POST-KYOTO IN THE CERAMIC TILE AND FRIT INDUSTRY

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ABSTRACT

The future of the emissions market created by Directive 2003/87/CE which establishes a regime for the trade in the emission rights of GHG (greenhouse gas) emissions in the EU (DOCE 225 October 2003), transposed by RD (Royal Decree) Law 5/2004, is uncertain. However, the development of a market and similar provisions in the U.S.A. (Chicago Climate Change project) provide it with continuity in time. The willingness to develop a real policy of GHG emissions reduction varies: the EU is proactive and at the March 2005 summit of heads of government, the EU committed itself to avoiding a critical increase of 2ºC in the mean temperature of the Earth, for which a reduction in the GHG emissions of between 15 and 30% is necessary in 2020 in regard to 1990. The present paper sets out a foresight regarding the reductions which could affect the ceramic tile and frit industry in the period 2013-2017. The foresight has been performed considering six features: (a) the results of the reduction of the non-regulated sectors in the periods 2005-2007 and 2008-20012, (b) the data and criteria deriving from RD 1866/2004 approving the National Emission Rights Assignment Plan (PNA), (c) the formulation of process alternatives that provide greater energy efficiency, (d) the incorporation of other GHG emission chemical compounds in the Kyoto catalogue, fundamentally HF and O_3*, (e) the incorporation of activities associated with the production of GHG emissions other than from combustion, (f) the reduction of emission thresholds in the regulated sector. The results indicate that the ceramic tile and frit industry could be net seller sectors of emission rights in the period 2013-2020. For this, the tile sector would need to upgrade its kiln engineering according to principles of gas confinement and recirculation inside the kiln, and the frit sector would need to apply, in a generalised form, the oxycombustion methodology in addition to avoiding* NO_x *emissions. The extension of the spectrum of GHGs to fluorated gases and ozone could increase the emission rights surplus in the period, but the upgrading efforts of the regulated industries are seriously threatened by the failure in the requirable reduction by the non-regulated sectors, which makes a drastic extension necessary of the regulated sectors, as well as a reduction in the thresholds of Directive 2003/87/CE in the regulated sectors. In this sense, a stricter adaptation to the directive of the thresholds for the tile sector seems reasonable, which should reach a reasonable fraction of the total production of the sector. The real solution to climate change is the substitution of fossil fuels and the development of the hydrogen economy: in the long term, the tile and frit industry could use wind energy associated with high-temperature water electrolysis, generalising hydroxycombustion (which uses hydrogen as fuel and oxygen as an oxidiser) without the intermediation of fuel cell devices.*

1. INTRODUCTION

1.1. CLIMATE CHANGE AND GREENHOUSE GASES (GHGs)

On 24 June 2005 the chemist Charles David Keeling passed away, considered the discoverer of the so-called greenhouse effect or climate change associated with the introduction and accumulation in the atmosphere of Greenhouse Gases (GHGs), when he was studying the so-called 'Keeling Curve' of the ascending evolution of CO_2 content over the years, studying the content in regions with very clean air like Mauna Loa in Hawaii[1]; thus, the mean values of the CO_2 content on Earth in 1957 were 315 ppm, in 2000 these had reached 368 ppm. Subsequently, coring studies on the succession of ice in glaciers, such as the 3-kilometre-long ice core extracted at the Vostok base of the Antarctic, have corroborated that the CO_2 values in the air (trapped as bubbles in the polar ice) did not exceed 180 ppm in inter-ice ages like the present one, nor 80 ppm in the ice ages during which the average temperature was 9ºC lower than now. The Keeling curve displays a growth rate with time as a result of two fundamental factors: (a) fossil fuel combustion, which accounts for 75% of the problem, the input of around 6 GtC/annum, the equivalent to a fire devastating half the forests of Canada every year; and (b) deforestation or, in a broader sense, the change of use of the land, involving a discharge of 2 GtC/annum. Studies indicate a good operation of the thermal buffer, since the terrestrial and oceanic ecosystems are able to sequestrate about 5 GtC/annum (2.9 the terrestrial and 2.4 the oceanic ecosystems, respectively)[2]. However, there are serious indications that this buffer capacity of the ecosystems is being exhausted[3]. Moreover, the effect of other pollutants with opposite effects to the GHGs, such as SO_2 and particulate aerosols, known as 'global darkening', of which there has been great abuse in the 20th century and which has been significantly reduced in the last decades as a result of health and environmental legislation, could accelerate global warming[4]. In 2002, despite the discrepancies with respect to the Kyoto Protocol, President Bush awarded Keeling the National Medal of Science, the highest American award to the nation's researchers. Keeling was a world leader in the study of carbon compounds in the atmosphere, who graduated in Chemistry from the University of Illinois, earning his Ph.D. from the Northwestern University, and worked in research in the prestigious American institution, Scripps Institution of Oceanography.

Greenhouse gases (GHGs) are gaseous substances with a capacity to absorb the long-wave infrared radiation that is re-emitted by Earth to space, raising the temperature of the atmosphere that is transferred to the surface of the Earth, slowly but inexorably. The main GHGs are listed in Table 1, together with their equivalent potential as greenhouse gases, the estimation by the IPCC (Intergovernmental Panel of Climate Change: technical advice body on climate change, established in the 1980s by the UN) of their increase in the atmosphere from pre-industrial periods to 2000, as well as the mean values of their concentrations and average residence time in the atmosphere.

Despite being the gas with lowest potential of the GHGs, CO_2 is the most important gas because of the great increases produced in the industrial age, about 70 ppm, followed in importance by methane from the anaerobic fermentations of landfills, 1 ppm, and nitrous oxide N_2O, produced by bacterial decomposition of nitrates introduced as artificial fertilisers.

GHG	EQUIVALENT POTENTIAL	PRE-INDUSTRIAL CONCENTRATION (1750)(ppm)	CURRENT CONCENTRATION (1994)(ppm)	VARIATION	$T_{1/2}$ (years)
CO_2	1	288	358 (in 2000 368)	+31%	50-200
CH_4	11	0.700	1.700 (in 2000 1.750)	+151%	12
N_2O	270	0.270	0.310 (in 2000 0.316)	+17%	120
O_3				+35%	-
CFCs *CF_4* *$CClF_3$*	 4500 3400	 0 0	 0.072 0.268	 decreasing by prohibition Montreal Prot. (1996)	 50000 50
HFCs $HCClF_2$	 1600	 0	 0.100	 general increase	 12
SF_6	3000	0	0.034	general increase	3200

Table 1. Variation in concentrations and potential of the main GHGs (Third Assessment Report of the IPPCC, the UN Intergovernmental Panel of Climate Change).

In view of the above, the strategy for the fight against climate change has three main fronts: reducing fossil fuel consumption (coal, oil and natural gas), the regeneration of carbon sinks by reforestation work, and the reduction of synthetic nitrates in agricultural fertilisation.

Traditional ceramic tile fabrication was based on wood or coal as basic fuel, with manual pedal presses and the comprehensive Moorish kiln as firing technology. The great technological revolutions in the ceramic floor and wall tile sector are associated with processes of growth and development crises in the industry, in 4 main stages or periods[4,5,6,7]. The First Stage, that of the 'Wall Tile Factories' featured firing in Moorish kilns, with wood and friction presses (1929-1966). The Second Stage, or that of the 'Wall Tile Manufacturers' evolved into continuous firing with tunnel kilns and multi-channel tunnel kilns with oil fuel (1966-1976). The so-called year of the great frost of 1956, 'l'any de la gelada', caused serious losses in the groves and harvests of citruses in the Castellón area, and in the following years some agrarian entrepreneurs started considering diversifying their investments. In 1960 the first tunnel kiln was installed in Vila-real; in 1966 there were already five. In the Third Stage or that of the 'Ceramic Companies' there is the revolutionary changeover to direct firing in single-deck kilns and single firing with methane gas (1976-1987). The combination natural gas–single-deck and single firing in single-deck kilns provided important advantages, which prevailed over traditional firing in tunnel kilns[9]: greater quality and flexibility in production, as well as a drastic reduction in emissions and elimination of lead poisoning. The present, Fourth Stage, that of the 'Ceramic Multinationals' is characterised by the development of porous single-fired tile and the diversification of ceramic bodies in a globalising world (1988-2004).

The ceramic floor and wall tile industry, just as the ceramic frit industry, has evolved based on fuel: wood → coal → oil → natural gas; this succession towards more effective fuels (Table 2 of heating value) and cleaner fuels has now been completed in the ceramic tile sector. In contrast, other strong fossil fuel-consuming sectors are still evolving (Table 3 of electric power generation in Spain, 2003). However, once natural gas has matured in the other sectors, the ceramic sector, together with the other sectors, will, basically starting in 2013, need to face a new revolution in fuel and ceramic firing kilns.

FUEL	PCI(Kcal/Kg)	PCS(Kcal/Kg)
Wood	4000	5000
Nº 1 Fuel Oil (S<2.7%)	9600	10,100
Natural Gas (86% CH_4)	13,000	
H_2	36,000	

Table 2. Lower heating value (LHV) and upper heating value (UHV)

SOURCE	%
Coal	30.23
Nuclear energy	23.87
Hydroelectricity	11.33
Fuel-Gas	6.86
Combined Cycle (gas natural)	11.7
Wind	5.35
Others	11.70

Table 3. Electric power generation in Spain (INE 2003).

2. THE KYOTO PROTOCOL AND THE CERAMIC TILE AND FRIT INDUSTRIES

In June 1992, at the Earth Conference of Rio de Janeiro, 154 countries signed the document entitled the *United Nations Framework Convention on Climate* (UNFCCC 1992), engaging to achieve the target laid down in article 2: 'to achieve…the stabilisation of the concentrations of greenhouse gases in the atmosphere at a level that will enable preventing hazardous anthropogenic interferences in the climatic system'. No country acted in a decisive way to materialise the non-concrete and hardly worked out goals, but at the COP3 follow-up conference at the Japanese city of Kyoto (December 1997), unexpectedly and somewhat surprisingly, the *Kyoto Protocol on climate change* was signed, formalising 'targets and timetables' for reducing emissions.

In May 2002 the European Union ratified the protocol, with Russian ratification pending, to reach 55% of the countries with 55% of the emissions, for the entry into force of the Protocol. In December 2004 Russia ratified the protocol that entered into force on 16 February 2005.

The implementation of the Kyoto Protocol in Spain has been enacted by means of Royal Decree Law 5/2004 on the regulation of the regime for emission rights trade of GHGs (transposing Directive 2003/87/CE) and RD 1866/2004, approving the National Emission Rights Assignment Plan (PNA), completed by decision of the Undersecretary's Office of the Presidency of 26 January 2005, which approved the individual assignment of emission rights to installations.

In general lines, the strategic frame for compliance of the Kyoto Protocol in Spain is grounded on the following approaches[10]:

- (I) Two initial periods in accordance with the Directive 2003/87/CE and successive five-year post-Kyoto periods: (a) stabilisation period, 2005-2007, seeking to stabilise the emissions at 2000-2002 average values, (b) compliance period, 2008-2012, seeking to reduce the emissions to reach a 24% increase in regard to 1990 (a 15% limitation target for Spain in the European bubble, plus 2% estimation of absorption by sinks, plus 7% credits in international market or through JI and CDM mechanisms), (c) subsequent five-year periods, which will follow the future reformulations of the protocol.

- (II) Spread of reduction efforts: 40% of the effort occurs in the activities of Annex I of Directive 2003/87/CE and 60% of the effort in the non-regulated sectors, which in the stabilisation period must implement a reduction of about 52 Mt CO_2 eq./annum (2.5% in regard to 2002). For this an Action Plan for 2004-2007 has been prepared on the basis of the E4 Strategy approved by Government in December 2003, which envisages actions such as:(a) Modal change: mobility plans, shuttles, modal exchangers, short shipping or navigation, (b) Efficient use of transport (transport consumes 36% of energy and produces 22% of the GHG emissions): avoiding air tankering of additional fuel loads taking advantage of differences in price, biofuels, vehicle emission limitations to 120 CO_2/km in 2012, renewal of fleets, urban tolls in congested environments, transport plans for companies with more than 200 employees, (c) Optimisation of consumption in residential, commercial and institutional sectors (responsible for 6% of the GHG emissions): actions on the building envelopes (facade and roof), introducing low-consumption electric lamps and class A household appliances, (d) Agricultural practices: adjusted fertilisation in zones vulnerable to nitrates, prohibition of stubble burning. (e) Fluorated gases: change of alumina feed in electrolytic tanks of the aluminium industry and substitution of gases in ammonia plant recovery units.

- (III) Distribution and calculation in individualised installations; only applied to combustion activities calculating the assignment after discounting the cogeneration and process emissions.

- (IV) New entrants. New entrants in the period 2005-2006 are reserved 3.5% of the emissions, which will be assigned with the same factors of compliance used in the PNA assignment, based on the 'first come, first served' order of applications.

2.1. THE PERIOD 2005-07 AND EMISSION RIGHTS IN THE CERAMIC TILE AND FRIT SECTORS.

The Castellón ceramic cluster, and in general all the sectors regulated by the emissions directive, reacted very strongly to the development of the GHG emissions market[11, 12]. In the case of ceramic tiles there is great concern regarding the numerous tile manufacturing companies that would exceed the thresholds of the directive: 145 tile manufacturing plants and 11 spray dryers, representing 66% of the total number of companies, and 75% of the emissions; there is also concern about cogeneration, in which the sector is the leader with 80 facilities that have a total power of 300 MW. An excessively strict calculation led to catastrophic conclusions regarding increases in production costs of 34%, and a reduction in production of 26%, with 64 company shutdowns and the loss of over 6,000 jobs. In the case of the frit sector, the data boded no better[11]. However, in the definitive Resolution of the assignments to installations (Table 4), things have worked out quite differently[13].

2.1.1. Ceramic tiles

Only 22 companies from the ceramic tile sector are regulated, as they exceed the thresholds (15 located in the Castellón cluster; in fact, most involve spray-dried powder producers, which have been included under the same head) and account for the 18.55 of the total emissions in the sector. In drafting the thresholds of RD Law 5/2004, a small controversy arose that has also largely affected the number installations involved. There is a difference in the drafting of these thresholds in Directive 2003/87/CE on the emission rights trade in GHG emissions, and the writing in its Spanish transposition into RD Law 5/2004.

Directive 2003/87/CE: manufacture of ceramic products (…), with a production capacity exceeding 75 tons per day, ***and/or*** *a kiln run capacity of more than 4 m^3 and more than 300 kg/m^3 charge density per kiln.*

The double conjunction 'and/or' of the directive is transformed into the simple 'and' in RD Law 5/2004. This change, which was defended by certain allegations in the public exhibition stage, leaves outside its scope all the tile manufacturing installations with single-deck kiln runs, as these rarely exceed 300 kg/m^3 charge density per kiln.

The granted emission rights cover, without any problems, the emissions of the installations involved for the period 2005-07. Generally speaking, the emission factors of the ceramic tile sector have improved notably in time: in 1985 about 12.5 kg CO_2/m^2 was emitted with the technology then available, which already included the major use of natural gas use in the sector; in 1990 this dropped to only 6.6 kg CO_2/m^2; in 2000, it was 5.6 kg CO_2/m^2, and 4.8 CO_2/m^2 in 2001 (12). Since in 2000 the sector produced 651 Mm^2, the gross emissions were of the order of 3.96 Mt CO_2 eq./annum. The sectoral allocation for 2006 of 875,395 t CO_2 eq./annum would be 22% of the gross emissions (similar to the figure of 18.55% adopted by the PNA, to which are to be added the 3.5% reserved for new entrants), which corresponds to 22 of the 301 registered installations (17 of these for non-finished products, spray-dried powder producers); i.e. only 7.3% of the installations, but with a predominance of facilities that sell spray-dried clay powder to the rest of the sector.

Italy has taken longer to solve its emissions assignment plan, which it has delayed until February 2005. The Italian plan allots a total of 251.97 Mt CO_2 eq./annum to the regulated sector in 2005 (Spain allotted 160.28 Mt CO_2 eq./annum), assigning to tiles rights for 3.02 Mt CO_2 eq./annum in 2007 and 137 installations involved with productions very similar to those in the Spanish sector (3.4 times the Spanish rights; 1.2% of the regulated total compared with 0.54% Spanish regulated total).

2.1.2. Frits

22 companies are affected (21 located in the Castellón cluster, Table 4). The emission rights assigned in 2005-2007 are 673,843 tCO_2 eq./annum. The emission factor for fritting is calculated as about 0.62 Kt CO_2 eq./Kt; the total emissions would be about 0.62 Mt CO_2 eq./annum that are covered in the PNA for the stabilisation period.

A SECTOR	EMISSIONS 1990 (Mt CO_2 eq./annum)	EMISSIONS/ ANNUM 2005-07* (Mt CO_2 eq./annum)	VARIATION % in regard to 1990 (Mt CO_2 eq./annum)	TARGET 2012** (Mt CO_2 eq./annum)	COST(M€/annum) (20 €/t)***
Electric	61.61	86.4	+40.3	76.39	200.2
Ceramic tile	0.41	0.88	+114.6	0.72	0.56
Frits	0.22	0.67	+204.6	0.59	0.44
TOTAL regulated	**119.17**	**171.2**	**37.9**	**147.8**	**-2.5**

B SECTOR	EMISSIONS 2005-07*(Kt CO_2 eq./annum)	% EMISSIONS IN REGARD TO TOTAL	Nº INSTALLATIONS KYOTO
Tiles SPAIN	875,395	0,51	22
Castellón Cluster	800,785	-	15
Rest of Spain	74,610	-	7
Tiles ITALY******	2.9(05)/2.96(06)/3.02(07)	1.12	137
Frits SPAIN	673,843	0.41	22
Castellón Cluster	668,898	-	21
Rest of Spain	4945*****	-	1

(*) Sum of the assignments to the sector by the Resolution of 26 January 2005, (**) Target calculated based on an overall increase of 24% in regard to 1990 (0.24x119.17+119.17=147.8 Mt) and considering that the electric sector alone accounts for this increase (0.24x61.6+61.6=76.39 Mt) so that there is a reduction of 10.01 Mt in regard to 2007, the rest of the sectors must reduce 13.4 Mt in regard to 2007, i.e. 0.16 Mt/Mt assigned in 2007 (0.16x0.88=0.14 Mt for tiles and 0.16x0.67=0.11 for frits). (***) It is considered the sector has not reduced its emissions and must go to the market, the reduction in 2012 is spread over the 5 years 2008-2012, i.e. 0.14x20/5=0.56M€/annum for tiles and 0.11x20/5=0.44 Mε/annum for frits). (****) This is indicated in Mt CO_2 eq./annum for each year of the period in brackets,(*****) La company has assignments of 9890 in 2005 and 2006, but in 2007 it is only assigned 4945 Kt.

Table 4. Assignment and projection for 2008-2012 of emissions in the Castellón cluster (Resolution of 26 January 2005): (a) Overall assignment, (b) Assignments to the ceramic cluster.

2.2. THE PERIOD 2008-2012 AND EMISSION RIGHTS IN THE CERAMIC TILE AND FRIT SECTORS.

2.2.1. Ceramic tiles

For the period 2008-2012, the comprehensive target for Spain, calculated on the base of an overall increase of 24% in regard to 1990, involves an assignment for the regulated companies of 147.8 Mt. Assuming that the electric sector alone accounts for that increase (taking on the weight of the reduction as occurred in 2005-2007), this sector is assigned 76.39 Mt, thus reducing 10.01 Mt relative to its assignment of 2007 (Table 4). The rest of the sectors must reduce 13.4 Mt in regard to 2007, i.e. 0.16 Mt/Mt assigned in 2007. This leads us to a reduction of 0.14 Mt for tiles. If the sector does not reduce its emissions and must go to the market, assuming a cost of 20 €/t, the reduction in 2012 is spread over the 5 years 2008-20012, i.e. 0.56M €/annum for tiles, which is not an exorbitant cost. If the sector does not want to pay emission rights, it must reduce its emissions by 16% in 2008-2012 with respect to 2007; as the calculations of the sector only evidence a possibility of 4%, the final cost it faces is 0.49 M€/annum.

The cost could be a little greater, since in the period 2008-2012 only 90% of the emission rights are free and the rest will be assigned in accordance with the corresponding assignment plan (Art. 16.2 of RD 5/2004). That means that the sector will have to buy at the relevant price, 10% of its foreseeable assignment in period 2008-2012 (0.1x(0.88-(0.14/5))=0.09 $MtCO_2$ eq./annum. If the assignment is at market price (20 €/t) this will mean 1.8 M€/annum, an important amount: However, hopefully the price of this 10% will be a political price.

2.2.2. Frits

If we perform a similar estimation to the foregoing one made for ceramic tiles, in accordance with the spread of the reduction efforts envisaged in the PNA 2005-2007 (Table 4), the frit sector will have to reduce 0.11 Mt CO_2 eq. in the period 2008-2012 relative to 2007, i.e. 0.022 Mt CO_2 eq./annum, 3.3% its annual assignment of 2006. Assuming an average market price of 20 €/t, if the sector does not reduce its emissions, the final cost will be 0.44 M€/annum.

The reduction capacity of the frit sector in this period exceeds this percentage and it should have no difficulty in meeting the target without needing to buy emission rights, possibly even becoming a rights 'selling' sector . Table 5 sets out the emission factors of natural gas–air kilns (HAG) and gas natural–oxygen kilns (HPG or oxycombustion)[14]. The use of oxycombustion enables reducing CO_2 emissions in frit fusion by 33%. It also allows reducing NO_x nitrogen oxides by 52%, which need to be reduced to maintain environmentally sustainable values and meet legislation, and to conform to the ceiling values assigned to Spain for this pollutant, as discussed above[15].

	HGA	HOG
Methane flow rate (Nm^3/h)	186	99
Air(Nm^3/h)	2056	0
O_2 (Nm^3/h)	O	199
Total flow rate (Nm^3/h)	2242	298
Flow rate at 1500ºC (m^3/h)	134,520	17,880
Interior velocity (m/s)	10.67	1.41
NO_x (ppm)	538	373
NO_x(mg/Nm^3) a 15%O_2	505.97	548.79
NO_x(g/t)	**2085**	**970**
CO_2 (Nm^3/t)	11	3.6
CO_2 (g/t)	**494.3**	**165.6**

Table 5. Emission factors of frit kiln runs with methane–air (HGA) and methane–oxygen (HOG).

However, as the sector has only 90% of its rights free in the period 2007-2012, the foregoing cost could increase by 0.1x(0.67-(0.11/5))=0.07 $MtCO_2$ eq./annum. At market cost this would mean an additional 1.3 M€/annum; however, the price of this percentage may be expected to be political, as already indicated.

3. PROSPECTIVE ANALYSIS 2013-2017

The willingness to put in place a real GHG reduction policy varies; the EU is proactive and in the EU Environment Ministers meeting of 10 March 2005, a 'path' was proposed of 30% of the GHG emissions in 2020 in relation to 1990, and 80% in 2050 (the Kyoto Protocol assumes a reduction of 5.2% in 2012 in regard to 1990). This European willingness became more nuanced in the later summit of government heads; the EU is committed to avoiding a critical increase of 2ºC in the average temperature of the Earth, which requires a reduction in GHG emissions of between 15 and 30% in 2020 in relation to 1990.

On 19 July 2005 the commissioner for the environment of the European Commission, Stavros Dimas, gave a speech before the American Chamber of Commerce in the European Union, in which he announced the European policy in the fight against climate change[16]:

- First, to continue using market-based instruments as the best system to achieve low costs.
- Second, to develop a determined impulse for the indispensable innovation, since new technologies are needed to achieve a society with low carbon consumption.
- Third, to include all the sectors, such as aviation, sea transport and forestry, as well as all the greenhouse gases to make the reduction effort cost-efficient.
- Fourth, to extend the participation in the effort for reduction to all the great emitters, like the U.S.A., and the rapidly emerging developing markets. The G8 summit has marked an important phase in this discussion. We hope that the UN conference on climate change in Montreal at the end of year will initiate formal negotiations on the regime of the future climate change.
- Fifth, to begin to develop policies that help adapt to the inevitable impacts of climate change. This requires identifying vulnerabilities and measures for increasing the elastic response, such as protection measures against floods, appropriate methods of use of the earth, appropriate insurance coverage, etc.

The prospective analysis has been performed considering six aspects: (a) the results of the reduction of the non-regulated sectors in the periods 2005-2007 and 2008-20012, (b) the data and criteria deriving from RD 1866/2004 approving the National Plan of Assignment of emission rights (PNA), (c) the formulation of processing alternatives that provide greater energy efficiency, (d) the incorporation of other GHG chemical compounds in the Kyoto catalogue, fundamentally HF and O_3, (e) the incorporation of activities associated with GHG emitting production other than from combustion, (f) the reduction of the emission thresholds in the regulated sector.

3.1. THE RESULTS OF REDUCTION IN THE NON-REGULATED SECTORS IN THE PERIODS 2005-2007 AND 2008-20012.

The PNA for 2005-07 establishes that the reduction effort shall be spread as a function of historical sectoral emissions: 40% for the regulated sectors, and 60% for the diffuse sectors. However, there is, in fact, a triple contradiction in the prospective analysis for the non-regulated or diffuse sectors, since if the reduction for the regulated sectors is 4.04 $MtCO_2$ eq./annum in 2007 in regard to 2002 (2.5% reduction, Table 6) corresponding to 40% of the effort, the effort for the non-regulated sectors should be 0.6x(4.04/0.4)=6.06 $MtCO_2$ eq./annum in 2007 in regard to 2002 (2.6% reduction). However, also considering the provisions established in RD 1966/2004 according to which the overall emissions are reduced in 2007 in regard to 2002 by 0.2%, the non-regulated sectors could increase their emissions in 2007 up to 240.42 $MtCO_2$ eq./annum (1.43% increase in 2007 in regard to 2002, Table 6). Finally, in the same RD 1866/2004, while assuring compliance with the foreseen measures, an emissions reduction is required of 52 Mt in 2005-2007, which entails a reduction of 21.9% of the non-regulated emissions relative to 2002, far exceeding the 60% reduction effort.

This triple contradiction is contradicted, in turn, by the evolution of the non-regulated sectors, basically transport, residential-commercial-institutional, agrarian, wastes and fluorated gases with growths superior to those of the period 1990-2002 calculated at an annual 3.45%.

The reduction strategy is grounded in the Action Plan for 2004-2007, based on the E4 Strategy approved by government in December 2003, as mentioned above, in the strategic infrastructure and transport Plan PEIT, and in the future Technical Building Code, which do not offer any serious guarantees of reduction .

SECTOR	1990	2002	2005-2007	TARGET 2012(**)	TARGET 2017(**)	TARGET 2020(**)
Regulated	119.17	164.32	160.28	147.8	134.9	127.21
Electric	61.61	95.95	86.4	76.39	69.7	65.74
Ceramic tiles	0.41	1.1	0.88	0.72	0.66	0.62
Frits	0.22	0.6	0.67	0.59	0.54	0.51
Non-regulated*	166.52	237.02	240.42			
TOTAL	285.69	401.34	400.70			

(*) Values calculated assuming assignments to the regulated sectors (reduction by 2.5% in 2005-2007 in regard to 2002) and totals (reduction by 0.2% in 2005-2007 in regard to 2002) RD 1866/2004.(**) Targets obtained by extrapolation of the criteria in PNA 2005-07 and other directives approved in the European Union.

Table 6. Evolution of the emissions ($MtCO_2$ eq./annum).

On the other hand, the attainment of increases in sinks equivalent to 2% of the emissions is in conflict with the progressive rise in forest fires, which in 2005 reached 94,000 Ha (up to 7 August 2005), compared with an average 72,000 Ha/annum in the last 10 years. Such an increase would mean, assuming that one Ha sequesters approximately 20 tCO_2/annum, 22,000x20 tCO_2eq./Ha.año=0.44 $MtCO_2$ eq./annum, a value very similar to the annual emissions of the frit sector.

Development of the flexibilisation mechanisms has already begun in their MCL version (Mechanism of Clean Development) with third party countries, by the electricity companies: ENDESA has approved a project for a hydroelectric plant in

Collahuaca in Peru, and the renovation of minihydraulics in Panama, while Iberdrola is negotiating a project on wind energy in Mexico and another hydroelectric plant in the valleys of Guatemala. as MCLs (Mechanisms of Clean Development). To reach 7% reduction in the emissions foreseen in the PNA for the period 2005-2012 may be possible, although the electric companies will probably claim the reductions for the electric sector.

3.2. DATA AND CRITERIA DERIVING FROM RD 1866/2004 APPROVING THE NATIONAL PLAN OF ASSIGNMENT OF EMISSION RIGHTS (PNA).

In order to extrapolate the reduction targets in the first post-Kyoto quinquennium 2008-2012 for the non-regulated sectors we may consider that the criteria already approved will be followed, in addition to those that have been used in the implementation of the emissions rights trade in the European Union and Spain (Directive 2003/87/CE establishing a regime for GHG emissions rights trade in the EU, RD Law 5/2004 regulating the regime for GHG emissions rights trade, and RD 1866/2004 approving the National Plan of Assignment of emission rights (PNA):

- (I) It is assumed that the reduction target approved by the summit of heads of State and of government of the European Union of March 2005 will remains at the average value between 15 and 30%, a reduction of 22.5% in 2020 in regard to 1990.
- (II) The reduction differential for Spain is assumed to be similar to that which was established in the application of the reduction target derived from the Kyoto Protocol in 1997. In that case the reduction on a global level was 5.25% and Spain was allowed an increase of 15% (a differential of 20.25%); in addition, it is assumed that the Spanish State will maintains a reduction associated with sinks in the 8 years 2005-2012 similar to the reduction in 8 years of 2005-2012 (2%), and also in this period is willing to move to the flexible systems and the payment of rights for 7% of the emission. When these conditions are applied with the same differential to the EU target for 2020, Spain could increase its emissions by 6.75% in regard to the emissions of 1990 (-22.5+2+7+20.25). With this increase the emissions target of the regulated sectors of the Spanish State is 127.21 $MtCO_2$ eq./annum; this means a reduction of 20.59 $MtCO_2$ eq. in period 2012-2020.
- (III) Just as in the period 2005-2012 it is assumed that the electric sector will conform to an increase of only 6.75% of its emissions in the period 2012-2020 in regard to its emissions of 1990: an increase of 4.13 $MtCO_2$ eq./annum, which involves a reduction on its emissions estimated in the previous section for 2012 of 10.65 $MtCO_2$ eq. As result the regulated non-electric sectors must reduce 9.94 $MtCO_2$ eq. in the period 2012-2020; i.e. 0.14 $MtCO_2$ eq. for each $MtCO_2$ eq. emitted in 2012.
- (IV) It is assumed that for new entrants a 3.5% of the emissions will be maintained.
- (V) Changes in the assignments associated with the emissions per capita are not considered, assuming the entry into the market of other States with very low per capita emissions (Chinese 2.2 tCO_2/h.annum, India 1 compared with Spain 8).

- (VI) It is assumed that banking actions will not be allowed in respect of the previous periods, that the assignment is free to 100% or only 90%, and early actions are not assumed.

3.2.1. Ceramic tiles.

The ceramic tile sector would have to reduce 0.1 $MtCO_2$ eq. in the period 2012-2020, which would mean an investment of 0.25 M€/annum if that reduction is not achieved, assuming a rate of 20€/annum and a free cession of emission rights. If the free cession is only 90%, the sector will have to buy 0.07 $MtCO_2$ eq./annum, which at 20 €/annum means an additional cost of 1.4 M€/annum.

3.2.2. Ceramic frits.

In accordance with above criteria, the frit sector would have to reduce 0.08 $MtCO_2$ eq. in the period 2012-2020, which would means an investment of 0.2 M€/annum annum if that reduction is not achieved, assuming a rate of 20 €/annum. If the free cession is only 90%, the sector will have to buy 0.05 $MtCO_2$ eq./annum, which at 20 €/annum means an additional cost of 1 M€/annum.

3.3. THE FORMULATION OF PROCESSING ALTERNATIVES THAT PROVIDE GREATER ENERGY EFFICIENCY.

As indicated above, the energy efficiency of the ceramic tile industry has improved throughout the years: in 1985 about 12.5 kg CO_2/m^2 was emitted with the technology of that time, which already included the use of natural gas; in 1990 this dropped to just 6.6 kg CO_2/m^2; in 2000, it was 5.6 kg CO_2/m^2, and 4.8 kg CO_2/m^2 in 2001[12]. This reduction has largely been the result of the implementation of cogeneration strategies and improvements in drying, however, there are authors who defend, with sound discernment, that the engineering of the single-deck kiln, has varied comparatively little from the point of view of energy efficiency by disregarding the inert charge in firing relating to the supports [17,18,19]. Table 7 details an estimation of the evolution in the relative consumptions of the tunnel kiln and single-deck kiln, based on data from the literature[18]. It is observed that the equivalent gross charge of the single-deck kiln, in spite of its reduction with time, continues to be greater than that of a traditional kiln tunnel, which did not have to heat the supports. In other words, the road travelled in raising energy efficiency in the tunnel kiln now needs to be followed in the single-deck kiln.

In this prospective improvement of kiln thermal efficiency, it must cease to be considered a mere total counter-current channel, and the release of air must be avoided, by means of judicious recirculations, since this diminishes energy efficiency and enables emitting pollutants into the labour environment. In this sense, it is considered convenient to work in several directions:

(a) Implementation of a compensation channel that enables the channel kiln to operate at depression or null pressure; this channel could allow diminishing consumption by 10%.

(b) Promoting recirculations in the kiln such as:

- recirculating air from the cooling zone at less than 700ºC as combustion air to the burners. This is the best recirculation option, which could provide savings of up to 20% in fuel, by avoiding recondensation and the production of defects caused by the SO_2 emitted above 500ºC in the heating zone, but which disappears in the firing zone by reaction with the dehydrated material.

- development of a pre-kiln zone by indirect heating with flue gases from the firing zone mixed with air, would allow the destruction of VOCs (Volatile Organic Compounds) from the increasingly important organic charge in the materials (glues, fixatives, deflocculants and binders). This operation would enable appropriate post-combustion of these VOCs, avoiding their emission into the environment, and the possible product losses caused by deposition of unburned particles. As regards fluorine, which is basically emitted in the firing zone (0.3 ppm) and in the cooling zone up to 700ºC (0.5 ppm), this would affect neither the quality nor the energy efficiency of the proposed recirculation.

(c) the promotion of more efficient oxidisers, such as air–oxygen mixtures or even pure oxygen, particularly in the case of kilns for porcelain tile, which need relatively high temperatures and heating of expensive and useless nitrogen, which produces thermal NO_x of a certain relative importance, already at those temperatures.

KILN	WEIGHT (Kg)	Cp (Kcal/Kg°C)	T(°C)	HEAT (Kcal)	GROSS CHARGE Eq.(Kg)*	Kcal/kg net
Tunnel Single firing, red body **1978**					1.290	927
Metallic structure	220	0.13	200	5720		
Bench	700	0.26	500	91,000		
Supports	551	0.26	1150	164,749		
Useful charge	416	0.26	1150	124,384		
TOTAL	1887			385,853		
Tunnel Single firing, red body **1978** with supports	1336			221,084	739	531
Single-deck Single firing, red body 40 min. **1990**					900	650
Single-deck Single firing, red body 40 min. **2000**					800	575

(*) estimated without considering endothermic reactions associated with firing that would diminish it by 20%.

Table 7. Evolution of relative consumptions in the tunnel kiln and single-deck kiln[17].

3.4. THE INCORPORATION OF OTHER GHG CHEMICAL COMPOUNDS IN THE KYOTO CATALOGUE, ESSENTIALLY HF AND O_3

Kyoto only considers six GHGs[20]: CO_2, CH_4, N_2O, CFCs, HCFCs and SF_6. In accordance with article 4 section 1 of the Kyoto Protocol, the reductions of the first three gases are in respect to the levels in 1990 and those of SF6 and the two families of fluorated gases, CFCs and HCFCs, in respect to the 1995 levels. In actual fact all the fluorated gases have a greenhouse effect. The European Commission has submitted a regulation proposal on certain fluorated GHGs; aspects include changing the alumina feed in the electrolytic tanks of the aluminium industry and gas substitution in the recovery units of ammonia manufacturing plants. It would seem reasonable to incorporate into the catalogue the fluorated GHGs that the ceramic tile industry emits, involving about 2,115,250 kg F/annum at a rate of 24 mg F/Nm^3 and an emission factor of 0.25 kg F/t. (in the EPER Report 2001, regulated companies declared 86.49 t/annum, approximately 4.1% of the gross emissions of fluorated gas, measured as fluorine) [21]. The reduction of these emissions by correction systems that immobilise fluorated gases to fluorita injecting CaO could involve, if we considered for HF a GHG potential of the order of 100, up to 0.2 $MtCO_2$ eq./annum (for the regulated companies, if the assumption is made that 18% of the emissions means 0.036 $MtCO_2$ eq./annum, which, in accordance with the reduction data in Table 4 could involve up to 36% of the overall reduction that the regulated installations in the sector would have to accept.

On the other hand, ozone O_3 is a gas to be preserved in the stratosphere for its protective effect against ultraviolet radiation to pave, but which, in the low atmosphere, is detrimental because of its oxidising power, with harmful effects on the plants, materials and human health. It is not a gas emitted by the industry or any other human activity. It is generated in the atmosphere by the interaction of three basic components: sunlight, nitrogen oxide emissions (NO and NO_2), and hydrocarbon vapours (VOCs or volatile organic compounds, basically vapours of petrols, diesel oil and other industrial hydrocarbons). In this sense, the fight against pollution by tropospheric ozone is also a battle against climate change. The frit sector emits around 4800 t NO_x/annum (with an approximate emission factor of 8 g/kg)[21]. Since we may estimate a GHG potential of 8 for ozone and a NO_x/O_3 conversion factor of about 0.001, the reduction by means of oxycombustion of the NO_x emissions by the frit industry, in addition to the emitted CO_2 by 66%, would entail an additional reduction of 0.2 Mt CO_2 eq./annum associated with the ozone reduction, since oxycombustion reduces NO_x emissions by 53% (Table 5); for the regulated industry, around 18% of the total involves a reduction of 0.036 Mt CO_2 eq./annum.

3.5. THE INCORPORATION OF ACTIVITIES ASSOCIATED WITH THE PRODUCTION OF GHG EMISSIONS DIFFERENT FROM COMBUSTION

The regulated sectors are the ones that conduct their activity directly with fossil fuels: generation of electricity, cement, oil refining, iron and steel industry, ceramics, glass, paper pulp. And within these sectors, only the installations that exceed a given threshold are involved. It is to be hoped that with the development and maturing of the emission rights market, new activities and installations with lower emission evolve.

The activities that should be incorporated into the emissions market are those of the aluminium industry, already mentioned when discussing the incorporation of fluorated gases and the great transport companies: aviation, transport by road, sea and high-speed rail. Forestry is also mentioned in the priorities of the European Commission[16].

The pollution from aviation is very important, not only in regard to introduction of GHGs, but also in the release of NO_x into the high layers of the atmosphere, where it can do most harm to the ozone layer. Aviation emissions have increased 73% in 2003 in relation to 1990 in Europe; 6% of the total corresponds to flights to third countries which would enable the EU to use these in the quota exchange mechanisms, and to restrain the rising tendency.

Road and sea transport are sectors that use fossil fuels in an intensive form; thus, a dump truck displays the emissions indicated in Table 8. Considering that the ceramic tile sector transports 10 Mt/annum and that after processing, it must transport the products an average of only 300 km, at a rate of 20 t/transport (route mine–factory–port), the net emissions of the ceramic tile transport fleet can be estimated at 0.65 $MtCO_2$ eq./annum, i.e. 9% of the estimated assignments to the tile sector for 2020 (Table 6) or 1,575 tNO_x/annum, 33% of the annual emissions of these compounds by the frit industry[20].

COMPOUND	AVERAGE EMISSIONS (g/km)
Organic acids	0.19
Aldehydes	0.19
Hydrocarbons	2.13
NO_x	21
CO	12.75
SO_2	1.50
Particles	0.76
CO_2	750

Table 8. Mean emissions of a dump truck of 600 metric horsepower (g/km).

The incorporation of new sectors into the emissions trade could, in principle, involve an increase in the offer of emission rights which could benefit the sectors that needed to go to the market. However, the evolution is, in fact, difficult to foresee.

3.6. THE REDUCTION OF EMISSION THRESHOLDS IN THE REGULATED SECTOR

The reduction of the thresholds also seems logical and in accordance with the projection by EPER of achieving 90% of the sectoral emissions and reach the small and medium-sized companies[21,22]. This threshold modification could fundamentally affect the tile sector, since in the PNA of 2005-2007, as necessary threshold, those companies with more than 300 kg/m^3 charge density per kiln had been considered, to which access was had because of real early actions, but used non-explicitly, since these actions are not envisaged in the PNA.

The only effect of this reduction is the incorporation of more companies into the emissions market, independently of their size, proportionally increasing the need to purchase rights or surplus rights, which seems, in addition to being fair, a generator of loyal competition, since not just a few with a scale economy must face the reduction. The regulation can be understood from a twin perspective, from a rights-buying perspective, if the sector considers itself short in emission rights, which is a short-term cost. However, from a selling perspective, if the sector considers itself able to reduce emissions, the regulation generates assets in the short term.

In the interphase of the last technological change in the sector, in the years 1985-1990, there were companies that took out loans, staking on the maturity of the tunnel and multi-channel kilns, thinking that the technology was stable and doubled the kiln capacity, because of possible breakdowns or production needs. Very shortly, the flourishing and competitive technology of the roller kiln forced them to abandon those installations, which had not been paid back, and had to take out loans again for the new installations. The possession of emission rights by the regulated facilities is a further incentive for the attainment of greater energy efficiency (recirculating kiln adapted to the pollutant emissions, change of strategy in fuel use, etc.), as also is, in a forced way, the rise in prices of natural gas dragged along by oil in a competitive market of stable or even falling prices. If the technological change is needed, adjusting rapidly is important and better, in a scenario with a certain capacity for financing through the sale of emission rights.

4. CONCLUSIONS: EMISSION SCENARIOS OF THE CERAMIC TILE AND FRIT SECTORS IN 2012-2020 AND FUTURE EVOLUTION.

From the data discussed above, several scenarios could emerge:

- SCENARIO A: scenario in which the results of the non-regulated sectors are very disappointing and the reduction considered is inefficient, which should lead the EU to decide to annul the market.

- SCENARIO B: this is the base scenario; the sectors are not able to reduce emissions.

  In this scenario the situation is the one indicated in the Table 6 and the sectors will have to buy in the market:

  (b1) Tiles 0.66 MtCO_2 eq. (of these 0.56 are 10% base awarded at a political initial price).

  (b2) Frits 0.48 MtCO_2 eq. (of these 0.40 are 10% base awarded at a political initial price).

- SCENARIO C: in this scenario, tiles modify the kiln run with recirculation systems which provide it with a 30% reduction and frits applies oxycombustion which enables it to reduce emissions by 33%. In this scenario the sectors have a rights surplus:

  (c1) Tiles: reduces in 2012-2020 0.88x0.3=0.264 MtCO_2 eq. reaching a rights surplus by 0.62-0.88+0.264=0.004 MtCO_2 eq. to share in the period.

  (c2) Frits: reduces in 2007-2020 0.67x0.33=0.22 MtCO_2 eq. reaching rights a rights surplus by 0.51-0.67+0.22=0.06 MtCO_2 eq. to share in the period of 13 years.

- SCENARIO D: in this scenario tiles, in addition to the kiln run, eliminates its fluorated emissions, which are recognised for it as GHG sink at a rate of 0.036 MtCO_2 eq./annum, and frits reduces with the oxycombustion the NO_x emissions that are considered an ozone sink for it at a rate of 0.036 MtCO_2 eq./annum. In this scenario both sectors have rights surpluses:

  (d1) Tiles: reduces in 2012-2020 0.88x0.3+0.036x8=0.552 MtCO_2 eq. reaching a rights surplus by 0.62-0.88+0.552=0.292 MtCO_2 eq. to share in the period.

  (d2) Frits: reduces in 2007-2020 0.67x0.33+0.036x8=0.508 MtCO_2 eq. reaching a rights surplus by 0.51-0.67+0.508=0.348 MtCO^2 eq. to share in the period of 13 years the 0.22 of direct CO_2 reduction, and in the period 2012-2020 the ones associated with ozone.

These scenarios can be modified by the factors mentioned of the increase in regulated sectors and lowering of thresholds.

However, in the face of a problem of raw materials supply, inefficiency of the existing ones, or generation of serious harm to health or the environment, the solution has always been substitution. The application of corrective measures allows a certain abatement of the problem but never its eradication. Thus, for example, the eradication of lead poisoning in the ceramic industry in the 1970s was achieved by replacing lead glazes in the new technology, lead pollution with anti-detonant tetraethyl lead petrol additives from automobile emissions was solved with the development of unleaded petrols, using other anti-detonants; first, metyl-tert-butyl ether MTBE and, subsequently, by alkylation processes that generate non-detonating formulations .

Similarly, the solution for climate change involves developing efficient technologies with non-carbonaceous fuels: in the words of Stavros Dimas, the development of the society of low carbon consumption. The reduction of the fossil fuel reserves, the rise in prices and the instability, as well as vulnerability, of the supply of these fuels are important incentives for substitution, while the development of renewable energies and more efficient processes are, furthermore, necessary.

From the perspective of ceramic production the substitution alternatives to be explored in the coming years are electricity by thermal firing or microwaves, and hydrogen–oxygen from alternative energies, such as wind or biomass energy.

Clean hydrogen production is to be sought in ‘water electrolysis’, using electricity generated from renewable sources of biomass and wind energy. At the present time, in August 2005, with oil prices rising, at over 60 dollars a barrel, hydrogen production with wind energy is already beginning to be profitable, at between 1.12 and 3.20 dollars a gallon (3.78 litres), when by means of the methane synthesis gas method the price is 2.17 dollar/gallon[23]. In accordance with Table 3, in 2003 wind energy produced 5.35% of the electric energy in Spain; the forecast for 2010 is that it will reach 10%, and 20% for 2020 with 75 GW of installed power, which is the basis for meeting the European commitment to reach 12% in the renewable component of energy production by 2010. Wind parks are multiplying and simplifying as a result of becoming taller, and achieving greater power: of the 500 KW per wind-driven generator 5 years ago to the present time, power has been tripled to 1500 KW and the power, stability and effectiveness time increase in the case of the offshore parks (assuring velocities of 8 m/s at a height of 60 m).

The Valencian Wind Plan anticipates the installation in the regions of Castellón of a power of 730 MW distributed in six zones. On the other hand, electrochemical studies are enabling important advances in the electrolytic water-splitting process: high-temperature electrolysis (1000ºC) of water, separating the hydrogen from oxygen in a ceramic molecular sieve provides efficiencies of 50%, which improve previous processes. If all the wind park of Castellón (730 MW) generated hydrogen and oxygen for ceramics, considering a mean park operation of 60%, for only 10 hours a day, the park would be able to produce 1599 GW.H/annum; assuming an electrolytic efficiency of 35%, of the order of 559 GW.H/annum, at the present time the ceramic industry consumes around 9,713,700 MT (11,243 GW.H), so that it could supply 5% of the industry. It would be necessary to improve electrolysis efficiency, electric power generation and the number of parks to achieve autonomy with hydrogen.

The changeover to a hydrogen economy depends on the solution of important problems of implementation. However, for the ceramic and frit combustion industry, the production of wind energy and high-temperature water electrolysis would enable generalising hydroxycombustion (hydrogen as fuel and oxygen as oxidiser) with criteria of proximity and efficiency, since the intermediation of fuel cell devices would not be not necessary in this case.

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