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SECTORAL CREDITING MECHANISMS: AN INITIAL ASSESSMENT OF ELECTRICITY AND ALUMINIUM

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FOREWORD

This document was prepared by the OECD and IEA Secretariats in September-November 2005 in response to the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy-makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document are those listed in Annex I of the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Korea and Mexico, as OECD member countries, also participate in the Annex I Expert Group. Where this document refers to "countries" or "governments", it is also intended to include "regional economic organisations", if appropriate.

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Executive Summary

There is much interest in addressing broad sectors and extending the scope of the project-based mechanisms established under the Kyoto Protocol, both pre and post-2012. As a contribution to this debate, we explore how a sectoral crediting mechanism (SCM) could work in the electricity and aluminium sectors and present preliminary insights on the pros and cons of such designs. Both the importance and potential reductions of GHG emissions from power generation are well-known. Fuel combustion for electricity generation is the largest emitting sector, and in 2002 accounted for 39% of fuel combustion emissions, almost 9.5 billion tons of CO_2. Further, other emissions from electricity generation are also responsible for local environmental pollution, especially in developing countries. Last, meeting growing demand for electricity has significant implications on developing economies' future capital and infrastructure needs. An effective SCM could mitigate the sector's pressure on the economies of developing countries and a number of related environmental problems.

Aluminium brings other interesting aspects, although its importance to global GHG emissions is much lower than that of power generation: it is internationally traded; and its production processes emit non-CO_2 greenhouse gases. Further, primary aluminium production is highly electricity-intensive, leading to potentially high levels of indirect emissions. Establishing a SCM in this sector could help foster the adoption of cleaner aluminium smelting technologies in developing countries. While this paper focuses on possible GHG-improvements to primary aluminium production, an SCM in this sector could also be developed to encourage greater recycling of aluminium.[1]

A SCM could rely on a baseline that considers the effects of a specific policy (policy-based), a rate of GHG emissions per unit of output (rate-based), or on a straight emissions limit (fixed limit). Further, it could operate at an <u>international</u> level (i.e. one baseline level across all countries) or allow for <u>national</u> variations (e.g., based on a formula to calculate the emissions baseline). This paper outlines each of these three possible designs for electricity generation and for primary aluminium production.

Although there are differences in each of the possible SCM designs examined, and the specific issues vary by sector, the following points would need to be defined up-front for any SCM:

- **Eligibility and boundaries**: the mechanism must establish a clear perimeter of eligible plants/activities. Thus, for the electricity sector the boundary might need to specify a minimum output capacity per plant and whether to include or exclude auto-producers of electricity. It must also define how electricity imports and exports will be included in the quantification of emission reductions, and which gases should be included (i.e. CO_2 only or CO_2, CH_4 and N_2O). For the aluminium sector, a SCM would need to establish whether it covers primary and/or secondary aluminium production (which have significantly different GHG intensities and profiles), which direct and/or indirect emissions would be included, and which gases.

- **Projections of business-as-usual output and emissions**. Whether such projections are used to determine the baseline for crediting or not, they will be needed to establish confidence in the environmental outcome of the mechanism.

- **Definition of a baseline**. A sectoral crediting mechanism will require a baseline to measure performance. How this is defined will depend on the SCM design, as well as on the definition of

[1] There are several different means of mitigating GHG emissions through changes in aluminium production processes and/or use. This paper focuses on the most GHG-intensive component of primary aluminium production: aluminium smelting.

sector. It will further be influenced by decisions on the appropriate spatial scope of a baseline (e.g. whether it should be set at a sub-national, national or international level), as well as on other boundary issues highlighted above.

Electricity

Encouraging a shift to lower-carbon fuels, more efficient combustion technologies, larger plant sizes, improved maintenance, better quality coals and/or better coal preparation, and end-use efficiency improvements could help reduce electricity-related CO_2 emissions. Since national variations in fuel mix and availability are significant, this paper assumes that any SCM developed for the electricity sector will be done at a national, rather than international, level. Baselines could therefore vary by country, allowing power generators with both different CO_2 intensities to generate credits by improving their performance.

Each SCM design features different design elements:

- A policy-based option would require an *ex-post* assessment of achieved reductions, as divergences from baselines may stem from various factors other than the targeted policy.

- A rate-based approach requires clear eligibility criteria for crediting: crediting may be attributed on a plant-by-plant basis, or based on the sum of all plants. Decisions will also be needed on whether the rate should be a single one for a whole country or grid, or whether it should be specified on a technology basis. While being less economical from a CO_2 mitigation perspective, and making credit generation from renewable electricity systems difficult, the latter would recognise that when endowed with large fossil fuel resources, developing countries are unlikely to stop using them in the near future.

- A fixed target applied to power generation emissions could encourage generators to take up a broader range of mitigation options, including end-use efficiency, neglected by a rate-based approach. As in standard cap-and-trade systems, a crediting mechanism based on a fixed limit would credit all reductions, whether or not linked to mitigation measures. This highlights the importance of business-as-usual projections in this option. A fixed target could also require some allocation of emissions within a sector and country, which can in itself be a resource-intensive process. In this option as in the previous two, *ex post* adjustments should ideally be limited to reduce risk borne by agents investing in mitigation and expecting credits as a result.

No design is inherently more environmentally-effective than another. Rather, it is the design details (such as baseline level and the system's boundary) that influence a SCM's environmental effectiveness.

Aluminium

Unlike the electricity sector, an international approach to sectoral crediting may be more appropriate for the aluminium sector. This is because new primary production plants (smelters) are usually located near cheap sources of electricity, an important cost element for this industry. Further, the aluminium industry has already adopted a number of voluntary initiatives to reduce their GHG emissions through a range of measures targeting both their direct emissions and electricity consumption.

Technology utilised in smelting, the most GHG-intensive part of aluminium production, is widely shared around the world, with new plants adopting generally the most energy-efficient and low PFC-emitting technology (Point Feeder Prebake or PFPB). However, many older, less energy-efficient and higher PFC-emitting smelters are still in operation, particularly in China and Russia. Further, specific design choices and plant management has a marked impact on process-related emissions of PFCs, with reported emissions from this technology type varying from 0.018 to 3.71 tCO_2eq per ton of primary aluminium at different plants in 2003 (IAI 2005).

The inclusion of "indirect" emissions related to power generation has a very significant impact on aluminium's overall GHG-intensity, as some electricity sources are carbon-free while others rely on fossil fuels. Establishing a single baseline level for GHG emissions per ton of aluminium that includes power generation emissions would have a strong impact on future production choices (including location, as producers would look for the least CO_2-intensive electricity resources). It may not be practical if it applies to current plant operations, as there is limited scope to reduce electricity-related emissions from existing suppliers.

A potential impediment of a sectoral-crediting approach in such a competitive sector is the possibility that it could reward laggards, in fact subsidising their GHG improvements while others have taken such measures without financial incentives. Crediting may thus distort the playing field and appear unfair to entities that have moved more promptly to reduce their emissions.

Issues for further consideration

Several issues should be explored further before any sectoral crediting mechanism is established. These include:

- How a SCM would interact with other agreements already in place in the same country or sector (e.g., Kyoto Protocol mechanisms, EU Emissions Trading Scheme, voluntary agreements and other domestic policies).

- The management/oversight required for an SCM, i.e. what approval process could be envisioned, whether an SCM was binding, who would be liable under such a mechanism, and what the role of national governments and industry bodies would be with regards to setting incentives, monitoring, reporting and review.

- How competitiveness concerns could be addressed for SCMs in sectors with internationally-traded products, and how any perverse incentives could be minimised.

1. Introduction

1.1 Why sectoral-crediting mechanisms?

Greenhouse gas (GHG) emission projections indicate rapidly growing emissions in developing countries. These countries have not committed to country-wide GHG objectives, raising two specific concerns other than GHG accumulation:

- Industrialised countries that have introduced emission objectives are faced with a risk of leakage: any constraint on the production of an internationally-traded good creates a competitive advantage for producers without an emissions constraint to relocate. This issue is particularly compelling for energy-intensive and GHG-intensive products such as steel, cement and aluminium.

- Rapidly growing activities with long-lived capital stocks may be locked in a carbon-intensive path, when developing countries decide to engage more actively in GHG mitigation. This may create large GHG-intensive capital stocks that will have to be retired early at some economic cost to meet emission goals. Alternatively, the existence of these GHG-intensive assets would result in a country adopting a higher emission target than it would have otherwise. The power generation sector is a typical example of such an activity.

35 proposed Clean Development Mechanism (CDM) projects expecting to generate 8.1 million credits per year during the crediting period have been registered by the Executive Board (EB) by November 15, 2005. The pipeline of projects under development is much larger, estimated to generate more than 138 million credits/year during the 2008-2012 period (Ellis and Levina, 2005). However, this is only a small fraction of projected energy-related CO_2 2010 emissions from non-Annex I countries and Annex I countries (11.2 $GtCO_2$ and 16.7 $GtCO_2$ respectively – IEA, 2004), and even smaller fraction of total GHG emissions.

There is much interest in addressing broad sectors and extending the scope of the project-based mechanisms established under the Kyoto Protocol, both pre and post-2012. Crediting GHG reductions on a sectoral basis would have several advantages, including:

- Creating incentives for greater investment and uptake of GHG-friendly technologies, thus potentially enhancing the sustainable development benefits for developing countries.

- Generating a greater number of emission reductions and increasing the supply of emission credits.

In so doing, a sectoral approach to crediting could help mitigate the concerns on leakage and lock-in mentioned above and could also pave the way for lower cost mitigation commitments by developing countries, when such commitments are discussed internationally.

Other fora have considered sectoral approaches to GHG mitigation (see e.g. Watson et al. 2005, Schmidt and Lawson 2005). This paper explores how a sectoral *crediting* mechanism (SCM) could work in the electricity and aluminium sectors, building on Bosi and Ellis (2005). Both the importance and potential reductions of GHG emissions from power generation are well-known. Aluminium brings other interesting aspects that make it another worthy sector for an illustrative SCM case study: it is internationally traded; its processes emit non-CO_2 greenhouse gases; and aluminium is also highly electricity-intensive, leading to potentially high indirect emissions. This paper explores possible designs of a "sectoral crediting mechanism" in the electricity and aluminium sectors, and presents preliminary insights on the pros and cons of such designs.

The analysis is based the following policy assumptions:

- The Kyoto Protocol will lead to some countries having country-wide GHG emission limits beyond 2012.
- Countries with emission commitments will have the possibility to rely on emission reductions achieved elsewhere – not all emission reductions are expected to occur in parties with emission limitations.
- Market mechanisms can be used to generate credits, and these credits can be used by countries with emission limitations commitments.

The paper is organised as follows: Sections 2 and 3 present case studies on electricity and aluminium, respectively. Section 4 presents cross-cutting issues and offers preliminary insights.

1.2 Design options

There are several ways of designing a sectoral crediting mechanism, examined in a previous paper (Bosi and Ellis 2005). Perhaps the first question in designing a sectoral crediting mechanism would be to examine whether or not a SCM should operate at an international level (i.e. one level across all countries), or whether it should be designed to allow for national variations (e.g. to agree a formula to calculate the emissions baseline, so allowing the baseline level to vary across countries).[2]

Another feature of the SCM is the nature of the goal, or baseline, on which it is based. In what follows, we distinguish three options:

- Policy-based: actors in a sector commit to implement a policy or set of policies that should contribute to reduce its GHG emissions. Credits will accrue if emission reductions are identified as the result of these policies.
- Rate-based (or indexed): a baseline is set in terms of tCO_2 equivalent (CO_2-e) per unit of output. If production performs beyond this baseline, the sector will be credited for the difference between its CO_2 content and the target level, times total output.
- Fixed sectoral limits: an absolute emissions limit is agreed. The difference between this limit and actual emissions recorded over an agreed period will be credited to the sector.

Beyond the type of design for a sectoral crediting mechanism, sectoral mechanisms raise the following issues, beyond the scope of our preliminary analysis:

- The binding nature of the target: a non-binding target would allow the sector to sell credits, but does not commit the industry to buying if emissions are higher than expected (Philibert, 2005).
- Liability: parties, not companies, have commitments under the Kyoto Protocol. The role of companies, especially when considering international sectoral agreements, must be clarified.

[2] A regional scale could also be envisioned, e.g., if a few neighbouring countries are in competition in these sectors, or face similar conditions.

Table 1: Summary characteristics of the electricity and aluminium sectors

	Electricity	**Aluminium**
Importance in global GHG emissions	High (CO_2)	Low (CO_2, PFCs)
Emission trends	Absolute emissions growing, emissions intensity trends very variable by country	Direct absolute emissions decreasing, relative emissions decreasing sharply
Current production/consumption in Annex I countries	10,577 TWh in Annex I countries; 16,000 TWh worldwide	52% of global 2004 production and 61% of 2004 consumption in Annex I countries
Demand growth to 2020	World: 2.7% per year; Transition economies: 2.0% p.a.: Developing countries: 4.5% p.a. (IEA, 2004)	Projections not available. Expected to grow at 3% p.a. to 2020[3]
Projected consumption shares in 2020	Developing countries total 41.4% with following generation breakdown: Coal, 47%; Oil, 7%; Gas, 24%; Nuclear, 3%; Hydro, 18%; Other Renewables, 2%.(IEA, 2004)	49.1% consumption in Annex I countries (Watson et al 2005)
Ownership	Public and private	Mainly private (exceptions include China and India)
International trade in product	Limited	Widespread
Type of SCM	National / Regional	International
Degree of GHG measurement uncertainty	Low	Low if done at plant level
Technical feasibility	Low-moderate (depending on national capacity)	High, if all international aluminium companies participate

[3] Personal communication, Robert Chase, International Aluminium Institute Global Mass Flow Model.

2. Electricity Sector

In 2002, CO_2 emissions from fuel combustion stood at 24.5 billion tons CO_2, representing almost 64% of global anthropogenic greenhouse gas emissions - excluding emissions/removals from land use change and forestry (IEA 2004). Fuel combustion for electricity generation is the largest emitting sector, and in 2002 accounted for 39% of fuel combustion emissions, almost 9.5 billion tons CO_2. Further, CO_2 emissions from electricity generation[4] have continued to grow in almost all world regions apart from economies in transition since 1990. Indeed, CO_2 emissions from electricity production increased by 37% globally, and by 24% in OECD countries, over 1990-2002 (IEA 2004).

Non-Annex I Parties accounted for approximately 40% of total electricity-related emissions in 2002. This proportion is expected to increase, as growth in electricity demand and production in non-Annex I countries and associated emissions is expected to continue to 2020 and beyond. For example, China and India's electricity generation is expected to grow at 5% and 4.7% respectively per annum between 2002-2020, with this sector's associated CO_2 emissions approximately doubling in the same time period to reach 3.2 billion tons CO_2 in China in 2020, and 980 billion tons CO_2 in India in the same year (IEA 2004b).

Looking to 2030, Figure 1 shows the increased in power generation capacity in Annex I and non-Annex I countries. Under the IEA's Reference Scenario, assuming no policies beyond those taken by 2004, developing countries would add some 1,848 gigawatts (GW) of capacity in fossil-fuel based generation, half of which would be coal-based, compared to 843 GW in industrialised countries, of which the vast majority would be gas.

Electricity emissions intensity remains high in many countries. Yet lower, low and no-carbon electricity generation options are feasible. There is also a large potential for end-use efficiency improvements that would also contribute to reducing power demand and associated CO_2 emissions[5]. A greater uptake of these technologies, fuel sources and policies could help to "decouple" the growth of electricity production and electricity-related emissions. This could in turn significantly reduce the growth in GHG emissions from the electricity sector.

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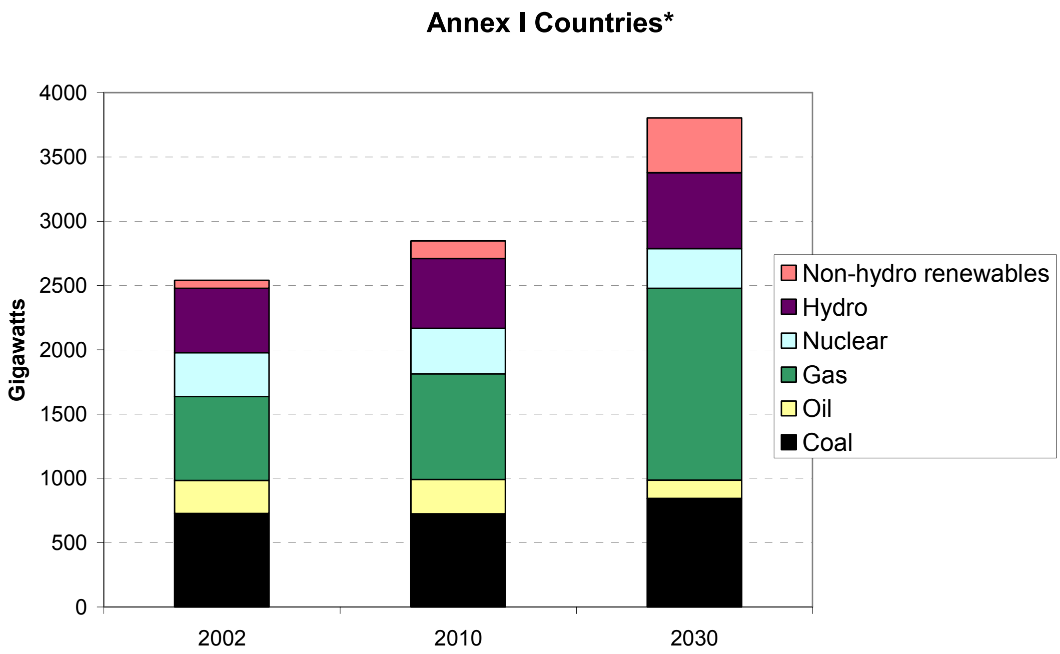
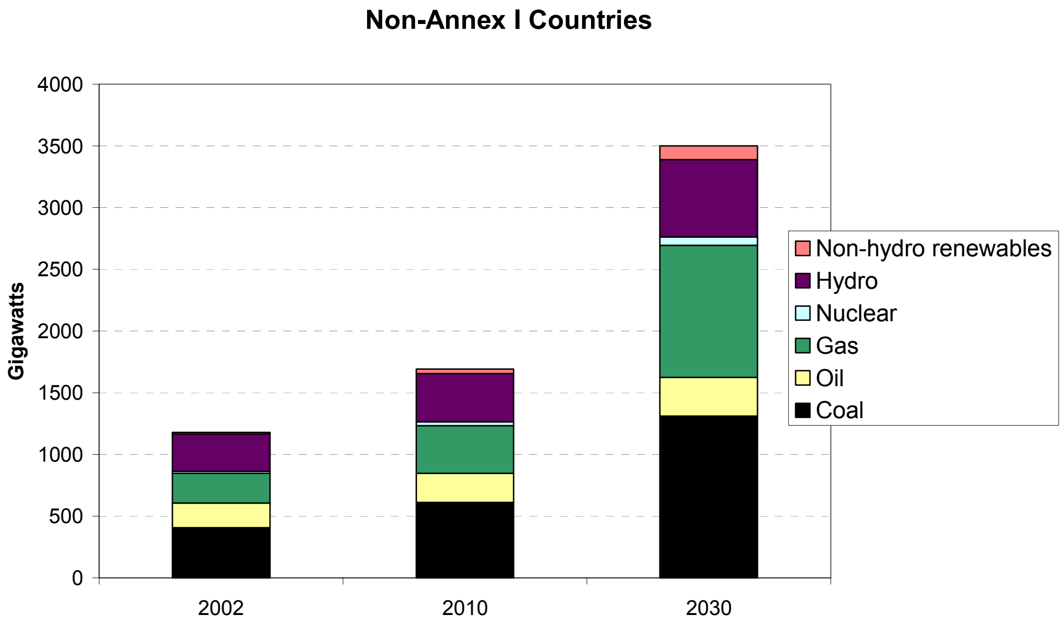
[4] The figures quoted represent combined emissions from "public electricity and heat production" and "unallocated autoproducers".

[5] See the Alternative Policy Scenario of the WEO which indicates that 67% of avoided CO_2 emissions in the developing world would result from energy efficiency improvements (IEA 2004b). These gains would be accompanied by lower investment needs in electricity supply and demand, with savings on the generation side more than offsetting investment needs on the demand-side. See IEA 2002 for estimates of electricity savings and related avoided CO_2 emissions in IEA countries, through appropriate policies on electric appliances.

Figure 1: Projected new capacity in power generation (2002-2030)



* Including Turkey



Source: IEA 2004.b

2.1 Trends and emission reduction opportunities

Fuel mix is the single most important factor that determines the level of GHG emissions from electricity generation. Worldwide, coal is the most important fuel used for electricity generation. Its importance has hardly changed since 1971, nor is a change expected in the foreseeable future: coal accounted for 40% of electricity generation in 1971, 39% in 2002, and is projected to account for 38% in 2020 (IEA 2004b). Gas is the second most important fuel for electricity generation at a global level, contributing 19% in 2002. This is expected to rise to 27% in 2020 (IEA 2004b). Biomass and other non-hydro renewables are expected to slightly increase their still small market share. The importance of nuclear power is expected to fall from 17% in 2002 to 12% in 2020 (IEA 2004b).

However, despite these global trends, fuel mix and trends varies significantly by region, by country, and even by regions within a country – depending on the availability of different fuels and other national circumstances. For example, over 75% of electricity is generated by coal in South Africa, China, and Australia; by gas in Iran and Malaysia; by nuclear power in France and Lithuania; and by hydropower in Brazil, Nepal and several African countries (IEA 2004c). Further, the importance of GHG-intensive coal has increased sharply (from 51 to 70%) since 1990 in India, and has also increased (from 72 in 1990 to 80% in 2003) in China.

These variations in fuel mix have a significant impact on the GHG-intensity of electricity generation, which can be under 10 g CO_2/kWh in hydro-dominated countries to more than 900 g CO_2/kWh in coal-dominated countries such as India.

Technology also plays a significant role in the GHG-intensity of electricity generation. The efficiency with which coal and gas are used to generate electricity can vary widely. For example, the efficiency of some currently existing coal-fired plants in India can be as low as 20%, whereas newer coal power plant efficiencies are often in the range of 34-36% (Sharma 2004). Supercritical coal plants with efficiencies higher than 40% are also possible, and more than 400 supercritical plants are in operation worldwide – including in some non-Annex I countries such as China and South Africa (World Bank). However, almost two thirds of the coal-fired power plants worldwide are more than 20 years old, have an efficiency of 29% and emit some 3.9 billion tons of CO_2 (CIAB, 2005).

The range in gas-fired power plants is even greater, with "open cycle" plants operating inefficiently as peaking power plants with 25% efficiency or less, and newer combined cycle gas turbines operating at efficiencies of over 50% (NEA/IEA, 2005).

The impact of these efficiency variations on GHG intensities in efficiency is further illustrated by comparing the coal electricity CO_2 intensities between India and South Africa. In 2002, one kWh generated by coal emitted 1.2kg CO_2 in India: 30% more than a kWh of coal-fired electricity in South Africa (calculated from IEA 2004c). Thus even though India uses coal to produce only 70% of its electricity, it has a higher overall electricity intensity than South Africa, which uses coal to produce 93% of its electricity.

Other factors also influence the GHG intensity of electricity production, although to a lesser extent than fuel type and technology. These include:

- Plant size (larger plants tend to be more efficient, but smaller plants are relatively common in many developing countries).
- Plant maintenance (poor maintenance will reduce plant performance).
- Coal type and quality (combusting poor quality coals containing high levels of stone or ash will reduce efficiencies).

- Coal preparation and handling prior to combustion (for example, coal washing can help reduce the level of impurities; coal drying improves efficiency as well, CIAB, 2005).
- Fuel oil quality.

Thus, encouraging a shift to lower-carbon fuels, to more efficient combustion technologies, larger plant sizes, improved maintenance, better quality coals and/or better coal preparation could help reduce electricity-related CO_2 emissions.

On the demand side, significant improvements in a range of end-uses could be achieved at no net cost, as illustrated by the IEA's Alternative Policy scenario (IEA 2004). However, this would require strong policy interventions in areas including electric appliances, buildings design and insulation, or industrial motors. A range of policies can be mobilised to that aim, including:

- Setting of energy efficiency standards, including removing less efficient appliances from the market.
- Labelling schemes to foster the market penetration of more energy-efficient appliances.
- Demand-side management programmes, initiated by power companies.

2.2 How could a sectoral crediting mechanism be designed?

As described above, there are significant national variations in fuel mix, fuel availability, and consequent GHG-intensity of electricity generation across regions of the world. Some countries have such abundant resources in coal and such extensive use of it in power generation that applying an emissions "standard" based on a regional average, including countries with large hydro or biomass potentials, would create distortions in both regions and deliver limited mitigation benefits (although potentially lots of credits). The standard would be out of reach for coal-rich countries, and lead to free-riding in the hydro-rich countries.

This paper assumes therefore that any SCM developed for the electricity sector will be done at a national level, which would allow for a variation in baselines. Countries with both lower and higher CO_2 intensities in electricity production could thus be encouraged to improve their carbon performance through GHG credits. We outline below issues for clarification in the three possible SCM designs.

2.2.1 Policy-based

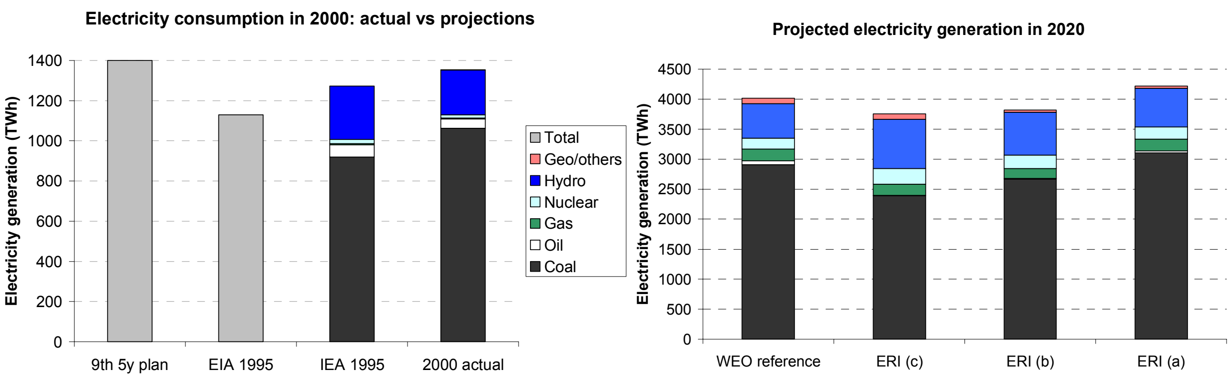
Rewarding the adoption and implementation of GHG-friendly policies in the electricity sector could further encourage countries' efforts to increase the efficiency and/or reduce the GHG-intensity of their electricity sector. This could in turn help reduce GHG emissions within the sector. There is usually a range of factors driving the adoption of policies, from economic to social and environmental considerations. Some policies may lead to GHG reductions as an ancillary (i.e., secondary) benefit of another policy objective. A country can therefore have a clear, local, advantage in introducing policies; observers may question a full crediting of the resulting CO_2 emissions in that case, as it was in the country's own interest to undertake such measures. On the other hand, potential revenues from the SCM may help convince stakeholders of a policy's validity, help finance it, or be used to offset negative impacts. This issue may also be handled by agreeing first on which policy initiatives would be eligible under a policy-based SCM for the power generation sector.

The baseline for a policy-based SCM would represent projected emissions of a sector in the absence of a particular policy. This baseline projection would be established using business-as-usual estimates for GDP, demand growth, etc. Credits for that policy would be generated by comparing without-policy projections to with-policy emissions. This assessment, after implementation of the policy, would require sorting out the effects of policy from other drivers for changes in emissions.

In order to implement a policy-based SCM in the electricity sector, the following would be needed:

- **Projections of business-as-usual emissions** in the electricity sector, i.e. emissions in a "without further policies" scenario. Annex I must provide projections of business-as-usual (BAU) and "with measures" emissions scenarios as part of their national communications; non-Annex I are not requested to do so however[6]. Establishing such projections is a resource-intensive activity. For example, BAU projections in the stationary energy sector in Australia required four different models (AGO 2004). Projections are also subject to considerable uncertainty. This is illustrated in Figure 2 for two sets of projections. The first set compares different projections made in the mid-1990s for Chinese electricity generation in 2000 with actual Chinese electricity generation in 2000. The second set outlines some current projections for electricity generation in the Chinese electricity sector in 2020. The figure illustrates the considerable uncertainty associated even with relatively short-term projections for rapidly-changing economies: actual 2000 electricity generation in China was outside the 1008-1262 TWh sensitivity range projected by the EIA just five years previously (EIA 1995).[7] Estimating future CO_2 from electricity generation involves assessing not only demand growth, the amount of electricity generated per energy source, but also the technologies. The uncertainty range for future CO_2 emissions is therefore important. For any mechanism that generates credits based on the difference between a baseline and actual emissions, agreement on methods used for projections and *ex post* estimates would be needed to ensure that any credits generated are an effect of policies, rather than that of generous projections. The baseline for a policy-based SCM is likely to be indicative only: circumstances are unlikely to match the baseline's original assumptions.

Figure 2: Differences in current and future projections for Chinese electricity generation



Sources: EIA 1995, IEA 1995, IEA 2004 and 2004c, ERI 2004

6 Decision 17/CP.8, Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention. http://unfccc.int/resource/docs/cop8/07a02.pdf#page=2

7 1995 EIA projections for CO_2 emissions in 2000 from US, EU, Japan, FSU, Mexico were also all outside the high-low projection ranges, cf. draft WRI study.

- **Estimates of the GHG effect of a particular policy**. It is difficult to "disentangle" the effect of several policies on a sector's emissions, or to separate the effect of a particular policy from other developments in a sector (e.g. national economic policies, the development of gas transmission infrastructure allowing a substitution of gas to coal). Further, these policies may affect the electricity sector directly (e.g. via efficiency standards) or indirectly (e.g. economic or general fuel-use policies). Electricity market reform or reduction in final price subsidies may reduce consumption and related emissions[8]; opening the market to international capital may increase the rate of capacity expansion; specific policies may encourage combined heat and power (CHP) or renewables, etc. For example, China has recently passed a law encouraging the use of renewable energy (REA 2005). China also already has other laws in place that should increase the GHG-efficiency of electricity generation (e.g. the Air Pollution Control Law, which requires washing of high-ash, high-sulphur coal, LBL 2000). Given the range of policies that could lead to GHG emission reductions in power generation, it is not likely that a single blanket assessment method could be defined *ex ante*. The following bullet points include some elements that ought to be covered in any assessment.

- **Defining sector boundaries**. Establishing a boundary round the electricity sector would require setting a threshold value above which installations are included. For example, the EU ETS chose 20 MW of thermal capacity as its threshold to include combustion plants for power or heat generation. In China, three quarters of all power plants have a capacity of 50 MW or less, producing only 18% of the total electricity (Tsinghua University 2005). A low threshold is likely to increase the system's administrative cost, while if set too high it would lower the environmental coverage of the mechanism. A choice could be made only to include larger grid connected plants (public electricity generation), or to include auto-producers. It would also need to be decided whether to include CHP as well as electricity plants. A broader coverage would render greater numbers of installations eligible to generate credits, but would also increase administrative cost and introduce monitoring costs for small installations. In defining the sector boundary, the country would also need to create, if needed, a procedure to record all new capacity, potential plant closures, and effects on total output.

- **Defining a geographical boundary**. It would also need to be specified if a boundary should be set at the grid or national level, whether electricity imports should be included, and how to deal with a change in the level of electricity imports over the crediting period. Of course, any projections would need to be made at the same geographical level and should be consistent with the definition of installations deemed eligible under the mechanism.

- **Which gases to include** should also be specified, e.g. CO_2 only, as in many electricity-generating CDM projects, or CO_2, CH_4 and N_2O. Monitoring costs would differ radically if non-CO_2 gases needed to be monitored, as these cannot be evaluated simply from aggregated fuel consumption statistics.

- **Defining eligible policies**. Clarification would also be needed on what policy types would be eligible in order to generate credits from a policy: Should they be limited to those specifically targeting GHG? Or should cross-cutting policies such as liberalisation[9] be eligible as well? Should policies be binding or voluntary? The policy's scope would also need to be agreed: could local policies generate credits in addition to other national policies? Could countries submit policies to review and eligibility for a policy-based SCM *after* they have implemented them for some years and could they seek crediting for past

[8] The effect of policy implementation on prices may be especially difficult to evaluate as time series of consumption levels by end-users are scant in developing countries. Without some econometric analysis of how consumers have responded to price changes in the past, estimating policy-related price effects would be controversial at best.

[9] Electricity market liberalisation can have different impacts on GHG emissions, depending on national circumstances: while it led to a "dash for gas" and consequent emission reductions in the (then) coal-dominated UK electricity sector, it increased the use of cheap domestic but GHG-intensive brown coal in coal-dominated Australia.

reductions? Or should policies be agreed before, and credits only accrue for reductions taking place after?

- **Defining the ownership of emissions credits**. Although this issue may not need to be resolved internationally, it may have strong bearings on the SCM's effectiveness in promoting lower GHG emissions. Under a policy-based approach, the detailed analysis necessary to assess reductions may identify the legitimate recipients of credits. Well-run plants may be responsible for all achieved reductions, for instance. The government need not, however, commit to direct credits on that basis, and may also want to keep a share of the credits for itself. In addition, governments generally own power generation assets in a number of developing countries, so this point may be moot. For more effective GHG mitigation, independent power producers, when they exist, would need to be encouraged as well. In the case of a policy that would bring reductions through electricity savings, it would be close to impossible to trace emission reductions to individual generators. The government could use credits to reward various stakeholders that implemented the policy (e.g. appliance suppliers), or use revenues for general budget purposes.

- **Validation/monitoring/reporting of emissions reductions**. A policy-based SCM as described requires a thorough analysis of reductions that can be attributed to the policy or set of policies that a country has subjected to the SCM. Because of the range of parameters affecting power generation and related CO_2 emissions (weather and fuel prices, to name two that have a marked impact), such analysis could prove lengthy and controversial. Methods or broad guidelines would need to be agreed *ex ante*, including the timing of assessments. With the notable exception of demand-side policies, in which generators may have little influence, government-owned utilities may be better candidates for policy-based SCM: the high uncertainty characterised by such an approach is likely to deter private sector participants from taking part more directly.

As discussed above, a policy-based SCM would function like a baseline-and-crediting system in which the baseline may need to be re-established after the commitment period. Emission reductions may also need to be evaluated against their intent: given the policy focus of this option, reductions attributed to other factors (plant breakdown, increase fuel prices, exceptional resource availability) may need to be factored out. However, it may be difficult to agree methods of doing this in practice, especially in countries with limited data and modeling capacity.

2.2.2 Rate-based (indexed)

Rate-based (indexed) crediting in the electricity sector would allow for credits to be generated by individual electricity plants whose emissions intensity is below a pre-defined threshold. The basis for crediting could be at the country, fuel type, technology type, individual plant or other (e.g. hybrid) level. What follows covers aspects that differ from the above presentation of a policy-based SCM.

- **Setting a baseline**. The baseline for a rate-based SCM would be expressed as tons of CO_2 per unit of electricity output (in tCO_2/MWh). The baseline could be defined either for a country's total generation, or for new plants, or some sort of average (e.g. as currently done for most electricity-generation CDM projects[10]). Different definitions would lead to different levels of baselines as newly built plants have access to new and more efficient technologies while the currently-operating generation plants reflect past investments and efficiencies of plants installed decades ago. Indeed, using a given formula to calculate the baseline level can lead to substantial variations by country (see Box 1). Another approach would be

[10] A commonly-used baseline for renewable electricity CDM projects (ACM0002) is based on the "combined margin" (a weighting of the average operating margin and build margin) for a particular electricity grid.

to set baselines on a fuel by fuel basis. While this can be criticised as promoting the use of all fuels including CO_2-intensive coal, it also recognises the specific circumstances of countries that have abundant coal resources and are likely to use them for power generation in the future. The rate-based approach could be used to foster coal plant technology that is ready for carbon capture and storage. Watson et al. (2005) argue that a fuel-by-fuel approach would be more effective in reducing GHG emissions. However, it would not generate credits for renewables, unless decided otherwise, even though renewables clearly reduce CO_2 emissions.[11] An approach similar to the CDM could be used to establish the baseline for renewable generation sources.

- **Eligibility criteria**. After having decided on a baseline methodology, e.g. a single country-wide standard, or a set of fuel-by-fuel standards – policy-makers should agree on which type of installations are eligible. Only those plants whose projects have been launched after the decision to introduce an SCM should be eligible to avoid undue creation of credits. This could encourage the postponement of some projects as their promoters may wish to be eligible for extra-revenues via the SCM. Such free-riding is unlikely to be significant as the risk would arise only in the initial phase of the mechanism. The main question is whether crediting is attributed on a plant-by-plant basis, or based on the sum of all new plants. In the latter case, plants that perform less well would automatically lower the amount of issued credits to plants that have performed better than the standard. In the former case, crediting plants that only perform better than the agreed standard would keep outside its scope emissions from newly-installed yet less efficient plants. Which standard is chosen (e.g. plant-by-plant or average) will significantly affect the level of the baseline, as will choices on whether to compare to all new plants' performance, or only to those plants performing above the baseline. The possible combination of options for baselines and eligibility are shown in Table 2.

Table 2: Design options for a rate-based SCM in the electricity sector

		Baseline definition	
		Plant by plant	Average of new plants, "combined margin" etc.
Level of dis-aggregation	Sector-wide	1. All new plants with less than x tCO_2/MWh are credited according to their output. Plants that emit more than x are not credited. Plants that emit less than x automatically generate credits, thus no additionality requirement needed.	2. Credits are computed based on e.g. the average CO_2 content of electricity produced by all new plants, the "combined margin" or some other agreed metric. Plants that emit more than x tCO_2 per MWh lower credits attributed to the sector. Data requirements are relatively high.
	Fuel by fuel (x, y, z)	3. New coal, oil, gas plants with less than x, y and z tCO_2/MWh respectively are credited according to their output. This type of baseline does not encourage fuel switch. Further, a different baseline methodology is required for new renewable energy plants if they are to be credited.	4. For each fuel type, credits are computed based on the average CO_2 content of all new plants.

[11] Under a full emissions trading mechanism such as the EU emissions trading scheme, the price of CO_2 would be reflected in all power generation relying on fossil fuels, granting a competitive advantage to renewable energy sources. There is no guarantee of such an outcome in the case of an SCM, especially in countries where power prices are set by the government. It may therefore favour creditable fossil-fuel projects against renewable energy projects.

Box 1

Examples of rate-based baselines used in proposed CDM projects

CDM project participants can use "approved methodologies" to calculate the number of emission credits generated by a particular project. One of the approved methodologies for renewable electricity projects (AM0005[12]) includes formulae defining a project's baseline as the "combined margin" of build margin and operating margin weighted 50:50. However, the actual level of a baseline calculated using this formula can vary significantly depending on the project location. For example, the following baselines for proposed or registered CDM projects have all been calculated using AM0005, and vary by a factor of two.

Project[13]	Baseline (kg CO_2/kWh)	Project location, status
Huitengxile (wind power)	0.915	North China grid, registered CDM project.
Guangdong (wind power)	0.673	Guangdong grid, China, project under validation
Rio Hondo (hydro)	0.784	Guatemala, project under validation
El Gallo (hydro)	0.587	Mexico, project under validation
Santa Rosa (hydro)	0.476	Bolivia, project under validation

Sources: project-specific documentation available on UNFCCC website.

A rate-based approach seems fairly straightforward, once the following have been cleared:

- Baseline method: a number of such methods have been developed in the context of the CDM. They could form the basis of broader targets.
- Eligibility and baseline levels, which should be considered in combination.

2.2.3 Fixed sectoral limits

A fixed-limit SCM would impose a cap on GHG emissions. This limit would be estimated *ex ante*, and be used as the baseline against which actual electricity-related emissions would be compared. When this difference is positive, an number of credits equivalent to the difference between the projections and actual emissions would be generated, regardless of other developments in the sector. In light of the uncertainty on future emissions in power generation, fixed limits could lead to crediting for reductions driven by exogenous factors – from a disruption of coal supply to plant unavailability or power transmission problems. Alternatively, it could lead to fewer (or no) emission reductions, e.g. if hydro resources were lacking, or demand increased beyond expectations. The principle of such uncertainty is accepted in standard cap-and-trade systems, as well as under Article 17 of the Kyoto Protocol.

[12] This methodology is available at http://cdm.unfccc.int/UserManagement/FileStorage/AM0005.pdf

[13] All projects under validation can be viewed at http://cdm.unfccc.int/Projects/Validation and http://cdm.unfccc.int/Projects/Validation/?archive=yes

An important feature of a fixed limit approach for the power sector is the incentive that it provides to pursue energy-efficiency measures in addition to supply-side measures, an option that a rate-based approach would not address. A rate-based approach could in fact discourage end-use improvements, since any plant operating with lower emissions per kWh than the baseline would be credited more as it produces more electricity. Energy efficiency policies could be eligible under a policy-based SCM, however.

In order for mechanism based on fixed sectoral limits to be set up, the following issues would need to be resolved:

- **Emission projections and limits**. Projections will form the basis of, although need not be identical to, the sectoral emission limits to be agreed by Parties. Host countries should provide a transparent outlook of planned plants and closures. Procedures could be agreed to address the uncertainties associated with electricity supply and emissions projections (e.g. an indication of observed year-to-year variations and what has been driving them, the likelihood of such drivers to occur in the future). Based on this, a policy choice would set emission limits either at the projected emissions level or below, if significant margins for improvements are available and could be financed easily with a crediting mechanism. An aggregate approach to the sectoral emissions limit could also be used. For example, a limit could be set by combining x% p.a. demand growth combined with y% autonomous energy efficiency improvement for various fossil fuel plants. In order to define limits that do not result in overly generous crediting, projections and limits could be revised closer to the crediting period as new information becomes available. This would, however, undermine the original choice of a fixed limit:

    - If emissions are projected to be much lower, adjusting limits downward is automatically at the expense of the host country. How any such adjustments would be done should be agreed in advance. Such *ex post* adjustment would resemble those envisioned under a policy-based SCM approach.

    - Host countries could legitimately call for upward adjustments in emission limits if exogenous factors played in the other direction. Without an upward adjustment, the instrument could be perceived as unfair: host countries were penalised, regardless of how emissions depart from earlier projections. However, if upward adjustments were agreed, they would be similar to automatic adjustments occurring in a rate-based approach, although upward emissions may not be driven solely by higher electricity output.

  In all, *ex post* adjustments of emission limits would add to the complexity of the option and impose on host countries conditions that Kyoto Parties have ruled out for themselves when taking fixed targets for 2008-2012.

- **Defining a geographical boundary and eligibility**. As outlined in section 2.2.1 above, a boundary should be set at the grid or national level. The boundary should also identify which sources would be covered and whether new plants and electricity imports are part of the system.

- **Assessing how/if to allocate credits at the plant level**. This would be done at the national, rather than international, level. Some plants may increase emissions and offset others' efforts. In a government-owned network, this need not be a problem. With independent power producers, however, there would be a need for clear domestic rules as to how credits are to be distributed across sources, if overall emissions are below limits. A transparent treatment of this question would require a plant by plant allocation against which actual emissions could be compared. This may be overly cumbersome for developing countries. The treatment of renewable plants raises another issue: all new power production by renewables displaces generation from fossil fuel plants. Under a standard cap-and-trade approach, the renewable energy sources benefit economically via the increase in electricity prices triggered by the CO_2

allowance price. This may not happen under a SCM, especially as the electricity sector is still regulated in many developing countries. If the generation sector is in the hand of a single actor, e.g. the government, the use of renewables would reduce emissions growth and be credited if overall emissions were below the fixed limit. The sector's decision-maker would therefore consider renewables among its options to generate credits. If renewables generators operate independently, any displacement of fossil-based generation does not necessarily benefit them: reduced emissions are credited to fossil-based generators that incur lower output. Crediting renewable generators as well as crediting reductions below the sector's limit would result in double crediting of such emission reductions.

With a fixed-target SCM, developing countries would move closer to domestic emissions trading systems existing elsewhere, although transactions would be in the form of transfers to other parties, and probably not, primarily, among domestic sources. This option combines implementation simplicity with broad coverage of mitigation options, from fuel-switching to energy efficiency improvements, both at plant and end-use levels. Here more than in the other two options, setting a fair yet environmentally ambitious limit would be critical.

2.3 Electricity sector summary

The three options for a national SCM applied to the power sector (policy-based, rate-based, fixed limits) share common features, but also differ in some respects (Table 3). At this stage of analysis, it is not possible to identify which (if any) option would deliver the most significant mitigation in developing countries (this is illustrated for China in Table 4). A number of parameters are missing, including a critical one: the willingness of host countries to adopt ambitious rather than business-as-usual baselines.

The differences between these three options have wide-reaching implications for the cost and resources needed to establish and implement sectoral crediting. This preliminary analysis points in particular to the heavy review needed at the end of the crediting period under the policy-based approach to assess the policy's actual contribution to GHG reductions. The quantification would be analytically challenging and some developing countries may not gather statistics that would allow a proper policy evaluation. In addition, the potential financial revenues accruing from the process are likely to make it a politically-charged exercise. Further, market players and financiers (international or local) may find it difficult to engage in an activity with such limited predictability about the financial outcome.

However, this policy-based approach may be of interest for countries with very specific, targeted policy options of limited scope, yet going beyond the scale of a single project – promoting renewable energy development in a specific region, a standard to remove less efficient electric appliances, a subsidy to re-power coal plants into gas plants or to introduce clean-coal technologies, etc. A publicly-owned electricity sector may be ready to submit such policies to external review, if there is a chance for *ex post* crediting as a result. One attractive feature of this option is the potentially limited data requirements, as some policies may not require country-wide emission inventories and projections for the sector.

Table 3: Main elements of SCM designs for the electricity sector

	Policy-based	**Rate-based**	**Fixed limit**
Which gases to include	Yes	Yes	Yes
Sector-wide emission projections and definition of baseline	Yes (sector projection) with *ex post* adjustments to account for exogenous factors.	Yes (multiple baselines may be required depending on the choice of option – see Table 2).	Yes
Eligibility criteria (plants / technologies are included in the mechanism)	Yes	Yes.	Yes
Estimate of the effect of measure(s)	Yes	No	No
Sector-wide monitoring and reporting of emissions	Yes	No / Yes. Yes if the rate is set at country level and crediting occurs on the basis of average CO_2-eq/kWh (option 2, Table 2).	Yes
Establishing ownership of any emissions permits/ reductions	Yes / No, depending on the policy type.	No / Yes. Preferable from an incentive perspective when crediting is based on a sector-wide average. Not required when all plants below the rate are automatically credited.	Yes
Ex ante allocation of emissions limits	No	No	Yes
Dealing with "tropical hot air"	Yes. *Ex post* analysis needs to distinguish the policy's actual effect on emissions from unrelated factors.	No	Yes

Rate-based and fixed-limits SCM have potentially similar data requirements for baselines: policy-makers and Parties will need to see reliable projections in order to agree on a baseline, whether it is a content of CO_2/kWh or absolute emission levels. The rate-based approach may be less demanding as it makes sense to restrict crediting to new plants, rather than all existing plants. Further, under a rate-based approach, a complete sectoral emissions inventory is not needed (unless the rate set is based on a country/sector average).

The experience of cap negotiations in nation-wide trading systems such as the US SO_2 allowances programme and the EU ETS indicates that agreeing on a fixed limit would not be without problem. Parties other than the host – or another neutral institution – would need to agree with the cap to reduce the risk of an over-generous cap that would undermine the environmental integrity of the mechanism and the international GHG market.

Table 4: Potential credit generation in 2020 by different SCM designs in the Chinese electricity sector

SCM type	Estimated credit generation	Comments
Policy-based	472 Mt CO_2-eq	Emissions reductions assuming increased uptake of nuclear and hydropower (ERI 2004).
	488 Mt CO_2-eq	Difference in electricity-related emissions between the “reference” and “alternative” policy scenario (IEA 2004)
Rate-based	233-302 Mt CO_2-eq	Assuming that all “incremental” generation between 2010-2020 from renewables, nuclear, gas and oil can generate credits if their emissions are below a rate-based intensity level. The lower end of the range uses the Chinese average CO_2/kWh for 1990-2002, the higher end of the range uses a “combined margin” rate-based baseline for the North China grid (as used in a registered renewable energy CDM project).
Absolute	Would vary widely depending on growth assumptions used	The possible wide variations in credits using an absolute limit illustrate one of the drawbacks of such an SCM design, particularly in areas where demand growth and/or technological change could be significant: this design could lead to either no credits, incentive-driven reductions, or “tropical hot air”.

3. Aluminium Sector

Aluminium, like electricity, is also a sector where demand is growing sharply: global aluminium production has grown 59% between 1990 and 2004 (IAI 2005c). GHG emissions from the aluminium sector accounted for 0.9% of anthropogenic emissions in 2004, of which 0.4% result from direct emissions from the aluminium industry and 0.5% from indirect emissions in electricity generation (Watson et al 2005, Robert Chase, personal communication). Aluminium can be produced either from bauxite (primary production) or from aluminium scrap (secondary production). Primary aluminium production is highly energy-intensive, requiring on average 15 MWh of electricity or some 54 GJ per tonne, whereas secondary aluminium production requires only 5% of that amount (Watson et al 2005).[14] Primary aluminium production also emits perfluorocarbons[15], PFCs, and process-related CO_2 emissions. Total GHG emissions associated with primary aluminium production average 10 tCO_2-eq/ton, including electricity-related emissions (Marks 2003). Secondary aluminium production is much less energy and GHG-intensive, and can be an important component of total aluminium production in countries where significant scrap is collected. There are clear environmental benefits of secondary aluminium production and the aluminium industry is developing a global action programme to encourage increased use of recycling (IAI 2005d). However, given the expected growth in aluminium consumption, primary production will continue to be the dominant production method worldwide for the foreseeable future. Without prejudging the potential scope of SCMs or other sectoral approaches in this industry, and for the sake of analytical simplicity, this section focuses on primary aluminium production, and in particular, aluminium smelting.

Primary aluminium production comprises three main stages: bauxite mining, aluminia refining and aluminium smelting. The aluminium smelting stage is by far the most GHG-intensive, as it entails both electricity-related emissions, and process CO_2 and PFC emissions. However, absolute emissions per tonne of aluminium produced can vary widely depending on the smelting technology and electricity source used. Figure 3 shows possible variations in total emissions based on different processes and different inputs for electricity generation.

Primary aluminium is produced in 47 countries (IAI statistics). The structure of the aluminium industry is very different from that of the electricity industry: a limited number of companies that operate worldwide dominate primary aluminium production. An exception is in China and, to a lesser extent, Russia – both relatively large aluminium producers – who have their own domestic industry.[16] The price of aluminium is set worldwide, at the London Metal Exchange. The structure of the industry is such that no single producer can influence international prices, an important consideration for companies' competitiveness.

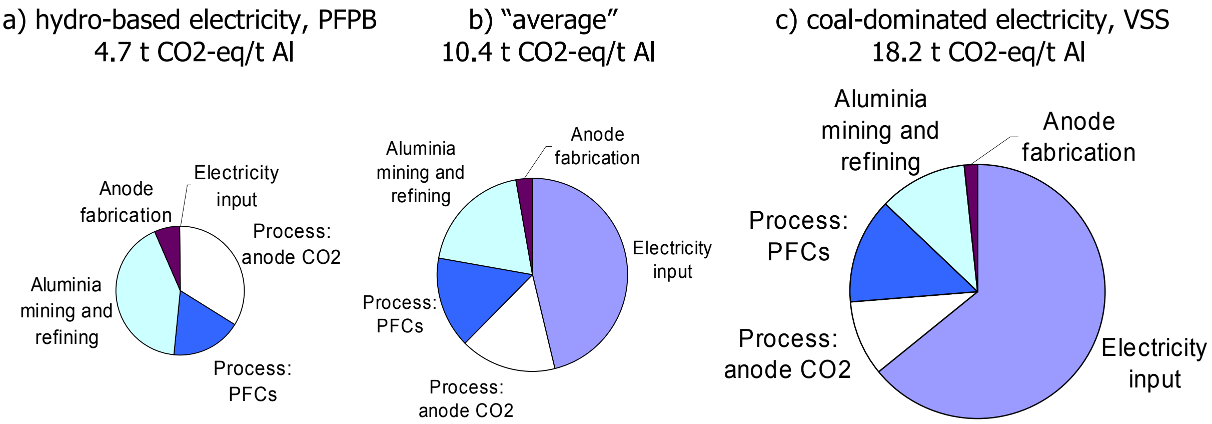
Annex I countries produced 55% and consumed 62% of primary aluminium in 2004 (Watson et al 2005). However, demand for aluminium in non-Annex I countries is expected to grow rapidly, with these countries expected to account for almost half (47%) of aluminium consumption in 2020 (Watson et al 2005). Growth in Chinese production has been particularly rapid, increasing 95% between 2001 and 2005 (IAI 2005b). This growth is expected to continue, with China's share of total aluminium consumption projected to grow from 21% in 2004 to almost 28% in 2020 (Watson et al 2005).

[14] Although producing aluminium is more electricity and GHG-intensive than e.g. steel, using aluminium in place of steel (for example in car manufacture) could help to reduce the car's weight, its energy consumption and thus GHG emissions during its lifetime. However, the issue of "lightweighting" is beyond the scope of this paper.

[15] Perfluorocarbons are a class of chemical compounds containing carbon and fluorine. The PFCs emitted in aluminium production are tetrafluoromethane, CF_4, and hexafluoroethane, C_2F_6.

[16] India (a much smaller aluminium producer) also has a national aluminium company.

Figure 3: Possible variations in GHG emissions from aluminium production



Sources: For all graphs, CO_2 from aluminia mining and refining taken from Marks 2003; data for average, Point Feed Prebake (PFPB) and Vertical Stud Söderberg (VSS) PFC emissions from IAI 2001; coal-dominated electricity GHG intensity based on Chinese average 1990-2002 (IEA 2004); hydro GHG intensity assumed zero; data for anode CO_2 taken from IPCC 1996 for PFPB and VSS and from Marks 2003 for "average".

3.1 Trends and emission reduction opportunities

There are several technologies available for primary aluminium production, each with different energy use and general PFC emission profiles.[17] However, as approximately 35% of total costs in an aluminium plant are related to electricity costs (IEA 2005), there is a significant economic incentive to ensure that new plants are as energy-efficient as possible – wherever they are built. An important consideration in the choice of location for new power plant is the availability of large, cheap power resources, with raw materials brought by boat sometimes over long distances. Recently, high electricity prices in Europe have led some aluminium producers to consider closing operating European aluminium plants (AFX 2005, Norsk Hydro 2005, Novis 2005).

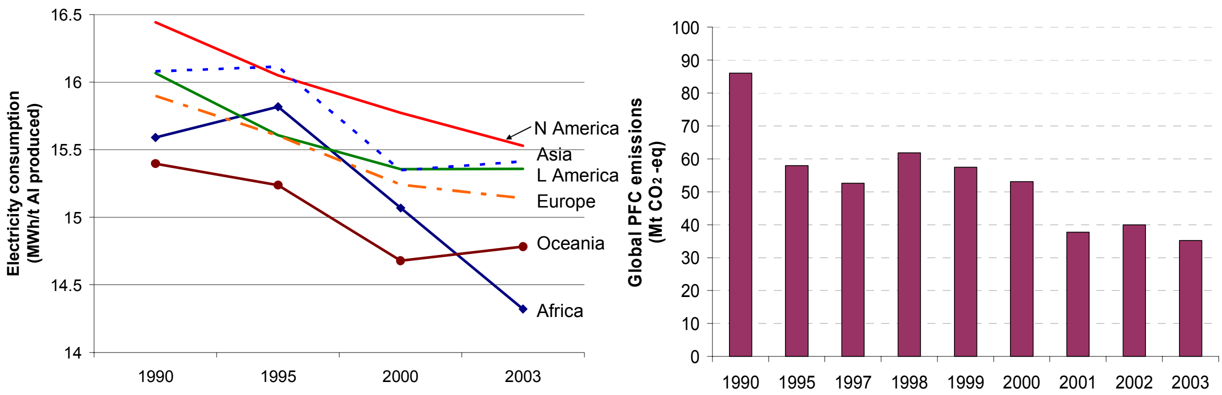
The "Point Feed Prebake" (PFPB) is the most electricity-efficient of all aluminium smelting technologies, with new plants estimated to require 13.3 MWh/t Al produced, compared to 16.6 MWh/t Al for the older Söderberg technologies (Bergsdahl et al 2004). The PFPB technology is the most widespread technology for aluminium smelting worldwide, and is becoming more so, as all new plants constructed after 1970 and most plant expansions are based on this technology (CEC 2003). Fortunately from a GHG perspective, the most electricity-efficient PFPB technology also tends to emit the lowest level of PFCs, although there are significant site-to-site variations (IAI 2005), as new smelting procedures allow to greatly reduce the so-called "anode effect" that releases PFCs. In general, the most PFC-intensive emitting technologies are side work prebake and the vertical stud and horizontal stud Söderberg technologies (IAI 2005).

Technological developments as well as an increased share of production from PFBC technologies has led to a significant reduction in average electricity-intensity for aluminium production in all world regions between 1990 and 2003 (Figure 4 below). Further, country-specific statistics indicate a 20% improvement between

[17] All primary aluminium production processes are based on the Hall-Héroult process. In this process, aluminia is dissolved in sodium aluminium fluoride, contained within a carbon or graphite-lined "pot". An electric current is passed through the mixture, and flows between a carbon anode and the lining of the pot (the cathode). Molten aluminium is then deposited at the bottom of the pot. There are two main types of technologies (Söderberg and Prebake). These use different types and numbers of anode. There are further variations within each technology type, depending on the position of the anode(s) in each "pot". Prebake technologies are much more energy-efficient than Söderberg. Further, the pots used in the Prebake process are also more enclosed, so reducing fugitive emissions.

1980 and 2000 in the electricity-intensity of aluminium production in China (ERI 2004). PFC emissions have also declined substantially in the same period. These trends should continue with the continuing phase-out or retro-fitting of the side work pre-bake and the above mentioned Söderberg technologies.

Figure 4: Trends in electricity intensity and PFC emissions for primary aluminium production



Source: calculated from statistics on IAI website and IAI 2005.

Process CO_2 emissions can also be a significant component of total aluminium-related emissions, shown above. These emissions occur during electrolysis in the aluminium smelting process. Most are due to the reaction of the carbon anode with alumina (Al_2O_3) (IPCC 1996). There is very little variation in anode CO_2 emissions from plants using similar technologies (IPCC 1996), and these emissions are an inevitable part of the electrolysis process as long as carbon-containing anodes are used. Emphasis on emission reductions from the aluminium industry therefore focus on PFC and energy-related emissions. Process CO_2 emissions are also generated for PFPB by the "baking" of anodes. Total process CO_2 emissions are slightly lower for PFPB cells than for Söderberg cells (IPCC 1996, IAI 2003).

3.2 How could a sectoral crediting mechanism be designed?

This section considers the implementation of the three distinct approaches to sectoral crediting outlined in section 1.2 above: policy-based; rate-based and sectoral limits. The sector has already taken steps at international level, through the International Aluminium Institute (IAI), to reduce GHG emissions. Multinational companies have made voluntary commitments which span all their facilities, going beyond national boundaries, sometimes taking into account the GHG reductions from broader use of aluminium instead of other heavier materials.[18] Although more limited in its scope, crediting as envisioned in this report can be seen as a new feature to add to such initiatives, although it is less clear in the case of aluminium that developing nations are less technologically advanced: the industry is global, technology is widely shared and new, less GHG intensive plants are sometimes located in developing countries rather than in industrialised countries. Crediting may thus be a less straightforward option for this sector. It does nevertheless raise interesting design issues which we explore here.

3.2.1 Policy-based

Since aluminium is generally produced by private companies and PFC emissions are influenced by management decisions at the plant level, it may be that there is little scope for government policies to

[18] Alcoa, *Energy Argus Monthly*, Volume IV, 8, August 2005.

encourage reduction of PFC emissions. Process CO_2 emissions are difficult to avoid and so the role of policies in this area also appears limited. The majority of the remainder of GHG emissions associated with primary aluminium production is indirect emissions from electricity generation, and so would be covered under any electricity-specific policies developed. Thus, the scope for a policy-based sectoral crediting mechanism for primary aluminium production appears limited because the industry already has significant incentives to reduce electricity consumption and reduce costs.

Nevertheless, a policy-based approach could be useful in encouraging increased use of secondary aluminium production as governments often play a key role in facilitating recuperation and recycling of used aluminium. Further, an approach based on specific mitigation measures at a company or sectoral level (even if not driven by government policies) may be useful in encouraging reduced GHG emissions from primary aluminium production. Indeed, both aluminium associations and individual companies have developed voluntary approaches to reducing GHG emissions. These are not designed to generate credits, but to reduce the GHG impact of aluminium production. Thus, there may be significant scope to consider other forms of agreements to encourage reductions in this sector as an alternative or complement to a SCM.

3.2.2 Rate-based (indexed)

A rate-based system would allow credits to be generated if emissions are below a pre-defined threshold. Since global aluminium production is dominated by (private) companies operating in several different countries, it would seem more appropriate to set any rate-based SCM at an international, rather than national level – at least in countries where aluminium production is dominated by private-sector companies. As for a rate-based SCM in the electricity sector, decisions would be needed on whether the baseline should be defined at a plant-by-plant or an average (new) plant level, and whether such baselines should apply sector-wide, or to particular technology types (PFBC etc.). Implications of each are not discussed here, for the sake of brevity.

Several issues would need to be resolved before any such SCM could be established. These include:

- **Eligibility of plants/units to generate credits under a SCM**. Construction of new aluminium smelters typically involves the most energy-efficient technologies that, depending on plant management, can also have relatively low PFC emissions. Since this energy-efficient activity is business-as-usual for the private sector it is unlikely to be further influenced by a sectoral crediting mechanism. Thus, a sectoral crediting mechanism in the aluminium sector is likely to have most impact in the following areas:
    - Encouraging reduction of PFC emissions in primary aluminium production;
    - Encouraging retrofits of GHG-intensive primary aluminum plants; and
    - Encouraging increased aluminium recycling.

  Which scope is chosen will have very different implications on the design and complexity of a SCM, as well as the incentives, the "messages" that it gives to aluminium producers, and the potential location of any credits generated from such a mechanism. For example, a rate-based "benchmark" that is developed for and can apply to the GHG performance of total aluminium production (both primary and secondary) could help encourage aluminium recycling and therefore more lower-GHG secondary production. However, this would only be true in more mature markets, where significant quantities of recyclable aluminium exist.

- **Setting a baseline**. It may not be straightforward to set a baseline for PFC emissions at a sector-wide level as significant plant-specific variations in PFC emissions can occur even within a particular smelting technology. Calculating a baseline level for energy use should be relatively straightforward for countries where aluminium production is dominated by private-sector multinational companies. However, it may be much less so for China, Russia and India, where national production companies can be important - and where there can be a large variation in PFC emission levels, both due to the range of aluminium smelting technologies in place and in management practices.

- **Data issues**. Depending on the scope of any SCM, it may require detailed data on aluminium production and GHG emissions at the plant level. Much of this data, e.g. on plant-specific PFC emissions, is already available for members of the IAI. Detailed plant-specific current, and maybe historical, performance data will also be needed for aluminium producers in China and Russia wishing to take part in any rate-based SCM.

- **Boundary issues**, i.e. which emission sources are included. In particular, a decision will be needed on whether to include or exclude indirect, electricity-related GHG emissions associated with aluminium production. This will influence which gases are included in any SCM.

- **Encouraging participation in a SCM and determining ownership of emission reductions**. Historically it has been national governments that have negotiated, signed and implemented international GHG agreements. However, any SCM involving the aluminium industry would also need to involve private-sector actors: the aluminium producers and/or their associations. Since the IAI has developed an emissions reducing target, the incentives for companies to participate in an international scheme, i.e. ownership of any credits generated by such a scheme, would need to be clarified. Similarly, because electricity-related emissions are indirect, and may be off-site, the ownership of any emission reductions associated with reduced electricity consumption needs to be clarified from the beginning.

- **Minimising perverse incentives**: Crediting could be used to help modernise and improve the management of existing plants. Depending on the scope of improvements that are eligible for crediting, there is a risk of setting a system that would subsidise technological improvements that other, more GHG-friendly producers have achieved under "business as usual" conditions. This would "reward" plants that perform less well than the best available technology and/or management[19]. It could thus improve the competitive edge of these "dirtier" plants, and generate credits for GHG mitigation that is happening elsewhere under business-as-usual. This would make such crediting hardly palatable to the industry as a whole, and deliver emission reductions that may well have happened otherwise.

3.2.3 Sectoral limit

Under this type of SCM, emissions from international aluminium production would be subject to a fixed limit.[20]. Producers would then be authorised to sell credits corresponding to emissions reductions below this limit. As is the case for a policy- or a rate-based SCM, the following elements are requisite to implement a fixed emission limit:

[19] We observe this phenomenon in HFC-23 mitigation: early movers motivated to reduce their emissions have missed the opportunity to register reductions as CDM projects while late movers are rewarded by the generation of non-negligible quantities of emission reductions for sale as CERs.

[20] Any sectoral emissions limit could be set at a higher, lower or at the same level as current sectoral emissions.

- **Setting a baseline**. The prospect of facing an absolute cap would encourage stakeholders to base negotiations on optimistic production and emission projections, as has been observed in the national allocation processes under the EU ETS. This dynamic is even more probable if aluminium were the only commodity addressed via a cap, while competing commodities may enjoy uncapped growth (steel, plastics, etc.).

- **Data issues**. Fixed emission limits could require installation-by-installation emissions information (existing and new) and, possibly, production data.

- **Boundary issues**. Here again, the decision to include emissions from electricity consumption would augment the system's coverage and provide the sector with a broader set of mitigation options to identify least-cost measures. It would immediately favour shifting production towards location where non-fossil fuel electricity resources are available. This would also increase the uncertainty surrounding baseline emissions, as these would be largely dependent on electricity supply technologies used for new plants.

- **Encouraging participation in a SCM and determining ownership of emission reductions**. The same issues as above apply here. In addition, the SCM would need to specify the treatment of plant closures and new entrants, two features that prove crucial in cap-and-trade systems. Should closing plants be credited for emission reductions and for how long? As new entrants would bring more emissions, how should they be granted potential credits, e.g. if they rely on best available smelting technology or process secondary aluminium? These questions may be left entirely to industry, provided that overall emissions remain below the agreed cap for the sector as a whole. It is important however that credits from emission below the sector's fixed limit are effective incentives towards least-GHG emitting technologies. A well-defined and transparent allocation process may be needed for this purpose. Already a fairly complex process for standard cap-and-trade systems, it may be made more difficult by the crediting objective of the system: increase in emissions by some installations would limit the quantity of credits available for other sources – unless the former are required to *acquire* emission allowances to offset their excess emissions. This would move the SCM towards a standard cap-and-trade regime.

This last remark hints at the importance of the governance structure needed for such an approach. Would the "allocation" of credits be left to industry or to domestic governments? What institutions should be in charge of monitoring emissions, given the international nature of the industry's agreement? These issues could be addressed in future work.

In summary, a fixed-limit SCM would provide incentives to look for GHG mitigation where they are less costly within the industry. As the sector's output is expected to grow, setting the limit and rules for access to credits for new plants will be challenging. Including electricity-related emissions in the sectoral emissions limit would improve the SCM's coverage and economic efficiency: it would provide a clear incentive to locate new production where electricity generates fewer emissions and to increase production through the much more energy efficient secondary production. However, any overlap between such a mechanism and one in the electricity sector would need to be carefully considered. Perhaps more importantly, the feasibility of establishing a SCM based on a sectoral limit is low for the aluminium sector, unless sectors that produce competing products (e.g. steel, plastics) also have emission limitations under a SCM or other mechanism. Absent such conditions, the industry would strongly argue for a limit that allows for demand growth..

3.3 Aluminium sector summary

If a sectoral crediting mechanism were designed for the aluminium sector, it might be more effective if done at the international, rather than national, level. This is because:

- Aluminium is widely traded, with production and consumption often in different locations (e.g. in 2004 the USA accounted for 8% of total production but 20% of total consumption);
- There are only a limited number of aluminium producers worldwide, often operating in several countries[21]. Most countries, however, may not host very many aluminium smelters, limiting the interest of a national-only SCM;
- Deciding where to site primary aluminium production is strongly influenced by electricity prices (rather than bauxite mines, for instance). New plants are more GHG-friendly than older plants, regardless of their location: multinational groups tend to use best available technologies as these are usually least-cost. Thus, GHG performance in non-Annex I countries can surpass that of Annex I countries. For example, recent Brazilian plants have below-average PFC emissions (ABAL 2000).
- The aluminium industry already has a strong co-ordinating body, the International Aluminium Institute. The global aluminium industry has already made specific (but voluntary) environmental commitments, including to reduce its PFC emissions and energy use from primary aluminium production. The IAI also has a voluntary objective to decrease energy smelting use by 10% between 1990 and 2010, and another voluntary objective to reduce PFC emissions by 80% from the 1990 baseline by 2010 (IAI 2005)[22]. There may be significant scope to consider other forms of agreements to encourage reductions in this sector, as alternatives or complements to sectoral crediting.

Given the difficulties in establishing a) a policy-based mechanism for an industry where the private sector plays an important role, and b) absolute sectoral limits in a rapidly-growing industry, the rate-based option for a SCM seems the most promising in the aluminium sector.

3.4 Other issues for the aluminium sector

The **choice of sector boundaries** for an SCM on the aluminium sector is critical. This is because electricity-associated emissions can account for the vast majority of GHG emissions related to aluminium production. While some aluminium producers also produce their own electricity, others acquire power through long-term contracts. In the latter case, the aluminium producer may have limited influence over the generator's choice of technology. The fuel source (and thus GHG profile) for power generation is, in this case, very much determined by the availability of domestic energy resources. If fossil fuels are used, the only margin for improvement would be to re-power the generation plant to adopt a more energy efficient technology.[23] Opportunities for generation-side CO_2 mitigation should therefore not be ruled out, all the more so as investment in new smelting capacity would be encouraged to adopt cleaner generation if they were receiving GHG credits as a result. The risk of generating "anyway tonnes", undue reduction credits, should not be minimised, however. Similarly, secondary aluminium production appears very cost-effective as it requires 5% of the electricity needed in primary aluminium. Crediting secondary aluminium production against a baseline for primary production could generate significant credits, while the economic case of secondary aluminium seems already strong without them.

[21] 26 companies account for 75% of aluminium production (IAI 2005).

[22] By the end of 2003, PFC emissions had been reduced 60% from 1990 levels, and energy use by 5.5% (IAI Statistics 2005).

[23] Fuel switching is unlikely to be an option – unless a plant were located near both a coal mine and a gas field, or hydro resources, which is unlikely.

Another, related, question for the design of such mechanism is the inclusion of secondary aluminium production, given the much lower electricity content of secondary aluminium. An important barrier to secondary aluminium production is the absence or the weakness of recycling possibilities and/or networks in some countries. Government intervention may be needed to foster recycling in countries where it is lacking.

In addition to above-mentioned issues related to data requirements, baseline setting, system boundaries issues and eligibility for crediting, the following features of the aluminium sector warrant special care.

- There can be significant **variations in PFC emissions** within a particular technology type. There would be significant uncertainties in estimating GHG emissions unless estimates for PFC emissions were based on actual measurements. Fortunately, the aluminium industry in conjunction with WRI/WBCSD has already developed a tool that outlines the steps needed to monitor and report corporate-level GHG emissions from aluminium production, which sources should be included, and how they should be calculated (IAI 2003).
- Aluminium **competes with other commodities**: would a sectoral-crediting mechanism distort such competition? Can it trigger leakage to other commodities that induce higher GHG emissions? Such risk may be minimal as aluminium players would only seek credits if the resulting revenues surpass costs, but it does create an "opportunity cost" that other commodities may not face.
- The aluminium sector has taken a wide range of **voluntary actions** to reduce its greenhouse gas emissions. Yet some installations record much higher emissions than others. Sectoral crediting would give them an incentive to improve, but also send the signal that good environmental practice can be "subsidised" via GHG credits, while other producers have done so at their own expense. This may raise fairness concerns and stand in the way of an international agreement on this matter.
- Aluminium is also targeted more or less directly by **international and domestic GHG mitigation policies** (Table 5). Any sectoral crediting mechanism applying to this sector could overlap with existing commitments by the industry, depending on their geographical scopes. Some technical issues may come as boundaries and baselines are unlikely to be identical. A transition period may be needed to homogenise approaches.
- How will **incentives** be passed on to individual plants or companies under each option? Which, if any, international body will oversee such international crediting mechanism? Are national governments to play a role in monitoring? These questions will require practical answers, beyond the scope of our preliminary analysis.
- Last, an international agreement bringing together the majority of aluminium producers – or major producers in any other global industry, for that matter – would raise concerns about **cartelisation**.

Table 5: Summary of international GHG measures affecting the aluminium industry

Measure	Coverage	Comments
Kyoto Protocol emission limitations	Annex I Parties (approximately 36% of global Al production)	National emissions limitation or reduction commitment from a basket of sources and gases (including aluminium production).
EU Emissions Trading Scheme	EU countries (approximately 14% of global Al production)	The aluminium sector is not explicitly covered in the first phase of the EU ETS. However, the impact of EU ETS on electricity costs combined with the global trade in aluminium (which reduces possible cost pass-through by producers) and aluminium's electricity-intensity means that the aluminium sector is indirectly affected by the EU ETS.
IAI voluntary objective	All aluminium producers**	Achievement of the IAI's voluntary objectives will be assessed at a global level, including IAI and non-IAI members.

4. Preliminary insights and cross-cutting issues for further analysis

Any sectoral crediting mechanism could be established in a multitude of different contexts (e.g. pre or post-2012, binding or not) and with different participation. These different contexts, and the current climate and energy regime affecting the sectors, would have a significant effect on the possible environmental and economic effect of a sectoral approach to crediting. This paper identifies implementation issues in the context of various approaches for SCMs, and for two sectors with widely different industrial structures and geographical scope: electricity and aluminium.

These sectors are of interest for different reasons. The electricity generation sector accounted for 39% of fuel combustion emissions, almost 9.5 billion tons CO_2, in 2002. Further, electricity-related emissions are expected to continue growing at a rapid rate, particularly in coal-based China and India. However, several technological options exist to reduce GHG emissions from electricity production, and the requirements for new electricity generating capacity provides an opportunity to fulfil electricity demand with fewer CO_2 emissions. Sectoral-crediting could foster investment in such cleaner technology and could thus mitigate the sector's pressure on the economies of developing countries and a number of related environmental problems. Because domestic resources vary widely from one country to the next, a **national** scope may be more suited for sectoral-crediting for electricity.

The aluminium sector accounts for a much smaller proportion (almost 1%) of anthropogenic emissions. These include energy-related and process CO_2 emissions as well as PFC emissions. Further, aluminium production is growing fast and is much more concentrated than electricity (and generally in private-sector companies). The industry has already established voluntary targets to increasing energy efficiency and reducing some process emissions. The widely-shared technology, the international competition and the high degree of concentration that characterise this sector suggest an **international** approach to sectoral crediting – at least in the majority of aluminium-producing countries.

Although there are differences in each of the possible SCM designs examined (based either on **specific policies**, on an **emissions rate** per unit of output or on a **fixed limit** on emissions), and the specific issues vary by sector, the following points would need to be defined up-front for any SCM:

- **Eligibility and boundaries**: the mechanism must establish a clear perimeter of eligible plants/activities. Thus, for the electricity sector the boundary might need to specify a minimum output capacity per plant and whether to include or exclude auto-producers of electricity. It must also define how electricity imports and exports will be included in the quantification of emission reductions, and which gases should be included (i.e. CO_2 only or CO_2, CH_4 and N_2O). For the aluminium sector, a SCM would need to establish whether it covers primary and/or secondary aluminium production (which have significantly different GHG intensities and profiles), which direct and/or indirect emissions would be included, which gases.

- **Projections of business-as-usual output and emissions**. Whether such projections are used to determine the baseline for crediting or not, they will be needed to establish confidence in the environmental outcome of the mechanism.

- **Definition of a "baseline"**. A sectoral crediting mechanism will also require a baseline to measure performance. How this is defined will depend on the SCM design, as well as on the definition of sector. It will further be influenced by decisions on the appropriate spatial scope of a baseline (e.g. whether it should be set at a sub-national, national or international level), as well as on other boundary issues highlighted above.

No design is inherently more environmentally-effective than another. Rather, it is the design details (such as baseline level, boundary) that influence a SCM's environmental effectiveness.

Beyond the above, we cannot draw conclusions applying equally to electricity and to aluminium. Further, issues raised by aluminium may not be valid for another internationally-traded commodity like steel. Nor would another domestic sector like transport or buildings necessarily follow the design features explored for the power sector in this paper.

Some challenges must be recognised as sectoral approaches gain ground in international climate policy debates. The following examples are drawn from aluminium and may apply to other internationally traded commodities:

- The CDM is a mechanism to promote more climate-friendly technologies in developing countries. SCMs are considered as a tool to broaden and quicken this dynamic. Yet a sector like aluminium shows that best available technologies are sometimes found in developing countries, where more recent plants are located. What additional incentives could SCM provide in this case? Rather than focusing on new plants, an improvement in existing operations may be more productive. However, this picture changes if electricity consumption by smelters is brought into the boundary of the SCM. Crediting could encourage the much more energy efficient secondary aluminium production.

- Some aluminium producers have taken steps to reduce their GHG emissions on a voluntary basis. Producers that have not taken such steps could generate credits under a SCM, thus rewarding their earlier inaction. A point of particular worry, although not analysed here, is the possibility that crediting could provide a competitive advantage to "laggards". If this were averred, it could be a barrier to an international agreement on sectoral crediting for this sector.

More generally, any approach towards limiting a whole sector's emissions at an absolute level must face the risk of an overly generous allocation, particularly if not all sectors that produce competing products implement a SCM. On the other hand, a stringent limit on a single sector is likely to meet strong resistance. Data and proper projections will be of paramount importance in baseline setting.

Several issues should be explored further before any sectoral crediting mechanism is established. These include:

- How a SCM would interact with other agreements already in place in the same country or sector (e.g., Kyoto Protocol mechanisms, EU Emissions Trading Scheme, voluntary agreements and other domestic policies).

- The management/oversight required for an SCM, i.e. what approval process could be envisioned, whether an SCM was binding, who would be liable under such a mechanism, and what the role of national governments and industry bodies would be with regards to setting incentives, monitoring, reporting and review.

- How competitiveness concerns could be addressed for SCMs in sectors with internationally-traded products, and how any perverse incentives could be minimised.

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