Analysing the interactions of renewable energy promotion and energy efficiency support schemes: the impact of different instruments and design elements.

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Abstract

CO₂ emissions reduction, renewable energy deployment and energy efficiency are three main energy/environmental goals, particularly in Europe. Their relevance has led to the implementation of support schemes in these realms. The coexistence of these mechanisms may lead to overlaps, synergies and conflicts between them. The aim of this paper is to analyse those interactions. Previous analyses have focused on the interactions between emissions trading schemes (ETS) and energy efficiency measures and ETS and renewable energy promotion schemes whereas the mutual impacts between energy efficiency measures and renewable energy promotion has been much less studied. The analysis in this paper transcends the “certificate” debate (i.e., tradable green and white certificates) and considers other instruments, particularly feed-in tariffs for renewable electricity. The goal is to identify whether the choice of specific instruments and design elements within those instruments affects the results of the interactions.

1.- Introduction.

Climate change mitigation and security of energy supply have allegedly triggered the implementation of a wide array of policies in Europe and, likely soon, in the U.S. This paper focuses on three of these policies: emissions trading schemes (ETS), support schemes for electricity produced with renewable energy sources (RES-E) and measures to encourage energy efficiency (EE)¹.

The combination of these instruments raises concerns about overlaps, conflicts and synergies in their interaction. Previous analyses have focused on the interactions between the EU ETS and RES-E promotion and between the EU ETS and EE policies. However, the analysis of the interaction between the three instruments (ETS, EE and RES-E promotion) and, especially, between the last two has been very scarce² and limited to two specific RES-E and EE instruments: tradable green and white certificates (TGCs and TWCs, respectively)³.

The aim of this paper is to analyse the interactions between EE and RES-E support schemes⁴, covering two main gaps in the literature. First, the analysis identifies whether the choice of specific instruments affects the results of the interactions. It transcends the “certificate” debate (i.e., TGCs and TWCs) and considers other instruments (particularly feed-in tariffs for RES-E)⁵. Second, this paper analyses the impacts of different design elements on those interactions, an issue which has not received much attention in the interactions literature

¹ For illustrative purposes, i.e., to highlight the possible interactions between instruments, this paper focuses on electricity.
² NERA (2005) focuses on the interaction between those instruments, but in a separate manner (i.e., for ETS and TWC and ETS and TGC) but the simultaneous interaction between TWC, ETS and TGC and even between TGCs and TWCs is disregarded.
³ See, among others, Bertoldi and Huld (2006), Oikonomou and Patel (2004), Farinelli et al (2005) and Klink and Langniss (2006). For example, Oikonomou and Patel (2004) observe that an integrated scheme of TWCs and TGCs could be feasible in terms of institutional setup. Bertoldi and Huld (2006) propose a combined tradable certificate scheme in which both RES and demand-side EE measures could bid in real time through the Internet to meet a specific obligation. Furthermore, they deal with the integration of both instruments and not on their mutual interactions. Our focus is not on the integration of schemes, which has proved a difficult issue anyway (see NERA 2005 and Oikonomou and Patel 2004), but on their interactions.
⁴ It has focused only on the issue of “integration” of instruments, whereas the real situation in the European countries is one of intended separation between both instruments
⁵ This analysis is deemed highly necessary because only six EU-27 countries have adopted “certificates” to promote RES-E and EE, whereas the majority use feed-in tariffs for RES-E promotion and non-certificate instruments to encourage EE (see European Commission 2008).
Accordingly, the paper is structured as follows. Section 2 discusses the methodology and the main assumptions. The instruments and assessment criteria are described in section 3. Section 4 and 5 analyse whether different support schemes and design elements lead to different interaction results. The paper closes with some concluding remarks.

2.- Methodology and main assumptions.

2.1. Methodology.

The analysis of interactions performed in this paper uses a qualitative method in a partial equilibrium framework, where the electricity sector is represented. The impacts of the interaction between those instruments can be rated by investigating how they affect a number of criteria and variables. The objectives of the instruments are depicted in specific energy, emissions, or other environmental targets and can conflict, overlap, complement or be neutral towards each other (Oikonomou and Jepma (2008)).

This theoretical/methodological framework has been used in the past by, among others, del Río et al (2005), del Río (2007), Jensen and Skytte (2003) and Sorrell et al (2009). This paper complements other studies, which either analyse the interactions between TGC and ETS (Jensen and Skytte 2002, 2003; Morthorst 2003; NERA 2005), between TWC and ETS (Sorrell et al 2009, NERA 2005) or between different EE policies (Boonekamp et al 2006)\(^6\).

2.2. Main assumptions.

- Separation between the three instruments is assumed, i.e., the commodities (certificates) from EE measures and RES-E promotion schemes are not translated into a CO2 emissions reduction value.
- A competitive electricity market is assumed, i.e., the costs of EE and RES-E support measures are fully passed to electricity consumers. RES-E and EE support schemes entail a cost (the so-called “add-on”), which is fully paid by electricity consumers in their bills\(^7\).
- EE measures only apply to the electricity sector, i.e., to increase the efficiency of energy conversion in the generation of electricity (i.e., not increase end-use efficiency). This assumption allows us to isolate the most relevant effects regarding the interactions of an ETS, EE and RES promotion within the boundaries of the electricity sector.
- No EE measures and RES-E technologies simultaneously fall under EE and RES-E support schemes\(^8\).
- In general, secondary effects are disregarded, except for the increase in retail electricity prices due to the implementation of EE and RES-E support instruments.

3. Linking ETS, RES-E and EE support schemes: instrument and assessment criteria.

3.1. Instruments for the promotion of RES-E and EE.

Several instruments are available to improve EE in different sectors. Some are currently applied in EU countries, such as taxes, voluntary agreements, subsidies, tax deductions, standards, information campaigns and soft loans. Regarding instruments to improve electricity efficiency\(^9\) more specifically, mandatory saving targets (with or without TWCs) and taxes have received most of the attention. Other instruments include BAT prescriptions, subsidies, procurement, demand-side management and information campaigns to electricity consumers.

On the other hand, RES-E promotion in Europe has traditionally been based on two main (primary) mechanisms\(^10\): feed-in tariffs and TGCs\(^11\). FITs are subsidies per kWh generated paid in the form of a total quantity (tariff) or as an amount on top of the wholesale electricity price (premium) fed into the grid. They are combined with a purchase obligation by the utilities.

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\(^6\) See del Río (2007) for an overview of the interaction literature, mostly focused on the interaction between ETS and RES-E support schemes.

\(^7\) Farinelli et al (2005) assume that the policy for EE (TWC) does not have a cost, i.e., that the increase in EE is free of costs to society. However, assuming no-cost of EE measures is a highly unrealistic situation, although it is possible that the add-on for EE support is lower than for RES-E support given that the many EE options are considered to be low-cost (Commission Europeans, 2005).

\(^8\) This is the case in those countries where TGCs and TWCs have been applied (Italy and U.K.).

\(^9\) In the context of this paper, the term “electricity efficiency” refers to a reduction in electricity demand, improvement in conversion efficiencies and reduction in transmission and distribution losses.

\(^10\) Since this paper focuses on the analysis of the impact of different RES-E support schemes and design elements on the interactions, we provide a more detailed albeit still short description of these instruments.

\(^11\) These instruments have been supplemented by other complementary instruments (investment subsidies, fiscal and financial incentives and green pricing). See del Río and Gual (2004) for a more detailed explanation of the functioning of all these systems.
TGCs are certificates issued for every MWh of RES-E, allowing RES-E generators to obtain additional revenue to the sale of electricity (i.e., two streams of revenue). Demand for TGCs generally originates from an obligation on electricity distribution companies to surrender a number of TGCs as a share of their annual consumption. Otherwise, they would have to pay a penalty. In both cases (TGCs and FITs), the costs are borne by consumers.

3.2. Assessment criteria and variables

The coexistence and interactions between instruments can be assessed according to several criteria (see, among others, Oikonomou and Jepma 2008, Konidari and Mavrakis 2007, and del Río and Gual 2004). However, the focus in this paper is on the effectiveness and economic efficiency (static and dynamic) criteria.12

* **Effectiveness.** An instrument is effective if it is able to achieve a certain target (i.e., emissions reductions, RES-E and EE investments).

* **Cost-effectiveness** refers to the achievement of a given emissions reduction, RES-E or EE target at the lowest possible cost. Cost-effectiveness is attained when an instrument encourages proportionally greater emissions reductions, RES-E or EE investments by firms with lower costs and lower emissions reductions RES-E or EE investments by companies with higher costs, leading to an equalisation of marginal costs across firms/plants (equimarginality). The administrative/transaction costs of the instruments should also be taken into account.

* **Dynamic efficiency** refers to the ability of an instrument to generate a continuous incentive for technical improvements and costs reductions in technologies. Currently expensive technologies with significant quality improvement and costs reduction potentials need to be supported today in order to have them available in the future to reach new targets at moderate costs.

We thus analyse the impact of the interactions on several key variables pertaining to the aforementioned three criteria.

- Regarding the effectiveness criteria, CO2 emissions, electricity demand and RES-E generation and investments are the main variables.
- Regarding static efficiency, the focus is on consumer costs (as shown by variations in the retail price of electricity, Pr). Pr is the result of adding the wholesale price of electricity (Pw) to the add-on for RES-E and EE support, whereas RES-E depends on Pw and the add-on for RES, EE investments mostly depends on the Pr.
- Regarding dynamic efficiency, we analyse the impact on RES-E and EE investments and particularly on the least mature technologies.

4. Do different support schemes lead to different interaction results?

We start by analysing the interactions when the RES-E support instrument is a TGC scheme and the EE instrument is a TWC scheme. We then analyse whether the results of the interactions change when a different RES-E support scheme is introduced.

In principle, the addition of a TGC scheme to a TWC scheme does not affect the functioning of the later and indirectly influences the uptake of EE measures, due to an increase in Pr stemming from the application of the RES-E promotion scheme.

On the other hand, adding a TWC scheme (or other EE instrument) to a TGC scheme can affect the TGC market, but only if the RES-E quota is set in percentage terms. In this case, a TWC would reduce electricity demand/production and the absolute RES-E requirement.13

Jensen and Skytte (2002) observe that Pw and the TGC price (Ptgc) move in opposite directions, i.e., a reduction in Pw triggers an increase in Ptgc, i.e., the subsequent reduction in Pw would increase Ptgc, leaving total support constant. However, support does not remain constant when electricity demand is reduced. Indeed, with a large demand reduction and a highly inelastic RES-E supply curve (MCres-e), there could be both a reduction in Pw and Ptgc (figure 1). In this case, there would be a double disincentive for RES-E investments if an EE measure is added to a TGC scheme.

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12 Efficiency and effectiveness are always present in any evaluation of instruments. While important, other criteria (such as equity and political acceptability/feasibility) are not considered here.

13 A lower TGC price would result and, thus, the highest cost renewable energy technologies which were previously needed to fulfill the quota would no longer be needed.

14 The Ptgc is the difference between the marginal costs of the marginal technology to meet the quota and Pw.

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Therefore, there is a conflict when EE support is added to RES-E promotion (reduction of RES-E) while the effect is slightly beneficial in the other direction. Thus, if RES-E and EE are to be promoted, and a quota with a TGC scheme is used as the RES-E promotion instrument, then the quota should not be set in percentage terms. If it is, then the negative effect of EE support on RES-E should be taken into account, setting the relative quota in a manner which considers this negative effect.

The aforementioned negative impact on RES-E investments would be particularly so for the most expensive technologies, which were previously needed to meet the quota. This further reduces the technological diversity in a TGC scheme, already low. However, the recent literature and policy practice acknowledge that those expensive technologies should be promoted by a different instrument (i.e., FITs).

On the other hand, a changing TGC price is as problematic as a low TGC price for RES-E investments. EE measures could increase the volatility of the TGC market, although probably not to a great extent. This would be a side-effect of the reduction of the TGC market volume, which reduces its liquidity and makes TGC price spikes more likely.

Would a different RES-E support scheme (FITs) be affected by the introduction of an EE measure which reduces electricity demand and, thus, Pw? In general, and compared to TGCs, FITs are less affected by EE measures. However, this conclusion depends on the type of FITs being implemented. Under a regulated tariff, support does not depend on Pw, but under a feed-in premium generators receive the Pw and the premium and, thus, part of the total support is affected. The reduction in Pw triggered by EE support reduces the overall incentive to invest in RES-E.

To sum up, the type of support scheme does have an impact on the results of the interactions, but this effect is mostly mediated by the design elements of those instruments.

5. Do different design elements within RES-E support schemes result in different interaction results?

In order to simplify the analysis, the literature on the interaction between the aforementioned instruments has usually considered an “idealised” instrument, disregarding the fact that measures may have different design elements, as in RES-E support schemes. However, the choice of design elements may affect the

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15 Quota targets for RES-E can be set either in relative terms (i.e., as a percentage of total electricity sales) or in absolute terms (i.e., an amount in MWh). All EU countries have set a relative quota target. This is due to the fact that targets in the Renewable electricity Directive (2001/77/EC) and the new Renewable Energy Directive are set in relative terms.

16 This might be different, however, because the reduction in electricity demand due to the implementation of EE support should be predicted, which is not an easy task.

17 Of course, we refer to expensive renewable technologies whose long-term costs would be just below the price of the TGC before the TWC is introduced, and which would be no longer needed to meet the quota once the TWC is applied. Other renewable technologies with even higher costs would not be affected by the introduction of the TWC, since they were not needed to meet the quota in the absence of the TWC anyway.

18 Only the cheapest technologies will be deployed with a TGC scheme without a technology-specific quota.

19 For example, in Italy solar PV is supported with FITs.

20 For example, NERA (2005, p.104) argues that “the aim is to understand the basic implications of a TWC scheme without complicating the analysis with market and design features that vary from scheme to scheme”. The design elements of RES-E support schemes (feed-in tariffs and TGCs) widely differ across countries, as shown by Ragwitz et al (2007) and European Commission (2008).
results of the interactions. Therefore, the aim of this section is to identify the impacts of the different design elements of RES-E promotion schemes on the results of the interactions.

Table 1 lists the main design elements of FITs and TGCs which will be discussed in this paper\(^{21}\). They will be described in the next subsections.

<table>
<thead>
<tr>
<th>FITs</th>
<th>TGCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed premium versus fixed tariff</td>
<td>-Target (absolute/relative).</td>
</tr>
<tr>
<td>Technologies excluded</td>
<td>-Technology-specific quota</td>
</tr>
<tr>
<td>Existing plants included</td>
<td>-Minimum prices for TGCs.</td>
</tr>
<tr>
<td>Cap system</td>
<td>-Maximum prices for TGCs.</td>
</tr>
<tr>
<td>Floor system</td>
<td>-Technologies included/excluded.</td>
</tr>
<tr>
<td>Stepped tariffs (technology-specific)</td>
<td>-Existing plants included.</td>
</tr>
<tr>
<td>Degression.</td>
<td>-Borrowing.</td>
</tr>
</tbody>
</table>


The analysis is carried out considering, first, that a RES-E support instrument is added to an ETS and EE support (5.2.1) and, second, that EE support is added to ETS and RES-E support. We identify the impact on the considered variables. A greater Pr encourages EE investments.

### 5.1. Adding RES-E support to an ETS and EE support.

#### 5.1.1. FITs

* **Fixed premium versus tariff**. The impact on PW of both alternatives is similar. They both encourage a greater RES-E generation, resulting in a lower Pw. However, the support under the premium can be expected to be higher than under the tariff alternative, leading to a greater Pr and a greater incentive to invest in EE. The reason is that the premium option is more risky for RES-E investors because the future trend of part of the support (Pw) is unknown, and highly dependent on difficult to predict factors, including the ETS itself. In order to compensate for the greater risk, governments may be tempted to increase the premium (i.e., the premium + Pw would be greater than the tariff)\(^{22}\). This would lead to the same RES-E increase in both options, but with a higher support level (add-on) in the premium case\(^{23}\).

* **Stepped FIT (technology-specific)**. Technology-specific FITs are one modality of stepped FITs, in which support levels are different across technologies to reflect technology-specific generation costs. This means that, with a flat FIT, the same level of support would be granted to different technologies. Under the stepped FIT, support would be adapted to the costs of the technologies, with higher support given to the most expensive and lower support to the cheaper ones.

Obviously, immature technologies would have a better chance to penetrate the market with a stepped FIT than with the flat FIT. Therefore, there would be more RES-E deployment (and, thus, a lower Pw) under the stepped alternative, because investments in both mature and immature technologies would occur.

It is difficult to tell whether the add-on would be higher in the stepped or the flat option. Figure 2 shows why. While the penetration of the immature technologies entails greater costs with a stepped FIT (areas “B+C” in figure 2.b), windfall profits (i.e., the difference between technology costs and the support level) would be greater in the flat alternative for the mature technologies (area “A” in figure 2.a). Whether one factor offsets the other is an empirical matter, and depends on the level of the flat FITs, the stepped FITs and the costs of the different renewable energy technologies. Since there is a lower Pw in the stepped FITs option, a slightly lower consumer cost seems likely in the stepped FITs option (and, thus, a lower Pw and incentive for EE investments).

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\(^{21}\) These are either included in current schemes in Europe or could be so in the future.

\(^{22}\) Indeed, Ragwitz et al (2007) empirically show that the fact that risks are greater in the case of the premium has made some countries chose the level of the premium in a way that the overall remuneration of this option is higher than the fixed tariff option (i.e., the Czech Republic and Estonia) in order to compensate for the higher risk for RES-E producers. In contrast, in Slovenia the overall remuneration is supposed to be the same for both options.

\(^{23}\) With an ETS in place, the risks for RES-E generators of the premium option are higher, but revenues are also likely to be higher, because the ETS pushes the Pw upwards.
* Cap price. In contrast to the previous ones, this is not a widespread design element, with Spain being the only country where it is currently adopted. By capping the total support to be obtained by RES-E generators \((P_w + \text{premium})\), it limits the influence of interactions “upstream” between the EU ETS and FITs and the impact on consumer costs.

If the cap mechanism is activated, then a lower level of support than without the cap and, thus, a lower level of RES-E (generation and investment) could be expected. There would also be a slightly higher \(P_w\) (given lower RES-E levels), but also a lower add-on, \(Pr\) and incentive to invest in EE measures could be expected.

* Floor. By putting a lower limit on the support level (premium + \(P_w\)), the floor limits the influence of interactions “downstream” between EU ETS and FITs.

If the floor mechanism is activated, then a higher level of support than without the floor and, thus, a higher level of RES-E could be expected. A slightly lower \(P_w\) (given higher RES-E levels) but a higher add-on, \(Pr\) and incentive to invest in EE measures would result.

* Degression. This refers to reductions in support levels for new plants over time with respect to the flat alternative. \(P_w\) would be slightly greater with degression, given the lower RES-E. The add-on and \(Pr\) would be lower. EE investments and RES-E generation and investments would also be lower.

Table 2. Impacts of selected FIT design elements on the interactions between instruments.

<table>
<thead>
<tr>
<th>Criteria/variable</th>
<th>CO2</th>
<th>(P_w)</th>
<th>Add-on</th>
<th>(Pr)</th>
<th>EE (secondary effect)</th>
<th>RES gen.</th>
<th>RES 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed premium (\text{reference: fixed tariff})</td>
<td>=</td>
<td>=</td>
<td>&gt;</td>
<td>&gt;</td>
<td>&gt;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

24 An antecedent was the cap applied for wind on-shore in Denmark in 2003-2004, and abolished in 2005. According to Ragwitz et al (2007), the premium depended on the electricity market price and was adjusted if the price rose above 3.49 €cents/kWh in such a way that the sum of the market price and the premium did not exceed 4.83 €cents/kWh.

25 This reduction in support is justified, given the cost reductions due to economies of scale and learning effects experienced by renewable energy technologies.

26 Nevertheless, investment risks are slightly lower with a degressive tariff, because it provides some clues on the evolution of RES-E support in the future. Whether this offsets the lower support is uncertain.
5.1.2. TGCs

* Quota target. A relative quota may lead to a greater or a lower absolute amount of RES than an absolute target because the level of electricity demand and electricity sales can not be predicted. Therefore, it is unknown how much RES-E will need to be deployed to meet the quota. Thus, the other variables (add-on, Pr, EE…) can also be either higher or lower. An absolute quota is preferable for investors, given the higher certainty on the amount of RES that will need to be produced, which reduces the costs of financing (lower risk premium).

* Technologies excluded (immature). A frequent criticism of quotas with TGC schemes is that they encourage the least mature technologies, whose costs are higher than the marginal technology needed to comply with the quota target and higher than the TGC price (del Rio 2005). Thus, technological diversity is hardly promoted. This has been ascertained by policy makers, leading to either a promotion of these expensive options with other instruments (such as FITs for solar PV, like in Italy) or to setting technology-specific quota. The first option is discussed below here.

There are two possible cases: one in which an expensive technology which would be part of the quota (i.e., the marginal technology) was excluded and another in which the technology would be too expensive to even be part of the quota. The first case is worth analysing. Excluding those technologies would involve reducing the quota accordingly. However, since they are expensive, their impact on the marginal costs of reaching the quota is greater than on the level of the quota itself. Therefore, excluding this technology from the target implies that the quota is slightly lower and is achieved at much lower marginal and total costs. Therefore, RES-E generation, the add-on, Pr and EE investments would all be lower (only Pw would be higher).

* Low penalty. An appropriate penalty is a must in any quota with TGC scheme to discourage non-compliance, i.e., it should be set above the marginal costs of the marginal technology which sets the TGC price. Absent this, a lower level of RES-E generation than expected could result. This would trigger a higher Pw. Consumer would be better off because the higher Pw is more than offset by the significantly lower add-on (lower RES-E promotion costs) and Pr. EE investments would be lower.

* Minimum TGC prices. They would be attractive for investors, since the volatility would be reduced and a minimum level of revenue would be ensured. If the TGC price was reduced below the minimum price, this mechanism would be activated. The lower risks for investors would translate into a lower risk premium and lower costs of financing, although this cost-saving for RES-E generators may not be passed on to consumers. Therefore if this was activated (which may never occur), the add-on, Pr, EE and RES-E

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27 Another case for exclusion would be renewable technologies which are already competitive and do not need public support. However, it would be quite incoherent to include then in a quota with TGC system. Therefore, this case is not considered worth analysing.

28 Excluding the technology for eligibility under the quota would not have any effect at all.

29 Of course, target setting is not independent on the technologies available. In reality, policy makers take into account the available technologies when setting the target.

30 If the immature are promoted with a different instrument (FIT), then the same amount of RES-E generation would result, but still at much lower costs than if the immature were part of the quota. The reason is that these would be the marginal technologies and would set the level of the TGC price. If the immature are not eligible for the target, this would result in a lower TGC price, which would reduce the costs of support. Therefore, there would be the same level of support for the immature (with FITs and TGCs) but a much lower level of support for the mature when the immature are not eligible for the quota, since the remuneration (TGC price) for the mature is lower.
generation would be higher than without a minimum price. This design element works very much like a floor price for FITs31 but, since TGC prices tend to be more volatile than FIT premiums, its benefits for dynamic efficiency are greater.

* Technology-specific quota. There are several ways to implement a technology-specific quota (Ragwitz et al 2007). It is assumed that targets for different technologies exist. This would result in a fragmentation of the TGC market, with one quota for the mature technologies and another for the non-mature. The static efficiency gains of such a reduced market would be lower and, also, a more volatile TGC price could be expected. On the other hand, the TGC price in the mature technology market would be lower compared to a single TGC market, because in this later case the price of TGCs would be at the level set by a more expensive technology needed to reach the quota32. With a technology-specific quota, this marginal technology would set the price of TGCs in the immature market, but not in the mature one. Therefore, this would result in a lower level of RES-E support in the case of technology-specific quotas. However, this is (partially) offset by the fact that trade benefits are lower with fragmented markets, which results in higher compliance costs. The first effect is likely to dominate and, thus, the add-on would be higher in the case of a single TGC market. Pr would also be higher, encouraging subsequent increases in EE.

* Existing plants eligible. As a general rule, existing plants should not be eligible under a TGC scheme, because only a very small additional generation/capacity would be promoted with significant windfall profits for existing plants33. Obviously, the overall costs would be lower if existing capacity was included, because cheap options would be enough to comply with the quota34. The inclusion of existing plants would negatively affect both new RES-E and EE investments (given the lower Pr).

* Banking. In general, banking would lower costs (more intertemporal efficiency), although it would probably boost RES-E generation in the short-term and less in the longer run35. On average, the add-on will probably be lower with banking, leading to a lower Pr, EE and RES-E investments. However, banking tends to reduce the volatility of the TGC price, which favours RES-E generation. Therefore, the impact on RES-E investments is inconclusive.

* Borrowing. Same effects as banking result, although, in contrast to banking, RES-E investments in the shorter-term are discouraged.

Table 3. Impacts of selected design elements of TGCs on the interactions between instruments.

<table>
<thead>
<tr>
<th>Criteria/variable</th>
<th>CO2</th>
<th>Pw</th>
<th>Add-on</th>
<th>Pr</th>
<th>EE</th>
<th>RES gen.</th>
<th>REST I</th>
<th>Less mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immature technologies excluded (ref.: all technologies included)</td>
<td>=</td>
<td>&gt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>= if immature supported with FITs</td>
<td></td>
</tr>
<tr>
<td>Low penalty (ref.: appropriate penalty)</td>
<td>=</td>
<td>&gt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>&lt;</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>Minimum prices. (ref.: no minimum prices)</td>
<td>=</td>
<td>&lt; (small effect)</td>
<td>&gt; (small effect)</td>
<td>&gt; (small effect)</td>
<td>&gt;</td>
<td>&gt;</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>Existing plants non-</td>
<td>=</td>
<td>=</td>
<td>&gt;</td>
<td>&gt;</td>
<td>=</td>
<td>&gt;</td>
<td>&gt;</td>
<td></td>
</tr>
</tbody>
</table>

31 For example, in Belgium, minimum prices are ensured if the sum of the electricity market price and the TGC price is insufficient to cover the costs of electricity generation (Ragwitz et al 2007).
32 The more stringent the quota, the greater the probability that very expensive technologies will be needed to reach it.
33 Sweden is one example where certificates are issued for old and new capacity in the same way.
34 The overall costs of the scheme including existing capacity are lower than when only new capacity is eligible for TGCs, but the costs of promoting new capacity are very high (dividing the overall costs of the scheme by the small amount of new capacity being promoted).
35 Amundsen et al (2006) show that the introduction of TGC banking may reduce price volatility considerably and lead to increased social surplus. Banking lowers average prices but may lead to higher TGC prices in the short-term. Therefore, the add-on and thus the Pr is higher in the short-run and lower in the long-run. On average (i.e., short-run and long-run) the add-on is lower with banking than without it.
To sum up, several RES-E design elements have a significant effect on the interaction with a previously implemented ETS and EE support including a premium and floor (FITs) and the eligibility of existing plants, the existence of a technology-specific quota and banking and borrowing (TGCs).

5.2. Adding EE policies to an ETS and RES-E support.

The impact of EE measures on RES-E can take place if they either affect the wholesale electricity price (Pw) or the add-on, i.e., the premium or the tariff (in case of FITs) or the TGC price.

5.2.1. FITs

* Fixed premium. Compared to tariffs, under a fixed premium RES-E generators and investors are much more affected by reductions in Pw due to the electricity demand reduction caused by EE measures. With a fixed premium, RES-E generators receive two streams of revenue (Pw and the premium). Variations in Pw directly affect the profitability of RES-E. In the case of tariffs, a total remuneration, which is relatively independent of the electricity price, is granted. Therefore, this design element is relevant to explain the different impact of EE measures on RES-E.

The add-on would be lower in the premium case since the lower Pw triggers a lower RES generation. However, the government may increase the premium when Pw is reduced in order to maintain revenues constant for RES-E generators. If this occurs, the incentives for RES-E deployment and consumer costs (add-on + Pw) would also remain constant and similar in both FIT options. The implementation of a premium option is assumed in the rest of this section.

* Cap. This mechanism is irrelevant in this context because it is activated only when the aggregation of Pw plus the premium exceeds a certain limit and the implementation of EE measures would only reduce Pw, not increase it.

* Floor. Floor prices would limit the impact on RES-E of a reduction in electricity demand and Pw triggered by EE measures because the total remuneration for RES-E plants would not fall below the floor price. Compared to the flat alternative, the add-on and consumers costs would be greater. The risks for investors would be lower and, if the floor price was activated, the remuneration would be higher than without it. This would encourage RES-E investments.

* Stepped (technology-specific). There are no significant differences in the impact of EE measures on the key variables between the stepped and the flat alternatives. The government is more likely to adjust the premium after a reduction in Pw when there is a technology-specific premium than under the flat alternative. It is more likely to increase it for the cheapest technologies, since in this case Pw represents a larger share of total support than for the most expensive technologies and they would be relatively more affected by a reduction in Pw.

* Degression. The reduction of Pw triggered by EE measures can be particularly problematic for RES-E investments in the case of degressive premiums, because it adds to the reduction of the premium over time (i.e., both streams of revenue). This impact could be mitigated with a floor price. Compared to the flat alternative, the impact of EE measures on the RES-E add-on is similar in absolute terms (i.e., €cents/kWh) with degression.

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36 Overall support costs are the result of multiplying the level of support by the amount of RES-E generated.
37 The reason is that the impact of the other design elements can be more clearly illustrated under this design element.
38 An alternative would be to introduce a mechanism with an automatic adjustment of support levels to respond to the impact of EE measures. However, it is unclear how such a system could be designed and how it would work.
Table 4. Summing up the impacts.

<table>
<thead>
<tr>
<th>Criteria/variable</th>
<th>CO2</th>
<th>Pw</th>
<th>De</th>
<th>EE Add-on</th>
<th>RES Add-on</th>
<th>Pr*</th>
<th>RES gen.</th>
<th>RES 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed premium</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(&lt; increase in both cases but less with premiums, unless adaptation occurs.)</td>
<td>(&lt; some reduction can be expected with premiums, whereas uncertain with tariffs)</td>
<td>(&lt; some reduction can be expected with premiums, whereas uncertain with tariffs)</td>
</tr>
<tr>
<td>(reference: fixed tariff)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap. (ref: no cap)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
</tr>
<tr>
<td>Floor (ref: no floor)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
</tr>
<tr>
<td>Stepped (technology-specific)(ref.: flat rate)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
</tr>
<tr>
<td>Degression. (ref.: flat rate across time)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(unchanged in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
<td>(increase in both cases)</td>
</tr>
</tbody>
</table>

Source: Own elaboration.

5.2.2. TGCs

The following relevant design elements make a difference regarding the impact of EE.

*Absolute versus relative quota.* The implementation of EE measures reduces the absolute amount of RES-E generation under a relative RES-E quota whereas such reduction does not occur with an absolute quota. EE support would reduce electricity demand. The relative target reduces the add-on and Pr compared to the absolute target case\(^\text{39}\). In turn, a lower Pr would negatively affect EE (rebound effect), although this secondary effect is unlikely to offset the “main” effect from the EE support.

*Technologies excluded (immature).* EE measures reduce De, the absolute quantity of RES-E and, thus, the add-on\(^\text{40}\). This happens whether expensive/immature technologies are eligible for the quota or not. However, when they are included, such reduction in the add-on (and, thus, in consumer costs) is greater. Figure 3 shows why.

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\(^{39}\) Note that, in this case, the variations in Pr result from the variations in Pw, the add-on for RES promotion and the add-on for EE promotion. A reduction in RES-E generation tends to (modestly) increase Pw and (significantly) reduce the RES-E promotion add-on whereas the EE measure tends to (significantly) put downward pressure on Pw and (modestly) increase the EE promotion add-on. Thus, a reduction in Pr can be expected. In the case of an absolute target, RES-E is not reduced as a result of the implementation of EE measures. Therefore, the final effects on Pr are uncertain, although a small increase is possible.

\(^{40}\) In order to better illustrate the impact of the other design elements, it is assumed in the rest of this subsection that a relative quota is implemented. This is the most common design element in existing quotas with TGC schemes.
Figure 3. Analysing the impact of EE measures when immature technologies are excluded.

Figure a represents the overall TGC market (i.e., both mature and immature technologies included), whereas figure b.1 shows the TGC market for the mature technologies only. For reasons of simplicity it is assumed that a TGC scheme applies only to the non-mature (b.2), although this is highly unlikely in real practice. The figures show the upward slope of the marginal cost curve for RES (MCre), the level of the quota (Q) and the TGC prices that correspond to the initial situation Ptgc0.

The introduction of EE measures reduces electricity demand, resulting in a lower absolute quantity of RES-E needed to comply with the quota. This is represented by a shift in the quota line to the left. This triggers a reduction in the TGC price, since this is set by the marginal costs of the marginal technology. The reduction is greater in the case of the overall market than in the TGC market with only mature technologies. This leads to a greater cost saving for consumers (given by the reduction in the Ptgc times RES generation) in the overall market. Graphically, area A is greater than the areas B1 + B2.

* Appropriate penalty. Too low a penalty would result in compliance problems, possibly causing a lower RES-E generation, add-on and Pr (recall this is the product of the TGC price less Pw times the amount of RES-E deployed) and a lower Pr than if the penalty was set at an appropriate level (i.e., higher than the Ptgc). EE measures mitigate the problem caused by a low penalty because, as shown before, EE measures would push down the TGC price. If this reduction was significant, then the Ptgc could be lower than the low penalty (figure 4). Nonetheless, De would have to be greatly reduced in order to significantly push TGC prices down (to Ptgc(1)), which seems unlikely. Whether this could occur is an empirical issue.

41 However this assumption is not crucial for our analysis. Indeed, the results would not differ substantially whether a quota with a TGC scheme or a FIT system was applied to the most expensive (immature) technologies.
42 The quota is represented in this figure as an absolute quantity of RES, corresponding to a percentage of total sales. This is done for illustrative purposes only and has no bearing on the results.
43 Obviously, the quota in percentage terms does not change, but there is a reduction in the absolute amount of RES-E needed to meet the quota.
44 It has been assumed that the reduction in RES is the same in both cases (i.e., \( Q_{0} - Q_{1} = (Q_{e0} - Q_{e1}) + (Q_{e0} - Q_{e1}) \)). In other words, the total reduction in RES experienced in the overall TGC market (a) is the same that the combined reductions of RES in the TGC market with only mature technologies (b.1) and with only immature technologies (b.2).
*Minimum TGC prices. Although it is very unlikely that EE support by itself pushes the TGC price below the minimum price, it could add to other factors leading to this situation. If this was the case, the minimum price mechanism would be activated. Whether this happens depends on several factors, among then the level of the minimum price and the impact of EE measures on De. Of course, if this mechanism was activated, RES-E and consumers costs would be greater than if it was not activated (i.e., a greater add-on would result).

*Technology-specific quota. The implementation of EE measures is more likely to reduce the add-on and consumer costs related to RES-E promotion when there is not a technological differentiation than when there is one. This is so because, in the non-differentiation case, there is only a TGC price set by expensive renewable energy technologies and, thus, this price is likely to be higher than the TGC price in the mature market in the case of a technology-specific quota. The cost-saving effect triggered by EE measures in this case is greater because it would significantly reduce the Ptgc compared to the existence of separate markets.\(^{45}\)

* Existing plants not eligible. If existing plants are eligible, the share of new RES capacity needed to meet the quota would be small even without the implementation of EE measures. But a reduction of De as a result of EE would further reduce the possibility that new RES capacity meets the quota. Such small new capacity would be especially affected because it is more costly than existing (almost paid-off) capacity.\(^{46}\) The add-on and Pr would be the same in both cases.

*Banking/borrowing. EE measures tend to reduce the amount of TGCs needed to comply with the quota. A smaller market increases the volatility of the TGC price and is certainly troublesome for RES-E investors. By allowing intertemporal transfer of TGCs, banking and borrowing mitigate this problem. Theoretically, this mechanism would result in greater intertemporal cost-effectiveness in RES-E deployment and, thus, a lower add-on. Again, EE support is unlikely by itself to create this narrower market problem in the first place although it can contribute to it, together with other factors. However, price spikes, which are less likely with banking/borrowing, may encourage RES-E generation by existing plants. Therefore, the impact on generation is ambiguous, whereas the effect on RES-E investments is clearer.

Table 5. Summary of the impacts.

<table>
<thead>
<tr>
<th>Criteria/variable</th>
<th>CO2</th>
<th>Pw</th>
<th>De</th>
<th>EE add-on</th>
<th>RES-E Add-on</th>
<th>Pr</th>
<th>RES gen.</th>
<th>RES I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quota target relative (Ref: absolute)</td>
<td>= (unchanged in both cases)</td>
<td>= (reduction in both cases)</td>
<td>= (reduction in both cases)</td>
<td>&lt; (reduction with relative target, unaffected with absolute target)</td>
<td>&lt; (reduction with relative target, unaffected with absolute target)</td>
<td>&lt; (reduction with relative target, unaffected with absolute target)</td>
<td>&lt; (reduction with relative target, unaffected with absolute target)</td>
<td>&lt; (reduction with relative target, unaffected with absolute target)</td>
</tr>
<tr>
<td>Immature technologies excluded (ref: all)</td>
<td>= (unchanged in both)</td>
<td>= (reduction in both)</td>
<td>= (reduction in both)</td>
<td>&gt; (lower reduction with exclusion of immature)</td>
<td>&gt; (lower reduction with exclusion of immature)</td>
<td>&gt; (lower reduction with exclusion of immature)</td>
<td>&gt; (lower reduction with exclusion of immature)</td>
<td></td>
</tr>
</tbody>
</table>

45 This is a similar result to the technologies excluded case.
46 In contrast, when existing plants are not eligible, only new capacity can comply with the target. Of course, part of this new capacity would also be affected by the EE measures reducing De, but only a small share (the highest cost), not all.
To sum up, the impact of EE measures on RES-E deployment is greater when a TGC scheme (with a relative quota) has previously been implemented. In the case of FITs, the impact is negligible if a tariff option is adopted and greater with a premium due to the effect of EE support on Pw (i.e., not on the premium itself). However, this later effect is both difficult to predict and hard to correct. The negative impact on EE can be mitigated with ex-post adjustments in the premium, or with a floor price. In the case of TGCs, the adaptation could involve changes in the target to take into account the possible influence of EE measures or minimum TGC prices.

The interaction of a EE support added to a TGC scheme is particularly problematic for the most expensive renewables, reducing the incentives to their deployment. In contrast, these negative dynamic efficiency effects are less likely under a FIT because only part of the support would be affected (Pw, and not the premium). EE and RES-E promotion measures to an ETS does not lead to additional CO2 emissions reductions. Therefore, the resulting instruments could be deemed redundant and their combination is more costly with respect to CO2 emissions reductions.

### 6. Conclusions

Traditionally, policy analysis of climate policy instruments has been based on an individual approach, i.e., separated from other measures with which they are likely to interact. However, the functioning of these instruments depends on these interactions and, in particular, on the type of instrument and its design elements. The results of this paper show that:

1. The interactions between RES-E support and EE measures are generally modest because these two instruments have different scopes, with no point of direct interaction. Their mutual impacts are mediated through electricity markets, with one instrument acting on the supply side and the other on the demand side.
2. The most relevant interactions between these two instruments occur when EE support is added to RES-E promotion, especially when TGCs with a relative quota have been implemented. EE measures would put a downward pressure on electricity demand reducing the absolute requirement for RES-E. The highest cost renewable energy technologies which were previously needed to set the quota would no longer be needed.
3. In order for an instrument to be part of an optimal set of policy measures, it should complement already existing measures, not overlap or lead to conflicts. In principle, adding EE and RES-E promotion measures to an ETS does not lead to additional CO2 emissions reductions. Therefore, those instruments could be deemed redundant and their combination is more costly with respect to CO2 emissions reductions.

<table>
<thead>
<tr>
<th>technologies included)</th>
<th>cases)</th>
<th>cases)</th>
<th>cases)</th>
<th>cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate penalty (ref.: low penalty)</td>
<td>(unchanged in both cases)</td>
<td>(reduction in both cases)</td>
<td>(increase in both cases)</td>
<td>(greater reduction with low penalty)</td>
</tr>
<tr>
<td>Minimum prices. (ref.: no minimum prices.)</td>
<td>(unchanged in both cases)</td>
<td>(reduction in both cases)</td>
<td>(increase in both cases)</td>
<td>(greater reduction with low penalty)</td>
</tr>
<tr>
<td>Existing plants non-eligible. Ref.: eligible.</td>
<td>(unchanged in both cases)</td>
<td>(reduction in both cases)</td>
<td>(increase in both cases)</td>
<td>(greater reduction with low penalty)</td>
</tr>
<tr>
<td>Technology-specific quota (ref.: non-specific quota).</td>
<td>(unchanged in both cases)</td>
<td>(reduction in both cases)</td>
<td>(increase in both cases)</td>
<td>(greater reduction with low penalty)</td>
</tr>
<tr>
<td>Banking and borrowing (ref.: no banking and borrowing).</td>
<td>(unchanged in both cases)</td>
<td>(reduction in both cases)</td>
<td>(increase in both cases)</td>
<td>(greater reduction with low penalty)</td>
</tr>
</tbody>
</table>

Source: Own elaboration. See text for further details.
4. Different instruments for RES-E and EE support may affect the results of the interactions differently. Particularly, the case of RES-E support schemes (FITs and TGCs) has been discussed. It has been shown that such interaction is likely to be more conflictive when a TGC scheme is adopted (rather than a FIT). In the case of FITs, there is no impact of EE on RES-E investment when a fixed tariff is adopted and a lower impact than with TGCs when a fixed premium is implemented.

5. Some conflictive aspects of the interactions between EE support and RES-E generation can be mitigated through either a change of instrument or a change in design elements. For example, the aforementioned problem of the relative quota could be circumvented with a FIT scheme. Two design alternatives of TGCs can mitigate the problem: either transforming the absolute target into a relative one or setting a minimum TGC price.

6. If possible, the regulator should seek some coherence, coordination and consistency between the respective targets taking into account the interactions between the three instruments. The problem is when the three instruments belong to different territorial/administrative levels. But at the national level, the interaction between RES-E and EE support instruments should be considered when setting targets in the RES-E and EE realms.

Acknowledgements
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References


