BIOENERGY EXPLAINED 5

BIOMASS FOR ENERGY: AGRICULTURAL RESIDUES & ENERGY CROPS

Bioenergy EUROPE

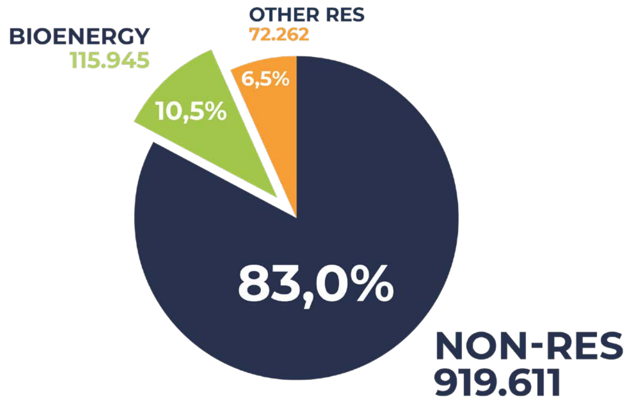
Bioenergy represents more than 60% of the renewable energy consumed in the EU28 and its contribution to the energy mix is pivotal to achieve a low carbon economy.

The capacity of agriculture to mobilise further unexploited potential will be crucial[1] to meet the EU long term emissions reduction target. To this end, bioenergy-oriented agriculture development will be a key driver to determine the long-term potential available.

With 95% locally produced biomass, the growth potential of bio-energy relies essentially on the potential of sustainable biomass resources available in Europe.

This paper aims at communicating the environmental and economic benefits of these agrobiomass types and points out at possible solutions to the existing barriers to increase their use.

EU SHARE OF ENERGY FROM RENEWABLE SOURCES IN THE GROSS FINAL ENERGY CONSUMPTION



Source: Bioenergy Europe Statistical Report 2018

AGRICULTURAL RESIDUES & DEDICATED ENERGY CROPS

The Renewable Energy Directive (2016/0382(COD)) describes biomass as the **"biodegradable fraction of products, waste and residues from biological origin from agriculture,** including vegetal and animal substances, forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin".[2]

Agricultural biomass refers to a broad category of biomass originating from agriculture and it includes the following:

- **crops** such as corn, sugarcane and beets
- **oilseeds** such as several plants of brassica family (e.g.
- rapeseed), sunflower seed and soybeans
- **agricultural residues** such as:
  - **herbaceous crop residues** as cereal straw, corn stover, rice straw
  - **permanent crop residues, e.g. orchard prunings and plantation removal wood**
  - **agro-industrial by products, such as olive cake, grape marc and sunflower husks**
  - **grassy and woody energy crops**
  - **leguminous crops**
  - animal waste (manure).

Among the vast category of agricultural biomass, and for the purpose of this paper, Bioenergy Europe has identified **agricultural residues** and **dedicated energy crops** as the most relevant ones due to their environmental and economic benefits and for their market growth potential. When it comes to end uses, we are particularly interested in heating and power generation, representing respectively 74% and 15% of the total bioenergy consumed in 2016.

Agricultural residues can be defined as primary or secondary depending on their origin. **Primary residues** are solid vegetal residues left in the field after harvest or pruning and manure. **Secondary residues** are the portion discarded during the processing phase (olive pits, nutshelling etc). Although they consist in a promising feedstock for bioenergy use and, in general, for EU bioeconomy, they are currently underutilised[3] mainly because of logistics constraints and lack of incentives. They positively contribute to rural development, representing a possible income for farmers, and if usedas bioenergy feedstock they contribute to climate change mitigation strategies.[4] The following table presents a non-exhaustive list of primary and secondary agrobiomass feedstocks[5] along with technical requirements for harvesting, benefits of mobilisation and seasonality.

Dedicated energy crops (grassy and woody) such as miscanthus, poplar, willow, are plants grown specifically for their energetic value (for heating and cooling, and electricity purposes). Adaptable to a wide range of climate and soils conditions, they can successfully be grown on lands not ecologically suited for conventional farming practices, while delivering several ecosystem services. Ligno-cellulosic crops have normally a higher GHG efficiency than rotational arable crops because of their lower input requirements and a much higher energy yield per hectare potential. When grown on marginal lands, they do not compete with rotational arable crops, acceptable yields can still be reached. [6]

PRIMARY AGRICULTURAL RESIDUES

Feedstocks examples	Harvesting requirements	Benefits of mobilisation	Seasonality
Straw, corn stover	Existing agriculture machinery (e.g. Baler)	No additional land required, considerate collection prevents pests, paying attention not to decrease SOC.	During crop harvesting season
Pruning	Agricultural machinery, usually modified for pruning	No additional land required, avoidance of pests / diseases, avoidance of emissions from open-field burning	After the pruning season (usually winter – spring)
Plantation removal wood	Excavators, large shredders, etc.	No additional land required, clear-up of field for new plantations, avoidance of disposal costs	At the end of an orchard's lifetime

SECONDARY AGRICULTURAL RESIDUES[7]

Feedstocks examples	Harvesting requirements	Benefits of mobilisation	Seasonality
Pits and residues from crushing from olive shells/husks from seed/nut shelling, grape marc.	No additional technical equipment; no additional infrastructure	By-Product; no additional land required; concentrated at processing site (no collection costs); avoids disposal costs (e.g. landfilling)	Year round

DEDICATED ENERGY CROPS[8]

Feedstocks examples	Harvesting requirements	Benefits of mobilisation	Seasonality
Short-Rotation Coppice Poplar, Willow, Eucalyptus, lucust	Machines needed to harvest efficiently (e.g. modified forage harvester)	Relatively fast growing; reduce soil erosion; can increase soil carbon and soil fertility in poor soils	All year round, though harvest for deciduous trees is done in winter
Perennial crops Miscanthus, Switchgrass, Reed canary grass, Cynara, Cardunculus, Other Grasses	Existing machinery (maize harvester, baler)	Can be grown on degraded land, can mitigate soil erosion, can increase soil carbon and soil fertility in poor soil	Harvest during autumn and winter. Grass can be harvested during summer and dried with the sun.

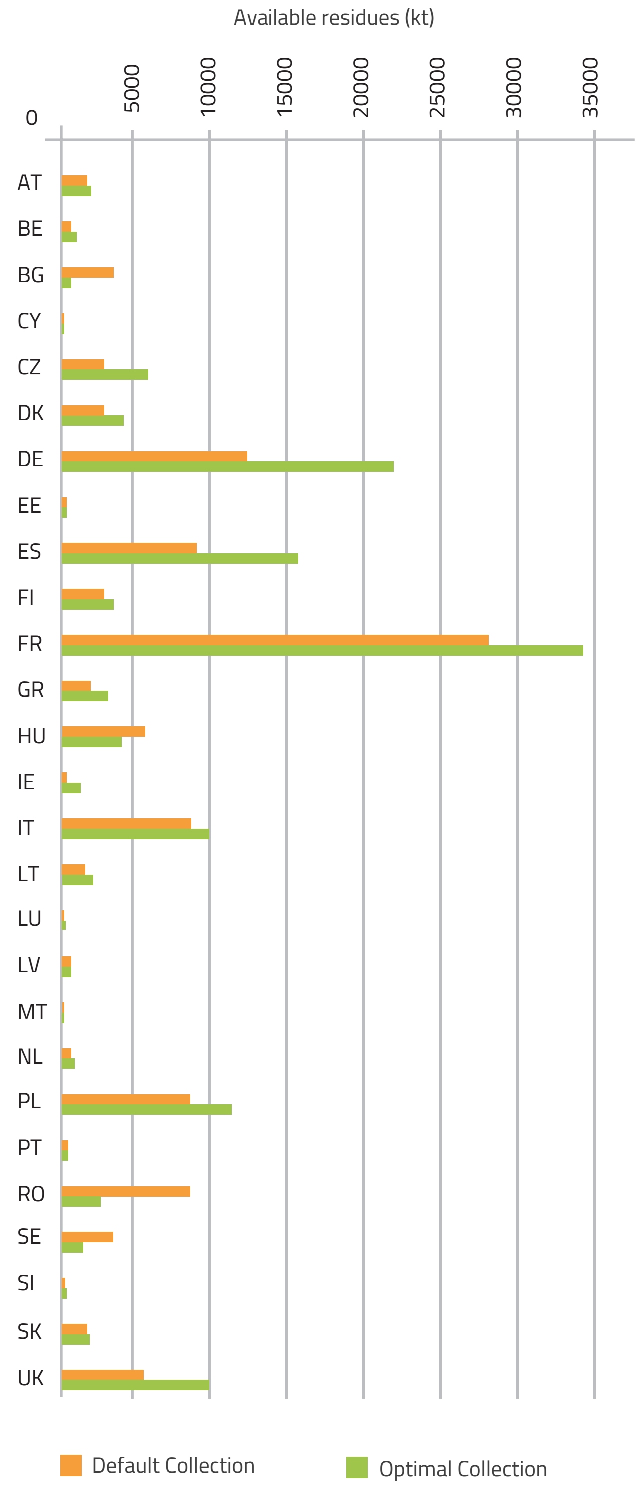
AVAILABILITY AND POTENTIAL

Agricultural Residues: Despite numerous studies attempting to estimate the level of production of agricultural residues in Europe, a series of methodological shortcomings are clearly identifiable. In fact, hard data are not collected at EU level, estimations are based on different assumptions, and sparse data is collected from different crop commodities.

The availability of collectible agricultural residues is influenced by a number of factors, such as the profitability, incentives, logistics, weather conditions, etc. Furthermore, a substantial percentage of residues needs to remain on the field to safeguard soil fertility (carbon and minerals) while a share of residues may serve other agricultural uses (e.g. straw use in animal bedding and horticulture).

Different collection rates for agricultural residues need to be applied to guarantee soil organic carbon (SOC) preservation. A number of factors need to be taken into consideration to avoid SOC depletion including climate, soil type, current and pre-existing farming practices. Tailored farming practices can increase the soil carbon stock and can halt the increase in human-related CO_2 concentration in the atmosphere.[9]

In terms of potential, agricultural residues are expected to play a key role in the future of bioenergy. A recent study suggests that 146,000 kt/year of dry residues could be sustainably collected, leading to a potential gross energy production of 55 Mtoe without impacting the current levels of SOC stocks.[10] The following graph compares residues availability when optimal collection practices or default collections are considered. There is a total relative difference of 42.9% between the two values, confirming that tailored collection practices can maximise availability while preserving SOC.



Dedicated energy crops[11] currently represent a minor fraction (0.1%) of the total biomass production, as reported in a 2018 JRC report.[12] Nevertheless, this is an approximation as official statistics about the land area or production yield of dedicated energy crops data are not published by Eurostat. Bioenergy Europe estimates that in 2017 an area of some 50 kha was cultivated with dedicated energy crops (e.g. miscanthus, willow, poplar)[13]. In particular, Poland has an area as big as 22,539 ha dedicated to energy crops while Sweden contributes with 14,552 ha.

The total represents a very trivial portion of the overall agricultural land used in Europe (106,9 Mha, in 2015[14]). Several studies evaluate that the potential for growth in this sector is substantial considering the amount of abandoned, degraded and contaminated land that could be used for energy crops cultivation.

The maps below illustrate the potentially available land as a percentage of total land for the production of bioenergy crop by 2030, (Figure1: amount of surplus land as a percentage of the total land) and the production costs for woody crops in 2005 (Figure2: production costs of woody crops) together indicate favourable locations for the production of biomass; especially Easter Europe and to a lesser extent South West Europe are promising.[15]

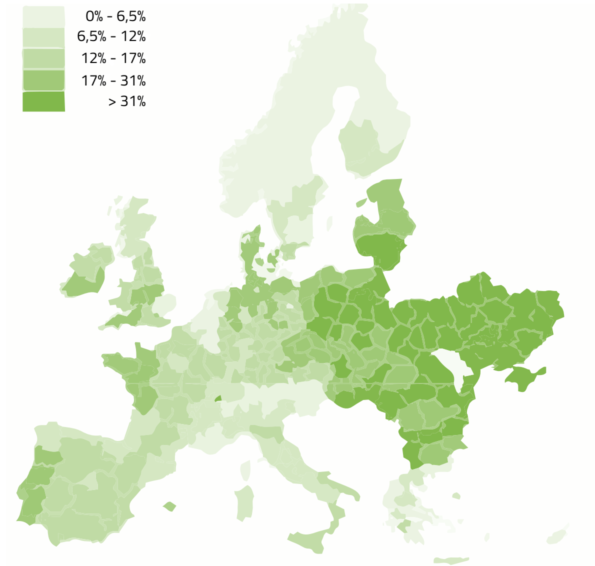


Figure 1: amount of surplus land as a percentage of the total land

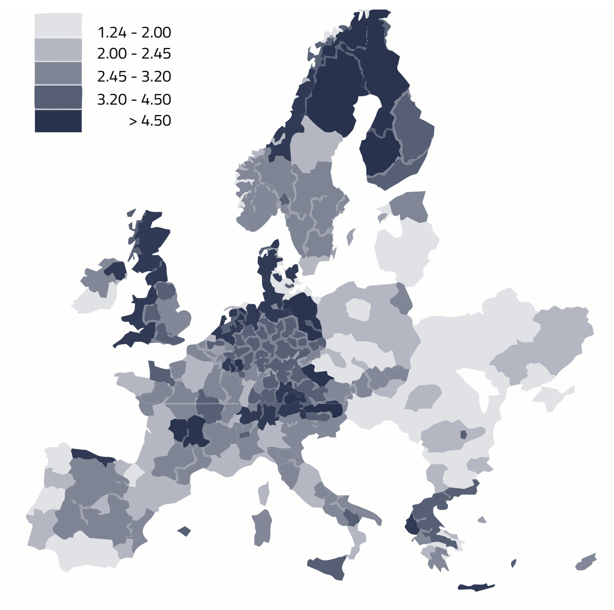


Figure 2: production costs of woody crops in Euro

According to the most conservative studies "around **1.35 Mha** of land in the EU has been identified as having potential for being investigated further for the purposes of dedicated energy cropping."[16] This would mean an area 27 times larger than the one cultivated at present could be used to grow dedicated energy crops. Cultivation on unfavourable agricultural land (where productivity is low or non-existent because of contamination, erosion or saline concentration) should also be taken into consideration. Only including the four top-countries with the largest surfaces classified as low productive, JRC estimates a further extension of 21.8 Mha.[17]

BENEFITS OF AGROBIOMASS

The use of agrobiomass for energy favours a general societal shift towards greater sustainability and energy self-sufficiency. This affects several areas: reduced GHG emissions, recovery of residues and recycling of waste, renewable resources, farming preserving soil fertility, and technological innovation.

SOCIOECONOMIC BENEFITS

#1 INCOME DIVERSIFICATION FOR FARMERS

Add value to residues: residues become commodities contributing to farm's income.
In the case of pruning removals, harvesting and sale (or on-site use) significantly decreases management costs.

Planting energy crops can diversify farmers' income and at the same time increase profitability of land[18], in the case of those areas that are low profitable because of low fertility, erosion or contamination.

#2 PROMOTE SOCIO-ECONOMIC DEVELOPMENT AT A LOCAL SCALE

Reinforcing farming activities in marginal rural areas, generating added value from non-conventional production, promoting job creation in biomass logistics and end-use.

#3 SELF SUFFICIENCY

Contribute to provide for farm's own energy requirements (energy self-supply and self-consumption). This can lead to substantial savings by reducing overall running costs.

#4 TRIGGERS NEW FORMS OF AGRO-INDUSTRIAL INTEGRATION

Agrobiomass contributes in replacing the consumption of fossil fuels while gaining significant reductions in GHG emissions.

ENVIRONMENTAL BENEFITS

#5 EMISSION SAVINGS

Agrobiomass contributes in replacing the consumption of fossil fuels while gaining significant reductions in GHG emissions.

#6 RESOURCE EFFICIENCY

Biomass from agricultural residues offers high resource efficiency, as it does not require additional land or input and elevated residues to the status of by-products.

Dedicated energy crops are usually low-input and high yielding with high resource use efficiency and good biomass quality.

#7 IMPROVES SOIL QUALITY & CARBON CAPTATION

Miscanthus: the perennial nature and belowground biomass improves soil structure, increases water holding capacity (up by 100–150 mm), and reduces run off and erosion. Reduced management intensity promotes earthworm diversity and abundance. Chemical leaching into field boundaries is lower than comparable agriculture, improving soil quality.[19] Indeed, input is typically required only during the first year of cultivation for miscanthus.

SRC (such as Willow and Poplar) lead to a long-term non-tillage management with increased litter amounts. As a result, an increased carbon sequestration in the topsoil of former ploughed arable soils and increased abundance of earthworms can decisively improve soil quality.[20] Willow can be cultivated without input , when grown conventionally, the use of pesticides is 1/4 compared to arable crops.

#8 IMPROVES WATER QUALITY

SRC plantation can remove significant quantities of nutrients and heavy metals, by doing so SRC plantation can help prevent chemicals leaching into local water courses causing eutrophication.[21]

#9 IMPROVES BIODIVERSITY

Short Rotation Coppices and perennial energy crops significantly increase biodiversity in agricultural landscapes when replacing annual biomass crops. High bird diversity and density have been recorded in SRC.

#10 PHYTOREMEDIATION

Phytoremediation is the direct use of living green plants for in situ risk management of contaminated soil. Both Miscanthus and SRC (willow in particular) can be used on degraded land for purification purposes.

CHALLENGES, SOLUTIONS & BEST PRACTICES

MOBILISATION OF BIOMASS

BARRIERS

Various assessments have demonstrated that there is a great potential for agrobiomass. Nevertheless, mobilisation is key for further deployment and, given the disperse nature of biomass, advanced logistic systems must be optimised.[22]

SOLUTIONS

- **Further support agricultural productivity**, with attention for soil carbon & ecosystem services. Through increased productivity, a more efficient management of agricultural land can be achieved.
- **Map contaminated/abandoned land at EU level and mobilise unutilised potentials** to grow dedicated energy crops.
- **Improve harvest logistics by stimulating the creation of regional clusters** for the sharing of harvesting and baling equipment and provide storage.
- **Incentivise local supply chains (both residues and dedicated energy crops)** and provide public financing to supper the SME's investments.
- **Create new forms of agro-industrial integration, such as Integrated Biomass Logistics Centers.**[23]

BEST PRACTICE #1

Serra City Council offering municipal services to farmers to dispose of their waste while preventing dangerous and polluting agricultural burnings. Farmers can give an added value to their residues thanks to the chipping equipment.[24]

BEST PRACTICE #2

A Biomass fuelled cooperative in Brittany, dehydrating and pelleting over 2000ha of Lucerne, maize and cereals for animal feed. The furnace was previously fuelled by coal. Now, 450 ha miscanthus have been planted by NovaBiom for the cooperative's members within a 60km radius.[25]

BEST PRACTICE #3

In Enköping (Sweden) an industrial symbiosis network involving the city, municipally controlled services and local farmers has been successfully put in place since the early 2000. Municipally owned combined heat and power plant delivers district heating to the city and sources most of its fuel from locally grown SRC willow. Willow farmers make use of effluents of the municipal wastewater treatment plant as well as sludge from private sewage systems to accelerate the growth of willow. fuel from locally grown SRC willow. Willow farmers make use of effluents of the municipal wastewater treatment plant as well as sludge from private sewage systems to accelerate the growth of willow.[26]

QUALITY OF AGROBIOMASS

BARRIERS

Agrobiomass quality is extremely variable especially when it comes to residues or herbaceous material, which is an obstacle to its marketability. Furthermore, the interpretation of the origin of biomass in national and regional legislation sometimes differs, creating legal uncertainties and market barriers.

SOLUTIONS

- **Promote** good practices during harvesting, transportation and other logistic steps in agrobiomass value chains to maintain a proper fuel quality (e.g. avoidance of soil contamination, etc.).
- Stimulate the process of **developing technical standards** (ISO) in order to turn lignocellulosic material into fully tradeable commodities.
- **Support** the introduction of industry-led quality **certifications**.
- **Convert,** when needed, low quality material to intermediate product (e.g. by applying screening, pelletization or briquetting steps).

BEST PRACTICE #4

RAGT has successfully developed the know-how to produce agro-pellets made of available raw material (such as of straw (CALYS certification).[27]

BEST PRACTICE #5

BIOmasud®[28] is a fuel quality certification scheme (analogous to ENplus® for wood pellets) that is specifically designed for various types of agrobiomass frequently available in Mediterranean countries: olive stones and nut shells (e.g. almond shells, hazelnut shells). The quality scheme has been expanded through the Biomasud Plus EU-funded project[29]; among others it intends to cover further types of nut shells as well as solid biofuels from olive tree and vineyard prunings.

KNOWLEDGE GAPS

BARRIERS

In absence of a value chain, farmers are not exploiting the full potential of agricultural residues such as prunings,often regarded as worthless leftovers. Correct agricultural practices can lead to significant variations in combustion characteristics, and harvesting times can impact of the quality of the feedstock for energy purposes.

SOLUTIONS

- **Finance capacity building projects** to present i) how to add value to agricultural residues to farmers and ii) the untapped opportunities of agrobiomass to ESCOs
- **Disseminate information on existing incentives to add value to residues**.
- **Disseminate best agricultural practices to improve** the quality of energy crops and agricultural residues for combustion and enhance their long-term sustainability.[30]
- **Disseminate and reward bioremediation properties (nitrogen removal) of dedicated energy crops such as willow.**
- **Finance research projects** to investigate and establish the most cost effective and sustainable uses of agrobiomass.
- **Promote bioenergy value chains**, disseminate the knowledge about the best available technologies, contribute to increase the level of information on biomass valorisation opportunities.

BEST PRACTICE #6

The EU-funded project OPTIMISC has investigated methods to optimize the production and use of miscanthus biomass Laboratory and field trials were performed in the context of the project. Performance of a small selection of germplasm types was evaluated on marginal lands in Germany and the UK. Variation in growth traits determining the potential of biomass quality and quantity was analysed. Several potential high-value bioproducts were identified.[31]

BEST PRACTICE #7

UP_running[32] is an EU-funded market uptake project aiming to promote the energetic utilization of woody biomass from agricultural prunings and plantation removals. The project aims to overcome the non-technical barriers associated with value chains based on these types of biomass resources by undertaking a series of actions, e.g. organizing short value chain demonstrations in four European countries (Italy, Greece, Spain, Ukraine), promoting real, "flagship" cases of utilization and training consultants.

VALUE CHAIN

BARRIERS

Low market prices and tight profit margins for residues lead to suboptimal residue collection in many parts of the EU. Harvest costs alone can represent 35-60% of the total costs of biomass production from agricultural residues or SRC.

SOLUTIONS

- **Measures to add more value** on-farm residues by upgrading them to products (e.g. pyrolysis oil in small-scale installations on-site) or using them to promote farm energy independence (e.g. CHP – Boilers)
- **Economics of Scale**: the existence of a considerable size end user (e.g. Anaerobic digester, biorefinery, pelleting plant) is a market incentive for residues collection and/or use of energy crops.
- **Promote the agrobiomass fuels with the end-users, building a relation of trust based on reliability, certified and standardised quality and availability.**
- **Incentivise residues demand** through appropriate legislative measures and dissemination of Best practices.
- **Improve harvest logistics** by stimulating the creation of regional clusters to the sharing of harvesting equipment for SRC.
- **Highlight intangible benefits** achieved through agrobiomass utilization (e.g. avoidance of pollution from open-field fires, creation of sustainable image for local communities and products, etc.)

BEST PRACTICE #8

The Denmark Energy Policy has been in place since 1976to achieve energy diversification and independence. From 1993, a large parliamentary majority entered a biomassagreement, which required the central power plants to take 1.4 million tons biomass per year, of which 1 million ton consisted of straw.

BEST PRACTICE #9

Fiusis[33] is a 1 MWe power plant in Puglia, Italy. It is the first biomass power plant in the world exclusively using olive tree prunings as a fuel. It consumes around 8,000 tons of prunings annually, having developed a sourcing system that involves around 60 % of the local farmers (1,200 individuals). 6 permanent jobs have been created in the plant itself, as well as an additional 10 permanent and 5 seasonal jobs for the logistics chain. The plant operation has also significantly reduced the air pollution from the uncontrolled open-field burning of prunings, which was the typical disposal strategy.

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DEFINITIONS

Lignocellulosic The term lignocellulosic covers a range of plant molecules/biomass containing cellulose, with varying amounts of lignin, chain length, and degrees of polymerization. This includes wood from forestry, short rotation coppice (SRC), lignocellulosic energy crops (energy grasses and reeds) and lignocellulosic agricultural residues (straw, prunings, etc.).[33]

Short Rotation Coppice (SRC) are woody fast-growing tree species that are cultivated with the aim to produce high biomass yields in a short period that can be used for energy purposes. Coppice is characterised by the ability of the selected tree species to re-grow with new sprouts after the plant is cut down.

Collectible residues portion of residues that can be sustainably collected and used for bioenergy purposes (a part of agricultural residues needs to remain on field for environmental purposes while another portion can be used for horticulture and animal beddings).

Bioenergy Europe, formerly known as the European Biomass Association (AEBIOM), is the voice of the bioenergy sector at EU-level. It aims at developing a sustainable bioenergy market based on fair business conditions.

Bioenergy Europe is a non-profit, Brussels-based international organisation founded in 1990, bringing together more than 40 associations and 90 companies.

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