Green Certificates and Their Influence on Biomass Supply for Bioenergy Projects In Southern Belgium

Certificados Verdes e sua Influencia sobre Projetos de Suprimento de Biomassa no Sul da Bélgica

Jean-François Van Belle[2]

Abstract: Further on the Kyoto protocol ratification, Europe is entering into a renewable energy era. To cope with the CO_2 emission reduction targets, Belgium has put into action a green certificate mechanism. This system takes into account the CO_2 emissions occurring during the bio-fuel supply for the certificate attribution. Depending on the type of wood, procurement systems and power unit efficiency, the coefficient may vary from 0.12 up to 0.85 without including cogeneration. This gives a premium ranging from 11 to 78.5 € MWh_e^{-1}, i.e. 37 to 262% above the grey price. Therefore, this new market mechanism will have a strong influence on the viability of bio-energy projects and selection of biomass and supply routes in the future. As the international trade of energy wood and other bio-fuels is growing, this is a factor to take into account before defining a supply strategy.

Key words: Biomass, CO_2, supply, Kyoto protocol, harvesting, green certificate.

Resumo: Com a ratificação do Protocolo de Quioto, a Europa está iniciando a era da energia renovável. Para atingir as metas de redução da emissão de CO_2, a Bélgica implementou o mecanismo do certificado verde. Esse sistema leva em consideração as emissões de CO_2 durante o suprimento de biocombustível para atribuição do certificado. Dependendo do tipo de madeira, dos sistemas de obtenção e da eficiência da unidade de energia, o coeficiente pode variar de 11 a 78 € MWh_e^{-1}, i.e., 37 a 262% acima do preço médio. Portanto, esse novo mecanismo de mercado terá uma forte influência na viabilidade dos projetos de bioenergia na seleção da biomassa e das rotas de suprimento futuras. O crescente aumento do comércio internacional de madeira para fins energéticos e outros biocombustíveis é um fator que deve ser levado em consideração antes de se definir uma estratégia de suprimento.

Palavras-chave: Biomassa, CO_2, suprimento, protocolo de Quioto, colheita e certificação verde.

1 Introduction

According to the Kyoto protocol, the European Union has committed itself to reduce its emissions of greenhouse gases of 8% by 2008-2012 relative to 1990. Therefore, an agreement was concluded among all the member states in order to distribute the efforts among them (burden sharing agreement). According to this agreement, some countries have commit themselves to reduce their emissions (Belgium, Denmark,

[1] Recebido para publicação em 15.11.2004 e aceito em 16.12.2004.
[2] Belgium Representative, International Energy Agency (OECD) - Bioenergy Task Force 31, CRA-W - 146, Chaussée de Namur - B-5030 Gembloux (Belgium), Phone: # 32 81 627 177 Cell.: # 32 495 67 22 31 Fax: # 32 81 61 58 47.

Germany, Italy, United-Kingdom, ...), while others were allowed to keep the same level (France, Finland) or even increase their emissions (Greece, Ireland, Portugal, Spain, ...). In the implementation of these targets, the development of renewable energy sources is expected to play an important role, since renewable energies only contribute marginally to the European energy balances although it could potentially be much more important. The target decided by the European Commission foresees that 22.1% of the electricity gross inland consumption must be covered by renewable energy sources by 2013. In order to reach this target, ambitious renewable electricity policy strategies are defined by all the member states.

The liberalisation of the electricity sector is an undergoing progressive process in all EU member states since the directive 96/92/EC on the common rules for the internal market in electricity. It is fundamentally changing the organisation of the electricity sector in the sense of a more competitive market, where the activities linked to the production and trade of electricity are strictly separated from the network responsibilities (unbundling). Hence, network operators remain monopolistic and highly regulated in order to ensure a fair and safe competitive market. With regard to renewable electricity, the liberalisation of the market brings opportunities and threats. The liberalisation of the electricity market offers the opportunity for new operators to enter the market as long as it guarantees free and indiscriminate access to the grid to all. Moreover, in most countries priority has been granted to the renewable electricity on the grid, as it was allowed in the European directive (96/92/EC).

The share of renewable energy in the electricity balances of the European countries varies a lot from country to country. It ranges from less than 2% in Belgium and UK to more than 70% in Austria and around 50% in Sweden in 1997. Indeed, in most European countries, renewable electricity accounts for less than 10% of the gross electricity consumption. An important part of renewable electricity appears to be generated by 4 large-scale hydro plants (e.g., in Austria, Sweden, Portugal, Italy, France, ...).

2 The Green Certificate Mechanism

The idea of the tradable green certificates was conceived in the United States in the early 1990s with a reflection on the "Portfolio Renewable Standards" (Rader, 2000; Espey, 2001; Berry and Jaccard, 2001). In Europe, the first system appeared in the Netherlands in 1998 under the impulse of the electricity industry. Rapidly, other European countries started to develop similar systems (Denmark, Italy, Belgium, Sweden, etc) and the European Union took an interest in it when preparing the directive on the promotion of renewable electricity in the liberalised market (Directive 2001/77/EC). At the same time, in 1999, a private initiative was created by the electricity industry to promote the use of tradable green certificates in Europe: RECS (Renewable Energy Certificate System). Nowadays, this organisation includes energy companies, environmental organisations and public authorities, aiming to create an international market for the green certificates with its own rules.

The tradable green certificate system is based on two traditional policy instruments: a quota (voluntary or mandatory) and a certification mechanism. The purpose is to create on one side a demand for the renewable electricity (quota) and, on the other side, a supply of guaranteed renewable electricity (certificates). Even if it was integrated only recently in the electricity policies, this instrument is not really "new", as generally stated, under a policy analysis perspective. Indeed, it is based on a traditional command (quota) and control (certification) regulation. The originality lies in the market mechanism that conducts the relations between the operators constrained by a quota and the operators granted certificates.

The idea of the tradable green certificate systems is to create a new competitive market for the environmental benefits linked to the renewable electricity and which are not valuated by the electricity market: the green certificate market. This market is strictly separated from the physical electricity market and the price of the certificate is therefore dependent upon the specific demand and supply for the certificates, rather than upon the price of the electricity in the spot market.

Therefore, the certificates serve both as an additional source of income and as a proof for fulfilling the quota. Indeed, on the one hand, the electricity producers obtain green certificates for the amount of renewable electricity they generate ,being able to sell those certificates on the green certificate market. On the other hand, the law imposes quotas of green certificates to certain categories of actors: final customers (Denmark), electricity suppliers (Belgium, UK), grid administrators (Belgium), electricity producers (Italy). Those actors are required to buy a certain amount of certificates in order to fulfil their quota. Nevertheless, the system may operate without the existence of legal quotas, as in the Netherlands where the market is based on the one hand on a voluntary demand for certificates on the one hand, from the electricity suppliers according to a collective commitment towards the green electricity and ,on the other hand, from the final consumers who benefit from tax reduction if they consume green electricity (Figure 1).

Using a wind turbine as an example, the idea may be described as follows: the wind turbine produces renewable electricity. At its meter, the renewable electricity is split into two products: the physical electricity and an environmental certificate. On the one hand, the physical electricity is fed into the distribution grid where it can no longer be distinguished from other electricity in the grid. The physical electricity is sold by the owner of the turbine as it is the case for all other power generation facilities at a price fixed in bilateral contracts or on the spot market (no favourable buy-back rate). On the one hand, the green certificate, which expresses the environmental benefits of the power generated, may be traded fully independently of the physical market.

Policy change in favour of a tradable green certificate system occurred in several European countries lately, but there is until now no generic green certificate system. In fact, national policies differ on several aspects, such as: the demand driver, the certificates, the eligible sources/technologies, the existence of a minimal price, the validity of the certificate with banking/borrowing opportunities and the import/export rules. All these options may define very different instruments based on a green certificate market. Therefore, one must be careful while talking about “the” tradable green certificate system since there might be as many systems as policies implementing this system.

These options in the definition of an operational tradable green certificate system allow a large range of systems with specific rules.

First of all, the demand driver for the green certificates may be either voluntary with related tax cuts (the Netherlands) or mandatory with quotas imposed on a specific category of actor (Belgium, Denmark, Italy, etc). However, in the future, the system of the quotas will predominate since the Dutch legislation is going to move to a mandatory green certificate system with the final consumers as target.

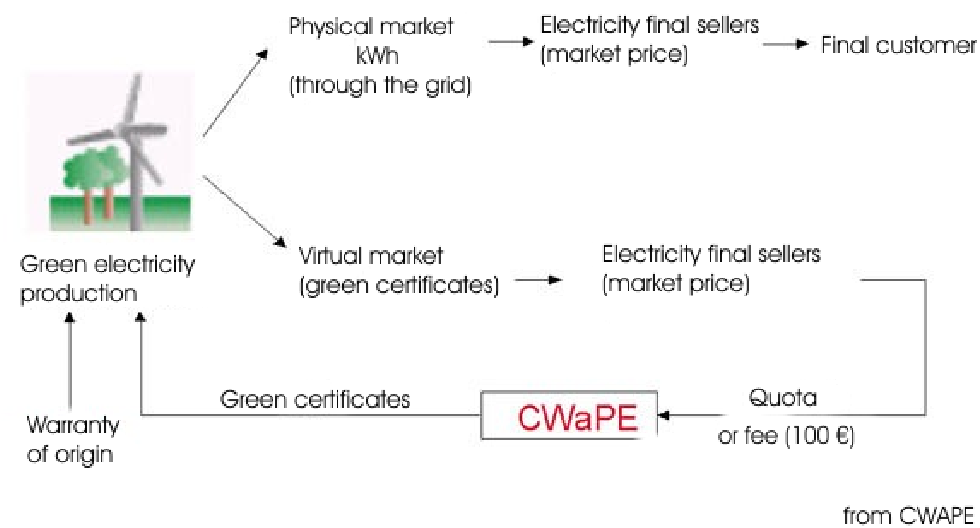

Figure 1 - Schematic diagram of the green certificate mechanism.
Figura 1 - *Diagrama do mecanismo de certificados verdes.*

Second of all, the rules that apply to the assignment of green certificates to the electricity producers vary from one system to the other according to the quantity of electricity produced and the link with CO_2 emissions. In most European countries, the certificates are allocated only in proportion to the quantity of eligible electricity generated (1, 10, 100 MWh). However, the certificates may also be allocated according to the reduction of CO_2 emissions achieved thanks to the use of a renewable source instead of a conventional energy fuel (for example, in Belgium-Wallonia). In this system a differentiation applies among the renewable energy sources according to their CO_2 reduction potential.

Third of all, only the eligible sources of renewable electricity are granted with green certificates and the definition of these sources differs in every country. The most controversial energy sources are the waste and "large" hydro plants (>1.5,10,20 MW), which are not eligible in most of the European countries.

Fourth of all, in every system with a quota, a penalty has to be paid by the actors 29 in case of non-compliance with the quota. On the green certificate market, the level of the penalty to be paid determines a price ceiling for the green certificates. Indeed, if the price of the certificates on the market exceeds the penalty, it is more interesting to pay the penalty than to buy the certificates. In addition, in several countries, legislation makes a provision for a guaranteed price for the green certificates (Denmark, Belgium, Sweden, the Netherlands). That way, the law may restrict the price of the certificates on the market within an interval defined by the level of the penalty, on the one hand and the guaranteed price, on the other hand.

Fifth of all, the green certificate market might turn out to be highly volatile in price, since the demand for the green certificates (quotas) is often very inelastic and the supply very elastic because of fluctuations in the production of the renewable electricity due to natural conditions (especially for wind power). In order to limit the volatility on the green certificate market, it is possible to extend the validity of the certificates (2, 5 years or unlimited period) as well as to allow banking and/or borrowing of certificates over time. Thus, the actors on the market can adapt their decisions (to sell or to buy certificates) on an extended period and thus make it more flexible to external shocks and pressures.

Finally, the tradable green certificate system is based on a market mechanism.

Therefore, the market of green certificates is expected to go beyond the national, or regional, borders and to integrate all European countries. Nevertheless, it appears that most countries tend to protect their market initially, by restricting the import and export of green certificates from other countries. In addition, as long as there is no common definition of the eligible renewable energy sources among the European countries, an international trading of green certificate will be difficult.

Thus, initially, every country will tend to adopt specific and restrictive rules while implementing a tradable green certificate system in order to develop and protect its own domestic renewable electricity sector.

3 The CO_2 Reduction Factor

Since the framework-decree of the Walloon government of 12 April 2001 on the liberalisation of the electricity market (which foresees the creation of funds to encourage the rational use of energy, financed by a charge imposed on the grid manager), and its implementing decree of July 2001, the government supports the production of green electricity through green certificate trading. The Walloon targets are expressed in terms of CO_2 emissions avoided so that the certificates (corresponding to 1MWh for a generation producing no emission) can also contribute (with appropriate weighing factors) to quality CHP. The Walloon government is planning for a quota of 2.9% by 1 January 2002, 5% by 1 October 2004 and 12% by 1 October 2009. The objective of 12% can be achieved by producing 8% from renewable energy sources (RES) and 12% from quality CHP. From September 2010, the quota will be increased each year by 10%. The fine for not reaching the target has been € 75 per certificate in 2002 and will be € 100 from January 2003 on. Besides, the Walloon government, after advice from the regulator, may operate a support system (65 € MWh^{-1}) for the green electricity producers who will have to choose either this system or the green certificate system.

The number of green certificates (*GC*) delivered is given by the electrical energy (*EE*) produced, multiplied by a CO_2 reduction coefficient (τ) (Eq. 1). A MWh_e is the electrical energy produced during 1 hour by a generation unit of 1 MW of power, equivalent to 3.6 GJ.

$$GC = EE \times \tau \qquad \text{(eq. 1)}$$

This CO_2 reduction coefficient (τ) represents the percentage of fossil CO_2 reduction of the green power unit (*G*) in comparison with the reference emission factor (E_{ref}) (Eq. 2).

$$\tau = G / E_{ref} \qquad \text{(eq. 2)}$$

E_{ref} has been defined as fossil CO_2 emissions (C_x) occurring during the supply and electricity generation of 1 MWh of electricity (MWh_e) in an optimal combined cycle gas power plant (Eq. 3). With the exception of nuclear power, which is not taken into account, this technology has been considered as the most CO_2 efficient among the fossil fuel classic power generation techniques. It consists of burning natural gas in a gas turbine and using the waste heat in the fuel gas to overheat steam. Further on, this steam is expanded into a steam turbine before being condensed. The overall electrical efficiency

(α_e) of such a plant is 55%.

$$E_{ref} = C_x / \alpha_e \quad \text{(eq. 3)}$$

The CO_2 coefficient (C_x) represents the amount of fossil CO_2 included inside the fuel (C_{xd}) and the fossil CO_2 generated for the fuel supply to the power plant (C_{xi}) (Eq. 4). C_x is given by 1 MWh or 3.6 GJ of low heating value of anhydrous fuel (MWh_p). In the calculation of C_{xi}, only direct fossil CO_2 emissions are taken into account, i. e., fossil fuel burned for extraction, distillation, drying, conditioning, storing, transporting, etc… … It has been decided that emissions occurring during equipment manufacturing would not be part of the calculation. For the reference supply chain, e.g. natural gas, C_x has been stated to be equal to 251 kg CO_2 MWh_p^{-1}.

$$C_x = C_{xd} + C_{xi} \quad \text{(eq. 4)}$$

with a C_x equal to 251 kg CO_2 MWh_p^{-1} and an electrical efficiency (α_e) of 55%, the reference emissions (E_{ref}) are equal to 456 kg CO_2 MWh_e^{-1}.

The reduction in CO_2 (G) are the subtraction of the emissions of CO_2 (F) occurring during supply and electricity generation of 1 MWh of green electricity (MWh_e) from the reference emissions (E_{ref}) (Eq. 5).

$$G = E_{ref} - F \quad \text{(eq. 5)}$$

4 CO_2 Emissions in Biomass Supply Chain

Different studies have been carried out to quantify fossil CO_2 emissions during the supply of bio-fuels to power plants. Usually, this emissions are low compared to the CO_2 sequestrated in the biomass. The models developed so far have mainly the purpose of giving a global balance of a carbon sequestration project. In this area, we can find the GORCAM model (Graz/Oak Ridge Carbon Accounting Model) developed by Schlamadinger and Marland (1996). This model divides the ecosystem in several compartments (vegetation, stem litter, soil, …) and takes into account the different future uses of the biomass (long lived products, short-lived products, bio-fuels, …) as well as the fossil fuel uses in the system. A similar model, CARBAL, designed by Ford-Robertson (1996) estimates the CO_2 emissions during the harvesting and logging of forest plantation to be 3% of what is absorbed from the atmosphere during growth.

Some studies have attempted to quantify fossil CO_2 emissions from specific supply chains. Dubuisson and Sintzoff (1998) made this calculation for the production, harvesting and supply of short rotation coppice of willow with very short logistic to fed a downdraft gasifier – dual fuel gas engine cogeneration unit. Three levels of crop management and harvest are taken into account from less intensive to full mechanized.

More studies were conducted regarding forest residues. The systems are often different in type and quite country specific. They give the results in different units but we tried to convert all of them in a common unit: the kg of CO_2 emitted to supply the equivalent of 1 MWh of primary energy content of bio-fuel at the conversion unit entrance. Forsberg (1999, 2000) made detailed calculation for different supply chains of forest residues (chipping vs baling, local vs long distance importation, …) for Sweden. If we take out the export contribution, we get a ratio of kg of CO_2 emissions per MWh_p, ranging from 2.2 kg up to 7.9 kg. In another study for Sweden, Borjesson (1996) states that harvesting and transport of forest residues emit 1 kg of carbon per GJ, i.e., 3.67 kg CO_2 GJ^{-1} or 13.21 kg CO_2 MWh_p^{-1}.

Malki et al. (2000) for obtained results varying from 6.95 kg to 9.19 kg for Finland. In these analysis, forest management and log harvesting are partially taken into account. Residues are chipped fresh or seasoned in the forest or at the roadside. A survey carried out for Austrian conditions (Jungmeier, 2000) and including harvesting, chipping, storage, drying and transportation to the energy plant reaches a final 51.1 kg of CO_2 per MWh of electricity. If we suppose a heat to electricity ratio of 25% and we take out the N_2O emissions included in that figure, we get a final emission of 8.6 kg per MWh_p.

For Belgium, the project Woodsustain (2001) estimated the emissions per bone dry tons of biomass equivalent to 27 and up to 162 kg. Going back to energy content, this gives a ratio ranging from 5.4 to 32.4 kg of CO_2 MWh_p^{-1}. Van Belle (2002), in a study ordered by the CWAPE (Walloon Commission for Energy) responsible for the CO_2 green certificate accreditation in Southern Belgium, calculated the most likely emissions that would occur during the harvesting and transportation of forest residues in Southern Belgium. The supply chains were defined based on a previous analysis defining optimal wood supply chains for co-combustion in a coal-fired power plant (Van Belle et al., 2003).

From the three supply chains, one is considered as highly productive and high capital intensive. It was designed to be the core of the wood procurement system for the power plant. Operations are taken into account only from forwarding as plantation, forest management and merchantable wood harvesting occur independently of the biomass collection for energy. Coniferous forest residues from mechanized clear-cut harvesting operations are transported by forwarders on the roadside. After seasoning, they are chipped using a drum chipper mounted on truck or 18 ton forwarder. Chips are blown into 35 m³ containers and trucked to the storage park next to the power plant. Emissions of CO_2 have been estimated for Belgium average conditions to 43.5 kg of CO_2 per ton of bone dry biomass (Table 1).

Emissions were also calculated for a low capital intensive supply system. In this case, the procurement is composed of chainsaw felling and bucking of tree tops or hardwood coppices, tractor skidding and hand fed manual chipping. Transportation is done using farm tractor. Overall emissions were estimated to 64.4 kg of CO_2 per ton of bone dry matter collected (Table 2).

Standard emission coefficients were eventually been fixed. They represent conservative high level figures for Belgian conditions (CWAPE, 2004). Considering this factor, the worst option is wood coming from short rotation coppice for energy purpose. In this supply chain, the C_x has been set up to 40 kg of CO_2 MWh_p^{-1}. Bio-fuel coming from harvesting, chipping and transport of forest residues is considered as having a C_x of 20 kg. Wood residues from sawmills or other industries, directly used on-site for power production have no emissions associated. Standard C_x for individual operations have also been fixed (Table 3).

Table 1 - CO_2 emissions for highly productive supply of forest residues
Quadro 1 - *Emissões de CO_2 para suprimento produtivo de resíduos florestais*

Supply phases	kg CO_2 per dry ton
Off-road forwarding	5.46
Roadside chipping	18.75
Road transportation	19.3
Overall supply	43.5

Table 2 - CO_2 emissions for low capital intensive supply of forest residues
Quadro 2 - *Emissões de CO_2 para suprimento intensivo de baixo capital de resíduos florestais*

Supply phases	kg CO_2 per dry ton
Chainsaw felling and bucking	2.4
Tractor skidding	20
Hand fed manual chipping	30
Tractor transportation	12
Overall supply	64.4

Table 3 - Emission coefficient for wood supply for energy project
Quadro 3 - *Coeficiente de emissão para suprimento de madeira para projeto de energia*

Supply chain or phases	C_x
Wood from energy crops	40
Wood from forest residues	20
Wood from industry	0
Crop production and management	20
Harvesting and forwarding	6.5
Chipping	3.5
Drying	10
Briquetting	10
Short distance transportation	5
Long distance transportation	25
Tractor transportation	12

5 Interactions Between Supply Chain and Electricity Generation

Before defining a bio-energy generation project, the electricity producer must take into account a lot of parameters. This includes type, location, physical characteristics and cost of bio-fuel. Energy generation techniques should also be carefully selected. Key parameters to appraise are capital investment costs, size, fuel characteristic constraints [Van Belle & Schenkel, 1999]. This in turn forces for supply chain selection such as harvesting machines, chipping equipment, transportation distances, ... All these factors together allow to define the best combination of power plant, biomass sources and supply chains in order to get the best electricity price or the highest rate of return on the cash invested in the project.

CO_2 emissions during production, harvesting, transportation and pre-treatment of biomass were normally considered as an externality and were not taken into account in the economic calculations. Today, the new green certificate scheme interacts with this techno-economic optimisation. CO_2 emissions are now internalised into the electricity price valuation and the overall project viability. This is done through the τ ratio which attributes a portion of the green certificate with regard to the CO_2 emissions saved. We have seen that this ratio was a function of the biomass type and the supply chain.

For woody crops such as short rotation coppice, the τ factor may vary from 0.12 until 0.71 depending on the electrical efficiency of the power plant (Figure 3). With forest

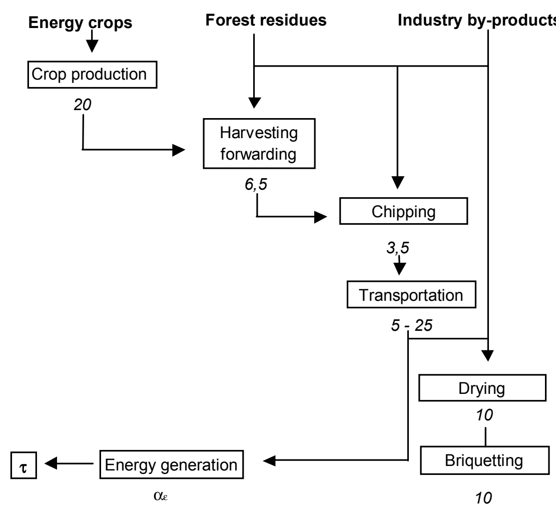

Figure 2 - Emission coefficient vs supply chains.
Figura 2 - *Coeficiente de emissão versus cadeia de oferta.*

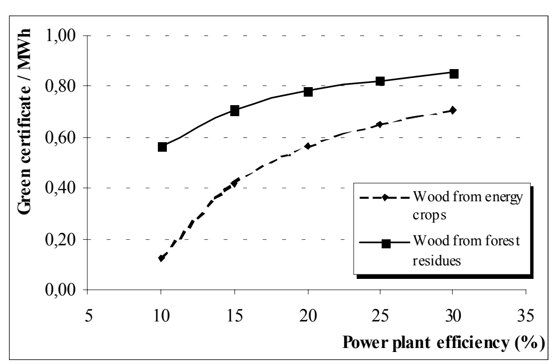

Figure 3 - Green certificate per MWh vs supply chain.
Figura 3 - *Certificado verde per MWh versus cadeia de oferta.*

residues coming from forest managed for lumber and paper production, this ratio is better and the amplitude of variation is 0.29. For each MWh_e generated, 0.56 green certificates are given at an efficiency of 10%. In the case of an electricity yield of 30%, it would be necessary to produce 1.17 MWh_e to receive 1 green certificate.

Starting from 85 € in 2003, the transaction price for the green certificate in Wallonia is today around 92 €. Last year, 192 273 certificates were exchanged for a total value of 16 389 350 €. For the first 3 quarters of 2004, the total number of trade is reaching 279 983 for a global amount of 25 727 684 €. Based on these results and assumptions, the additional an electricity producer may receive from generating power with wood varies from 11 € up to 78.5 € per MWh_e. If we consider a grey price of 30 € per MWh_e, this is a premium of 37% in the worst case and 262% in the best case. Looking at these figures, it is easy to deduce that biomass supply chain must be chosen carefully in regards to their CO_2 emissions and not only based on the delivered price per ton or GJ.

References

BERRY, T.; JACCARD, M. The renewable portfolio standard: design considerations and an implementation survey. **Energy Policy**, v. 29, p. 263-277, 2001.

BORJESSON, P. Emission of CO_2 from biomass production and transportation in agriculture and forestry. **Energy Conversion Management**, v. 37, p. 1235-1240, 1996.

CWAPE. **Le régime des certificats verts dans le cadre de l'ouverture du marché de l'electricité en Wallonie**. 2003. 9 p.

CWAPE. **Les coefficients d'émission de CO_2 des filières de production d'électricité verte, définis en application de l'article 38, §2, du décret du 12 avril 2001 relatif à l'organisation du marché régional de l'électricité**. 2004. 7 p.

DUBUISSON, X.; SINTZOFF, I. Energy and CO_2 balances in different power generation routes using wood fuel from short rotation coppice. **Biomass and Bioenergy**, v. 15, n.4/5, p. 379-390, 1998.

FORD-ROBERTSON, J. B. Estimating the net carbon balance of the plantation forest industry in New Zealand. **Biomass and Bioenergy**, v. 10, n. 1, p. 7-10, 1996.

FORSBERG, G. **Bioenergy transport systems:** Life cycle assessment of selected bioenergy systems. Uppsala: The Swedish University of Agricultural Sciences, 1999. (Report, 5)

FORSBERG, G. Biomass energy transport: Analysis of bioenergy transport chains using life cycle inventory method. **Biomass and Bioenergy**, v. 19, p. 17-30, 2000.

JUNGMEIER, G. **Greenhouse gas balance of bio-energy systems:** A comparison of bio-energy with fossil energy systems. Graz, Austria: Joannum Research. 2000. 18 p.

MALKI, H.; HARJU, T.; VIRTANEN, Y. Life Cycle Assessment of logging-residue-based energy. In: PROCEEDINGS OF IEA BIO-ENERGY, **Bio-energy from sustainable forestry:** Principles and practices. Coffs Harbour, Australia: Task 18: Conventional Forestry Systems for Bio-energy, 2000. p. 92-107.

RADER, N. The hazards of implementing renewable portfolio standards. **Energy & Environment**, v. 11, n. 4, p. 391-405, 2000.

SCHLAMDINGER, B.; MARLAND, G. Full fuel cycle carbon balances of bio-energy and forestry options. **Energy Conversion and Management**, v. 37, p. 813-818, 1996a.

SCHLAMADINGER, B.; MARLAND, G. Role of forest and bio-energy strategies in the global carbon cycle. **Biomass and Bioenergy**, v. 10, n. 5-6, p. 275-300, 1996b.

Van BELLE, J. F.; LEMAIRE, P.; SCHENKEL, Y. Potential for biomass energy in Wallonia. In: CHARTIER, P. et al. (Eds.) **Biomass for energy and the environment**. Pergamon, 1996, p. 813-818.

Van BELLE, J. F.; SCHENKEL, Y. **Energy from residues in the forest industry**. NNA-Bericht. v. 12, Issue 1, 1999.

Van BELLE, J. F.; TEMMERMAN, M. Bio-energy and sustainable forest harvesting. In: INTERNATIONAL CONFERENCE UNDER THE BELGIAN PRESIDENCY OF THE EUROPEAN UNION. **Carbon sinks and biodiversity**. Liège, Belgique: 2001.

Van BELLE, J. F. **Estimations des émissions de CO_2 liées aux filières bois-énergie en Wallonie**. Commission Wallonne pour l'Energie (CWAPE) 2002.

Van BELLE, J. F.; TEMMERMAN, M.; SCHENKEL, Y. Three level procurement of forest residues for power plant. **Biomass and Bio-energy**, v. 24, p. 401-409, 2003.

WOODSUSTAIN. Contributions du bois-énergie au développement durable en Belgique. 2001. (Rapport Final, SSTC).