The fundamentals of the future international emissions trading system

Loreta Stankeviciute, Alban Kitous, Patrick Criqui

LABORATOIRE D'ECONOMIE DE LA PRODUCTION
ET DE L'INTEGRATION INTERNATIONALE

UMR 5252 CNRS - UPMF

CAHIER DE RECHERCHE

N° 3/2007

The fundamentals of the future international emissions trading system

Loreta Stankeviciute[1]
Alban Kitous[2]
Patrick Criqui[3]

septembre 2007

[1] Doctorante au LEPII
[2] Enerdata, Gières
[3] Directeur du LEPII

LEPII
BP 47 - 38040 Grenoble CEDEX 9 - France
1221 rue des Résidences - 38400 Saint Martin d'Hères
Tél.: + 33 (0)4 76 82 56 92 - Télécopie : + 33 (0)4 56 52 85 71
lepii@upmf-grenoble.fr - http://www.upmf-grenoble.fr/lepii

The Fundamentals of the Future International Emissions Trading System

Loreta Stankeviciute[a*], Alban Kitous[b], Patrick Criqui[a]

[a]*Laboratoire d'Economie de la Production et de l'Integration Internationale, rue des Résidences, 38040, Saint-Martin d'Hères, France.*

[b]*ENERDATA, 2 Avenue de Vignate, 38610 Gieres, France*.

Abstract

The study aims to examine the efficiency aspects of the international carbon market, with a focus on economic impacts on the European energy system, by analyzing the sectoral Marginal Abatements Cost Curves (MACC) and the trading under different global carbon market configurations in 2010 and in 2020. To produce a consistent and realistic assessment we employ sources such as: second NAPs under ETS, GHG National Inventories, EIA data and POLES world energy model to constitute the sectoral base year and 2010, 2020 emission levels in different countries and regions. We then use the market analysis tool ASPEN, which enables to derive supply and demand from sectoral MACCs produced with POLES model, and to evaluate the economic impacts on the carbon market participants. The paper shows in particular that in compliance with 2020 emission reduction targets, the benefits of an extended carbon market gain importance since more than 50% of the reduction target is achieved by ETS sectors and especially electricity sector. Furthermore, the new flexibility margins provided by a longer time-period for the adjustment of investments in new generation capacities compensates for the increasing pressure towards stronger emission reductions.

Keywords: emission trading; international carbon market; CO_2 price

Introduction

International cooperation through the market-based Kyoto Protocol mechanisms is crucially important for greenhouse gas emissions (GHG) abatement policies if in the future a significant number of countries remain subject to a system of emission quotas, in a "cap and trade" regulation system (Criqui, 2002). The European Union was the first region to set up a broad carbon market: the European Emissions Trading System (EU ETS, thereafter referred to as ETS), which started

[*] Corresponding author: tel.: +33456528587; fax: +334 56528571.

E-mail addresses: loreta.stankeviciute@upmf-grenoble.fr (L. Stankeviciute), alban.kitous@enerdata.fr (A. Kitous), Patrick.Criqui@upmf-grenoble.fr (P. Criqui).

functioning by the first of January 2005[1]. Additionally, the European Parliament adopted the “linking directive”[2] which opens the ETS to other carbon trading systems as well as to Kyoto “project-based” mechanisms, i.e. the Clean Development Mechanism (CDM) and Joint Implementation (JI)[3]. The CDM and JI are considered to be a key option to engage countries outside the EU in the international climate change process and in the emerging international carbon market[4].

Given the size already reached by the ETS, the system could constitute the very heart of the global carbon market for many years and serve as a reference for other markets. Furthermore and in parallel with the ETS policy, the European Commission proposes a quantity objective of 20% reduction of GHG emissions in Europe in 2020 based on the 1990 emission levels, which might be extended to 30% reduction if an international agreement justifies (Council of the EU, 2007). It thus clearly shows its commitment to long term actions aiming at stabilization in GHG concentrations.

Meanwhile, the value of the global emission markets might be as high as € 200 billion by 2010 according to the leading carbon market analyst Point Carbon (2004). Besides the growing popularity of CDM and JI projects, the domestic *cap-and-trade* systems are under discussion or already operate in Norway, Switzerland, Canada, Japan and several states of America (Angers, 2006). In that context, the estimation of CO_2 prices for 2010 and beyond is becoming a key risk-management issue for utility analysts. While a number of modeling teams have tried to project the prices for GHG emissions in 2010 and in 2020, the levels found differ widely, from \$3 to \$74/tCO_2. This is basically because of different business-as-usual emissions projections and of differentiated models’ design features (Springer and Varilkek, 2004, ICF, 2005, Anger, 2006). As an example, Klepper and Peterson (2004) use a computable general equilibrium model of the European Union to quantify the various consequences of a range of likely schemes for the implementation of NAPs (National Allocation Plans under the ETS). The analysis of the simulation results highlights a number of interesting details in terms of aggregate allowance trade-flows between member countries, of allowance prices, so as in terms of the role of the accession countries in the ETS. The efficiency aspects of international carbon market as well as economy-wide competitiveness effects are further on elaborated in Alexeeva-Talebi and Angers (2007).

Our study complements the researches on the efficiency aspects of the carbon market, with a focus on economic impacts on the European energy system, by analyzing the sectoral marginal abatements cost curves and the trading under different global carbon market configurations. A static and competitive equilibrium environment is assumed given a set of worldwide sectoral targets by country in 2010 and 2020. A number of variables have a significant impact on the fundamentals of the demand

---

[1] Directive 2003/87/EC.

[2] Directive 2004/101/EC.

[3] In the analytical results given in this paper, “JI” countries refer to: Russia, Ukraine, Bulgaria, Romania, Albania, Bosnia-Herzegovina, Croatia, Macedonia, Serbia & Montenegro. “CDM” countries refer to all non-Annex B countries of the Kyoto Protocol.

[4] “Carbon” and “CO_2” are utilized interchangeably throughout the article.

and supply of carbon allowances. Thus in this type of exercise, a whole set of reasonable and consistent hypotheses have to be formulated, including:

- the tightness of the sectoral objectives in the ETS system, which to a large extent refers in this exercise to the formal or implicit second NAPs, and to other carbon trading systems;
- the ‘hot air’ influence, which can be defined as emissions credits resulting from above-the-reference emission targets, especially from Russia and Ukraine[5], and the availability of credits from JI projects;
- the availability and costs of credits originating from CDM projects.

To explore the economic impacts of various organizations of global carbon markets and key variables mentioned above, we use the market analysis tool ASPEN, which enables to derive supply and demand from sectoral Marginal Abatement Cost Curves (MACC) produced with the reference scenario of POLES world energy model. ASPEN then computes the market-equilibrium price, the flows of CDM/JI credits, the quantities exchanged and the reduction costs for each country in each sector for different global carbon market configurations.

The paper develops along the following: in section 1, we first describe the approach chosen for sectoral endowments of CO_2 emission allowances for different countries or regions in 2010 and 2020; in section 2, we actually display and discuss the marginal abatement costs curves derived from POLES Reference scenario; then in section 3, we proceed with the ASPEN software and introduce the five scenarios representing consistent configurations of the future carbon market; 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 in compliance with 2020 emission reduction targets, the benefits of an extended carbon market gain importance since more than 50% of the reduction target is achieved by ETS sectors and especially electricity sector. Furthermore, the new flexibility margins provided by a longer time-period for the adjustment of investments in new generation capacities compensates for the increasing pressure towards stronger emission reductions.

1 THE SECTORAL CO_2 ALLOCATIONS FOR 2010 AND 2020

The assumptions that influence the demand and supply of allowances are major elements for the assessment of the carbon price. The countries, regions and sectors of POLES world energy model described in Annex 1, define the participants to the carbon market in our exercise. We take into account 25 European countries, 11 Annex B countries or regions and 16 non-Annex B countries or

[5] Excess permits that have occurred due to economic collapse or declined production for reasons not directly related to intentional efforts to curb emissions.

regions[6]. In this exercise, only the energy-related CO_2 emissions are taken into account and the detail of their sectoral representation is shown in the Table 1.

Table 1 : Sectoral identification of CO_2 emissions

Sectors	Industry				Energy		Transport			Others		
Sub-sectors	Chemistry	Metals	Minerals	Others	Electricity	Other transf.	Road	Aviation	Others	Residential	Services	Others
EU 25	v	v	v	v	v	v	v	v	v	v	v	v
Rest of Annex B	v				v		v			v		
Non-Annex B	v				v		v			v		

National Inventories, which have to be annually submitted by the parties to the United Nations Framework Convention on Climate Change (UNFCCC), provide a detailed sub-sectoral representation of CO_2 emissions in a common format. We used these inventories to establish the base year (usually 1990) sub-sectoral emissions, whenever possible. For the countries or regions that do not produce such inventories, we use statistics from the US Energy Information Administration (EIA).

1.1 CO_2 allowances for EU 25: 2010 and 2020

The fact that European countries – along with the other parties who ratified the Kyoto protocol – do have legal obligations to fulfill their objectives in the period 2008-2012, provides part of the assumptions on the allocations in 2010: these assumptions have to fit with the reduction objectives under the Kyoto protocol. Additionally, the national reduction obligation has to be split domestically between the ETS and non-ETS sectors – like transport, buildings and small industries (see Table 1). The distribution among the sectors appears to be very important since generous endowments in the ETS sectors will imply higher abatement costs for the non-ETS sectors (and vice-versa), as long as the Kyoto objectives are strictly met.

The starting point for the sectoral CO_2 emissions distribution was the establishment of a database of the NAPs for the second phase of the ETS in 2008-2012[7]. As for the non-ETS sectors, the latest national GHG emission inventories were employed to constitute their sub-sectoral shares to be inserted in the CO_2 emission quota for 2010, as allowed by national Kyoto targets.

Concerning the post-Kyoto period, a number of countries have already signaled that their domestic initiatives will have a lifetime well beyond 2012, clearly indicating that carbon emissions will have a cost (and reductions a value) also from 2013 onwards (Point Carbon, 2007). Additionally, the European Commission in its Strategic Energy Review package of 2007 proposed a 20% reduction of the GHG emissions by 2020, for which, according to the Commission, the key economic instrument will remain the ETS. Taking into consideration these propositions we assume a 20% reduction of CO_2 emissions in 2020 relative to 1990 and with sectoral endowment proportions as in 2010. Additionally the burden-sharing scheme we used for the 20% reduction in 2020 in EU-25 is based on the study

[6] Countries defined as in Kyoto protocol.

[7] Database includes 21 approved caps by the EC and 4 proposed caps by the national governments as of June, 2007.

performed by the German Institute for Economic Research (2007), presented in Annex 2. The resulting sub-sectoral CO_2 allowances for EU-25 are summarized in the Table 2.

Table 2: Assumptions on sub-sectoral CO_2 allowances in EU-25 in 2010 and 2020

		Base year	2004	Kyoto	2020	Difference							
						(base year-Kyoto)		(base year-2020)		(2004-Kyoto)		(2004-2020)	
		Mt CO2				*Mt CO2*	*%*	*Mt CO2*	*%*	*Mt CO2*	*%*	*Mt CO2*	*%*
Industry	Chemistry	128	106	86	76	-42	-33	-52	-41	-20	-19%	-30	-28%
	Ferrous metals	222	151	221	196	-1	0	-26	-12	70	46%	45	30%
	Minerals	330	289	281	255	-49	-15	-75	-23	-7	-2%	-34	-12%
	Others	102	103	79	69	-23	-22	-33	-32	-24	-23%	-34	-33%
Total Industry		782	649	668	596	-115	-15	-186	-24	19	3%	-53	-8%
Energy	Electricity	1348	1292	1156	1013	-192	-14	-335	-25	-135	-10%	-279	-22%
	Other transf.	248	217	164	147	-84	-34	-101	-41	-54	-25%	-70	-32%
Total Energy Industries		1595	1509	1320	1160	-276	-17	-435	-27	-189	-13%	-349	-23%
Transport	Road	694	875	832	715	137	20	21	3	-43	-5%	-160	-18%
	Aviation	18	24	19	17	1	8	-1	-5	-4	-18%	-7	-28%
	Others	40	39	40	33	0	0	-7	-17	1	2%	-6	-15%
Total Transport		752	938	891	765	139	18	13	2	-47	-5%	-173	-18%
Others	Residential	527	474	484	418	-42	-8	-109	-21	10	2%	-56	-12%
	Services	200	187	183	158	-17	-9	-42	-21	-4	-2%	-29	-15%
	Others	107	77	87	74	-20	-19	-33	-31	10	13%	-3	-4%
Total Others		834	738	754	650	-79	-10	-184	-22	16	2%	-88	-12%
Total Energy		**3963**	**3833**	**3633**	**3171**	**-331**	**-8**	**-792**	**-20**	**-200**	**-5%**	**-662**	**-17%**

According to Table 2, Kyoto objectives for European countries represent a shortfall of 331 Mt CO_2 and the target assumptions for 2020 correspond to a reduction of 793 Mt CO_2 relative to the base year emission levels. However, if applying the 2004 national GHG emissions inventories, we see the Kyoto shortfall shrinking to 200 MtCO_2 in 2010 and to 662 MtCO_2 in 2020. It's indeed not a secret that the major contribution to the reduction of the shortfall is a consequence of the reunification of East and West Germany and of the consequent phasing out of coal. In parallel, the massive introduction of North Sea gas in UK in the 1990s also played a significant role (Kolstad, 2005). The table above indicates as well that the largest reductions in absolute quantities in 2010 and 2020 should be accomplished in the electricity sector, while the highest emissions increases relative to the base year are in the road transport sector. We notice as well that the European Industry of ferrous metals in principle benefits of a generous allocation in 2010 and 2020 relative to its 2004 CO_2 emissions level.

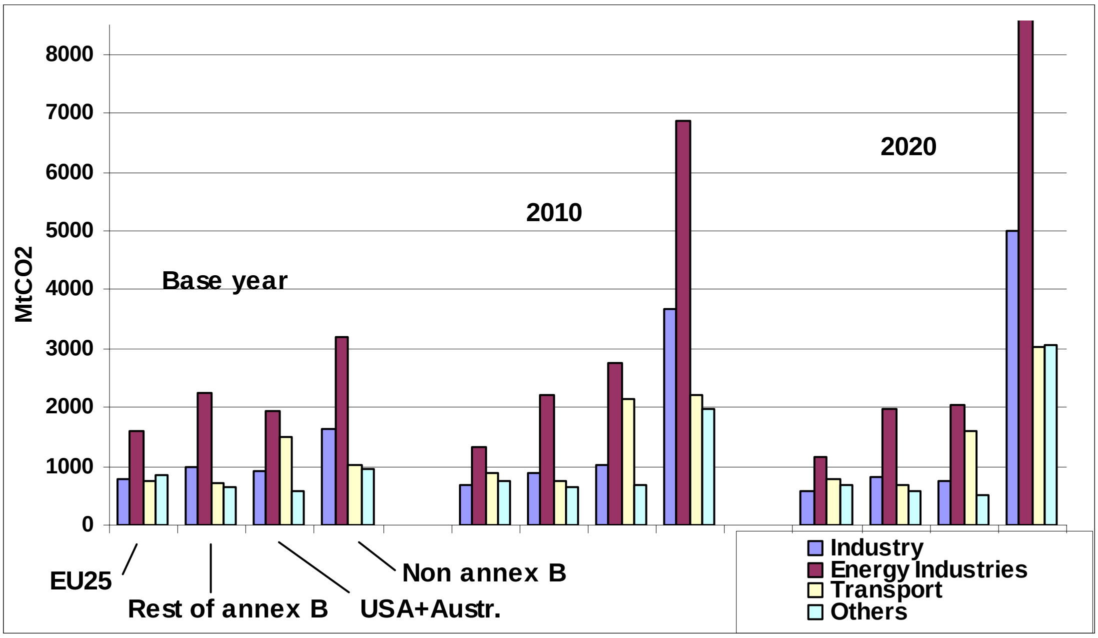
1.2 CO_2 allowances for the rest Annex B and non-Annex B countries: 2010 and 2020

In the same way as for the European countries, the key assumption of binding Kyoto objectives also applies to the rest of Annex B countries that ratified the treaty. Concerning the post-Kyoto period (2020), we assume that their climate change policy will lead to a 10% reduction compared to the 2010 emission level, *i.e.* a 12.2% reduction compared to the base-year level of these countries. To simplify the approach for CO_2 emissions distribution across sectors in 2010 and 2020, we apply the sectoral shares that appear in the latest national GHG emission inventories. This approach might, however, not fully correspond to the allocative efficiency for future reduction options between sectors.

The countries that refused the protocol, notably the USA and Australia, have indeed presented policies to combat climate change, but in the absence of binding quantitative targets, the emission reductions are not known in their cases. However, we consider that the rising interest for the cap and trade systems expressed in several states, combined with the pressure for a federal cap-and-trade system, will result in the USA becoming a full member of the global carbon market in 2020. Thus, for our study we constrain the CO2 emissions in USA and Australia by imposing an extended proposal of senators McCain and Lieberman, *i.e.* stabilizing the CO2 emissions in 2020 relative to 1990 level[8] (Pizer and Kopp, 2003).

Observing the international debates on global climate policy, the development of non-Annex B countries is not expected to be carbon-constrained until 2020, even though certain climate policies and measures are already in place in some of these countries[9]. Our study assumes that the level and sectoral distribution of CO_2 emissions in 2010 and 2020 for non-Annex B countries follows the developments of POLES Reference scenario. The Figure 1 summarizes our set of hypothesis for CO_2 sectoral emission endowments in 2010 and 2020 for the different countries and regions of the world.

Figure 1: Worldwide sectoral CO_2 emission endowments in 2010 and 2020 and, Mt CO_2



Looking at Figure 1 we notice that, in spite of the emission reductions that are imposed in many regions, the global CO2 emissions increase by more than half relative to the base-year level, and by 18% relative to the 2010 level. This considerable growth in CO2 emissions is explained principally by the doubling of emissions levels in non-Annex B countries, as a result of the absence of carbon constraints in these rapidly growing regions.

---

[8] 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.

[9] With the recent passage of China's new Renewable Energy Law, China's government imposed a national renewable energy requirement that is expected to boost the use of renewable energy capacity up to 10% by 2020 (Renewable Energy Access, 2005).

In this section, we defined the sectoral and country or region based CO_2 emissions endowments for 2010 and 2020. Besides the fundamental analysis of the demand and supply in the carbon market, other factors might as well influence the volatility and liquidity of the market in the real world. These include: other GHG emissions besides CO_2, permits allocation methods, weather or wind factors, as well as market structure in each country or market power and strategic behaviors. These issues are not covered in this paper but for strategic behavior for instance, one can refer for instance to Rousse, 2004 and Schwartz, 2005.

2 MARGINAL ABATEMENT COSTS CURVES

This section is dedicated to the analysis of the sectoral marginal abatement cost curves (MACC) derived from POLES model. After a short methodological explanation we describe and comment the anticipated MACCs for key sectors in the energy system and for several European countries as well as for the whole EU-25.

Methodology for MACC

POLES model basically simulates energy and environment policies through the introduction of a shadow tax for the considered emissions. In the case of CO_2 emission reduction policies, the shadow carbon tax is introduced in every module where fossil fuels are burnt, proportionally to their carbon content. This shadow carbon tax can represent either an actual carbon tax, the price of an emission permit or also the dual cost of a technical standard or Policy and Measure. It is thus denominated with a generic term: the Carbon Value (CV), which represents the cost accepted by society for reducing one ton of CO_2 (Criqui and Mima, 2001).

The marginal abatement costs curves are technically obtained by successive simulations of POLES Reference scenario with stepwise increases in CV from 2005 until 2020, illustrating the progressive introduction of climate change policy. These simulations allow building the MACCs for CO_2, which can then be identified either at the sub-sectoral, sectoral, national or regional level. The marginal cost of decreasing emissions varies enormously across sectors, as well as countries as shown in the next sub-section.

Marginal abatement costs curves by several European countries and sectors

The large number of European countries makes it difficult to represent the MACCs for all sectors and countries. Therefore we chose three representative European countries: France, Germany and UK, as well as the total of EU-25 and four sectors in the energy system: *Industry*, *Energy*, *Transport* and *Others* (see Table 1)[10]. The following figures show the value of carbon that allows reaching the

[10] However, throughout the article, we also discuss the results for other European countries

national Kyoto and 2020 objectives as well as the sectoral reductions that will be implied for the MAC equalization. The presentation adopted in Figure 2 and Figure 3 shows emissions reduction levels with an increasing carbon value in 2010 and 2020 relative to the base year emission levels.

The total MAC curve in Figure 2 indicates that reaching Kyoto objectives for the countries considered requires a carbon price well above 42€/tCO_2. However, at the European level, this CO_2 price is sufficient to reach the Kyoto objectives, mainly due to the low or zero cost reductions in new accession countries. The MAC curve for *Industry* stays on the right of the target line for each three European countries as well as for the total of EU-25, signifying that *Industry's* emissions are projected to be low, even in the reference case. This identifies *Industry* as a potential seller on the permit market, especially if the endowments under the ETS are not stringent (see Table 2). We perceive as well that the MAC curve in the *Transport* sector is rocketing in all countries representing a very low elasticity to carbon price and expensive reductions in the short term. The reductions in the *Others* sector appear to be less costly comparing to the *Transport* sector or even close to zero cost for some countries including Denmark, Finland, Ireland, Sweden and the new member countries. However, the *Others* curve is showing a low elasticity to carbon price meaning that further emission reductions in this sector might be expensive once the low cost reductions are exploited. Meanwhile, the reductions in the *Energy* sector, where the principle emissions come from the electricity sector, seem costly in the short term, but at the same time flexible and reacting highly to the carbon value increases because of the switching opportunities from coal to gas.

Figure 2: Marginal Abatement Cost curves 2010

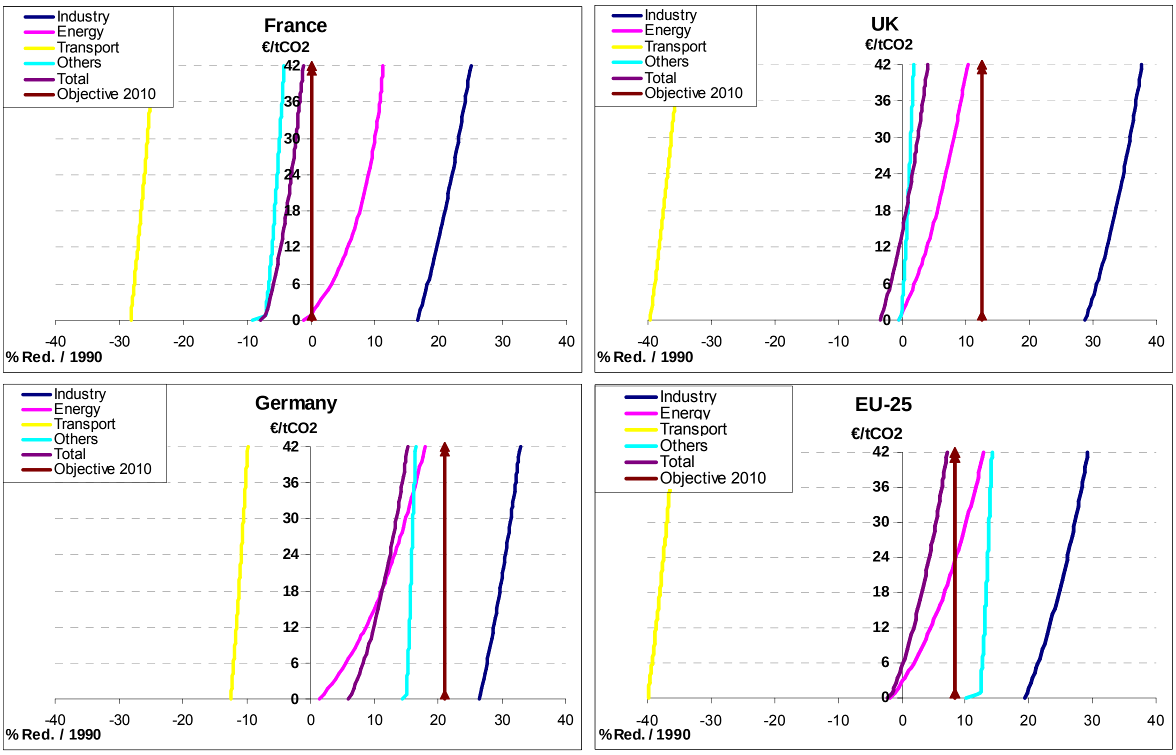
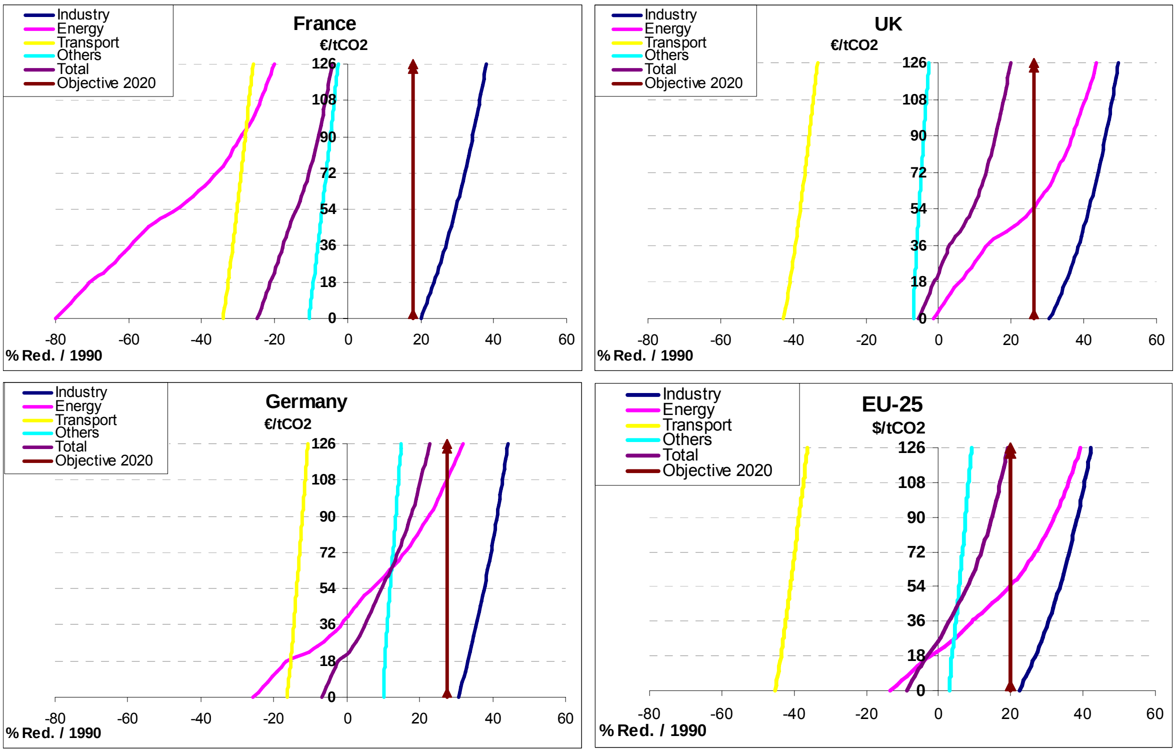


Figure 3 extends the presentation of the MACCs until 2020. We notice right away the crooked form of the *Energy's* curve confirming the sector's ability to swiftly respond to increases in carbon price, with threshold effects. The longer time period enables to account for adjustments through investments in low carbon technologies and even induces the development of carbon capture and sequestration technologies. The carbon prices needed to induce such radical changes depend largely on the sensitivity of the different countries' power industries to the CO_2 price and ranges from 18€/tCO_2 in Germany, to 37€/tCO_2 in UK and to 48€/tCO_2 in France. We observe as well the apparent zero-cost position of *Industry's* curve compared to the average target; no carbon policy is needed to reduce the emissions in industry sectors, but the statement depends of course from the stringency of the CO_2 endowments (see Table 2).

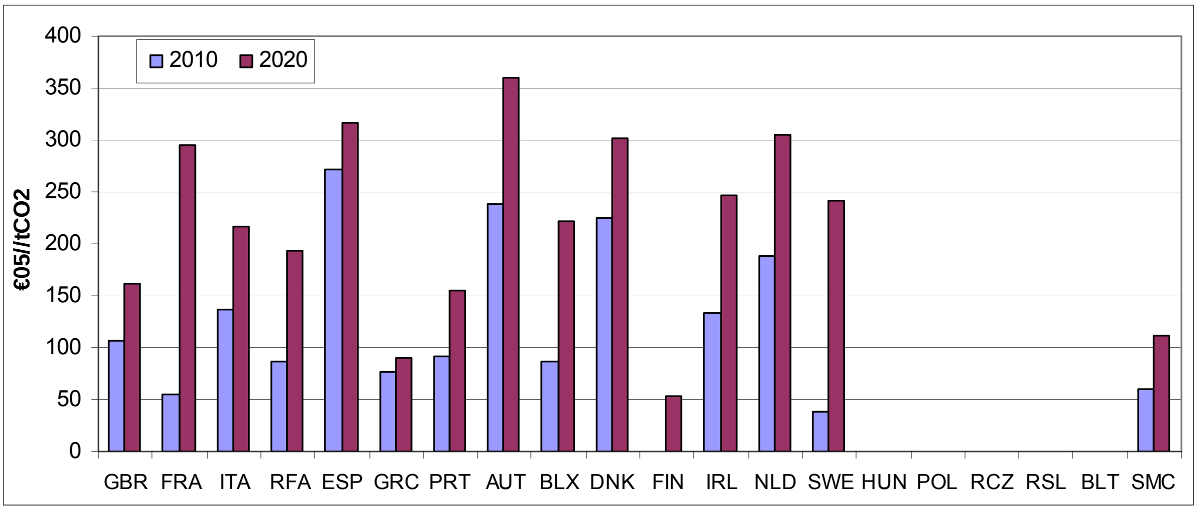
Figure 3: Marginal Abatement Cost curves 2020



Before analyzing the carbon market under different market configurations, one can take a look at the national marginal abatement cost (MAC) for reaching Kyoto and 2020 emissions reduction targets in the European countries (Figure 4). In terms of domestic reduction possibilities, Figure 4 provides us with a good indication on which countries are meeting the targets easily and which will have to seek for cheaper reduction alternatives via ETS or Kyoto project-based mechanisms. The Kyoto and 2020 targets are costless for almost all new member countries apart Slovenia. The trading will obviously profit these countries. The highest costs for complying with Kyoto targets are incurred by Spain, Austria and Denmark, where the marginal abatement cost is in the range of 224-271€/tCO_2.

The greater reduction effort in 2020 implies higher MACs for all European countries except the majority of new member countries. The MACs increase significantly for France and for Sweden and, to a lesser extent, but still by a factor more than 2, for Germany and Belgium. The fairly high national MACs show the importance of the ETS, especially when industry and power sector bear an important part of the effort, and the necessity for the carbon market to be extended to the rest of the world regions. This is analyzed further down in Section 4.

Figure 4: Marginal Abatement cost for European countries: 2010 and 2020



After exposing the differences in the MACs between countries and sectors, the next section defines the configurations of the potential global carbon market and introduces the ASPEN software for its analysis.

3 ASPEN: THE ANALYSIS OF CARBON MARKETS

ASPEN is an analytical model that uses the MAC curves produced by POLES model as inputs for the simulation − on simple but robust micro-economic grounds – of tradable emission quotas systems. The principle used is one of cost-minimization through trading: if a set of economic actors – sub-sectors, sectors, countries or regions, each characterized by its own MAC curve and emission constraint − participates in an emission trading market, then the price of the allowance will equalize, through the process of exchanges, the Marginal Abatement Cost for each participant (Criqui and Mima, 2001). The demand and supply of the CO_2 allowances is defined in function of sectoral endowments for each country, as described in section 1.

ASPEN differentiates emissions sources along the sectoral coverage of POLES model (see Table 1). For any given market configuration (countries, participating sectors, levels of constraint, presence of CDM reductions or 'hot air'), the model produces global allowances supply and demand curves. It then determines the carbon price on the market, the sales and purchases of allowances per sector and per country, the flows of JI and CDM credits. It calculates as well the national total abatement cost with and without trading. The results are discussed in section 4, but it is first needed to define the scenarios and variants of the global carbon market.

3.1 Defining the carbon markets: five scenarios

Undertaking an analysis of the supply and demand for CO_2 allowances in 2010 and 2020 involves a number of hypotheses, for which political decisions are yet to be taken. The principal variables on the supply side are (i) the availability of Kyoto mechanisms' project-based credits as well as (ii) the role of 'hot air' in the carbon market. 'Hot air' in our study refers principally to the above-the-reference emission targets especially in Russia and Ukraine, but it also includes other countries where the targeted levels happen to be higher than POLES model Reference scenario's emissions levels. As for the demand side, it may vary for reasons of CO2 endowments stringency or of increased/decreased participation in the carbon market of Annex B countries.

To analyze the future carbon market we identified five scenarios, representing different configurations (Table 3). The first scenario corresponds to the actual ETS where the carbon market is dominated by European electricity and industry sectors. The utilisation of credits from CDM projects might alleviate European emissions reduction efforts in the second scenario. Furthermore, the lower cost reduction opportunities via JI projects in the industry and the power sector are presented in the third scenario. The fourth scenario extends the third by including cap-and-trade systems in Japan, Canada, Switzerland, Norway and Iceland in 2010 and adding USA and Australia in 2020. The trading activities in the first four scenarios cover only electricity and industry sectors. Finally, the fifth scenario includes the participation of all countries and all sectors.

Table 3: Scenarios*

Countries / Regions	EU 25	Opening to CDM non-Annex B	Opening to JI Russia, Ukraine, Bulgaria, Romania, RCEU*	Inclusion of Rest Annex B	All countries
Trading Sectors	*industry+electricity*				*all sectors*
Scenarios					
S1	V				
S2	V	V			
S3	V	V	V		
S4	V	V	V	V	
S5	V	V	V	V	V

**RCEU - Albania, Bosnia-Herzegovina, Croatia, Macedonia, Serbia & Montenegro*

However, before finalizing the scenarios, two additional factors, *i.e.* the 'hot air' presence and the availability of CDM and JI projects, ought to be discussed. It is well accepted that the climate protection benefits anticipated in the Kyoto targets would be threatened by a combination of weak targets in Russia and Ukraine and, thus, are politically unacceptable by many countries. The resulting ‘hot air’ reduces the need for domestic action. Therefore, a number of countries have now committed themselves to not purchasing ‘hot air’ allowances; these include Canada, Germany and Netherlands (Karmali et al, 2005). As for CDM projects, a large part of their theoretical potentials should be excluded 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. Nevertheless, the expectations for credits are high and justified. According to OECD, by the middle of 2006 there were already more than one thousand CDM projects in the pipeline,[11] with an estimated GHG emission reduction potential of 146 $MtCO_2$-eq/year in the commitment period (Ellis and Karousakis, 2006). Meanwhile, the institutional processes associated with JI projects are rather slow; by the end of 2006, there were only 20 $MtCO_2$ of verified JI credits (Point Carbon, 2007).

Hence, in addition to the description of scenarios in Table 3, we make the following assumptions; first the availability of theoretical CDM potentials in the market is set at 15% in 2010 and 2020, second, two variants over the presence of ‘hot air’ in the market are chosen: 0% or 50% in 2010 and 0% or 100% in 2020.

4 RESULTS

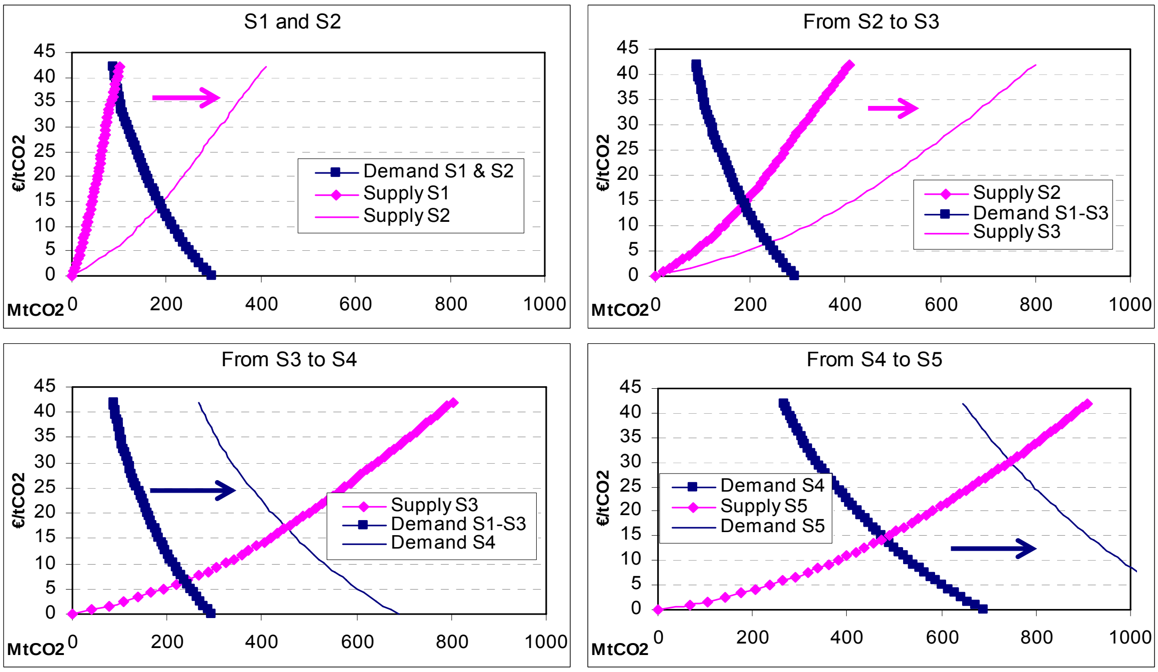
The resulting various configurations of the carbon market open up a diversity of interesting results. In presenting them, we begin with the carbon price associated with the five scenarios listed in Table 3. Later on, we analyze the sectoral allowance trade for the representative European countries as well as for the total of EU-25 under a limited number of realistic carbon market configurations in 2010 and 2020. The associated costs of trading in compliance with objectives are then discussed for key European countries and key Annex B and non-Annex B countries.

4.1 Associated CO2 allowance price in an international carbon market in 2010 and 2020

The carbon price for 2010 and 2020 is derived from the carbon supply and demand analysis under the five scenarios listed in Table 3. Figure 5 demonstrates an example of such an analysis for 2010, where a good picture of the changing size of the market is provided under the various scenarios as more sectors and more countries participate.

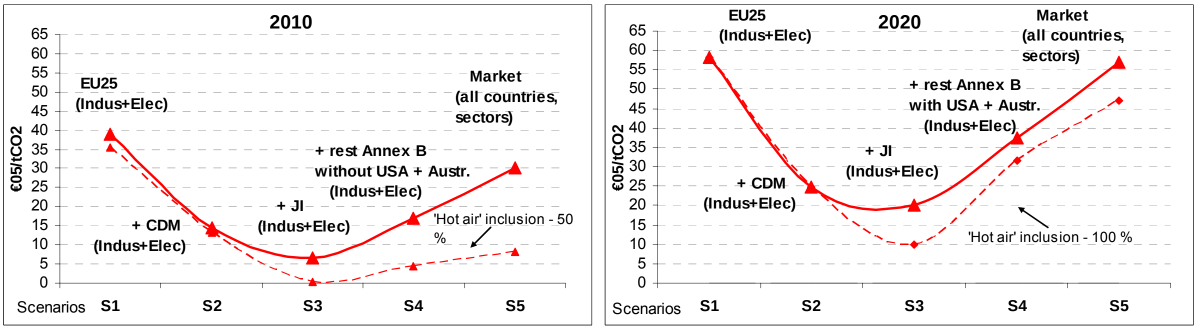
[11] Defined here as projects that have developed a project design document, and/or that have received approval by a host country designated national authority.

Figure 5: International carbon market under five scenarios, outlook for 2010



In these different market configurations, the price of CO2 rises and falls, according to the changes in global supply and global demand that reflect the progressive widening of the market. Figure 6 displays the carbon prices under the five scenarios for 2010 and 2020, while taking into consideration the hypotheses for the key variables described in sub-section 3.1.

Figure 6: Carbon price under 5 scenarios: 2010 and 2020



Scenario 1

- With a limited participation of the actors in the first scenario as only European electricity and industry sectors (ETS) operate on the CO2 market, we might expect the carbon prices to settle at 39 €/tCO_2. Such price level is a result of increasing national marginal abatements costs in Europe combined with the absence of an extended international carbon market. The reference scenario results comparing to the CO2 emissions endowment assumptions indicate a shortfall of 295 MtCO2 in ETS in 2010. The Kyoto target shortfall in non-ETS sectors is, however, more important (383 MtCO2) indicating that the benefits from the international carbon market might be undermined due to a generous allocation to ETS sectors.

- As for 2020, the EC objective of 20% reduction over the European energy sector creates more constraints for the ETS than non-ETS sectors; shortfalls of 646 $MtCO_2$ and 595 $MtCO_2$ respectively, and emphasizes the important benefits that could be gained from the international carbon market. If the ETS remains an isolated system under the conditions of the first scenario until 2020, then we might see carbon prices climbing up to 58 €/tCO_2, which is the highest carbon price level in 2020 among all the scenarios. The competitiveness issues for the European Industries, which have already been raised for the existing ETS, will surely be a serious argument against the existence of such isolated system (Reinaud, 2004, Egenhoffer and Fujiwara, 2006, Demailly et al, 2007).

Scenario 2

- Under the second scenario, the key variable for lowering the carbon price is of course the availability of CDM credits in the market. With 15% of theoretical potentials of CDM projects in 2010, the price drops down to 14 €/tCO_2. The resulting quantity of CDM credits is equivalent to what has been projected by OECD; 146 $MtCO_2$-eq/year in the commitment period of 2008-2012 (Ellis and Karousakis, 2006)[12].
- In 2020, the increasing reduction constraints in ETS sectors raises the carbon price to 25 €/tCO_2 even though the quantity of CDM credits doubles, representing 347 $MtCO_2$ at the market equilibrium.

Scenario 3

- Under the third scenario, the reduction efforts of the ETS participants are furthermore facilitated with the access to JI projects. In 2010, the equilibrium carbon price shrinks to 7 €/tCO_2, at which the proportion in the supply of credits is 82 $MtCO_2$ for JI and 133 $MtCO_2$ for CDM. It should however be mentioned that 'hot air' in the electricity and industry sectors of the JI host countries (besides the JI host countries in EU-25) accounts for 228 MtCO2. The overall European demand might be dampened once more than 35% of 'hot air' becomes available on the market in 2010. Consequently, the carbon price falls to zero and the market becomes senseless as the overall environmental objective is reached without any effort. Of course it is highly unlikely that Russia will give for free its allowances attached to 'hot air', automatically limiting its amount on the market.
- The carbon price attains 20 €/tCO_2 in 2020 with the supply of 141 $MtCO_2$ of JI and 277 $MtCO_2$ of CDM credits at the market equilibrium. Demand for the permits growths slightly on the market due to increasing carbon constraints in JI host countries, which, for their reduction objectives in 2020,

[12] Following the recent decision of EC to include the aviation sector in the ETS from 2011, we performed additional calculations in order to evaluate the impacts of this decision on the carbon market (Carbon Finance, 2007). If we consider the configuration of the second scenario, where the carbon market is composed of existing ETS plus 15% of theoretical potential of CDM projects, the inclusion of aviation in the ETS, in our case in 2010, raises the shortfall of allowances by additional 129 $MtCO_2$. The increased demand sends bullish signals to the carbon market raising the CO_2 price from 14 €/tCO_2 without aviation to 20 €/tCO_2 with aviation. The supply of CDM credits also becomes more important providing around 203 $MtCO_2$ at the market equilibrium instead of 146 $MtCO_2$ without aviation.

could be referred more as to ex-JI countries. Hence, the investment trend diminishes equally in JI projects compared to CDM projects.

Scenario 4

- Under the fourth scenario, the bullish carbon price trends dominate the market due to the linking of cap-and-trade systems worldwide: Japan, Canada, Iceland, Norway and Switzerland. The additional demand for allowances in the rest of Annex B countries (393 $MtCO_2$) rises the carbon price up to 17 €/tCO_2 in 2010. Under the new market equilibrium, the supply from project-based credits grows to 241 $MtCO_2$ for JI and 163 $MtCO_2$ for CDM projects. However, the inclusion of 50% of 'hot air', originating largely from Russia and Ukraine, weights a lot on the carbon price, reducing it to 5 €/tCO_2.
- The inclusion of USA and Australia in the carbon market in 2020 adds around 1593 $MtCO_2$ to the existing demand pushing the price up to 37 €/tCO_2. CDM projects continue to take over the JI projects in the long run with a distribution of 516 and 336 $MtCO_2$ in the supply of credits respectively under the new equilibrium.

Scenario 5

- Under the market conditions of the rather speculative fifth scenario, the carbon price rises to 30 €/tCO_2 in 2010 and doubles to 57 €/tCO_2 in 2020. The introduction of carbon constraints for the other sectors, specially the transport sector that bears high marginal abatement costs, contributes strongly to the rise in the CO_2 price. The impacts of 'hot air' on the CO_2 price are very apparent in 2010 while they are quite marginal in 2020 because of growing constraints in ex-JI countries.

From the hypotheses and results of the scenarios, it appears to us that the second scenario should be considered as the most likely for 2010, so as the fourth for 2020. The two following sections provide further analyses on some economic impacts of these two scenarios for the participants in the carbon market.

4.2 The second scenario and the international carbon market for 2010

Taking into consideration a rapid rise of CDM projects - an increase of almost 50% between December 2005 and May 2006 -, we chose the second scenario for a more detailed analysis of the carbon market in 2010, which includes the current ETS and credits from CDM projects with an availability factor of 15%. Table 4 summarizes the results for the second scenario in terms of sectoral allowance trade flows, reductions costs and trade gains for different actors in the market.

Table 4: Allowance trade-flows and reduction costs under the second scenario – 2010 (*negative values: sale of permit*)

		Reduction objectives, MtCO2		Domestic reduction, MtCO2		Sales / Purchases of CO2 allowances, MtCO2		Domestic costs without trading, M€	Domestic costs with trading, M€
		Electricity	Industry	Electricity	Industry	Electricity	Industry		
EU25	France	8	0	8	0	0	0	52	52
	Germany	68	0	35	4	33	-4	915	667
	UK	60	9	12	5	48	5	2955	864
	Italy	6	13	6	3	0	10	337	209
	Rest of Europe	115	16	68	9	47	8	5385	1280
	Total EU 25	257	39	129	21	128	18	9644	3072
CDM	China			47	28	51%	51%		-635
	India			11	6	12%	10%		-137
	Rest Asia			16	7	18%	13%		-172
	Latin America			3	3	4%	6%		-53
	Africa+Middle East			11	9	12%	16%		-169
	Turkey			3	2	4%	3%		-40
	Total CDM			91	55	-91	-55		-1205

From Table 4 we notice that the emissions reduction burden in ETS belongs largely to the electricity sector: 257 MtCO2 compared with a burden of 39 MtCO2 in the industry sector. Clearly, the purchases of credits via Kyoto project-based mechanisms constitute an important part of the compliance (49%) since in the short term, power generation capacities are fixed and only the fuel and capacity switching opportunities can be exploited. The result is however not very compatible with the import limits on project-based credits into ETS set by European countries in their second national allocation plans. For example, France's limit on credits import into ETS is 17.9 MtCO2 while in our study domestic reductions in France are sufficient to comply with ETS. The quantities of credits set in Italian and German NAPs are also too generous according to our market fundamental analysis; out of 29.4 $MtCO_2$ fixed in Italian NAP2 only 10.4 MtCO2 would be necessary and out of 54 MtCO2 fixed in German NAP2 only 29 MtCO2 would be needed. The contrary is true for UK where credits purchases account for 52 MtCO2 in our study while the allowable limit in NAP2 is only 19.7 MtCO2.

The reductions, even though less important, are still necessary in the overall industry sector of the ETS. However, the domestic reductions in Europe, favored by the low or zero cost marginal abatement curves for industry as seen in Figure 2, outweigh the purchases for the Kyoto projects-based credits in this sector. The picture is quite similar for the European electricity sector even though the objectives are high. The marginal abatement costs appear to be low enough as to induce an additional reduction besides the compliance with ETS power sector targets in countries like Greece, Portugal, Belgium, Finland, Ireland and the new member countries except Slovenia and Poland.

The economic effectiveness of emission trading, when the marginal abatement costs are equalized across actors and only the least-cost reductions are undertaken, is quantified in the last two columns of Table 4. The cost without carbon market highly exceeds the cost with trading for compliance with ETS targets for all European countries, by up to a factor of four for some countries (UK for instance). The UK and Germany keep the highest costs, even though the trading smoothes the differences with other countries. Conversely, France has a relatively low effort for reaching its objective (for industry and the power sector).

The gains of the carbon market are highly differentiated for the CDM host countries, clearly benefiting to only some of them, China in particular. Asia provides the largest part – 81% of the total of CDM credits, far more than Africa-Middle East with 12% or Latin America and Turkey with only 8%. We remind from Figure 6, that without this quantity of CDM credits (146 MtCO2), the CO_2 price might climb to 39€/tCO_2 for the existing ETS in 2010, while the imports of credits reduce the price by more than two, to 14€/tCO_2.

4.3 The fourth scenario and the international carbon market for 2020

The latest statements from the EU-Council suggest that “the EU emissions trading scheme is and will remain one of the most important instruments for the region’s effort to curb GHG emissions and meeting the objective of limiting the global average temperature increases to not more than 2°C above pre-industrial levels” (Point Carbon, 2007). The Council equally evokes the importance of linking the comparable cap-and-trade systems worldwide as well as the necessity of a continued recognition beyond 2012 of credits from project-based mechanisms. Thus, for the analysis of the carbon market in 2020, we chose the fourth scenario, which best reflects the Council statements. It includes the participation of European industries and power sector, the increases of CDM credits on the market, the participation of ex-JI countries and lastly, the involvement of the rest Annex B countries with USA and Australia. Table 5 resumes the results of this fourth scenario.

Table 5: Allowance trade flows and reduction costs under the 4th scenario – 2020 (*negative value: sale, gain*)

		Reduction objectives, MtCO2		Domestic reduction, MtCO2		Sales / Purchases of CO2 allowances, MtCO2		Domestic costs without trading, M€	Domestic costs with trading, M€
		Electricity	*Industry*	*Electricity*	*Industry*	Electricity	Industry		
EU25	France	85	0	25	6	61	-6	8100	2803
	Germany	210	0	110	8	99	-8	8168	5868
	UK	91	17	51	10	40	7	4415	3195
	Italy	22	4	15	7	7	-3	686	655
	Rest of Europe	171	45	170	37	1	7	6699	3335
	Total EU25	580	66	371	67	208	-1	28068	15856
	USA+RJAN*	1573	20	1240	108	333	-88	35063	33724
	Canada	165	26	73	8	92	18	13426	5584
	Japan	343	144	153	56	190	88	27430	14449
	Rest of Annex B	11	0	3	0	7	0	941	344
	Total Rest Annex B	2092	190	1469	172	623	17	76860	54101
CDM	China			170	78	46%	53%		-4795
	India			37	18	10%	12%		-1115
	Rest Asia			66	19	18%	13%		-1662
	Latin America			30	9	8%	6%		-688
	Africa+Middle East			64	24	17%	16%		-1619
	Total CDM			367	149	-367	-149		-9879
ex JI	Russia	0	0	232	52	-95%	-56%	0	-5998
	Total ex JI	152	6	396	99	-244	-93	1356	-7159

**RJAN – Australia and New Zealand*

As in 2010, the CO2 emission endowment we assumed in sub-section 1.1 seems to favor the European industry sector: it is indeed short of allowances, but only by 66 MtCO2 in 2020. Additionally, this shortfall is practically entirely covered by the domestic reductions favored by the low marginal abatement costs curves for industry shown in Figure 3. Contrary to the industry sector, the European electricity sector is extremely short of allowances by 580 $MtCO_2$. The electricity sector alone is carrying almost half of the reduction burden needed for all European energy system in 2020 (the reductions account for 595 MtCO2 in non-ETS sectors). Thus, the import of CDM/JI credits into the ETS electricity sector increases, but less than the domestic reductions do. The longer time period provides wider domestic reduction opportunities through the adjustment of less polluting investments.

Germany displays a strong demand for allowances in its electricity sector. Consequently, the emissions reductions appear to be the most expensive for Germany among the rest of European countries as it is shown in the last two columns of Table 5. This might be explained by the electricity generation mix, which, in the absence of a significant increase in renewable electricity, is dominated by more efficient, but still highly polluting coal plants, requiring more allowances. This come-back of coal is mostly explained by the phasing out of existing nuclear facilities, which is supposed to occur by 2025. Reduction costs for France increase significantly compared to 2010 because of limited abatement opportunities due its initial nuclear capacities. However, the trade of permits allowed by the carbon market reduces the reduction costs by a factor of three, and along with UK, the reduction costs remain relatively low, i.e. in the range of comparable European countries. The new member countries can still reduce domestically more than required by the objectives in 2020 and benefit from exports on the carbon market.

The longer time-horizon (2020), allows the renewal of carbon intensive capital in the power sector of USA, providing considerable domestic reductions. The weak targets for industry in the USA make the domestic reductions easily meet the target and create export opportunities on the carbon market. The gains from a carbon market are important for Canada and Japan, decreasing their reductions costs by the factors of 2.9 and 2.3 respectively.

Asia remains the dominant supplier of CDM credits with 76%, but the distribution within Asia changes: the contribution of India decreases to 11% and the share of China decreases to 49%. The total profit for CDM host countries increases and reaches 10 billion €, which is 10 times the profit of 2010. We also notice that the industry sector of ex-JI countries is short of allowances, but the reductions are cheap enough to have these countries reduce more than their objectives: Russia and Ukraine are particularly important net sellers of credits.

5 CONCLUSION

Studying of the fundamentals of the emerging carbon market requires quite a lot of assumptions for the worldwide carbon supply and demand flows in the future. To produce a consistent and realistic assessment we employed sources such as: second NAPs under ETS, GHG National Inventories, EIA data and POLES reference scenario results to constitute the sectoral base year and 2010, 2020 emission levels in different countries and regions. However, the market fundamentals analysis is also made difficult by a number of variables: the quantity of ‘hot air’ and the availability of project-based credits, for which reasonable assumptions have also to be performed throughout the study.

The resulting sectoral and country based CO_2 endowments for 2010 and 2020 imply an important burden to European and other Annex-B countries’ energy sector that is to say primarily the electricity sector. However, the sectoral analyses based on marginal abatement costs curves show that the power sector is also the most flexible and reacts highly to the increases in carbon price: in the short term via the switching opportunities and in the long term via the investments in less carbon intensive capital. Weak reduction targets, along with low marginal abatement costs prevail in the European and other Annex-B countries’ industry sectors. In ETS, the domestic reductions in industry are much larger than the purchases of project-based credits in 2010 and especially in 2020.

However, the benefits of enlarged carbon market for ETS participants are important in terms of cost reduction and CO_2 price; without the import of 146 $MtCO_2$ CDM credits into the ETS in 2010, the CO_2 price would jump to 39€/tCO_2, instead of 14€/tCO_2 with the CDM credits. The economic benefits of the international carbon market are less evident on the countries level since more than 50% of Kyoto targets are accomplished by non-ETS sectors. In the long term, the study emphasizes the important gains from an enlarging carbon market for all participants, especially the European countries since the major reduction should be achieved in ETS sectors.

In the short term, the role of ‘hot air’ is a major factor influencing the volatility of the carbon price and its full availability on the market would dampen the European and the rest Annex-B countries’ demand combined. It is however unlikely, that JI host-countries will be willing to sell their allowances at zero costs, and they will limit the amount on the market. Moreover, a number of countries have now committed themselves to not purchasing allowances attached to ‘hot air’.

Typically, the marginal abatement costs are highest for the non-ETS sectors: transport and to lesser extent building sectors. The recent decision of European council to reduce the primary energy consumption by 20% as well as to increase the renewable energy production by 20% in 2020 would also allow exploiting emissions reduction opportunities in these sectors. The interactions between different council objectives remain a topic for further research.

References

Alexeeva-Talebi, V., Angers, N., 2007. Developing Supra-European Emissions Trading Schemes: An Efficiency and International Trade Analysis. Discussion Paper No. 07-038. Center for European Economic Research, Germany.

Angers, N., 2006. Emission Trading Beyond Europe: Linking Schemes in a Post-Kyoto World. Discussion Paper No. 06-058. Center for European Economic Research, Germany.

Carbon Finance, 2007. Commission wants 30% cut in GHGs by 2020. December 2006 / January 2007, Volume 4, Issue 1, Fulton Publishing.

Criqui, P., Kouvaritakis, N., 2000. World energy projections to 2030. International journal of global energy issues 14 (1/2/3/4), 116-136.

Criqui, P., Viguier, L., 2000. Kyoto and technology at world level: costs of CO_2 reduction under flexibility mechanisms and technical progress. International journal of global energy issues 14 (1/2/3/4), 155-168.

Criqui, P., Mima, S., 2001. The EU Tradable Emission Permit System: some policy issues identified with the POLES-ASPEN model. Presented on February, 8-9 in ENER Forum 1, Krakow, Poland.

Criqui, P., 2002. Les permis d'émission négociables: du cadre d'analyse à la mise en œuvre en Europe. Février, Annales Des Mines, Réalites Industrielles, 59-64.

Demailly, D., Grubb, M., Hourcade, J.C., Neuhoff, K., Sato, M., 2007. Differentiation and dynamics of EU ETS competitiveness impacts. Climate Strategies EU ETS Competitiveness Workstream Interim Report, Available on: 〈 http://www.climate-strategies.org/item_list.php?item=document 〉.

Egenhoffer, C., Fujiwara, N., 2006. Reviewing the EU Emissions Trading Scheme: Priorities for Short-Term Implementation of the Second Round of Allocation (Part II). March, CEPS Task Force Report, Center for European Policy Studies.

Ellis, J., Karousakis, K., 2006. The Developing CDM Market: May 2006 Update. May, Head of Publications Service, OECD/IEA.

German Institute for Economic Research, 2007. Highly uneven distribution of reduction targets in Europe – fair burden-sharing recommended. June, weekly report, No. 3.

Karmali, A., Foot, S., Osmancik, N., 2005. Clearer Signals Ahead. ICF Consulting.

Klepper, G., Peterson, S., 2004. The EU-emissions trading scheme – allowance prices, trade flows and competitiveness effects. European Environment 14 (4), 201-218.

Kolstad, C., D.,2005. Climate change policy viewed from the USA and the role of intensity targets. Emissions trading for climate policy: US and European perspectives, Cambridge University Press.

Official Journal of the European Union, 2003. Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.

Official Journal of the European Union, 2004. Directive 2004/101/EC of the European Parliament and of the Council amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms.

Pizer, A., W., Kopp, J., R., 2003. Summary and Analysis of McCain-Lieberman – "Climate Stewardship Act of 2003". Resources for the Future.

Point Carbon, 2004. The Size of the Global Carbon Market in 2010. December 29, Carbon Market Analyst.

Point Carbon, 2007. Carbon 2007 - A new climate for carbon trading., Røine, K. and H. Hasselknippe (eds.), Norway.

Reinaud, J., 2004. Industrial Competitiveness under the European Emissions Trading Scheme. IEA Information paper, Paris.

Renewable Energy Access, 2005. China Passes Renewable Energy Law. March 9, Available on: 〈 http://www.renewableenergyaccess.com/rea/news/story?id=23531 〉.

Rousse, O., 2004. La mise en place d'un marché de permis d'émission dans des situations de concurrence imparfaite. Centre de Recherche en Economie et Droit de l'Energie, Cahiers de recherche.

Schwartz, S., 2005. Marchés des permis de pollution et concurrence imparfaite. Revue française d'économie 3 (XX), 183-225.

Springer, U., Varilek, M., 2004. Estimating the price of tradable permits for greenhouse gas emissions in 2008-12. Energy Policy 32, 611-621.

UNFCCC, 2006. Annex I Greenhouse Gas Inventories. National Inventory Submissions 2004.

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[13], which allows maximizing the consistency of the exogenous hypotheses for the different time horizons and across the different technologies.

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

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