From energy efficiency obligation to carbon savings certificate to achieve carbon neutrality: does it fit the path?

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Abstract
One way to contribute to carbon neutrality in 2050 is to reduce energy consumption but this will not be enough. To this end, many energy policy instruments (regulations, taxes, incentives, etc.) have been used for many years and well before the goal of carbon neutrality and need to be reassessed to be in line with decarbonisation especially in the context of the EED review.

In many European countries, energy efficiency obligation schemes (EEOs) are used in line with EED Article 7. These schemes are usually expressed in terms of primary energy savings as in Italy or final energy savings as in France and to our knowledge only one which has been expressed in terms of carbon as in the UK. Initially the UK EEO was expressed in energy and moved from energy to carbon. However, this movement has not been followed in Europe, even though European policy is increasingly focused on reducing carbon emissions.

There are several ways of integrating carbon into an EEO scheme: from the simplest by considering the carbon content of energy when sharing the level of obligation among obligated parties to the most complex by valuing the certificates directly in carbon units.

By considering both energy and carbon in the same EEO scheme, a double reward is possible to reduce consumption and promote low carbon energy. In this way, new energy savings and carbon reduction potentials could be incentivised, especially in industry and transport in case of fuel switching.

Including carbon in the scheme also means putting a price on carbon in the market, beyond a shadow value for sectors not covered by the historical EU-ETS I without the need to extend the EU-ETS to the building and transport sectors (EU-ETS II).

This paper aims to challenge this situation and to propose a shift from energy to carbon in an EEO scheme. To do so, we propose to take the case of the French EEO as an example and to assess how this existing scheme can evolve to better integrate the carbon dimension and contribute effectively to the national carbon mitigation strategy.

Introduction
The European Union (EU) has a long-term strategy to be carbon neutral by 2050 (European Commission 2022a) In addition, there are other shorter-term objectives by 2030: 32.5 % of final energy savings[1] and 32 % of the energy should come from renewables (European Commission 2022b). Historically the EU relies on several directives and regulation to carry out its energy policy:

- Energy Efficiency (EED 2012/27/EU) (Ciucci 2021a),
- Energy Performance of Buildings (EPBD 2010/31/EU) (Tenhunen 2021),
- Renewable Energy (RED 2009/28/EC) (Ciucci 2021b),

1. 36 % for final energy, 39 % for primary energy and 40% of renewable energy in the « fit for 55 » proposal.

- Ecodesign (2009/125/EC) (European Commission 2022d).

The "Fit for 55" is a package proposed to revise and update the EU policy to reach at least -55 % Green House Gas (GHG) emissions[2] by 2030 (European Council 2022). To apply this EU strategy, the EPBD currently in revision, introduces the objective of decarbonisation of the total stock of buildings in 2050 and zero-emission from 2030 in new buildings. Likewise, the proposed target for the EU-ETS is -61 % of GHG emissions[3] by 2030. Moreover, the targets for sectors not covered by the EU-ETS in the proposal are -40 % GHG[3].

Some carbon emissions are regulated by the EU-ETS, which focuses on the industrial and energy sectors[4], but the building and road transport sector are not directly concerned[5]. The creation of a separate EU-ETS II dedicated to direct emissions in the buildings and road transportation sectors was proposed by the Commission that will put a price on GHG emissions from these sectors (European Commission, 2021). It is believed by some (Maćkowiak-Pandera 2021, Graf & Buck 2021) that without pricing CO_2 emissions from buildings and transport, Europe will miss its emissions target, but there are political risks (Kurmayer 2021). Thus, the proposed scheme appears to be in jeopardy in the short term as some countries are reluctant (Taylor 2021). In addition to emission quotas like in EU-ETS, there are carbon taxes in the framework of energy taxation (e.g. in Sweden[6], in France[7] (Hansen et al. 2019)) and plans for a carbon tax at EU borders (carbon border adjustment mechanism) (European Council 2022).

As far as Energy Efficiency Obligation (EEO) schemes are concerned, they are currently implemented in the framework of the EED under Article 7. Article 7 of the directive stipulates that 0.8 % of energy savings per year must be achieved either by an EEO scheme or by alternative measures (tax, regulation, voluntary agreement...). EEOs remain a key policy tool because it is supposed to represent 34 % of the energy savings of Article 7, much more than the other schemes (Fawcett et al. 2019).

However, a certain number of current EEO schemes put in place in European countries date from before the implementation of the directive (e.g. Italy, France). Today, in Europe, some fifteen EEO schemes are in place (Fawcett et al. 2019).

Both the EED directive and the EEO schemes, although they have evolved over time, date from before the GHG reduction targets and usually take account of the carbon emissions indirectly through energy savings as part of a portfolio of energy policy tools. So, these EEO schemes are therefore usually expressed in terms of primary energy savings as in Italy or final energy savings as in France and to our knowledge only one has been expressed in terms of carbon as in the UK. Initially the UK's EEO was expressed in energy and moved from energy to carbon[8]. However, this movement has not been followed in Europe, even though European policy is increasingly focused on reducing carbon emissions. But energy (final or primary) is not a sufficient indicator to drive the reduction of GHG emissions: it must combine both the reduction of energy consumption and the use of low carbon energy. This seems understandable given that most of the EEOs in Europe came into effect after the EED Art 7 energy savings obligation (expressed in final energy) came into being. However, art. 7 has evolved to include more GHG considerations into the proposed EED recast (e.g. inegibility of technologies that directly combust fossil fuels).

The question arises as to the most effective way of achieving the GHG long-term objective with the current tools developed within the framework of directives that are regularly revised but whose general framework remains long-standing. To support our argument, we will use the French system as a case study, but we will try to remain general in order to broaden the reflection to the whole range of European EEO schemes.

The first section of this paper presents an overview of EEOs at the European level, the second section describes the principle of an EEO scheme followed by the description of the French EEO scheme. The fourth section addresses the question of carbon in the EEO with possible ways of evolution and finally the last section discusses the policy implications.

The European EEOs overview: where is the carbon?

Basically, from an energy user's perspective, an EEO scheme acts both as an energy efficiency subsidy and as a tax on the price of energy (Giraudet et al. 2020). An EEO scheme is generally defined by primary principles (Bertoldi & Rezessy 2008, Bertoldi et al. 2010):

- Global obligation level to define the amount of energy savings to be achieved during a defined period.
- Obligated parties (generally utilities – DSO or retailers) which share the target to be achieved.
- Portfolio of eligible actions to be implemented.
- Control process to deliver certificate as a means of accounting for savings.
- Penalty in case of non-compliance.
- Cost recovery mechanism to finance the EEO scheme.

The first 3 points are likely to include both consideration of carbon and energy savings and will be described in more detaile in the following sections. We must notice that the possibility of interaction between tradable EEOs and EU-ETS was discussed since 2008 (Bertoldi & Rezessy 2008, Sorrel et al. 2009).

Historically the European EEO schemes started to focus on electricity consumption (UK, Denmark[9]) to expand to other energies (e.g. in the danish EEO gas in 2000, oil and district heating in 2006 (Fawcett et al. 2019)). Furthermore, the French EEO scheme[10] started mainly with the building and industry sectors in 2006 and was enlarged in 2011 to the transport sector (DGEC 2021b).

2. Compared to 1990.

3. Compared to 2005.

4. Including electricity production and large district heating installations.

5. 45 % of GHG emissions in France are subject to the EU-ETS (Hanssen et al. 2019).

6. €114/tCO_2.

7. €44,6/tCO_2.

8. It is now expressed in terms of lifetime bill savings, given its primary focus on energy poverty alleviation.

9. The Energy Savings Agreement started in the '90s with information and in 2006 introduced energy savings targets (Fawcett et al. 2019). The scheme ends in 2021 (Surmeli-Anac et al. 2018).

10. The Energy Savings Certificate (CEE – French acronym of Certificat d'Economie d'Energie) started in 2006 and the current phase is 2022-2025 (DGEC 2021b).

The EEO schemes in Europe are amended regularly, beyond savings ambition, to adapt to the problems encountered or to the context and technological progress (Rosenow 2012, Rosenow and Bayer 2017, Osso et al. 2020, Malinauskaite et al. 2019). It is interesting to give a brief historical overview of the former UK EEO scheme, which is, to our knowledge, the only system that has, in one way or another, taken direct account of GHGs.

The UK EEO scheme, one of the oldest schemes in Europe, evolved from energy (Energy Efficiency Standards of Performance - EESoP 1994–2002 and Energy Efficiency Commitment - EEC 2002–2008) to carbon emission (Carbon Emissions Reduction Target – CERT 2008–2012). Even when the target was expressed in energy in EEC, they were carbon weighted and discounted (Rosenow 2012). In 2013, The ECO scheme replaced the CERT and Community Energy Saving Programme (CESP) and required domestic energy suppliers over a certain size to achieve carbon and notional bill savings by promoting and installing energy efficiency measures into domestic homes. There have been three stages of ECO with an increasing shift towards social aims (ECO1 2013–2015, ECO2 2015–2018, ECO3 2018-2022 focused entirely on energy poverty). The UK scheme has reduced its energy savings ambition in 2018 only with ECO[11] to support low income, vulnerable and fuel poor households (DBE&IS 2021, DBE&IS 2019, Malinauskaite et al. 2019). The ECO target is based on lifetime bill savings of the implemented measure.

We must notice that in France the possibility of weighting the EEO certificates according to the GHG emissions avoided is feasible since 2019. This possibility was used in industry, the bonus[12] for operations involving equipment subject to the EU-ETS and allowing the substitution of a very carbon-intensive energy by a less carbon-intensive one (ADEME et al. 2021). Concerning the housing sector, some bonuses were applied to EEO certificates (like heat pump or biomass boiler in replacement of a fossil boiler) but without explicit mention of the GHG emissions reduction.

DEFINING THE UNIT OF EEO OBLIGATION

In this paragraph we will only detail the choice of the unit[13] of the certificates, the question of the level of the obligation having been addressed elsewhere (osso et al. 2021). We must note that other consideration concerning evaluation of energy savings like ex-ante vs. ex-post, free-rider, rebound effect, lifetime (Rosenow and Bayer 2017) across the different schemes are also not discussed here. Different units and timeframe are possible to define the ambition of an EEO scheme:

- Primary energy expresses in tonne of oil equivalent (toe) like in Italy[14] (Di Santo & De Chicchis 2019) or Poland (Rosenow et al. 2020).
- Final energy in PJ like in Denmark (Surmeli-Anac et al. 2018) or expresses in kWh like France (DGEC 2021b).
- Carbon dioxide like in CERT in UK (DBE&IS 2019).
- Bill savings like in ECO in UK (DBE&IS 2021).

In some EEO scheme like in France, there is no difference in certificates between energies, at the opposite in the Italian scheme there are 4 different types of certification depending on the energy used mainly due to tariff component (Di Santo et al. 2011).

On another note, the temporal dimension of savings is also different depending on the schemes, which calculate energy savings either for the year of implementation alone (e.g. Denmark) or over the lifetime of the action (e.g. France) or between the two (e.g. Italy (Stede J. 2017)).

The choice between primary or final energy and first-year or lifetime savings appears to be of importance to guide the implemented actions inside the scheme. A debate between these approaches is noted in the Danish scheme which concluded that the differences in lifetime (gas vs. electricity action) were balanced out by the differences in impact on primary energy consumption of these energies (ENSPOL 2015).

Even if the last 2 points above are not directly related to GHG, they have an impact on energy savings (hence indirectly on GHG).

SHARING THE ENERGY SAVINGS OBLIGATION

As we have just seen, the EEO obligation is not generally expressed in carbon terms, but it is possible to introduce the issue of GHGs when allocating it to the obligated parties. The question of the impact of an obligation directly expressed in GHG on the distribution between obligated parties is also a point to be investigated in addition to this previous one.

Once the level of obligation at national level is defined timeframe, it is necessary to distribute this obligation among the obligated parties according to a certain rule. Usually the individual obligations are based on sales percentage or an absolute value (Bertoldi & Rezessy 2008).

In the UK each obligated supplier has an overall target based on its share of the domestic energy market in hte UK (OFGEM 2022). In Italy, the electricity and gas distributors (DSO) are obliged on the basis of market share of distributed gas and electricity (Bertoldi & Rezessy 2008). In Poland, the obligation to submit EEO is based on the amount of revenue from the sale of energy but a buy-out price exists (Rosenow et al., 2020).

In France, the energy savings obligation was initially shared based on physical quantity (25 %) and value (75 %) of the market share of obligated energy suppliers. For the 2022–2025 period, the target is then only based on quantity of energy sales by retailers (DGEC 2021b). This change of rule leads to the relative increase of obligation for fossil fuels.

We must notice that in some EEO schemes there is some flexibility as non-obligated parties could issue tradable EEO certificates (e.g. France, Italy).

LIST OF ELIGIBLE ACTIONS

As presented above, an EEO scheme relies usually on a portfolio of eligible actions. The choice of these actions is a possible way to steer the retrofit market towards the more efficient and

11. ECO4 will run from April 2022 to 2026 and will also focus entirely on energy poverty.

12. Bonuses were already considered at the beginning of EEOs to encourage specific actions (Bertoldi & Rezessy 2008).

13. We can note that the unit of a certificate is not necessarily linked to the way energy savings are calculated (e.g. savings calculated in primary energy but valued in final energy in some case in the French EEO scheme).

14. Energy efficiency certificate (TEE, Italian acronym of Titoli di Efficienza Energetica) started in 2005 (Di Santo et al. 2011).

less GHG emissions. However, in some cases no strong choice is made to avoid a lock-in effect[15] (Risholt & Berker 2013). To avoid this, the EED is being recast to prohibit the eligibility of even the most efficient fossil fuel technologies. This deviation from the usual technology neutrality of the EED energy savings obligation should helps to align it with the goals of the Fit for 55 package, without the need to shift away from the final energy consumption basis.

A portfolio of 215 eligible actions in 5 different sectors[16] is featured in the French EEO scheme. However, the carbon content of the energy of these actions is not explicitly considered. In insulation actions in France no difference is made between fossil fuel and electric space heating although the energy and carbon savings are different due to the different energy efficiency of these equipments or the characteristics of dwellings. Furthermore, between fossil fuels (gas vs. domestic oil) no difference is made even though the carbon content of these energy sources is different (Table 1). Today it is still possible to claim savings from an incentive for a domestic oil boiler in the French scheme[17].

There is one exception to energy accounting in the French scheme concerning the purchase of a new efficient vehicle where the amount of EEO certificate is directly proportional to the vehicle's emissions[18].

The French case study: an EEO scheme in its teens

The French EEO scheme will be shortly described here as it was presented in various paper ((Bertoldi et al. 2010, ENSPOL 2015, Rosenow & Bayer 2017) some of which are recent (Osso et al. 2020, Osso et al. 2021). The French EEO scheme has grown to becoming the most stringent in the world according to IEA (Giraudet et al. 2020). The French EEO scheme is a key tool to drive politics of the renovation sector.

The obligated parties in the French scheme are the energy retailers/suppliers (electricity, gas, LPG, heat and cooling, fuel oil and motor fuels). Other entities (delegate, eligible) can generate EEOs without carrying an obligation creating the basis for an exchange of EEOs in a market or over-the-counter.

The scheme is mainly based on standardised measures based on fact sheet providing deemed savings calculation. Most of the actions implemented concern the housing sector (69 %) followed by industry (17 %). Technically, they mainly concern insulation of buildings, heat recovery equipment, efficient electrical motor, efficient boiler and air source heat pump.

These energy savings are expressed in kWh of final energy savings cumulated over lifetime and discounted (at 4 % per year) (i.e. kWhc). The energy savings are deemed savings calculated in relation to a market reference[19] (net savings) or in relation to the existing situation (gross savings) depending on the implemented measure. The savings valued in this EEO scheme therefore do not reflect the totality of the real savings but additional (marginal) savings (Osso et al. 2015). Additional energy savings bonuses are also possible in certain cases (fuel poverty, overseas territories, energy performance contract…).

An important point is that although the French EEO is expressed in final energy as specifically stated in the Article 7 of the EED, when a fuel switching occurs during the implementation of the eligible actions, the savings are, valued on the basis of the gains in primary energy despite the lack of regulations in this case but as a principle requested by the French energy agency. Because it prohibits some energy efficient and decarbonized technologies, this last point will be crucial in the evaluation of the GHG mitigation generated by the EEO scheme.

In the following sections, we will use the French EEO scheme as an application case to provide quantified insights.

The carbon, the energy and the EEO

EEO schemes are not optimised to reduce GHG emissions as much as possible but are designed to promote energy savings and GHG mitigation appears to be a co-benefit. Not differentiating between the carbon content of implemented actions may seem a sub-optimal allocation of resources in the short term even if in the long term all efficient actions must be implemented. As GHG emissions in the atmosphere are a long-term cumulative phenomenon[20] the most important emissions should be addressed first through explicit criterions.

Of course if the EU-ETS is enlarge to builing ands transport (EU-ETS II), the rationale for EEOs may then be discussed. This issue is addressed in the discussion section.

STATEMENT AND OBJECTIVES

In order to assess the carbon impact of EEO operations, the carbon content of energy clearly shows the difference between the final energy saved, as it ranges in the French context[21] from less than 60 gCO_2/kWh to more than 300 gCO_2/kWh depending on the energy carrier (Table 1). Furthermore, the carbon content of electricity beyond an average value is variable depending on the end uses and the sectors involved (Table 2).

As there is not direct proportionality between EEO (kWhc) and GHG (in gCO_2) the sole energy or its value is not fully operational to maximise GHG reductions in the framework of an EEO scheme.

The GHG savings potential linked to an EEO action could be estimated simply on the basis of a single Emission Factor (*EF*) of the energy saved[22] ($\Delta C_{initial}^{final}$) but in the absence of fuel switching only:

$$GHG_{savings} = C_{initial} * EF_{initial} - C_{final} * EF_{final} = \Delta C_{initial}^{final} * EF_{initial,final}$$

with:

$GHG_{savings}$: Green House Gas savings (in gCO_2).

15. Renovation choice not questioned before the end of the implemented action's lifetime.

16. Agriculture, residential, tertiary, industry and network (DGEC 2021b).

17. Energy saving Certificate, BAR-TH-106 - high energy efficiency individual boiler (DGEC), at least until July 2022 when new equipment installed for space heating or domestic hot water may not exceed a GHG emission ceiling of 300 gCO_2e/kWh lcv (.decree n° 2022-8 - 5 January 2022).

18. Replacement of vehicles with new efficient vehicles in a professional fleet (EEO fact sheet TRA-EQ-114) with CO_2 emission below 116 gCO_2/km (DGEC).

19. Implemented measures under the framework of Ecodesign are valued as marginal savings.

20. Approximate residence time in the atmosphere: 100 years for the disposal of a large half of the CO_2 emission surplus (Jancovici 2007).

21. Only the carbon content of electricity is country dependant.

22. This paper will not discuss the issue of net to gross energy savings (see Osso et al. 2015).

Table 1. Energy sales, carbon content and price of energy (DGEC 2021, DGEC 2020, MTE 2020).

Energy	Sales projections 2020-2025 (TWh lower calorific value/yr)	Carbon content ($kgCO_2e$/kWh lower calorific value)	Price (€/kWh lower calorific value)
Domestic fuel oil	55.5	0.324	0.091
Motor fuel	445.7	0.320	0.158
LPG	5.2	0.272	0.116
District Heating & Cooling	36.8	0.116	0.078
Electricity	298.0	0.0571	0.186
Gas	195.1	0.227	0.093

Table 2. Carbon content of electricity by end-uses in 2020 (Mainland France, monthly average by end-use method) (ADEME 2020).

Sector & end-use	$kgCO_2e$/kWh
Air conditioning	0.0410
Industry – base & cooling process (excluding air conditioning)	0.0583
Sanitary Hot Water	0.0585
Residential – cooking & other (construction and civil engineering, research, army…)	0.0587
Transportation	0.0601
Public lighting	0.0615
Residential - lighting	0.0625
Space Heating	0.0693

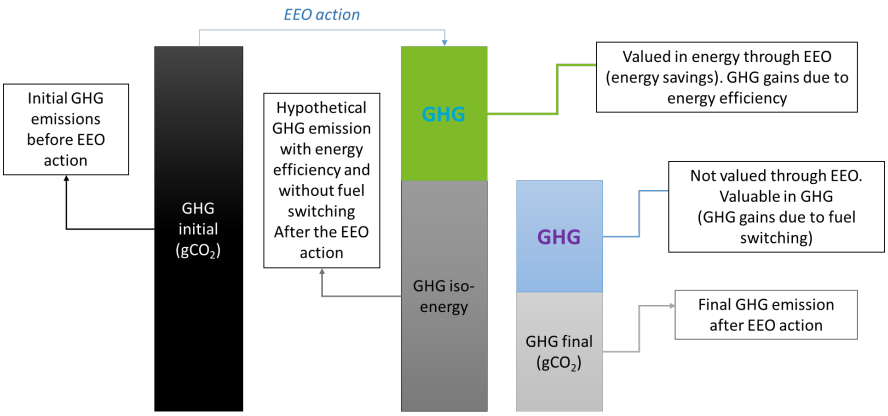

Figure 2. Schematic representation of the valuation of GHG gains with fuel switching in the context of an EEO scheme.

EF: Emission Factor of energy before ($EF_{initial}$) or after (EF_{final}) (in gCO_2/kWh).

C: energy consumption before ($C_{initial}$) or after (C_{final}) EE action (in kWh).

But this increases complexity in the EEO fact sheet to move to final energy to GHG mitigation if the energy carrier used before and after the implementation of the energy efficient action changes. Indeed, part of the GHG gain is not valued according to Equation 1 leading to a failure to direct stakeholders towards the most effective actions in terms of reducing emissions. GHG savings that would be higher emissions than those made possible by the reduction in consumption are not valued (Figure 2).

A systematic carbon valuation in an EEO scheme can be envisaged with the following objectives as far as possible:

- To value the GHG gains based on the savings valued in EEO (energy unit).
- Subsidise low carbon energies that are compatible with the 2050 carbon neutrality trajectory and avoid the subsidizing of fossil fuel equipment.

In the following sections we present 2 ways to better integrate GHG emissions into an existing EEO scheme to reinforce the energy savings as well as GHG emission mitigation. We must notice that a recent study (ADEME et al. 2021) encompasses 6 different ways of integrating carbon consideration into an EEO ranging from the integration of carbon in the allocation of the obligation to the introduction of a carbon certificate and a corresponding obligation.

THE PATH OF LEAST RESISTANCE: SHARING THE OBLIGATION ACCORDING TO CARBON EMISSIONS

A first and simple way to better integrate carbon into an EEO scheme is to allocate the EEO obligation based on carbon emissions rather than the quantities consumed or the value of sales (Equation 2). This approach, which does not radically change the existing EEO scheme, puts pressure on the most carbon-intensive energies by putting more pressure on retailers and and increasing their price (cost recovery).

$$\%\, obligation = \frac{criteria^{i}}{\sum_{i}^{energy} criteria^{i}}$$

with criteria: quantity (kWh), Value (price (€/kWh)*quantity (kWh)), GHG (quantity (kWh)*carbon content ($kgCO_2$/kWh)).

The choice of the obligation distribution key is far from neutral in the French case because there is no convergence between the three variables of volumes consumed, amounts spent and GHG emissions (Table 3). The differences in the obligation distribution according to energy and criteria vary from 50 % to over 300 %. Thus, for the most carbon intensive energy (i.e. domestic fuel oil) the obligation varies by more than double (between 3 % in value criteria and 8 % in carbon criteria). Similarly, the low-carbon nature of electricity in France and its higher price lead to significant differences (7 % in carbon criteria vs. 36 % in value criteria).

This possibility of sharing the EEO obligation on the basis of GHG emissions was considered by the public bodies for the period 2022–2025, but was abandoned due to the complexity of its implementation (e.g. energy suppliers selling energy with different carbon contents) (ADEME et al. 2021). According to the Ministry of Ecological Transition, a marginal adaptation of the French EEO scheme seems possible to increase GHG gains, whereas an in-depth transformation would risk greatly disrupting its operation by increasing the complexity of its implementation (MTE 2022).

THE NARROW PATH OF COHERENCE: CARBON EMISSION CERTIFICATE

The rational approach to maximising GHG emission reductions is to have a fully carbon compatible EEO scheme. Energy savings come as a co-benefit in the opposite way to what is achieved today. In the French case, this safeguard is applied in the context of renovation to avoid an increase in GHG emissions following an energy carrier change.

So, EEO eligible actions could be valued in terms of GHG savings in case of energy switch and based on final energy savings as following by replacing. C_{final} by $C_{initial} - \Delta C_{initial}^{final}$ in the eq. 1, the current EEO valuation (energy savings), leads to:

$$GHG_{savings} = \Delta C_{initial}^{final} * EF_{final} + C_{initial} * (\Delta EF_{initial}^{final})$$

The Equation 3 is similar to Equation 1 but has the advantage of separating energy savings from additional carbon gains due to fuel switching.

This approach allows a double benefit: an orientation toward the most efficient actions in terms of GHG emission reduction by taking into account the whole GHG emission reduction (Figure 1) and also the valorisation of new actions within the scheme which are very efficient in terms of GHG emissions and less in energy.

NEW EXPLOITABLE CERTIFICATE POTENTIALS

Some GHG emission reduction actions, especially in industry and transport, with energy carrier switch are not covered by the French EEO scheme because of an unfavourable primary energy calculation (i.e. low or negative primary energy savings). The methods, based on an energy gain calculated in primary energy and then a valuation in final energy, lead to the following actions not being valuable in Transport (PHEV, Trolleybus) and Industry (all technologies of electrical furnaces – resistance, arc, induction, conduction, electrical boiler, replacement of steam turbines by electric motors). In all other cases (EV, Mechanical Vapour Compression), the energy gain remains low compared to a final energy savings calculation (-60 % to -70 %) whereas all these actions allow CO_2 gains of a factor of 6 to 16.

More specifically in the industry and transport, there are many opportunities for GHG emission savings, with these available technologies, through process electrification, that could be exploited corresponding to EEO certificates of:

- 82 TWhc of electric furnaces: energy savings[23] between 20 % and 50 % (gains of 85 to 90 % in CO_2 emissions).
- 76 TWhc of heat pumps: energy savings of 75 % (gains of 96 % in CO_2 emissions).
- 49 TWhc of Mechanical Vapour Compression: energy savings of 78 % (gains of 97 % in CO_2 emissions).
- These 207 TWhc represents just under 10 % of the 2500 TWhc of EEOs to deliver between 2022–2025.
- Concerning the transportation sector, new GHG savings that could be exploited are:
- Ship to shore connection,
- Start and stop locomotive and dual mode locomotive,
- Efficient vehicle.

In addition, EEO fact sheets with energy-switching (e.g. heat pump) in the building sector already exist but could be better valorised through GHG gains.

With these new GHG saving potentials presented above, the French EEO contribution to the CO_2 trajectory of the national low carbon strategy (SNBC[24]) up to 40 % of the -122 $MtCO_2$/year by 2030 compared to year 2020 (i.e. around 50 $MtCO_2$/yr of GHG savings). This assessment could be compared with the evaluation from (ADEME et al. 2021) giving GHG savings of 32 $MtCO_2$/yr due to the EEO scheme in its current configuration (2022-2025) (i.e. 30 % of the SNBC). The difference can be explained in part by the carbon accounting of EEOs in our estimate but also in some part by different assumptions.

By way of comparison the French Ministry (MTE 2022) indicate that from 2015 to 2018, the EEO scheme would have contributed to 40 % of the observed GHG savings and 20 % of the targets set by the SNBC.

23. final energy gains compared to fossil fuel processes.

24. In french Stratégie National Bas Carbone.

Table 3. Breakdown of the EEO obligation according to the criteria used in Equation 2 in the French case (see Table 1 for initial figures).

	Criteria: Quantity	Criteria: Value	Criteria: GHG
Domestic fuel oil	5%	3%	8%
Motor fuel	43%	46%	63%
LPG	1%	0.4%	1%
District Heating & Cooling	4%	2%	2%
Electricity	29%	36%	7%
Gas	19%	12%	19%

Table 4. EEO cost of avoided CO_2 emission (w/o bonus) and GHG savings potential assessed in the French EEO (authors calculation) and market share of EEO by sector (source: DGEC).

sector	€/tCO_2 cumulated	% EE in 2018-2021	2022-2025 GHG savings potential MtCO_2/yr (cumulated)
AGRI	26	1,8%	na
IND	26	16,9%	10
BAR	59	69,5%	47
BAT	51	7,2%	3
TRA	9	3,4%	5.9
	Weighted average: 51	100%	Total: 66

THE ESTIMATED COST OF CARBON IN THE FRENCH EEO

For the period 2022-2025, with a volume of 625 TWhc/yr to be produced and a certificate price[25] of €7.74/MWhc, the financial amount involved in the French EEO scheme is of the order of more than €4 billion /year. An assessment of carbon savings cost based on the EEO price and the GHG savings (Equation 2) was conducted for 5 sectors based on the main energy efficiency actions implemented (Table 4). The weighted average cost of carbon savings is about €50/tCO_2 (cumulated). According to the (ADEME et al. 2021) study the carbon price should be about €30/tCO_2 (cumulated) in case of carbon accounting in the EEO.

It should be noted that this carbon price only concerns the value of the EEO (the amount of the financial incentive and cost of the scheme as a first approximation) and not the totality of the up-front cost, so it cannot be compared with a value external to this study (like in Glachant et al. 2020) in order to estimate the interest of the actions implemented under the scheme.

Conclusion and policy implications

This paper deals with the alignment of energy and climate policies and discuss of a possible future of the European EEOs in the context of more stringent GHG mitigation ambition. The first step should be to focus on the highest GHG emitting energy carriers and end-uses. As the introduction of an ETS scheme dedicated to transport and buildings does not seem to be supported by all Member States, it may be interesting to rely on and to evolve the existing schemes. It can be noted that electricity is already subject to 2 different schemes: EU-ETS for its production and EEO for energy savings, the potential roll-out of the EU-ETS II is not incompatible with an EEO expressed in carbon.

However, the issue of accounting only for emission reductions from non-ETS fuels could be discussed, especially in the case of pure carbon accounting. The role of the EEO should then be discussed: ensuring only societal cost effectiveness and fair distributional outcomes or working together as a carrot (EEO) and stick (EU-ETS II).

This question should be raised as to whether the carbon dimension should be better integrated into energy efficiency EEO schemes, following the example of other energy policy schemes such as the Energy Performance Certificate (EPC) or the environmental regulation for new buildings in France (RE2020). An EEO scheme that does not properly account for GHG emissions leads to lose opportunities to maximise GHG mitigation and to create lock-in effect.

Thus, the 2021 revision of the French EPC integrates a double scale (primary energy and GHG) in its label estimation, keeping as final value the worst of the two. Likewise, the new French thermal regulation (RE2020) considers both maximum threshold of primary energy consumption (total and non-renewable primary energy) and of GHG emissions.

The objective of carbon neutrality requires both a sharp reduction in energy consumption and a response to the remaining consumption with low carbon energy. It is interesting to note that this alignment has already been implemented on certain transport EEO fact sheets in the French scheme. The amount of EEO issued for the purchase of a new efficient vehicle is thus directly proportional to the vehicle's emissions of this vehicle. This practice is not implemented for EEO issued in the

25. EEO weighted average price in 2021 (source: EMMY).

building sector, where the amount of EEO issued does not consider the initial thermal energy. If it is considered that the heating replaced is provided by the same energy carrier, this logic is appropriate. However, it is not suitable if we consider that there is a substitution between energy carriers, particularly in the context of a change of equipment in favour of a low-carbon energy source (UFE 2019).

Therefore, the "energy efficiency first principle" and the Article 7 of the EED requirements for energy efficiency require the maintenance of the EEO schemes in their current configuration (based on final energy). However, this is not incompatible with a EEO expressed in GHG as a double accounting scheme is possible but burdensome. Furthermore the optimized sequence between reducing energy consumption and the use of low-carbon energy is today debatable (technological rationality vs. climate emergency).

According to (ADEME et al. 2021) the obligated retailers of fossil fuel are the most resistant to setting an carbon target for the French EEO scheme as the scheme would encourage the reduction consumption of the most carbon-intensive energies and the electrification of end-uses. Electricity that will be increasingly produced with a low carbon content in Europe in the future is an opportunity to be seized. However, many of the stakeholders are in favour of gradual changes in the EEO scheme from energy to carbon-saving, without reducing the level of support provided to other actions. The proposal of the Commission in the recast of the EED to render ineligible fossil fuel Combustion technologies could be a first change in the EEO scheme. The modification of the energy savings calculation without using primary energy in case of fuel switching a second one.

The position of some stakeholders putting forward the principle of "one target, one scheme" could be difficult to understand in view of the number of EU targets (primary and final energy, renewable energy, GHG) and of all the energy and environmental policy tools that contribute more or less to all these targets and whose synergy should be better exploited. Moreover, the carbon neutrality can only be achieved by drastically reducing energy consumption and replacing fossil fuels with low-carbon energy. To complete the EEO incentive and to consider additional GHG savings not valued by the EEO, a voluntary offset scheme is practicable (INFCC 2022) but the risk of double counting should be avoided.

The results of this study are preliminary to open the debate and further studies (such as ADEME et al. 2021) are welcome to provide additional insights. But this debate cannot be limited to France alone.

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