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# Tradable green certificates in Flanders (Belgium)

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**Abstract**

The paper provides details on green certificate systems in Belgium. The Flemish region has established a system and the Walloon region is preparing a slightly different one. The lack of uniformity and consequently of transparency in one country emphasises the need for more EU leadership in the field. The main part of the article analyses the established Flemish system. Green certificates are complementary to other instruments that promote renewable electricity, e.g. direct subventions on the feed-in price of green electricity or direct subventions on capital investments. Certificates execute a forcing effect on the actual development of green power if the imposed shares of green power in total sales are significant and if the fine level is at the height to enforce the quota. If the fine is too low the incentive effect turns into a financing tax effect. When the green certificate system does the job it is designed for, i.e. operating at the edge of the RES-E development and organise the transition from a non-sustainable to a sustainable power system, certificate prices will be high and reduce end-use consumption of electricity. A segmentation of the RES-E sector along the various RES-E technologies is a necessity to keep any certificate system affordable, effective and efficient. One can segment the tradable certificate market or one can assign a different number of certificates to a different RES-E technology project. Both solutions require an intensive follow-up of cost structures and of other policy measures (subventions), but given the infant state of understanding and experience segmenting markets may be best in the nearby years.


*Keywords:* Green certificates; Renewable energy; Policy instruments

## 1. Green certificate systems (proposed) in Belgium

### 1.1. Actors responsible for energy policy in Beligium

The situation in Belgium is complicated by the legendary institutional complexity of the country. Belgium is a federal state consisting of three regions: Flanders, Wallonia and Brussels. In Belgium 'energy' falls under the responsibility of both the federal and the regional authorities for certain matters.

The federal authorities are responsible for:

- The national equipment programme in the electricity and gas sector,
- Electricity generation (power stations),
- Electricity transmission (high-voltage lines),
- Tariffs.

The regional authorities are responsible for:

- Local transmission and distribution of electricity (under 70 kV),
- Public gas distribution,
- Cogeneration,
- Promotion of renewable energy sources (RES),
- Rational use of energy (RUE).

Flanders has introduced a green certificate system, with an obligation starting January 1, 2002. Wallonia is about to introduce a slightly different green certificate system, that also includes co-generation.

The Brussels region adopted a new electricity law in July 2001, which will come into practice in 2003. This new law opens up the possibility for a regional certificates scheme covering the Brussels region, but it is unclear if a market system for green electricity will ever be proposed.

A separate arrangement will operate at the federal level. The federal obligation will apply to large customers directly connected to the grid. Offshore windmills don't belong to one specific region and are therefore a federal matter in Belgium. Offshore windmills will probably sell their certificates to the grid operator, who will then sell them on to distributors at whatever price he can obtain. Details have not been made official yet.

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### 1.2. Purpose of a green certificate market

The main objective of a legally enforceable 'quota-based system' is to stimulate the penetration of a predefined amount of Renewable Energy Sourced Electricity (RES-E) into the electricity market. According to the RES-E Directive (2001/77/EC), the indicative national target for RES-E for 2010 for Belgium is 6.0%. In 2001, the actual level of RES-E generation was 0.7% (excluding waste incineration) or 1.3% (including waste incineration).

The main characteristic of a tradable green certificate (TGC) system is the creation of a *separate* market for the "*greenness*" of the RES electricity, beside the market for *physical* electricity (Schaeffer et al., 2000, p. 7). RES-electricity is treated as any other electricity in the (physical) electricity market, and certificates are traded separately as *financial assets*. The green certificate market will function as a *financial* one. There is however a one-to-one link between the number of green certificates and the number of (physical) kWh produced by renewable technologies.

### 1.3. General description of the TGC systems in Belgium

Generators of RES-E are certified for producing RES electricity. For the production of each unit of RES electricity, they will receive a tradable green certificate (TGC) from the regional authorities [(1) in Fig. 1]. Because the certificate is unique, it is the only official proof and guarantee of a unit RES electricity having been produced.

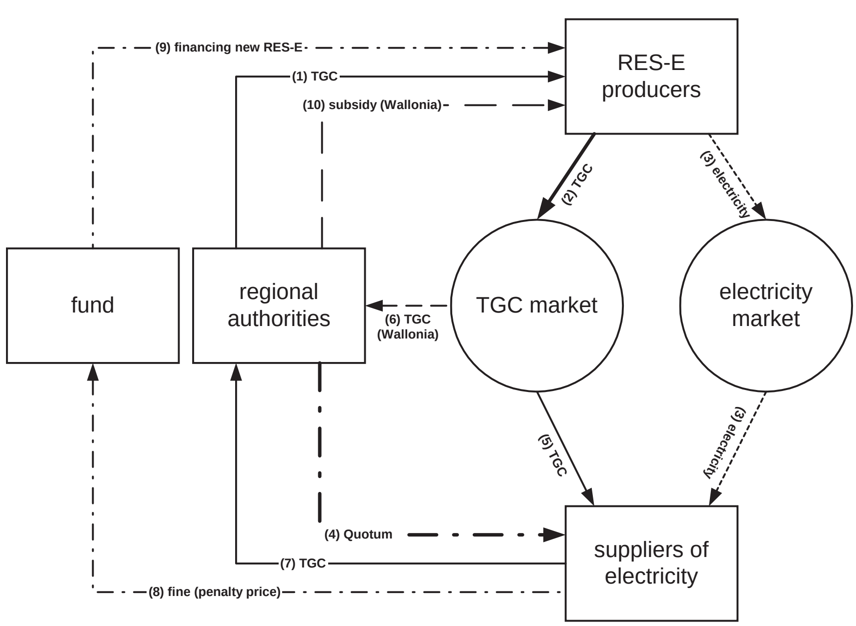
In Flanders the regional authority will issue a TGC of 1000 kWh for each 1000 kWh RES electricity generated by the RES-E producers in their own region. In Wallonia, a green certificate will be issued for each 450 kg of $CO_2$ avoided. E.g. 1 MWh wind and hydro electricity receives 1 certificate. On average 1 MWh cogenerated electricity will stand for 0.2 certificate while 1 MWh cogenerated with biomass as a fuel, will get 2 certificates. The RES-E producers can sell the TGCs to suppliers of electricity (wholesale power distributors) [(2) in Fig. 1].

Each producer of RES electricity thus produces two distinct goods:

- Physical electricity, which is fed into the grid (exported) and sold at market prices in the 'physical electricity market' [(3) in Fig. 1],
- Tradable Green Certificates, where each TGC represents the 'added value' or 'greenness' of one pre-defined unit of electricity produced from RES-E.

Demand for green certificates is imposed by the regional governments on the suppliers of electricity selling electricity to the end-users in their region, because they must cover a given share (quota) of electricity generated by RES-E [(4) in Fig. 1]. The quotas differ for the Flemish and Walloon regions (see Table 1).

To meet this obligation, each electricity supplier may be allowed to himself produce RES-E, or buy a specific number of TGCs from the RES-E producers,




*Source: CWAPE*; Europese Commisssie. Staatsteun nr. N 550/2000 – België Groenestroomcertificaten.

Fig. 1. Structure of the green certificate markets in Flanders and in Wallonia. *Source*: *CWAPE*; Europese Commisssie. Staatsteun nr. N 550/2000—België Groenestroomcertificaten.

corresponding to a percentage (quota) of their total electricity supplied to the end-users during one calendar year [(5) in Fig. 1].

The government itself can also act as a buyer of green certificates, e.g. by securing a minimum price. This is only the case in the Walloon region [(6) in Fig. 1].

At the end of each year a volume of tradable green certificates corresponding to the quota will be withdrawn from the market by the regional government. Electricity suppliers have to hand over a certain amount of certificates to the regional regulating authorities [(7) in Fig. 1].

Electricity suppliers have an incentive to buy certificates from the producers, because penalties are set if they are not able to meet their obligation [(8) in Fig. 1]. The penalties differ for the Flemish and Walloon regions (see Table 1).

The penalty or fine is used for feeding a regional Renewable Energy Fund. This Fund can be used to finance new renewable installations [(9) in Fig. 1]. In the Walloon region, RES-E producers may exchange their TGCs to the regional authority for a subsidy [(10) in Fig. 1].

The Flemish and Walloon TGC systems will co-exist with other renewable energy regulations. These regulations include, for the household sector, a reduction in income taxes for investments such as the installation of solar panels for sanitary hot water production or the installation of photovoltaïc panels, or the SOLTHERM program in Wallonia, providing a subsidy of 620 euros for the installation of $4\,m^2$ solar panels, plus 74 euros per extra $m^2$. For the industry local authorities will continue to provide financial support for the development of renewable energy.

### *1.4. Particularities of the Flemish and (proposed) Walloon green certificate markets*

(See Table 1).

## 2. Economic analysis of the green certificate system in Flanders

In this part of the article we hook up with the discussion on green certificates in Europe (see e.g. Mothorst 2000; Schaeffer et al., 1999, 2000; Huber et al., 2001, 2002). Most authors suggest that one has to investigate thoroughly the TGC instrument before engaging in practical experiments, and we join this argument after study of the Flemish system vested since January 1 2002. Main concerns are that TGC systems are less effective than other support mechanisms and that TGC systems create high windfall profits for incumbent RES-generators.

For the analysis it is assumed that:

(a) There is a liberalised "physical electricity" market, with perfect competition. The balance between electricity supply and demand determines the electricity market equilibrium price $P_E$. Every RES-E producer has the possibility to feed into the grid at non-discriminating conditions.
(b) There is a "tradable green certificate" market, with transparent price determination at a green certificate exchange. The balance between TGC supply and demand determines the TGC market equilibrium price.
(c) There is no international trading, and for case of simplicity we do not consider the possibility of banking certificates over the years. Therefore the analysis is mainly static.
(d) There is a consensus among stakeholders, including all electricity end-users, that the actual non-sustainable fossil-fuel and nuclear based power system should be phased out and replaced by a sustainable one based on renewable energy.

Our analysis takes the structure of a static supply–demand analysis.

### *2.1. The supply side of RES-E*

In the present perspective of energy sector liberalisation and of stimulating private entrepreneurs, government will not itself deploy RES-E investments[1] but rather expect from private investors to divert their funds to RES-E projects. In this context it is good to remember how private investors make investment decisions.

### *2.2. Private investment decision making rule*

Abstracting from the rules of irreversible investment decision-making under uncertainty Dixit and Pindyck, (1994) where option values can delay the timing of projects, we refer to common Discounted Cash Flow (DCF) analysis.[2] An investor accepts a project when its Net Present Value is positive, or:

$$NPV(i,n) \geqslant 0.$$

In this case the rate of return on investment at least equals i, the hurdle rate of acceptance, the net cash flows of the project being assessed over n time periods (years), or

$$\sum_{j=0}^{n} \frac{Revenues(j)}{(1+i)^j} - \sum_{j=0}^{n} \frac{Costs(j)}{(1+i)^j} \geqslant 0.$$

[1] In the 1980s the first and only wind farm in Belgium at Zeebrugge (4.5 MW) was realised by the Ministry of Infrastructure.

[2] We also abstracted from these aspects of risks as, e.g., covered in Lemming (2002).

Table 1
Flemish and (proposed) Walloon TGC systems compared

| | Flanders | Wallonia |
|---|---|---|
| Legal references | "Het decreet van 17 juli 2000 houdende de organisatie van de elektriciteitsmarkt" (B.S. 22 september 2000), a.k.a. the "Elektriciteitsdecreet", in particular articles 21–25.<br>"Besluit van de Vlaamse regering van 28 september 2001 inzake de bevordering van elektriciteitsopwekking uit hernieuwbare energiebronnnen" | "Le décret du 12 avril 2001 à l'organisation du marché régional de l'electricité".<br>Proposal "Arrêté du Gouvernement wallon relatif à la promotion de l'électricité verte". This bill organizes the green certificates market and the promotion of green electricity in Wallonia, and has been sent to the Council of State for advice |
| Starting date | January 1, 2002 | Not yet operational |
| EU competition law clearance | The EC has approved the Flemish system on July 25, 2001 "Steunmaatregel N 550/2000—België" | The EC has approved the proposed Walloon system om November 28, 2001<br>"Steunmaatregel N 415/01—België" |
| Obliged actors | Electricity suppliers selling electricity to end-users in the Flemish region | Electricity suppliers selling electricity to end-users in the Walloon region |
| Quantitative obligations (Quota) | A percentage obligation in kWh supplied<br>The number of certificates to be submitted for a given year is fixed according to a certain equation. For the following years, the percentage obligation coincides with the Flemish targets regarding the use of renewables:<br>2002: 1,41%<br>2003: 2,05%<br>2004: 3%<br>2010: 5% | A percentage obligation in kWh supplied<br>1/10/2002—30/9/2003: 3%<br>1/10/2003—30/9/2004: 4%<br>1/10/2004—30/9/2005: 5%<br>1/10/2005—30/9/2006: 6%<br>1/10/2006—30/9/2007: 7.2%<br>1/10/2007—30/9/2008: 8.6%<br>1/10/2008—30/9/2009: 10.2%<br>1/10/2009—30/9/2010: 12%<br>From september 2010 onward, the quota will be multiplied annualy by a factor of 1.01. |
| Homogeneity of obligations | No technological differentiation of obligations | No technological differentiation of obligations |
| Issuing body | Regional regulator (public authority)<br>VREG (Vlaamse Reguleringsinstantie voor de Elektriciteits- en Gasmarkt). | Regional regulator (public authority)<br>CWAPE (Commission wallone pour l'énergie) |
| Renewable energy technologies included | Solar energy (solar thermal power and photovoltaics)<br>Wind-energy (but offshore wind production falls under the federal jurisdiction)<br>Small scale hydropower (< 10 MW)<br>Tidal stream energy and tidal wave energy<br>Geothermal electricity<br>Biogas from the fermentation of organic wastes<br>Animal manure, including biogas generated from animal manure<br>Biomass, including biogas generated from biomass, if not processed alongside residual wastes<br>Energy generated from:(a) Dead animals<br>(b) Road verge trimmings<br>(c) Vegetables, fruit, and garden waste (VFG)<br>(d) Seperately collected or sorted organic wastes<br>(e) Purification sludge<br>(f) Frying oil used for making 'chips' or 'French fries' (the national dish in Belgium)<br>The Flemish region will introduce a separate certificate system for "high quality CHP". | Renewables, as defined in the "RES-E Directive" (European Parliament and Council, published 27 October 2001 PB L 283 27.10.2001, p. 33)<br>"High quality CHP" (certificates will be issued on the basis of avoided $CO_2$-emissions) |
| Technologies excluded | Residual wastes and combined processing with residual wastes | |
| Banking | YES | YES |
| Borrowing | NO | NO |
| Maximum price | Defined by the penalty | Defined by the penalty |
| Minimum price | NO | Producers of RES-E may exchange |

Table 1 (*continued*)

| | Flanders | Wallonia |
|---|---|---|
| | | their TGC to CWAPE for a subsidy, at a fixed price of 65 per TGC (1 TGC = 1 MWh) |
| Penalty for non-compliance | Penalty is a fixed price per missing TGC | Penalty is a fixed price per missing TGC |
| | 2002: 50 € per missing TGC (1000 kWh) | 2002: 75 € per missing TGC (1000 kWh). |
| | This fine will gradually increase to a maximum of 124 € per missing TGC | From April 1 2003 onward: 100 € per missing TGC (1000 kWh) |
| Period of validity | 5 years<br>TGC can only be produced for meeting the RES obligation during the year of production and five years thereafter. | 5 years |
| International trading | Certificates from installations outside the Flemish region plus the Belgian territorial sea, are not taken into account within the regional obligation. They may however be used to sell "green power" to end-users in the Flemish region, under the provision that the certificates are submitted to the authorities in the region where they were issued.<br>Intention to co-operate with Wallonia to make certificates exchangeable between these two regions | Certificates will be tradable within Belgium Trade with other regions or countries still to be decided. |

A market agent considering investing in RES-E pledges to no other rationality than any other rational market agent. But RES-E is a special product with characteristics that limit its handling in the same manner as other economic products.

### 2.3. Inherent characteristics of RES-E

RES-E projects generally exhibit the following properties (Twidell and Weir, 1986):

- The cost of the project is predominantly the capital investment cost, because it is running on free energy supplies. For simplicity, we will neglect exploitation costs, although e.g. in biomass projects exploitation costs are significant.
- Capacity installed refers to a particular capacity to intercept free energy currents when available at design conditions (mostly the best ones accessible on a particular site), and to convert these currents into electricity.
- Free energy supplies are really 'free' and the investor has in most projects no discretionary impact to steer the supplies (e.g. wind, solar, run-of-the-river hydro, bio-mass when it is offered as a free source because it otherwise has to be wasted). One only can decide to bypass the free flow of energy (Twidell and Weir, 1986).
- It follows that the short-run marginal cost of RES-E is nearly zero, but that the supply is not under control. One only can throttle the free currents and spill part of it, but this is not a rational option when there is a demand for the product, as is the case when the project is connected to the power grid.
- When the renewable power can be supplied to an interconnected and competitive power system, it is worth the avoided costs of the power system, i.e. at any moment the delivered kWh is basically worth the short run marginal cost or system $\lambda$.[3] When the power system works under perfect market conditions we can state that at any moment (hour or $\frac{1}{2}$ or $\frac{1}{4}$ h) the $p_e = \lambda$.[4]

### 2.4. Profitability of RES-E under free market conditions

When the RES-E supplier can participate in the established power markets he sells all generated power at $p_e(t), t = 1, \ldots, 8760$ (hourly pricing). To assess the market revenues of the project the RES-E investor has to make the convolution of the probability density function of $p_e(t)$ and the probability density function of $g_r(t)$ with $g_r(t)$ the physical output of the project at any hour $t$, $t = 1, \ldots, 8760$. In principle one has to assess the convolutions for all future years of the project's life span of $n$ years.

Simplifying one replaces

$$\int\int p_e(t) \cdot g_r(t) \text{ by } \hat{p}_e(j) G_r(j),$$

where $\hat{p}_e(j)$ expected (weighted) average price of RES-E power delivered in year $j$, $G_r(j)$ total amount of renewable generation in year $j$.

In this setting and with $RC(j)$ = running costs of the project during year $j$, the investor accepts the investment

[3] Perfect competitive power systems and perfectly planned power systems will come up with the same system $\lambda$'s.

[4] We do not extend the analysis to the reliability margin or congestion margin that can come on top of the system $\lambda$ direct generation costs.

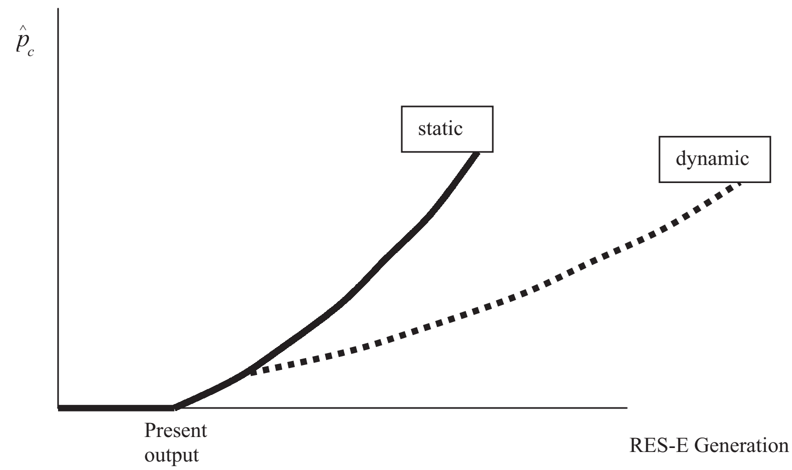



Fig. 2. The supply curve(s) of RES-E for given certificate prices.

when

$$NPV = \sum_{j=0}^{n} \frac{\hat{p}_e(j).G_r(j) - RC(j)}{(1+i)^j} \text{—Investment (year 0)} \geqslant 0.$$

In our present non-sustainable societies, appraisals of most RES-E project proposals with the above formula, end in a preference for other investment options above green electricity generation.

### 2.5. RES-E profitability adjusted by public policy

Public policy promotes RES-E investment by private decision-makers by amending the above formula.

$$NPV = \sum_{j=0}^{n} \frac{\{\hat{p}_e(j) + S(j)\} \cdot G_r(j) - RC(j) + \hat{p}_c(j)G_r(j)}{(1+i)^j} - \{Inv - SubInv\},$$

where $S(j)$ is a per kWh RES-E subsidy assigned in year $j$. This can also take the form of changing the feed-in prices $\hat{p}_e(j)$ directly (e.g. in Belgium there is a direct support of green electricity with 2.48 €ct or 4.96 €ct/kWh), or indirectly (e.g. allowing the revolving electricity metering when PV-panels are installed).

$\hat{p}_c$ is the expected price per RES-E kWh that follows from an established system of green power certificates.

SubInv is a direct investment subsidy at the time the capital investment is made (e.g. in 2001 the Flemish government covered 75% of PV investment costs).

The public policy maker therefore has at least three major direct[5] instruments to promote the development of RES-E. They can be applied simultaneously because they do not contravene one another.

[5] More indirect instruments also can be used to promote RES-E, e.g. tax credits, soft loans, risk coverage, R & DD grants, etc.

Focusing on the green certificate system at $NPV = 0$, and $PV[\ldots]$ representing the present value of the cash flows within brackets.

$$PV[\hat{p}_c(j)G_r(j)] = NetInvestment - PV[\{\hat{p}_e(j) + S(j)\}G_r(j) - RC(j)].$$

Assuming $\hat{p}_c$ as the "levelised" certificate price, it follows:

$$\hat{p}_c = \frac{NetInvestment}{PV[Generation]} - \frac{PV[Sales] - RunningCosts}{PV[Generation]},$$

$$\hat{p}_c = \frac{capitalcost}{\text{kWh}} - \frac{netsalesrevenue}{\text{kWh}}.$$

For every individual RES-E project it passes the test of profitability at $NPV = 0$ when the certificate price bridges the gap between (partly subsidised) capital cost and (partly subsidised) net sales revenue per kWh. In a nation there exists a multitude of RES-E project opportunities. Some are realised before the certificate system was deployed, i.e. at $\hat{p}_c = 0$ the net sales revenues could cover the capital costs. The static supply curve of RES-E is as shown by the full line in Fig. 2. By technological improvement it is expected that the costs of RES-E generation will fall (dotted curve in Fig. 2).

The supply curve is the horizontal aggregation of the long-run[6] marginal cost curves of the numerous individual projects. Because certificates are storable (and non-perishable when banking is permitted), their trade is disconnected from the volatility of the electricity

[6] The relevant marginal costs are indeed the 'long-run' ones, and not the 'short-run' ones as is the case in markets with non-storable goods forthcoming from available capacities in diversified generation systems that can be composed optimally (and where in the optimum long-run and short-run costs are equal). We would compare the RES-E/TGC market with the housing market: renting prices are not equal to the short-run marginal costs of dwellings but to the long-run costs of supplying housing stock.

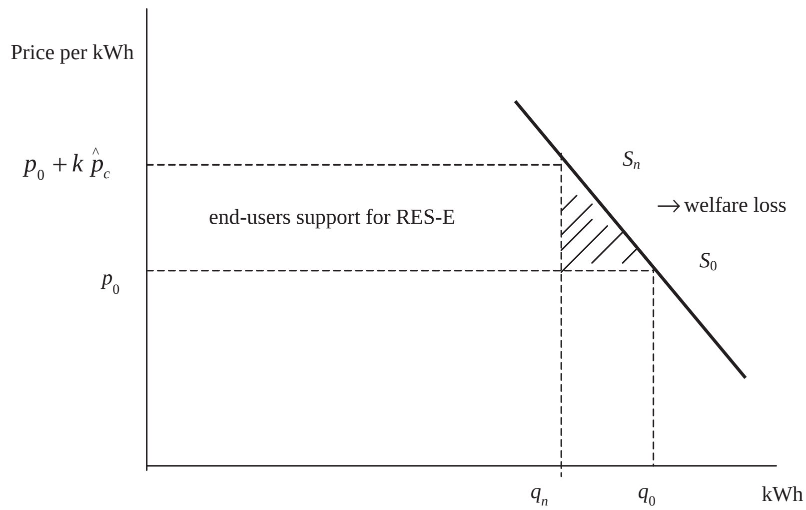



Fig. 3. End-use demand for electricity.

spot market. Moreover, TGC-quota are not imposed as momentary obligations but as an annual aggregate. The trade in TGC therefore will be axed on RES-E capacities and their expected outputs, not on the momentary output of RES-E plants.

The actual shape and slope of the curves depend on a multitude of factors (technology, availability of sites and sources, public policy with respect to feed-in prices, direct investment subventions and other policy instruments). Therefore the curves may be very different from country to country and shift significantly over time. When comparing supply curves among countries and over time, one must look after all the ''upstream'' policy differences to be taken into account.

Several RES-E projects are not withheld because investors increase discount rates with (high) risk premiums due to economic and regulatory uncertainties. Also with respect to the TGC prices $\hat{p}_c$ uncertainty may be high when the regulatory framework is unstable and when future RES-E technologies would become much cheaper than the present ones. An expected dip in the $\hat{p}_c$ values during some years e.g. may totally block the development of the RES-E market.

### 2.6. Demand for RES-E

At the demand side for RES-E two parties are involved and connected 'in series': the end-users of electricity and the supply companies (that must meet the quota system).

### 2.7. End-users

The demand of the end-users is represented by a standard down-sloping demand curve, with one point known (the present end-use at the given price) and price elasticity difficult to assess accurately (Fig. 3).

When the supplier must process a quota of RES-E equal to $k$% of his sold volume, when certificates are sold at $\hat{p}_c$ per kWh RES-E and the full certificate price is paid by the end-users, the power price increases by $k\hat{p}_c$. Depending on the price elasticity of demand at $S_0$ consumption will be reduced from $q_0$ to $q_n$ with some of the consumer surplus converted into support payments for RES-E (certificates or fines) and some social welfare loss.[7] The actual amounts depend on a multitude of variables ($k, \hat{p}_c, S_0, \varepsilon_0$ and the variables determining these). But under normal assumptions, consumption of electricity is lower at higher prices.

### 2.8. Power suppliers

Power suppliers must yearly deliver an amount of certificates kV with V the sales volume of kWh and k the fraction of sales to be covered by RES-E.

For every unit of kV not covered by a certificate the supplier must pay a fine $F$ or penalty per unit. The certificate system therefore is steered by the two parameters $F$ and $k$, but also influenced by the volume $V$.

The demand curve for certificates (RES-E) by the suppliers is given by a horizontal line segment at height $F$ up to the quantity $k_i V$ where it changes into a vertical line segment up to the abscissa, where it becomes horizontal again at a zero price. When banking is allowed the demand curve around $k_i V$ will be more elastic (Fig. 4).

[7] There is an argument that considers the $k\hat{p}_c$ price increase as the payment for transiting from the present non-sustainable system to a sustainable system. Then, $p_0 + k\hat{p}_c$ is the 'right' price and one is increasing social welfare (avoiding welfare losses) by installing this right price.

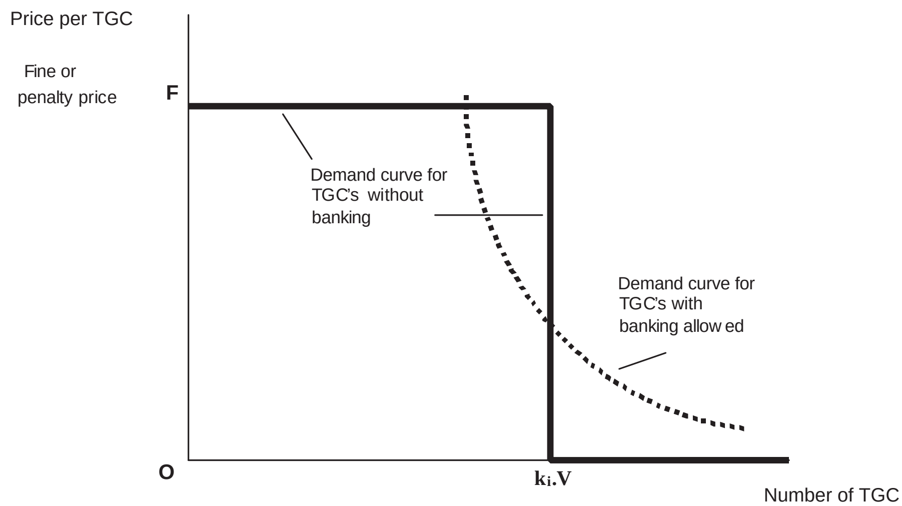



Fig. 4. Demand for TGC by suppliers.

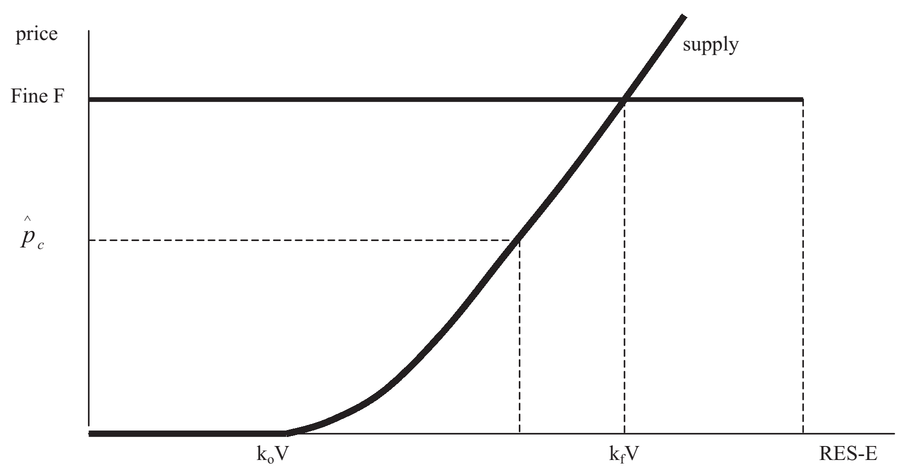



Fig. 5. Market equilibrium in the TGC-market changes with set $k$ values.

### 2.9. Equilibrium on the RES-E and certificates market

Supply of RES-E and demand for RES-E (through certificates) meet in the certificate market (Fig. 5). It is easy to verify the two $k$-values that bring the certificate market in a different price regime, as:

| | $k<k_o$ | $k_o<k<k_f$ | $k>k_f$ |
|---|---|---|---|
| $\hat{p}_c =$ | 0 | Amended Marginal cost of RES-E supplies | $F$ (fine) |
| Stimulus RES-E development | None | From $k_oV$ to $k_fV$ | Not further than $k_f\ V$ |
| Taxing effect | None | $P_c$ plays the role of an incentive tax | Incentive and financing tax effect |

The regulating authorities have to establish quota in such a way that an appropriate development of new RES-E capacity will take place (Morthorst 2000, p. 1090). If k is set too low, the equilibrium TGC price may be too low to secure the development of new RES-E capacity at all. If k is set too high, the optimal RES-E capacity development will be lower than prescribed by the quota. The certificate price plays the role of an incentive tax when it is stimulating the development of the RES-E market (Verbruggen, 2002).

When $\hat{p}_c$ hits the Fine-cap it turns over in a financing tax.[8] Depending on the height of the values of $F$ and $k$, on the cost of RES-E supplies and on the price elasticity of demand, the green certificate system will have some impact on the end-use of power.

[8] Discussing environmental policy, it is argued that taxes are imposed for the pursuit of three main goals: (1) incentive taxing of target groups for undertaking or refraining from particular activities, (2) financing taxes to transfer money from target groups to public treasuries, (3) compensating taxes for making polluters pay the true costs of the (Pareto-irrelevant) externalities (Verbruggen, 2002).

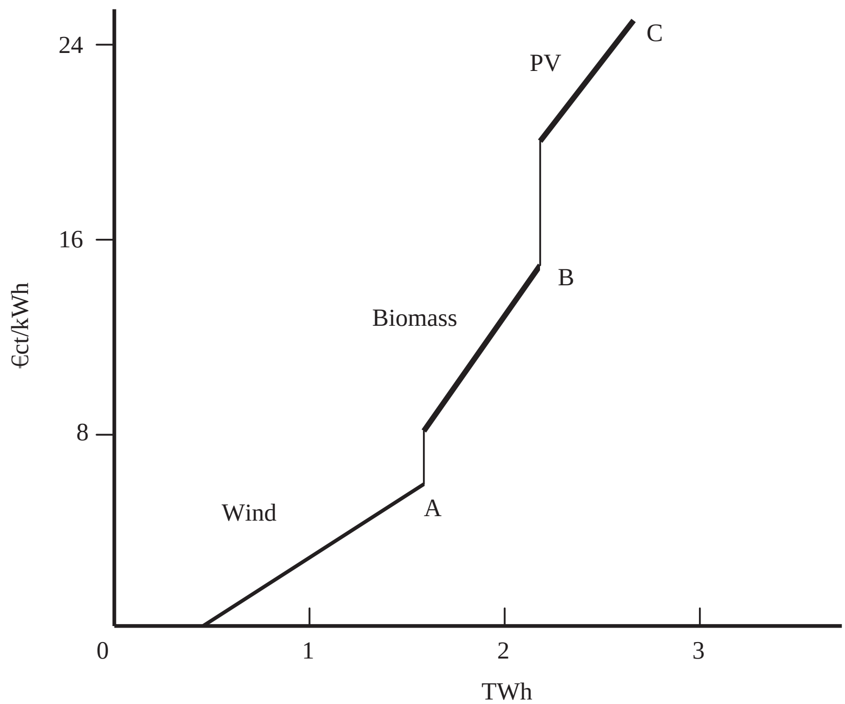



Fig. 6. TGC supply curve (Flanders).

We have selected some parameter values[9] for assessing the impact of green certificate propositions. We assume a linear end-use demand curve through a market equilibrium at $q_0 = 50$ TWh ($10^9$ kWh) and $p_0 = 0.10$ €/kWh, with a price elasticity of demand $\varepsilon$ at 0.4. We consider three types of RES-E technologies: mature ones (e.g. wind-power), at arms-length ones (e.g. bio-mass) and distant ones (e.g. photo-voltaïc power). The supply curve of RES-E certificates is given by stepwise linear segments, starting at an RES-E output of 400 GWh, and with a slope of respectively 0.5, 0.75 and 1.0 E-10 €/kWh$^2$. The TGC supply curve is shown in Fig. 6.

TGC can force the RES-E technologies into the market. Every costlier technology requires a forcer forcing power of the quota-fine pair.

To bring the first group of RES-E projects based on the least-cost options (represented by 'Wind-power') fully in the market a 3.3% quota is required with a forcing fine of at least[10] 7 €ct/kWh. The impact on end-use is small and welfare losses negligible. The picture changes totally when less available and more costly RES-E options have to be addressed to meet the quota (see Table 2).

If a single certificate price is applied, this price must step up enormously to bring the marginal technology in the market. It creates a significant price effect (and demand reduction) and it transfers large amounts of cash from the end-users to the RES-E generators. Some of this transfer is required to cover part of the RES-E costs, but an increasing share is rents received by the sub-marginal RES-E generators. While rents within the same technology group are acceptable (and comparable to the working of other markets), the technology diversity amalgamated under the common heading of RES-E creates windfall profits for the mature technologies. In the example, situation B means that 40% of the payments by end-users are windfall profits to wind-power investors, while in situation C even 54% of the payments are windfall profits acquired by (mainly) wind-power and by bio-mass RES-E generators. The weight of the TGC-system on the end-users will also grow to unacceptable burdens. The high TGC-prices will significantly increase the end-use electricity price (e.g. by 1.45 €ct/kWh in point C). At a price elasticity of end-use demand of 0.4 the reduced end-use demand would be larger than the generation of RES-E.

It is evident that forcing the 'distant' RES-E technology into the market through a single quota-fine ($k$, $F$) pair creates a lot of bias. The less distant technologies reap significant windfall profits, simply by freeriding on the system. It makes the system very expensive and it would loose all credibility with the end-users that have to pay the bills. This point was addressed extensively by Huber, et al. (2001, 2002). For reducing the windfall surpluses they suggest to limit the validity

[9] The values are not based on an in-depth analysis of the real situation in Flanders.

[10] The fine set in practice is best a little bit higher than the marginal forcing fine to keep the TGC market lively.

Table 2
Forcing RES-E with the TGC system (non-segmented market; single target and price)

| | Wind-power (point A) | Bio-mass (point B) | Photo-voltaïc (point C) |
|---|---|---|---|
| Quota (% supplies) | 3.3 | 5 | 6 |
| Quota forcing Fine (€ct/kWh) | 7 | 16 | 25 |
| Certificate price (€ct/kWh) | 6.18 | 15.18 | 24.25 |
| End-use power reduction (TWh) | 0.408 | 1.518 | 2.910 |
| RES-E generation (TWh) | 1.637 | 2.424 | 2.825 |
| Certificate revenues (Meuro) | 101 | 368 | 685 |
| Cost coverage (Meuro) | | | |
| Wind-power | 38 | 38 | 38 |
| Bio-mass | 38 | 96 | 96 |
| PV | — | — | 89 |
| Producer surplus (Meuro) | | | |
| Wind-power | 63 | 210 | 359 |
| Bio-mass | — | 23 | 95 |
| PV | — | — | 8 |
| Windfall profits (Meuro) | — | 147 | 367 |

Table 3
Forcing RES-E with the TGC system (add-on segmented markets; technology specific targets and prices)

| | Wind-power (point A) | Bio-mass (point B) | Photo-voltaiçï (point C) | Total |
|---|---|---|---|---|
| Quota (% supplies) | 3.3 | +1.7 | +1.0 | 6 |
| Quota forcing Fine (€ct/kWh) | 7 | 16 | 26 | |
| Certificate price (€ct/kWh) | 6.18 | 15.54 | 25.57 | |
| End-use power reduction (TWh) | 0.408 | 0.513 | 0.479 | 1.400 |
| RES-E generation (TWh) | 1.637 | 0.834 | 0.486 | 2.957 |
| Certificate revenues (Meuro) | 101 | 129 | 124 | 354 |
| Cost coverage (Meuro) | 38 | 103 | 112 | 253 |
| Producer surplus (Meuro) | 63 | 26 | 12 | 101 |
| Windfall profits (Meuro) | — | — | — | — |

of certificate rights in time (e.g. a RES-E plant built in 2000 can sell rights only until 2010). We believe this regulation will be administratively difficult to follow up (e.g. when 'some' retrofitting on the above plant occurs in 2008), and it does not solve the issue of the diversity in technologies.

As did Schaeffer et al. (2000) in general, we propose to segment the certificates market by technology (group), e.g. wind-power, hydro, biomass, and E-solar in Flanders. For every technology group t one has to study in detail the TGC-supply curve and to find the $(k_j^t, F_j^t)$ pairs that help to force the target market development of the technology over time (years $j = 1, \ldots, n$).

The electricity suppliers are subjected to a quota for every technology. This makes the TGC market segments thinner, but the system is more transparent and feasible (affordable, acceptable by electricity end-users). Assuming the same parameter values as above, we have repeated the calculations for a segmented TGC-market, where the three technologies are introduced consecutively for meeting the same 6% target as in the previous example and where the present RES-E generation is considered to be wind-power. Results are shown in Table 3, contrasting with the numbers of Table 2.

Because windfall profits among technologies are excluded, the cost of the system is much lower. In every technology segment there remain some producer surpluses, but this can create a stimulus for further technological development that will lower costs. The impact on end-use is smaller. The electricity price is increased in three smaller steps and overall with 1.1 ct/kWh. This has an impact on consumption in less of 1.4 TWh. Because this impact is smaller and the aggregate quota is kept at 6% of sales volumes, the RES-E output is about 132 GWh larger than in the previous case.

Our analysis does not match the conclusions by Jensen and Skytte (2002) on the ambiguous effects of TGC's on the price and consumption of electricity. Our TGC supply curve is an amended marginal cost curve net of subsidies and receipts by selling the electricity in the market. When the price of the latter decreases, the supply curve of TGC will shift to the left, and the higher electricity prices to the end-users will remain unaffected.[11] Higher prices will reduce demand. Our conclusion is that TGC as an instrument to force RES-E generation into the market goes hand in hand with higher end-use prices that will stimulate electricity savings. When the RES-E targets are set bullish, the fine levels have to be fixed at heights that society

[11] In the end-user price $Pe+k.P_c$, the decrease in $P_e$ will be evenly compensated by an increase in the $kP_c$ term due to raising $P_c$ values.

considers unacceptable today. The fines and the forthcoming certificate prices are really functioning as an incentive and financing tax.

### 2.10. Evaluation of the Flemish TGC market system

It is early days yet to evaluate the performance of the Flemish TGC market system. By April 1 2002, 13 RES-E producers had been officially recognised in the Flemish region. From July 1 onward TGCs are registered and monitored as electronic records in a central Internet-based database (before that date TGCs were *paper* certificates). End of June 2002 (6 months after the introduction of the TGC market system), only one supplier and three potential buyers of TGCs have made themselves known to the Flemish regulating authority VREG. As far as we know, no actual trade of TGCs has yet taken place. VREG has the legal obligation to publish the amount of certificates for sale, and the average price of a TGC on a monthly basis. As of July 1, 2002, the website of the VREG has not made public any information on traded volume or prices ( http://www.vreg.be/groenestroomcertificaten.htm).

The low number of suppliers and potential buyers of TGCs so far may in part be due to electricity suppliers in Flanders producing the own RES-E to meet the 2002-quota (1.41% of sales), and partly to the "thinness" of the present Flemish electricity market.

## 3. Conclusions

TGC may become an effective instrument. It can also be made an efficient one when it is handled with foresight and care. Particular attention is needed for the actual segmentation of the RES-E sector. Hydropower, windpower, bio-mass, PV-solar are very different physical, technological and economic realities. A policy promoting renewable energy that has choosen to use the TGC instrument can address this diversity in several ways.

One way is to diversify and to fine-tune the more direct support measures for the various renewable technologies. When a uniform TGC is maintained, these measures will prove necessary and will play the dominant role in promoting RES-E. The TGC system can be used as a closing mechanism and as a source of funding.

A second way is to assign a different number of TGC per MWh output along the type of technology (project) that generates the RES-E. When the optimal weight of every single RES-E technology is found, one can maintain a single TGC market.

A third way is to segment the certificate market along RES-E technologies with common cost properties, and for estimating RES-E cost functions and their development over time. Also the setting of the parameters $k_i$ =quota% of RES-E in total supplies and of $F_i$ =fine per kWh shortfall to the quota for the various technologies i and for the years to come, needs careful consideration. The three ways of marrying the TGC instrument to the diversity of the RES-E sector all require an in-depth study and follow-up of the cost structures in the various submarkets. Without this understanding, every approach will fall short in effectiveness and efficiency. A clear market segmentation has the advantage that policy makers cannot avoid the effort of fully understanding the sector and the market, but it has as a disadvantage that the market in every segment becomes thin.

1. TGC is not conflicting with other instruments supporting RES-E development. TGC can be handled as the instrument that is complementary to the other supports, and that forces the development of RES-E in the market along the potentials and the targets set forward. TGC must be matched to the impact of other instruments, in particular direct kWh support for RES-E (e.g. through improved feed-in conditions) and capital subsidies.
2. TGC's and in particular also the installed fines (price caps of TGC's) exercise a taxing effect on electricity end-use. Final demand will be choked by the higher power prices following the payment for TGC quota by the suppliers. The overall effect depends on the elasticity of demand and on the cost of RES-E technologies. The welfare losses remain small, but the payments by end-users for the development of RES-E become a visible share of their bills.
3. If the diversity in technologies and their cost realities are not recognised, the taxing effect of the TGC system becomes very important when the system wants to function at the edge of the marginal RES-E technology. A large share of the tax money would be collected as windfall profits by the investors in mature RES-E solutions.[12] The payments by end-users would grow so high that the system would implode under its own weight.
4. The crucial key for RES-E to penetrate is and remains (of course) the technical and economic performance of the various RES-E technologies. A diversified TGC system is effective to force RES-E development to the edge, but over the edge it becomes mainly a taxing instrument that stimulates end-users to energy efficiency and that creates funds to develop RES-E solutions. R&DD to develop renewable technologies to enhance reach and to lower cost remains the most important policy instrument.

[12] After weeks of discussion in Flanders it was decided not to include the combustion of municipal solid waste as a RES-E source. If the outcome of this debate had been otherwise, this technology would have been the first beneficiary of windfall profits when the certificate price would start its climb.

5. Through the instrument of green certificates public policy can force the transition of a non-sustainable energy system to a sustainable one finally based on renewable energy. It can make the energy consumers pay for this costly transition, but it should safeguard that payments are always kept as low as possible, because the transition is a very costly operation. Intensive study and a broad societal debate are required to decide on the pace of the transition and on the way burdens are allocated among classes of end-users.

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