Reducing GHG Emissions with SRC

IULIA MIRCEA[1,2], OANA FALUP[1,2], ROXANA IVAN[1,2], IOANA IONEL[1]*

[1] "Politehnica" University of Timisoara, 2 Pta Victoriei, 300006, Timisoara, Romania

[2] Institute for Studies and Power Engineering, 1-3 Lacul Tei Blvd. , 20371, Bucharest, Romania

This article refers to Short-rotation coppice (SRC) for production of biomass as fuel for district heating. SRC was identified as the most energy efficient carbon conversion technology to reduce greenhouses gas emissions and is considered one of the promising energy source to contribute to meeting the European targets to increase the amount of renewable energy. For one GJ of energy produced from biomass around 7 kg CO_2 are released compared to 79 kg CO_2 released when the same amount of energy is produced from oil, resulting in an over 90% reduction in emissions. Located in the eastern part of Europe, Romania provides substantial land resources suitable for bioenergy production. In Romania, first biomass cogeneration plant was launched in 2008 at Radauţi and has a capacity of 29 MW.

Keywords: Short-rotation coppice, GHG emissions, energy crops

The European Union (EU) set the target of reducing greenhouse gas emissions by 20 % of 1990 levels by 2020. As part of this goal, 20 % of EU energy consumption is set to come from renewable resources by 2020. Biomass is to play a key role in helping to achieve this goal, foreseen to provide 78 % of the renewable heating and cooling output in the EU by 2020 [1].

One of the emerging markets in the renewable energy sector for biomass heating is the short rotation coppice plantations, where wood material is compressed to create highly energetic pellets mainly for combustion heating.

Short rotation coppices (SRC) can be defined as the long term culturing of fast growing (often regenerative) tree stands on mainly agricultural, fallow or grassland, with short harvest intervals. Stands of these trees can be cultivated and harvested over a period of 20 - 30 years with a rotation cycle of 2 - 10 years. SRC woodchips can be utilized for energy production, heating and cooling, and as raw material for pellet and briquette production.

The fraction of bark in SRC wood is higher than normal round wood, resulting in a respectively high net calorific value (up to 19.5 MJ/kg) due to the high carbon content. However, the inner bark contains the growth layer of the tree which has high contents of nitrogen, sulphur and ash forming minerals. SRC material also has potentially higher levels of heavy metals.

SRC are perennial plantations of broadleaf trees species that are, in comparison to conventional forests and forestry plantations, harvested on very short rotation cycles. The EC defines biomass from SRC as a conventional agricultural product.

A range of different tree species may be used in short rotation coppice. Depending on the soil type, temperature and rainfall, the most common species used are poplar and willow (on land with rather high rainfall) as well as robinia (on rather dry land). For both poplar and willow, a mix of different varieties and/or clones is generally used, to create genetic diversity within the plantation and lower the risk of crop diseases. In recent years, the cultivation of paulownia has become more common, in most cases in very warm locations and in combination with irrigation.

One of the most popular energy crops in Romania is willow (Salix) being spread across the country in areas such as Suceava, Bacau, Brasov, Harghita, Covasna, Timisoara, Satu Mare and Calarasi. These plants have a high calorific value, but are much cheaper than wood and easier to produce. Willow can be used in the form of chips or briquettes/pellets for biomass power plants.

The planting density is very high, between 6,500-10,000 plants/ha. Once established, the rootstock is capable of generating regrowth after the upper woody portions have been harvested. There are generally between 3 and 10 coppice cycles before replanting. In most plantations special energy crop clones are used as the parent material.

Experimental part

SRC is considered one of the future based renewable resources that can be used at small and large scale. Biomass currently contributes 14% to the global primary energy consumption [2]. For three quarters of the world population that lives in developing countries, biomass is the most important energy source. About 16% of global final energy consumption presently comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity.

Life on earth is based on green plants that convert carbon dioxide and water from the atmosphere into organic matter and oxygen using the energy provided by the sun. This process is called photosynthesis. Carbon dioxide from the atmosphere and water from the soil through the process of photosynthesis are combined resulting carbohydrates forming constituents of biomass. Solar energy is stored by photosynthesis in the chemical bonds of the structural components of biomass. When the biomass is burned, oxygen in the atmosphere combines with carbon in plants producing carbon dioxide and water. The process is cyclic so that enough carbon dioxide in the atmosphere is absorbed by the plant again and there are no pollutant emissions into air. In figure 1 is presented carbon cycle.

Biomass is defined in LCP Directive as a product consisting of the whole or part of a vegetable matter from agriculture or forestry which can be used as fuel in order to recover its energy content.

SRC such as willow, poplar, giant reed contains large amounts of water and is burned in power plants to produce heat. Even if the chemical composition of the biomass are slightly different and the amount of mud and dirt affecting

* email: ioana.ionel@upt.ro: Tel.: 0040256403670

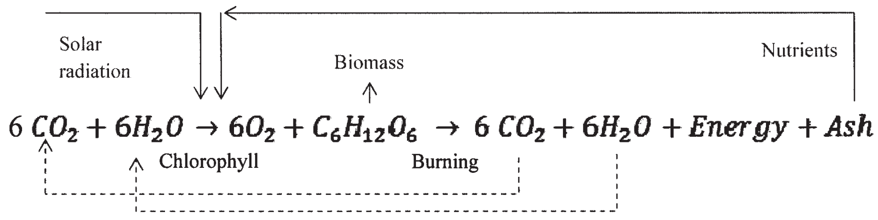

Fig. 1. Carbon Cycle

Table 1
CHARACTERISTICS OF DIFFERENT BIOMASS SOURCES FROM CROPS

Crops	Dry mass yield (tDM*/(ha year))	Lower heating value (MJ/kgDM*)	Energy production per ha (GJ/ha)	Water content at harvest (%)	Ash content (wt. %)
Straw	2–4.0	17	35–70	14.5	5.0
Miscanthus	8–32	17.5	140–560	15	3.7
Hemp	10–18	16.8	170–300	n/a	n/a
Willow	8–15	18.5	280–315	53	2.0
Poplar	9–16	18.7	170–300	49	1.5
Giant reed	15–35	16.3	245–570	50	5.0
Reed canary grass	6–12	16.3	100–130	13	4.0
Switchgrass	9–18	17.0	n/a	15	6.0
Black locust	5–10	19.5	100–200	35	n/a
Wood	3–5	18.7	74.8	50	1–1.5

*DM – dry mass

ash content and composition, biomass from forestry and wood industry is largely a common qualities as a fuel.

SRC is generally considered as a crop that improves the water quality in a certain area, and this is mainly attributed to different management practices and crop characteristics compared to arable crops. For example, herbicides are used only during the establishment phase, in low amounts when compared to other arable crops, and they are not used thereafter [3].

Below is a table to have a more complete picture of the characteristics of biomass [4] that can be used as fuel.

The chemical process of combustion and the temperature achieved will vary depending on the type of fuel particles and their position on the grate. The grate allows all fuels to be first dried and then pyrolyzed. Modern control outbreaks grate ensures optimal air supply for combustion and thus low in unburned components in the exhaust gases.

For biomass combustion plants, the simultaneous generation of heat and power is by far the most important technical and economical way to increase fuel efficiency. According with BREF BAT - 2006, if only electricity is produced efficiency obtained is about 20% and when operating in cogeneration (heat and power) efficiency achieved is between 75-90 %.

In the combustion of biomass the ash resulted will remain majority on the grate and will be collected. Only small amounts leave the furnace as fly ash and must be collected with dust reduction devices that use fabric filters or electrostatic precipitators. There are a number of possibilities for recycling such by-products of combustion.

Emissions of sulfur dioxide are not considered as wood biomass does not contain sulfur.

For biomass burning on grate, the technique of distribution in furnace and grate combustion was considered BAT to reduce NOx emissions.

BAT to minimize emissions of CO is complete combustion, which is identified with designing a good furnace, using high-performance monitoring techniques and control process, and also combustion system maintenance.

There are three thermo chemical processes, which can be used to convert energy stored in the willow chip to usable energy – heat, and/or electricity: Combustion, Gasification, and Pyrolysis [5].

At the small-scale level, the direct combustion technologies are largely available. However, small-scale Gasification technologies have yet to complete their commercial development and Pyrolysis is still at the research and development stage.

Combustion is the most efficient way to produce heat from wood chip. The reaction of a fuel with oxygen to produce energy is known as direct combustion. This can be done with coal or biomass on their own or by combining the two as a feedstock, which is then called co-firing [6]. The products from combustion are mainly CO_2 and H_2O with traces of NOx and SOx[2].

For combustion on a large scale, the existent technologies are presented in table 2.

The decision on the scale of a scheme is likely to be led by the opportunity to supply power or heat locally and the possibility to sale the electricity to the grid.

Technical requirements that must be considered and addressed before decision-making of investment are the following:

- fuel supply: if it can be grown in the area, availability, reliability of supply and cost;
- alternative fuel sources: larger scale projects will need to guarantee an alternative source of fuel in order to acquire financial support, particularly during the early years as SRC plantations are developed and reach maturity; the most likely alternative fuel source is woodland residues;
- transport links and for large vehicles: for delivery of fuel;
- water supply and discharges: consent of the water company and the Environment Agency will be required for larger power plants depending on location and planned operations;
- access to grid connection: cost and ease;
- smaller schemes or those producing heat only, are likely to face fewer problems.

Technology type	Description	Characterization
Fluidised Bed Combustion	A suspension of gas and solid bed material (normally silica sand) is introduced into the fluidised bed from the bottom and it aids the fuel to burn.	The particle size of the Bubbling Fluidised Bed material (BFB) is 0.5-1 mm while that of the Circulating Fluidised Bed (CFB) is 0.2-0.4 mm. Similarly the velocity of the suspension in a BFB is 1-2 m/s while that of a CFB is 5-10 m/s
Fixed Bed Combustion	In a fixed bed reactor, drying, gasification and combustion of the fuel occurs in primary air. The combustion gases produced are then introduced into a separate chamber along with some more air to burn them off.	Vibrating and rotating grate systems and underfeed stokers are the fixed bed systems that can be used, due to the low ash melting points and high moisture content in biomass.
Pulverised Fuel Combustion	The fuel and primary air are introduced into the chamber and the combustion of the fuel occurs while it is suspended in air.	This technology is only good for fuels with particle sizes < 2 mm. The introduction of more secondary air helps to burn the combustion gases

Table 2
COMBUSTION TECHNOLOGIES

Ore content of fuels include various substances depending on their origin. Biomass has certain concentrations of elements that can be pursued such as heavy metals [7]. In most cases, heavy metals evaporate during combustion processes and process later condenses on the surfaces of fly ash particles. So that BAT to reduce emissions of heavy metals from flue gases from the combustion of biomass to be used as high performance filters, electrostatic precipitators having retention rate of 99.5 % [8].

In plants that burn wood biomass in particular the emissions of dioxins and furans were measured emission levels below 0.1 mg/Nm^3 is generally regarded as reasonable.

In Romania, first biomass cogeneration plant was at Radauţi, owned by the Austrian company Holzindustrie Schweighofer. The power plant, launched by 2008, has a capacity of 29 MW total, of which 24 MW heat and 5 MW electric-power, and the investment was about 20 million euro. Further at Sebes another biomass cogeneration plant with a power half that of Radauti, which will have a capacity of 8.5 MW of electricity was opened. The cogeneration plant operating at Radauti consumes biomass sterile 40 m^3/h, and the heat produced is currently used to dry timber in the self-owned factory (also Holzindustrie Schweighofer), but also to heat the 7000 flats in Radauti, the electric electricity being supplied to the national energy system. Another biomass plant was finalized in 2013 in the enclosure of CET Suceava. The biomass plant is an investment of Bioenergy Suceava, whose shareholder is Adrem Invest Company. The equipment supplier is Austrian company URBAS. The new biomass plant has an installed electrical capacity of 29.65 MWe and a thermal capacity available in the heat exchanger for district heating of 71.43 MWt. The biomass consumption is approx. 154,800 t/year.

Results and discussions

One of the major drivers for growing SRC is its potential for the reduction of Greenhouse Gas emissions (GHG). There are potentially two ways in which growing willow as a source of renewable energy can offset carbon emissions.

Carbon mitigation:

- the energy content of dry willow wood chip is approximately 19 MJ kg^{-1}. One hectare of SRC willow produces the equivalent energy of 3,300 – 5,700 litres of light heating oil [9] and an average medium sized house will burn around 3000 litres of oil per year, which releases 8 tones CO_2;

- SRC Willow wood is a carbon neutral fuel. The carbon that is released during its combustion has been absorbed by the plants when they were growing. For every GJ of energy produced from wood chip around 7 kg CO_2 is released compared to 79 kg CO_2 is released when the same amount of energy is produced from oil, resulting in an over 90% reduction in emissions.

Carbon sequestration:

- while growing SRC willow has the potential to sequester (capture) carbon, thus preventing its release as GHG;

- after the above ground biomass has been harvested for wood chip carbon can be stored in three ways: in the non-harvested above-ground biomass (stumps); the below-ground biomass in the form of course and fine roots; and the input of the carbon onto the soil organic matter;

- SRC willow can sequester around 0.12 t of carbon ha-1 yr-1;

- factors that will determine the rate of change as well as the total amount of soil carbon sequestered by SRC willow. These include the carbon inputs to the system – i.e. during the net primary production phase; decomposition of the major carbon pools – which is affected by soil moisture and temperature; the initial carbon content of the soil – there is an inverse relationship with the sequestration rate; crop management – e.g. harvest intervals, re-plantation; depth of soil influenced by the willow – which will influence the total amount of carbon sequestered;

- amount of carbon captured by SRC willow can be further enhanced if plantations are used for the bioremediation of effluents and sludges.

Conclusions

Potential of biomass from energy crops in mitigating carbon dioxide emissions comes from:

- replacing fossil fuel sources for heat generation in the first instance and with further developments in the technologies, small to medium scale electricity generation;

- the carbon dioxide neutral status of biomass from energy crops, where the growing crop consumes as much atmospheric carbon dioxide in its growth processes as is released back to the atmosphere when the biomass is converted to useable energy as heat and/or electricity;

- total carbon budgets for the generation of electricity from biomass, gas, and coal show carbon dioxide emissions of 60 g, 400 g, and 1,000 g per kWh electricity;

- the carbon balance (the ratio of energy used in cultivation compared to that produced) of SRC willow is good. SRC willow crop will yield 14 times more energy than is needed to produce and deliver it.

SRC can produce energy with no net increase in atmospheric carbon.

SRC plantations, usually of willow or poplar, can provide landscape variety, and a habitat for many species of plants, birds and other wildlife. Blocks are planted over a two to five year period (usually three), and then harvested in rotation, so fields within the growing area will always represent all age classes.

Converting existing arable land to SRC will reduce the amount of agricultural chemicals required as SRC is a low-input crop: once established it requires a very much lower input of chemicals than conventional arable crops.

A wide range of yields can be expected depending of site, weather conditions and all the other factors which normally determine yield from conventional crops but can be expected to be in the range 7-12 tones dry matter (t DM) per hectare per year (21-36 t DM on a three-year harvest cycle).

Acknowledgement The paper is part of the Ph.D. program of eng. Falup Oana, Mircea Iulia and Ivan Roxana as Ph.D. - students at the Politechnica University Timisoara. Also data support from the project AirQ, financed by UEFISCDI as Ro Fr (Ideas) project Nb PN-II-ID-JRP-2011-1 is acknowledged (http://mec.upt.ro/airq).

References

1. *** European Commission - Biomass - Green energy for Europe, Luxembourg: Office for Official Publications of the European Communities, 2005, http://publications.eu.int.

2.CASLIN, B., FINNAN, J., MCCRACKEN, A., Short rotation coppice willow - best practice guidelines, ISBN 1-84170-575-6, April 2011

3. DIMITRIOU I, BUSCH G, JACOBS S, SCHMIDT-WALTER P, LAMERSDORF N (2009) A review of the impacts of short rotation coppice cultivation on water issues. Landbauforschung 59(3):197-206

4.IONEL, I., DOBRIN, M., CEBRUCEAN, V., Potential of short rotation coppice as renewable energy source. examples from Romanian practice, Journal of Environmental Protection and Ecology 13, No 3, 1503 –1512 (2012)

5. LOO, S. V., KOPPEJAN, J., The handbook of Biomass Combustion and Cofiring, CPI Antony Rowe, UK, 2008

6 TRIF-TORDAI, G., IONEL, I.,CIOABL , A., CEBRUCEAN, D., POPESCU, F., Comparative results concerning co-firing of biomass residues with pit coal in a pilot plant, Journal of Environmental Protection and Ecology 13, No 2, 700–709 (2012)

7 GUIDI, W., TOZZINI, C., BONARI, E., „Estimation of chemical traits in poplar short-rotation coppice at stand level", Biomass and Bioenergy, Volume 33, Issue 12, Pages 1703-1709

8. Integrated Pollution Prevention and Control - Reference Document on Best Available Techniques (BAT) for Large Combustion Plants, European Commission, July 2006

9.SZCZUKOWSKI, S., STOLARSKI,M., TWORKOWSKI, J. PRZYBOROWSKI, J., KLASA , A., Productivity of willow coppice plants grown in short rotations, PLANT SOIL ENVIRON., 51, 2005 (9): 423–430

Manuscript received: 4.02.2014