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DEFRA and DfT

Including Aviation into the EU ETS: Impact on EU allowance prices

Final Report

01 February 2006

powered by perspective

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About ICF Consulting

ICF Consulting is an international management, technology, and policy consulting with more than 35 years experience helping public and private sector clients address complex issues in the energy, transport, environment, and economic development fields. Our more than 1,500 full-time professionals are based in major business centres in Europe, Asia, and the Americas.

Climate change has been a core competence of ICF Consulting since the mid-1980s and, globally, approximately 200 employees work full-time for a variety of corporate and government clients to help devise and implement climate change related strategies. We have considerable experience working with several stakeholders within the financial community, in particularly providing advice on the carbon impacts on asset valuation. Over the past decade and a half, ICF Consulting has carefully earned an international reputation in the field of climate change consulting for its analytical rigour, in-depth market expertise, and technical integrity through scores of climate change related assignments undertaken for:

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- financial institutions in the City and Wall Street, particularly those with an interest in developing the valuation protocols and impact analysis of environmental issues on companies in the energy and energy-intensive sectors
- international and regional institutions such as the European Commission, IPCC, OECD, IEA, Prototype Carbon Fund, International Finance Corporation, World Bank, Asian Development Bank, and UNEP
- national governments in more than 50 countries including the UK, Ireland, Canada, the US, Russia, and Ukraine.

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Glossary of Acronyms

AAU	Assigned Amount Unit
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO2e	Carbon dioxide equivalent
DET	Domestic Emissions Trading
DR	Discount Rate
EC	European Commission
EEA	European Economic Area
ERU	Emission Reduction Unit
ETS	Emissions Trading System
EU 25	All current EU member states
EU ETS	European Union Emissions Trading Scheme
EUA	European Union Allowance
InCaP	International Carbon Pricing Model
IPM®	Integrated Planning Model
JI	Joint Implementation
LCPD	Large Combustion Plant Directive
LFE	Large Final Emitters
LNG	Liquefied natural gas
MAC	Marginal abatement cost
MACC	Marginal abatement cost curve
Mt	Mega tonne
NANGAS	North American Natural Gas Analysis System
NAP	National Allocation Plan
O&M	Operations and Maintenance

OECD	Organization for Economic Cooperation and Development
RGGI	Regional Greenhouse Gas Initiative
USD	U S Dollar

1. Executive Summary

Concern over the effects of increasing concentrations of the atmospheric trace gases that produce the greenhouse effect and in particular the contribution that greenhouse gases (GHG) emissions related to human activities are making to changes in the earth's climate have been mounting since the mid-1970s. In 1992, more than 140 nations participated in the negotiations to create the United Nations Framework Convention on Climate Change (UNFCCC) and in 1997, industrialized Parties to the UNFCCC accepted binding emission targets under the terms of the Kyoto Protocol.

Resolute over its commitments, the EU has taken the lead in promoting the stabilisation of GHG emissions. A key element of EU policy is the EU Emissions Trading Scheme (EU ETS), which was established by EU Directive (2003/87/EC). During the pilot phase of trading (2005-2007), emission caps were specified for five industrial sectors and companies within those sectors were issued tradable allowances partially covering their projected emissions. At present, the European Commission is considering approaches to expanding sectoral coverage within the EU ETS to include aviation and under the UK presidency of the EU (July-December 2005) this has become a top priority. ICF Consulting has been commissioned by DEFRA to provide a quantitative assessment of the impacts that including aviation in the EU ETS will have on the price of EU allowances (EUA) during Phase II.

1.1. Methodology

The implications for EUA prices resulting from including the aviation sector in the EU ETS were derived using our proprietary carbon market model, InCaP. InCaP is designed to provide decision makers with a rigorous analysis of the range of factors that will determine the price of tradable carbon instruments for time periods out to 2027. Key components of the model applied for this study include:

- Legally binding and voluntary emission commitments by countries and regions that might participate in international emissions trading during the 2008-2012 period
- Forecast emissions for each of the participating countries/regions under three different economic growth scenarios,
- Emissions and emission targets for the six EU ETS sectors, including aviation,[1]
- Emission reduction cost forecasts under three fuel price scenarios;
- Carbon credits available through project activities under the Clean Development Mechanism (CDM); and
- "Track I" ERUs that could enter the market due to investments in emission reducing projects in countries with economies in transition.

Based on these and other inputs, InCaP generates characteristics of the carbon market and establishes the equilibrium price via the interaction of supply and demand for carbon instruments. Since carbon trading will be a global activity during the Kyoto compliance period, the EU ETS will be linked with other trading systems either directly or indirectly through the

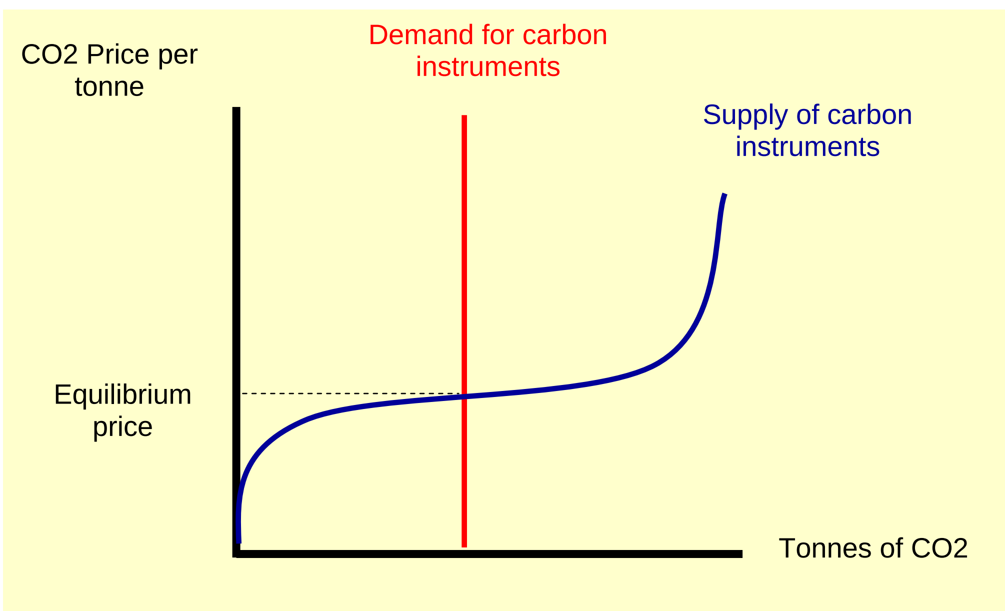
[1] InCaP includes data on a total of 19 sectors some or all of which can be selected when using the model. The sectors currently included in the EU ETS are: pulp and paper; glass, ceramics, power, cement, and iron and steel,

Kyoto Mechanisms. Thus, InCaP is designed to solve for the global price of carbon instruments with the basic assumption that in well functioning markets, average annual prices of carbon instruments will tend to equalize across trading systems as emissions trading expands into additional regions.

The **demand side** of the carbon market in InCaP is based on net global demand for carbon allowances and credits, obtained by calculating the gap between projected business-as-usual (BAU) emissions and the emissions cap for each of the countries participating in the trading market and then aggregating demand for all individual countries to get global demand for carbon allowances and credits.

The **supply of carbon instruments** is developed from the various sources of tradable carbon allowances and credits, and an aggregate marginal abatement cost curve (MACC). The supply includes: AAUs made available as a result of domestic abatement activities, CERs based on CDM project activities, and Track I ERUs based on JI projects. Figure 1 offers a stylised[2] solution to estimating the price of carbon.

Figure 1: Stylised solution for estimating the price of carbon



[2] In general, MACCs are not smooth curves such as the one shown here, but rather have horizontal segments reflecting the tendency for some abatement options to produce significant quantities of reductions at a single cost per tonne of reductions.

1.2. Policy Options Assessed

ICF Consulting's analysis in this paper is an extension of a preliminary analysis of carbon market and price effects done by CE Delft for the European Commission. In their report, "Giving Wings to Aviation," CE Delft evaluated three trading system options structured from seven key attributes. The choices made to define the policy options CE Delft analysed are presented in the table below.

Figure 2: CE Delft review of EU ETS aviation policy options

Design Element	*Option 1 (Intra-EU)*	*Option 2 (EU departing flights)*	*Option 3 (EU airspace)*
Coverage of climate impacts	CO_2 and multiplier for non-CO_2 climate impacts	CO_2 only (with flanking instruments for other impacts)	CO_2 only (with flanking instruments for other impacts)
Geographic scope	Intra-EU	Emissions of departing flights from EU airports	EU airspace
Trading entity	Aircraft operator	Aircraft operator	Aircraft operator
Decision on allocation rules	Uniform approach set at EU level	Uniform approach set at EU level	Uniform approach set at EU level
Interplay with Kyoto Protocol	Aviation buys allowances from other sectors above a historic baseline	Unrestricted trading based on AAUs borrowed from other sectors	Trading with other sectors based on a gateway mechanism
Allocation method	Baseline	Benchmarked allocation	Auctioning
Monitoring method	Actual trip fuel reported by aircraft operator	Actual trip fuel reported by aircraft operator	EUROCONTROL DATA (ex ante and radar)

After estimating the emissions and emission reductions that would be required under each of these options, CE Delft concluded that incorporating the aviation sector in the EU ETS would not result in significant price effects. Their results, however, are purely assumption driven and not sufficiently robust for purposes of policy implementation. Our analysis takes as a starting point the options defined in the CE Delft report along with the emission and emission reduction requirements they calculated and incorporates these into three InCaP carbon market scenarios to assess the impacts aviation sector trading could have on carbon prices.

1.3. InCaP scenarios

Three unique InCaP scenarios were defined for this project. We refer to these as the low-, base-, and high-case scenarios in reference to the general implications of the variables selected for the overall level of demand for carbon instruments. The definitions applied for each of the six key variables are presented in the table below.

Figure 3: 2008-2012 Scenario assumption overview

	Scenario 1 (low)	*Scenario 2 (base)*	*Scenario 3 (high)*
Gas prices	Low	Base	High
German Nuclear closure	Delayed	As planned	As planned
Abatement activity	All sectors active	All sectors active	All sectors active
"Track I" ERUs entering the trading system	30% - 100%	0%-30%	0%
CERs available for purchase	120 Mt CO2e	90 Mt CO2e	60 Mt CO2e
Other gases and sectors in EU ETS	None added	None added	None added

1.4. Price Effects of Including Aviation in the EU ETS

Using the carbon market scenarios outlined above and the policy options considered in the CE Delft report, ICF Consulting generated nine different price forecasts. The results of all nine of the runs of InCaP are summarised in Figure 4. As indicated, the addition of the aviation sector does not cause a change in EUA prices under any of the scenarios examined. The low-, base-, and high-case scenario prices (€5, €11, and €21 per tonne of CO2e respectively) do not change when aviation sector emission reduction requirements are placed on the system. Other changes, however, do occur. Specifically, the level of purchases of "Track I" ERUs under the low-, and base-case scenarios, and in the level of abatement on the part of the energy sector in the high-case scenario are affected when aviation sector demand for carbon instruments is added to the EU ETS.

Figure 4: Impact of aviation of projected EUA prices for 2008-2012

Impact of aviation sector on EUA price forecast						
Policy option	Price forecast					
	Low		Base		High	
	Change in Demand (CO2e)	Price	Change in Demand (CO2e)	Price	Change in Demand (CO2e)	Price
Aviation not included in EU ETS	0	€5	0	€11	0	€21
Intra-EU	10.12 Mt	€5	10.12 Mt	€11	10.12 Mt	€21
Departing from EU	12.72 Mt	€5	12.72 Mt	€11	12.72 Mt	€21
EU airspace	11.14 Mt	€5	11.14 Mt	€11	11.14 Mt	€21

Emission and emission reduction estimates for the aviation sector indicated an average annual increase in system wide required CO2e emission reductions of 10.12 Mt for the Intra-EU policy option, 12.72 Mt under the Departing from EU policy option, and 11.14 Mt under the EU Airspace option.

1.4.1. Low-case Scenario

The analysis from InCaP indicates that total required reductions in the low-case scenario equals 702.1 MtCO2e when aviation sector emission reductions are not included. Relative to the reductions required of aviation under the three policy options, this amount is quite large. As a result, the increase in demand for CO2e instruments is easily absorbed by increased purchases of “Track I” ERUs.

1.4.2. Base-case Scenario

As with the low-case scenario, the increase in average annual required emission reductions under the three policy options results in relatively small changes for the overall market in this scenario as well. Likewise, in this scenario, these changes in required reductions are easily absorbed by changes in purchases of “Track I” ERUs. These changes occur without having an impact on the average annual market price of carbon allowances.

1.4.3. High-case Scenario

Again, relative to the level of reductions required in the market as a whole, the increase in average annual required emission reductions under the three aviation policy options is small in this scenario. The notable difference between this scenario and the other two scenarios is that in this case, Track I ERUs are not available for purchase in the carbon market. As a result, all of the additional demand for allowances must be accommodated through reductions in power sector emissions. In particular, the number of Track I ERUs purchased remains at 0 and power sector abatement increases enough to free-up all of the extra allowances needed to accommodate the additional demand coming from the aviation sector.

2. Introduction

Since the mid-1970s growing international concern at rising atmospheric concentrations of Greenhouse Gases (GHGs) has led to increased scrutiny of human sources of emissions. This scrutiny has been translated into international agreements to limit GHG emissions (e.g., 1992 United Nations Framework Convention on Climate Change; and negotiation of specific country GHG emissions targets in the 1997 Kyoto Protocol).

The Kyoto Protocol helped stimulate the creation of regional policies, including the EU Emissions Trading Scheme (EU ETS), which began operation in 2005 and will evolve into a second phase in 2008-2012. Carbon trading schemes are also being developed by Canada, Japan, Norway, 12 US-States and the Australian Territories. These systems are also set to commence in 2008, to coincide with the implementation of the Kyoto Protocol.

The EU Directive (2003/87/EC) established the EU ETS within the European Community as a key instrument to stabilise EU carbon emissions originating from five sectors in the pilot Phase I: 2005-2007. The language of the legislation further enables additional industrial sectors as well as other greenhouse gases to be incorporated into Phase II of the EU ETS: 2008-2012.

Growth in the aviation sector and associated GHG emissions has prompted the UK Government to propose that the best way of ensuring aviation contributes towards the goal of climate stabilisation is through participating in a well-designed emissions trading regime. The Government further expresses the desire to see aviation joining the EU ETS from 2008, or as soon as possible thereafter. Under the UK presidency of the EU (July-December 2005), the Government has made taking forward the work programme for the inclusion of intra-EU air services into the EU Emissions Trading Scheme a top priority.

The European Commission is considering ways of reducing the climate change impacts of aviation, one of which is the inclusion of aviation emissions into the EU ETS. At present Phase 1 of the scheme does not include emissions from aviation and, in addition, international aviation emissions are not covered by the Kyoto Protocol. The Commission has carried out a study (by CE Delft) entitled *'Giving Wings to Emissions Trading: Inclusion of aviation under the European emission trading system (ETS): design and impacts'* [3] The study assesses alternative approaches to incorporating aviation in emissions trading during the 2008 – 2012 commitment period.

Because its abatement costs are high when compared to other sectors, it is generally anticipated that placing an effective emissions cap on the aviation sector will mean that the sector will be a net buyer of allowances. In other words, if the aviation sector is given an emissions cap requires the industry to reduce emissions, it will most likely find that it is more cost-effective to purchase emission reductions rather than undertake abatement. It is important to understand the implications of this for the price of carbon allowances and, by extension, the potential commercial impacts on other industries in the EU ETS during Phase II (2008-2012).

[3] CE Delft (2005) "Giving wings to emissions trading: Inclusion of aviation under the European Emissions Trading System – design and impacts" European Commission. Available at: http://www.europa.eu.int/comm/environment/climat/pdf/aviation_et_study.pdf

There are other factors that will influence the allowance price, including the number of allowances issued in Phase II of the EU ETS and the number of project credits (JI/CDM) introduced into the market.

To inform policy development and respond to any Commission proposal, DEFRA has commissioned ICF Consulting to quantify the impacts of including aviation in the EU ETS with consideration for likely impacts of the inclusion of aviation in the EU ETS on the EU allowance price.

3. Methodology

3.1. Introduction

Our analysis of the CO2e cost implications of including aviation in the EU ETS was developed using ICF Consulting's proprietary International Carbon Pricing Tool (InCaP). InCaP is a state-of-the-art model of the global carbon market that generates estimates of the average annual price of tradable carbon instruments—allowances and emission reduction credits—over the short, medium, and long-term. This section provides an introduction to the key variables used by InCaP, including inputs provided by another of ICF's proprietary models, and a discussion of the base case assumptions used in estimating the price effects of aviation sector participation in emissions trading.

3.2. The International Carbon Pricing Tool

InCaP was created to aid decision making by governments assessing climate policy options and by firms facing carbon constraints as a result of national level policies designed to reduce emissions of GHGs. The model was constructed from bottom-up analyses of the full range of factors that determine the demand for and supply of tradable carbon instruments. The key components applied in this study include:

- Legally binding and voluntary emission commitments by countries and regions that might participate in international emissions trading during the 2008-2012 period
- Forecast emissions for each of the participating countries/regions under three different growth scenarios,
- Emissions and emission targets for the six EU ETS sectors, including aviation (InCaP includes data on a total of 19 sectors some or all of which can be selected when using the model. In addition to aviation, model runs for this analysis included the following sectors: Power; Refineries; Pulp and paper; Glass; Iron and steel; and Cement, bricks, ceramic),
- Emission reduction cost forecasts under three fuel price scenarios;
- Carbon credits available through project activities under the Clean Development Mechanism (CDM); and
- Track I ERUs that could enter the market as a result of investments in GHG abatement in countries with economies in transition.

InCaP uses these and other inputs to construct demand and supply curves representing the market for carbon instruments. The equilibrium market price of carbon instruments is determined by the interaction of the two sides of the market. Since carbon trading will be a global activity during the Kyoto compliance period, the EU ETS will be linked with other trading systems either directly or indirectly through the Kyoto Mechanisms. Thus, InCaP is designed to solve for the global price of carbon instruments with the basic assumption that in well functioning markets, average annual prices of carbon instruments will tend to equalize across trading systems as emissions trading expands into additional regions. The following provides an overview of the dynamics of the model.

3.2.1. Demand Side Analysis

Two of the key elements determining the demand side of the market for carbon instruments are the emission commitments of countries and other entities that will be participating in emissions trading and the level of actual emissions that these entities will be required to address. The demand for carbon instruments will ultimately be driven by the difference between Assigned Amounts and actual emissions.

InCaP contains data on the emissions and emission commitments of all Annex I countries that agreed to cap their GHG emissions under the terms of the Kyoto Protocol. In addition, InCaP provides users with the option of setting emission limits for each of these countries as well as for three of the largest developing countries for commitment periods that could follow 2008-2012. Targets for all countries that have ratified the Kyoto Protocol are relative to the base year specified in the Protocol (generally 1990).

For each country and region, InCaP also contains GHG emission forecasts that are derived from projected underlying economic activity. For each country in the model, GHG forecasts were created for a set of three alternative economic growth scenarios with unique estimates of growth rates used in estimating economic activity and resultant emissions.

Emissions and emission projects for each of the individual sectors within each country covered by InCaP are also included in the model. Users of the InCaP tool have the option of defining emission caps applicable to trading sectors for each country.

3.2.2. Supply Side Analysis

On the supply side of the model the key variables include emission reduction potential and costs for each of the industries included in the model, the quantity of CERs available as a result of CDM related activities, and the quantity of Track I ERUs that could enter the market.

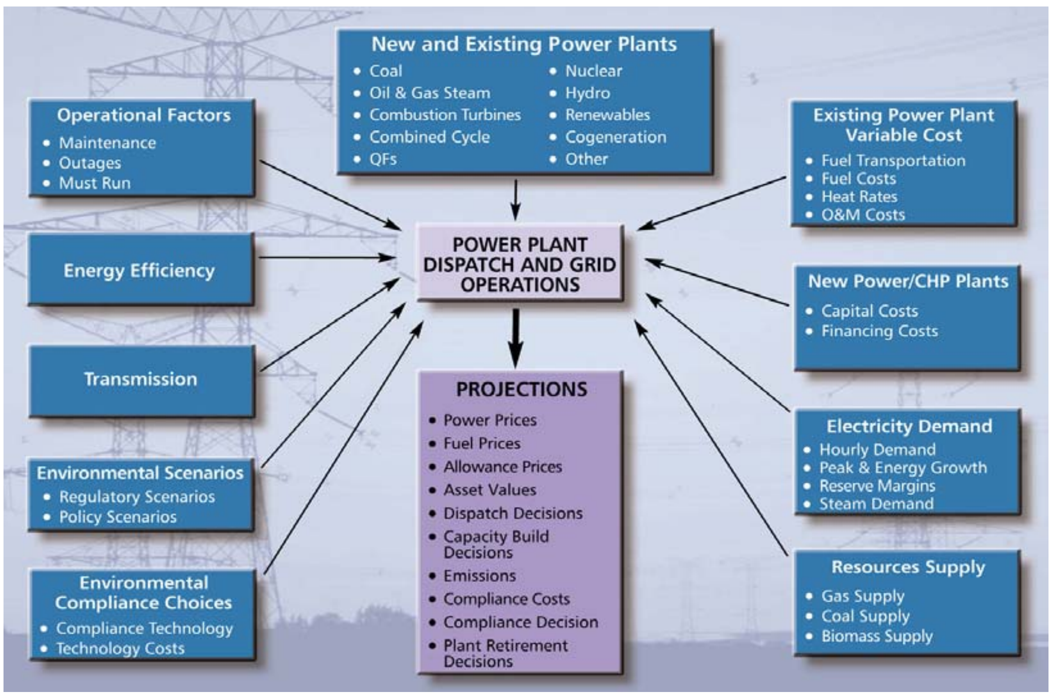
- **Marginal Abatement Cost Analysis**

For each of the sectors included in the model, marginal abatement cost (MAC) analysis is used to provide information about emission abatement potential and costs. MAC curves used in the model are based on research and analysis previously performed by ICF Consulting as well as information available from other sources. To derive results for use by InCaP, MAC curves for individual sectors are aggregated to form a single curve that relates the costs of reductions, and hence the costs of freeing up allowances for sale in the carbon market, with the quantity of reductions/allowances available for purchase.

ICF Consulting's Carbon Market Model uses an aggregate MACC that was constructed using information on abatement options across multiple sectors. For all sectors other than the power sector (see discussion of the IPM model that follows), points on the MACC were developed using engineering data on technical potential to reduce emissions and a discounted cash flow analysis to estimate the costs associated with implementing the option. This type of analysis takes into account the initial cost of equipment associated with a new technology, costs related to installing new equipment, operations and maintenance costs throughout the useful life of the technology, scrap value at the end of equipment's useful life and any additional revenues (such as from the sale of landfill gas) generated as a result of using the technology.

For the power sector, InCaP incorporates MAC results derived using ICF Consulting's Integrated Planning Model (IPM). The IPM is an optimisation model that uses a dynamic linear programming formulation to select investment options and to dispatch generating and load management resources to meet overall electric demand today and on an ongoing basis over the chosen planning horizon, subject to appropriate security requirements, resource mix, unit operating characteristics, environmental restrictions, transmission possibilities, and fuel costs (see Figure 5). As one indicator of the model's currency, it is licensed by several major energy market participants to inform strategic decision-making and globally has been used to support financing of more than 100 GW of investments in the past 3 years alone. For a further detailed explanation of the IPM please see Appendix A.

Figure 5: Integrated Planning Model approach



- **Certified Emission Reductions**

The supply side of the model also incorporates estimates of the number of CERs that will be available for sale in the carbon market. See Figure 6 for a detailed discussion of CERs and ERUs.

Figure 6: CERs vs ERUs

CERs vs ERUs
Certified Emission Reductions (CERs) obtained as a result of CDM projects effectively expand the emissions ceiling implied by Party commitments under the Kyoto Protocol. That is, because CERs are generated by undertaking emission abatement projects in countries

that are not covered by Kyoto commitments, when credits based on those projects enter the international trading system they allow countries with commitments to increase their emissions relative to their targets. Thus, CERs are an additional source of tradable CO2e instruments and must be added to the supply of instruments in calculating the emissions trading market.

Emission Reduction Units (ERUs), the tradable instruments investor nations are eligible to receive by funding Joint Implementation projects, do not have the same implications for the trading regime. When ERUs are created and transferred to an investor nation, the Assigned Amount of the host is reduced by an amount equal to the quantity of ERUs received by the investor nation. As a result the overall cap remains the same and hence, ERUs do not represent an additional supply of instruments in the market for carbon instruments.

The development of ERUs vary according to the "Joint Implementation Track" through which they were generated. The track process is applied to participating countries and represents the process through which Joint Implementation projects may be designed. "Track I" Joint Implementation countries are required to meet strict eligibility criteria enabling the host country to set its own additionality criteria for projects on a project-by-project basis through bilateral agreements between the participating countries. "Track II" Joint Implementation countries need only meet a limited number of eligibility criteria and consequently require a UNFCCC Supervisory committee to assess the additionality criteria of potential projects.

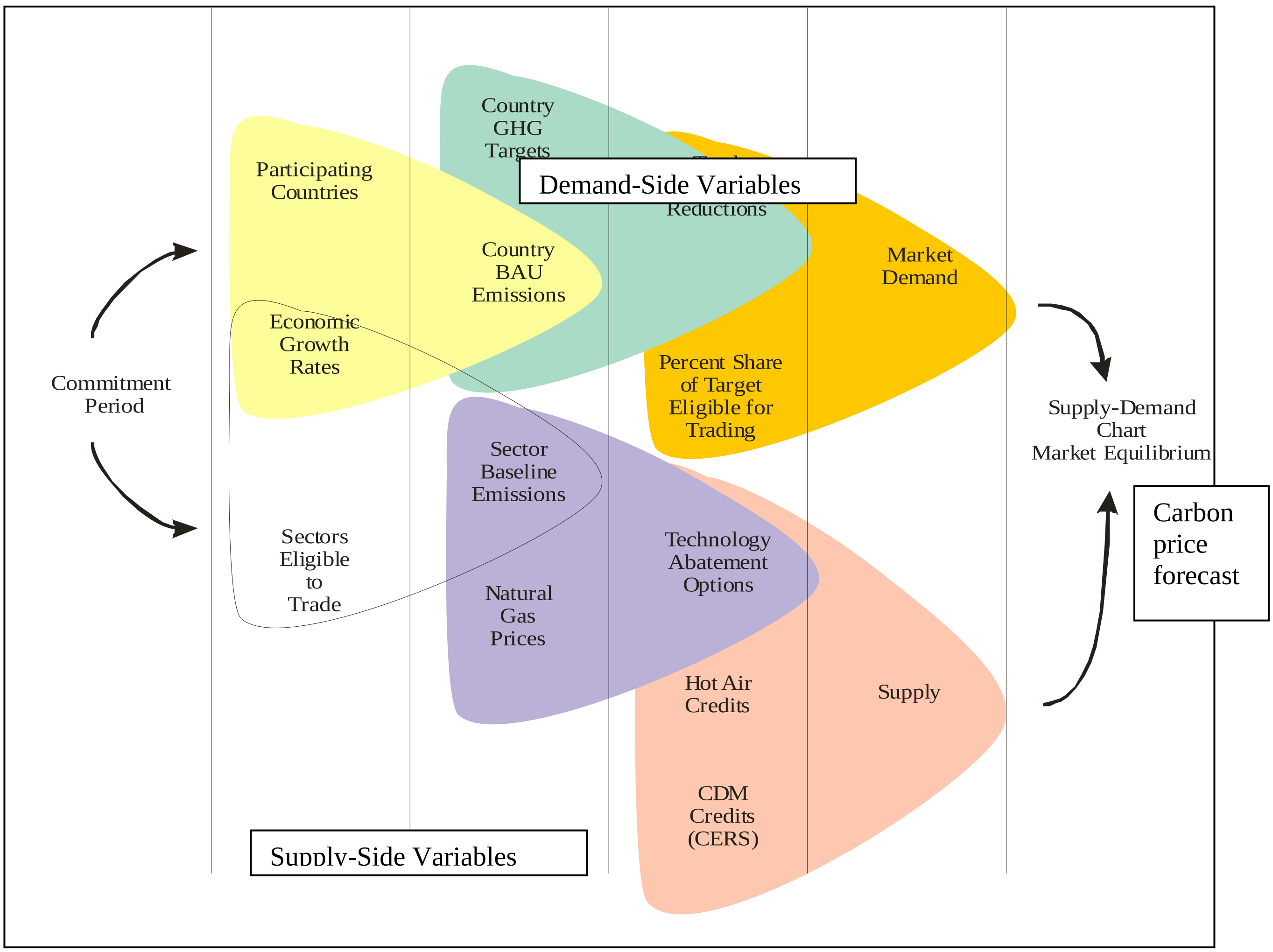
- **Track I ERUs**

On the supply side of the analysis, InCaP incorporates the potential for surplus AAUs from Russia, the Ukraine, and other countries that have experienced significant economic downturns since the 1990 base year on which commitments are based in the Kyoto Protocol to be converted into Track I ERUs and sold into the carbon market. For the Kyoto Period, InCaP's treatment of these instruments is based on an assumption that investor nations could obtain ERUs as a result of undertaking abatement projects in countries holding surplus AAUs and that as long as the investments are cost effective, investor nations will have an incentive to undertake these types of projects. The approach to modelling the flow of Track I ERUs is based on revenue maximization as controlled by counties with economies in transition. That is, InCaP calculates the quantity of Track I ERUs entering the market based on an assumption that countries such as Russia and the Ukraine will limit investments in JI projects and thus limit the flow of Track I ERUs so as to ensure that the returns they realize are at a maximum.

Banking of unsold AAUs is also allowed by the model with potential sales permitted in the first commitment period following Kyoto (2013-2017). Note that as mentioned in the text box above, converted AAUs from countries with economies in transition do not increase the overall cap on the international trading system. Track I ERUs displace surplus AAUs with total required reductions remaining the same.

Figure 7 illustrates the grouping of the supply-side and demand-side factors and the information flow that generates the supply and demand equations for each commitment period included in InCaP.

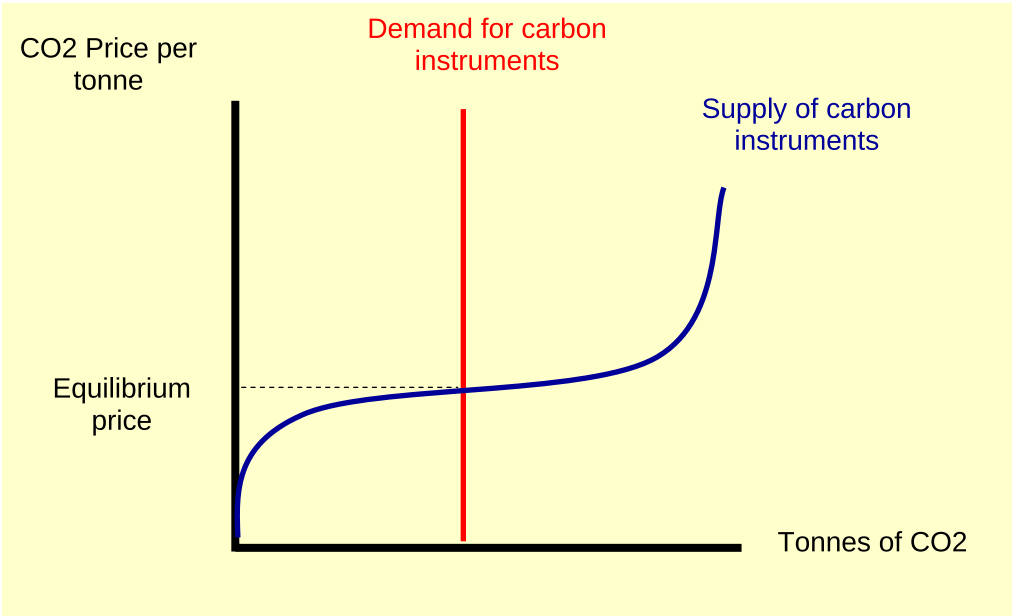
Figure 7: Information flow within the InCaP Tool



The **demand side** of the carbon market in InCaP is based on net global demand for carbon allowances and credits, obtained by calculating the gap between projected business-as-usual (BAU) emissions and the emissions cap for each of the countries participating in the trading market and then aggregating demand for all countries included in InCaP to derive global demand for carbon allowances and credits.

The **supply of carbon instruments** is developed from the various sources of tradable carbon allowances and credits, and an aggregate marginal abatement cost curve (MACC). The supply includes: AAUs made available as a result of domestic abatement activities, CERs based on CDM project activities, and Track I ERUs. Figure 8 offers a stylised[4] solution to estimating the price of carbon.

Figure 8: Stylised solution for estimating the price of carbon



[4] In general, MACCs are not smooth curves such as the one shown here, but rather have horizontal segments reflecting the tendency for some abatement options to produce significant quantities of reductions at a single cost per tonne of emissions.

4. CE Delft aviation report analysis

4.1. Introduction

The aviation sector's contribution to global climate change is growing. The Intergovernmental Panel on Climate Change (IPCC 1999) estimated that in 1992, the aviation sector's annual contribution to radiative forcing was 3.5 percent of the total from all GHG sources related to human activities. In addition, the IPCC projected that by 2050 this amount could increase to around 5 percent. The UK Government has expressed the view that the best way of ensuring that the aviation sector is engaged in efforts aimed at climate stabilisation is through participating in a well-designed emissions trading regime. The Government further expresses the desire to see aviation joining the EU ETS from 2008, or as soon as possible thereafter. Under the UK presidency of the EU (July-December 2005), the Government has made taking forward the work programme for the inclusion of intra-EU air services into the EU Emissions Trading Scheme a top priority for the UK Presidency of the EU (July-December 2005).

During the pilot period from 2005-07, the EU Directive (2003/87/EC) establishing a framework for GHG emissions trading within the European Community includes only CO2 originating from five sectors. The language of the legislation, however, provides for the addition of other industrial sectors as well as other gases during the period 2008-2012.

The European Commission Report "Giving Wings to Emissions Trading" addresses a range of design considerations and potential impacts associated with expanding the EU ETS to cover the aviation sector. The report provides an analysis of seven basic system design options, assesses three alternative scenarios for capturing the climate impacts of aviation, and provides an analysis of three specific trading system designs that could be implemented to cover the aviation sector.

The purpose of the present paper is to evaluate the market impacts assessment contained in the EC report, provide an analysis of the strengths and weaknesses of the assumptions on which the analysis are based, and ultimately determine the quality of the conclusions drawn as regards the impact on the market for carbon allowances of opening the EU ETS to aviation.

4.2. Policy Options Assessed in the EC Report

The EC report analysed alternatives for specifying seven key emissions trading system design elements in a trading scheme that covers aviation sources. Choices for each of these elements were made to form three trading systems that are referred to as policy options for the aviation sector. Figure 9, which is reproduced from the report, provides the specifications for the three policy options.

Figure 9: CE Delft review of EU ETS aviation policy options

Design Element	*Option 1*	*Option 2*	*Option 3*
Coverage of climate impacts	CO2 and multiplier for non-CO_2 climate impacts	CO2 only (with flanking instruments for other impacts)	CO2 only (with flanking instruments for other impacts)
Geographic scope	Intra-EU	Emissions of departing flights from EU airports	EU airspace
Trading entity	Aircraft operator	Aircraft operator	Aircraft operator
Decision on allocation rules	Uniform approach set at EU level	Uniform approach set at EU level	Uniform approach set at EU level
Interplay with Kyoto Protocol	Aviation buys allowances from other sectors above a historic baseline	Unrestricted trading based on AAUs borrowed from other sectors	Trading with other sectors based on a gateway mechanism
Allocation method	Baseline	Benchmarked allocation	Auctioning
Monitoring method	Actual trip fuel reported by aircraft operator	Actual trip fuel reported by aircraft operator	EUROCONTROL DATA (ex ante and radar)

While it is possible to quibble with the choices made in any type of analysis where all feasible alternatives are not evaluated, the options defined for this study serve the purpose for which they were elaborated—i.e., to examine the implications of different approaches to covering aviation in the EU ETS. Moreover, the arguments made regarding the choices are sound and the report states very clearly that the objective was not to find the "optimum" policy approach but rather to examine alternatives. Thus, while it might be argued that due to the high degree of scientific uncertainty associated with the use of a multiplier to capture non-CO2 climate impacts, considering a system in which coverage is defined in this manner (see Option 1 above) is unlikely to contribute to finding the "optimal" system, given the context within which the options were specified, it does make sense to consider as many of the alternative ways of defining the design elements as can reasonably be done within the limited number of options that could be evaluated.

4.3. Carbon Market Impacts

For each of the Options defined in the table above, the report provides estimates of the emission impacts associated with implementing the option. These effects were calculated from estimated changes related to higher airline operating costs and resulting changes in ticket prices that CE Delft estimated would come about as a result of higher costs. Ten basic assumptions, which are listed at the beginning of Chapter 5 of the report, form the basis of the analysis. Key assumptions include assuming the cost of allowances would range from €10 per tonne of carbon equivalent to €30 per tonne and that an emissions limitation would be set at 2008 business-as-usual emission levels as projected using the AERO-MS model.

In addition, the analysis assumes that the aviation sector will grow by 5 percent per year over the period from 2004 through 2012 but the growth in emissions will be somewhat lower because of fuel efficiency improvements, which are assumed to take place at a rate of 1 percent per year for a net increase in emissions per year of 4 percent.

The results of this analysis of the change in aviation sector emissions are presented in the Figure 9 below, which is reproduced here from Table 25 of the report. Note that in deriving their results for options 1 and 2, CE Delft assumed that opportunity costs associated with an emissions cap would be fully passed on by airlines to consumers.[5]

Figure 10: Analysis of aviation sector emissions

	Option 1	*Option 2*	*Option 3*
BaU emissions in 2012	71 Mt	178.5 Mt	156.5 Mt
Allowance price: €10 tCO2e			
Reduction of CO2e.	20.3 Mt	25.9 Mt	22.7 Mt
Share of 2012 aviation emissions under the scope considered	29%	15%	15%
Allowance price: €30 tCO2e			
Reduction of CO2e	19.9 Mt	25.9 Mt	22.7 Mt
Share of 2012 aviation emissions under the scope considered	28%	15%	15%

To assess the implications of the trading system options for the EU ETS, the report goes one step further and provides estimates of the number of allowances that the aviation sector will want to purchase from the EU ETS in 2012. These results, which are found in Table 30 of the report, are reproduced in the following table.

[5] For a complete discussion of the approach CE Delft used to develop these estimates see Chapter 5 of their report "Giving Wings to Emissions Trading."

Figure 11: Estimated demand of allowances by the aviation sector

	Allowances (in million tonne)	*Percent of present allowances in ETS*
Allowances CO2 emissions present Emission Trading System (2005-2007)		
Allocated CO2 emissions	2,200 Mt	100.0%
Allowances bought by aviation from other sectors (2012)		
Allowance price € 10 per ton		
Option 1	20.0 Mt	0.9%
Option 2	24.8 Mt	1.1%
Option 3	20.7 Mt	0.9%
Allowance price € 30 per ton		
Option 1	19.3 Mt	0.9%
Option 2	22.7 Mt	1.0%
Option 3	17.1 Mt	0.8%

In addition to the assumptions in Chapter 5 where environmental impacts are estimated, three additional assumptions were made to produce the results in the table above:

- The number of allowances in the EU ETS in 2012 will be similar to the number of allowances in the system during the 2005-2007 phase—i.e., 2,200 Mt
- No new sectors other than aviation will be added to the EU ETS; and
- The allocated amount in National Allocation Plans will not be significantly different in 2012 vs. 2005.

The general conclusion reached for carbon market impacts is that the relatively small increase in demand for carbon allowances that is likely to come out of the aviation sector for any one of the three options considered is unlikely to result in a significant impact on the price of allowances during the second phase of the EU ETS. Over the longer run—i.e., for any commitment phase beyond 2012—the report concludes that continued growth in aviation could result in stronger impacts on the carbon market. However, the report concludes that existing participants in the EU ETS will realise a net benefit from the addition of the aviation sector to the EU ETS, stating, “the additional mitigation costs incurred would be more than outweighed by the financial transfer received in return for allowances sold to the aviation sector.”

It is important to note, that the above statement about the net effects of higher carbon prices is correct from an economic theory perspective. That is, on *net* current participants will gain from the inclusion of aviation in the existing EU ETS. Only some current participants, however, will gain if the price of carbon allowances rise. Others, notably those that are buyers both before and after the addition of the aviation industry, will lose. Firms and even industries that do not have cost-effective mitigation options will face higher costs and experience real losses if adding aviation causes even a small rise in their cost of compliance with emission targets. Thus, unless those firms that gain as a result of including aviation somehow compensate those that suffer when allowance prices rise, adding aviation to the EU ETS will have detrimental effects on a subset of current participants in the trading system.

4.4. Commentary

Overall "Giving Wings to Emissions Trading" offers a reasonable platform from which to build our own analysis. While the analysis in the EC Report is grounded in solid analytics, for purposes of assessing carbon market impacts, two of the assumptions used in performing the analysis are pivotal to the results and thus merit closer examination. Specifically, the report assumes that 2008 emission levels will serve as the cap on the sector and considers only two allowance prices €10 and € 30 per tonne of CO2e.

The rationale for relying on these assumptions to assess potential market impacts is not entirely clear. The choice of specific carbon prices might have been dictated by constraints within the AERO model that require the change in ticket prices as an input. It is not, however, evident from the report that this is the case. The report does not suggest that these two prices are likely outcomes from incorporating aviation in the EU ETS and does not address the question of whether either price is inclusive or exclusive of aviation sector participation in emissions trading. The report, however, does conclude that including aviation in the EU ETS will not have an impact on carbon prices. Thus, from the perspective of the analysis presented the €10 and € 30 per tonne of CO2e could be viewed as including aviation.

The choice of 2008 as the base year for the analysis of required emission reductions is not explained at all and we can think of no compelling reason to limit the analysis to consider this as the only possibility. It may be an unrealistic choice in that, to date, other sectors within the EU ETS have been issued allowances on the basis of historical reference years. For example, in the 2005-2007 trading period, the number of EUA issued has typically considered reference year emissions ranging from 1999-2004. A key determinant of whether or not the aviation sector will have a material effect on carbon prices is the level of emission reductions that the sector will be required to make and that will be strongly dependent on the choice of the base year. It would have been instructive to consider additional options. This would have allowed a more thorough evaluation of the potential effects of incorporating aviation in the EU ETS.

Carbon market impacts discussed in the report are purely assumption driven and lack complete background documentation. The report does not offer an in-depth analysis of the actual impacts on carbon prices or the potential changes in abatement costs that could follow introduction of the aviation sector in the EU ETS. Two areas are especially important in regard to our study.

First, as stated above, the estimates developed to predict changes in operating costs and ticket prices are based on assumed allowance prices of €10 and €30 per tonne of carbon dioxide. Although the authors state that predicting the future price of carbon allowances is difficult, the basis for selecting these two prices for purposes of the analytics is not explicit. While the €10 and €30 per tonne prices suffice for illustrative analysis, additional work is required to assess the potential for the introduction of the aviation industry into the EU ETS to cause the price of allowances to change and to determine the potential magnitude of the change.

Second, the analysis assumes that the stringency of the caps placed on current participants in the first phase of the EU ETS will remain the same during the second phase. While this assumption might be necessary at present when little is known about National Allocation Plans for Phase 2, most anticipate that emission reduction requirements under the second phase will be more onerous. If this is the case, the additional demand for allowances created by increasing the burden on current participants coupled with the increase in demand for allowances related to the addition of aviation to the trading system, could have far more significant impacts on the price of allowances.

More generally, an assumptions driven analysis as contained in the CE Delft report is not sufficient to conclude that the effects will be minimal. An unfortunate gap in the analysis provided by the report is that the emission reduction options available to the aviation sector that were assessed by the AERO model are not sufficiently characterised to be incorporated in a more in-depth study of carbon market effects. While the EC study does consider how the aviation sector might respond in terms of reducing its emissions both in the case where opportunity costs of allowances are passed on to consumers and where they are not, the change in emissions at alternative allowance prices is not provided. Rather, the report presents findings indicating that more abatement will be undertaken by the industry when opportunity costs are passed on than when they are not. It does not, however, quantify the extent to which these reductions are related to reduced demand for aviation services versus changes in technologies and/or operational measures.

5. Summary of EU Emissions Trading Scheme Phase I

From the NAPs issued by Member States for 2005-2007, we estimate that the overall shortfall compared to business-as-usual projections is roughly 60-70 MtCO2e/year. The price range during this period has already fluctuated considerably between €6-30 /tonne C02e. There are many reasons for this fluctuation including the relatively small size of the shortfall as a proportion of the overall number of EUA issued (2.2 billion) and the role of variables such as the spread between coal and gas prices and weather-related factors that can cause significant swings in the price by substantially changing the actual shortfall (+/-at least 100 MtCO2e). In addition, in the start-up period of trading, the scheme has been affected by low liquidity and delays in registries being operational (resulting in participating installations not having receipt of their EUA). Moreover, there is little indication that industry is inclined to implement abatement options since early action might adversely affect their 2008-2012 allowance allocation. Abatement actions taken in 2005-2007 could lead to fewer allowances being allocated to the installation during 2008-2012. As a result, it appears that many abatement options are being 'saved' for implementation in the next trading period or until more has been published about the Second NAPs.

During 2005-2007, we expect the dominant portion of abatement will come from the power sector, primarily taking the form of fuel switching between coal and natural gas. The point at which fuel switching by the power sector occurs is not set as a response to the price of carbon alone. Rather, it is also determined by the difference in fuel costs (particularly costs for coal and natural gas) for power generators positioned in the mid-merit portion of the dispatch curves across each electricity markets. On the margin, power generators are experiencing changes to both the fuel cost and EUA cost portions of overall marginal costs. Presently, natural gas is experiencing very high demand as is reflected in its price. As a result, coal plants are running harder and purchasing EUA to cover the additional emissions that coal generates.

We anticipate that CERs will not be an important factor determining the price of EUA during this period for two reasons. First, the CER approval process is not progressing as fast as many had hoped. As a result, few CERs are currently available and there is the possibility that few will be available until quite late in the 2005-2007 timeframe. Second, many companies are likely to "bank" their CERs and save them for use in the more stringent 2008-2012 trading period.

We expect that the market-clearing price for CO2e will exhibit medium to high volatility during the 2005-2007 period due to the inexperience of market participants. Price volatility could also be affected by weather conditions, volatility in coal and gas prices, and the timing of the entry of Eastern European participants into the market.

6. Assumptions underlying scenarios for the EU Emissions Trading Scheme Phase II

6.1. Introduction

Price forecasts are inherently uncertain. Markets are affected by a variety of unforeseeable factors, such as changing political, social, and economic conditions as well as natural forces such as weather and natural disasters. These all impact the day-to-day operation of markets and thus prices and quantities exchanged. There are, however, a number of basic drivers of carbon market transactions that can be assessed with sufficient confidence to build plausible scenarios of future carbon prices.

This section highlights the major drivers that will have a material influence on the underlying price of CO2e. These factors are differentiated into two groups according to the likely strength of their influence on CO2e allowance prices in 2008-2012:

- Primary factors, of which our ongoing analysis of multiple scenarios suggests that the two most material variables are the fate of surplus AAUs and fuel prices.
- Secondary factors, which mostly impact the evolution of the European electricity market

6.2. Primary Factors Affecting CO2e Prices

In the EU 25, the burden allocation will be specified in the National Allocation Plans for 2008-2012. In other Annex I countries that have ratified the Kyoto Protocol, the burden on the trading sector will be defined in national regulations. In the United States and Australia, the burden will be determined via negotiations among sub-national—States and Territorial—governments. The burden allocation between trading and non-trading sectors is essential to gauge the level of the expected demand for European allowances and other emissions allowances in non-EU Annex I countries. Each region is analysed in the proceeding sections.

6.2.1. EU ETS

For the EU, the likely shortfall in emissions allowances for the trading sectors and the likely emissions reduction burden in non-trading sectors in the EU 25 for 2008-2012 is shown in Figure 12.

Figure 12: Average allocation of the emission reduction burden in EU 25 in 2008-2012[6]

State	EU/Kyoto Emissions Reduction Target	Credit Purchase by Government	Abatement required by Non-Trading Sector	Abatement required by Trading Sector
EU 15	-8%	71	123	212
Acceded States	-8%[7]	1	22	7
Total Shortfall		**72**	**145**	**219**

The shortfall of the trading sectors corresponds to the demand for CO2e for each EU state. Figure 12 is based on a number of assumptions and previous studies:

- **2008-2012 National Allocation Plans**

Since the National Allocation Plans for the period 2008-2012 have not yet been published, it is assumed that EU 25 governments proceed to the allocation of the overall reduction burden in s manner that is similar to the process used in developing the Phase I NAPs. It is also assumed that while the stringency of the emissions cap will tighten, the share of the burden between government and the trading sectors will be roughly the same in Phase II.

- **Non-trading sector abatement**

Previous studies undertaken by ICF Consulting[8] have estimated potential GHG emissions abatement by non-trading sectors, given the specific marginal abatement costs of these sectors.

Our approach assumes that non-trading sector policies are used in all countries that undertake an emissions reduction strategy.

It is outside the scope of this study to consider the applicability of all non-trading sector abatement for all countries party to adopting GHG emissions caps.

6.2.2. Other Annex I countries

Our analysis suggests that the EEA States (Norway, Iceland and Switzerland) will contribute only marginally to the demand of CO2 in 2008-2012. This is due mainly to the relatively small size of these countries. In particular, due to its very large endowment of geothermal energy sources Iceland is likely to be an exporter of CO2e, while Norway's growing offshore oil and gas installations and mainland chemical sectors are likely to face most of the reduction requirements on the trading sector.

By contrast, other Annex I countries, especially Japan and Canada, are going to contribute significantly to the future demand for CO2e. Whilst Japan has yet to determine whether it will create a mandatory ETS subsequent to its recently commenced voluntary scheme, companies that could be covered by such a scheme are likely to have to take on a shortfall of around 67 Mt

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[6] Source: ICF Consulting, 2005

[7] Target correct for all Acceded States excluding Poland and Hungary: -6% Kyoto Targets

[8] DoEHLG, 2003, Determining the Share of National GHG Emissions for Emissions Trading in Ireland; IEA, 2003, International Analysis of Methane and Nitrous Oxide Abatement Opportunities: Report to Energy Modeling Forum, Working Group 21

CO2e per annum, a much larger shortfall than in any of the European countries covered by the EU ETS.

The proposed Canadian domestic trading system is described in 'Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment.' The document outlines reductions from Large Final Emitters (LFE's) equal to around 45 Mt CO2e per annum, the phasing out of coal-fired power plants, and the purchase of Kyoto-compliant carbon instruments. Our own modelling exercise suggests that an efficient allocation of the Canadian emissions reduction burden would entail an abatement requirement from the trading sectors substantially higher than 45 Mt CO2e per annum. Finally, New Zealand companies might have a small shortfall in allocated allowances, due to its large energy reserves and forest stock, the nation as a whole is likely to be an exporter of CO2e.

6.2.3. Non-ratified Annex I countries

Australia and the United States might contribute to the demand for CO2e in 2008-2012. For those U.S. States and Australian States and Territories operating under cap-and-trade schemes, we assume they will participate in international emissions trading on the demand side only. That is, we assume they will be free to purchase Kyoto-compliant instruments, but they will not be allowed to sell emission reductions into the market.

6.2.4. Utilisation of Kyoto Protocol Flexible Mechanisms

Governments of Annex I countries must decide to what extent they will make use of the Protocol's Flexible Mechanisms at country and/or at company level to become Kyoto compliant. Governments may allow companies to purchase credits derived from Clean Development Mechanism (CDM) and Joint Implementation (JI) projects and to participate in the trade of Assigned Amount Units (AAUs) or they might restrict of forbid these activities to companies.

- **AAUs**

The supply of surplus AAUs in countries with economies in transition is very large. Surplus AAUs become available when economic slow-downs result in a decrease in GHG emissions to levels that are below those in a country's baseline. A number of restructuring economies have experienced this and are currently in a position of emitting less than they did in the 1990 base year established under the Kyoto Protocol. As indicated in Figure 13, the quantity of surplus AAUs from this set of countries is 1094 Mt CO2e.

Figure 13. Potential average annual AAUs supply from Annex I countries in 2008-2012[9]

Country	*Kyoto Target*	*Projected average annual excess Allowances in 2008-2012*
Poland	-6.0%	137
Hungary	-6.0%	1
Czech Rebublic	-8.0%	45
Lithuania	-8.0%	27
Latvia	-8.0%	14

[9] Source: ICF Consulting, 2005

Estonia	-8.0%	21
Ukraine	0.0%	202
Belarus	0.0%	35
Russia	0.0%	613
Total		**1094**

International efforts are aiming to prevent purchases of surplus AAUs from being substituted for real reductions in GHG emissions. A key to allowing access to these allowances without jeopardising the environmental benefits of the Kyoto Protocol is for buyers to ensure that any allowances purchased are available as a result of real reductions in GHG emissions. In the case of countries with economies in transition, this could be done through Green Investment Schemes or via Joint Implementation projects. The InCaP model can incorporate differing quantities of surplus AAUs that could be "greened" and then made available for sale in international carbon markets. For simplicity, AAUs that are available as a result of abatement activities in countries with surplus AAUs are all referred to as "Track I" ERUs. InCaP also allow for Track I ERUs to be banked for use in compliance periods after 2008-2012.

- **Certified Emission Reductions**

The delivery of CERs is another potentially important component in establishing the final price of CO2e. Late delivery of CERs is a real possibility due to the CDM Executive Board's slow approval process. Indeed, most registered CDM projects have already forward-sold the majority of CERs for the period 2008-2012. Figure 14 summarises the maximum potential CERs supply given the existing CDM projects to be implemented around the world and the potential supply taking into account late deliveries. ICF Consulting's estimates differ from those of Pointcarbon and the World Bank because not all CDM projects in the pipeline are reported to data providers such as Pointcarbon. In addition, through our own pipeline of CDM projects and direct engagement with the CDM project process, we may have a different set of expectations about the timetable for delivery of CERs.

Figure 14. Potential CERs supply from non-Annex I countries in 2008-2012 in Mt CO2e/year.

Source	*Point Carbon*	*ICF Consulting*
Maximum CERs supply	90	120
Delayed CERs supply	70	60

If the supply of CERs is small, Annex I countries will face strong competition in buying these credits, which will drive the prices of CERs up. Forward purchases of CERs are presently valued at around €5-€8/tCO2e. Since CERs prices are negotiated in bilateral agreements and since CERs carry several distinct types of risks compared with government issued allowances, so far there has been little price convergence between CERs and EUAs. It is, however, expected that a stronger relationship will form as the market matures. In theory, the price of CERs and ERUs should be greater than that of EUAs, since they can be banked and reused within different trading periods, unlike EUAs.

6.2.5. Linking of Emissions Trading Schemes in Annex I countries

Several countries are currently planning domestic cap-and-trade system that might connect directly or indirectly with the EU ETS in 2008-2012, altering the demand and supply for EUAs and carbon credits.

Article 25 of the EU ETS directive affirms that possible links of the EU ETS with other GHG emissions trading schemes should be established. It states that agreements should be concluded with third Annex I countries that have ratified the Protocol to provide for the mutual recognition of allowances between the Community scheme and other greenhouse GHG trading schemes. In the case of such agreements, the Commission shall draw up any necessary provisions relating to the mutual recognition of allowances. Moreover, the so-called European Linking Directive states that the European Commission should examine, once the Kyoto Protocol enters into force, whether it could be possible to conclude agreements with non-Annex I countries to provide for the recognition of allowances between the Community scheme and possible mandatory cap-and-trade schemes in those countries.

We analyse below the linking possibilities between the EU ETS and several Annex I countries (Norway, Canada, and Japan) as well as with the Australia Territories and the U.S. States that are planning to engage in emissions trading in 2008-2012.

- **Norway**

The government of Norway has been exploring the potential design of an emissions trading system since 1998. In August 2001, the Government released a white paper on climate policy, which included recommendations on a domestic emissions trading system that would replace the then current carbon dioxide tax law. The European Commission envisages that once the EU ETS legislation has been incorporated in the EEA Agreement, possibly with adaptations granted by the Commission, then full linking between the two schemes will be possible likely by 2007.

- **Canada**

Whilst much of the Canadian domestic emissions trading system (CA DET) has yet to be defined, the upper price of carbon credits within the scheme is fixed at CA $15/tCO2e by government commitment to limit compliance costs to this level. If the price of carbon credits compliant with the CA DET falls below CA $15 companies will be expected to purchase credits from outside their domestic trading scheme if adequate credits are not available internally. If the price for carbon rises above CA $15, the Canadian government will increase the quantity of carbon instruments in the DET by purchasing carbon allowances from international markets. By setting an upper limit on the price of carbon within the Canadian DET, the scheme might be precluded from linking with the EU ETS, potentially lowering its own liquidity. However, in case the two schemes are linked, then the price of CO2e will be less than or equal to the CA $15 tCO2 cap. Alternatively, if EUAs prices exceed CA $15, carbon prices within the CA DET and EU ETS will diverge.

- **Japan**

The Japanese government is considering the establishment of a domestic ETS (JET). One approach under consideration for the JET is to impose mandatory emission caps on Large Final Emitters (LFEs) and let those companies that have achieved reductions beyond the caps sell allowances in the market. The government will spend roughly two years studying the system before deciding on its introduction in fiscal 2007. More recently, in 2005, the Japanese government has entered agreement with around 50 LFEs under a voluntary JET scheme.

Under the scheme, participating companies are offered financial incentives to implement abatement technologies.

- **US**

Although the US Federal Government did not ratify the Kyoto Protocol and will not participate in trading during the 2008-2018 period, several individual states have indicated plans to engage in emissions trading as participants in the Regional Greenhouse Gas Initiative (RGGI).

Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont, California, Washington, and Oregon are all currently part of RGGI and account for 16% of US GHG emissions.

To date, analysis undertaken by ICF Consulting on behalf of the RGGI process has included assessments of several CO2 reduction scenarios with caps defined as a reduction from 1990 levels. Scenarios examined have ranged from 5% to 35% reductions from 1990 levels by 2020, but the final cap and timing have not yet been determined. Emissions trading will be adopted in time to meet the 2010 emissions target, it will likely be synchronised with the EU ETS and will most likely include Kyoto-compliant credits.

- **Australia**

Australia did not ratify the Kyoto Protocol, but has announced its intention to meet its Kyoto targets. State and Territory level governments announced an agreement in April 2005 to develop an Australian ETS (AU ETS) that will regulate energy sector emissions and potentially other sectors, without federal government support. States and Territories engaged in developing an AU ETS recognise its similarities to their U.S. State counterparts; the scheme is therefore likely to have similar characteristics. Since the characteristics of the ETS are yet to be defined, it is not clear whether the AU ETS will be eligible to link with the EU ETS. It can, however, be anticipated that linking directly or indirectly with the EU ETS will lead to a harmonisation of carbon prices between the schemes.

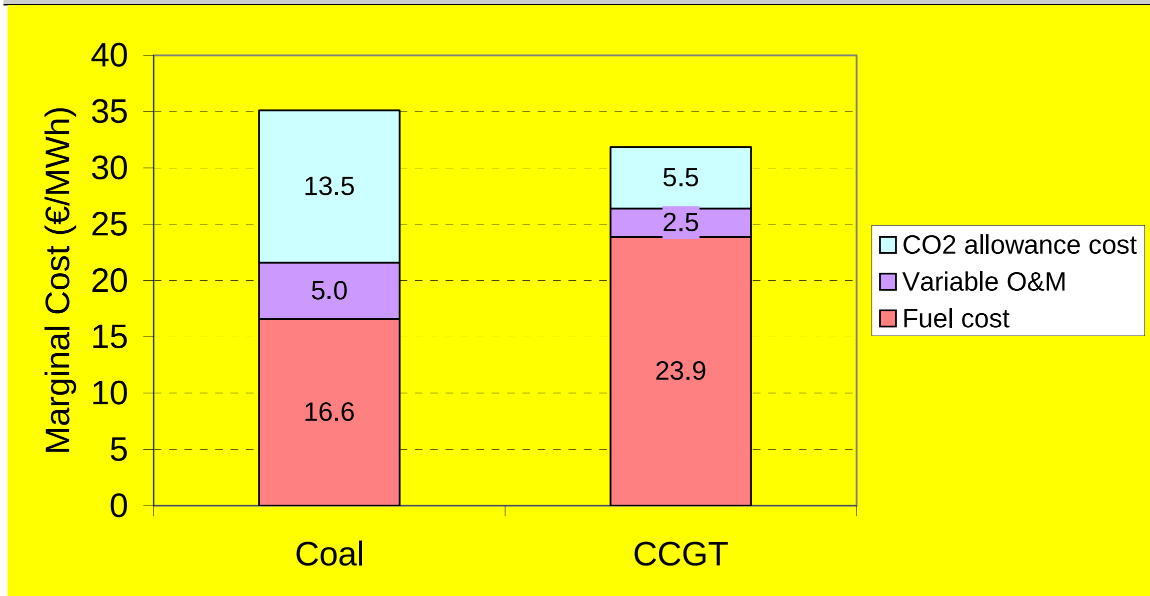
6.2.6. Price relationship between coal and gas

The relationship between natural gas prices and coal prices is an essential factor that will have a significant impact on the price of carbon. With rising gas prices, it becomes cheaper to shift from gas to coal-fired power plants that will need to buy additional allowances to cover their increased carbon emissions. Electricity generators thus become short of allowances and demand more allowances in the market. This drives the price of carbon up, other things being equal.

In the case of most European electricity markets, the reference unit will be a thermal power station consuming coal or gas. As fuel prices vary, so will the cost of production. With carbon, the appropriate response at an operational level is quite straightforward: the value of CO2e should be included in the cost structure of generation in the same way as fuel costs are. This is true even if enough free allowances are held to cover the output because those allowances have an *opportunity* cost equal to the revenue that would have been earned by selling them. From a technical standpoint, the thermal efficiency of a typical pulverised coal (PC) power plant is far less than that of a new gas turbine in combined cycle configuration (CCGT). The efficiency of a PC is around 36% whilst that for a newer CCGT is 50%, measured in terms of delivered energy and based on higher heating value of the fuel. After taking into account the carbon content of the fuel and the thermal efficiencies, our reference PC plant will produce more than twice the amount of CO2 per unit of electricity delivered than a gas-fired CCGT (about

900kg/MWh against 370kg/MWh). For any CO2 price, therefore, the impact on the marginal operating costs would be nearly three times greater for a PC plant than a CCGT.

Figure 15: Comparing PC and CCGT Marginal Production Costs



Note: Based on efficiency ratings of 36% and 50% net HHV efficiency respectively. CO2 at €15/tonne. Price of gas at 3.50€/MMBTu (35€c/therm) and coal at 1.75 €/MMBTu (42€/tonne at 6,000kcal/kg).

Figure 15 illustrates how a CO2 price of €15/tonne would be sufficient to reverse the competitive position of PC and CCGT plants. Without a CO2 constraint, coal-fired plant would be expected to operate at higher load factors. Under a CO2 constraint, however, the opposite could be true. In the case of our reference plants, when the price of CO2 falls below €9/tonne, the PC plant will operate ahead of CCGT and vice versa.

Figure 16: Impact of EUAs on Marginal Production Costs

Cost of CO2 (€/tonne)	Price (€/MWh) impact based on technology	
	Coal-fired plant	*CCGT plant*
5	4.5	1.8
10	9.0	3.7
15	13.5	5.5
20	18.0	7.3

Figure 16 shows the impact of CO_2 on marginal production cost for our two reference power plants. Depending on which technology sets the electricity price, the price of electricity will rise by the product of (1) the price of CO_2 and (2) the carbon intensity factor of the marginal plant - 0.37tCO_2/MWh in the case of CCGT or 0.90tCO_2/MWh for PC. It is important to keep in mind that what matters is not the *average* carbon intensity factor but the carbon intensity factor of the *marginal* unit. To understand the impact of the EU ETS, imagine an *equilibrium* where the output and hence CO_2 emissions from coal and gas-fired plant are in line with EU CO_2 reduction targets. For any given level of electricity demand and carbon-free generation from hydro, nuclear and/or renewables, any unmet demand will have to come from fossil-fired plant. The tighter the emissions cap, the greater the scarcity value of CO_2 and the greater the share of generation from gas-fired plants needed to meet the target. This has implications for the dynamics of the carbon market and therefore electricity prices, both of which have large implications on all existing and future power market participants.

Figure 17: Range of CO2 Price Outcomes

	Resulting in LOWER CO2 Price	Resulting in HIGHER CO2 Price
Relative price of gas and coal	*Low*	*High*
Hydro, nuclear and renewable plant output	*High*	*Low*
High electricity demand	*Low*	*High*

Figure 17 provides a simplified summary of expected dynamics. Taking each row in turn, if EU coal prices were to fall relative to gas prices, this would encourage a switch towards coal. However, given that there is a largely fixed number of EUAs, the additional demand for EUAs will increase the scarcity value of CO_2 allowances. The resulting increase in the CO_2 price will be enough to return the generating mix to the *equilibrium*. If precipitation were higher than expected across the EU, higher hydro output would reduce the output required from fossil-fired plant. This in turn would put less pressure on demand for EUAs and lead to lower CO_2 prices. Energy efficiency programmes designed to reduce demand for electricity would have a similar impact. In all three scenarios, high CO_2 prices can be expected if the opposite turns out to be the case. These impacts, however, might not be correlated, giving rise to various shades of grey.

6.2.7. Abatement costs for sectors facing emissions reduction targets

The cost of emissions abatement for industries in the trading sectors and especially those included in the EU ETS is essential to determine whether these sectors will be net suppliers of emissions allowances or will need to buy some allowances in the market in order to meet their targets. Sectors with relatively low-cost abatement options will prefer to reduce their emissions and sell the resulting excess allowances. In this case, an increased supply of allowances will drive carbon prices down, everything else being equal. Conversely, it will be more efficient for sectors with high-cost emissions reduction options to buy additional allowances to meet their targets. This would increase the demand for allowances and drive allowances prices up.

Key variables that will affect the ability and incentive to invest in abatement options include country-by-country applicability, coal-natural gas price ratios, electricity demand, oil prices, and labour costs. In general, the power sector is the most likely candidate to undertake large-scale GHG emissions abatement investments, since abatement opportunities in this sector substantially exceed potential abatement by non-power sector industrial players. No-cost and low-cost options are also available in other industrial sectors. The cumulative abatement potential of other sectors, however, is small relative to abatement potential in the power sector.

The marginal abatement cost curve (MACC) represents the quantity of CO2e emissions (presented in million tonnes) abated given the net costs of abatement—that is, the break-even price of CO2e expressed in €/t CO2e abated. The calculation of these two estimates is based on two analyses: 1) discounted cash flow analysis of the costs and benefits (e.g., sale of recovered methane); and 2) analysis of applicability of mitigation options to the projected emission scenario. ICF Consulting's InCaP model includes detailed sets of abatement options for each sector. The formula applied to calculate each MACC option is summarised below.

Analytical Framework of MACCs

Assuming a constant quantity of abated GHGs throughout the lifetime of a mitigation project, the nets cost of abatement is expressed as:

$$P = C * \text{Annuity Factor} + O\&M - B$$

Where:

P = net cost of abatement for particular mitigation option (2000 €/t CO_2 Equivalent)

C = investment cost (2000 €/t of CO_2 Equivalent)

A = annuity factor expressed as $DR/(1-(1+DR)^{-N})$

DR = discount rate

O&M = operation and maintenance costs (2000 €/t CO_2 Equivalent)

B = benefits (2000 €/t CO_2 Equivalent)

N = lifetime of mitigation option

6.3. Secondary Factors Affecting CO2e Prices

Secondary factors are considered to be those that have marginal affects on the price of carbon, but are not expected to be price setters. Secondary factors will change depending on what time period is being considered. For example in Phase I of the EU ETS, the key factors determining the price of carbon are weather and fuel prices. In Phase II of the EU ETS, as other factors come to bear in the market, weather is less likely to impact the price of carbon.

The next sections describe the key secondary factors expected to marginally impact the price of carbon in 2008-2012.

6.3.1. Influence of weather

Weather has numerous effects on carbon prices. Cold winters increase demand for heating leading to higher energy demand and consequently higher carbon emissions. Hot summers negatively affect the generation of clean hydropower, decrease the availability of cooling water for nuclear power plants and increase demand for electricity for air conditioning.

Rainfall and wind speeds affect the share of power generated by non-emitting sources and thus emission levels in countries and regions relying on hydro- and/or wind power.

Weather can alter circumstances for power producers and cause a change in their position vis-à-vis their required emission reductions. Moreover, rainfall is not uniform across Europe and therefore some regions and companies are more exposed to weather risk than others.

Weather can increase volatility of carbon prices. For instance, the combination of a cold winter and a warm summer could cause power consumption and emissions to soar.

6.3.2. Changes in renewable and transmission landscapes

At low levels of penetration, renewables, especially wind, play only a secondary role in power markets. However, as their contribution increases, GHG abatement costs of the power sector tend to decrease.

Within the power sector there are transmission limits between countries that lead to market separation and prices differentiation, so that no uniform power market or price exist yet. This situation could change in 2008-2012, since European countries are engaged in improving transmission interconnections between countries in order to create a European-wide competitive power market.

6.3.3. EU Large Combustion Plant Directive (LCPD)

Additional upcoming EU legislation, such as the EU's revised Large Combustion Plant Directive (Directive 2001/80/EC) will more likely impact the dynamics of the power sector and indirectly carbon prices. This directive sets new limits for the emission of sulphur dioxide (SO2), nitrous oxides (NOx) and fine dust particles for all new plant with a capacity of 50MW or larger. New limits for "existing" plants, those 50MW or larger that were licensed before 1st July 1987, will be binding from 1st January 2008. This means that by 2016 at the very latest, unless they use the opt-out provision severely limiting the average load factors, all major coal-fired power plants will have to install additional abatement technologies. This will increase investment costs for coal-fired power plants and make other power plants based on less polluting energy sources more economically attractive.

7. Price scenarios for the EU Emissions Trading Scheme Phase II

7.1. Introduction

Having specified a set of assumptions in the previous chapter that describe the most likely form the carbon market will take, we establish here three scenarios that reflect the dynamics of the carbon market and how they can interact to determine the price of carbon.

The focus of this chapter is on the three scenarios, given alternative views of the critical assumptions described in Chapter 4, with the objective of deriving three carbon price forecasts for EU ETS Phase II. Each of the forecasts is generated through applying ICF Consulting's proprietary InCaP model.

7.2. Overview of Phase II of the EU Emissions Trading Scheme: 2008-2012

We anticipate that the trading period 2008-2012 will be characterised by significant growth in the size of the market compared to 2005-2007. Two main factors will contribute to the increase in the size of the market. First, it is likely that additional carbon emission reductions will be required of European trading sectors when the 2008-2012 NAPs are completed to enable Member States to meet their Burden Sharing targets. Second, additional Parties to the Kyoto Protocol will commence emission trading and are likely to link to the EU ETS directly or indirectly through the use of the CDM and JI market. While these two factors indicated an increase in the size of the market and the potential for a much larger number of transactions, they do not necessarily mean that the price of carbon instruments will be higher. With the introduction of several new supply drivers such the Kyoto carbon instruments, the market is likely to have access to a greater supply of carbon credits than were available in 2005-2007.

During this trading period we assume all Annex I Parties[10] that have ratified the Kyoto Protocol meet their agreed targets and apply the policy measures they have pledged to undertake. With the notable exception of the aviation sector (see Chapter 8), due to timing constraints of the European Parliament, no additional GHGs or industrial sectors are expected to be added to the EU ETS in 2008-2012. The chemical and aluminium sectors could be required to adopt an emissions cap from 2013 onwards.

Since the Annex I Parties that have ratified the Kyoto Protocol from 2008 onwards will begin to participate (if they have not begun already) in emissions trading, there will be an increase in demand for Kyoto-compliant instruments such as AAUs and CERs. Additionally, countries and regions that set up emissions trading schemes in parallel to the EU ETS may allow trading sectors to use EUAs to help meet compliance targets. The result of other countries entering carbon trading will be an overall increase in net demand for carbon instruments.

[10] Annex I Parties are the set of industrialised nations listed in Annex I to the UNFCCC. The subset of Annex I countries that agreed to emission caps under the Kyoto Protocol are listed, along with their specific commitments, in Annex B to that document.

7.3. Scenario overview

Here we describe in detail the assumptions for each scenario we constructed with the InCaP model. Assumptions are broken into two sections: those that are applied in all scenarios and those that are scenario specific.

Assumptions applied to all scenarios

- The set of countries that will participate in carbon trading
- GHG emission reduction targets for countries and sectors

Scenario-specific assumptions

- Projected gas prices
- German nuclear plant closure
- The number of CERs entering the market
- The number of Track I ERUs that could enter the market

7.3.1. All scenario assumptions

It is important to note that in 2008-2012, there will be significantly more convergence in the price of carbon since all Kyoto-compliant carbon instruments will be able to be used to meet compliance obligations. Our expectation, reflected in all scenarios, is that several countries may link to the EU ETS by 2008. Even if there is no formal linkage, countries will be linked indirectly as they compete to purchase CERs, ERUs, and AAUs.

Participants in carbon trading during this compliance period are summarised in Figure 18 below:

Figure 18: Participants in carbon trading 2008-2012

Participants in carbon trading 2008-2012	
• **EU 25**	All present EU Member States + Bulgaria and Romania
• **EEA States**:	Norway, Iceland, and Switzerland
• **Other Annex I Countries**:	Japan, Canada, New Zealand
• **12 US States**:	Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, California, Washington, Oregon.
• **Australian Territories**:	New South Wales, Queensland, South Australia, Tasmania, Victoria, Western Australia, Australian Capital Territory, Northern Territory

Figure 19: 2008-2012 GHG reduction targets

Country/World Region	*Emissions Cap in Kyoto*
EU (25)	-8%
EEA states: Norway, Iceland, Switzerland	+1 %, +10 %, -8 %
Other Annex I: Japan, Canada and New Zealand	-6 %, -6 %. 0 %
Australia Territories	+8%
US 12 States	-7%

7.3.2. Scenario assumptions overview

Through this project, ICF Consulting has had the opportunity to compare its fuels forecasts with the latest estimates from the UK Government. We have determined that there is considerable convergence, certainly enough convergence during 2008-2012 such that there would not be a material difference in the estimates of the equilibrium price of carbon. ICF Consulting forecasts natural gas prices in two regions—North America and Europe. Our Henry Hub forecast is based on ICF's North American Natural Gas Analysis System (NANGAS), reference 2005 Case. This case reflects higher oil prices, averaging just over $40 per barrel, and a modest carbon policy in the United States. Under this case we expect a continuation of tight natural gas supply in the near term. The importation of larger amounts of LNG around 2008 and a domestic response to current high prices will increase gas supply and moderate gas prices. Non-electric gas demand will stagnate, increasing at less than 1% per year. Electric demand for gas will continue to grow at 5 percent per year through 2015. Higher demand for gas will push up prices until the Alaska pipeline enters the market in 2016 with substantial amounts of gas. LNG imports continue to increase, reaching 12.9 Bcf per day by the end of the period. International competition for LNG however raises the price of LNG, which along with the growing demand for gas in the power sector, increases prices at the end of the forecast period.

ICF has linked LNG prices to world oil prices for the post 2015 period, based on expectations of demand growth for LNG in Asia, where LNG prices are tied to oil. Our European gas price forecast is based on the historic relationship between distillate oil prices and gas prices. Contracting in Europe typically ties gas prices to distillate prices with a lag. Our forecast of European gas prices represents a linkage between Brent, distillate margins, and observed gas relationships. The near term gas price forecast is driven by the expected high distillate premium as Europe demands less polluting diesel and distillate heating fuels. Prices decline as refinery margins contract. The relationship between North American and European prices is evolving.

The markets remain structurally very different with North American prices set by gas on gas competition and European prices set by contracts to distillate prices. Over time, with the growth of LNG trade and expanding Russian imports to Western Europe, gas on gas competition may emerge, in which case, we can expect some linkage in prices through LNG movements. In our current forecast, the linkage between the markets is determined by the relationship of gas to oil in Europe, and LNG to oil in North America.

Figure 20 highlights in summary the assumptions made for each scenario.

Figure 20: 2008-2012 Scenario assumption overview

	Scenario 1 (low)	*Scenario 2 (base)*	*Scenario 3 (high)*
Gas price (refer to Annex)	Low gas price	Base case gas price	High case gas price
German Nuclear closure	Delayed	As planned	As planned
Abatement activity	All sectors active	All sectors active	All sectors active
"Track I" ERUs	30% - 100% enter trading system	0%-30% enter trading system	0% enter system
CERs	120 Mt CO2e	90 Mt CO2e	60 Mt CO2e
Other gases and sectors in EU ETS	None added	None added	None added

7.4. Detailed scenario description and price forecast

7.4.1. Scenario 1: Low demand, high supply

Key attributes	Low gas price, expected CDM delivery, unconstrained AAU supply
EUA Price	€ 5 tCO2e

Summary description

With oil prices set to decline from their current high levels (USD $65/bbl), European gas prices, which in the short-term are indexed to oil, will follow suit to levels that are lower than market expectations, particularly as LNG infrastructure comes on line. This will lead to less coal demand and a comparable fall in power sector emissions.

Enormous potential to reduce emissions in countries with economies in transition exists and these reductions can be achieved at very low costs. As a result, there is a potentially very large supply of Track I ERUs that could be brought to the market. Investor nations will decide upon their level of investment in GHG abatement in transition economies based on a revenue maximizing criterion.

The CDM instrument delivers sufficient quantities of CERs to meet OECD government announced purchases.

EU Member States fulfil their renewable directive obligations and their Large Combustion Plant Directive obligations leading to a greater supply of renewable energy and a shift away from the use of coal-fired power station, and towards Combined Cycle Gas Turbine (CCGT).

Assuming that all countries meet their emission targets as adopted under the Kyoto Protocol, or State level voluntary targets, our analysis forecasts annual demand in the range of 700 Mt CO2e.

Detailed variable description

Here we provided a detailed description of each how each of the key variables contributed to the overall price scenario.

- **Track I ERUs**

Track I ERUs entering the market will have a significant affect on the price of carbon. Low cost abatement options are abundant in countries with economies in transition and host nations will encourage mitigation projects with a view toward maximising their returns from the sale of Track I ERUs.

- **Natural gas and LNG coming to market**

Substantial natural gas supplies are likely to enter the market as a result of recent exploration and infrastructural investments in Europe and Russia. LNG is also expected to become a spot market commodity in coming years. The low case in the InCaP model is built on the assumption that the price of natural gas becomes lower in 2008-2012 compared to present levels. This will tend to make fuel switching more attractive to the power sector, reducing GHG emissions and, therefore, the need for carbon allowances.

- **Industrial abatement**

As a result of more stringent emissions caps compared to 2005-2007, European industry is expected to play a more substantial role in abating domestic emissions. During Phase I of the EU ETS, almost all trading sector participants, with the notable exception of the power sector, postponed the implementation of GHG emissions abatement until 2008-2012. The market psychology for this attitude is justified by the perception from business that low cost abatement options should be ‘saved’ for use when reduction targets were made tighter in the EU ETS Phase II.

- **Certified Emission Reductions**

Problems associated with the slow approval process for CDM projects could be resolved by the 2008-2012 trading period. This will mean that the supply of CERs entering the market could increase significantly as compared to 2005-2007.

We have also assumed that the CDM mechanism delivers sufficient quantities of CERs to meet OECD government announced purchases.

7.4.2. Scenario 2: Base demand, base supply

Key attributes	Base gas price, expected CDM delivery, constrained AAU supply
EUA Price	€11 tCO_2e

Summary description

With oil prices set to fall from their current high levels (USD $65/bbl) European gas prices, which in the short-term are indexed to oil, will follow suit in line with market expectations. This will lead to less coal demand and a comparable fall in power sector emissions.

No more than 30% of the surplus AAUs available in countries with economies in transition can be cost-effectively "greened" through Green Investment Schemes and Joint Implementation. The more limited supply of Track I ERUs reduces the total supply of carbon instruments available to the market.

As in the other cases, we assume CDM delivers sufficient quantities of CERs to meet OECD government announced purchases.

EU Member States fulfil their renewable directive obligations and their Large Combustion Plant Directive obligations leading to a greater supply of renewable energy and a shift away from the use of coal-fired power, and towards Combined Cycle Gas Turbine (CCGT).

Assuming that all countries meet their emission targets as adopted under the Kyoto Protocol, or State-level voluntary targets our analysis forecasts annual demand in the range of 700 Mt CO_2e.

Detailed variable description

Here we provided a detailed description of each how each of the key variables contributed to the overall price scenario.

- **Track I ERUs**

Track I ERUs continue to dominate the carbon market under this scenario. Only around 30% of surplus AAUs need to enter the carbon market as Track I ERUs to enable investor countries to pursue a revenue maximisation strategy.

- **Natural gas and LNG coming to market**

The same as with Scenario 1; except the base case gas price is applied, meaning that the price of natural gas is expected to fall in line with market expectations. A fall in gas prices would lead to its increased use compared to coal leading to an overall fall in demand for carbon allowances.

- **Industrial abatement**

Same as with Scenario 1.

- **Certified Emission Reductions**

Same as with Scenario 1.

7.4.3. Scenario 3: High demand, low supply

Key attributes	High gas price, late CDM delivery, severe AAU supply restriction
EUA Price	€ 21 tCO2e

Summary description

Oil prices do not fall as much from their current high levels (USD $65/bbl). European gas prices remain high due to delayed investments in LNG infrastructure in Russian and Europe. This will lead to continued high coal demand and less power sector GHG emission abatement.

Whilst the majority of OECD governments participating in carbon trading adopt policies that allow so called 'greened' or converted AAUs to enter the carbon market, institutional barriers in transition countries significantly restrict the flow of Track I ERUs. As a result governments and companies have to rely on alternative carbon instruments to satisfy their compliance requirements.

The CDM instrument suffers further institutional setbacks which lead to delays in delivering CERs to the carbon market; moreover, government policies further restrict the use of CERs for trading sector companies to meet compliance targets.

EU Member States fulfil their renewable directive obligations and their Large Combustion Plant Directive obligations leading to a greater supply of renewable energy and a shift away from the use of coal-fired power, and towards Combined Cycle Gas Turbine (CCGT).

Assuming that all countries meet their emission targets as adopted under the Kyoto Protocol, or State level voluntary targets our analysis forecasts annual demand in the range of 700 Mt CO2e.

Detailed variable description

- **Track I ERUs**

This scenario assumes that no Track I ERUs from economies in transition will be available to the market. The analysis indicates that the price of CO2e would increase to approximately €21 tCO2. Eliminating this source of supply means the price of carbon instruments will tend to rise.

- **Natural gas and LNG coming to market**

Higher gas prices reflect continued high oil prices and the resulting delay of investment in natural gas supplies and infrastructural across Europe and Russia. The power sector continues to use coal to meet base-load energy demand, which in turn needs to be serviced by the further use of carbon instruments in order to meet compliance targets. With continued high gas prices many gas powered facilities decide to reduce their operations and sell any unused allowances to the carbon market – effectively to the coal power plant operators. The overall impact is an increase in demand for allowances.

- **Industrial abatement**

Industrial abatement is likely to be undertaken in line with expected carbon market prices. Where the cost of abatement is lower than the price of carbon allowances, abatement action is presumed to be undertaken. It is assumed that a delay will be experienced between the point in time of investment and the resulting reduction in GHG emissions. Our analysis suggests that such reductions will be seen within the five year trading period.

As the price of carbon instruments rises, more industrial abatement will be undertaken.

- **Certified Emission Reductions**

Problems associated with the slow approval process for CDM projects continue into the 2008-2012 trading period. This will mean that the supply of CERs entering the market remains lower than market expectations, placing additional pressure on the price of carbon instruments and contributing to higher prices.

7.4.4. Note on the US-12 State and Australian Territories

For all scenarios we assume that the Australian Territories and 12 US States will participate in emissions trading during 2008-2012. We assume that there will be some form of linking between these emissions trading schemes and the EU ETS enabling EUAs to be an accepted 'currency' and also that there would be some recognition of external allowance currencies also, which would enable the use by EU companies to meet compliance targets (e.g., as is likely to be seen between Norwegian ETS and the EU ETS). In testing the sensitivity of the price of carbon, however, we found that relaxing that assumption did not have an impact on the overall price of carbon. This may be explained by the fact that Australian Territories will likely supply enough carbon instruments to the market to effectively provide for all of the instruments the US States would demand.

7.4.5. Scenario conclusions

What our scenario analysis has highlighted is that the base case of carbon for the period 2008-2012 is controlled predominantly by two key drivers. Power sector abatement will be a determining component for setting the price of carbon instruments and access to cost-effective investments that generate Track I ERUs will also be a key factor in determining allowance prices.

Chapter 8 will assess the impact of introducing aviation into the EU ETS on the base case carbon price scenarios developed here.

8. Impact assessment of EU aviation sector on EU Allowance price scenarios

8.1. Introduction

Based on the three scenarios described in Chapter 7, we develop a quantitative assessment of the price signal likely to be experienced by EUAs as a result of applying the three proposed policy options for including European aviation emissions within the EU ETS referred to by CE Delft. By considering the likely impact of each aviation sector policy option against each of the carbon price scenarios we will determine the consequent EUA price signal under nine separate scenarios. Through offering a comprehensive view of how each policy option might affect each carbon price scenario we aim to establish the overall price impact aviation may likely bring to the EU ETS and therefore its financial materiality.

8.2. Methodology

ICF Consulting recognises that the scope of aviation activities included within the EU ETS remains undetermined. The breadth of aviation activity covered by the EU ETS will directly impact the amount of carbon it regulates and therefore the size of demand for EUAs and other carbon instruments. With consideration for the key policy options for including aviation within the EU ETS as proposed by CE Delft, ICF Consulting analysed the following policy options within the context of the market scenarios defined in chapter 7:

- Intra-EU flights—this option covers emissions from flights from one locale to another within the EU.
- Departing from EU—this option covers emissions from any flight that departs from the EU, regardless of its destination.
- EU airspace—emissions from any flight, regardless of departure or destination point, that are release over EU airspace are covered by this option.

Having agreed with DEFRA on the three policy options for including aviation within the EU ETS, we will apply the options to each of the price forecast scenarios, the output of which will be the following:

- Total demand for EUA and other carbon instruments within the market
- Increase in EUA price (if any) that results from increased demand as a result of aviation's participation in the EU ETS

A summary of the 'all-scenario-options' that will be the output of our analysis is provided in Section 8.2.3.

8.2.1. Aviation sector carbon emissions data

Data estimating present and projected aviation sector carbon emissions was ascertained from the CE Delft report. In addition, we assessed the CE Delft data against a number of other independent sources including company disclosures and the European Commission. We used baseline emissions provided in Table 11 of the CE Delft report and employed an annual growth factor of 4% as determined from information provided in Table 12 of the same report. The resulting growth in emissions is presented in Figure 21. These results are consistent with projections in the CE Delft report.

Figure 21: Carbon emissions from aviation 2008-2012 (Mt/year)

CO2 Emission projections									
Policy option	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Intra-EU	51.9	54.0	56.1	58.4	60.7	63.1	65.7	68.3	71.0
Departing from EU	130.4	135.6	141.0	146.7	152.6	158.7	165.1	171.7	178.5
EU airspace	114.3	118.9	123.6	128.6	133.8	139.2	144.7	150.5	156.5

Based on the analysis presented in Figure 20, we present total net carbon emissions reduction required by the aviation sector, under each policy option in Figure 22.

Figure 22: Net carbon reductions required by aviation under each policy option (Mt/year)

Projected CO2 emission reduction required under each option					
Policy option	**2008**	**2009**	**2010**	**2011**	**2012**
Intra-EU	0.0	4.9	9.9	15.2	20.6
Departing from EU	0.0	6.1	12.5	19.1	25.9
EU airspace	0.0	5.4	10.9	16.7	22.7

Having incorporated aviation emissions into the InCaP model we demonstrate in Chapter 8.3 the impact of including the aviation on each of the three forward EUA price scenarios.

8.2.2. Abatement from the aviation sector

Consideration for available abatement the aviation sector might undertake was made by ICF Consulting with reference to CE Delft's report. While the report clearly states that abatement measures are available in several categories including changes in fleet mix, technical measures, and operational measures, specific options are not identified and quantified in terms of their abatement potential and costs. Thus, the data contained in the CE Delft report are not suitable for incorporation into the MACC analyses used in our model of the carbon market.

For purposes of considering the potential impacts of adding aviation to the EU ETS, however, there is some merit in considering what could happen if the industry does not abate emissions at all and then assessing the implications on the price of carbon. Thus, in developing our analysis, we have made the "worse-case" assumption regarding aviation sector abatement and evaluated the potential effects on price assuming that the sector is not able to alter its emissions profile at all. While this is *not* a realistic outcome, even in the short run the industry does have and can be expected to implement abatement options, the assumption will provide an indication of the maximum possible impact that aviation could have on carbon prices given the 2008 base year assumption.

8.2.3. Scenario assumptions overview

Incorporating the price scenarios from Chapter 7 and aviation policy options in this chapter we summarise here the 'all-scenario-options' that will determine our carbon price forecasts.

Figure 23: All scenario options

All-scenario-options summary			
Policy option	**Applied price scenario**		
Intra-EU	**Low**	**Base**	**High**
Departing from EU	**Low**	**Base**	**High**
EU airspace	**Low**	**Base**	**High**

8.3. Price Effects of incorporating aviation sector emissions

Price forecasts were produced for each of the three policy options under each of the three market scenarios developed for this analysis. The results of all nine runs of InCaP are summarized in the table below (see Figure 24). As indicated, adding the aviation sector does not result in a change in EUA prices under any of the scenarios examined. The low-, base-, and high-case scenario prices--€5, €11, and €21 per tonne of CO2e respectively—do not change when aviation sector emission reduction requirements are placed on the system. Other changes do however occur, notably in the level of purchases of Track I ERUs under the low-, and base-case scenarios, and in the level of abatement on the part of the energy sector in the high-case scenario. These changes are discussed in greater detail below.

Figure 24 Projected Aviation sector demand (Mt/year) and EUA prices for 2008-2012

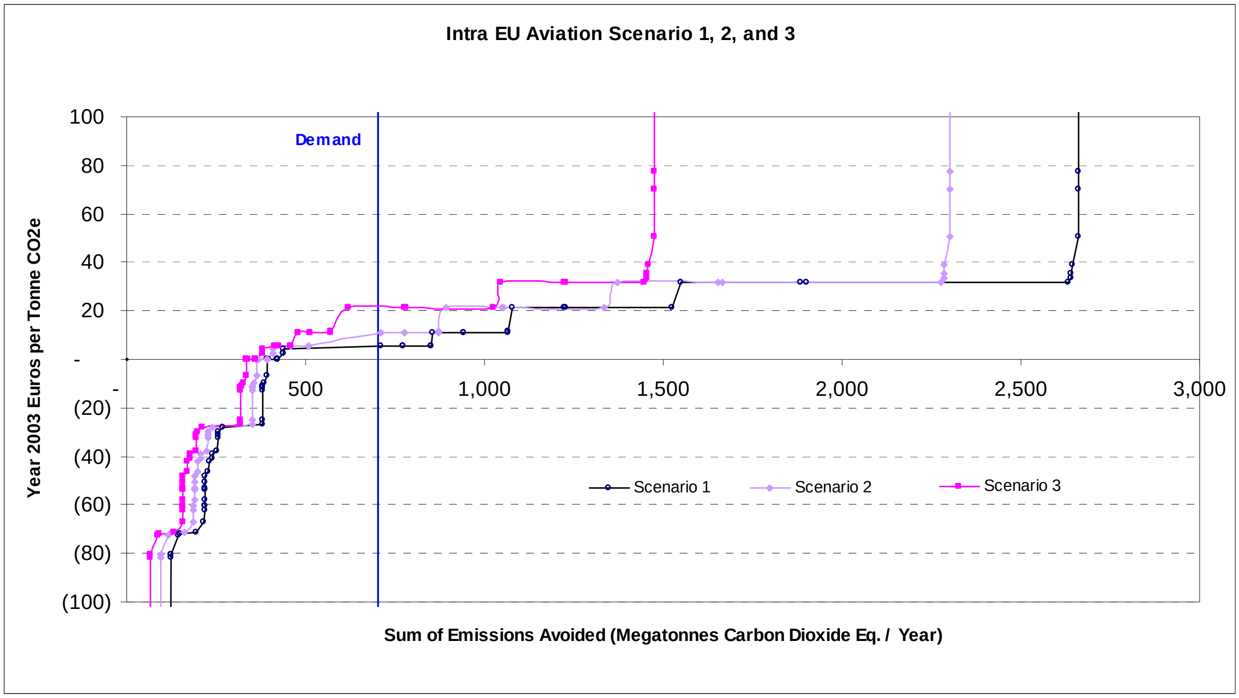
Impact of aviation sector on EUA price forecast						
Policy option	**Annual Price forecast**					
	Low		**Base**		**High**	
	Change in Demand	**Price**	**Change in Demand**	**Price**	**Change in Demand**	**Price**
Aviation not included in EU ETS	0	€5	0	€11	0	€21
Intra-EU	10.12 Mt	€5	10.12 Mt	€11	10.12 Mt	€21
Departing from EU	12.72 Mt	€5	12.72 Mt	€11	12.72 Mt	€21
EU airspace	11.14 Mt	€5	11.14 Mt	€11	11.14 Mt	€21

8.3.1. Intra-EU Option

Based on the results reported in the figure above, the addition of the aviation sector means an average annual increase in system wide required CO2e emission reductions of 10.12 Mt for the Intra-EU policy option, 12.72 Mt under the Departing from EU policy option, and 11.14 Mt under the EU Airspace option. Relative to total required reductions in the market scenarios, these amounts are quite small and easily absorbed by the market.

Figure 25 displays the results of the InCaP analyses of the Intra-EU trading option under all three market scenarios. For this option, average annual demand for CO2e instruments from all sources, including aviation, is 712 Mt. The market clears at € 5 per tonne of CO2e for the low-case scenario (see the intersection between the demand line and the scenario 1supply curve). Under the base case scenario, the market clears at a price of €11 (see intersection with the scenario 2 supply curve) and for the high-case, the price equals €21 at the equilibrium point.

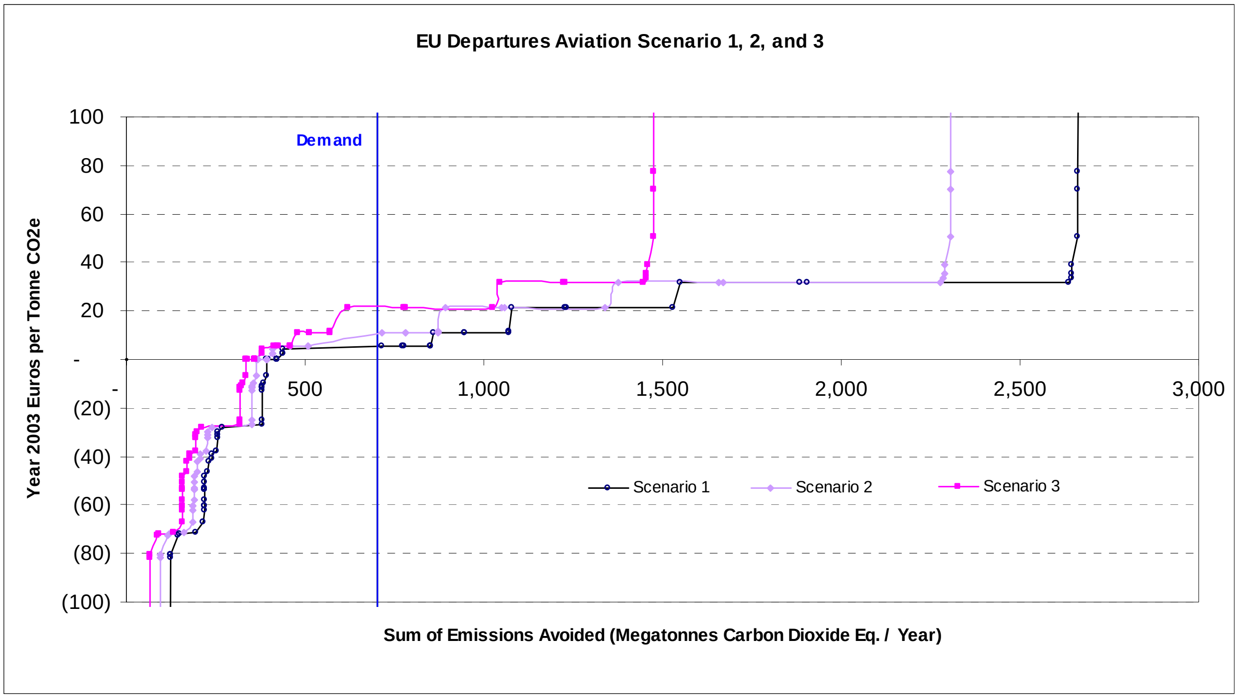
Figure 25: Market Results for the Intra EU Option



8.3.2. Departing from EU Option

Results from our analysis of the Departing from EU option under each scenario are provided in Figure 25. Average annual demand for CO2e instruments equals 714 Mt and equilibrium in the carbon market occurs at €5 per tonne of CO2e in the low-case scenario (scenario 1 in the graph). The base-case scenario (shown as scenario 2 in the graph) results in a price per tonne of CO2e of €11 and the market clearing price for the high-case scenario (see the scenario 3 supply curve) is €21. Note that these are the same prices as noted for the Intra-EU option.

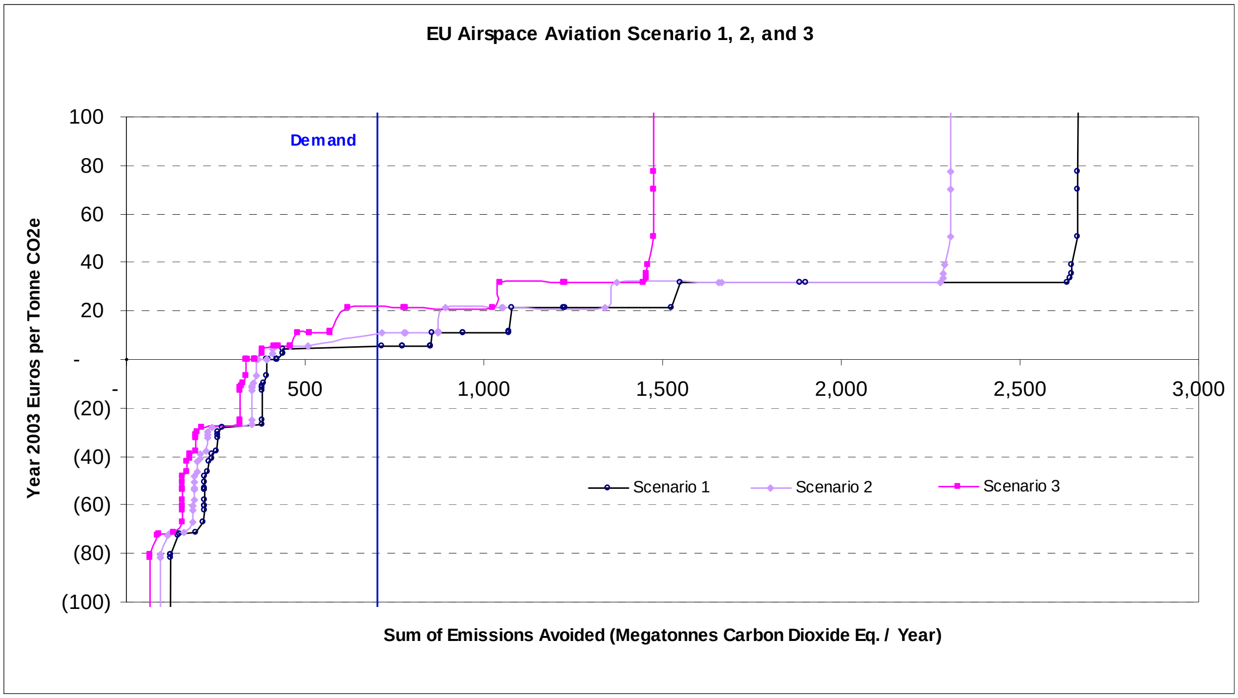
Figure 26: Market Results for the Departing from EU Option



8.3.3. EU Airspace Option

Equilibrium prices for CO2e are again the same under the different scenarios for this option as well. As in the two graphs above, the low-case is illustrated by the scenario 1 supply curve, the base-case is shown in the scenario 2 supply curve and the scenario 3 curve illustrates the high-case. Total average annual demand for CO2e instruments, given the EU airspace option, equals 713 Mt. Under the low-case scenario the market clears at €5 per tonne. Under the base-case scenario the equilibrium price is €11 and under the high-case scenario the price equals €21.

Figure 27: EU Airspace Option



8.3.4. Market Impacts conclusions

The results reported above indicate that even under the worse of conditions in which the aviation sector undertakes no abatement at all, the impacts on the price of carbon allowances associated with including aviation emissions using any of the three options analysed in the CE Delft report are zero. In both the low-case scenario and the base-case scenario defined for this study, purchases of Track I ERUs, produced by economies in transition, increase by the amount of the required reductions from aviation. In the high-case scenario where Track I ERUs, from economies in transition, are not available for purchase, the capacity to achieve emission reductions within the energy sector is sufficiently large to again allow for the increase in demand coming from aviation to be satisfied without causing a change in the cost of allowances.

Relaxing the assumption that aviation will not abate and taking a more realistic perspective that even in the short run, the sector will undertake abatement actions, makes an even stronger argument that the impacts on CO2e prices during the 2008-2012 compliance period will be minimal. On a day-to-day basis, purchases by members of the aviation industry might have some impact on spot prices. On an annual basis, however, the increase in demand for CO2e instruments associated with including aviation in the EU ETS will not be large enough to cause an increase in average annual prices in the carbon market.

An additional area for future analysis is to consider the effects of including the aviation sector in trading when the period of the analysis extends beyond the 2008-2012 timeframe. One danger in relying on a short term view is that it could mask the importance of the price effects under future compliance periods, especially in light of the fact that the demand for aviation services is forecast to continue to exhibit substantial growth for the foreseeable future. Small price effects in Phase 2 could give way to very significant price effects with far more serious implications for other sectors in later periods. While the analysis ICF Consulting is performing for the current study is limited to examining the effects during the 2008-2012 period, we believe that a study with a longer time horizon is also needed to provide a complete picture of potential carbon market effects of incorporating aviation in the trading system.

Another area that would be appropriate to assess in this regard is how the choice of a different base year for the analysis of aviation sector trading might affect the overall demand for carbon instruments. Following the methodology used by CE Delft, our study has assumed that the base year for emissions is 2008. If, as with other sectors in the EU ETS, the base year selected for aviation falls between 1999 and 2004, the results predicted in this paper should be re-examined to be certain that they will continue to hold.

9. Conclusions

ICF Consulting used its proprietary model of the carbon market, InCaP, to provide a rigorous analysis of the implications of including the aviation sector in the EU ETS beginning in 2008. Our findings indicate that for the set of policy options selected for analysis in CE Delft's report for the European Commission and the set of scenarios defined for this analysis, adding the aviation sector to the EU ETS will not have a discernable impact on average annual prices of carbon instruments. Addition of the aviation sector will produce a small increase in demand for EUAs and could place some upward pressure on prices in the short term. However, even a small increase in short term prices for EUAs will encourage an increase in either the quantity of Track I ERUs that are supplied to the carbon market, or induce additional abatement by the power sector. Either or both of these changes mean that the global carbon market can adjust to the increased demand coming from the aviation sector without causing a detectable change in the average annual price of carbon allowances and credits.

Our analysis is essentially a worst case scenario, since we assume that there is no reduction in aviation emissions due to an increase in operating costs associated with a cap on emissions.

Figure 28: Impacts of including aviation in EU ETS

Market Scenario	Equilibrium price of CO2e	Change in annual purchase of ERUs	Change in annual abatement by power sector
Low-case	€5.30	10.1—12.7 Mt	0
Base-case	€11.4	10.1—12.7 Mt	0
High-case	€21.20	0	10.1—12.7 Mt

A key assumption leading to the results from InCaP is that the base year for aviation is 2008. This means that across the time period covered by Phase II of the EU ETS, only small increases in aviation sector emissions are likely given the projected growth rate for emissions is 4% per annum. If a different base year is selected for the analysis—e.g., 2004—the growth in aviation sector emissions through Phase II might be sufficiently high to result in the increase in demand for CO2e instruments that would result in an increase in the price of EUA.

A related issue that deserves some attention in future analyses is that of the implications for price effects over longer time horizons than 2008-2012. If, as projected, the demand for air transport services continues to grow at roughly 5% per year, the price implications of including aviation in emissions trading have the potential to become far more significant.

We have assumed that allocation to the aviation sector will be in line with that of other sectors (i.e., use of historical reference years). Sensitivity analysis using InCaP reveals that to induce a noticeable increase in price would require a substantially larger shortfall on the order of roughly an extra 150 Mt Co2e per year.

It must also be noted, however, the dearth of information on the marginal costs and emission reduction potential of aviation sector abatement options inhibits analysis of the mitigation actions that will be implemented by the sector in response to emission caps. The sector's ability to respond to GHG limitations by investing in changes in the fleet mix or implementing technical or operational measures is not well known outside of the industry. It is generally thought that, particularly in the short run, the costs of achieving reductions in aviation are high, relative to costs in other sectors. However, as demonstrated in CE Delft's analysis, abatement potential does exist within the sector and the potential for finding cost effective options can be expected to increase over time. This suggests another area where further investigation could be valuable is in developing rigorous estimates of the costs and abatement potential of mitigation options available to the sector.

Appendices

Annex A: ICF Consulting approach to power market modelling

ICF Consulting is well qualified for power market modelling and has advised dozens of developers and financial institutions on very similar assignments throughout the world, including in Western Europe, Eastern Europe, the US, Asia, and South America. ICF is also very knowledgeable on issues facing the European power markets: the team members have participated in market studies across the EU-25 and neighbouring countries. In addition, we have expert knowledge of fuel and environmental markets.

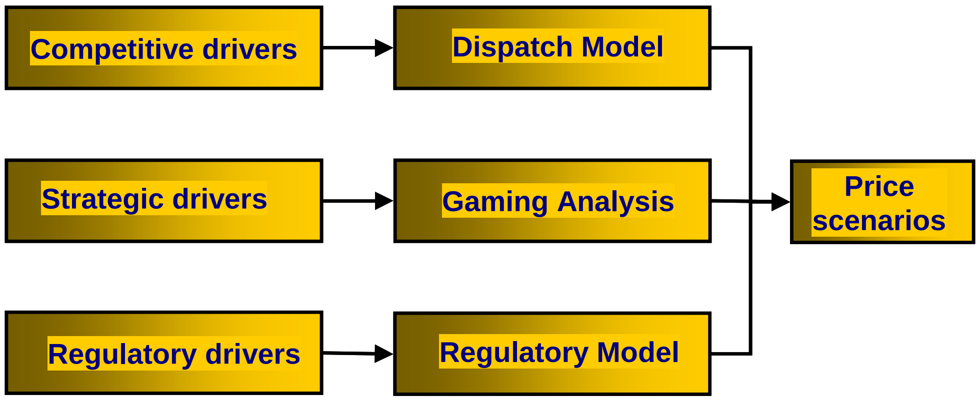
The ICF knowledge base in all these areas is integrated into a single approach and proprietary modelling system, the Integrated Planning Model™ (IPM™), used to analyse the power markets. We have used this modelling framework for power market analysis in support of the development, acquisition, and financing of billions of dollars of power plants across North America, Europe, and Australia.

Our modelling approach enables the cost/value of electricity and the value of transmission rights and environmental allowances to be assessed simultaneously in a unified network.

ICF is highly respected by the power industry, rating agencies, and banking institutions. Furthermore, ICF is the only organization the US federal government uses for comprehensive power market analysis. We are also the only organization to accurately call and go on record with forecasts for price spikes in the Mid-West in the US, California, and the Nordic region. In the remainder of this section we review the ICF modelling experience and analytical approach followed by an introduction to our proprietary software, the IPM™.

Modelling European Power Markets

We categorise the drivers of electricity prices into three generic groupings. These include *competitive drivers* associated only with production costs and physical constraints on the system, *strategic drivers* that arise from the interdependency of actions of (larger) electricity generators and finally *regulatory drivers*. It is the combination of these that is likely to determine the current and future bidding strategies by market participants, which in turn will determine the price in the wholesale generation market and the value of generating assets.



ICF typically commences long-term power assessments using a competitive market framework. We believe the competitive market is a useful benchmark for non-competitive scenarios and is reflective of the attempt of regulatory authorities to create a competitive market via divestiture. The ICF modelling approach is based upon a detailed understanding of the costs and characteristics of the gensets on the system, transmission constraints and opportunities for new capacity or technological improvements to existing capacity.

Power markets with relatively few and large players are characterised by a relatively high degree of interdependence among the decisions of the generating companies. Our knowledge of game theoretical techniques allows us to assess how "players" will react. Our qualitative analysis considers the electricity regulator and Governments as main participants in the "game". Our modelling approach enables the cost/value of electricity, the value of transmission rights and environmental permits (if applicable) to be assessed simultaneously in a unified framework.

ICF's Integrated Planning Model

ICF's Integrated Planning Model (IPM™) has strong environmental capabilities that can be used to reflect renewables or emissions markets in the overall power market. The IPM™ has a number of applications including:

- power market price forecasting and analysis;
- environmental compliance planning of SO_2, NO_x, CO_2, mercury (Hg), fine particulates;
- generating unit and transmission line asset valuation;
- fuel market forecasting and analysis;
- retail deregulation analysis; and
- combined heat and power (chp) market analysis.

ICF integrates unsurpassed expertise in the energy industry with the best modelling tools available to evaluate a broad range of issues facing industry and government today. The IPM™ is a culmination of ICF's 25 years of experience helping private and public sector clients evaluate the complex dynamics of electric, fuel, and environmental markets.

IPM™ is a unique price forecasting tool for power industry participants. The model uses ICF's dynamic linear programming approach to price forecasting to develop profit-maximizing forecasts for plant dispatch, capacity expansion, and power prices given scenario-based inputs for environmental, transmission, fuel, energy demand, operational, financing and reserve margin constraints.

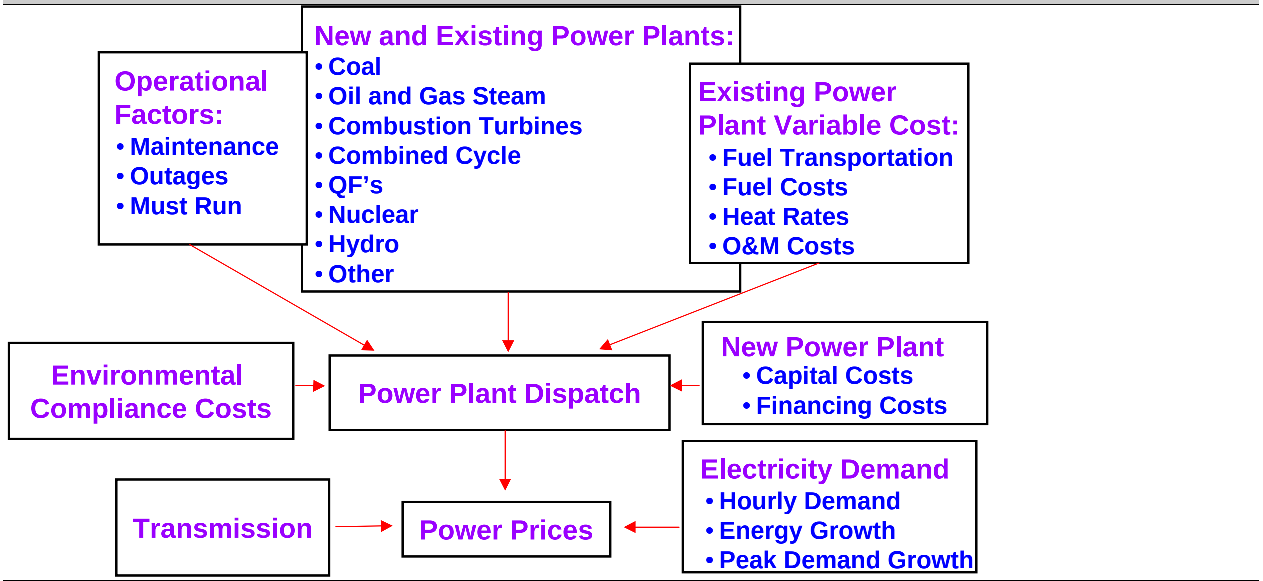
IPM™'s Unique Capabilities and Features

- Covers many international regions capturing interregional power flows and potential transmission construction
- Optimises demand- and supply-side options while performing an accurate system dispatch
- Forecasts hourly energy prices, and annual capacity prices
- Models all major environmental compliance strategies including boiler pollution control retrofits, repowering, fuel switching, co-firing, clean coal technologies, renewable resources and environmental dispatch
- Models the impact of deregulated retail markets on price and load shapes
- Comprehensive modelling of natural gas, coal, and oil fuel markets
- Models the impact of deregulated retail markets on price and load shapes
- Features a sophisticated, flexible user interface and a comprehensive database
- Includes ICF's latest forecasts for all key input parameters, including fuel prices, hourly demand, development costs, and other data

IPM™ Modelling Structure

IPM™ is a versatile model that leads the market in capabilities. IPM™ is the premier tool for investment and due diligence decisions, designed specifically to handle forward price analysis over a multi-year horizon. IPM™ integrates ICF's gas, coal, oil and wholesale consulting practices and is the authoritative source for environmental decisions. IPM™ empowers you to make informed decisions in an uncertain power market.

IPM™ Modelling Structure



Source: ICF Consulting

In addition, IPM™'s flexible interface allows users the ability to analyse, track and compare multiple market scenarios and to probabilistically assess the likelihood of various price results. The IPM™ model when equipped with a complete data set runs on a PC using Microsoft™ Access™. This gives market participants a system that allows the licensee to manipulate ICF's forecast or to develop their own forecast, taking into account their own industry information. This model can also be linked to other ICF systems such as Energy Vision™ and NANGAS™. IPM™'s versatility enables users to answer a series of broad questions affecting business decisions and operations by providing reliable and trustworthy forecasts.

If you are struggling with a key question such as:

- What markets offer attractive investment opportunities?
- What types of assets provide the most value in a given market?
- How does one comply with complex environmental regulations and maximize profits?
- How will plants be dispatched in the future?
- How does one prepare for power price spikes in today's volatile market?
- What is the value of generation portfolios?
- What is the market risk of being short- or long-on generation?
- What is the real option value of environmental compliance decisions?

IPM™ can help answer all these questions.

Marginal Abatement Cost Curve Methodology

This appendix discusses the methodology ICF used to develop the marginal abatement cost curves that are incorporated in InCaP. Each point on a marginal abatement cost curve relates the emissions reduced from baseline levels due to use of a particular abatement technology or practice to the cost of achieving that reduction. Elements of the curve are estimated based on sector-specific inputs that represent emission reductions (expressed as percentages off baseline levels) for each of the abatement options. In addition, each abatement option has an associated cost. Methods used to calculate the cost of each option, expressed as €/TCE (Euros per metric tonne of carbon equivalent), are discussed below.

A discounted cash flow analysis is used to estimate the cost of achieving emission reductions through instituting potential mitigation options. The practice of using discounted cash flow analysis reflects the decision-making process that manufacturers use when considering investments in emission reduction practices. This decision-making process is typically a cost-benefit analysis, where both costs and benefits are estimated for each potential mitigation option by comparing the positive costs (e.g., the financial burden associated with each option) with the negative costs (e.g., the financial savings and/or emission benefits associated with that option).

Discounting Costs

Positive costs associated with abatement options are typically categorized as either one-time (capital) investment costs (e.g., costs incurred for new equipment or a retrofit option), or as annual costs (e.g., operation and maintenance (O&M) costs associated with labor, routine repairs, electricity or fuel use). Mitigation options might have one or both of these types of costs, and both affect the viability of the option. Where country-specific pricing information are not available (either as an absolute price or as a price relative to that in the United States), international costs are estimated from corresponding U.S. figures using adjustment factors. The nature of these factors varies by country and region according to the most pertinent variable affecting the price of each option; factors used include relative labor rates (for labor-intensive options) and relative electricity prices (for energy-intensive options). Finally, some options and sources are considered in the context of an international market in which prices are not highly variable by country. In these cases, international costs are assumed to be the same as in the United States.

The process of "discounting" costs involves calculating the present value (PV) of each cost incurred. The present value of an initial one-time cost is equal to the cost itself, since the one-time cost is assumed to be incurred at the initiation of the project. It is added to the present value of the stream of annual costs incurred.

The following equation calculates the present value of a stream of annual costs denoted by $C_0,...C_n$ paid out over the timeframe of *n* years, where *r* is the annual interest rate (or discount rate) and C_0 is the amount of one-time costs paid out in the first period.

$$PV[C_0,\ldots,C_n] = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i} \qquad \text{Equation 1}$$

Discounting Benefits

Benefits factored into the MAC curve represent savings achieved through reducing emissions. For example, where HFC emissions can be reduced by substituting other less expensive gases, the difference in the price of the HFC and its substitute is counted as a benefit. Where HFC emissions are reduced through equipment modifications, the benefit is the avoided cost of replacing the HFC gas that would otherwise have been emitted. In some cases, benefits occur indirectly as a result of process efficiencies that also lower other annual costs (e.g., costs associated with maintenance requirements or energy use).

The present value of benefits can be calculated similarly to that of costs. In practice, however – for the purposes of this analysis – both costs and benefits associated with abatement options (raw, before discounting) serve as inputs to Equation 4 as presented below.

Tax Adjustments

In some scenarios, the present value calculations of costs and benefits are adjusted using an implied tax rate in addition to the discount rate. The present value of annual O&M costs and emission reduction benefits, calculated using Equation 1, requires additional manipulation when tax rates are considered. Because the taxable income of a particular entity is assumed to be reduced by the cost of a mitigation option, introducing a tax rate multiplies the (financial and emissions-related) present value calculations by the factor *(1 – TR)*, where *TR* represents the applied tax rate. This, in effect, reduces the absolute present value of the annual financial costs or benefits associated with an option.

One-time costs are also affected by the introduction of a tax rate. This effect is quantified through an additional calculation that estimates potential tax savings realized as a result of the depreciation of capital. Depreciation measures the decline in value of any capital investment or asset, generally arriving from use, time, or obsolescence through technological or market changes. The depreciation period of a fixed asset is essentially the useful economic life of that asset. Generally, the depreciation period associated with each mitigation technology or option is equal to the number of years included in the time horizon of each option (i.e., the number of years that the specific practice change or technology is expected to last). Equation 2 presents the calculation for the depreciation of an investment.

$$\text{Depreciation (€/yr)} = \frac{\text{Capital Cost (one-time investment)}}{\text{Depreciation Period (years)}} \qquad \text{Equation 2}$$

Tax savings associated with one-time costs are estimated by multiplying the depreciation of the investment by the tax rate.

Calculating the Break-Even Price

The methodology used to account for costs, benefits, and tax adjustments is summarized by the following equation:

$$\sum_{t=1}^{T}\left[\frac{(P\times ER)(1-TR)+R(1-TR)+TB}{(1+DR)^{t}}\right]=CC_{0}+\sum_{t=1}^{T}\left[\frac{RC(1-TR)}{(1+DR)^{t}}\right] \qquad \text{Equation 3}$$

where: *P* is the break even price of the option in €/TCE
ER is the annual emissions reduction achieved by the technology, in TCE
TR is the tax rate

R is the revenue generated from energy production (scaled based on regional energy prices) or savings (e.g., from the use of less expensive ODS substitutes), in year 2000 U.S. dollars.
TB is the tax break equal to CC/T * TR
T is the option lifetime, in years
DR is the selected discount rate
CC_0 is the capital cost of the option
RC is the recurring (O&M) cost of the option (scaled based on regional labor costs)

Solving for *P* and assuming that ER, RC, and R do not change on an annual basis yields:

$$P = \frac{CC_0}{ER(1-TR)\sum_{t=1}^{T}\frac{1}{(1-DR)^t}} + \frac{RC}{ER} - \frac{R}{ER} - \frac{CC_0}{ER \times T}\frac{TR}{(1-TR)} \qquad \text{Equation 4}$$

P, the "break-even price," represents the point at which an entity (individual, corporation, industry, etc.)—regardless of environmental, legal, or policy concerns—will be financially indifferent in deciding whether to undertake an emission mitigation option. Any option with a cost per ton of reductions less than *P,* is cost effective whereas the reverse is true for any option with a cost per ton of reductions that exceeds *P*.

Marginal Abatement Cost Curves

A MAC curve is derived by ranking individual reduction options in ascending order by €/TCE and plotting the corresponding emission reductions cumulatively. Each point along the MAC curve shows the marginal cost of abating an incremental amount of GHG emissions. The break-even cost of each option determines its placement with respect to the y-axis. Moving away from the origin, each point on the curve represents a cumulative sum of emission reductions with respect to the x-axis. Points corresponding to a zero or negative €/TCE value along the y-axis represent a market in which the benefits of reducing the GHG pay for themselves. These improvements, in many cases, have not yet been made due to various institutional or technical barriers and informational asymmetries that often prevent their implementation. As discussed above, these costs imply that it is cost-efficient to adopt the measure (i.e., the option will result in financial savings). Positive break-even values imply costs that could only result in a cost-efficient market solution if external benefits (e.g., tax or other incentives) were introduced.