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DRAFT PAPER

Power Service

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Environmentally Sustainable Solution for a Gas Turbine Upgrade Clean Development Mechanism Application in a Non-Annex I Country

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ALSTOM Power Service

Executive Summary

ALSTOM Power Service delivers solutions not only to recover degradation, but also to increase the performance and efficiency of the installed global power generation fleet. Such performance improvements also reduce greenhouse gases and particularly CO_2 emissions. The mechanisms of the Kyoto Protocol promote the implementation of CO_2-reducing state-of-the-art technologies to developing and emerging economies.

ALSTOM, having installed the world's largest power generation fleet, wants to make use of the Clean Development Mechanism (CDM) to make technology implementation economically attractive for non-Annex I countries.

This paper gives an overview and outlook for environmental mechanisms and technologies, the value proposition and some experience in pioneering a CDM project with a gas turbine upgrade in a non-Annex I country. It is shown that in a crediting period of 10 years 3 million tons of CO_2eq can be saved on a mid-sized power plant. Assuming a price of € 8 per ton of CO_2eq for Certified Emission Reductions this would lead to an annual revenue of 20 % of the initial implementation cost, representing a very attractive business case for the plant operator.

The described CDM application can be a decisive factor for proceeding with a fuel switch or an upgrade. The revenues earned from emission trading enables the plant operator to make the investment to reduce Kyoto-relevant emissions.

A project example and experience may be shown in the final version of this paper.

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Solution durable pour l'environnement pour une application du mécanisme pour un développement « propre » avec un upgrade d'une turbine à gaz dans un pays ne figurant pas à l'annexe I

ALSTOM Power Service fournit des solutions non seulement pour restaurer la dégradation, mais aussi pour augmenter la performance et l'efficacité de la flotte de génération d'énergie installée globalement. De telles améliorations de performance réduisent aussi l'émission de gaz à effet de serre, et plus particulièrement de CO_2. Les mécanismes du Protocole de Kyoto promeuvent l'implémentation des dernières technologies de réduction de CO_2 dans les économies en voie de développement et émergentes.

ALSTOM, ayant installé la flotte la plus grande au niveau mondial, veut utiliser le mécanisme pour un développement « propre » (CDM) pour rendre l'implémentation de la technologie économiquement attractive pour des pays ne figurant pas à l'annexe I.

Ce rapport donne un aperçu et une perspective des mécanismes et technologies, la proposition de valeur et quelques expériences du premier cas d'un CDM avec un upgrade des turbines à gaz dans un pays ne figurant pas à l'annexe I. Il est démontré que dans une période de crédit de 10 ans 3 millions de tonnes de CO_2eq peuvent être économisées sur une centrale électrique de taille moyenne. En présumant un prix de 8 € par tonne de CO_2eq pour les unités de réduction certifiée des émissions, ceci aboutirait à un revenu annuel de 20 % du coût initial d'implémentation, représentant une proposition économique très attractive pour l'opérateur d la centrale.

L'application de CDM décrite est un facteur décisif pour procéder avec un changement de carburant ou un upgrade. Les revenus gagnés par le commerce des émissions permettent l'opérateur de la centrale de faire les investissements pour réduire les émissions pertinentes à Kyoto.

Introduction

Today's energy markets are being shaped by various influences: De-regulation, increasing capacity demands, rising fuel costs and increasing environmental requirements are only some of the demands power plant operators are currently facing. Some of them only view one aspect, others have to contend with multiple challenges. This paper concentrates on the environmental aspect of power markets and introduces ALSTOM's value proposition and technical solutions in that space, with a focus on already existing gas-turbine (GT) and combined-cycle (CC) power plants.

Within the last decade the majority of climate scientists have concluded that the rise of CO_2 in the atmosphere over the last 200 years was beyond the scope of natural fluctuations, hence is mainly man-made. The Kyoto Protocol (KP) was launched in 1997 and for the first time addressed the correlation between human-caused Greenhouse Gas (GHG) emissions and global warming. The Kyoto Protocol finally came into power in February 2005. So far more than 150 countries have ratified the KP covering more than 55 % of the worldwide GHG emissions.

Economics

Power plants usually are state-of-the-art at the time of their installation and then offer best technologies available with regard to power output, thermal efficiency, environmental impact, etc. Due to significant investment costs, they are usually operated for a time-span of 20, 30, 40 or more years. This already hints at the high-tech character of technologies required in order to enable such tremendous lifetimes.

But, as time passes, demands grow: “Higher, further, faster”. And so, technologies have to be pushed.

Thus more recently installed power plants are equipped with better technologies, offering many advantages in comparison to earlier technologies available.

The power plant operators of ‘older’ equipment face serious competition from more modern plants. New power plants have higher reliability, higher availability; they offer more power output, and lower (as per MW produced) fuel consumption.

Correspondingly power demands are increasing from the end-user. It can be assumed that worldwide energy demands will rise by 50 % during the next 15 years. Therefore, all installed power generation capacities, regardless of age, have to be used to satisfy the increasing power supply demands. Simply switching off capacities which are no longer state-of-the-art and replacing them with latest technology would imply a high price to be paid by the end customer. Whether this scenario would technically be feasible still is another question.

Environmental Aspects and Mechanisms

Today the awareness and responsibility of power generation providers towards the environmental aspects of power generation and supply to the public has risen considerably.

Gas-turbine and combined-cycle power plants utilize fossil fuels containing carbon (C). which is converted to CO and CO_2 in the combustion process with air. CO_2 today is seen as a major contributor to the greenhouse effect. By utilizing fossil fuels with their very high power densities, GT/CC power plants, amongst others and regardless of the vendor, also release significant amounts of CO_2 into the atmosphere during operation.

Another pollutant is NO_x. It is formed during combustion and develops from the natural N_2 (nitrogen) and O_2 (oxygen) content of the ambient air and does not depend on the type of fuel in principle.

A 100 MW CC power plant, fired with diesel fuel and with a moderate thermal efficiency of 55 %, running 8,000 hours per year, releases about 350,000 tons of CO_2 into the environment on an annual basis. Operation of that plant at a 25 ppmv

NO_x level would translate into 230 tons of NO_x released per year. Such a plant could provide electricity to a modern western European city with 150,000 to 200,000 inhabitants. By comparison an automobile releases about 3 tons of CO_2 into the atmosphere every year.

Environmental Technologies

Reduction of CO_2 emissions is currently the focus of numerous research institutes. CO_2 capture mechanisms are under development, but are still in an early stage. However, merely switching fuels, e.g. from diesel to natural gas firing, immediately saves about 15% of CO_2 (as the carbon content of the fuel is approx. 15 % lower).

Another CO_2 reduction approach is to reduce the carbon content per megawatt produced. This directly translates into thermal efficiency increases: Less fuel (and thus less carbon to be burned) for the same amount of power output. So thermal efficiency is key here.

Formation of NO_x can be significantly reduced by so-called lean pre-mix combustion. With that technology, both fuel and air are homogeneously mixed before combusting, thus reducing temperature peaks in the flame (as found with inhomogeneous mixtures), which drive the NO_x production.

Environmental Value Propositions

ALSTOM with the largest installed power generating fleet has, so far, supplied over 25 % of the world's installed power generation capacity.

Thus, ALSTOM not only devotes itself to advancing power generation technologies for higher availabilities, higher reliabilities or higher outputs, it also commits to moving forward on environmental technologies.

In the next 20 years the number of installed power plants which are older than 40 years will double. ALSTOM offers leading-edge technologies for new power plants, and is dedicated to keeping existing power plants competitive.

For NO_x reduction of existing GT/CC power plants, ALSTOM offers its environmentally friendly burner technology. NO_x reductions up to a factor of 5 are achievable by replacement of old diffusion burner technology.

For CO_2 reduction, thermal efficiency is key. Service providers can already offer efficiency upgrades for the majority of its GT fleets in the field, including those built from the 1950s up to today. Further upgrades are under development.

A typical GT efficiency upgrade improves GT thermal efficiency by up to 5 %, which directly translates into fuel savings and thus reduces CO_2 emissions by 5 % per MW produced.

Service providers have developed special methodologies to assess all plant components, revealing efficiency improvements and overall optimization potential. Achievable CO_2 reductions are strongly dependent on the actual condition of the specific plant.

Remote online monitoring of GT/CC plants worldwide allows analysis of power plant data and identification of issues like recoverable degradation of thermal efficiency – translating into increased CO_2 production – to provide recommendations for improvements to the plant operators.

All these products and services are compliant with and support the Kyoto protocol.

The Kyoto Flexible Mechanisms

The Kyoto legislation distinguishes between so-called Annex I countries, which comprise all OECD countries and the Non-Annex I countries (see Fig. 1), namely developing countries (including India and China).

- The Annex I countries have committed themselves to controllable reduction targets with respect to their Greenhouse Gas (GHG) emissions (= CO_2, CH_4, N_2O and industry gases like HFC, PFC, SF_6) in the arbitrarily chosen base year 1990 by 5 % within the Kyoto period (2008-2012).
- Non-Annex I countries were not obliged to any reductions.

In the succeeding conferences after Kyoto the Annex I countries modified their reduction targets in the so-called burden sharing due to economical capacity, future perspectives and environmental ambitions, e.g. while the EU-15 agreed to –8 % (further burden sharing within EU-15), the US –7 %, Eastern Europe and Switzerland –8 %, Russia, Ukraine and new Zealand accepted a 0 % target (i.e. maintaining 1990's emissions) Australia, Iceland and Norway were allowed to even increase their emissions by 3-10 %.)

Given that the warming effect of Greenhouse Gases remains the same, no matter where they are released, the Kyoto protocol foresaw from the beginning the opportunity of emission trading, mainly to minimize the GHG mitigation costs. While economic productivity and efficiency varies worldwide, the marginal CO_2 abatement costs vary too. Hence with a given amount of money a maximum of CO_2 emission reduction can be achieved in economies of low productivity.

At the same time emission trading was considered a tool to promote technology transfer (to avoid the environmental mistakes of the OECD countries) from industrialized to developing countries, thereby enabling them to improve their living conditions by producing electricity more efficiently and/or in alternate ways.

This compromise between the economic interests of industrialized and developing countries made the UN approval process of the Kyoto flexible projects (see Fig. 2) very complex.

Flexible Mechanisms due to the Kyoto Protocol to Reduce Abatement Costs

The reduction commitment of the Annex-I countries has been achieved by including flexible mechanisms:

1. Trade of emission rights – CO_2 credits between Annex-I countries:
   - **Joint Implementation (JI)** – Bilateral agreements:
     Emission Reduction Unit = **ERU**
   - **Emission Trading Scheme (ETS)** – Multi-lateral agreements
     Common CO_2 market, e.g. EU (since Jan 1, 2005):
     EU allowances = **EUA**
2. Trade of emission rights between Annex-I and Non-Annex-I countries:
   - **Clean Development Mechanism (CDM)** – Bilateral agreements:
     Certified Emission Reduction = **CER**;
     Non-Annex-I countries have no own reduction commitments due to Kyoto → Project-
     based CO_2 credits

The differently named emission rights all have the same unit (reduced or avoided t CO_2eq) and are transformable into each other. The transfer and transformation of CER's and ERU's into EU allowances 1:1 is regulated by the EU Linking Directive (part of the EU legislation on emission trading). CER's (emission rights of CDM projects) can be transferred into the EU Emission Trading Scheme (ETS) since the beginning of the ETS in 2005 while ERU's (emission rights of JI projects) can be transferred into the ETS from 2008 on (Kyoto period runs from 2008 until 2012). The different GHG's possess a different warming potential in the atmosphere, the worst are the fluorinated/chlorinated hydrocarbons, methane which has a 21 times higher warming potential than CO_2, which nevertheless is the most frequently, released GHG. Therefore, all mitigation measurements are transformed into tons CO_2eq. According to the Kyoto flexible mechanisms and the ratification status of the KP the world currently consists of different markets, see Fig. 1.

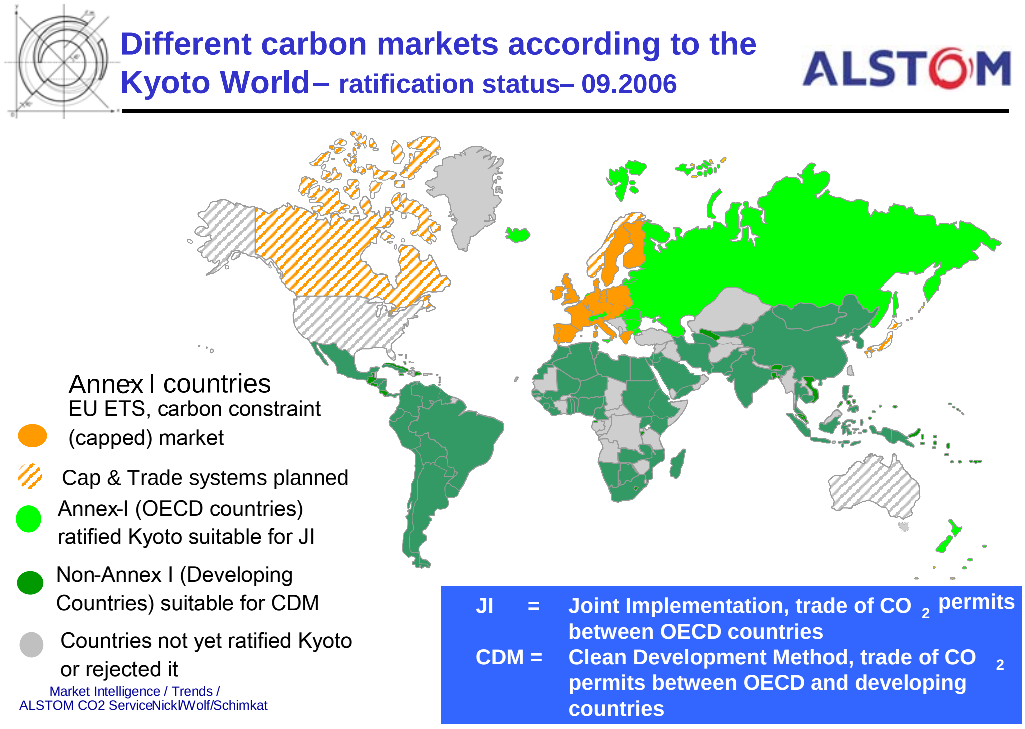

Fig. 1: Ratification status of the Kyoto Protocol

The complexity of the approval process outlined in Fig. 2 is also reflected in the transaction costs for a typical project (in the range of € 100,000 – € 150,000 until UN registration) depending on the project type and the host country (maturity of CDM infrastructure, political stability etc). The transaction costs consist of fees and salaries to be paid to the various entities or partners in the approval process, e.g. consultants who help to set up a PIN (= Project Idea Note) which describes on several pages who is doing which kind of project, where and what the supposed emission reduction will be. The more sophisticated and detailed report is the PDD (= Project Description Document), which can make up more than 100 pages. The PDD finally has to be checked and approved by a DOE (= Designated Operational Entity which must be approved by the UNFCCC) like TÜV Süddeutschland, DNV etc. There are further transaction costs occurring in the implementation period, after the project has already started to produce electricity, mainly for the monitoring of emissions and getting the saved CO_2 reductions annually confirmed by a DOE as an independent evaluator. The validation steps which have to be executed by the DOE's entail a validation fee and together with the registration fee and costs for consultants make up the project specific transaction costs in the CDM/JI process.

Country specific risks and the supposed project size (reduced t CO_2eq per year) have to be taken into account to minimize transaction costs. The amount of avoided CO_2eq emissions in a typical CDM project can range from several hundred or thousand tons (small scale CDM) to several million tons per year. Given the “high transaction costs” a potential CDM project should deliver a minimum of 50,000 t CO_2eq per year to be economically attractive.

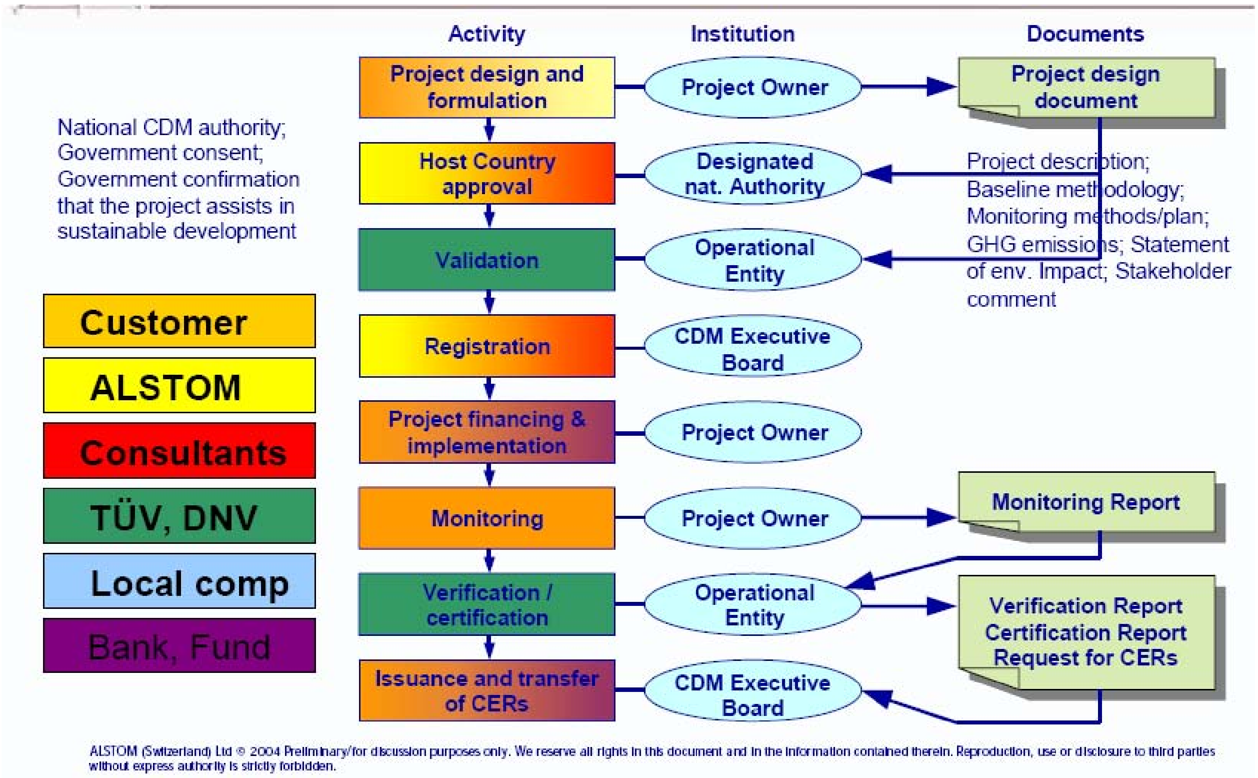

Fig.2: CDM Approval Process

Typical CDM project types are the deconstruction of fluorinated/chlorinated hydrocarbons, methane capture from waste sites or coal mines, combined heat and power (co-generation), fuel switch to less carbon containing fuels as well as the efficiency increase on the demand and supply side.

The Kyoto legislation (legal framework of emission reduction targets and of emission trading) will be valid until 2012. Negotiations about the post-Kyoto (post-2012) targets (who has to reduce how much) have started in 2006 and will last at least until 2009. The current uncertainty about the post-2012 legislation already affects the economical viability of CDM projects under development or of future projects due to that CER price guarantees (in forward contracts) are only given until 2012.

The EU and other countries are determined to limit a more than 2 °C global average temperature rise until 2100, which due to the International Community of Climate scientists (IPCC = International Panel on Climate Change) is equivalent to an atmospheric CO_2 concentration of 550 ppm level.

Taking into account the anticipated future increase of power generation capacity, especially in developing countries, which to a significant extent still will be based on fossil fuels, a stabilization of CO_2 at 550 ppm would imply a GHG emission reduction of approximately 27 Gt until 2030 and of 46 Gt until 2050 compared to the Business-As-Usual (BAU) case. This fact makes it inevitable that the biggest emitters of today (USA) and the most likely ones of tomorrow, India and China, must be a part of future climate commitments.

By defining obligatory emission reduction targets the Kyoto Protocol is supposed to promote a more energy efficient and sustainable economy by enhancing the efficiency of energy generation or making it less carbon intensive. The latter is possible by either a switch to less carbon containing fuels (e.g. coal to gas) or a partial/complete substitution of fossil fuels by renewables in the mid- and long-term.

Efficiency increase both on the supply and the demand side is supposed to give the biggest GHG emission reduction potential. Moreover, improvements in the average efficiency of coal-fired power plants are feasible now. Two thirds of all coal fired power plants worldwide are older than 20 years, have an average net efficiency of 29 % or lower and emit 3.9 Gt of CO_2 per year[1]. If all these were upgraded to state-of-the-art or replaced by new plants (45 %), the upgraded/new plants could emit up to 36 % less CO_2 or up to 1.4 Gt CO_2 less per year. If all gas power plants, whose average efficiency worldwide is about 42 % (2003)[2], could be improved to today's standard of 58 % or 60 % in the future, the CO_2 emissions could be reduced by up to 30 %.

The CDM/JI market comprises mostly countries where electricity is generated on a low general efficiency level produced by utilities of which the majority is short in money. Hence, there is both a great modernization potential and a great lack of funding.

ALSTOM's CDM Experience

ALSTOM is now pioneering the application of the Clean Development Mechanism (CDM). We are proposing a business model for a combined-cycle power plant with two gas turbines and one steam turbine. Located in a non-Annex I country, the power plant has a total power output of about 300 MW, an average thermal efficiency of 45 % and generates more than 1.2 billion kWh of electricity annually.

The main fuel currently is residual fuel oil. The CDM project activity comprises the conversion to dual fuel. The main fuel will be natural gas. The fuel switch will result in a substantial reduction of emissions on CO_2 and on NO_x. Old single burner combustors could be replaced with advanced burners leading to significantly reduced NO_x emissions.

A further improvement of combined-cycle efficiency by about 0.6 % (multiplicative) can be achieved through installation of a fuel gas preheater. An increase of the turbine inlet temperature has the potential to additionally raise combined-cycle efficiency by about 1.7 % (multiplicative) and power output by about 20 MW. This would require minor hardware adaptations.

[1] IEA Energy Technology Perspective 2006
[2] IEA Energy Technology Perspective 2006

Benefits and Business Case

The project would result in a significant reduction of CO_2 emissions which on a global level will reduce the greenhouse gas effect: Based on the forecasted operating hours and fuel consumption, the project is expected to generate an average annual CO_2eq emission reduction of more than 300,000 tons. In the crediting period of 10 years in total this will be more than 3 million tons CO_2eq. This has been calculated using the approved CDM fuel switch methodology AM0008[3].

Assuming a price of € 8 per ton of CO_2eq for Certified Emission Reductions this would lead to an annual revenue of 20 % of the initial implementation cost, representing a very attractive business case to the plant operator.

Thus the CDM application can be a decisive factor for proceeding with a fuel switch or an upgrade. The revenues earned from emission trading enables the plant operator to make the investment to reduce Kyoto-relevant emissions.

Outlook

Financing of such projects, which is greatly dependent on obtaining the full CDM revenue, depends on the post-Kyoto regulations and the international reduction targets. These, however, are not yet defined, and the current period of uncertainty could endanger the reliability of future business cases. In addition the currently quite cumbersome approval process places an additional burden on the investor, who is already exposed to a large risk due to the high-investment and relatively long lead-time for bringing a plant on stream.

After approval of the CDM project by the designated national authority, ALSTOM supports the customer to find a buyer for the Certified Emission Reductions. This is part of the scope offered by ALSTOM as a full-service provider.

As is often the case with many visionary ideas, the idea to apply the Clean Development Mechanism to a power plant upgrade was initially also met with skepticism. Now that the idea has moved from being a concept to a viable business proposition, its true potential has become apparent. Assuming that regulations similar to the Kyoto Protocol will be defined for the post-2012 period, there will be more business cases in the near and long-term future that will be mutually beneficial for the environment, plant operators and developing countries.

[3] http://cdm.unfccc.int/UserManagement/FileStorage/CDMWF_AM_446454474

Attachment:

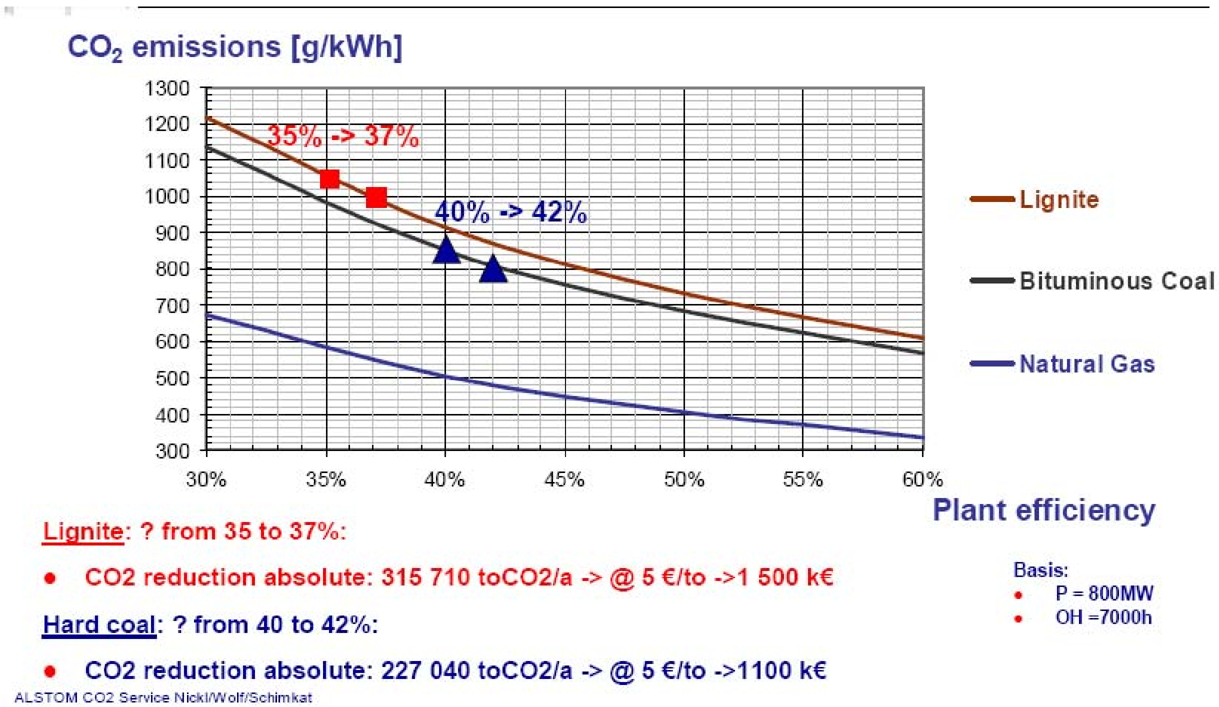

Fig. 3: Example of how an efficiency increase project for different fuels reduces the CO_2 emissions of a power plant. The surplus emission rights can be sold on the market. The here assumed CDM market price was € 5 per ton CO_2

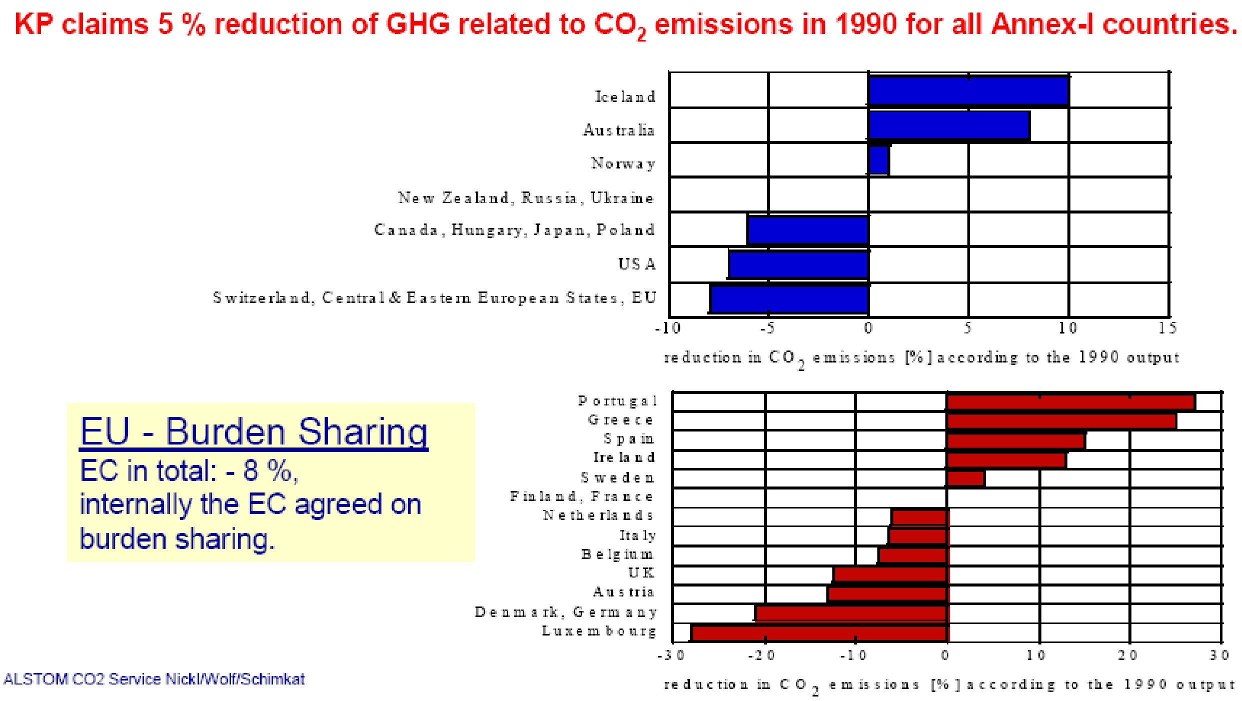

Fig. 4: KP Reduction Targets