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Mitigation of CO_2 emissions in 2020: impacts of the "20/20/20" European policy

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Abstract

Purpose - The study aims to quantify the interactions between the three European objectives in the horizon of 2020: (i) the reduction of 20% of greenhouse gas emissions (GHG) (2) the saving of 20% of the energy consumption and (3) the share of 20% of renewables energies in the overall energy consumption. Particular focus is, however, placed on the influence of the environmental policies on the CO_2 emission reduction and the carbon price in 2020.

Design/methodology/approach - The national objectives for the energy savings and renewables energies in our study are realized with the quota systems in every country: white and green certificate systems, while the CO_2 emission reduction is carried out at the European level within the ETS in the context of international carbon market. In order to exploit the interactions among the different environmental policies, a number of scenarios are tested within a combination of two powerful modeling tools: POLES world energy model and ASPEN, dedicated for the analysis of quota systems.

Findings - The paper shows, in particular, that the order of environmental policies does not affect significantly the reduction of emissions and the carbon price. On the other hand, the presence of these policies diminishes highly the marginal European reduction cost and, consequently, the compliance costs for ETS participants.

Keywords - CO_2 emissions, carbon price, white certificate price, green certificate price, European objectives in 2020

Paper type - Research paper

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Introduction

European Council decided to achieve three ambitious obligations in the horizon of 2020: (1) the reduction of 20% of greenhouse gas emissions (GHG) (or even 30% if an international agreement justifies it) (2) the saving of 20% of the energy consumption and (3) the share of 20% of renewables energies in the overall energy consumption. The key element of these ambitions, in relation to the fight against the climate change, is the reduction of GHG emissions (Criqui, 2007). The European emissions trading scheme (EU ETS, thereafter referred to as ETS), which includes large European industries, electricity production and at least 45-50% of CO_2 emissions in Europe, will remain, according to the European institutions, the key instrument in reaching Kyoto and post-Kyoto targets. The council does not indicate the burden share per country, nor specifies the particular instrument for increasing the share of renewable energies to 20% in the energy consumption. The feed-in tariffs proved to be effective in increasing the utilisation of renewable energies, often though, by favoring certain types of technologies like wind in Germany and Spain for example. Quota systems coupled with the exchange of green certificates (GC), proving the origin of the production, are likewise gaining the interest in the Member countries. Market instruments are equally high on agenda for stimulating energy efficiency and savings. An instrument, frequently quoted by economists, concerns the energy saving obligations coupled with the exchange of certificates representing the savings achieved and often named as white certificates (WC).

The accentuated benefits of the energy efficiency represent the consecutives energy savings, which, in return might diminish GHG emissions due to avoided production[1]. The increased utilisation of renewable energies could likewise replace the polluting activities even if the primary objectives would be other than the reduction of emissions, that is security of supply, employment or regional or local benefits. The interactions exist, therefore, in terms of emission reductions, but also in terms of costs of the programmes chosen to reach their respective objectives. Several studies have analysed the possible interactions on theoretical grounds (NERA, 2005, Bertoldi and Rezessy, 2006, Doucet and Percebois, 2007). Additionally, the authors analyze the integration possibilities of different quota systems in Europe: ETS, GC and WC. For the short term, they conclude in favor of separate quota systems in consequence of double counting possibilities for one action undertaken as well as of the related complexities of integration, which, eventually, might dampen its benefits.

Our study does not analyze the integration of the three quota systems, neither their specific design, but evaluates and quantifies the influence of the council's objectives in the field of renewable energies and energy savings on the CO_2 emissions reduction and the price of carbon in 2020[2]. The respective national objectives for the energy savings and renewables energies in our study are realized with the

[1] It should be noted that energy efficiency does not always produce energy savings for possible "rebound effects" (Herring, 2006). Energy savings might likewise result from the behavioral changes leading to conservation of energy. In our study, we keep in line with Bertoldi and Rezessy who consider that only "additional energy savings justify a policy intervention: policy may support measures that involve either investments or achieved savings (or both) provided that they are measured against the same system conditions" (Bertoldi and Rezessy, 2006).

[2] "Carbon" and "CO_2" are utilized interchangeably throughout the article.

quota systems in every country: WC and GC systems, while the CO_2 emission reduction is carried out at the European level within the ETS.

In reality, the three policies for: energy saving, renewable energies and CO_2 emissions, interact simultaneously. For an analysis *ex-ante* represented by our study, different scenarios should be tested in order to exploit the interactions among the different policies in the horizon of 2020. Given that the primary objective of the study is to examine the impacts of different environmental policies on the CO_2 emissions, we chose a number of scenarios representing the priorities of different policies, but starting usually with the WC systems since the reduction of energy consumption is often considered as the low-cost reduction option (Bertoldi et al., 2005). The scenarios are tested with a combination of two powerful modeling tools: POLES world energy model and ASPEN, which is dedicated for the analysis of quota systems[3].

The paper develops along the following: in section 1, we introduce the principal policies for reducing GHG emissions as well as increasing energy savings and renewable energies in EU; in section 2 we reveal the theoretical interactions among ETS, GC and WC systems; then in section 3 we display the methodology for quantifying these interactions; section 4 later delivers and analyses the main results of this study; lastly, we present our main conclusions in section 5. The paper shows, in particular, that the order of environmental policies does not affect significantly the reduction of emissions and the carbon price. On the other hand, the presence of these policies diminishes highly the marginal reduction costs and, consequently, the compliance costs for ETS participants.

1 CONTEXT OF ENVIRONMENTAL POLICIES IN EUROPE: CLIMATE POLICIES, ENERGY SAVINGS AND RENEWABLE ENERGIES

EU is generally acknowledged for having played a strategic role in the field of climate negotiations. The types of policies and measures adopted at the European level are important not only for the emission reductions in the Member countries, but also for the international climate regime evolution. The lessons learned in formulating the common and coordinated climate change strategy at the European level, in particular the failure of the introduction of the carbon tax, have lead to a reflection over the alternative policies, efficient and perhaps more appropriate in market conditions. In establishing the ETS directive and in proposing the quantitative objectives in the field of energy savings and renewable energies in 2020, EU shows it's preference towards "cap & trade" and "baseline & credit" systems, where the quantitative objectives are known, but not the marginal costs of the actions to be undertaken, whereas with the taxes, the accepted cost level is known initially (at least the marginal cost), but not the quantities to be eventually achieved (Weitzman, 1974). In theory, the market instruments minimize the cost for the society when reaching a certain objective (static

[3] Refer to Annex 1 for a short description of POLES world energy model.

efficiency) and create the incentives for innovation and improvement of the performance (dynamic efficiency).

1.1 European emission trading system (ETS)

ETS is founded on the idea that the most efficient way is offered to the Member countries to assure their Kyoto obligations and to progress towards a low carbon economy in the future. The system relies on the creation of a price for carbon emissions by establishing the market for emission allowances or quotas. From the economic point of view, the market solution for the quotas allows minimizing the total costs of a particular programme since the exchange of the quotas equalizes the marginal costs of emission reductions among the participants and mobilizes only the least-cost options (Criqui, 2002). The system results from an initial allocation of quotas to the participants, then from the choice that is given to them to sell or to buy these quotas.

ETS should allow the EU to achieve its Kyoto target at a cost of between € 2.9 and € 3.7 billion annually. This is less than 0.1% of the EU's GDP. Without the scheme, compliance costs could reach up to € 6.8 billion a year (European Commission, 2004). The system is founded on the six main principles: (1) it is a "cap & trade" system, (2) its initial focus is on CO_2 emissions from big industrial emitters, (3) implementation takes place in two phases (2005-07 and 2008-12) with periodic reviews and opportunities for expansion to other gases and sectors, (4) the allocation plans (NAPs) are decided periodically by the Member countries in line with the Kyoto objectives, (5) it includes a strong compliance framework (the penalty for exceeding the quotas is fixed for the two phases € 40 and € 100 respectively per ton of CO_2), (6) ETS taps emission reduction opportunities in the rest of the world through the use of Clean Development Mechanism (CDM) and Joint Implementation (JI) projects, and provides for links with compatible schemes in other Annex B countries (refer to Directive 2004/101/CE).

In operation, the ETS has shown itself so far to be an administrative success, with the overwhelming majority of installations reporting their independently verified CO_2 emissions and surrendering the appropriate number of allowances to cover them to the required deadlines. However, the emission reductions might turn out to be less impressive. The verified emissions in 2005 showed that the CO_2 market was long of allowances and not short like it was anticipated in the beginning of the programme. The surplus of allowances was probably due to a combination of two factors: (1) generous allocation and (2) internal reduction. The market analysts consider that the first factor was by far the most important (Point Carbon, 2007). The scientists estimate that both factors have occurred, the second one even greater than the first one (Ellerman and Buchner, 2006). In either case, the European authorities have retained the lessons from verified emissions; the process for the second NAPs turns out to be more vigorous involving the reductions of national quotas for almost every Member country. The success of ETS, in the short term, will be principally judged on the two factors: the emission reductions and the appearance of the stable and efficient carbon price. It remains to see this success in the second phase of ETS.

1.2 The European policies for energy savings

The directive on energy end-use efficiency and energy services, which is in effect from April 2006, aims at fostering cost effective improvement of energy end use efficiency and at transforming and promoting the market for energy services (2006/32/EC). The directive establishes an indicative energy savings target of an additional 1% annually in the nine years following the adoption of the directive. The base year for the energy savings is calculated using the average energy consumption during the last five years before the entry into force of the directive. It applies to all the sectors of final energy consumption except aviation and industries under ETS. To achieve this objective, Member States must prepare three national energy efficiency action plans and ensure that the public sector fulfils an exemplary role regarding investments, maintenance and other expenditure on energy-using equipment as well as energy services.

Additionally, according to the *Green Paper*, EU could save 20% of its energy consumption in 2020 (European Commission, 2005, 2006). Experience shows that the diffused potentials for energy savings in the residential, service or transport sectors are not sufficiently exploited through the classical instruments used in numerous European countries – informing of consumers, regulation, fiscal subsidies and incitations – because the feasible energy savings are not sufficiently valued by the concerned decision-makers (Moisan, 2004). Furthermore, with the gradual opening of electricity and gas markets to the competition, the instruments for promoting efficient use of energy should be compatible with the market conditions. Market instruments are relevant for completing the cost-effective exploitation of energy savings potential and are compatible with the new market conditions.

The combination of an energy saving obligation for some category of operators (distributors, suppliers, consumers, etc.) coupled with a trading of certificates (WC) representening the energy saved has already attracted the attention of some European countries. This type or similar systems exist in Italy, France, United Kingdom and Flanders, Belgium. The discussions are in process for the establishment of such a system in Netherlands[4]. However, in their analysis Bertoldi and Rezessy show that the existant systems are very different one from another with respect to the actors involved under regulation, eligibles measures and sectors as well as their comparative experiences. Therefore, even if the economic reasoning in terms of cost-efficiency supports such a system at the European level, it is too early and difficult to visualize it at the moment.

1.3 The European policies for renewable energies

Increasing share of renewable energy sources in the final energy consumption and, in particular, in the electricity generation is the Community's target for 2010 declared in the Directive of electricity production from renewable energy sources 2001/77/CE. The principal support schemes comprise

[4] Refer to Bertoldi and Rezessy, 2006 and NERA, 2005 for a detailed description of these systems.

price-based feed-in tariffs and quantity-based quota systems and to a lesser extent the calls for tenders and financial incentives.

The feed-in tariffs allow the producers to sell the green electricity at a fixed price per kilowatt hour (kWh). This price or tariff is usually above the market price and is guaranteed for a number of years. The quota system or the GC system consist of (i) the establishment of quotas for the production of green electricity imposed on the operators intervening on the electricity market; distributors, retailers or producers-importers, and (ii) the flexibility associated with the trading of certificates among the operators under the regulation to achieve their objectives. They have the possibility to produce themselves the desired quantity of green electricity, to negotiate the long term contracts with the specialized producers or to purchase the certificates corresponding to a certain quantity of green electricity. (Menanteau et al., 2002). In general, the GC systems are favoured by the Commission because they satisfy better the cost-efficiency rationale as well as unique electricity market conditions comparing to feed-in tariffs (Lauber, 2002). However, advantages and disadvantages existe for both instruments (refer for example to Menanteau et al., 2003, Ragwitz et al., 2007).

Nevertheless, only five European countries exercise GC systems: Belgium, Italy, Poland, Sweden and United Kingdom. Even if these systems present the theoretic advantages, they remain complex to implement and operate well only if the market infrasttracture necessary for the functioning of GC systems is constructed correctly. Several authors also indicate that GC systems introduced at the European level would probably be more efficient than those introduced at the national levels since bigger market would produce more stable GC price and diminish the problems related to the fixing of adequate quotas (del Rio, 2005).

On the other hand, the feed-in tariffs have proven their efficiency by enabling the marked growth of the installed production capacities (Commission, 2005). The important increases in the green electricity production have occurred in Germany and Spain, the countries with the feed-in tariffs policy. However, these increases are usually presented as inefficient in terms of allocative resource efficiency and offering little incentives towards the reduction of the production costs despite of their undeniable efficiency to stimulate the green electricity production (Menanteau et al., 2002).

The theoretic interactions among the three instruments: ETS, WC and GC are highlighted in the next section.

2 INTERACTIONS IN THEORY

Theoretical interactions have been analysed in NERA (2005). Here we recapture the aspects relevant to our empirical analysis.

We identify several forms of interaction.

- The impacts of WC and GC systems on the overall CO_2 emissions and on the emissions in the ETS.

The WC system alone could diminish the CO_2 emissions only if the installations are not included in the ETS. The reduction of direct consumption of fuels in households fits well to the reduction of CO_2 emissions driven by WC system. However, the reduction of network electricity consumption in households does not generate additional reductions because they are already included in the cap of ETS. In theory, the WC system does not influence the reduction of emissions originating from ETS because the quota in ETS is defined *ex-ante*. However, the ETS cap migh be weakened if two systems are to be integrated. This could be explained by the risk of double counting, in particular, with respect to the savings in electricity production. The conversion of avoided electricity to the avoided emissions and it's import to ETS would result in double counting of the same CO_2 quantity since electricity saved also diminishes the emissions in the electricity sector under ETS. The displaced fossil fuel generation would free up ETS allowances that would be used to cover emissions elsewhere.

As to GC system, it would reduce CO_2 emissions only if the green electricity replaces polluting, that is fossil fuel generation of electricity. Indeed, ETS already encourages indirectly low-carbon investment and punishes emitting technologies. However, ETS would spur the investments in renewable energy technologies only after all the low cost options are exhausted on the market. Furthermore, the double counting problems would again appear if the emission reduction benefits were counted by the GC system (Sorell, 2003).

- The impacts of WC and GC systems on the costs of the overall and ETS CO_2 emissions reduction.

The introduction of the WC and GC systems might lead to the reduction of the demand for allowances in ETS and, consequently, of CO_2 price on the market. The preceding takes place when the WC and GC systems "pay" for certain emission reductions *via* the decrease in polluting production. Consequently, the compliance costs for the participants in ETS are reduced. However, the global cost of compliance under ETS might rise if the high-cost emission reduction options under WC and GC systems replaced lower-cost reduction options under ETS. This situation is, however, less likely to occur for WC system since the majority of the reduction options are considered to be low-cost (Commission Européenne, 2005).

- The impacts of WC and GC systems on the electricity market in the ETS

The WC and GC systems could decrease the price of electricity if the energy savings achieved or the renewable technologies replaced fossil fuel-based electricity generation. The reduced demand for electricity might then lead to a marginal production at a lower cost (or to a decrease in polluting production, which usually fixes the market price) and therefore to a lower level of electricity price[5]. This decrease could be, however, compensated by the pass through of costs related to energy-saving or renewable technologies. Typically, the increase in electricity price should be more important within the three systems: WC, GC and ETS rather than within one. For example, "the rebound effect" could prevent the decrease in polluting electricity production and consequently, the price of electricity. In the

[5] It depends on the merit order in the electricity production of every country.

long term, the impacts on the electricity producing mix and its price are less clear since they depend from the investments in new generation capacities, which in return, depend partially from the expected costs related to environmental regulations.

The following section introduces the methodology for quantifying different interactions among the three systems in Europe.

3 METHODOLOGY

Firstly, we explain our approach for defining and deriving national and European objectives in the field of energy savings, renewable energies and ETS and the respective national and European prices to attain these objectives. Secondly, we define the scenarios relevant for the interaction analysis among the three policies.

National objectives for energy savings are defined with respect to the European objective announced by the Council: saving of 20% of the EU's energy consumption compared to projections for 2020 (Council of EU, 2007). However, the share of the efforts needed by each Member country to achieve the European objective was not preciced by the Council. In our study, we employ the Reference scenario of POLES model for the projections of primary energy consumption, which, without any environmental policies, corresponds to 1995 Mtoe in EU25 in 2020. In order to comply with the Council's objectives, primary energy consumption in the European community should be around 1596 Mtoe in 2020, which represents a cumulative reduction of consumption of 9.8% from the base year 2005 or an average annual reduction of 0.65% from 2005. Marginal primary energy consumption curves are then produced for every country using successive simulations of POLES model with progressively increasing energy consumption taxes. Furthermore, the curves are analysed in ASPEN module, which allows deriving the implicit national WC prices in function of national objectives.

National objectives for renewable energies are defined with respect to European objective of 20% share of renewable energies in the overall energy consumption in Europe in 2020 (Concil of EU, 2007). Contrary to the objective of energy savings, the council indicates that national objectives for renewable energies should be defined in function of potentials and efforts already put in place:

> "differentiated national overall targets … with due regard to a fair and adequate allocation taking account of different national starting points and potentials, including the existing level of renewable energies and energy mix"
>
> and "leaving it to Member States to decide on national targets for each specific sector of renewable energies (electricity, heating and cooling, biofuels)"

Taking these remarks into account, in our study we employ the indicative national targets for 2010 under the Directive of electricity production from renewable energy sources, which are compatible with the objective of 12 % share of renewable energies in the final energy consumption and, in particular, with 21% share in the electricity consumption. As for 2020, we adjust the indicative targets so that they reach the share of one third in the electricity consumption as it was indicated by International Energy

Agency (IEA, 2007). We will see later, in section 4 of the study, that this renewable share of electricity production is quite compatible with the global European objective of 20% of renewable energies in the final energy consumption. Once the national objectives are defined, the marginal renewable electricity production curves are produced by a number of sensitivity analyses with increasing feed-in tariffs in POLES model, which allows later to obtain the implicit national GC prices from ASPEN module.

National objectives for CO_2 emission reductions are defined with respect to European objective of 20% GHG emission reductions in EU25 comparing to 1990 (Council of EU, 2007). In our study, however, we cover only CO_2 emissions. The burden-sharing scheme used is based on the study performed by the German Institute for Economic Research (2007), presented in Annex 2. The sectoral distribution of the 2020 emissions quota comprises the information from the second NAPs under ETS for the ETS sectors and the latest GHG emissions inventories for the non ETS sectors. The sectoral proportions found are then inserted in the 2020 national emissions quotas. Using the POLES model, we then produce a number of sensitivity analyses with an increasing carbon value in order to derive the sectoral marginal abatement cost curves (MACC) in every country or region. In their turn, the MACCs are inserted to ASPEN module for the analysis of the international emissions trading system. In function of the national and sectoral emissions quotas and their participation in the carbon market, ASPEN calculates the equilibrium carbon price, project-based credit flows, reduction costs and equilibrium burden sharing among the countries[6].

The carbon market in 2020, besides the EU25, is supposed to include (i) the participation of the rest of annex B countries that ratified Kyoto protocol with constraints to reduce their CO_2 emissions by 10% comparing to 2010 level, (ii) the participation of USA and Australia with constraints to stabilize their CO_2 emissions in 2020 to 1990 level as it was proposed by the American senators McCain and Lieberman[7] (Pizer, et al., 2003) and (iii) the participation of non Annex B countries with the emissions trajectory following the developments from the POLES reference scenario, which imposes no carbon constraints. As for CDM projects, a large part of their theoretical potentials is, however, excluded from the market due to high transaction costs explained by the lack of information or skilled personnel, political or economical obstacles, trade barriers or general politics of the developing country.

In order to quantify the possible interactions among the environmental policies: WC, GC and ETS, we have created a number of scenarios representing different merit orders for the introduction of environmental policies (Table 1). We remark, from the Table 1, that the last four scenarios place the priority for the energy savings, that is firstly we find the implicit national WC prices, secondly, in the case of last scenario for example, we insert the WC prices and run the sensitivity simulations to find the CO_2 price and thirdly, having the WC and CO_2 prices, we produce another set of sensitivity simulations to obtain the GC prices. The three set of prices are then combined to produce a final simulation of the scenario **WC+CO2 ETS+GC**.

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[6] For a more detailed methodology on MACCs and ASPEN module refer to Stankeviciute et al, 2007.

[7] According to the proposal of McCain-Lieberman, during the first six years of the program (2010-2016), annual GHG emissions would be limited to the amount released in 2000 and in subsequent years, the limit would be reduced to the 1990 emissions levels.

Table 1: Scenarios

Scenarios	Description
Reference	No environmental policies
CO2 total	Sensitivities of carbon value to all sectors of energy system → CO2 price
CO2 ETS	Sensitivities of carbon value to ETS sectors → CO2 price
GC	Sensitivities of feed-in tariff to the renewable electricity generation → national GC price
WC	Sensitivities of energy consumption tax → national WC price
WC+GC	National WC price + (Sensitivities → national GC price)
WC+GC+CO2 ETS	National WC price + (Sensitivities → national GC price) + (Sensitivities → CO2 price)
WC+CO2 ETS	National WC price + (Sensitivities → CO2 price)
WC+CO2 ETS+GC	National WC price + (Sensitivities → CO2 price) + (Sensitivities → national GC price)

The distinction should be made between the scenarios **CO2 total** and **CO2 ETS**; in the scenario **CO2 total** we apply the objective of 20% reduction of CO_2 emissions in all the sectors of the energy system (ETS and non ETS) in 2020 comparing to 1990 emission level, while in the scenario **CO2 ETS** we calculate the reduction of emissions in ETS sectors in line with 20% objective and apply it only to ETS sectors: large European industries and power sector. Therefore, CO_2 emissions in non ETS sectors in the latter case, are reduced by the energy saving and renewable energy policies depending on the scenarios that follow.

The list of scenarios open up a diversity of interesting results exposed in the next section of the study.

4 RESULTS

To begin the analysis of the numerous results we refer to the implicit national WC and GC prices as well as to the European or international CO_2 prices. Afterwards, we look more closely at the effects of different scenarios on the CO_2 market, renewable energies and energy savings as well as on the changes in the European electricity production mix.

Energy savings by 20% comparing to the reference projections in 2020 result in relatively high national implicit WC prices shown in Table 2[8]. We notice that the WC prices are heterogeneous among the countries, the prerequisite condition for the establishment of the WC system at the European level. The introduction of WC trading among the countries would equalize the marginal costs of energy consumption reduction and would result in the European WC price of 883 €/toe in 2020. However, we remind that only national WC prices are taken into account in our study.

[8] The early results from the Italian WC system lasting from 2005 to 2009 indicate the WC price of around 100€/toe (Bertoldi et al, 2006).

Table 2: National WC prices

EU25 countries	Cons. 2005, Mtoe	Objective 2020, Mtoe	WC price 2020, €/toe	Burden sharing comparing to 2005
UK	237	213	832	-10.7%
France	275	248	906	-9.5%
Italy	179	162	822	-10.8%
Germany	343	309	894	-9.6%
Spain	151	136	1198	-5.2%
Greece	32	29	1691	3.7%
Portugal	25	22	1205	-3.5%
Austria	35	31	727	-12.8%
Belgium, Lux	64	58	540	-15.7%
Denmark	22	20	1692	-1.4%
Finland	36	33	799	-11.2%
Ireland	16	14	1766	4.9%
Netherlands	85	76	987	-8.3%
Sweden	51	46	171	-25.0%
Hungary	26	23	870	-10.1%
Poland	98	88	1028	-7.1%
Czech Rep.	43	39	782	-11.9%
Slovakia	16	15	733	-13.9%
Baltic countries	21	19	347	-22.2%
Sloven.-Malta-Cyprus	14	12	329	-18.9%
EU25	**1769**	**1596**	**EU25 WC price = 883 €/toe**	

One third of electricity produced from renewable energy sources in 2020 implies the implicit national GC prices shown in Table 3. We notice, from Table 1, that there are three sets of GC prices corresponding to different scenarios or the order of the introduction of renewable policy: (1) **GC**, (2) **WC+GC**, (3) **WC+CO2 ETS+GC**. The prices remain very important exceeding largely 2 €/kWh in the first two scenarios for the majority of European countries. Even if we allow the exchange of GC among the European countries, the European GC price in the scenario **GC** would still remain very high at 82 €/kWh, which implys that the objectives are challenging needing the support of other environmental policies. In the second scenario **WC+GC**, the introduction of WC prices stimulates the reduction of demand along with the need for electricity production, but not sufficiently as the European GC price remains highly elevated at 18 €/kWh. Only in the third scenario **WC+CO2 ETS+GC** where, besides the reduced energy consumption driven by the WC prices, CO_2 price signal induces the increase in the renewable energies utilisation and reduces European GC price to 0.44 €/kWh.

Table 3: National GC prices

Scenarios	GC		WC+GC		WC+CO2 ETS+GC	
EU25 countries	Green electricity in 2020, %	Corresponding GC price, €/kWh	Green electricity in 2020, %	Corresponding GC price, €/kWh	Green electricity in 2020, %	Corresponding GC price, €/kWh
UK	20%	> 2	21%	> 2	21%	0
France	31%	> 2	30%	> 2	29%	> 2
Italy	37%	> 2	35%	> 2	34%	> 2
Germany	20%	> 2	19%	> 2	18%	0,1044
Spain	44%	> 2	42%	> 2	40%	0,3394
Greece	36%	0	46%	0	50%	0
Portugal	69%	0	76%	0	78%	0
Austria	80%	> 2	80%	0,0357	80%	0
Belgium, Lux	24%	0	26%	0	27%	0
Denmark	43%	> 2	41%	> 2	40%	> 2
Finland	62%	0	73%	0	74%	0
Ireland	60%	0	64%	0	67%	0
Netherlands	21%	> 2	18%	> 2	18%	2
Sweden	80%	0,0488	80%	0,0434	80%	0,0371
Hungary	30%	> 2	31%	> 2	34%	> 2
Poland	21%	0	24%	0	25%	0
Czech Rep.	21%	> 2	22%	> 2	24%	> 2
Slovakia	46%	> 2	44%	> 2	43%	> 2
Baltic countries	30%	> 2	29%	> 2	28%	> 2
Sloven.-Malta-Cyprus	50%	> 2	47%	> 2	46%	> 2
EU25, % and €/kWh	33%	82	33%	17,736	33%	0,4352

We turn to the analysis of CO_2 market: price, emissions, project-based credits as well as the reduction costs (Table 4). Looking at the Table 1, we notice that we should have four sets of CO_2 prices corresponding to scenarios: (1) **CO2 total**, (2) **CO2 ETS**, (3) **WC+GC+CO2 ETS** and (4) **WC+CO2 ETS**. A distinction should be made between the first scenario **CO2 total**, where CO_2 market is confined to Europe that is all the reductions or purchases of allowances are effectuated within EU25 and between the rests of scenarios, for which, the international carbon market is assumed as it is described in section 3. Therefore, we observe in the Table 4, that the reduction objective is highest in the scenario **CO2 total** due to the fact that all sectors are subject to 20% reduction of CO_2 emissions and with the absence of project-based credits on the carbon market, the realization of European objective becomes very costly in terms of reduction costs and CO_2 price, which reaches 87 €/tCO_2. The reduction objective as well as European marginal reduction cost remain relatively high under the **CO2 ETS** scenario since only carbon price signal induces the diminution of emissions in ETS sectors. The import of project-based credits is, therefore, needed to alleviate the efforts of European industries. We notice, however, that the domestic European reduction exceeds highly the need for purchases of project-based credits (487 against 238 MtCO_2). This could be explained by the new flexibility margins provided by a longer time-period (2020) for the adjustment of investments, which compensates for the increasing pressure towards stronger emission reductions. The needed reductions in CO_2 emissions as well as the marginal reduction costs decrease significantly in the last two scenarios due to the introduction of environmental policies in the field of energy savings and renewable energies. The decrease is also important in the compliance costs for ETS participants in the last two scenarios with respect to the first two scenarios. The decreased comsumption of energy and the increase in renewable energies utilisation allow EU25 to sell the overreduced allowances on the international carbon market under the scenario **WC+GC+CO2 ETS**. We remind, however, that in order for the resulting CO_2 market to be valid under this scenario, we have to go through the national GC prices, which are very significant and even on the European level reach 18 €/kWh (see Table 3). Indeed, the last scenario **WC+CO2 ETS** shows that at least for the reduction of emissions, the significant GC prices are not worth of undergoing since only with energy savings policies introduced by the national WC prices we manage to obtain comparable results in the carbon market under both scenarios. The CO_2 prices are likewise alike under the last two scenarios, which again does not justify scenario **WC+GC+CO2 ETS**, merely the reduction costs differ by almost a factor of 2.

Table 4: CO_2 market in 2020: prices, reduction costs, sales / purchases of credits (negative value: sales)

EU25	Reduction objective, MtCO2	European reduction, MtCO2	European Marginal Reduction cost, €/tCO2	Sales / Purchases of credits, MtCO2	Reduction costs without trading, M€	Reduction costs with trading, M€	European CO2 price, €/tCO2	International CO2 price, €/tCO2
CO2 total	1224	1224	87.2	0	67695	40089	87.2	-
CO2 ETS	725	487	56.7	238	26447	16289	-	34.5
WC+GC+CO2 ETS	216	259	25.6	-43	5899	2658	-	30.5
WC+CO2 ETS	289	305	29.2	-16	8691	4231	-	30.9

The following analysis focuses on the global CO2 emissions, renewable energies utilisation and energy savings achieved under all scenarios listed in Table 1 (Table 5). From the environmental point of view, the reference scenario would be a disaster in all the three fields targeted by the Commission. Scenario **CO2 total** improves the situation in terms of emission reduction and increases the energy savings as well as the share of renewable energies, but the price to pay is, nevertheless, high: 87€/tCO_2. Scenario **CO2 ETS,** represented only by the actual ETS, does little for the global CO_2 emission reductions and even less for stimulating the reduced energy consumption and increased renewable energies utilisation. The focus only on the increase in renewable energy utilisation, represented by the **GC** scenario, is the least worthy according to our analysis since it undergoes very high national GC prices (82€/kWh at the European level) and provides slight merits in the rest of domains. The exploitation of energy savings potential, represented by **WC** scenario, is more advantegous for the CO_2 emission reductions, especially in non ETS sectors: residential, services and transport[9]. However, 8% CO_2 emissions reduction does not confirm the council's expectations. Scenario **WC+GC** is still away from the European objective of CO_2 emission reductions even though it undergoes very high national GC prices (18€/kWh at the European level). The compliance with the three council's objectives is realized in the scenario **WC+GC+CO2 ETS**, but again involving the same high GC prices for reaching renewable energies objectives. The policies merely stimulating energy

[9] We notice, in Table 5 that, due to the dynamics of the model, under the **GC** and **WC** scenarios we come close, but not enought to reach the respective council's objectives: 17% for renewable energies and 15% for energy saivngs. Iteratives games were performed to attain the objectives, but the national GC and WC prices found were extremely high so that the addition of the CO_2 price in the following scenarios would overreach all the council's objectives. Therefore, we prefered to leave the national **WC** and **GC** prices described in Table 2 and Table 3 (which, by the way, in the sensitivity analysis attain the objectives but not in the final simulations), complying, as the results revealed, with the councils objectives in the following scenarios also including CO_2 price.

savings and CO_2 emission reductions, represented by the scenario **WC+CO2 ETS,** remain close to the objectives in the three domains, showing also that the two policies are the driving forces towards reaching the three objectives. The change in the merit order of renewable policy introduction, represented by the last scenario **WC+CO2 ETS+GC**, likewise fullfils the European objectives, but at a more reasonable prices to attain renewable targets (this time European GC price is only 0.44€kWh). This last scenario shows the importance of carbon price signal, which stimulates at the same time the increase in renewable energies utilisation and the decrease in energy consumption. The same could not be affirmed for the GC price signal; it does much less for the reduction of emissions and energy savings.

Table 5: Impacts of the scenarios on CO_2 emissions, renewable energies and energy savings in 2020

Scénarios	**CO2 emissions**			**Renewable energies**		**Energy savings**
	ETS, MtCO2	Non-ETS, MtCO2	Reduction comparing to 1990, %	% in the final consumption	% in the electricity production	% comparing to the Reference (in the primary energy)
Reference	2454	1949	11%	15	21	0
CO2 total	1356	1822	-20%	17	26	12
CO2 ETS	1850	1944	-4%	16	24	5
GC	2325	1949	8%	17	30	1
WC	1949	1681	-8%	17	23	15
WC+GC	1817	1680	-12%	20	30	16
WC+GC+CO2 ETS	1510	1665	-20%	21	31	22
WC+CO2 ETS	1584	1667	-18%	18	26	18
WC+CO2 ETS+GC	1514	1665	-20%	20	30	20

The final analysis concentrates on the changes in the Europpean electricity production mix according to different scenarios (Table 6). Typically, the electricity production is lowest in the last three scenarios, where all or almost all environmental policies are in place. Fossil-fuel based generation is likewise smallest in scenarios **WC+GC+CO2 ETS** and **WC+CO2 ETS+GC**, which include the three systems of policies. Green electricity production is slightly higher in the scenario **WC+GC+CO2 ETS**, but also much more expensive as we have shown earlier. Comparing the scenario **CO2 ETS** with scenarios including all environmental policies (**WC+GC+CO2 ETS** and **WC+CO2 ETS+GC**) we notice that the latter scenarios reduce the fossil-fuel based electricity generation by around 280 TWh in 2020. In concequence, in presence of other environmental policies the CO_2 allowance cap under ETS should be reduced for the electricity sector in order to account for the decrease in polluting production. In terms of polluting production, all scenarios are more performant than the Reference scenario, but at what price? We think that the scenario **WC+CO2 ETS+GC** is the most reasonable in terms of costs involved to achieve the Council's expectations.

Table 6: Impacts of the scenarios on the electricity production in 2020, TWh

	Reference	CO2 total	CO2 ETS	GC	WC	WC+GC	WC+GC+CO2 ETS	WC+CO2 ETS	WC+CO2 ETS+GC
Thermal	2816	2311	2437	2649	2487	2317	2135	2252	2153
of which:									
Coal	1240	578	903	1155	1051	965	749	804	759
Gas	1213	1375	1163	1107	1105	995	1017	1100	1028
Biomass and wastes	242	267	259	283	240	280	285	255	282
Nuclear	868	880	904	827	793	762	802	838	811
Hydro+Geoth	393	407	401	423	391	420	424	397	419
Solar	1	2	2	1	2	2	2	2	2
Wind	280	367	339	456	273	440	456	325	432
Hydrogen	0	1	0	0	0	0	1	1	1
Total	4359	3967	4083	4356	3946	3942	3819	3816	3818

5 CONCLUSION

The methodology employed in the study allows the partial evaluation of the interactions among the dfferent objectives for 2020 announced by the European Council: (i) the reduction of 20% of greenhouse gas emissions (GHG) (2) the saving of 20% of the energy consumption and (3) the share of 20% of renewables energies in the overall energy consumption. In the study, energy saving and renewable energy objectives are feasible with the national quota systems: WC and GC systems, while the CO_2 emission reductions are carried out at the European level within the ETS. We calculate, therefore, the respective national and European prices in function of the scenarios identified. Additionaly, supposing the trading of certificates among the European countries, we expose the European WC and GC prices to attain the respective objectives.

Given that the primary objective of the study is to examine the influence of WC and GC systems on the CO_2 emission reductions, we construct a number of scenarios representing the order of environemental policies, but focusing mainly on the energy consumption reduction as the primary policy to be introduced and the others to follow. The principal difference among these scenarios remains in the level of GC prices to attain the renewable energy objectives: the national WC prices and especially the CO_2 price stimulate the increase in energy savings and in renewable energies utilization and diminish the national as well as European GC price (0.44 €/kWh in EU25) to achieve renewable energy objectives in the scenario **WC+CO2 ETS+GC**, otherwise, in the scenario **WC+GC+CO2 ETS**, where renewable energy policy goes first of carbon price signal, the national as well as European GC prices are rocketing (18€/kWh in EU25). Nevertheless, the national GC prices remain high in all scenarios indicating that the objectives are quite ambitious and merely the introduction of GC system at the European level would facilitate and equalize the efforts.

The study also shows that the merit order of environmental policies, represented by scenarios **WC+GC+CO2** and **WC+CO2 ETS**, remains insignificant towards CO_2 emission reductions and the CO_2 price (30-31 €/tCO_2) even though the first scenario involves high GC prices. On the other hand, the introduction of WC and GC systems decreases highly the European marginal reduction costs and, consequently, the compliance costs for ETS participants. This has also been confirmed by the changes in the electricity production mix, where the presence of all environmental policies reduces significantly the need for fossil-fuel based electricity generation in comparison with the quantity produced in the scenario influenced only by the carbon policy.

The scenario **ETS only**, which is based on the current ETS system and no policies in the areas of energy savings and renewable energies, has shown that merely with the carbon price signal Europe would move away from the council objectives in all three targeted domains and would increase the compliance costs for ETS participants.

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Annex 1: Poles model and reference scenario

POLES is a partial equilibrium world simulation model for the energy sector (Criqui and Kouvaritakis, 2000, Criqui and Viguier, 2000). It works in a year-by-year recursive simulation with endogenous international energy prices and lagged adjustments of supply and demand by world region. The model enables to produce:

- Detailed long term (2100) world energy outlooks with demand, supply and price projections by main region;

- CO_2 emission Marginal Abatement Cost curves by region and/or sector, and emission trading systems analyses, under different market configurations and trading rules;

- Technology improvement scenarios – with exogenous or endogenous technological change – and analyses of the value of technological progress in the context of CO_2 abatement policies (LEPII-EPE, 2005).

The reference scenario used to produce the marginal abatement cost curves describes a world that would develop on the basis of the economic fundamentals and technical constraints. Projecting long-term energy profiles involves a large number of assumptions. World population is expected to increase from 6.5 billions today to 8.9 billions in 2050 with a marked decrease in average growth, which is due to the demographic transition and to stabilize in the second half of the century. The rate of economic growth in industrialized regions converges to under 2%/yr in the very long-run. Growth in Asian emerging economies falls significantly after 2010, while conversely it accelerates in Africa and the Middle East. As a result, global economic growth is expected progressively to slow from 3.5%/yr in the 1990-2010 period to 2.9%/yr between 2010 and 2030 and then 2.2%/yr until 2050. Total world GDP in 2050 is four times the present GDP. The US Geological Survey is the base source of information used for oil and gas Ultimate Recoverable Resources. It provides a set of estimates and attached probabilities that are consistent on a world and region-by-region basis. Technological developments regarding energy technology costs and performances are derived from a dedicated database TECHPOL[10], which allows maximizing the consistency of the exogenous hypotheses for the different time horizons and across the different technologies.

[10] developed in the framework of European projects: FP6 SAPIENTIA and CASCADE-MINTS.

Annex 2: Burden sharing in EU-25 for 20% reduction of GHG emissions in 2020 relative to 1990

Country	Reduction, %
Belgium	-19
Denmark	-26
Germany	-31
Finland	-22
France	-22
Greece	-6
UK	-30
Ireland	-6
Italy	-14
Luxembourg	-14
The Netherlands	-19
Austria	-10
Portugal	3
Sweden	-24
Spain	11
Estonia	-51
Latvia	-56
Lithuania	-57
Malta	5
Poland	-29
Slovakia	-38
Slovenia	-14
Czech Rep.	-36
Hungary	-29
Cyprus	8
EU-25	***-20***

Source: German Institute for Economic Research, 2007