8 mm and a length up to 40 mm. Their bulk density is to 600 – 650 kg/m^3, about 4 times higher than that of baled biomass, which allows for even more economic transort and reduced storage area requirements. Pelletization is however an energy-intensive process and is not so widespread for herbaceous biomass as with woody biomass. Pellets can be produced by dedicated equipment on the field (03-02-01c), but by far the most common solution is to produce in pellet plants, where the herbaceous biomass is brought in baled form (03-02-07).

The form of agro-industrial residues differs depending on the process or the raw material but they are most often **husks, shells or kernels**. The material is mostly used as it is, although it is also possible to produce pellets.

Figure 01-02 2 presents the different forms of herbaceous biomass along the fuel supply chain. The form of the fuel and its characteristics, the most important of which is the energy density, along with the process requirements determine the different steps of the supply chain. Herbaceous biomass logistics are considered in detail in Chapter 03-02.

Figure 01-02 2: Common forms of herbaceous biomass along the fuel chain: chopped straw (top left, source: http://www.ukagriculture.com), straw bale, top right, straw pellets (below left, source: CERTH), rice husks (below right, source: Wikipedia).

01-02-01d: Herbaceous biomass: properties and processes

Herbaceous biomass can be a very flexible feedstock and can be considered for practically all conversion technologies and for the production of all energy carriers (liquid and gaseous biofuels, heat, power). However, the following main issues need to be considered:

- Most types of herbaceous biomass contain a greater percentage of hemicellulose and cellulose compared to lignin. The positive side of this is that, since hemicellulose and cellulose are relatively easier to digest and/or ferment compared to lignin (although a pre-processing step is generally required), herbaceous biomass is a better candidate for the production of liquid and gaseous biofuels with biochemical processes compared to woody biomass. The negative side is that the heating value of the fuel is lower compared to woody biomass and this affects its combustion as well as the economics of the supply chain.
- Due to the quicker growth rate of herbaceous plants compared to trees, herbaceous biomass tends to accumulate higher contents of elements and materials that can be

problematic for several conversion technologies or that have a negative environmental impact when they are released back to the environment after combustion. The most typical case would be the high chlorine and ash content of herbaceous biomass and its impact on thermal processes.

The following table summarizes the current state of the art for different conversion technologies and their potential applicability for herbaceous biomass. More detailed presentations of the process properties of herbaceous biomass and each conversion technology are presented in Chapter 04-02 – further information can also be found in the Fuel Analysis, the Fuel Behaviour and Ash Appendix. Generally, herbaceous biomass is a more challenging fuel compared to woody biomass but its wide range of possible applications ensures that it will play a major role in the development of bioenergy in the coming years, as will be seen in the following section.

	Deployment Status	Main Advantages	Important Issues
Thermal processes			
Combustion – domestic scale	Commercial	Well-known and proven technology; Well-fitted to heating needs of farming communities;	Usually Corrosion issues; Emissions may be high; High ash content means higher cleaning frequency – less comfort or users;
Combustion – large scale	Commercial	Well-known and proven technology; CHP possible; Large-scale systems better equipped to deal with ash related problems and to clean flue gases;	Ash causes problems during the process; Ash utilization routes not always clear;
Gasification	Semi-industrial	Production of a very flexible energy carrier (gaseous fuel);	Ash causes problems during the process; Gas cleaning problematic;
Pyrolysis	Semi-industrial	Production of a variety of energy carriers (solid, liquid, gaseous fuels);	Ash causes problems during the process; Ash remains in solid products and causes problems during combustion;
Biochemical processes			
Fermentation	Commercial (1st generation biofuels) Semi-industrial / close to commercial (2nd generation biofuels)	Production of a very flexible and valuable energy carrier (liquid biofuel); High moisture feedstock can be used;	Pre-treatment of the fuel for breakdown of organic structure may be required; Technical solutions under development;
Digestion	Commercial	Production of a very flexible energy carrier (gaseous fuel); High moisture feedstock can be used;	Pre-treatment of the fuel for breakdown of organic structure may be required;

Table 01-02 1: Overview of current status of herbaceous biomass conversion technologies.

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01-02-02: Herbaceous biomass – its role in Europe and the world

Although wood – in its different forms and sources – is currently the most widespread biomass resource, herbaceous biomass is expected to play an increasingly important part in the future. There are three main reasons for this:

- Global demand for bioenergy is expected to increase considerably as a result of policy decisions and increasing fossil fuel prices.
- Wood resources are limited and there is more competition for their use – not only as high quality biomass fuels, but also for the wood industry, paper and pulp production, etc.
- Herbaceous biomass resources can be used for the production of different energy carriers, from liquid and gaseous biofuels to heat and power.

The estimations of the future role of herbaceous biomass in energy supply differ depending on the assumptions of each study: which resources are sustainable, what policy measures will be implemented, what will be the level of technology development for 2nd generation biofuels, etc. Some indicative figures from studies are presented below.

Within the EU energy co-operation AEBIOM there is a working group specialised in biomass, i.e. “the biomass technology panel”. The publications include strategic plans and scenarios and can be found at http://www.rhc-platform.org/publications/. Excerpts from these reports are presented in table 02-02 1 below.

		2007		2020		2030		2050	
		Surface [Mha]	Biomass [Mtoe]	Surface [Mha]	Biomass [Mtoe]	Surface [Mha]	Biomass [Mtoe]	Surface [Mha]	Biomass [Mtoe]
Agriculture	Energy crops	5.2	10	20	43	25	75	30	129
	By-products		4		20		30		30
	Other						5		15
Forestry	Residues		18		40		55		55
	Industry by-products		54		65		65		66
Waste			10		32		40		35
Imports			2		20		30		40
Total		5.2	98	20	220	25	300	30	370

Table 02-02 1: Expectations of biomass supply in the EU (Source: Biomass Panel, ETP-RHC)

The global bioenergy technical potential, as estimated by the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation data, Chapter 2: Bioenergy suggests that agricultural resources have by far the largest potential: 15 – 70 EJ/yr from agricultural residues, 0 – 700 EJ/yr from energy crops on arable land and 0 – 110 EJ/yr from energy crops on marginal lands compared to 0 – 110 EJ/yr for forest biomass (see also Table Table 02-00 1).

On the basis of IPCC data and own calculations, the IEA Technology Roadmap for Bioenergy for Heat and Power suggests that by 2050 biomass demand will grow to 100 EJ for the production of heat and power, in addition to 60 EJ for production of transport fuels, essentially a doubling of the current use of biomass (50 EJ in 2009). This additional capacity should be mobilized with a primary focus on "available" feedstocks such as residues and wastes, but will also need to include energy crops.

Such changes on a global or European level can be achieved in part not only through national efforts but also through local and regional initiatives. For a system planner, this raises the issue of identifying herbaceous biomass resources and finding means of connecting the production (or the by-products) of the agricultural sector with bioenergy applications.

01-02-03: Sustainability issues with herbaceous biomass

When considering the sustainability of any type of biomass resource, including herbaceous biomass, it is typical to follow what is commonly known as the three pillar approach (which was introduced in Chapter 01-00): the environmental, social and economic sustainability must be demonstrated.

The environmental sustainability is the first and foremost concern, since the reduction of greenhouse gas emissions is the primary policy goal behind the use of biofuels. However, for a bioenergy project to be truly of benefit to local communities, a positive social impact should be maintained – and, as always, the economics need to be considered.

Since herbaceous biomass is produced mostly through agricultural activities, the question of whether the production and use of such materials is sustainable leads inevitably to questions on the sustainability of the agricultural sector and the impact of certain of its practices. This subject is too broad to be discussed here in all its details; however certain points on the sustainability of herbaceous biomass for energy applications will be made on the paragraphs below.

01-02-03a: Environmental sustainability

Securing the environmental sustainability of biomass resources should be the top priority for any bioenergy system – otherwise, they cannot justify the policy support they receive and would only be a poor substitute for fossil fuel systems.

The first concern is to demonstrate that the use of a biofuels actually results in reduced greenhouse gas (GHG) emissions over the fossil fuel alternatives. The GHG emissions from the combustion of biomass are actually considered as zero, since the carbon dioxide released is thought to be returning to the natural carbon loop (see 01-00-02b). However, fossil fuels are used throughout the value chains of biofuels, mostly for cultivation and harvesting and for transporting, but also for the energy needs of conversion and densification processes (for example for the production of liquid biofuels or densified products). These GHG emissions from these activities comprise the direct emissions of the biofuel lifecycle. Direct emissions may not result only from fossil fuel use but also from chemical fertilizers. Direct emissions are fairly easy to measure, by keeping track of the inputs along the fuel value chain.

Indirect emissions are caused by land-use changes - for example, converting a forest area into agricultural land releases considerable quantities of stored carbon in the atmosphere, which is not returned to the natural loop, since the type of vegetation changes. Land-use changes are less easy to define but certain certification schemes for biofuels currently used in Europe require certain land-use criteria before a material can be qualified as sustainable biomass and be eligible for support or be counted towards a country's targets.

Both direct and indirect emissions comprise what is commonly called as the "carbon footprint" of the fuel. The EU has set guidelines for "sustainability criteria" based on calculating and verifying GHG emissions savings. This is compulsory for liquid biofuels (see the Renewable Energy Directive 2009/28/EC – commonly known as "RED") and a GHG emissions savings of at least 35%, rising to 50% after 2017 must be demonstrated. For solid and gaseous biofuels, the European Commission has issued recommended guidelines for member-states that wish to adopt sustainability criteria (see (COM2010) 11 - Report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling); the guidelines are not compulsory and each member states has different policies on the subject. It should be noted that biomass production from the agricultural sector in the EU must also comply with the environmental requirements of the Common Agricultural Policy.

Generally, for raw materials produced in Europe without any land use changes, the GHG emissions savings are very high in the case of heat and/or power production – typically over 80% - compared to fossil fuel alternatives. For the production of liquid biofuels, the savings are generally lower, since the processes required for producing liquid biofuels are quite energy-consuming. The exact values depend also on the feedstock type (residues result in higher savings than the use of seeds) and the process technology, including the fuel used. For example, typical GHG savings from the production of ethanol from wheat is only 47% if the process fuel is natural gas in a CHP plant compared to 69% if the process energy is supplied by burning straw in a CHP plant; the estimated savings rise to 85% if the feedstock changes to straw.

Apart from GHG emissions, there are certain other environmental aspects that need to be considered in the case of herbaceous biomass resources. Since the economies of scale favor larger rather than smaller units, in order to produce fuel for a sufficiently large unit large areas of land may be converted to the cultivation of a single or a limited number of crops. These large monocultures negatively affect an area's biodiversity and can often be a key issue for public acceptance (see 01-02-04b). The irrigation requirements, as well as the need for other inputs, that certain energy crops require for achieving profitable yields also poses additional environmental strains on a given area. These two issues are also relevant for the agricultural sector in general.

An environmental issue that is particular to bioenergy is the other, non-GHG, types of emissions that result from biomass combustion, such as dust, NO_x and SO_x emissions. See the Fuel Behavior Appendix for more information on such emissions. It should be noted though that many agricultural residues are actually combusted on the field without any form of energy recovery and with significant pollutant emissions – bioenergy applications are definitely an improvement over such practices. The need to maintain the levels of the organic carbon in the soil is another environmental considerations that needs to be considered when extracting herbaceous biomass residues – see section 02-02-01b for more details.

01-02-03b: Social sustainability

The social sustainability pillar refers to the ability of a bioenergy project to fulfill a crucial societal need, e.g. energy supply, without compromising other critical demands, such as food supply. It also concerns the possible contribution of a bioenergy project to regional and national development. Social sustainability is not easily quantified and remains one of the most disputed aspects of projects based on agricultural biomass.

The "food vs. fuel" debate is the main point associated with social sustainability issues. This is a concern mostly for energy crops, which compete with food crops over limited land resources. For example, the increased use of corn for the production of liquid biofuels has been credited with an increase in the corn prices, which directly affect the livelihood of billions of people in the undeveloped world.

On the other hand, it has been argued that the cultivation of energy crops offer a possibility for poorer crop growers to raise their incomes and thus their livelihood by benefitting for the higher prices that their produced biomass can fetch in the energy market.

The future potential of energy crops in meeting the global bioenergy demand is varying widely from study to study depending on different assumptions (see section 02-02-02c on the future role of energy crops in the EU). Generally, the use of marginal lands for energy crops is considered as a more promising option compared to the use of prime arable land; however, the yields achieved in these lands may not be sufficient for the economic production of energy crops.

Given that the local/regional food demand in Europe is currently not met only by domestic production, it is not expected of a system planner to foresee and take into account all issues related to the "food vs. fuel" debate. The general policy direction and decisions are taken on a national or European level – however, it is generally a good practice to give priority to herbaceous biomass resources, such as residues, that have limited impact on the more delicate food supply.

On the other hand, there is another aspect of social sustainability which system planners can quantify more easily and which is generally positive for herbaceous biomass – that of job creation. A bioenergy project based on herbaceous biomass can create new jobs in all stages of the fuel value chain:

- Directly in the agricultural sector, through the number of people required for cultivating and/or extracting the biomass. The number of jobs created may be limited if the resource is a residue, but new opportunities arise if marginal or previously uncultivated land is used to grow energy crops.
- In the fuel logistics, through the number of people required for transporting, storing, densifying, etc the resource. The set-up of a biomass supply chain is one of the most important causes for regional job creation.
- In the energy plant. The number of people employed varies on the technology adopted. For domestic heating applications, the jobs created relate mostly to installation and periodic maintenance but not operation. For larger units, there is growing need for operators as the unit size increases. This is an important difference of bioenergy systems compared to other renewable energy technologies, which require only limited personnel for maintenance and administration.

Finally, social acceptance is of paramount importance for a bioenergy project to go through. The level of social acceptance depends on several factors, one of which is the fuel source: agricultural residues and energy crops are generally more "acceptable" compared to agro-industrial residues, which are often thought of as harmful waste. The size of the unit and its impact on people's lives is also important – the larger the unit the greater the difficulty in securing public acceptance. Acceptance is also not a static thing – it may change during a project's lifetime depending on its yearly results. If a project performs poorly compared to "advertisements" for job creation, income generation or environmental performance or if it is found to be not so robust in terms of changing conditions (e.g. fuel deficiencies due to bad weather conditions), it may lose quickly the support of the public. Thus, social acceptable should be considered by all system planners before embarking on a bioenergy project.

01-02-03c: Economic sustainability

The economic part of sustainability is probably the one that is easier to quantify and can be understood by everyone – in the end, only projects that are profitable for all involved parties will be realized or will continue. For the major parties of any project:

- The farmers or contractors that supply the biomass should be offered a reasonable fuel price that covers the costs of cultivation (for the case of energy crops) and harvesting/extraction.
- The logistics companies should at least cover the costs for transporting, handling, densification, storage, etc

- The energy plant should have such revenues so as to cover the cost of investment, personnel, maintenance, insurance, etc.
- Finally, the energy consumers should pay a reasonable price for the final energy carrier, comparable to other alternatives.

The starting point of course is the field – and here it should be stressed that it can be quite costly to harvest and collect the biomass, hence the fuel cost is one of the most important characteristics of an herbaceous biomass system. This increased fuel cost is one of the most important differentiations between bioenergy systems and other RES (where there is no fuel cost).

On the other hand, it is one the level of the final consumer that the project is assessed – if the cost of the energy carrier is lower than that of conventional solutions, then it is economically viable. If not, then some sort of subsidy or support is required. Bioenergy systems are often associated with some type of subsidy, which could lead to the impression that they can never be profitable from a market point of view. Whether a form of economic support or subsidy is actually required depends on the form of the energy carrier that is produced.

For example, heat production from biomass – including herbaceous biomass – can be achieved with a minimal of economic support, since the biomass fuel cost is actually lower than that of the main fossil fuel alternatives used in Europe: natural gas and heating diesel. In addition, heat markets tend to differ considerably depending on local conditions, thus leading to customizations of the support scheme. In most cases, the economic support – if any – takes the form of subsidizing wholly or in part the retrofitting or replacement of a fossil fuel boiler, since this can be a significant investment on the part of a household or a community. However, the heat produced is rarely subsidized directly.

On the other hand, when it comes to producing electricity, there are cheaper fossil fuel alternatives, such as coal. Other more expensive fossil fuels, such as natural gas, are also popular choices, in part due to technical reasons (e.g. quick speed of start-up and load change), environmental reasons (lower GHG emissions compared to coal) and economic reasons (lower investment cost, lower maintenance cost) and can still lead to electricity prices lower than that generated by biomass. The development of the European Trading System for carbon dioxide emissions from industrial sources has narrowed the gap between the electricity from fossil fuels and biomass, however, under current market prices of CO_2, additional support is needed and the standard practice is to provide certain incentives for the electricity production from biomass, such as feed-in tariffs or green certificates (see Chapter 05-00).

Liquid biofuels are in most cases intended to be used in the same engines as their fossil fuel counterparts – hence, the direct comparison of the fuel cost provides an assessment of the economic sustainability. The price of liquid fossil fuels often exhibits great variations and is, as has been noted, one of the main reasons for the interest in the production of liquid biofuels. However, the gap is usually not directly bridged and certain support measures are needed, e.g. tax incentives or credits. The introduction of a “carbon tax” on fossil fuels in certain countries is also contributing to make liquid biofuels – and biofuels in general – more competitive.

In the previous cases, the financial support on the energy carrier is transferred in part back to the biomass producer (e.g. the farmer) and is used to cover its production cost. Other forms of support target directly the farmers, e.g. subsidies for the production of energy crops.

It should be noted that a trend that has been observed in several EU countries is that legislation actually favors or contributes to the utilization of agricultural biomass resources, for example by providing higher level of support for such types of biomass or by setting obligatory quotas that energy producers have to meet.

Overall, the support policy for bioenergy is decided on a national level basis and is justified by certain boundary conditions (e.g. EU-targets for RES production and emissions reduction) or policies aiming for regional development and minimization of fossil fuel imports. Local/regional system planners should obviously take the support policy scheme into account when investing the economic viability of a project. However, given the current economic conditions in Europe and the cut-down of support schemes in certain cases, it is wise to investigate the sensitivity of a bioenergy project to changes in the level of the support schemes.

More detailed information on the financial evaluation and economics of a bioenergy project can be found in Chapter 05-00 and Chapter 05-02 for herbaceous biomass in particular.

01-02-04: Planning aspects

Herbaceous biomass can come from a variety of sources – essentially, if there is an agricultural sector in a given area, it is expected that there will be some type of herbaceous biomass that can be used for energy production.

The present chapter has presented a short introduction on the types, tradable forms and properties and processes of herbaceous biomass. Essential planning aspects are discussed in the respective chapters – this section devotes the planning aspect to the more general but extremely important question: is it sustainable to use herbaceous biomass, especially energy crops?

The answer is not always straightforward – the issue of sustainability has global dimensions, while the system planner has to operate within the limits of a region or local area and under specific national and European conditions. Generally though, the following points should be considered:

- A good knowledge of current legislation is indispensable; EU regulation and sometimes national legislations are quite advanced in terms of environmental protection. Certain agricultural practices, such as open-field burning of residues or

extensive use of fertilizers may be prohibited under current laws and provide a framework for the development of the ties between the agricultural sector and the bioenergy sector.
- A common sense in the scale of the projects is also required. Large monocultures are bound to have more significant social and environmental repercussions than limited cultivations.
- Social acceptance is required; positive impact on all aspects of sustainability will have to be demonstrated to the public.
- Financial support and subsidies are common for most types of bioenergy projects; in the long run though, there must be plans to reduce the level of dependence of the viability of a project on them.

References

The importance of herbaceous biomass for the future of bioenergy is documented in several publications, such as:

- Strategic Research Priorities for Biomass Technology
- IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation data, Chapter 2: Bioenergy
- IEA Technology Roadmap for Bioenergy for Heat and Power

The above publications also include discussions on sustainability issues.

For further sources, the reader is referred to the Reference section of Chapter 02-02, 03-02 and 04-02.

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