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The 2013 reforms of the Flemish renewable electricity support: Missed opportunities

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ABSTRACT

The Flemish renewable electricity support system has struggled to address a number of problematic issues in the past. These included excessive profit margins and general malfunctioning of the green certificate market, as well as a lack of qualification of various existing renewable energy technologies. The Flemish government responded to these issues by introducing major reforms in 2013, including "banding" to differentiate the support for various technologies. However, reliable methods for differentiating renewable electricity technologies and calculating support levels have not been sufficiently developed. The main objective of the 2013 reforms was to reduce support costs, but application of German feed-in tariffs on 18 reference technologies has shown that most projects in Flanders continue to receive high levels of support. The 2013 reforms did not succeed in addressing malfunctioning of the green certificate market. On the contrary, the confidence of investors in renewable electricity plants has decreased as the terms of support can be altered retroactively by adjusting remuneration levels and through political interventions. Future adaptations are likely to be made which will further decrease the overall stability and effectiveness of the system.

1. Introduction

The primary areas of concern regarding current energy supplies in the European Union are: (i) low shares of renewable energy sources in the energy mix; (ii) negative impacts of energy use on the global carbon cycle, and consequently on the climate; (iii) increasing dependency of the European Union (EU) on energy imports (higher than 50%) from non-EU countries [1,2]. In addition to effectively reducing fossil fuel consumption through energy efficiency measures, increased use of renewable energy sources (RES) mitigates current levels and future growth rates of atmospheric CO_2 emissions, but also decreases dependency on fossil fuels [2]. Furthermore, using electricity from renewable energy sources (RES-E) provides favorable political, social and economic benefits as it increases domestic (local) employment, contributes to improving the trade balance by lowering fossil fuel imports and offers greater diversity of energy sources [3].

However, RES-E is still more expensive than electricity sourced from established non-renewable sources, such as nuclear or fossil fuels [4,5]. Investments in nuclear and fossil power plants have, in many cases, been written off and their external costs are not reflected in the cost of electricity [2]. To encourage a more widespread deployment of RES for electricity production and an optimized energy mix from a social-economic perspective, active government interventions are necessary to correct market inefficiencies [6]. Nearly 120 countries have put in place various national and/or regional (financial) incentives[1] to support the production of green electricity [7–9]. These incentives include technology push measures, such as R&D grants and tax credits, and

Abbreviations: BD, Banding Divisor; BF, Banding Factor; CREG, Commission for Electricity and Gas Regulation; FG, Financial Gap; FIT, Feed-in Tariff; LCOE, Levelized Cost of Electricity; MSW, municipal solid waste; PV, Photovoltaic; RE, Renewable Energy; RES, Renewable Energy Source; RES-E, Electricity from Renewable Energy Sources; ROI, Return on Investment; SERV, Social and Economic Council of Flanders; TGC, Tradable Green Certificate; VEA, Flemish Energy Agency; VREG, Flemish Regulator for the Electricity and Gas Market; WWT, Waste Water Treatment.

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[1] More than 150 different policy instruments to support green, low-emission and climate-resilient investments were identified in a study of the United Nations Development Programme (Glemarec, 2011).

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market pull (demand pull) measures, such as carbon pricing and deployment incentives (green certificates, feed-in tariffs). An optimal balance between RES-E subsidy schemes and policies that catalyze corporate investments in RES-E technologies will be necessary to decrease the overall burden of support on the government budget [10]. Many existing RES-E support policies have been reformed and/or expanded numerous times following their initial deployment [11].

This present work focuses on the 2013 reforms of the Flemish renewable electricity incentive scheme based on tradable green certificates (TGC), previously analyzed by Verbruggen [12–14]. Offshore wind energy has been excluded, since this is part of federal jurisdiction. Our objectives are: (i) to describe the most important changes resulting from the 2013 TGC reforms in Flanders; (ii) to identify the missed opportunities of the new scheme compared with the previous TGC scheme; (iii) to quantify the level of support for 18 RE categories through the Flemish TGC as compared to feed-in tariffs (FIT) assuming that German FIT rates would have been applied to the Flemish RES-E installations and to their outputs. This contribution is structured as follows: Section 2 describes the history of the green certificate scheme in Flanders and its impact on the deployment of renewable energy (RE). Section 3 elaborates on the data sources that were analyzed. Using these data sources, Section 4 provides an overview of the 2013 TGC reform process and discusses critical issues about the current reformed TGC system relative to its previous version. Section 5 includes a simulation exercise comparing the Flemish scheme with the FIT scheme using the German FIT rates. The final section summarizes the policy lessons and main conclusions.

2. Background of the RES-E policy in Flanders

In 2002, the Flemish government introduced a quota-based TGC system to support the deployment of RES-E. With its introduction, Flemish authorities issued one TGC for every 1 MWh of RES-E generated by RES-E producers, irrespective of the technology or source used [15]. There was no time limitation for obtaining TGC, i.e. the certificates were assigned as long as the RES-E unit continued to produce electricity. TGC are purchased by companies that supply electricity. On a yearly basis, every March 31, the latter must submit certificate quota to the Flemish Regulator for the Electricity and Gas Market (VREG). The mandated quota equal annually increasing shares of the suppliers' electricity sales of the previous year. In addition to buying TGC, electricity suppliers have the option of producing RES-E themselves for which they receive additional TGC [15]. A high penalty is charged for the inability to submit a certificate; this penalty also serves as the ceiling price for TGC exchanges (Fig. 1).

In 2004, functioning of the free market slowed considerably due to the fact that RES-E producers had the right to sell TGC at a guaranteed minimum price to the distribution network company located in their region. Distribution network companies are required to buy certificates from RES-E units that are connected to their distribution grids and commissioned on or after June 8, 2004 at a mandated minimum price over a period of 10 years [16]. This obligation was extended for PV beginning on January 1, 2006 with a payment plan extending over 20 years [17]. The obligations introduced some differentiation by technology, as the minimum amount of support differed depending on the RE technology used [13] (Table 1). Since 2004, the minimum level of support for the different RE technologies has changed several times, as shown in Tables 1 and 2. The guaranteed minimum price and remuneration period changed the most for photovoltaic (PV) power generation (Table 2). Electricity supply companies were no longer interested in buying PV TGC as their minimum prices were higher than the

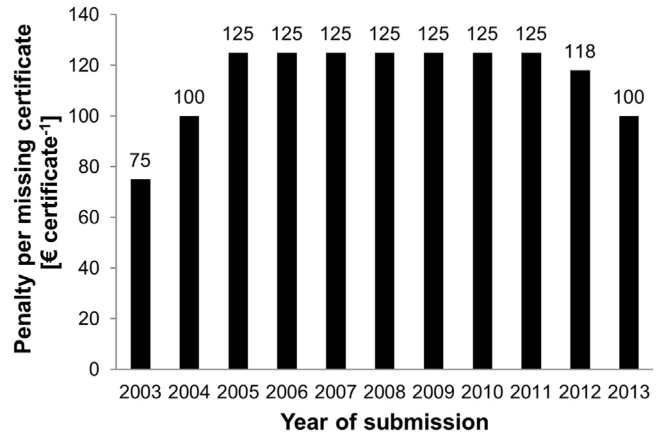

Fig. 1. Evolution of the penalty for missing certificates at submission date (period 2003–2013). Source: [16].

penalty levels until mid-2012 (compare Fig. 1 with Table 2). The high minimum support for PV was in fact the reason why PV certificates were not offered in the TGC market. The obligation imposed on distribution network companies to buy PV certificates at prices higher than the TGC penalty level, assigns the properties of an actual feed-in premium for PV owners to the prices paid.

In addition to revenues earned from TGC sales at (posted or negotiated) variable prices to power suppliers or at minimum prices to distribution network companies, RES-E producers earn revenues from selling (physical) electricity to the grid, or from lowering their electricity costs in case of own RES-E use. In addition to RES-E support systems, a diverse range of direct and indirect measures at different government levels (federal, regional and municipal) exists to encourage RES-E investments. A full overview of these support measures is beyond the scope of this article.

The number of TGCs issued in Flanders cannot be considered to be a precise indicator of RES-E generated power, but is the most representative indicator up to 2012 (Fig. 2a). Following the introduction of RE support in 2002, the share of RES-E in the electricity supply increased slightly from 0.6% in 2002 to 1.1% in 2004 [18]. Since 2004, minimum levels of support have been guaranteed and the number of issued TGC is growing at a faster rate, with the RES-E share in supplied electricity increasing to 7.5% by 2011 [18]. The impact of high support levels is most explicit for PV: from 1356 certificates in 2006 to 1.95 million in 2013 [19]. The high support rate, combined with significantly declining investment outlays per kW_p, resulted in a financial payback period of about five years for well-designed systems. The high prices per MWh generated guaranteed surplus profits over a 20-year support period. In 2013, a relapse of the increase of assigned TGC for PV occurred.

Fig. 2b also reveals high growth in assigned certificates for bioenergy, from 0.1 million in 2002 to almost 3 million in 2013, with a slight decrease in 2013 as compared to 2012. Biomass from separately collected or sorted organic waste, and biomass from agriculture and forestry were the highest contributors to this growth in terms of certificates with a 75% share in the bioenergy mix in 2012 (Fig. 2b). The steep increase in 2005–2006 in the share of biomass from agriculture and forestry is due to co-firing biomass in (existing) coal power plants. The surge of biomass from separately collected or sorted organic waste is associated with the eligibility of two existing biowaste incineration plants (81 MW and 55.7 MW) and the commissioning of four new plants between 2004 and 2006 (installed capacity of 69.8 MW), followed by the addition

Table 1
Minimum support for various renewable energy technologies excluding solar photovoltaic panels. Source: [16].

Technology	Minimum support during 10 years [€ certificate^{-1}]		
	Unit commissioned before Jan. 1, 2010	Unit commissioned as of Jan. 1, 2010	Unit commissioned between Jan. 1, 2012 and Dec. 31, 2012
Onshore wind energy, biomass (organic-biological substances) and biogas (organic-biological substances)	80	90	90
Organic fraction of municipal solid waste, landfill and biogas from waste water treatment	80	60	60
Biogas from fermentation of mainly agrarian flows, biogas from selected waste with composting	100	100	100–110
Hydropower, tidal and wave energy, geothermal energy	95	90	90
All other technologies for the generation of electricity from renewable energy sources	0	60	60

of six new plants between 2009 and 2011 with a joint installed capacity of 110 MW [20]. The organic-biological fraction of municipal solid waste (MSW) qualifies for TGC beginning in April 2004, which explains the appearance of MSW incineration in 2004, while this capacity had been available earlier [13]. The share of biomass from agriculture and forestry decreased considerably in terms of certificates issued in 2010 due to the fact that a part of the electricity generated from cofiring biomass was deemed no longer eligible for certificates as of January 1, 2010.

3. Materials and methods

Initially, official documents issued between 2001 and 2014 by several Flemish public authorities – the Flemish government, the Flemish Energy Agency (VEA) and the Flemish Regulator for the Electricity and Gas market (VREG) – specific to the Flemish renewable electricity support system were analyzed (i) to describe both the previous and current systems, and (ii) to illustrate the most important changes and (potential) impacts on the deployment of RES-E. The methodology used to differentiate the Flemish support, i.e. the financial gap methodology (FG), was evaluated and compared with the levelized cost of electricity (LCOE) methodology in terms of data requirements and objectivity.

Next, official documents issued by the German Federal Environment Ministry (BMU) related to the FIT scheme were examined to evaluate the technological differentiation applied in the reformed Flemish support scheme with the differentiation provided by the German FIT scheme. Germany is considered as a benchmark for RES-E policies [11]. To determine whether the 2013 reforms achieved their main objective, namely decreasing excessive support for RES-E technologies, we compared the RES-E support by the reformed Flemish TGC system with the support provided by the German FIT scheme. To make this comparison, we used a simulation exercise to assess revenues for RES-E generators earned from both sales of TGC and of physical electricity on one hand, and through FIT on the other. The calculation methodology applied to this simulation is presented in Section 5.1.

Table 2
Support for electricity generated by photovoltaic installations. Source [17].

Date of commissioning of the PV unit	Minimum support [€ certificate^{-1}]	Duration of the support guarantee [years]
July 2002–December 2005	150[a]	10[a]
January 2006–December 2009	450	20
January 2010–December 2010	350	
January–June 2011	330	
July–September 2011	300	
October–December 2011	270	
January–March 2012	250	
April–June 2012	230	
July 2012	210	
August–December 2012	90	10

[a] In addition to the obligation on Flemish distribution network companies to buy certificates from PV installations commissioned as of January 1, 2006, the Belgian transmission system operator (ELIA) was obliged to buy certificates from PV installations commissioned after July 1, 2003 and before August 1, 2012 for a period of 10 years at 150 € certificate^{-1} [16,17]. However, one certificate can only be sold once making the second option obsolete as of 2006, given the lower minimum price.

4. Discussion and evaluation of the 2013 TGC reforms in Flanders

4.1. Reforms of the green certificate scheme

The Flemish green certificate system has been subject to several modifications since January 1, 2002. These changes failed to address a major concern for the support system, i.e. excessive profits due to a lack of qualification of RES-E technologies

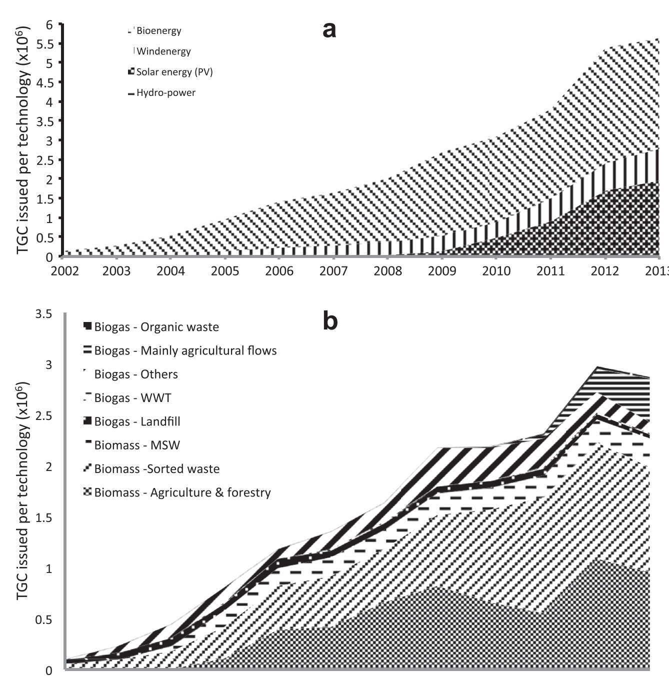

Fig. 2. (a) Issued Tradable Green Certificates (TGC) by technology in Flanders from 2002 to 2012 - general overview. Source: [19]. (b) Issued Tradable Green Certificates (TGC) by technology in Flanders from 2002 to 2012 - focus on bioenergy fraction (WWT: waste water treatment; MSW: municipal solid waste). Source: [19].

[12–14,21]. RES-E encompasses a range of technologies with specific attributes and developmental phases, each requiring different levels of support [14,22]. Regardless of their attributes, all RES-E plants received one certificate per MWh production. As a consequence, some technologies benefited by free riding (e.g. cofiring biomass in old coal power plants), while other more innovative technologies did not pass the hurdle rate (e.g. innovative biomass conversion technologies as gasification).

From January 1, 2013 onwards, banding factors (BF) are applied to the issued certificates. RES-E plants are classified into 18 categories depending on the type of RE source, the technology and the capacity of the power plant. The categories are assigned with a BF based on the gap between estimated profitability of reference plants by category and preset returns on investments (ROI). For PV plants with a peak capacity higher than 750 kW_p, wind energy turbines with a capacity higher than 4 MW, and other RES-E units with capacities higher than 20 MW, individual and specific plant BF are determined at the time RES-E plant owners apply for support [23].

The ROI calculations of RES-E plants assume ownership of the technology by either private households (PV < 10 kW_p) or by companies (all other RES-E investments). The various owners are assumed being submitted to different financial conditions and rules (e.g. tax regimes) that affect their final net return on their investments, with varying demands on the hurdle rates. The “financial gap” (FG) is estimated on this basis as an annual amount of subsidies required to guarantee the preset ROI. The subsidy is expressed in € per MWh RES-E produced by the project.

The applied formula is [24]:

$$\text{NPV (FG)} \equiv -\text{I} + \sum_{t=0}^{T_b+T_c} \frac{OCF_t(FG)}{(1+r)^t} = 0 \qquad (1)$$

with FG = the financial gap, I = the amount of the total investment, T_b = the policy period, T_c = the construction period, OCF_t = the operational cash flow in year t, and r = the desired return on investment (ROI) [25]. While this formula appears relatively simple at first glance, the effective calculation of the financial gap is in fact more complex due to the numerous parameters that need to be considered in order to calculate operational cash flow over the considered period.

To implement the regulation, a large number of parameters for the various reference technologies have to be fixed. Examples of these parameters are: electrical efficiency, generated electricity, full load hours of the RES-E plant, share of RES-E in electricity used on site, the owner's interest rate on bank loans, the owner's debt/equity ratio, the owner's taxation rate, etc. (see Appendix B for the full list of parameters). Assessed financial gaps (FG) in € MWh^{-1} RES-E are divided by a common banding divisor (BD) of € 97 $certificate^{-1}$, to obtain the category specific BF (BF = FG/BD). The BF represents the number of certificates attributed to 1 MWh RES-E within a specific category. The BF cannot be higher than 1 for plants commissioned in 2013, and can never exceed 1.25 overall [24,26]. The BD is set at € 97 $certificate^{-1}$ as the Flemish authorities assume that the average ‘market’ price will be somewhat lower than the penalty, which is stipulated at € 100 per missing certificate as of March 31, 2013 (Fig. 1). BF by category is re-calculated at least once a year (twice a year for PV) by the Flemish Energy Agency (VEA) to incorporate price evolutions. When the difference between the initial BF and the updated BF is larger than 2%, the updated BF is applied both to new installations and to earlier commissioned installations, inserting retroactive changes to assigned remunerations.

To illustrate the 2013 reforms of the support scheme, we can consider the practical example of solid biomass-fired conversion plants. Up to December 31, 2012 irrespective of the installed capacity, such plants received one certificate for every MWh of electricity generated. Since January 1, 2013, each solid biomass-fired plant with an installed capacity up to 20 MW receives 1 certificate for every 1.02 MWh of electricity generated (BF for solid biomass ≤ 20 MW: 0.98). A plant larger than 20 MW must apply for a project specific BF to be eligible for TGC support.

Insufficient preparation for reforming the green certificate system led to numerous missed opportunities [27]. We have identified a number of items of concern as listed in Table 3 and discussed our results in Sections 4.2–4.5.

4.2. Parameters used in the remuneration calculations

The parameters and the spreadsheet used for calculating FG of the RE categories are made publicly available to increase transparency and investors' confidence in the reformed TGC scheme. Included are general parameters as well as company specific parameters, such as company tax rates and investment tax reductions (see Appendix B). The inclusion of company tax rates in calculating the FG causes potentially considerable errors, as such rates vary significantly from the official Belgian company taxation rate of 33.99% assumed in the calculations [28]. The identification of effectively imposed profit-related taxes requires an individual and detailed business analysis for each investment, entailing the production of annual accounts. Such an approach is not practical from an administrative point of view.

Inclusion of the federal investment tax reduction, which is allowed for RES-E investments, also depends on the imposed tax rate and thus increases the aforementioned error. This triggers the discussion on how and whether or not non-TGC support should be included. Flemish farmers, for example, receive a 28% investment subsidy for installations using RES, e.g. in cogeneration units [29].

Pre-tax calculations, excluding company-specific parameters, correspond more closely to a fair incentive scheme. A calculation of the LCOE, following Eq. (2), which takes into account investment and operating costs, as suggested by the IPCC [30], is preferred over the complicated financial gap calculations described in Section 4.1:

$$LCOE = \frac{\sum_{t=0}^{T} \frac{(I_t + M_t + F_t)}{(1+r)^t}}{\sum_{t=0}^{T} \frac{(E_t)}{(1+r)^t}} \qquad (2)$$

with I_t = investments in the year t; O_t = operating costs in the year t; F_t = fuel expenditures in the year t; E_t = electricity generation in the year t; r = discount rate or ROI and T_b = policy period.

4.3. Technology qualification

The 2013 reforms of the Flemish green certificate system were intended to improve the cost-effectiveness of TGC remunerations by harmonizing support levels on the basis of financial gaps. By setting remunerations at the level of the generation costs, windfall profits earned by low-cost technologies should be reduced or avoided altogether. The 2013 reforms differentiate support levels by classifying RES-E technologies into 18 categories. Identification of these categories appears to be arbitrary. Some categories include conversion technologies with diverging attributes and capacities, e.g. combustion of solid biomass with a capacity up to 20 MW is placed in one category, whereas a 100 kW and a 20 MW installation differ significantly in scale, in economies of scale, and therefore in investment per kW and in operational costs per kWh. An additional, but insufficient, differentiation by plant capacity (0–5 MW

Table 3
Items of concern about Flemish support for electricity from renewable energy sources before and after January 1, 2013.

Items of concern	Up to Dec. 31, 2012	Reformed TGC scheme since Jan. 1, 2013
Parameters applied in calculating specific support levels	Not applicable	Large number of parameters, including a number of company-specific parameters (see Appendix B)
Qualification	Poor differentiation in minimum support; no qualification of RES-E technologies on their merits. Exclusion of (expensive) less mature, innovative technologies	Differentiation based on RE technology and unit capacity. Limited qualification for biogas and biomass technologies. Exclusion of (expensive) less mature, innovative technologies (BF > 1)
Investment security	Financial risk mainly due to price volatility on the electricity and TGC markets. Guaranteed minimum support offers safety valve for investors	Price volatility on the markets plus additional financial risks by uncertainty about future BF values depending on annually re-calculated financial gaps. Minimum support also dependent on BF
Market functioning	Poor functioning of the TGC market	No adequate solutions offered in reformed system
Long-term vision	No consistency and no long-term vision	No consistency and no long-term vision
Grid compensation	No additional grid compensation fees for RES-E units	Grid compensation fees for small-scale RES-E units ≤10 kW rescinded due to legal entanglements
Windfall profits	High windfall profits for plants with marginal costs far lower than TGC prices and by slow adjustment of PV support levels	Limitation of windfall profits by technological differentiation and introduction of a project specific approach for the largest units

and 5–20 MW) and by source (landfill, sewage, etc.) is only applied for biogas technologies. A finer sub-categorization on the basis of the installed (peak) capacity, as applied in the German Renewable Energy Sources Act, is lacking. This causes less accurate assessments of levelized cost prices, and as a corollary, less effective incentives. Fine-tuning the regulatory treatment based on the attributes of every RES-E 'source–technology' combination would allow for more precise classification of the various combinations in diverse groups with adapted incentive levels (BF in the Flemish case) [31]. In addition to the unit capacity and the RE-category, types of employed biomass or biogas fuels, and types of technologies deployed (conventional versus innovative, for example standard steam versus organic Rankine cycles) should be taken into account [32]. Bonuses or increased BF for RES-E units using biomass feedstock with additional (ecological) benefits, or biogas upgraded to natural gas quality and injected into the conventional gas pipeline, are not considered in the current scheme.

RES-E incentive policies are designed to support the deployment of RES-E technologies, but could also help in transferring or remunerating external costs or benefits. Cost assessments of ecological impacts of the various RES-E 'source-technology' pathways could contribute to an improved qualification of biomass or biogas sources. Such assessments may suggest slight differences in the support for plants within a given RES-E category. For example, the European Commission's Costs Assessment for Sustainable Energy Systems (CASES) revealed large differences in external costs of biomass combustion systems depending on the source used (straw versus wood-chips) [33]. For an estimation of the actual emissions and the potential GHG savings – and thus the external costs of RES-E – the whole life cycle should be considered [34,35]. The GHG reduction potential of bioenergy depends on the biomass feedstock, on the cultivation method, on the transportation as well as on the conversion technology and efficiency [36]. These elements should be taken into account in the design of RES-E support measures to ensure that adequate support is made available to the most beneficial RES-E pathways. Currently, VREG considers some socio-economic and ecological aspects in determining the number of TGC for biomass and biogas units as it only issues certificates with a financial value for units using resources that meet the criterion of 'social responsibility', e.g. wood that can be used for other (industrial) applications cannot qualify for TGC with a financial value [37]. However, no distinction in the level of support is made between the different solid biomass sources that qualify for TGC.

The 2013 reform also provides the possibility for the Flemish government to limit – by decree – the value of the BF, regardless of the FG calculations [26]. Arbitrarily limiting BF to a maximum of 1 (during 2013) and of 1.25 (during the following years), limits expenditure of the support system by only supporting those RES-E technologies that are less expensive. Long-term innovation potential, or local socio-economic benefits and environmental benefits, may justify higher initial expenses, and thus BF with values above the 1 or 1.25 thresholds. Innovative technologies are generally expensive in their development phase, but become economically feasible once they pass to maturity [38,39]. Decreasing unit costs by learning is demonstrated by PV, which proved to be profitable without government support in Flanders following the abolishment of additional grid compensation fees initially planned for small-scale PV (see Section 4.5). Focusing too much attention on short-term cost-effectiveness lacks long-term perspective necessary to deciding how the various RES-E technologies should be developed to contribute to an overall stable and reliable electricity supply. Although the Flemish government annually determines future RES-E targets, with indicative sub targets for the different technology categories, this is not translated into targeted support within the TGC scheme (e.g. with higher banding factors for targeted RES-E categories). Moreover, these targets do not take into account the contribution of deployed large-scale RES-E installations. An electricity system based on 100% renewable sources can rely predominantly on wind and solar supplies [40], but requires balancing and back-up power from bio-energy based supplies or from other alternatives, such as demand side management, imported electricity, etc. A well-considered RES-E support scheme aimed towards developing such an electricity system, one with the flexibility to adjust support in a timely manner and on an as needed basis, is currently absent in Flanders.

4.4. Investment security and market functioning

Flemish politicians [41] argue that the 2013 reforms intend to offer investors a certain level of security by providing sufficient support to make investments in specific technologies profitable. Quota systems are praised for their ability to achieve certain predefined goals with respect to the future share of RES-E in the energy mix [42]. But they are less reliable for the investors due to the unknown level of future incentives, as this largely depends on the TGC prices [3,22]. In 2004, Flemish legislators decreased the overall volatility of TGC prices by guaranteeing minimum prices as a safety measure for RES-E investors (see Section 2). This minimum support also reduces downward pressure on TGC prices in years when there is excess supply [42]. Also, the long-term bilateral purchasing agreements for TGC, at prices that are fixed or linked to the average monthly transaction price, reduce the downward pressure on TGC prices [43]. The 2013 reforms further reduce the volatility of TGC prices by limiting their range by equalizing the minimum price to € 93 certificate^{-1} and decreasing the penalty to € 100 certificate^{-1}.

However, measures aimed at mitigating excess profits have offered little reassurance for owners who invested in RES-E units prior to the 2013 reforms and have led to decreased general confidence in the future of the TGC system. The retroactive limitation of TGC assignment to a period of 10 years for projects commissioned before the reforms (i.e. before January 1, 2013) is exemplary. Obtaining an extension beyond the 10-year period is a tedious procedure and depends on conditions related to full load hours or unamortized investments. An extension is only possible if the amount of received certificates is more than 5% below the predetermined amount. If this is not the case, the owner could demonstrate unamortized investments in the RES-E unit of a minimum of € 100 000. The investments are required to have been made before the end of the initial support period of 10 years, and should exclusively consider essential components required for the production of RES-E [44].

In theory, new installations commissioned after of January 1, 2013 face lower investment risks when compared to RES-E units commissioned prior to the 2013 reforms, new installations receive a minimum level of support that only can be changed on the basis of new financial gap calculations. Changes in the BF for new installations are contingent upon changes in electricity prices, i.e. lower BF with increased electricity prices, and vice versa. However, the significant decrease of PV support following the abolishment of grid compensation fees (Section 4.5) showed that other factors (in this case, an exceptional legal entanglement impacting the PV ownership costs) could also influence the BF, and thus the support. The effectiveness of the (minimum) support is also affected by the arbitrary cap on the BF and the calculation of the BF based on the expected market price (€ 97 per certificate) instead of the minimum price (€ 93 per certificate).

Large RES-E installations, which are not included in the 18 project categories defined by the VEA, are required to apply for a project specific BF calculated by the VEA based on the same parameters (Appendix B) as smaller RES-E units, without considering socio-economic or ecological impacts. Although this BF can be requested via a simple form, the assignment of the project specific BF is dependent upon receiving approval from the Flemish Minister of Energy, who can deviate from the suggested BF following approval by the Flemish government. To date, two large biomass RES-E units (230 MW and 600 MW) have received a BF with considerable potential impact on the existing surplus of TGC.

The surplus of available TGC compared to the submitted TGC adds to the market dysfunction. Since 2006, the surplus has accumulated to reach almost 4.6 million certificates as of March 31, 2013, i.e. 120% surplus certificates on top of the number of certificates submitted on March 31, 2013 necessary to fulfill the quota (Fig. 3) [45]. This surplus is the result of a combination of more certificates being issued together with a barely increasing demand for TGC. The higher issuance rate of TGC is partly due to the snowball effect of households and commercial investors responding to overly generous remunerations (the case of PV is most illustrative, given the steep decline of investment costs per kW). Initial acceptance of the organic-biological fraction of municipal solid waste for TGC remuneration since April 2004 also contributed to this increase.

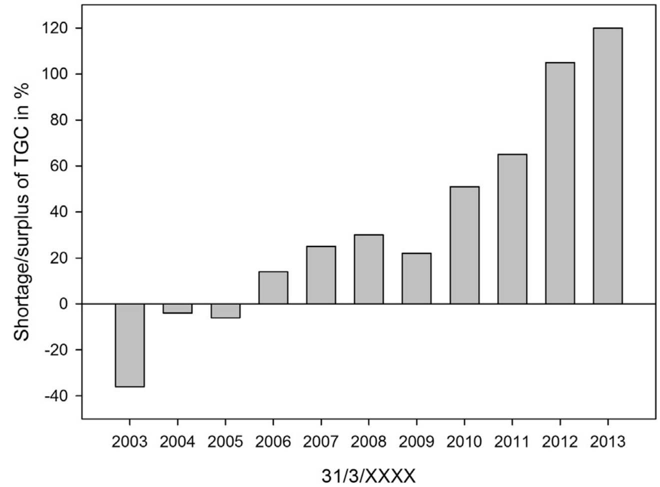

Fig. 3. Flanders (2003–2013): Tradable green certificates (TGC) shortage or surplus at submission date March 31, expressed as percentage (= [available, accumulated TGC]/[TGC to be submitted] − 1). Source: [45,47].

These failures showcase the inability of the Flemish authorities to design, organize, monitor, and control the certificate market. Prior to 2007, an automatic coupling between produced certificates and the certificates to be submitted (=quota) in the same year was used, explaining the steep increase of excess since the decoupling occurred without enhanced target quota for upcoming years [14,46]. In 2012, the quota were changed and increased, and the quota calculation methodology was adapted. As of March 31, 2013, quota for individual electricity companies are determined based on the following formula [26]:

$$C = Gr^{*}Ev^{*}Btot \tag{3}$$

with C = amount of TGC to be submitted by a certain electricity supply company in the year n, Gr = an annually increasing value or quotum that is determined by decree, Ev = the total amount of electricity, expressed in MWh, delivered by the electricity supply company to its customers in the year n-1 and $Btot$ = the ratio of the number of acceptable TGC issued in year n-2 to the total gross production of green electricity in year n-2 in the Flemish Region.

The increase of Gr from 2012 to 2013 (0.07 in 2012 and 0.14 in 2013) was largely countered by the introduction of Btot in the new formula (which is lower than one) and the decrease of Ev to ensure the competitiveness of energy intensive companies, paving the way for additional surpluses. The surpluses increased considerably in 2013 despite these quota changes (Fig. 3).

The lack of a functional TGC market also decreases the investment security for both new and existing RES-E units, while increasing the cost of the support scheme. Since the start of the TGC scheme, the certificates have largely been exchanged on a bilateral basis with mostly long-term contracts between RES-E producers and electricity suppliers. While the bilateral TGC market is a market in and of itself, it does not exert the effect of common supply and demand. The 'market players' do not have a role in establishing market equilibrium, nor on establishing the market-clearing price, which differs from the average price of bilaterally traded certificates determined by (mostly) long-term agreements. Only a negligible amount of certificates were traded on BELPEX's special Green Certificate Exchange [48]. Since its launch in 2009, BELPEX organized 11 trading days with five days without transactions (Fig. 4). As of 2011, BELPEX did not organize trading days as very few transactions were anticipated due to the

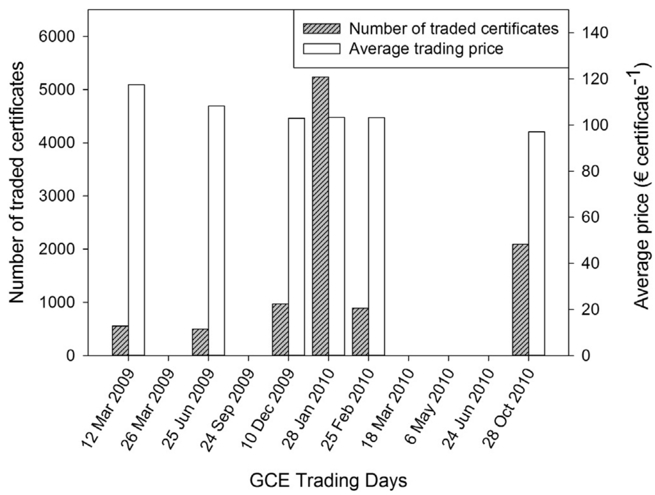

Fig. 4. Flemish tradable green certificates traded at BELPEX Green Certificate Exchange during the 11 trading days in 2009 and 2010 (an empty field above a date indicates that no certificates were traded that day). Both quantity and price are shown. Source: [48].

market circumstances in the TGC scheme [49]. It is extremely difficult – if not impossible– to establish a competitive TGC market on top of a non-competitive conventional electricity market [11,31]. The smaller spread between the minimum price and penalty fees since the 2013 reforms will most likely increase the dominant position of the distribution network company, further decreasing the market functioning. The weighted average price of bilaterally traded TGC was € 103.5 per certificate for the period 2006-2012. The price was € 93.7 per certificate during the submission period of 2013 [50].

The large existing and growing surplus of certificates, together with the key role the distribution network companies play in purchasing certificates, increase the debts of the distribution network companies and threaten to increase future support scheme costs since distribution network tariffs were frozen up to the end of 2014 [51]. These costs will be transferred to either the electricity consumers through a future increase in electricity distribution tariffs or to taxpayers in the case that certificates are purchased by the government.

Higher risks involved with recovering investments due to the volatile TGC market, combined with uncertainty about the future evolution of BF and electricity sales prices for installations commissioned on or after January 1, 2013, lead to an additional risk premium further increasing support costs of the transition to RES-E [22,52].

4.5. Grid compensation fees for small-scale RES-E units

Although grid compensation fees – strictly speaking – are not included in the Flemish RES-E policy, this measure is highly interwoven with the policy of RE support, and therefore merits discussion here. In Flanders, a system of net metering is currently in place for small-scale decentralized RES-E facilities ≤10 kW (mainly PV) connected to the grid under which electricity from qualified facilities delivered to the utility grid may be used to offset electricity provided by the utility during the billing period [53]. Net metering makes use of a revolving meter that is able to spin and record electricity flows in both directions, spinning forward when a customer draws electricity from the grid, and backward when electricity is sent back to the grid. Alternatively, customers can decide to install a second meter at their own cost to measure incoming and outgoing electricity flows separately. In both cases, the customer is only billed for the net electricity used since excess energy sent to the utility is sold back at retail price [53,54].

Since electricity customers contribute to the distribution grid costs on a kWh basis and the majority of residential RES-E unit owners have a revolving meter, these customers generally pay little or no grid fees. This state of affairs was considered unfair since RES-E owners make use of the distribution grid twice [55]. In response, the Flemish distribution system operators requested the introduction of a grid compensation fee for decentralized small-scale RES-E units with a nominal power up to 10 kW, which was approved by the federal Commission for Electricity and Gas Regulation (CREG), on December 6, 2012 [53]. On January 1, 2013, a new grid compensation fee for residential RES-E unit owners was introduced as a lump sum fee per kW installed RES-E capacity. This grid compensation fee differed among distribution network companies, distributed regionally, ranging between € 44 and € 69 and averaging € 53.5 per kW installed capacity [56].

Consequently, the Flemish government decided to grant small-scale PV units one TGC for every 4347 kWh produced, as FG calculations showed that this technology requires an incentive of € 22.6 per MWh to yield a fixed ROI of 5% after the introduction of these grid compensation fees [23,57,58].

Following a law suit filed by the association of PV installers, however, the Court of Appeal of Brussels declared the grid compensation fee invalid and void in November 2013, because (i) the grid compensation fee was based on a tariff methodology that had not been approved, and (ii) the principle of equality was violated since owners of large units were treated differently from small-scale unit owners [59]. The grid compensation fee only took into account the installed nominal capacity of the transformer and not the real electricity production, as is the case for larger scale RES-E unit (≥10 kW) owners who are required to install a second meter [53]. The disappearance of the legal basis of this grid compensation fee structure resulted in a repayment of all collected amounts by the distribution system operators.

The consequences for the RES-E owners who opted to install a second meter, at their own costs, instead of paying a lump sum grid compensation fee, remain unclear. Small-scale RES-E owners who received TGCs in 2013, based on the initially set BF, keep these certificates if they have produced sufficient electricity to obtain a complete certificate. After February 17, 2014, no support has been provided for PV units ≤10 kW commissioned in 2013 (BF: 0) and electricity produced by these units no longer qualifies for TGC issuance. The sudden introduction of grid compensation fees in response to the 'injustice' caused by the use of revolving meters is a good example of the ill-considered and ad-hoc energy policy in Belgium, which increases uncertainty for investors. Structurally well thought through reforms of the RES-E policy have proven to be essential to provide a stable legal basis to support necessary long-term RES-E investments.

5. Estimating windfall profits in the Flemish support scheme

This section presents an estimation of the windfall profits in the Flemish support scheme by comparing the RES-E support by the reformed Flemish TGC system with the support provided by the German FIT scheme. For this comparison, we simulated both revenues for RES-E generators from TGC and physical electricity sales, and revenues from FIT. This simulation is based on data gathered from official documents issued by the German Federal Environment Ministry (BMU) and several Flemish public authorities (Section 3).

5.1. Calculation methodology: quantitative comparison Flemish TGC with German FIT

The Flemish authorities differentiated support for RES-E by classifying the eligible RES-plants into 18 RES-E technology categories. For each of these 18 RES-E categories, the Flemish Energy Agency (VEA) defined one reference unit via an elaborated list of parameters [23,58,60]. First, we calculated the support for these 18 RES-E units with the Flemish TGC scheme assuming the units had been commissioned on January 1, 2013, and using the BF effective on this date. An exception was made for small scale PV ($\leq$10 kW) since support for this category was revoked on February 17, 2014 and this modification applies for all small scale PV units commissioned as of January 1, 2013 (see also Section 4.5).

We then applied the German FIT rates effective on January 1, 2013 to the different reference units depending on the deployed RES-E technology and their respective rated capacity, by using the methodology demonstrated in the German Renewable Energy Source Act [61]. The most recent information, for the modified FIT for solar energy in particular, was obtained from the website of the German Federal Network Agency [62] and has been included in our analysis. We applied only German base tariffs for the withhold technologies, as Flanders does not differentiate further than the subdivision in 18 RES-E categories. Therefore, details about the statutory requirements or potential FIT increases or reductions, from bonuses based on e.g. substance class of the feedstock used for biomass technologies or the processing of biogas for feeding into established natural gas networks [61,63], are not considered here. Appendix A provides an overview of the base FIT rates guaranteed by the German support scheme.

An electricity sales price of € 50.6 MWh^{-1} is adopted for all RES-E categories, based on the ENDEX year-ahead price in 2012 [58]. We assume constant electricity prices over the studied time period, in contrast to the FG calculations by VEA that include yearly price increases of 2%. Our assumption is based on electricity futures at the ENDEX market; the futures reveal price stabilization, with even a decrease in Belgium [64]. The TGC price is set at € 93 per certificate, representing the minimum support guaranteed by the Flemish system.

The approach that we used to calculate the revenues through the different support schemes involved two main steps. First, revenues for an investor-operator of a RES-E plant were calculated for one operational year of the RESE-E plant in 2013. This provided the differences in revenues between the two support schemes without differences caused by unequal length of the full support period. Second, the one-year revenues were extrapolated over 20 years to quantify the impact of the length of the support period on the net present value (NPV) of the total revenues. German FIT are guaranteed for 20 years, whereas Flemish TGC are only issued for 15 years after commissioning for wind and PV, and for only 10 years after commissioning for other technologies. After this period, the only revenues that RES-E generators receive in the TGC scheme are revenues from the sales of physical electricity, as is also the case in Germany when the FIT period ends. The annual monetary values were discounted using the return on investment (ROI) reported by the VEA for the various categories. By using different discount rates for the different RE categories, we incorporated the differences assumed by VEA in risks associated with the various investments.

5.2. Results and discussion

FIT are evaluated as the most efficient and effective support system for stimulating deployment of RES-E [7,65–67]. We compared the RES-E support by the 2013 reformed Flemish TGC system with the support provided by the German FIT scheme, as Germany is considered to be a benchmark for RES-E policies [22]. The comparison is based on assessed revenues for RES-E generators through the sales of TGC and of physical electricity on the one hand, and through FIT on the other.

For 11 out of the 18 reference units, the TGC scheme (including the sales value of the generated RES-E) results in higher revenues than the FIT scheme, when considered both over a period of one year and over a period of 20 years (Fig. 5). Based on the predefined reference units (Table 4), the higher remunerated investments are PV units $\leq$ 10 kW_p, wind turbines $\leq$ 4 MW, biogas units $\leq$ 5 MW and $\leq$20 MW for the digestion of mainly agricultural streams, sewage sludge and other streams, and all biomass incineration units $\leq$ 20 MW, excluding the incineration of MSW. Three out of the 18 reference units (PV units of 125 kW_p, biowaste fueled biogas installations of 1.3 MW and of 7 MW) earn higher revenues from TGC over one year, but there is a reversal in favor of FIT when revenues are discounted over 20 years. The difference between revenues through the TGC and FIT schemes for the three technologies is relatively small (max. 5%). Three reference units are insufficiently supported through the TGC scheme as compared to the FIT scheme, in particular RES-E generated from landfill gas which is subdivided into two categories based on the capacity of the plant. The BF of biogas units with a capacity up to 5 MW was set at 0.2. The BF is 0 for biogas units with a capacity between 5 and 20 MW, excluding the units from TGC support. This causes the significant difference (up to 32%) between the assessed TGC and FIT revenues.

Differences between Flanders and Germany in the treatment of digestion residues could objectify disparities in support for biogas RES-E units. In Flanders, with its high agricultural nutrient surpluses for the limited land area, digestate cannot be spread on agricultural land without prior treatment [68]. Such treatment increases the complexity of the RES-E units and investment costs. In several areas of Germany, however, direct spread is of digestate is permitted [69]. Stricter flue gas treatment requirements for solid biomass RES-E units in Flanders could further objectify differences in support [70,71].

Electricity from the organic-biological fraction of MSW does not receive FIT in Germany [63]. Since 2013, new MSW incineration units no longer receive TGC in Flanders as the financial gap calculations showed that MSW electricity generation is profitable without government support, while existing installations commissioned before 2013 maintain TGC for a support period of 10 years [60].

A sensitivity analysis was carried out to investigate the robustness of the results by changing the electricity price and the discount rate, *ceteris paribus*. Both an increase and a decrease of the electricity price up to 20% largely confirm the higher remunerations from TGC demonstrated in Fig. 5. Decreasing (increasing) the electricity price slightly reduces (increases) the difference between FIT and TGC in the case of excess support, while considerably increasing (decreasing) the differences in the case of a shortage, e.g. for biogas from landfill. Only small-scale biogas from agricultural streams, that showed limited excess support in the base case scenario, is insufficiently supported with a 20% decrease of the electricity prices. The BF normally increases with decreasing electricity prices, which provides additional support, but this is not possible for this specific technology as it already has a BF of 1 (currently the maximum BF). Additionally, adjustment of the discount rate to up to 50% confirms earlier findings, with only changes in sign for the technologies that showed a minor surplus or deficit in the base case scenario.

The higher support provided by the reformed Flemish TGC

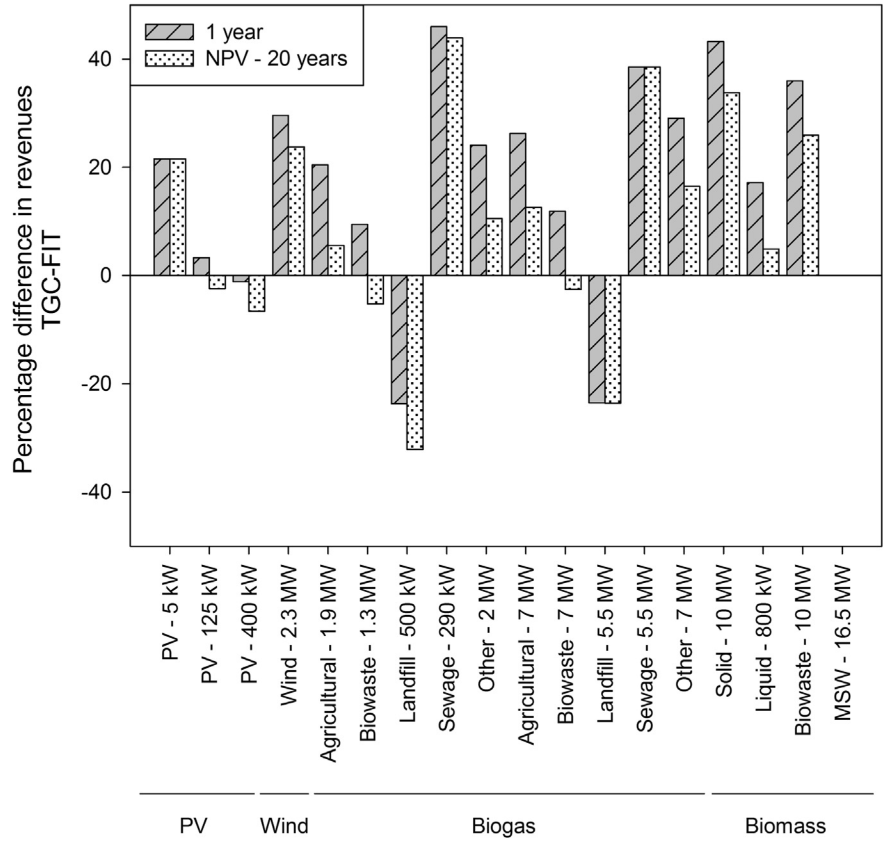

Fig. 5. Relative difference (%) between the revenues by 2013 Flemish tradable green certificates (TGC) and the revenues by 2013 German feed-in tariffs (FIT) for 18 RES-E reference units (revenues: once over one year, once net present value discounted over 20 years) – Positive value: higher revenues through TGC; negative value: higher revenues through FIT.

scheme compared to the support of the German FIT scheme corresponds with the findings of earlier studies [14]. In 2012, the total cost of the TGC scheme in Flanders amounted to € 992 million for an overall RES-E generation of 6046 GWh (10.2% of the gross final electricity consumption), without considering the additional revenues for RES-E generators through the sales of physical electricity [51,72]. The support for Flemish RES-E generators thus averaged € 164 MWh^{-1}, on top of the sales or savings of electricity valued at

Table 4
Assessed revenues obtained by RE producers through the (Flemish) TGC scheme and (German) FIT scheme, based on the listed parameters [acronyms and abbreviations explained in Appendix A and list of abbreviations]. Sources [23,58,60–62].

Categories	U	VU	η_{el}	Electricity generated	BF	BF (max.)	EV_{EL}	EV_{GSC}	ZA_{EL}	$P_{EL,ZA}$	r	Rated capacity	Average FIT	Total revenues TGC	Total revenues FIT
	[kW]	[h]	[%]	[MWh]			[%]	[%]	[%]	[€ kWh^{-1}]	[%]	[kW]	[€ kWh^{-1}]	[k€]	[k€]
PV															
PV ≤ 10 kW	5	850	100	4.25	0.00	0.00	0.0	0.0	100	0.217	5	0.49	0.170	11	9
PV ≤ 250 kW	125	850	100	106	0.63	0.63	0.0	0.0	65	0.151	5	12.13	0.169	218	223
PV ≤ 750 kW	400	850	100	340	0.49	0.49	0.0	0.0	65	0.132	5	38.81	0.151	599	639
Wind															
Wind ≤ 4 MW	2300	2000	100	4600	0.83	0.80	0.0	0.0	0	n.r.	8	525	0.088	5215	3974
Biogas ≤ 5 MW															
Agricultural	1900	7000	39	5187	1.59	1.00	10.0	0.4	0	0.111	12	1518	0.114	4208	3973
Biowaste	1300	7200	39	3650	2.12	1.00	22.0	0.0	30	0.111	12	1068	0.146	2958	3113
Landfill	500	4600	35	805	0.20	0.20	2.0	2.0	0	0.187	12	263	0.085	378	499
Sewage	290	3000	32	278	0.21	0.21	2.0	2.0	90	0.111	12	99	0.067	243	136
Other	2000	7000	39	5460	1.66	1.00	10.0	0.0	10	0.111	12	1598	0.114	4661	4171
Biogas ≤ 20 MW															
Agricultural	7000	7000	39	19,110	1.24	1.00	10.0	2.4	0	0.104	12	5594	0.104	15,321	13,395
Biowaste	7000	7200	39	19,656	1.48	1.00	22.0	2.0	30	0.104	12	5753	0.139	15,507	15,907
Landfill	5500	4600	35	8855	0.00	0.00	2.0	2.0	0	0.104	12	2888	0.063	3284	4059
Sewage	5500	3000	32	5280	0.00	0.00	2.0	2.0	90	0.104	12	1884	0.060	3796	2333
Other	7000	7000	39	19110	1.33	1.00	10.0	2.0	10	0.104	12	5594	0.104	16,037	13395
Biomass ≤ 20 MW															
Solid	10,000	7900	26	20,540	0.98	0.98	2.0	2.0	40	0.083	12	9018	0.087	19,762	13,081
Liquid	800	3000	40	960	1.92	1.00	1.2	10.0	40	0.111	12	274	0.131	978	930
Biowaste	10000	7900	26	20540	0.83	0.83	2.0	2.0	30	0.083	12	9018	0.087	17,667	13081
Municipal Solid Waste	7167	7800	20	11,181	−0.08	0.00	2.0	54.2	30	0.083	10	14,692	0.000	5630	5630

prices between € 40 MWh^{-1} and € 220 MWh^{-1}. The electricity value obviously depends on a number of factors, such as the ownership of the RES-E unit (private household vs. company), share of self-consumption, etc. [58].

In Germany, RES-E generators received € 19.12 billion of FIT support for an overall RES-E generation of 143.8 TWh in 2012 (22.9% of the gross final electricity consumption), including the non-supported RES-E technologies [73,74]. This yields an average support of € 133 MWh^{-1}, illustrating the large difference in total revenues between RES-E generators in Germany and Flanders. Several studies have indeed shown that countries, which adopted the FIT scheme, generally provide less support while demonstrating higher deployment rates of RES-E [22,66,75,76]. A well-designed FIT system ensures high future price certainty throughout the lifetime of the RE project. This increased security for investments decreases costs of the transition to RES-E as it provides a downward pressure on the price of borrowing, it reduces the request for high ROIs and it stimulates technological development, which also contributes to reducing costs [32].

6. Conclusions and recommendations

We assessed whether the 2013 reforms of the Flemish TGC scheme remedy important shortcomings of the system: missing qualification of RES-E technologies, excess profits and dysfunction of the TGC market. At the onset, the concept was that a TGC market system was feasible and would dominate other support systems in effectiveness and efficiency. This initial belief was based on the adage 'the market picks the winner', implying 'equal' treatment for all RES-E technologies, sources, and power plants. Avoiding individual qualification of technologies, sources, and plants was an essential component of the TGC market based instrument. It was also predicted that this would be the source of systematic and significant so-called windfall or excess profits for mature technologies which could potentially experience such strong growth that the "system would implode under its own weight" [12]. Based on both previous issues, it proved to be almost impossible to start and run a TGC market based instrument that could merit the label of being a market. Very few transactions took place, and it was evident that regulatory and political interventions determined certificate pricing rather than forces of supply and demand.

As a surrogate for proper qualification of RES-E supplies and cataloging them into collectively exhaustive and mutually exclusive classes, technology bands introduce a certain degree of differentiation of RES-E, but fail to fully qualify RES-E by taking into account all relevant attributes of the various 'source-technology' combinations. Fine-tuning of remunerations, as conceived and demonstrated by the German FIT scheme, is still far away. Total expenses for the Flemish support system are reduced by imposing a ceiling to the BF of 1.0, regardless of financial gap calculations. This contributes to preventing more expensive, but potentially promising RES-E technologies, from receiving support needed for development and practical deployment. More rigorous R&D policies may provide a solution regarding technology development, but the deployment of innovative technologies in new real-life circumstances is dependent on sector policies covering items such as industrial innovation, regional development, climate change, and environmental protection.

The Flemish authorities intended to establish a competitive artificial TGC market on top of a non-competitive electricity market. However, no functional TGC market was successfully created. With the large surplus of certificates and with a limited number of actors holding dominant positions in the power sector, the future for a workable TGC market does not look promising. The way in which Flanders initiated extensive reforms to its TGC scheme in 2013 does not offer a sufficient solution to this issue.

Politicians are motivated to reduce total costs of the TGC system, specifically by focusing on mitigating excess profits. By excluding medium to large RES-E units from the predefined RE categories, investors are required to file an application for a project specific BF which determines whether their RES-E projects will receive any support. In most cases, the support is necessary to obtain funding from shareholders and financial institutions. The retroactive limitation of TGC eligibility to 10 years for units commissioned before the reforms further decreased the general confidence of investors.

Up to 2012, the Flemish TGC scheme was characterized by high excess profits due to the lack of qualification of the technologies and sources, and to the slow adjustment of PV support levels, when solar panel investments significantly declined. Our simulation exercise comparing the revenues for 18 RES-E reference plants in the 2013 Flemish system with the revenues that the same plants would receive if submitted to the German FIT scheme, confirms the continued occurrence of excess profits. Further, this supports earlier findings that higher support is required to compensate for lower investment security under TGC schemes. The obvious volatility of the RES-E support policy also impacts investment security by increasing the required return on investments for investors.

Despite these observations, it is too early to determine the overall impact of the implementation of the 2013 TGC reforms on RES-E deployment levels in Flanders. Given the considerable decrease of support for biogas units for the recuperation of landfill gas and for the digestion of sewage treatment sludge and municipal solid waste incineration plants, investments in these technologies will likely be cut back given that no new units have been commissioned in the first semester of 2013 [77].

The 2013 reforms are presumably not the last, since the share of green electricity in the total electricity production in Flanders is still limited as compared to the zero carbon economy and the issues discussed in this contribution will only become worse if no adequate solutions are provided. Therefore the Flemish support scheme would be served by a scientifically based and thoroughly deliberated reform. In the end 'green' electricity producers would benefit from a fair, transparent and consistent support system. A reliable and long-term support system allows investments and the development of robust technology and industrial policies, all needed for the full development and deployment of RES-E.

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Appendix A. Feed-in tariff rates for various RE technologies applicable for installations commissioned on January 1, 2013. Sources: [61,62].

German FIT levels (as of January 1, 2013)	€ kWh^{-1}
PV	
≤10 kW	0.1702
10 kW – 40 kW	0.1614
40 kW – 1 MW	0.1440
1 MW – 10 MW	0.1178
Wind energy	
Base tariff	0.0480
Initial tariff for 5 years	0.0880
Biogas and biomass units	
≤150 kW	0.1401
150 kW – 500 kW	0.1205
500 kW – 5 MW	0.1078
5 MW – 20 MW	0.0588
Biowaste fermentation	
≤500 kW	0.1568
500 kW – 20 MW	0.1372
Small manure digesters	
≤75 kW	0.2450
Landfill gas	
≤500 kW	0.0847
500 kW – 5 MW	0.0580
Sewage gas	
≤500 kW	0.0669
500 kW – 5 MW	0.0580

Appendix B. Parameters used by the Flemish Energy Agency (VEA) for calculating financial gaps. Source: [24].

Symbol	Description	Unit
U	The electrical capacity of the unit	[kW_e]
η_{el}	The net electrical efficiency of the unit	[%]
EV_{EL}	Internal use of electricity by the unit, to determine the net green electricity production (share)	[%]
EV_{TGC}	Share of the gross green electricity production not qualified for TGCs	[%]
K_i	Specific overnight capital investment per unit of power	[€ kW_e^{-1}]
r	The desired return on the total investment (ROI)	[%]
E	Equity capital share in the total investment	[%]
r_d	The interest rate on the bank loan	[%]
T_b	The policy period	[year]
T_a	The depreciation period	[year]
T_c	The construction period	[year]
T_r	The period of the bank loan	[year]
i	The part of the investment eligible for investment allowance	[%]
IAP	The percentage of the investment tax reduction	[%]
VU	The average annual full load hours	[h]
ZA_{EL}	The use of electricity for own consumption (share)	[%]
$P_{EL,ZA}$	The avoided cost of electricity in case of own consumption (year 0)	[€ kWh^{-1}]
$P_{EL,ZA,t}$	The avoided cost of electricity in case of own consumption in year t, before actualization	[€ kWh^{-1}]
$P_{EL,V}$	The sales market value of electricity in year 0	[€ kWh^{-1}]
$P_{EL,V,t}$	The sales market value of electricity in year t, before actualization	[€ kWh^{-1}]
P_{IN}	The cost for the fed-in electricity in year 0 (feed-in tariff)	[€ kWh^{-1}]
$P_{IN,t}$	The cost for the fed-in electricity in year t, before actualization (feed-in tariff)	[€ kWh^{-1}]
P_{TVB}	The market value excluding taxes, levies and avoided grid costs of the avoided primary fuel for the same quantity of useful heat in year 0	[€ kWh^{-1}]
$i_{EL,ZA}$	The expected average yearly change of the avoided costs of electricity for own consumption	[%]
$i_{EL,V}$	The expected average yearly change of the sales market value of electricity	[%]
i_{PBW}	The expected average yearly change of the market value of the avoided primary fuel for the same quantity of useful heat	[%]
I_V	The discount value of the replacement investments per power unit in year 0	[€ kW_e^{-1}]
K_V	The fixed costs per power unit year 0	[€ kW_e^{-1}]
K_{Var}	The variable costs per unit of electricity generated in year 0	[€ kWh^{-1}]
i_{OK}	The expected average yearly change of the market value of the operational costs	[%]

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(*continued*)

Symbol	Description	Unit
P_B	The price of fuel in year 0, including financing costs for the purchase of fuel	[€ kWh^{-1}]
i_B	The expected average yearly change of the market value of the fuel	[%]
M_{IS}	The quantity (mass) of incoming material on a yearly base	[ton]
PO_{IS}	The costs or revenues from the incoming material per ton in year 0	[€ ton^{-1}]
i_{IS}	The expected average yearly change of the market value of the incoming material	[%]
M_{US}	The quantity (mass) of outgoing material on a yearly base	[ton]
PO_{US}	The costs or revenues from the outgoing material per ton in year 0	[€ ton^{-1}]
i_{US}	The expected average yearly change of the market value of the outgoing material	[%]
b	The corporate tax rate	[%]

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