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# A SECTORAL APPROACH, AGREEMENT AND MECHANISM (SAAM) FOR THE MITIGATION OF GREENHOUSE GAS EMISSIONS IN JAPAN'S IRON AND STEEL INDUSTRY

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# A Sectoral Approach, Agreement and Mechanism (SAAM) for the Mitigation of Greenhouse Gas Emissions in Japan's Iron and Steel Industry

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## List of Abbreviations

APP	Asia-Pacific Partnership
BF/BOF	Blast Furnace and Basic Oxygen Furnace
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CHP	Combined heat and power
COURSE50	CO <sub>2</sub> Ultimate Reduction in Steel-making Process by Innovative Technology for Cool   50
DRI	Direct reduction of iron
DPJ	Democratic Party of Japan
EAF	Electric Arc Furnace
EScert	Energy savings certificates (within India's PAT scheme)
ETS	Emission Trading Scheme
EU	European Union
GSEP	Global Superior Energy Performance Partnership
I&S	Iron and Steel
IATA	International Air Transport Association
IISI	International Iron and Steel Institute
IMO	International Maritime Organisation
JISF	Japan Iron and Steel Federation
LDP	Liberal Democratic Party
METI	Ministry of Economy, Trade and Industry
MoE	Ministry of Environment
MOFA	Ministry of Foreign Affairs
MRV	Measuring, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NEDO	New Energy and Industrial Technology Development Organisation (of Japan)
PAT	Perform, Achieve, Trade
PCM	Phase change materials
R&D	Research and Development
RDD&D	Research, Development, Diffusion and Deployment
REDD	Reduced Emissions from Deforestation and Degradation
SA	Sectoral Approach
SAAM	Sectoral Approaches, Agreements and Measures
SCM	Sectoral Crediting Mechanism
SNLT	Sector-no-lose target
SOACT	State-of-the-Art Clean Technologies
TGR-BF	Top Gas Recycling Blast Furnace
ULCOS	Ultra-Low CO <sub>2</sub> Steel-making
UNIDO	United Nations Industrial Development Organisation
WSA	World Steel Association

## Introduction

This report outlines a sectoral approach, agreement and mechanism (SAAM) for the mitigation of greenhouse gas emissions in Japan's iron and steel sector. It does so by first summarizing the stakeholder needs and desires that were taken into account to determine the practical and political suitability of various approaches. The report then reviews how technology may develop and the financial impacts that a SAAM would have on the Japanese iron and steel sector. A detailed description of the SAAM is then set out, and the interrelationships with other strategies to mitigate climate change explored. The report concludes with how the SAAM could be moved towards implementation.

The report concentrates solely on proposing what is considered to be the most realistic SAAM for the sector. It does not seek to compare how effective or efficient such a SAAM would be compared to other potential policies, for example a carbon tax or an Emission Trading Scheme (ETS). Neither does it assess the potential for demand reduction - from the steel sector in particular or from the economy in general - nor consider the option of replacing steel with substitute products from any existing or future product mix.

The starting point for the analysis has been to ascertain how much progress the iron and steel sector in Japan could make on a unilateral basis. The premises are: that anything that requires international agreement or co-ordination becomes more difficult to implement<sup>1</sup>; and a significant reduction in projected climate change globally will require significant reductions from Japan in general, and from all its sectors (including iron and steel) in particular. The unilateral focus does not preclude international actions and co-operation - which could lead to a range of benefits - but the analysis starts with what would work nationally first. If this could then be replicated internationally, or credited by other countries as being of value in mitigating greenhouse gas emissions, then this could lead to an international approach being developed from the 'bottom up'. The study has not considered 'top-down' international approaches, which many other studies have analysed.

While offsets (reductions in other countries) may have some role to play, notably in the short- to medium-term, the analysis focuses on the fundamental challenge of reducing emissions domestically. The approach developed in this study argues that Japanese steel sector GHG emissions can only be reduced to sustainable levels through the successful development and implementation of breakthrough technologies and/or CCS. This could happen under business-as-usual activities - R&D efforts are underway, Japanese steel companies are aiming to develop new technologies for future markets and a range of activities on CCS are being undertaken. This study argues that a better approach would coordinate government targets, existing R&D programs and contributions from the iron and steel industry to **ensure that the effort put into R&D is sufficient to convincingly achieve Japan's national targets within an acceptable timeframe.**

This report is an output from Climate Strategies' 18-month project *International sectoral approaches and agreements: case studies of the steel sector in China, India and Japan*.<sup>2</sup> The scope of the project was deliberately focused on one sector (steel) and three countries (Japan, China and India), in order to allow for the detailed analysis needed to progress the design and discussion of a sectoral approach. A consultation paper on the *Proposed Steel Sectoral approach for Japan*<sup>3</sup> was published in November 2010. Separate reports on the China and India case studies have also been released, along with two synthesis documents:

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<sup>1</sup> A detailed analysis of the history of SAAMs, including conclusions on why it is considered that international 'top-down' approaches have not delivered more, is included within the synthesis paper *Exploding the Myths of Sectoral Approaches (and renaming them Sectoral Approaches, Agreements and Measures)*, developed as part of this study and available at: <http://www.climatestrategies.org/research/our-reports/category/54/305.html>

<sup>2</sup> All reports from this project are available at: <http://www.climatestrategies.org/our-reports/category/54.html>

<sup>3</sup> <http://www.climatestrategies.org/our-reports/category/54/272.html>

1. *International sectoral approaches and agreements: case studies of the steel sector in China, India and Japan – Emerging Policy Recommendations*<sup>4</sup>, which draws mid-study recommendations for how countries should consider and develop their SAAMs; and
2. *Exploding the Myths of Sectoral Approaches (and renaming them Sectoral Approaches, Agreements and Measures*<sup>5</sup>, released in February 2011, synthesises the three country case studies and draws a number of lessons for how SAAMs could realistically be taken forward.

It is planned that the SAAM for Japan will also be written up in the form of an academic paper for submission to a leading journal.

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<sup>4</sup> <http://www.climatestrategies.org/research/our-reports/category/54/264.html>

<sup>5</sup> <http://www.climatestrategies.org/research/our-reports/category/54/305.html>

## 1. Scope

Japan's steel sector is recognised as the world's most advanced technologically. There is little that can be done to improve energy efficiency or emissions using currently available technologies.<sup>6</sup> With projections of steel production over the next 3 decades largely flat, we can thus expect no more than relatively minor reductions in GHG emissions from Japanese steel production over the period under business-as-usual conditions (see Figure 1).

**Figure 1: CO<sub>2</sub> emissions to 2050 in Japan under BAU (RITE, 2008)**

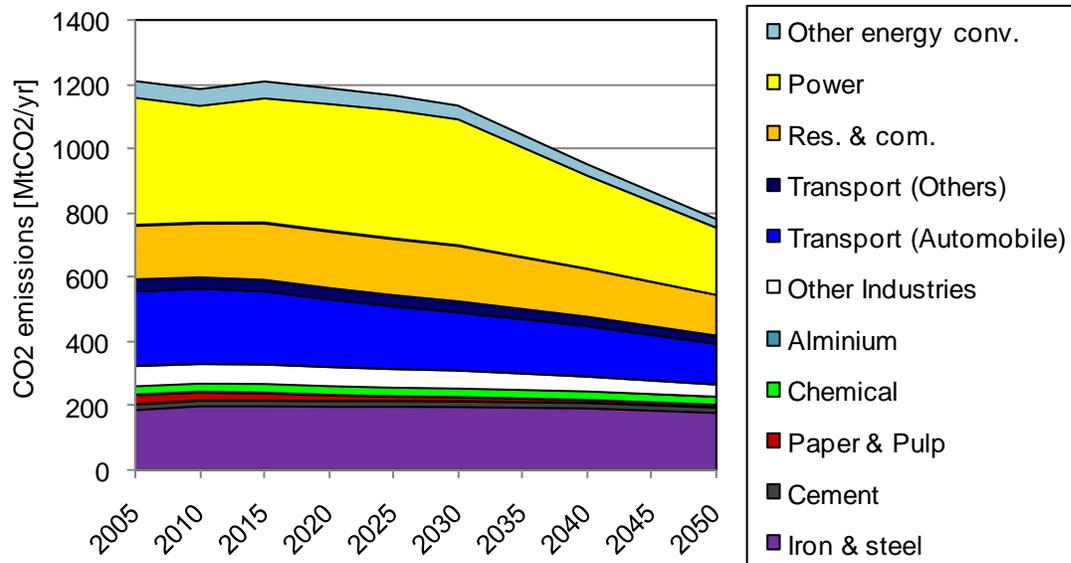
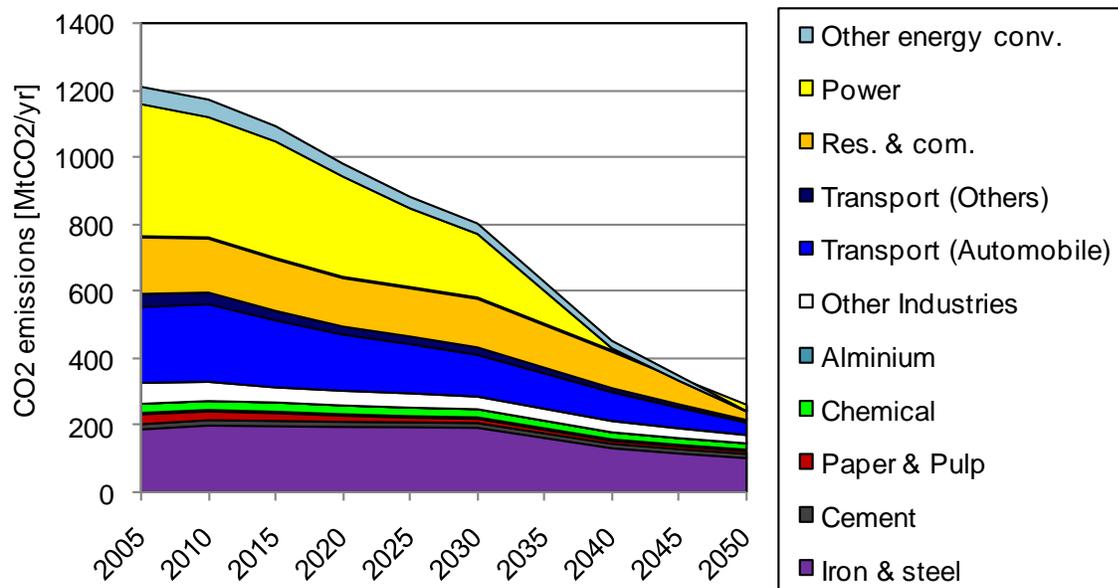


Figure 1 indicates that Japan could expect a one-third reduction in its emissions by 2050 under business-as-usual conditions, largely as a result of reductions from the power (generation) and transport (automobile) sectors. If Japan wishes to make more significant emissions reductions from within its own boundaries by 2050, for example meeting the 80% reduction from 1990 levels proposed by the Cabinet in 2010 under the 'Basic Act' (MOE, 2010), then reductions will be needed from iron and steel and other sectors: we cannot expect other sectors to carry all of the burden on their own. Assuming steel production remains at around today's level, and the share of recycled steel in the mix does not increase, then reductions would require a major improvement in the primary steel production process – currently blast furnaces fed predominantly by coke – and/or by the capture and storage of carbon dioxide emissions (CCS). Current, non-captured emission levels per tonne of steel from blast furnaces are not sustainable if deep cuts in national emissions are required. Figure 2 illustrates a case where the iron and steel sector has been able to reduce its emissions by about one-half as part of an economy-wide reduction of 80%, largely through successful development of an improved blast furnace with CCS which becomes available around 2030.

<sup>6</sup> Noting that some plant in Japan is relatively old, and its replacement with new plant would result in some reduction in GHG emissions.

**Figure 2: CO<sub>2</sub> emissions to 2050 in Japan with 80% reduction from 1990 (RITE, 2008)**


The scope of the analysis has been set as follows:

- a. *Increasing the use of scrap.* GHG emissions could be reduced by increasing the use of scrap in Japan, for example by increasing net imports of scrap. This would be unlikely to decrease emissions from steel worldwide, as scrap is a very valuable commodity and is already traded internationally and collected at very close to the maximum possible rates worldwide. The option to increase scrap use in Japan is not considered further in this report.
- b. *Crediting downstream activities.* Groups including the World Steel Association<sup>7</sup> are suggesting that downstream reductions should be credited to upstream producers (for example steels which make cars lighter than they were previously, are used in wind turbines or improve fossil-fuel fired electricity plants' electricity generation efficiency). Such opportunities could also be included in offset schemes supported by Japan (see Box 1). Technical issues around setting system boundaries and calculating emissions reductions remain very challenging, and the debate on whether we should move away from production-based accounting of GHG emissions towards consumption-based accounting is controversial. Such a move would be unlikely before at least the medium term. The possibility for downstream crediting is not considered explicitly within this report, although issues around systems boundaries are an essential part of the detailed design presented in *Section 3.4*.
- c. *Using offsets.* The introduction stated that the focus of this report was on unilateral action. Much of the debate on environmental action from sectors such as iron and steel in Japan at present (March 2011) revolves around the possible uses of offset mechanisms. Box 1 summarises current Japanese activities and the key issues. There could be advantages to the purchase of offsets, but these are not unequivocal and may not assist in meeting a significant global reduction in emissions. This report focuses on the actions that Japan could take

<sup>7</sup> See Annex C for details.

unilaterally, although it is noted that including offsets in the SAAM is an option that could be useful, particularly in the short- to medium-term and if it helped to demonstrate technology or assisted in the development of technology which could subsequently be used in Japan.

d. *Links with other Japanese policies and measures.* Japan, in common with a number of other countries around the world, already has a series of policies and measures governing the steel sector in general and its GHG emissions in particular. Of note are:

- the Keidanren's Voluntary Action Plan on the Environment<sup>8</sup>, and its successor, Commitment to a Low Carbon Society, with their progressive voluntary targets on energy efficiency;
- the APP (Asia-Pacific Partnership)<sup>9</sup> and its successor the Global Superior Energy Performance Partnership (GSEP)<sup>10</sup>, whose work on the steel sector has largely involved identifying technology options and improving opportunities for its members to invest in each other's economies;
- the energy and carbon tax, which applies to coal and petroleum products purchased by industry.

Amongst any number of future policies which could be implemented are federal and prefecture-level ETS (Emission Trading Schemes), which are currently under discussion in Japan. The 'Basic Act on Global Warming Countermeasures' ('Basic Law') (MOE, 2010) discussion held in the Japanese Diet in the final quarter of 2010 essentially precluded the possibility of a Federal ETS in the near future. Building on and using existing policies and measures is one of the core principles of the analysis undertaken, and is referred to throughout the rest of this report.

e. *Sources of finance.* The Basic Law will lead to a new, economy-wide carbon tax, which will be introduced in October 2011<sup>11</sup> and whose precise level and the destination for the revenue raised are expected to be finalised during calendar year 2011. The new 'environment tax' may see revenues being hypothecated, much as the current 'coal and petroleum tax' levied on industry, which is used to finance NEDO, who in turn finance programmes such as COURSE50 (an RDD&D scheme for the steel industry). The discussions around the new environment tax illustrate the key issue of hypothecation: will it be possible to levy new charges, and can these be fully or partially redirected to the benefit of the sectors on how they are levied? Consistency with the 'polluter pays' principle must be matched against political realities, including Japan's industrial policy and the strategic importance it places on the steel industry. Sources of finance are a key part of the detailed design presented in *Section 3.4*.

### **BOX 1: Offsets from bilateral or multilateral schemes**

Japan has been pursuing new offset mechanisms actively over the past two years, and the debate on their design and use is now very strong. There have been various shows of support for increasing the role of offsets. Many commentators suggest that meeting the carbon commitments of the DPJ cannot be done using 'clear blue water', i.e. from reductions from within Japan alone. Largely for this reason, but also because of reasons including concerns over the CDM (what projects are eligible and where the profit from the scheme goes) and the desire to support its domestic industries, Japan is setting up a major bilateral crediting programme, with its own monitoring, reporting and verification (MRV) mechanism.

The "Hatoyama Initiative", introduced by the then Premier at the UNFCCC COP in Copenhagen on 17 December 2009, set out Japan's wish to set up a new mechanism, with a wide range of parameters: it could include clean technologies but also production facilities, opening the way to claims for downstream improvements by technology manufacturers; and not closing the door on any bilateral or multilateral

<sup>8</sup> See Annex A for details.

<sup>9</sup> See Annex D for details.

<sup>10</sup> The APP Steel Task Force is currently being wound down with a replacement Steel Working Group set up under the GSEP, and to be hosted at the IEA in Paris. This working group will build upon the work of the APP Task Force (Clean Energy Ministerial, 2010).

<sup>11</sup> And then increased in April 2013 and April 2015.

potential solution. Japan's Bank for International Cooperation (JBIC) was mandated by the Japan Finance Corporation Act in March 2010<sup>12</sup> to support "Global action for Reconciling Economic growth and Environmental preservation (GREEN)" projects, i.e. those that are expected to reduce GHG emissions. JBIC's projects will use the new "J-MRV" scheme to monitor the impacts of the projects. The fiscal budgets of 2010 and 2011 of the Ministries of Environment and of Economy, Trade and Industry include funding for around 30 project feasibility studies.

Japan has not formally proposed a new mechanism to the UNFCCC. Neither has significant support for Japan's ideas been forthcoming. Thus we will at this stage assume that any new initiatives Japan has proposed would be bilateral in nature, i.e. additional to the UNFCCC's 'flexible mechanisms' (international emissions trading, the CDM and JI). It is not within the scope of this paper to discuss how a new mechanism would alter the dynamics of the UNFCCC process for better or worse.

We must now ask whether bilateral offsets should be part of Japan's approach in general, and of an iron and steel sector SAAM in particular. Given that there is little that the Japanese steel sector can do to reduce emissions from its existing facilities in the short- to medium-term, purchasing bilateral offsets would allow GHG reductions to be made before the long-term. This of course depends on the additionality of the offset schemes – using the example of the CDM, different commentators assess the additional reductions made very differently. Nevertheless, we could conceive of certain projects – for example Japanese investment in CCS in Indonesia – which would be highly additional. And projects such as these are likely to generate GHG reductions at lower cost than those available from the Japanese steel sector, the key point of trading in markets. On the negative side, various commentators<sup>13</sup> note that purchasing offsets transfers resources out of the Japanese steel sector, reducing their ability to invest in the development and implementation of new technologies and solutions.

A further issue to consider regarding bilateral offsets is whether they would help or hinder the core aim of this study: *ensure that the effort put into R&D is sufficient to convincingly achieve Japan's national targets within an acceptable timeframe*. On the positive side, it could be argued that investment in projects in developing countries would assist the development of technologies which could later be used in Japan. Conclusive evidence has not been seen to illustrate this effect, but it is possible to conceive of examples, such as demonstrating generic new technologies which could equally well be achieved in a country outside Japan as within Japan itself. Again the example of CCS is a good one.

<sup>12</sup> The "Revised JFC Act", as reported in JBIC (2010).

<sup>13</sup> "In my opinion, Japan should avoid purchasing carbon credits, because that would mean a drain on national wealth". Quote from Atsushi Yamaguchi, UBS Analyst for Steel and Non-ferrous Metals Sector (Ishinabe, 2010). The Nippon Keidanren, heavily opposed to such a [offset] policy, have claimed that it would slow R&D efforts by diverting funds into the purchase of carbon credits and lead to carbon leakage (Nippon Keidanren, 2010).

## 2. Stakeholder needs and desires

The analysis of stakeholder needs and desires was carried out through two complementary and ongoing processes: first, identifying various stakeholders and researching their official activities regarding climate change mitigation and sectoral approaches; and second, a series of consultations with various stakeholder representatives, with initial meetings taking place in October 2009 and follow-up meetings in October 2010.

Two major groups of stakeholders were identified:

- a. The Japanese political establishment: in particular,
  - the two leading political parties, the Democratic Party of Japan (DPJ) and the Liberal Democratic Party (LDP); and,
  - the ministries of Economy, Trade and Investment (METI), Environment (MOE) and Foreign Affairs (MOFA).
- b. The Japan Business Federation, known as the 'Nippon Keidanren', and its members from the steel sector, represented by the Japan Iron and Steel Federation (JISF).

### a. The Japanese political establishment

It is evident from a review of Japan's political landscape that general support for climate change policy-making is strong. Both major political parties have manifestos that propose targets for CO<sub>2</sub> reduction in the medium term, increasing the use of environmental taxes and promoting low-carbon energy generation. The current ruling party, the DPJ, is the most ambitious, favouring more stringent targets and the introduction of an emissions trading scheme (ETS),<sup>14</sup> as illustrated in the table below. All of the most important minor political parties – the New Komei Party, the Social Democratic Party and the Japan Communist Party – have manifestos whose climate policies are closer to the DPJ than the LDP in terms of policy measures, implying relatively strong domestic support for more ambitious climate change policy-making (JACSES, 2009).

**Table 1: Summary of climate policies in DPJ and LDP political manifestos, 2010**

	Targets for CO <sub>2</sub> reduction	Environmental taxation	Energy policy
Kyoto targets	<ul style="list-style-type: none"> <li>• 6% by 2010 (1990 base year)</li> </ul>	–	–
DPJ	<ul style="list-style-type: none"> <li>• 25% by 2020 (1990 base year)</li> <li>• 80% by 2050 (1990 base year)</li> </ul>	<ul style="list-style-type: none"> <li>• establish ETS from 2011</li> <li>• introduce climate change taxes</li> </ul>	<ul style="list-style-type: none"> <li>• encourage nuclear</li> <li>• feed-in tariffs for renewables with a 10% target by 2020</li> </ul>
LDP	<ul style="list-style-type: none"> <li>• 15% by 2020 (2005 base year)<sup>1</sup></li> <li>• 80% by 2050 (2005 base year)</li> </ul>	<ul style="list-style-type: none"> <li>• no mention of ETS</li> <li>• green entire tax system</li> </ul>	<ul style="list-style-type: none"> <li>• encourage nuclear</li> <li>• increase solar PV by 20 times by 2020 and 40 times by 2030</li> </ul>

<sup>1</sup> equivalent to an 8% reduction from a 1990 base year.  
Source: (JACSES, 2009)

<sup>14</sup> The introduction of a Federal level ETS now (March 2011) looks very unlikely in at least the near term.

At the level of ministries, it is generally recognised that a rough split exists between, on the one hand, the Ministry of the Environment, seen to be closer to the ruling DPJ; and on the other hand, the Ministry of Economy, Trade and Industry (METI), seen to be closer to opposition party the LDP and industry group the Nippon Keidanren. There are historical reasons for this divide: until 2009 the LDP ruled Japan almost uninterrupted for over 50 years, during which time METI and the Nippon Keidanren cooperated extensively to drive the country's economic recovery after the Second World War, bringing all three into well-established interrelationships. By contrast, the DPJ styles itself as an iconoclastic party, wanting to shake up the traditional institutional structures of power (DPJ, 1998).

The practical ramifications of this are that the DPJ and the MoE favour more stringent targets and increased government intervention, including an ETS and support for the Kyoto Protocol; whereas the LDP and METI are more closely aligned with the interests of industry, criticising the Kyoto Protocol for failing to tackle carbon emissions from large developing countries and favouring a sectoral approach to climate change mitigation (van Asselt, Kanie, & Iguchi, 2009). Indeed, at the UNFCCC's COP-10 in 2004, the Industrial Structure Council – a METI think tank – published a proposal for a post-Kyoto framework featuring a sectoral approach (Industrial Structure Council, 2004).

The Ministry of Foreign Affairs appears to have no affiliation with any specific approach to climate change mitigation, instead focusing its efforts on more tangible political outcomes: preserving Japan's reputation as an environmental leader at the same time as supporting the country's primary political ally, the United States, and trying not to lose out in terms of trade competitiveness to China, the country with the largest share in its import market. According to van Asselt et al. (2009), these tensions explain Japan's membership in both the Kyoto Protocol and the non-binding, international sectoral approach, the Asia-Pacific Partnership on Clean Development and Climate (APP), considered by some to have been an attempt to form an alternative to the Protocol.

## **b. The Nippon Keidanren**

Born in 2002 from the merging of the Keidanren (the Japan Federation of Economic Organisations) and the Nikkeiren (the Japan Federation of Employers' Associations), the Nippon Keidanren is an industry group representing the majority of Japan's major economic organisations. This includes the Japan Iron and Steel Federation (JISF), a consortium made up of the majority of Japan's iron and steel companies. The Nippon Keidanren has been Japan's biggest proponent of a sectoral approach to mitigating climate change, seemingly on the basis that Japanese industries tend to perform at extremely high levels of efficiency, making this a low-cost option, and that it can avoid cumbersome government regulation with voluntarily action.

Since 1997, the Keidanren has been heading one of the world's most significant sectoral agreements, the 'Keidanren Voluntary Action Plan on the Environment', with the endorsement of the Japanese government. The agreement sets out a range of objectives for 36 national industries to achieve by 2010, with a common goal shared by all participants as a minimum: "to reduce CO<sub>2</sub> emissions from the industrial and energy-conversion sectors to below the levels of 1990 by 2010" (Keidanren, 1997). Within this, the JISF set itself a more stringent target of reducing absolute levels of energy consumption in 2010 by "about 10%", as well as increasing the use of plastic waste and unused energy, contributing towards more energy-efficient final steel products and contributing "to energy conservation through international technological cooperation" (Keidanren, 1997). From the outset, the plan contained provisions for an annual review with publically available results, to be released on the internet and through other media.

A review of the Nippon Keidanren and the JISF's official statements showed that this commitment to publish annual follow-up reports was indeed met (see Annex A), with standards becoming increasingly more robust as the initiative matured, including the establishment of an Evaluation Committee to ensure submissions were transparent and credible (Nippon Keidanren, 2002). In 2007, a change was announced to bring the Action Plan's targets into coordination with Japan's Kyoto Protocol commitments, but the

JISF's commitment has otherwise remained the same (Nippon Keidanren, 2007). Despite setting its target in terms of absolute energy consumption, it should be noted that the JISF also went as far as reporting absolute levels of CO<sub>2</sub> emissions and CO<sub>2</sub> emissions intensity.

According to Wakabayashi and Sugiyama (2007), no government initiatives were regularly evaluated in the same depth, giving credence to arguments that the plan set out practical, achievable commitments "developed and negotiated through in-depth discussions among administrative officials, experts and industries". At the same time, it is clear from the Keidanren's own reports that it failed to take action on a number of recommendations made by the Evaluation Committee – for example, providing a comprehensive account of factors that might have affected CO<sub>2</sub> fluctuations (including changes in products or the possible transfer of operations overseas) and analysing the cost-effectiveness of the Voluntary Action Plan. In addition, according to the JISF's last available report, energy consumption in 2006 was only 5.2% lower than 1990 levels, casting doubt over whether or not the voluntary plan will have provided sufficient motivation to achieve the ultimate 2012 target of a 10% reduction (Nippon Keidanren, 2007).

Japan's relatively positive experience with an industry-led sectoral approach, as well as the Nippon Keidanren's future plans, show that sectoral approaches are a serious option for the country's mitigation of climate change. The Nippon Keidanren had already begun to outline a follow-up sectoral approach, the Commitment to a Low Carbon Society, announced in a public statement in 2009 that proposed to set new voluntary CO<sub>2</sub> reduction targets until 2020, pursue "a PDCA cycle [plan-do-check-act] in partnership with the government to ensure that the initiatives... are steadily and reliably implemented," and develop low-carbon technologies to halve carbon emissions by 2050 (Nippon Keidanren, 2009). Other statements make it clear that the group opposes any policies that would increase Japan's already high-cost business environment (including the creation of an ETS), believes the 25% by 2020 target should be reconsidered and is in favour of further developing bilateral offset mechanisms (Nippon Keidanren, 2010).

### **c. Areas of agreement and areas of conflict**

The stakeholder perspectives identified in this study imply that there are a number of areas where parties might find themselves in agreement and others where they may experience conflict. It would appear that the driving force behind any SAAM over and above the Keidanren's existing plans would come from the ruling Japanese government, the DPJ, whose goals for climate change mitigation are ambitious and who exist somewhat outside existing power structures and alliances. Combined with the array of forces – the Nippon Keidanren, METI and the LDP – lined up against other approaches to climate change mitigation, such as an ETS, there are certainly grounds to further pursuit of SAAMs in Japan is likely avenue for action, especially given the relative success of Nippon Keidanren's Voluntary Action Plan. At the same time, it is difficult to foresee how any more stringent agreement might realistically put the JISF in a position to reduce its absolute CO<sub>2</sub> emissions by any significant amount unless it reduces production or significantly altering its production methods, the first of which is politically unfeasible and the second of which will require significant time and effort in research and development. This implies that a government-industry agreement over a comprehensive and convincing plan for technology development is an appropriate way of navigating the various needs and desires of stakeholders in the mitigation of CO<sub>2</sub> emissions in Japan's iron and steel sector.

### 3. Proposed sectoral approach, agreement and mechanism (SAAM)

#### 3.1 Summary

The proposed SAAM aims to:

***develop and implement breakthrough technologies and/or carbon capture and sequestration (CCS), as quickly as possible.***

Two variants are proposed:

1. **implement a fully-resourced plan of RDD&D** to develop breakthrough technologies and CCS by certain dates, with companies needing to meet minimum levels of effort.
2. **regulate CO<sub>2</sub> limits** such that steel plants exceeding these could not be constructed or operated after certain dates, leaving industry to pursue its own RDD&D path.

The first variant requires the identification of funding and a plan for its expenditure; the second leaves actions and their organization to those involved in the Japanese steel sector.

In order to propose details for these two variants (presented in Section 3.4), it is necessary to understand how the technology to make steel may develop (see Section 3.2) and to assess the costs of development and implementation within the context of the resources available in the sector (see Section 3.3).

#### 3.2 Technology Development

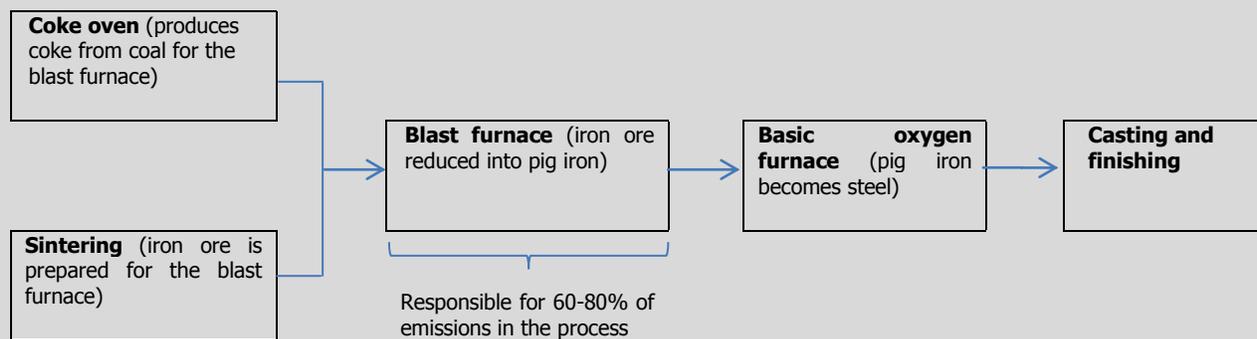
A brief summary of steel-making technology and how it might be developed is shown in Box 2; details are provided in Annex B. The Box notes two major research programmes currently underway – ULCOS in Europe and COURSE50 in Japan – and highlights the need to improve the performance of the key process in steel production – the ‘primary route’, using the blast furnace. Progressing either of the two potential SAAM variants mentioned above requires development and implementation of one or both of:

- i. *Breakthrough technologies.* There is no clear breakthrough technology which Japan could invest in and would be guaranteed to reduce GHG emissions by a significant amount (e.g. 50%). Fundamental research continues across the world, but there is a general consensus that breakthrough technologies will not be commercially available within 20 years. The COURSE50 (Japan) and ULCOS (Europe) projects have identified a limited number of the most promising technologies, and are taking these towards demonstration. Both are co-operative programmes, with COURSE50 financed by government and ULCOS including government and industry funding. Both programmes include CCS components. Neither of the programmes, or any other we could point to or conceive of, can guarantee that it will successfully develop breakthrough technology;
- ii. *CCS.* Capture of carbon from the blast furnace appears technically feasible, although the economics have yet to be proven. Worldwide, there have been over 30 roadmaps for how CCS could be developed and implemented. Annex E reviews CCS activities in Japan, concluding that the steel sector could become more involved in the transport and sequestration of captured carbon. This is perhaps the key unknown in Japan - is there sufficient storage capacity available to sequester carbon, and is it financially and politically possible to develop pipelines to transport the captured carbon to these sites? Without these assurances, talking of CCS as an option appears premature. Uncertainty can be reduced by further work and expenditure in the area, but who should be responsible for this work is somewhat unclear at present.

How these two groups of technology should best be developed and implemented is the focus of the SAAM presented in this report.

### BOX 2: Technology Development in the iron and steel sector

Although more and less carbon-intensive steel-making processes exist, there are various practical limitations which mean that the most carbon-intensive of these – the use of a blast furnace combined with a basic oxygen furnace – is unavoidable in the creation of significant amounts of new or 'primary' steel. This process, illustrated very basically below, emits around 2 tonnes of CO<sub>2</sub> per tonne of steel produced from a relatively modern plant. It is difficult to reduce emissions because this process requires carbon as part of the chemical reaction that takes place in the blast furnace: it is the only cost-competitive agent that can separate oxygen from the iron in the ore, which it does by forming CO<sub>2</sub>. There is therefore little that efficiency gains or the development of low-carbon energy can do to reduce emissions. Without major alterations to the inputs, the process itself, of the treatment of outputs, CO<sub>2</sub> is an inescapable by-product of steel-making.



Steel can also be easily recycled, with electric arc furnaces (EAF) able to take scrap and process it ready for the casting and finishing stage. Emissions from the process are only those from the electricity used, and, depending on the electricity generation mix, tend to be on average around 20% of those from blast furnaces (see Annex B for details). The use of EAF is dependent on the availability of scrap.

From the 'primary' (blast furnace) route, the only realistic way to substantially reduce CO<sub>2</sub> other than reducing production and consumption is to research and develop new inputs, processes or ways of treating outputs. Given the large amount of investment this would require, and the significant risks and externalities that surround R&D investment, it is questionable if this would take place without some form of intervention. It is possible that an ETS might create the appropriate incentive but – given current discussions – it is unlikely that an ETS will be implemented in the short- to medium-term, and no design details are known (for example it is not clear if a future Japanese ETS would apply to the steel sector). The Nippon Keidanren, heavily opposed to an ETS policy, have claimed that it would slow R&D efforts by diverting funds into the purchase of carbon credits and lead to carbon leakage (Nippon Keidanren, 2010). Research and development is already ongoing and suggests a variety of promising possibilities. Emissions-saving technological developments that have been identified include biocoal, hydrogen reduction, new smelting reduction processes, electricity-based steel-making, top-gas recycling, carbon capture and sequestration and the development of new steel products that can save emissions in their uses downstream, with various timescales for market entry, though the earliest being predicted after 2020 (for a more in-depth explanation of these options, see Annex B).

Two major research programs were identified as pioneers in this research field. The first, **Ultra-Low CO<sub>2</sub> Steel-making (ULCOS)**, is a cooperative R&D program, begun in 2004 and operated by a consortium of 48 European companies and organisations from 15 European countries, with funding in the first phase being paid 60% by members and 40% by the European Commission. Early research involved mapping out seventy different potential steel-making processes, five of which are now being pursued in a second

research phase, 2010–2015, with a budget of €700-800 million (US\$ 1.0–1.1 billion), including a demonstration of CCS technology. Its goal is to cut CO<sub>2</sub> emissions by at least 50% from today's cleanest steel-making routes, with timescales for implementation around 2025-2030 (ULCOS, 2009; Birat, et al., 2008). The second is an existing Japanese R&D program, **CO<sub>2</sub> Ultimate Reduction in Steel-making Process by Innovative Technology for Cool Earth 50 (COURSE50)**. Run by the New Energy and Industrial Technology Development Organisation (NEDO), an incorporated administrative agency funded largely by METI, it has created a technology "development schedule" and contracted out R&D tasks to private actors with public funds. Its plans focus on substituting some of the carbon in the blast furnace with hydrogen, by treating gases from coke ovens, and developing processes to capture CO<sub>2</sub> from blast furnace gases (but not to transport or store it). Its 2008-2010 budget was ¥10 billion (US\$ 120 million) and its goal is to "establish" technologies that can reduce CO<sub>2</sub> emissions by approximately 30% by 2030 and for these to be "industrialized and transferred" by 2050 (NEDO, n.d.; IEA, 2009; JISF, n.d. a.; JISF, n.d. b.).

### 3.3 Financial impact of the approach on the steel sector

#### Overview

Analysis of Japanese iron and steel sector financials was undertaken to compare the costs of SAAMs to the potential financial resources available to the sector. Comparisons have been made on the basis both of key financial indicators within the sector – profit, investment and depreciation – and to the tax received by the government of Japan from the sector. The analysis is designed to provide context to the potential costs of SAAMs, not to conclude that these costs should be paid by government or industry, singly or in combination.

The financial information has been sourced directly from the major Japanese companies' Annual Reports, which are publicly available. Data from these sources is considered to be robust, is clearly uncontroversial to the industry and is presented in the terms that industry uses. By contrast, economic statistics can sometimes lead to disputed understandings and interpretations.

Financial statistics were collected over a ten-year period. The data show significant year-on-year variation, particularly when we look at profit and investment. Assessing the sector on the basis of a single year's financial information is thus potentially misleading, as the year in question may be one that was extremely profitable, where the price of steel in the world market was very low or where some sort of company restructuring or acquisition had led to an unrepresentative set of financials.

Data was collected for the four largest ('Big 4') companies in Japan, which together are responsible for approximately 70% of the sector's steel production<sup>15</sup>, or around 75 million tonnes of crude steel per year:

1. Nippon Steel
2. JFE Steel;
3. Sumitomo Metals;
4. Kobe Steel.

These companies primarily produce using the primary (blast furnace) route, with the other quarter of the sector, which includes Tokyo Steel, having little blast furnace capacity but a disproportionate amount of Japan's electric arc furnace (EAF) capacity. The 'Big 4' has less than 10% of EAF capacity.

#### The economic cycle and comparisons between companies

Financials for the period 2000-2009 for the four largest Japanese companies are shown in Figure 3. Operating income, a measure of profit, increased sharply for all four from 2003, following the glut in steel

<sup>15</sup> They jointly produced 71% of Japanese crude output in 2008.

production around the turn of the century. It then fell sharply following the financial crisis which started in 2008. Capital expenditure showed a similar pattern, illustrating the strong link often observed between profit and investment (often with a time lag of 1-3 years). Depreciation again followed a similar pattern, with only cash flow figures illustrating similar differences between companies.

Figure 4 illustrates some of the drivers of the trends. The price of hot rolled coil (HRC) steel almost doubled between its low in 2003 and 2008; prices of two of the key inputs to the blast furnace production route (iron ore and coking coal) saw even higher increases. The prices of inputs and outputs do tend to be linked across the economic cycle.

The financials of the 'Big 4' companies are considered to be sufficiently similar to allow a consolidated sector to be used as the basis for the analysis: there is not considered to be any significant value in analysing at the company level. It is also clear from Figure 3 that there is considerable year-on-year variability, driven by the economic cycle but also with other contributory factors. Figure 5 shows the annual trends in EBIT, depreciation, capex and the cost of sales.<sup>16</sup> We see strong growth in revenue, and also how profit was almost completely squeezed out when steel prices were at their lowest in 2003. It should be noted that the graph has been normalised across the period by applying a constant 75 Mt production figure to all years.<sup>17</sup> Actual production levels have altered based on both changes in overall demand and in acquisitions and capacity extensions by the companies.

Simple averages for the period 2000-09 are shown in Table 2. Per tonne of steel, the cost of sales was ¥68,500. Of this:

- EBIT (¥11,500/tonne steel) represented around 17% of the cost of sales;
- Capex (¥8,000/tonne steel) was 12%;
- Depreciation (¥6,500/tonne steel) was 9%;
- Tax<sup>18</sup> (¥4,500/tonne steel) was 7%.

For an output of 75 Mt/year, the Table indicates an annual cost of sales of around ¥5,000 billion, with EBIT, Capex, Depreciation and Tax around ¥800 billion, ¥600 billion, ¥500 billion and ¥350 billion respectively. The Table includes US\$ equivalents, using a typical exchange rate from the past few years of US\$=¥100.<sup>19</sup> Revenue was around \$50 billion per year, with EBIT, Capex, Depreciation and Tax each in the range US\$3-9 billion/year.

These figures give an idea of the resources available to the sector. No attempt has been made to scale up from this total to the whole of the sector (which would add another 30% or so of gross production). Any estimates of resources available from the sector are thus a conservative estimate.

### Comparing costs to the resources available to the sector

The costs of a number of programmes and actions that the steel sector is either undertaking or has planned or at least costed are known:

- Japan's COURSE50 programme will cost ¥10 billion in its first phase (2008-12) and ¥15 billion in its second phase (2012-17), for a programme which will include research and demonstration on increasing the hydrogen content within the blast furnace and carbon capture;
- the European 'ULCOS' project has seen US\$20 million per year invested in its first phase (2004-10) and envisages US\$200 million per year in the second (2010-15);

<sup>16</sup> EBIT (Earnings before interest and taxes) is a measure of profit; the cost of sales is a measure of revenue.

<sup>17</sup> To average financials per tonne for each year in the period.

<sup>18</sup> Calculated by simply applying a corporate tax rate of 40% to the EBIT. Specific figures on tax receipts are not available from the companies' Annual Reports.

<sup>19</sup> The exchange rate of 30 January 2011 was approximately 20% lower, at US\$=¥82.06 ([www.oanda.com](http://www.oanda.com)). This difference is not considered to have any material impact on the conclusions reached in this study.

- the CCS demonstration plant at Florange in Europe is estimated to have a capital cost of approximately US\$400 million. If four plants (one for each of the 'Big 4') were installed over a 10 year period, the cost would average US\$160 million/year;
- the ULCOS project has postulated that a demonstration plant for a breakthrough technology could be built at a cost of €1,500 million. If this were financed over a 5 year period, it would require US\$400 million per year.

Table 3 and Figure 6 compare these costs to the resources available to the sector. COURSE50 and the first phase of ULCOS require up to 0.3% of EBIT, 0.5% of Capex and 0.9% of Tax. Phase 2 of ULCOS, and the putative demonstration of four CCS units over a decade, would require approximately 2% of EBIT, 3% of Capex or 5% of Tax. The breakthrough technology demonstration plant, financed over 5 years, would require around 5% of annual EBIT or Capex and just over 10% of Tax.

Comparing the required revenues to carbon emissions or to the quantity of steel produced yields some interesting results. Assuming emissions of 2 tCO<sub>2</sub>/t steel, costs of the programmes and actions considered are about \$1/tCO<sub>2</sub> for the CCS demonstration plant programme or ULCOS second phase, around \$3/tCO<sub>2</sub> for the breakthrough technology demonstration and no more than \$0.2/tCO<sub>2</sub> for COURSE50 or ULCOS first phase. Per unit of steel produced, figures are simply doubled, and range from funding needs of \$0.3-5.3/tonne steel produced.

Raising more money for RDD&D activities will at some point start to suffer from declining returns, and, for research, this point is not necessarily far in advance of current expenditure levels. What is also clear is that there does appear to be the resources to significantly scale up current activities. Purely as an illustration of the resources available, and limited to the 75 Mt/year production of the 'Big 4' companies:

- \$10/tCO<sub>2</sub> (¥1000/tCO<sub>2</sub>) raises \$1.5bn (¥150bn)/year
- \$10/t steel raises \$0.75bn (¥75bn)/year
- 10% of EBIT is \$0.9bn (¥90bn)/year
- 10% of Capex is \$0.6bn (¥60bn)/year

It is easy to make calculations of this sort, but we are still faced with the question of how effective increased expenditure would be: there are uncertainties in terms of technology development, costs and impacts.

#### *How much of the extra costs could the customer pay?*

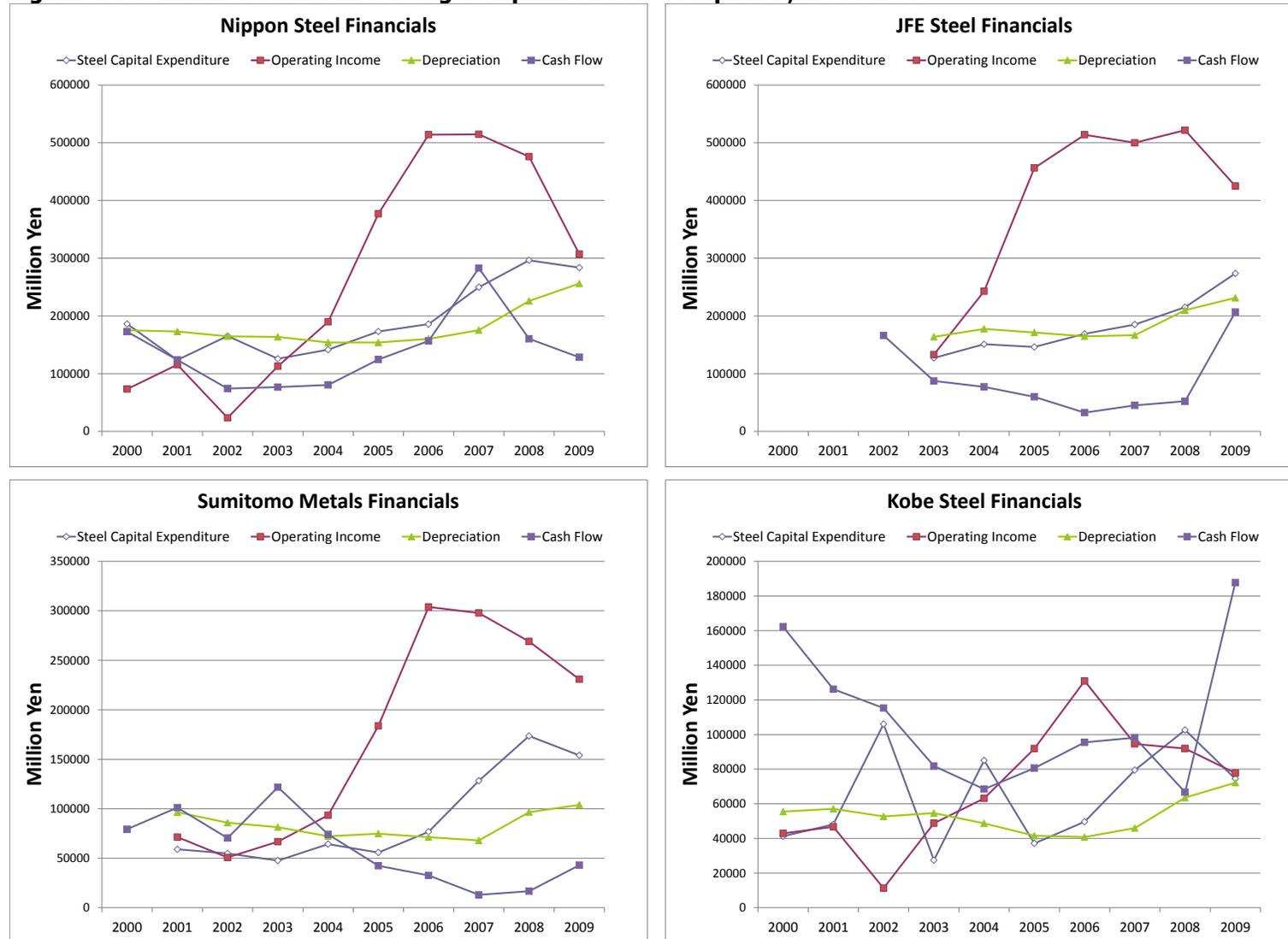
Certain evidence indicates that increased costs of steel production can be passed onto customers in Japan. A leading metals analyst interviewed in Ishinabe (2010) states that, "*historically, Japanese steel makers succeeded in passing almost 100% of ... increased costs on to other parties*", noting that recent cost increases were passed onto automakers in Japan, but that it was harder to do so for shipmakers (which does not need such high quality steels). More general literature (for example Climate Strategies work on carbon leakage<sup>20</sup>; Wooders and Cosbey, 2010) indicates that there is almost always some level of cost pass-through to consumers, but that drawing either general or specific figures as to how much is challenging.

These analyses look at carbon prices of the same order of magnitude as today's prices. The conclusions – both in terms of how much of the cost increase could be passed through to customers and how much leakage of carbon reductions there would be – may change radically if much higher carbon prices (for example at the levels needed to support CCS investments) were the norm.

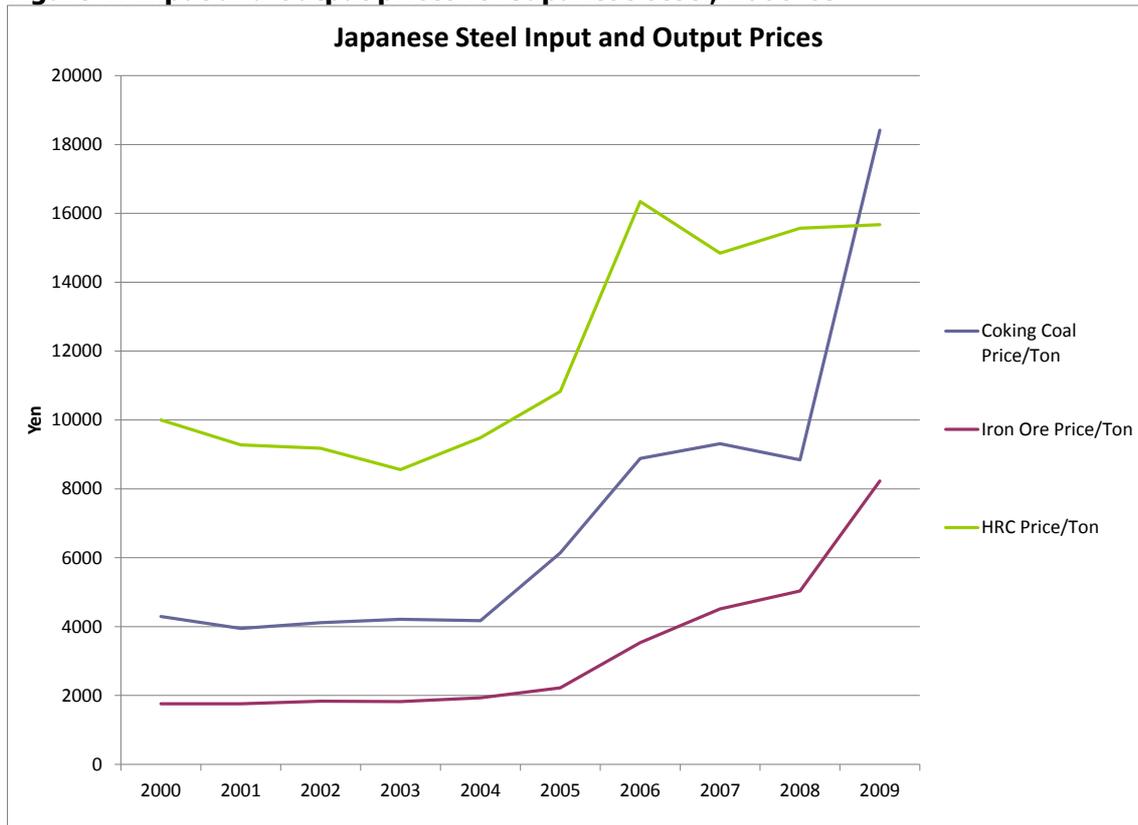
It should be noted that extra costs to producers may ultimately fall, at least partially, on consumers. This of course still represents a cost, but alters the discussion around whether industry would be deserving of compensation or some form of protection if its carbon costs were increased.

<sup>20</sup> See the Climate Strategies website section on "Tackling Leakage in a world of unequal carbon prices", at <http://www.climatestrategies.org/research/our-reports/category/32.html>

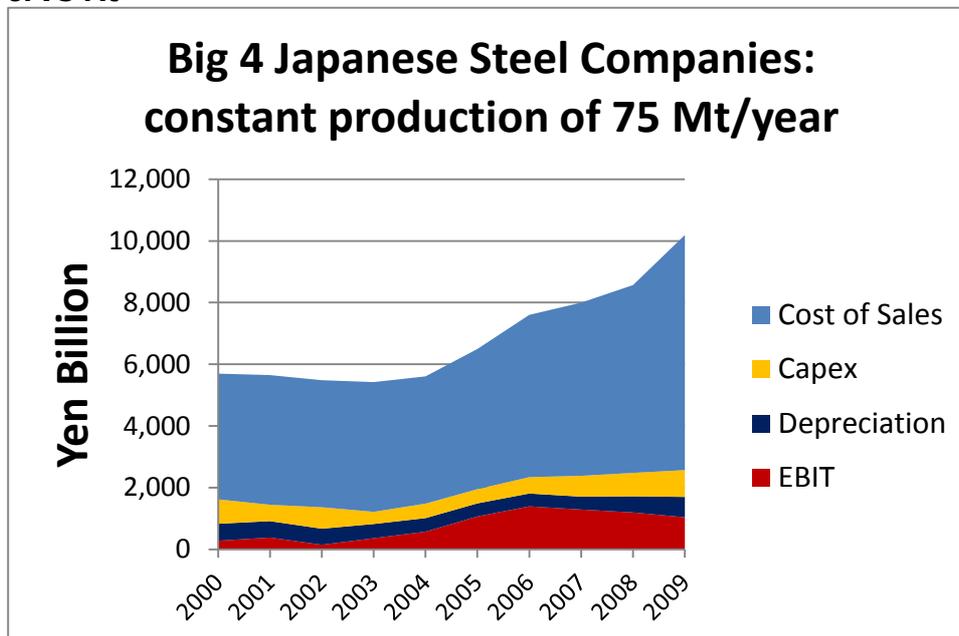
**Figure 3: Overview of Financials of 'Big 4' Japanese Steel Companies, 2000-2009**



**Figure 4: Input and Output prices for Japanese steel, 2000-09<sup>21</sup>**



**Figure 5: Combined financials for 'Big 4' Japanese steel companies, based on annual production of 75 Mt**



<sup>21</sup> IEA 2010, UNCTAD 2010, Asuka, 2009.

**Table 2: Average financials for the 'Big 4' together (at a constant production level of 75 Mt/year)**

Big 4, 75Mt/year	¥ billion	\$ billion	¥/t steel	\$/t steel
Cost of Sales	5,141	51.4	68,544	685
<b>Capex</b>	<b>608</b>	<b>6.1</b>	<b>8,108</b>	<b>81</b>
Depreciation	487	4.9	6,491	65
<b>EBIT</b>	<b>865</b>	<b>8.7</b>	<b>11,534</b>	<b>115</b>
Tax*	346	3.5	4,614	46

\*Calculated as 40% of EBIT

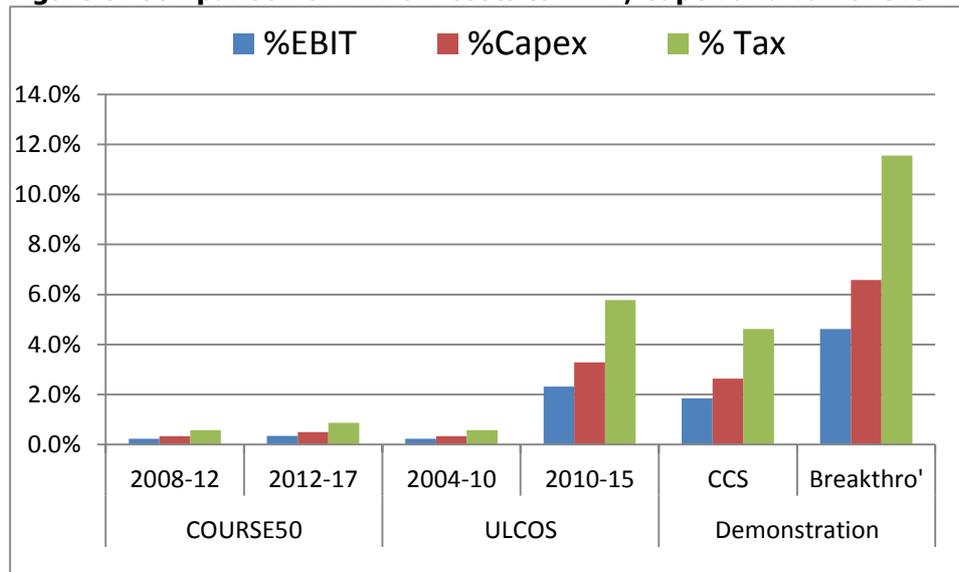
**Table 3: Comparison of RDD&D costs to EBIT, Capex and Tax of the 'Big 4'**

Programmes		¥bn/year	\$mn/year	%EBIT	%Capex	% Tax	\$/tCO <sub>2</sub> *	\$/t steel*
COURSE50	2008-12	2	20	<b>0.2%</b>	<b>0.3%</b>	0.6%	0.1	0.3
	2012-17	3	30	<b>0.3%</b>	<b>0.5%</b>	0.9%	0.2	0.4
ULCOS	2004-10	2	20	<b>0.2%</b>	<b>0.3%</b>	0.6%	0.1	0.3
	2010-15	20	200	<b>2.3%</b>	<b>3.3%</b>	5.8%	1.3	2.7
<b>Demonstration Plants</b>		¥bn/year	\$mn/year	%EBIT	%Capex	% Tax	\$/tCO <sub>2</sub> *	\$/t steel*
CCS Florange Capex**	2 years	16	160	<b>1.8%</b>	<b>2.6%</b>	4.6%	1.1	2.1
ULCOWIN, ULCOYSIS***	5 years	40	400	<b>4.6%</b>	<b>6.6%</b>	11.6%	2.7	5.3

\*Assuming 75 Mt steel/year output, 150 MtCO<sub>2</sub>/year emitted

\*\*Capex €260 million for ArcelorMittal plant at Florange

\*\*\*Estimated capex €1500 million, for breakthrough technology

**Figure 6: Comparison of RDD&D costs to EBIT, Capex and Tax of the 'Big 4'**


### 3.4 Detailed descriptions of the two SAAM Variants

This report focuses on the actions that Japan could take unilaterally, although it is noted that including offsets in the SAAM is an option that could be useful, particularly in the short- to medium-term and if it helped to demonstrate technology or assisted in the development of technology which could subsequently be used in Japan.

The UNFCCC's preparations for Copenhagen (COP-15, December 2009) included considerations of: what would make CSA (co-operative sectoral approaches) in the interest of developed countries, developing countries and all countries; and the design issues that a CSA would need to include in order to develop them to levels which decision-makers can consider seriously. Box 3 shows this list<sup>22</sup>, to which IISD (the author of this report) has added 'purpose' and 'governance'. The list contains much of use, but has many items which

<sup>22</sup> FCCC/AWGLCA/2009/INF.2.Add.2. This lists items 1-11; "Purpose" (0) and "Governance" (12) have been added by IISD.

apply only to a SAAM (or CSA) which generated carbon credits for trading. SAAMs which generate credits are only a small subset of the possibilities.<sup>23</sup>

**BOX 3: UNFCCC list of design issues needed for Co-operative Sectoral Approaches**

0. Purpose
1. Criteria for eligible countries and sectors
2. Determination of sector boundaries
3. Treatment of potential leakage between sectors
4. Methodology and process for determining reference level (including preparation, submission, review, approval)
5. Monitoring, reporting and verification requirements for emissions
6. Issuance, allocation, management and accounting of credits/units
7. Means of engaging stakeholders (public and private)
8. Duration of crediting/trading periods
9. Carry-over of credits/units between periods
10. Eligible credits/units for purposes of achieving trading thresholds/targets
11. Consequences of not achieving a reference level, including facilitative measures
12. Governance

Informed by the UNFCCC’s list, a smaller list of six key design issues was developed for the two variants considered in this report. The potential design of the two variants is now presented against these. Where appropriate, opinion has been given on what the best option amongst a series of choices options would be; in other cases, such choices and decisions will need to be made by stakeholders in Japan.

Target setting over the long term is a challenge for both variants. Box 4 notes that it may be possible – and advisable – for governments to ‘give direction’, progressively building up and specifying targets through a process rather than attempting to set down detailed targets immediately.

**BOX 4: Giving direction – a process to set targets progressively**

Detailing a precise long-term target at the beginning of a process immediately presents technical and political challenges. It is also clear that targets will need to be open to review and adaptation as new information comes to light.

One possible approach is for a government to ‘give direction’ on how a target will develop. In terms of process, governments could annually add further information to a set of principles and more detailed quantification. In the early stages, such statements may simply cover general principles, for example: “this government will require significant reductions in GHG emissions intensity from all steel-producing plant within a period of not more than 20 years”; or “this government is minded to require CCS to be fitted on all new plant from 2030 unless such plants can demonstrate emissions intensity reductions of at least 40% compared to best available technology available today”.

The idea of ‘giving direction’ is to provide investors with more certainty as to which investments are likely to become less profitable going forward and which may become more so. Statements must always build on previous ones, and amendments and changes of direction should be strongly avoided.

<sup>23</sup> See *Exploding the Myths of Sectoral Approaches (and renaming them Sectoral Approaches, Agreements and Measures)*, developed as part of this study and available at: <http://www.climatestrategies.org/research/our-reports/category/54/305.html>.

<b>Variant 1: Implement a fully-resourced plan of RDD&amp;D (5 March, 2011)</b>	
<b>a. the mechanism to be employed</b>	
Discussion	Fundamental research tends to be financed by government, with industry then developing promising options towards commercialisation. In Japan, it is the steel sector companies who have tended to perform this second role and who have retained the IPR (Intellectual Property Rights). The COURSE50 programme involves funding from NEDO, a public body which receives its funding from a share of the proceeds of the carbon and energy tax. It is natural to think of national level collaboration but this is not necessarily the best option. If company-level research and development is the normal model, then there will almost certainly be some disadvantages in moving away from this. Conversely, demonstration programmes can be expensive and sharing costs and learning nationally and even internationally is indicated. The debate as to whether demonstration projects should be financed by government, industry or as a combination continues.
Proposal	The first step is to set out a plan showing how both breakthrough technologies and CCS could be most quickly developed and implemented, independent of financial, IPR or any other constraints. The starting point should be existing initiatives in Japan, notably COURSE50. Industry, government and the research community should all be involved in the planning exercise. It is recommended that research is conducted at a national level unless it can be shown that there are advantages in moving to a company level, or to an international one. Demonstration programmes should look for international partners as a way to share experiences and costs.
<b>b. how finance would be raised</b>	
Discussion	At the government level, the possibility of increasing the scale of finance above current levels comes from the 'environment tax' planned for the economy in 2011. Both the scale of this tax, and what it could be used for, remain uncertain and will be debated through 2011. The alternative, separately or in combination, is to make the steel sector liable for raising the necessary finance, whether this is spent internally within the companies or if it goes into a wider fund or scheme.
Proposal	The working assumption is that finance should be higher than the current financing for COURSE50. Notably, finance for CCS demonstration programmes should be included, and finance for the steel sector's contribution to a feasibility study and the development of carbon sequestration in Japan. Who should contribute the finance is a matter for Japanese politics, but a contribution from the iron and steel sector in addition to the new 'environment tax' deserves serious consideration. The ideal for finance would be an extended carbon tax, but a tax on production of steel from the blast furnace route would be a suitable proxy.
<b>c. what the targets should be</b>	
Discussion	The proposed SAAM requires technologies to be developed and implemented as fast as possible. This requires sufficient – perhaps defined as 'the maximum cost-effective' - resources and effort to be put in. Ascertaining what the optimum level is, and then measuring it, presents technical difficulties. It is also clear that the indicator would be an input, rather than a result. A financial indicator may be the easiest – for example a fixed charge per tonne of carbon emitted from the primary production route - although quality of how funds were spent is a key consideration.
Proposal	Financial targets, annually over the next first 5 years and then 5-yearly thereafter, are recommended. These should then be apportioned down to the company level. A review mechanism for technology development and implementation is also required. Using the 'giving directions' method of progressively developing targets (see Box 3) is indicated.
<b>d. whether offsets should be included</b>	
Discussion	Including offsets in the SAAM is an option that could be useful, particularly in the short- to medium-term and if it helped to demonstrate technology or assisted in the development of technology which could subsequently be used in Japan.

Proposal	Perform a feasibility study on the pros and cons of including offsets within the SAAM. Review on a periodic basis, whether or not offsets are included. The recommendation at this stage is that they should not be included.
<b><i>e. who would be responsible for meeting the targets</i></b>	
Discussion	Responsibility could be either at the sectoral or company level, depending on the design of the scheme.
Proposal	Recommendation is that liability is devolved to the companies.
<b><i>f. the possibilities of making the SAAM international</i></b>	
Discussion	There are clear attractions to combining RDD&D efforts, at all stages of the cycle. Demonstration plants are often expensive and the latter stages of development and implementation may be most attractive for international collaboration on the basis of cost.
Proposal	Research programmes should actively look to share experiences and even combine with other countries. Demonstration programmes should look for international partners as a way to share experiences and costs.

<b>Variant 2: Regulate CO<sub>2</sub> limits (5 March, 2011)</b>	
<b>a. the mechanism to be employed</b>	
Discussion	Limits could be set at the sectoral or plant level.
Proposal	Regulations would be set governing maximum permissible levels of GHG emissions from individual plants. A phased approach is indicated, with regulations first applied to new plant and then, at a later date, to existing plant. No requirements would be set as to how plants should meet these limits. One design option which could improve the acceptability of the option would be for buy-out price to be included, i.e. for plants which had not met the permissible level to be allowed to continue to operate by paying a penalty. The level at which this penalty should ideally be set would allow the money raised to finance equivalent reductions in other sectors of the Japanese economy. Given how expensive emission reduction options are understood to be in Japan, and the very large reductions needed in the economy by 2050, such a buy-out price would likely to be prohibitively high. An alternative approach would be to set absolute caps on emissions from the sector. This is essentially what an ETS does, and is not considered further.
<b>b. how finance would be raised</b>	
Discussion	This would be up to the companies involved. Step-change effects are important: if new regulations are put in place from a certain date, a company may decide to make no investments or changes and simply take its plant out of commission from the date; alternatively, it may choose to build up savings to allow it to stay operational after the new regulations come in place.
Proposal	Conduct studies and discuss with the industry what the likely 'step-change' impacts would be, and plan against these.
<b>c. what the targets should be</b>	
Discussion	Targets could be set on all steelmakers or only a subset of them. The precise values to be set, and when they would come in, are difficult to be precise about at an early stage in the SAAM.
Proposal	Targets would only be set on steelmaking using the primary route (currently blast furnaces in Japan). There does not appear to be any need to include steel production from scrap in electric arc furnaces (EAF), at least if the current Japanese electricity mix continues and the marginal new plant is not fossil-fuel fired. Difficulties arise because scrap steel can be used to some extent in primary route plants, and EAF can be housed on a site which also has a blast furnace. Targets should reflect what share of reductions are required from the steel sector. An indicative first level for the target for blast furnaces could be 50% of current emission levels, i.e. around 0.8 tCO <sub>2</sub> /t steel, with new plant needing to comply by 2025 and existing plant by 2030. A second, more stringent, target could be set at a later date. Using the 'giving directions' method of progressively developing targets (see Box 4) is strongly indicated.
<b>d. whether offsets should be included</b>	
Discussion	Including offsets in the SAAM is an option that could be useful, particularly in the short- to medium-term and if it helped to demonstrate technology or assisted in the development of technology which could subsequently be used in Japan.
Proposal	Perform a feasibility study on the pros and cons of including offsets within the SAAM. Review on a periodic basis, whether or not offsets are included. The recommendation at this stage is that they should not be included.
<b>e. who would be responsible for meeting the targets</b>	
Discussion	Responsibility could be at sector, company or plant level.
Proposal	Responsibility should be at the plant level.
<b>f. the possibilities of making the SAAM international</b>	
Discussion	The proposed approach is a unilateral one, and does not assume any coordinated, equivalent

	<p>or other actions from other countries. If Japan takes on and enforces stringent targets unilaterally, the Japanese steel sector could be exposed to significant competitiveness and leakage impacts. As an example, CCS in Japan may cost of the order of \$100/tCO<sub>2</sub> captured, or of the order of \$200/t steel produced from the primary route. This is of the order of 20% of the value of steel, roughly equivalent to the combined average profit (EBIT) and capital expenditure of the steel sector over the past decade. Clearly the Japanese steel sector would be likely to lose out in export markets and also in the domestic market at this level. For Japan to be willing to make such a unilateral commitment, it would be very likely to need to implement a protective measure such as a border tax applied to both imports and exports. A better alternative would be international agreement but, based on experience to date, this is likely to be very difficult to agree in practice.</p>
<p>Proposal</p>	<p>Japan should proactively seek partners who would join in with the approach. Japan should also develop proposals for protecting its industry, notably for when its targets are imposing significant costs on its industry. It should also develop rules for when, and under what circumstances, such protective measures can be implemented.</p>

### 3.5 Compatibility with other climate change mitigation strategies

Nationally, Japan's ongoing debate about whether or not to introduce an ETS, and how it should be designed, could have major implications for emissions reductions in the iron and steel sector. Internationally, there are a number of processes ongoing of similar significance. If the SAAM proposed in this report is to be viable, it must not be in conflict with such efforts and would ideally be designed to complement their expected strategies. This section briefly reviews such considerations.

- **ETS:** how could SAAMs as described and ETS co-exist, or are they competitive? The question has become somewhat moot, at the Japanese level because of the lack of prospects for a Federal level ETS in at least the short term, and at the international level with the very slow progress being made on scaling up international trading of credits.

At a more theoretical level, the key consideration is that of overlap. If a SAAM led to carbon pricing and trading, then it would have significant overlap with an ETS. If it does not – and the first variant proposed in this study would not – then the two mechanisms can co-exist on a technical level. The key considerations are the total level of costs that the sector would be subjected to via the 'stacking' of mechanisms<sup>24</sup>, and whether having choices specified or constrained by a SAAM should obviate at least partially the need to pay a carbon price.

- **UNFCCC:** The variants proposed are national approaches, which could be internationalised if interest is shown. There are clear advantages to such an internationalisation, notably because the fear of making industry uncompetitive constrains unilateral actions world-wide. The UNFCCC could be a forum for such a discussion but there are alternatives. The study Synthesis Paper<sup>25</sup> concludes: *There are good reasons for holding more detailed discussions at the sector-specific level, and discussing all the issues that concern sectors – for example trade, subsidies and environmental regulation – concurrently with climate change. A specialised forum of this sort could be set up within the UNFCCC, and indeed an earlier Policy Brief from this Climate Strategies project<sup>26</sup> recommends investigating the setting up of a steel-specific forum within the UNFCCC and providing it with technical expertise. But other forums may be at least as useful and may be able to make progress more quickly.* Of these other forums, the OECD Steel Committee and WTO are both worthy of careful consideration.
- **World Steel Association (WSA):** the WSA, formerly the International Iron and Steel Institute (IISI), is an international industry association that represents 180 steel producers, including 19 of the world's 20 largest companies. Its purpose is "[to provide] global leadership on all major strategic issues affecting the industry" and "[to promote] steel and the steel industry to consumers, the industry, media and the general public". (WSA, n.d.) Its activities include monitoring the global steel industry, lobbying, conducting research and sharing information between members.

Annex C details the work of the WSA of relevance to this report. In summary, the WSA has an ongoing policy on sustainable development that was first established in 2002. Its key commitment is to optimise the resource and energy efficiency of steel-making and steel products. Industry performance is reported according to a number of indicators, measuring social, environmental and economic sustainability. Although reporting to date has been less than ideal (see Annex C. for more details), the WSA claims that with the setup of a CO<sub>2</sub> emissions data collection program in 2008 "from now on, consistency is assured" (WSA, 2010b). In addition to this, in a 2007 policy statement the WSA proposed a sectoral approach for the global steel industry, focused on technology development and intensity-based targets for CO<sub>2</sub> reduction (WSA, 2007a). In a position paper published later in the same year, the WSA claimed that it had the support of China's steel industry for a sectoral approach that would begin with collection and reporting of CO<sub>2</sub> emission data, and follow with the creation of benchmarks and national or regional commitments for improvements (WSA, 2007b). The second paper also stressed the importance of

<sup>24</sup> Various studies, for example a joint study commissioned by the the Energy Intensive Users' Group and the Trades Union Congress in the UK (Waters Wye Associates, 2010), have noted that energy-intensive industry are subject to the 'stacking' of many policies and measures driven by different strands of climate change policy-making.

<sup>25</sup> See *Exploding the Myths of Sectoral Approaches (and renaming them Sectoral Approaches, Agreements and Measures*, developed as part of this study and available at: <http://www.climatestrategies.org/research/our-reports/category/54/305.html>.

<sup>26</sup> International sectoral approaches and agreements: case studies of the steel sector in China, India and Japan – Emerging Policy Recommendations. <http://www.climatestrategies.org/research/our-reports/category/54/264.html>

technology development and the role that could be played by the WSA's 'CO<sub>2</sub> Reduction Programme'. It is not clear if this programme simply represents coordination between various regional and national initiatives, such as ULCOS and COURSE50, or if it amounts to an additional, dedicated R&D effort on behalf of all steel companies. Like the Nippon Keidanren, the WSA positions itself explicitly against the inclusion of steel companies in any country or regional ETS and stresses the importance of new steel products that can reduce CO<sub>2</sub> mitigations in the use of their end-products.

Although the proposed sectoral agreement in this report may overlap with one aspect of the WSA's activities – namely, the WSA's CO<sub>2</sub> Breakthrough Program – this would appear to be more of a complement than a conflict. An increase in the ambition of Japanese industry plans and government involvement could, on the one hand, positively influence other members of the association; and on the other, the WSA could offer a useful forum to ensure that any additional efforts on the part of Japan do not needlessly replicate research being conducted elsewhere.

- **The Asia-Pacific Partnership on Clean Development and Climate (APP)/ Global Superior Energy Performance Partnership (GSEP):** the APP is a group that was formed in 2005 at the Twelfth Meeting of the ASEAN Regional Forum in Vientiane, Laos, five months after the Kyoto Protocol entered into force. Essentially a sectoral approach to the mitigation of climate change, its six members, Australia, China, India, Japan, the Republic of Korea and the United States (with Canada joining as a seventh in 2007) agreed to set up task forces to coordinate non-binding national activities in eight key sectors, one of which was steel.

The APP Steel Task Force is currently being wound down with a replacement Steel Working Group set up under the GSEP, and to be hosted at the IEA in Paris. This working group will build upon the work of the APP Steel Task Force (Clean Energy Ministerial, 2010).

The APP Steel Task Force's eventual Action Plan, agreed in 2006, outlined a range of activities but the most important ones – agreeing quantitative indicators that can be used to benchmark and measure changes in steel sector energy use and impacts on the environment, and the development of "milestones" to guide improvements in energy- and environment-related performance – have still not had any results (APP, 2008; Kakudo, 2009c). The only tangible products to have emerged from the process are a technical manual on state-of-the-art technology, by the United States, and several 'diagnostic' visits by Japanese experts to Chinese and Indian steel plants to identify potential areas for energy- and environment-related improvements (APP, 2009; Tateishi, 2009). It is difficult to determine the likelihood of any meaningful leadership from the APP in the future as it is not fully transparent about its activities and there is a sense in its publically-available records – summaries of annual meetings – that momentum has been lost (see Annex D for more details).

Given the activities listed in its current Action Plan, especially taking into account the uncertainty over their actual status, there is no reason to suppose that the sectoral agreement proposed in this report would be in contradiction with Japan's role in the APP/GSEP, or indeed that the APP/GSEP is a very active player in this area. Rather, the APP/GSEP might be a useful forum for Japan to benefit from a successful sectoral approach on R&D in the steel sector – either operating as a forum for agreements over technology transfer or serving as a model for other APP/GSEP Task Forces.

## 4. Moving towards implementation

Initial consultations have indicated that there is very little support for the second Variant – *Regulating CO<sub>2</sub> limits*. Moving the first Variant - *Implement a fully-resourced plan of RDD&D* – forward requires selling the approach to various stakeholders and promoting it within Japan and internationally.

On the technical level, the first unresolved issue is whether CCS is really an option for the steel sector. From the literature (see Annex E for full details), we can conclude that there is storage potential (mostly undersea), that the steel sector is not currently significantly involved or investing beyond the capture phase and that there is no clear, integrated plan on taking CCS forward for Japan as a whole. This review does not appear to give sufficient confidence to enable CCS to be included definitely within a SAAM.

Again technically, there remains uncertainty as to whether scaling up RDD&D beyond current levels (e.g. COURSE50) would really yield strong results. Certain members of the steel industry have voiced their concerns, and this is an issue where more detail as to precisely what might form part of an extended RDD&D effort would be helpful.

The scale of resources required for the initial RDD&D phase appears to be affordable with respect to the resources available to the sector.<sup>27</sup> A number of challenges arise:

1. the **hypothecation of government revenues to specific programmes and actions represents a challenge** in all countries, including Japan. The possibility of setting up hypothecation depends on the general political outlook – for example, it is understood that the DPJ wishes to reduce the amount of revenue that is hypothecated in favour of it being directed into general coffers;
2. while it may be within the resources of the sector to finance the early stages of RDD&D, **implementation is likely to involve a step change in expenditure**. The examples in the text above show that a levy of around \$1/tonne steel would fund early CCS RDD&D. If it were implemented, CCS would be likely to cost around \$25-100/t steel in Japan (\$50-200/tCO<sub>2</sub> captured) – there is a major step change to overcome. There is thus a danger in this hypothetical example that companies may not make the necessary savings to allow them to continue to operate if and when CCS were introduced, and a mechanism to help smooth progress over the step may be necessary ;
3. **how much the sector is willing to put in depends on how much it is already putting in, and whether it feels that this is fair**, including in comparison to its competitors. For a region such as the EU where there is already an ETS with a significant carbon price, the sector will find it easier to argue that extra regulations and their costs would be an unfair burden. There may be more chance to argue that raising additional revenues from the sector would be possible in a country like Japan without an ETS, and this case will be much easier to make if some or all of the additional revenues were hypothecated for the benefit of the sector itself. This consideration is a key one within the design of the SAAM for Japanese steel within this study.

Again from the initial consultations, we can identify the factors that appear to resonate to sell the SAAM within Japan:

- Technology leadership (and sales overseas);
- Contribution to the green economy;
- Reduces exposure to fossil fuel price rises;
- Improvement of security of supply.

Many of the issues raised in the report are generic in their type (e.g. the issue of hypothecation is common to many countries) or in their solution (e.g. many countries wish to demonstrate CCS). International fora – notably the OECD's Steel Committee – offer the option to both promote any Japanese scheme and to investigate whether it could be internationalised. Climate Strategies *Policy Recommendations* paper published under this project in

<sup>27</sup> By means of illustration, depending on what is specified within the programme, resources of the order of 1% of EBIT or \$1/tonne steel produced (\$2/tCO<sub>2</sub>) may be sufficient in the early stages.

August 2010<sup>28</sup> identifies that there is a need for detailed international discussions on steel, and concludes that these could be met within a specific negotiating forum at the UNFCCC. There are many advantages to using the UNFCCC, but if this is not possible then the OECD Steel Committee WTO, World Steel Association or some other forum could also be used. Whatever the forum, it will need a group of 'champion' countries to push forward the need for discussion, identify a forum and secure a negotiating mandate.

There is clear scope for investigating the internationalisation of the SAAM, again once there is a more detailed domestic proposal with more support. There is also the potential to extend the SAAM to other sectors of the economy, particularly if they would benefit strongly from the development of CCS.

The recommendations made in this report are necessarily of a preliminary nature. Further detailing the SAAM – based on the summary tables included in Section 3.4 – is a necessary next step, and should be conducted in consultation with a wide range of stakeholders. Variant 1 of the SAAM - *Implement a fully-resourced plan of RDD&D* – resonated strongly with many stakeholders in Japan during the Climate Strategies project, and is worthy of further development and discussion. The reduction of GHG emissions from key sectors in key countries is essential if ambitious reductions in climate change impacts are to be achieved.

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<sup>28</sup> International sectoral approaches and agreements: case studies of the steel sector in China, India and Japan – Emerging Policy Recommendations. <http://www.climatestrategies.org/our-reports/category/54/264.html>

## Annex A: Views of the Nippon Keidanren

### The Nippon Keidanren

The Keidanren (the Japan Federation of Economic Organisations) was originally established after the Second World War and became the most significant association of businesses in Japan, playing a significant role in the development of the Japanese economy and being consulted as a matter of course during informal and formal negotiation rounds over environmental policies under consideration by the government. In May 2002, it merged with the Nikkeiren (the Japan Federation of Employers' Associations) to form the Nippon Keidanren (literally, the Japan Business Federation). As of May 2009, the Nippon Keidanren was made up of 1,295 companies, 129 industrial associations, and 47 regional economic organizations, largely representing the industrial, energy, construction, commercial and transport sectors. (Keidanren, 2009; Wakabayashi, 2007) The Japan Iron and Steel Federation (JISF) is widely accepted to be one of the Keidanren's most important and powerful members.

### The Voluntary Action Plan

The Keidanren Voluntary Action Plan on the Environment was released on 17 June 1997, precipitating the conclusion of Kyoto Protocol negotiations by roughly six months. (Keidanren, 1997) It set out a range of objectives for 36 national industries to achieve by 2010. Although it was at least in part motivated by fear of government regulation, it was ultimately approved by the government and became the basis for industrial climate policy in Japan. (van Asselt, Kanie, & Iguchi, 2009).

The plan, the Nippon Keidanren's existing sectoral approach, consists of an 'outline' which summarizes the types of objectives industries have committed to achieve and measures they intend to take with respect to global warming and waste disposal, followed by 38 industry-specific sub-sections, explaining the specific targets and measures agreed by different associations of companies, from the limestone mining industry to the electric power generation and real estate sectors. At the time of launching the plan, the Keidanren announced that its 'common goal' regarding climate change was "to endeavour to reduce CO<sub>2</sub> emissions from the industrial and energy-conversion sectors to below the levels of 1990 by 2010" (Keidanren, 1999).<sup>29</sup> Industries adopted a range of different targets, with some seeking to reduce energy-use or CO<sub>2</sub> emissions per unit of output, some setting absolute targets and others focusing on reducing energy consumption in the final use of their services or products. Importantly, the targets were not binding on individual firms but on sectors as a whole, (Wakabayashi, 2007) essentially making the Voluntary Action Plan a bottom-up, industry-led, voluntary sectoral approach and agreement.

The steel sector, represented by the Japan Iron and Steel Federation (JISF), committed to take the following steps:

- reduce absolute levels of energy consumption in 2010 by "about 10%" as compared to 1990<sup>30</sup>
- make use of plastic waste and unused energy
- supply high-grade steel which will make it possible to save energy in final products
- "contribute to energy conservation through international technological cooperation"

Although the entire initiative is voluntary in nature, it has been argued that this carries more weight in Japan than many other cultures. Sawa (2008) stresses that 'voluntary' is derived from the Japanese word 'Jishu', which is more accurately conveyed by the idea 'self-binding', to the extent that "it is not at the liberty of the actors to comply or not to comply as the translation implies." (Sawa, 2008) Moreover, Wakabayashi (2007) identifies a number of additional incentives for companies to follow through on their commitments:

<sup>29</sup> Note that this CO<sub>2</sub> commitment applies only to the industrial and energy-conversion sectors, which "implies a relatively weak contribution from other sectors, namely the commercial and transportation sectors. Among the 58 participants [as of fiscal year 2005] 35 are from industrial and energy-converting sectors and all of them submit their own follow-up reports to the Keidanren's annual follow-up survey." (Wakabayashi, 2007)

<sup>30</sup> According to Wakabayashi (2007), the JISF adopted this target because "emissions coefficients for the iron and steel industries are not clearly defined or available, whereas energy consumption data is available from existing statistics."

- after the Kyoto Protocol was negotiated, Japan adopted a 'step-by-step' approach that established the potential introduction of regulation if domestic efforts did not achieve their targets, including an environmental tax or a mandatory cap-and-trade scheme;
- given the importance of their relationship with the Keidanren, member companies often support its policies, even at short-term financial cost;
- and private companies in Japan are very aware of their social responsibilities.

From the outset, the plan contained provisions for an annual review with publically available results, to be released on the internet and through other media. According to the Keidanren, this process would be used to improve the industries' environmental policies, leaving the door open to adaptation of their commitments.

## Performance to-date against the Voluntary Action Plan

The Nippon Keidanren followed through on its commitment to publish an annual follow-up report on the Voluntary Action Plan for the Environment at least until 2007. The reports, which became increasingly more robust as the initiative matured, detailed the overall performance of industry and energy-conversion sectors, as well as the progress of different participating sectors towards their individual targets. A number of important developments took place during the life of the plan, summarized below:

- 4 June 2002 – Japan ratified the Kyoto Protocol. (UNFCCC, 2009)
- 23 July 2002 – In the fifth follow-up report on the Voluntary Action Plan, the Nippon Keidanren established an Evaluation Committee for the Voluntary Action Plan on the Environment, with a mission to ensure that industry submissions and secretariat analysis for the annual review would be transparent and credible. The Committee was also instructed to recommend improvements where necessary. According to Wakabayashi (2007), it is made up of academic experts, although Nippon Keidanren's records show that the original membership included a representative from Kobe Steel Ltd. and the Green Purchasing Network. (Keidanren, 2002)
- 26 Mar 2003 – The Evaluation Committee released its first Keidanren Voluntary Action Plan Evaluation Report for fiscal year 2002. It concluded that, although "participating industries are doing their best in the context of their particular circumstances, and that the aggregation methods used by the Nippon Keidanren Secretariat are appropriate", improvements were needed in a number of areas. (Evaluation Committee for the Voluntary Action Plan on the Environment, 2003)
- 18 Nov 2004 – Russia ratified the Kyoto Protocol, satisfying the clause that required ratification by at least 55 of the parties representing at least 55% of the world's CO<sub>2</sub> emissions in order for it to come into force. (UNFCCC, 2009)
- 26 Nov 2004 – In the seventh follow-up report, the Nippon Keidanren stated its intention to follow the recommendations made in a July 2004 proposal called "Towards the Steady Implementation of Global Warming Measures", as part of its efforts to reduce emissions from the "transportation, offices and household sectors". This includes the development and diffusion of energy-saving products; the provision of information and services on energy-saving to the public; and the promotion of measures to combat global warming in distribution, forestry maintenance activities, and homes and offices. (Keidanren, 2004)
- 16 Feb 2005 – The Kyoto Protocol entered into force. (UNFCCC, 2009)
- 25 Apr 2005 – The Evaluation Committee released its evaluation of the seventh follow-up report. It recommended that:
  - comparisons with counterparts in other countries "are indispensable in terms of identifying levels of energy efficiency within a given industry as well as accurately assessing industrial efforts to boost energy efficiency";
  - Nippon Kaidanren should create uniform policies for industries who want to revise their stated targets;

- offshore relocation of elements of the manufacturing sector should be included as a factor of analysis in explanations of changes in the level of CO<sub>2</sub> emissions;
- and participating members should estimate the cost of complying with the Voluntary Action Plan, in order to make it possible to compare its cost-effectiveness with other methods of reducing CO<sub>2</sub> emissions.

The evaluation notes that following the enforcement of the Kyoto Protocol, it is "imperative that the existing Voluntary Action Plan be steadily phased in as the foundation of reduction measures for the industrial and energy-converting sectors". (Evaluation Committee for the Voluntary Action Plan on the Environment , 2005)

- 18 Nov 2005 – In the eighth follow-up report, the Nippon Keidanren embraced the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI) mechanism as "important supplementary means" to achieve the Voluntary Action Plan's objectives, and noted that a number of industrial associations and corporations had invested in GHG-reduction projects or made financial contributions to domestic and international climate funds. The report also mentioned that the Nippon Keidanren had encouraged its members to publish environmental reports to further disclose information on their environmental activities. In its conclusions, it highlighted the fact that in February 2004 the Cabinet approved a "Kyoto Protocol Target Achievement Plan", in which it was stated that the Keidanren Voluntary Action Plan "will play a central role in the industrial and energy-converting sectors' efforts towards the achievements of targets". It also reported that South Korea's industry had decided to introduce its own initiative, modelled on the Voluntary Action Plan. (Keidanren, 2005)
- 19 Apr 2005 – The Evaluation Committee released its evaluation of the eighth follow-up report. (Evaluation Committee for the Voluntary Action Plan on the Environment , 2006) It announced progress on most of the indicators listed in previous evaluations, and noted that Nippon Keidanren should conduct a general study of policies and programs to combat global warming after 2010, in order to determine how the Voluntary Action Plan could be continued in the future.
- 14 Nov 2007 – The ninth follow-up report notes that the Nippon Keidanren called for businesses to consider actively raising their current targets if it was probable that they would achieve them by 2010, resulting in 17 industry groups increasing their target levels. In order to better contribute towards Japan's commitments under the Kyoto Protocol, the Keidanren also announced a change in their final target period: instead of achieving goals by 2010, participating industries were required to achieve them as a five-year average during the first commitment period of Kyoto, 2008-2012. (Keidanren, 2007)

The ninth follow-up report on the Voluntary Action Plan is the last update of progress available in English on the Nippon Keidanren's website, despite the fact that reports should have been published over the course of the next three years. Given that the plan was formally announced in a report dated 17 June 1997, it can be assumed it was originally intended to conclude on 17 June 2010, although this has presumably now been extended to 2012, in recognition that the 2010 goals have been extended to a five-year average during 2008-2012. There has been no formal announcement in English by the Nippon Keidanren on the end-date of the plan.

The following tables, adapted from the ninth follow-up report, are therefore the most up-to-date available assessments of the Keidanren's initiative in English. Figures suggest that it was likely to achieve its 'common goal' of 2010 emissions lower than their 1990 equivalent for industry and energy-conversion industries: in fiscal year 2006, CO<sub>2</sub> emissions were 1.5% lower than in 1990 (Table A1), which the report attributes in large parts to industry efforts to save energy and implement "other CO<sub>2</sub> reduction measures". However, despite the relatively high level of efficiency compared to an international benchmark, it is less clear that the steel sector would be able to achieve its goal of a 10% reduction in energy consumption from 1990 levels by 2010: in fiscal year 2006, energy consumption was only 5.2% lower than 1990 levels.

Table A1	Total CO <sub>2</sub> emissions and energy consumption in Nippon Keidanren's industrial and energy-conversion sectors												
	Fiscal Year											2006 vs. 1990	2006 vs. 2005
	1990	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006		
CO <sub>2</sub> emissions <sup>a</sup>	51,203	52,993	50,166	51,247	50,623	49,062	49,976	50,399	50,497	50,567	50,458	-1.5%	-0.2%
Energy consumption <sup>b</sup>	16,710	17,789	16,989	17,182	16,880	16,298	16,577	16,688	16,827	16,836	16,876	+1.0%	+0.2%

<sup>a</sup> CO<sub>2</sub> measured in units of 10,000 tonnes.  
<sup>b</sup> energy measured in units of 10,000 kl of crude oil equivalent.  
 Source: adapted from (Keidanren, 2007)

Table A2	International Comparison of Energy Efficiency: Integrated steelworks energy consumption intensity (Japan Iron and Steel Federation)					
Japan	South Korea	EU	China (large scale)	China (whole country)	U.S.A.	Russia
100	105	110	110	120	120	125

Source: Data from Korea Iron & Steel Association, China Iron and Steel Industries Association, and individual interviews, in (Keidanren, 2007)

Table A3	Trends in the CO <sub>2</sub> emissions and energy consumption in the Japan Iron and Steel Federation												
	Fiscal Year											2006 vs. 1990	2006 vs. 2005
	1990	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006		
CO <sub>2</sub> emissions <sup>a</sup>	20,371	20,212	19,033	19,607	18,796	18,305	18,805	19,016	19,208	19,046	19,326	5.1%	+1.5
CO <sub>2</sub> emissions intensity	1	0.97	0.96	0.96	0.95	0.95	0.94	0.93	0.93	0.93	0.92	-	
Energy consumption <sup>b,c</sup>	6,520	6,491	6,102	6,251	6,005	5,819	5,957	6,004	6,081	6,043	6,178	5.2%	+2.2
Energy consumption intensity	1	0.97	0.96	0.96	0.95	0.95	0.94	0.93	0.93	0.93	0.92	-	
Production activity index	1	0.92	0.81	0.88	0.96	0.91	0.98	0.99	1.01	1.01	1.05		

<sup>a</sup> CO<sub>2</sub> measured in units of 10,000 tonnes.  
<sup>b</sup> energy measured in units of 10,000 kl of crude oil equivalent.  
<sup>c</sup> NB. the Japan Iron and Steel Federation committed to a target of -10% energy consumption compared to 1990 levels by 2010.  
 Source: (Keidanren, 2007)

From available information, it appears that the Nippon Keidanren's sectoral approach and agreement is likely to have been relatively successful. In its favour, Wakabayashi (2007) notes that no measures implemented by the governmental plans to achieve Japan's Kyoto commitments were regularly evaluated in the same depth as the Voluntary Action Plan, and that it resulted in clear goals, "developed and negotiated through in-depth discussions among administrative officials, experts and industries" (Wakabayashi, 2007), giving

credence to arguments that sectoral approaches often result in practical, achievable commitments to climate change mitigation.

On the other hand, despite Nippon Keidanren's positive assessment of its own performance, there are a number of concerns that should be noted:

- i. According to Wakabayashi (2007), it is extremely difficult to determine what emissions might have been in a 'business as usual' scenario. This is because the number of companies covered by the Voluntary Action Plan makes it "methodologically impossible" to establish a comparison group.
- ii. Despite being twice recommended by the independent Evaluation Committee to take into account a range of factors in the explanation of CO<sub>2</sub> emission fluctuations, in its reports the Nippon Keidanren only takes into account the influence of changes to production levels and the CO<sub>2</sub> intensity of electricity supplies (with this latter factor being taken into account because of the retirement of a number of nuclear reactors). They did not take into account a range of other factors, such as changes in products or – importantly – the transfer of operations overseas, which might significantly weaken the conclusion that CO<sub>2</sub> reductions were due to the efforts of industry.
- iii. Despite recommendations from the independent Evaluation Committee, the final follow-up report did not publish an analysis of the cost-effectiveness of the Voluntary Action Plan.
- iv. Japan's Kyoto Protocol target was to reduce its emissions by 6% compared to 1990 levels by 2012, considerably more ambitious than Nippon Keidanren's goal to simply achieve emissions 'lower' than 1990 levels by 2010. Although this disconnect was in part due to the Kyoto Protocol's slow start, it undermines the credibility of claims that the Voluntary Action Plan could be relied on to make meaningful contributions to national targets.

## Future plans

There are four major policy statements that have been made in the last two years which shed light on the Nippon Keidanren's attitude towards international climate change negotiations and set forth its future plans.

### **1. Proposal for a Post-2010 International Framework: The Japanese Business Community's Positions on the COP 14 Agenda**

The "Proposal for a Post-2012 International Framework" statement was released on 18 November 2008, in anticipation of the UNFCCC COP 14. It set out the Nippon Keidanren's attitudes towards future international climate change agreements. (Nippon Keidanren, 2008)

It states that the following elements would be "essential" for a future framework:

- participation of all major emitters, including the U.S., China and India
- "equitable medium-term targets" (with no tangible explanation of this term)
- measures to directly accelerate the development of innovative technologies and the diffusion of existing technologies

As regards more specific details, it sets out the following ideas:

- It is necessary to have a long-term vision, such as the G-8 agreement in Hokkaido to support a treaty aiming for 50% reductions in CO<sub>2</sub> emissions by 2050. [This agreement does not appear to have specified a base year.]
- Although high-emitting developing countries should be part of the agreement, it might be most appropriate for them to accept intensity-based targets.
- A country's emissions reduction potential should be determined by assessing the sector-specific reduction potentials and these into a national estimate.
- It is unfair for reduction commitments to be made from a specific base year. The statement recommends using "multiple base years, including the latest year for which data is available".

- The agreement should include a focus on potentials for carbon absorption, particularly in forestry.
- Barriers to technology transfer should be removed.
- Intellectual property rights are important in the development of innovative technologies and they should be protected.
- It may be effective to take a sectoral approach to technical assistance, like that taken by the APP. The private sector should be given due recognition for its role in such endeavours.
- It would be difficult to design a sectoral crediting mechanism that achieved its goals, so the pros and cons of such a system would need to be seriously considered.
- Adaptation should be primarily funded by the public sector, although the private sector might be able to contribute through new technologies.

## 2. Nippon Keidanren's Commitment to a Low Carbon Society

On 15 December 2009, the Nippon Keidanren announced that it was formulating a "Commitment to a Low Carbon Society", explicitly identified as a continuation of the Voluntary Action Plan, and made up of three core policies: (Keidanren, 2009)

1. To provide society with low-carbon technologies while maintaining or improving current levels of efficiency. The Nippon Keidanren see new technology as fundamental to the feasibility of halving carbon emissions by 2050, and propose that industrial sectors, universities and other research centres cooperate to create a technology development strategy to identify key technical challenges and pursue a medium- to long-term roadmap for their development and dissemination.
2. Industry will publically announce and pursue voluntary absolute or intensity-based CO<sub>2</sub> reduction targets to be achieved by 2020. Targets are to be based on an international comparison of energy efficiency and the assumption that the best-available technology will be used to build all new facilities, "demonstrat[ing] to the international community that the targets represent the deepest reduction levels attainable".
3. To "pursue a PDCA cycle [plan-do-check-act] in partnership with the government to ensure that the initiatives by participating industries are steadily and reliably implemented". This is likely to mean a continuation of annual reports, evaluated by an independent body, although perhaps with increased government involvement.

The new Commitment would also continue to actively participate in the APP and aim to demonstrate leadership in international private-led cooperations in industries such as electric power, steel, chemicals and cement.

## 3. Achieving Growth Through Green Innovation: Proposals for Japan's New Growth Strategy and Other Initiatives in the Environmental Sector

This statement, dated 16 March 2010, sets out a broader set of recommendations for the direction of Japan's future economic growth, though it considers green innovation to be at the core of development – it is, essentially, a 'green economy' vision paper. Its principal argument is that technology diffusion, development, commercialisation and transfer is the key to balancing environmental and economic needs, making Japanese industry more internationally competitive and creating employment. (Nippon Keidanren, 2010) Recommended strategies include:

- "...create demand in the environmental and energy sectors". Suggestions for this include tax breaks and subsidies for eco-cars, green buildings or renovations and sustainable public procurement.
- "...educate consumers about environmental issues and encourage them to be more proactive in purchasing low-environmental-impact products and services." Suggestions for this include providing consumers with life-cycle emissions data about products, education about recycling and compulsory schooling and community education programmes.
- "regulatory reform and implementing environmental model projects". Suggestions for this include zoning laws (influencing building patterns) and using subsidies, tax breaks, "financial support measures", PFIs/PPPs to pay for projects like smart grids and electric vehicle infrastructure.
- "develop overseas markets". This includes liberalizing trade in environmental goods and services, independent schemes to supplement the CDM and "strategic public-private collaboration" on

development-related activities like funding the installation of best-available technologies in developing countries or the provision of education and training.

- "proper protection of intellectual property rights" The statement argues for "suitable safeguards for intellectual property rights from both legislative and enforcement perspectives", without out going into further detail. This may be important as regards a sectoral agreement that focuses on technology development.
- "encourage green innovation" This includes providing 1% GDP to R&D; getting industry, academia and government to identify challenges that need to be overcome, so investments can be strategic; strengthening links between industry, academia and government, especially through models like the EU's European Technology Platforms; and providing support commercialisation (valley of death, standardisation etc.).

Importantly, the statement also argues that "the government should not consider partial optimisation within sectors such as industry, commerce and households, or transport, but establish and implement comprehensive policies from a life-cycle perspective that includes the usage phase of products and services". It is not made explicit, but seems to imply that the Nippon Keidanren is turning away from support for sectoral approaches, on the basis that they are 'blind' to important parts of product-life-cycles.

#### **4. Achieving a Low Carbon Society of Global Scale: Proposals for Climate Change Policy**

Most recently – 14 September 2010 – the Nippon Keidanren released a statement called "Achieving a Low Carbon Society of Global Scale: Proposals for Climate Change Policy". This appears to have served two functions: first, to respond to a number of ongoing developments in national climate change policy; and second, as a reminder that industries represented by Nippon Keidanren have their own activities ongoing. (Nippon Keidanren, 2010)

The response to ongoing developments is mostly based around the concern that "the government is discussing a domestic emission trading scheme, a global warming tax and a feed-in tariff scheme for renewable energy as separate issues rather than taking an integrated approach". Their primary objections are:

- Japan already has a high cost-structure and businesses should not have extra costs placed on them at a time when the economy is already suffering. Moreover, placing extra costs on businesses will impede their ability to invest in innovation.
- The target of reducing emissions 25% from 1990 levels by 2020 should be reconsidered. An international framework is needed that includes all major emitters, including the U.S. and China.
- A life-cycle approach is needed to design measures against climate change. By controlling emissions within particular sectors, governments may penalise high-emitting companies who are nonetheless supplying large volumes of products that reduce emissions elsewhere in the product life-cycle.
- In particular, a cap-and-trade system would i) prevent corporations from taking an LCA perspective; ii) impede fair and efficient competition; and iii) slow R&D efforts, as companies can comply by just buying credits.
- Japan should be expanding its tax incentives for R&D.

It notes positively, however, that the CDM is "procedurally complex, time-consuming and costly", so bilateral offset mechanisms – which the Nippon Keidanren recommended in its statement 'Achieving Green Growth Through Green Innovation' – are very welcome. It recommends that the focus of Japan's plans be technology: its diffusion in corporate activities, commercialisation for consumers and transfer to other countries, as well as the development of new and innovative technologies.

The statement reports that following the "Commitment to a Low Carbon Society" last year, a number of industries are formulating action plans and that the Nippon Keidanren is seeking government cooperation in monitoring its commitment using a "plan-do-check-act cycle".

## Annex B: Review of Technology Options

### Breakthrough technologies

#### Summary of existing technologies

New or 'primary' steel is produced by taking iron ore (the rocks and minerals which naturally contain iron) and 'smelting' it in order to create a high-carbon form of iron called 'pig' or 'sponge' iron. This involves stripping oxygen from the iron it is naturally bonded to in the ore, a process known as 'reduction'. A second process, which reduces the amount of carbon in the pig iron, is then required to make it into steel. Steel can also be made by taking existing steel – 'scrap', from products that have reached the end of their life-cycle – and recycling it, although supplies of scrap vary and there is not enough to meet total world steel demand. Today, there are three technologies that account for the majority of steel production:

1. **Blast Furnace and Basic Oxygen Furnace (BF/BOF):** this is a two-step process, in which the Blast Furnace begins by smelting the iron ore into pig iron. This is done by tipping the ore, coke and limestone into a tall cylindrical furnace in which various hot 'reducing gases' are moving upward, removing oxygen content from the iron ore feedstock as it moves downward. Coke – a metallurgical-grade, carbon-rich form of coal – is required because it provides enough carbon to remove the oxygen from the ore, as well as the heat to melt the iron. (APP, 2007)

The second step then takes place. The molten pig iron is taken to the Basic Oxygen Furnace, where it is injected with oxygen. This progressively combines with the carbon in the pig iron, exiting the molten iron as CO<sub>2</sub>. Once the carbon content of the iron has been reduced from about 4% to less than 2%, the iron has become steel. The process is largely used for the creation of virgin steel – although a percentage of scrap can be recycled in the Basic Oxygen Furnace, this is relatively low, at around 10-30% of the volume being processed. When a Blast Furnace and a Basic Oxygen Furnace exist on the same site, a steel plant is referred to as an 'integrated steel mill'. (Wooders, 2009; IEA, 2009; APP, 2007)

The IEA note that the Blast Furnace is the most CO<sub>2</sub> intensive part of the BF/BOF process, emitting 1.5–2.0 tonnes of CO<sub>2</sub> per tonne of iron produced (IEA, 2009). Wooders (2009) reports that the largest and most advanced plant is able to operate at 1.5 tonnes of CO<sub>2</sub> per tonne of steel produced. Assuming similar tonnage of pig iron and primary steel, this is roughly equal to 60-80% of the total CO<sub>2</sub> produced per tonne of steel.

2. **Direct Reduced Iron and an Electric Arc Furnace:** this is a similar two-step process to the one above. First, the Direct Reduced Iron method removes oxygen from the iron ore, typically by passing a 'reducing' gas up through a shaft furnace at the same time that the ore is moved downward. The gas is either carbon monoxide or H<sub>2</sub> or a mixture of these gases, which can be produced from either natural gas (if available at a low price) or coal. This method is more energy-efficient than a Blast Furnace because the reduced iron is not melted. DRI has a more limited choice of feedstocks, however, as the ore needs to have relatively low levels of impurities, and plants tend to operate on a smaller scale than an integrated steel mill.

The resulting iron – known as 'sponge iron' – can then be turned into steel by an Electric Arc Furnace. This production method can use a wide range of feedstocks, the total volume of inputs potentially consisting of sponge iron, up to 30% molten iron and over 90% scrap iron. The furnace melts the feed materials using electricity and, as in the Basic Oxygen Furnace, impurities and the carbon content of the iron is reduced by blowing oxygen into the molten mixture. The EAF can be used to create batches of steel that are virgin, a mix of virgin and recycled material or largely made of recycled material. Like DRI, an EAF can operate on a smaller scale than integrated steel-making, allowing for the existence of 'mini-mills'. (Wooders, 2009; IEA, 2009; APP, 2007)

According to Wooders (2009), the DRI/EAF production process has the potential to emit significantly less CO<sub>2</sub> than the BF/BOF method, although CO<sub>2</sub> emissions are within a significant range depending on whether the reducing gases are created by using natural gas or coal. Using natural gas, emissions are thought to be approximately 1.1 tonnes of CO<sub>2</sub> per tonne of steel produced, whereas

using coal they are substantially higher, at approximately 2.5 tonnes of CO<sub>2</sub> per tonne of steel produced, higher than the CO<sub>2</sub> intensity of a modern BF/BOF. According to the APP's Steel Task Force, this means that DRI plants tend to be near to natural gas supplies and to operate at a higher cost than coal- or coke-based processes. (APP, 2007) In addition to the restriction mentioned above – that DRI requires relatively pure iron ore supplies – this might pose another practical limit to their profusion.

- 3. Electric Arc Furnace:** if there are sufficient quantities of scrap available, the first step of transforming iron ore into pig or sponge iron can be skipped entirely. Scrap can simply be heated and cast in an Electric Arc Furnace, saving the raw materials and energy involved in transforming raw materials. The CO<sub>2</sub> intensity of recycling depends on the electricity generating mix, but is typically around 0.4 tonnes of CO<sub>2</sub> per tonne of steel produced. (IEA, 2009) However, as explained earlier, the ultimate limit on EAF-recycling is the availability of scrap metal. According to modelling conducted under the IEA's BLUE scenario – which assumes CO<sub>2</sub> emissions are cut by 38% from 2006 levels by 2050 – recycling would only be able to represent 54% of world steel production. (IEA, 2009) Steel production from scrap currently makes up of the order of 30% of world production.

BF/BOF is the most CO<sub>2</sub>-intensive steel-making process but difficult to substitute because the only alternatives, DRI and EAF, also have limitations – the first requiring cheap supplies of natural gas in order to be affordably CO<sub>2</sub>-competitive and only able to process relatively pure iron ore; and the second being largely designed for either sponge iron or the re-processing of scrap steel, supplies of which are limited by available gas-based DRI plants and the varying availability of scrap steel.

**Table B1** Summary of the characteristics of main steel production methods

	energy inputs	average CO <sub>2</sub> /t steel	potential raw materials	share of world production (approximate)	other features
BF/BOF	coke	2.0	iron ore (100%) scrap (10-30%)	65%	
DRI/EAF	gas or coal	1.1 – 2.5	iron ore (100%) scrap (20–50%)	5%	requires access to cheap gas supplies in order to be CO <sub>2</sub> -competitive; only works with relatively pure iron ore feedstock
EAF	electricity	0.4	sponge iron (100%?) molten iron (max. 30%) scrap (>90%)	30%	can only process a maximum of 30% iron ore

Sources: (IEA, 2009; Wooders, 2009; OECD, 2008; APP, 2007)

## Prospective breakthrough technologies

In its 2009 report *Energy Technology Transitions for Industry*, the IEA identifies a number of key breakthrough technologies that could significantly reduce CO<sub>2</sub> emissions in the steel sector. It also identifies the associations that are currently working towards their development.

### Key technologies

The key technologies fall into a number of basic categories:

#### 1. *Developing ways to make existing steel-making processes less CO<sub>2</sub> intensive*

The IEA identifies a number of technologies that hold promise in reducing the CO<sub>2</sub> intensity of existing steel-making by changing the inputs, slightly amending the core process or capturing the CO<sub>2</sub> outputs. The technologies identified by the IEA largely focus on improving the environmental performance of the Blast Furnace in the BF/BOF method.

#### a. Biocoal

Charcoal is a form of carbon fuel produced by removing water and other elements from animal and vegetable matter. Currently, it cannot be used in a Blast Furnace because it lacks the 'mechanical stability' of coke. Research is underway to develop a charcoal-making process that would correct for this problem, with the resulting coke-substitute being referred to as 'biocoal'. The IEA report that costs could be favourable with coke but note that significant price volatility might be expected as biomass feedstocks become increasingly linked to fossil energy prices. There are also presumably the same concerns to be raised with biocoal as there are with biofuels more generally – the need for a careful life-cycle analysis to ensure that net CO<sub>2</sub> emissions actually represent a reduction and that there are no undesired side-effects, such as damaging ecosystems through land-use conversion. It is not stated, but presumably charcoal could also be used as an energy input in coal-based DRI.

#### b. Waste plastic

Like biocoal, waste plastic can be used to reduce CO<sub>2</sub> emissions in blast furnaces and coke ovens. It does so by being injected into the process. According to the IEA, Japan already uses this method and has set a target to use 1 million tonnes of waste of 2010. It notes that plastic waste is projected to triple by 2050 but that there will be competition over the resource. It is not clear to what extent plastics can be used to substitute coke in the steel-making process.

#### c. Plasma injection into existing processes

The IEA simply note that plasma injection is possible and a proven technology. It has yet to be "introduced into existing processes", one of which would include blast furnaces, and could reduce CO<sub>2</sub> emissions by 50%.

#### d. Carbon Capture and Storage (CCS)

CCS is the highest-profile technology that could reduce CO<sub>2</sub> emissions in steel-making. Given the large amounts of CO<sub>2</sub> emitted from blast furnaces – thought to emit 75% of emissions across the entire BF/BOF method – this part of the process has been focused on as the most cost-efficient application of the technology. CCS could also be used to capture the carbon emitted by the gas or coal burnt in the DRI method.

The IEA do not discuss the technical challenges to be overcome in the development of CCS itself, rather focusing on how it might be applied to steel-making process – these revolve around creating a process would give off CO<sub>2</sub> in a form that is easy to capture. Potential ways of doing this that are appropriate to steel-making include:

- Injecting oxygen into blast furnaces could generate a pure CO<sub>2</sub> off-gas that could be removed from the 'flue', the chimney at the top of the furnace. The IEA report that this method could reduce CO<sub>2</sub> emissions from the 'core processes' by 85–95%, which, assuming a 'core process' footprint equal to 70% of total emissions, would amount to around 59–66% of total emissions. Attempts are ongoing to demonstrate this on an industrial scale between 2015 and 2020.
- The CO<sub>2</sub> and carbon-monoxide-rich waste gases currently emitted from blast furnaces could be collected and reformed. No estimates are given of how much CO<sub>2</sub> this could reduce. The IEA report that this method is currently being researched in Japan, Korea and China.
- Entirely new steel-making methods – such as FINEX and HIs melt, described below – could automatically separate CO<sub>2</sub> as part of the basic process. It is estimated that such technologies could capture between 56–70% of the CO<sub>2</sub> emitted by the entire steelmaking process.

The IEA report that CCS in blast furnaces is currently estimated to come at a cost of around US\$ 40–60 per tonne of CO<sub>2</sub>, accounting for capture, transportation and storage. By contrast, it is thought that using CCS with gas-based DRI would cost US\$ 25 per tonne of CO<sub>2</sub>.

## 2. *Developing entirely new steel-making methods that are less CO<sub>2</sub> intensive*

Alternatively, another suite of technologies focus on finding new ways to make steel. The IEA identifies the following prospective developments:

### **a. New smelting reduction processes (FINEX, HIs melt and H<sub>2</sub> plasma smelting reduction)**

Smelting is a way of extracting a metal from its ore using heat and a 'reducing agent'. In the BF/BOF process this reducing agent is coke. New processes propose using either coal or H<sub>2</sub> as the reducing agent.

Coal is the focus of both the FINEX and HIs melt processes that are currently in development. According to the IEA, a FINEX demonstration plant is currently able to operate at the same rate of coal per tonne of steel as the best Blast Furnaces – 700 kg per tonne of product – at 80% of the investment cost and 85% of the operating cost, with projects to further reduce coal-use ongoing. HIs melt is reported to currently operate at a higher use of coal but claims to be able to reduce this significantly – from 810 kg per tonne of product to 710 kg per tonne. If combined with a pre-reduction process called Circofer, it is thought that even lower rates are possible, down to 555 kg per tonne of product. No information about cost of investment or operation are reported. Both processes offer gains over existing technology by saving the demand for coal in the furnace, as well as pre-furnace processes such as coking and sintering. With a high-efficiency coke oven, for example, it is thought that HIs melt could reduce coal demand by 20% across these phases. Both technologies are also appropriate for the application of CCS, with FINEX demonstration plants currently able to ready for capture equal to 56% of the emissions from the entire steel-making process and HIs melt ones equipped for 70%.

H<sub>2</sub> plasma smelting reduction – using atomic or ionised hydrogen to reduce iron at extremely high temperatures – is in a much earlier stage of development, far from demonstration. Although research is being conducted in this area, in order to be climate-friendly the technology would require substantial, low-cost and CO<sub>2</sub>-free supplies of H<sub>2</sub> and electricity.

### **b. Electricity-based steel-making**

According to the IEA, research is currently being conducted by the Massachusetts Institute of Technology (MIT) to produce iron by 'molten oxide electrolysis', a method that would produce no CO<sub>2</sub>. Substantial engineering hurdles, however, need to be overcome – a new type of material needs to be developed to provide an 'anode' for the process, an electrode through the which electric current could flow, and it is thought that large amounts of electricity would be needed. The IEA speculates that this technology is unlikely to gain significant market share in the next 20 to 40 years.

## Developing new steel products that would reduce CO<sub>2</sub> emissions downstream

Steel is designed for use in a large number of products and as a consequence a variety of 'special' steels exist – a commonly recognised example being stainless steel. In order to be produced, these must be treated with additional processes and can offer a range of characteristics such as resistance against corrosion or added strength. Steel companies have argued that improvements in areas such as the longevity of steel, the performance of steel products (allowing for machines to operate at higher heats or for steel to conduct electricity more efficiently) and the weight-strength ratio of the product (allowing for less steel to be used and machines such as cars to operate using less energy) have offset a significant amount of CO<sub>2</sub> in recent years. The IEA reports that few studies have examined the potential for savings from improved materials and identifies no specific prospective steel products that have the potential to significantly reduce CO<sub>2</sub> emissions downstream of the industry. Although such products may exist, it would also be necessary to identify any additional CO<sub>2</sub> emissions inherent in the additional processes used to create them and to determine clear rules for crediting the steel industry with CO<sub>2</sub> offsets that take place in other sectors.

**Table B2 Summary of prospective breakthrough technologies for CO<sub>2</sub> reduction in steel-making**

	CO <sub>2</sub> reduction potential	Development timescale	Cost (US\$ /tonne CO <sub>2</sub> )	Other considerations
<b>Reducing emissions from existing steel-making processes</b>				
1. Biocoal	<unknown>	<unknown>	25–150	Env. impacts Pollution
2. Waste plastic	<unknown>	in operation	0–50	
3. Plasma injection	50%	<unknown>	75–200	
4. CCS...				
...for DRI	<unknown>	<unknown>	25–50	
...for BF	56-70%	<unknown>	40–60	
...for smelting reduction	56-70%	<unknown>	25–50	
<b>Developing entirely new, low-CO<sub>2</sub> steel-making processes</b>				
<b>1. New smelting reduction processes...</b>				
...FINEX	<unknown>	demo plants	<unknown>	
...HIsmelt	<unknown>	demo plants	<unknown>	
... H <sub>2</sub> plasma smelting	100%*	long term	<unknown>	
<b>2. Electricity-based steel-making</b>	100%*	long term	<unknown>	Technically difficult

\* assuming CO<sub>2</sub>-free inputs, e.g. H<sub>2</sub>, electricity generation.

Source: (IEA, 2009)

### Associations working toward development of these key technologies

- **CO<sub>2</sub> Ultimate Reduction in Steel-making Process by Innovative Technology for Cool Earth 50 (COURSE50)**

COURSE 50 is a Japanese research program investigating innovative technologies for the reduction of carbon emissions in steelmaking. It was started in response to the Cool Earth 50 program, which called for a 50% reduction in GHG emissions by 2050.

The program is run by NEDO, the New Energy and Industrial Technology Development Organisation, an incorporated administrative agency largely funded by the Ministry of Economy, Trade and Industry (METI). Its purpose is to create broad networks between industries, universities and public research

organisations (NEDO, n.d.), which it seems to have done in the context of COURSE 50 by creating a technology "development schedule" and contracting out R&D tasks to private actors using public funds.

COURSE 50's goal is to develop technologies that can reduce steelmaking-related CO<sub>2</sub> emissions by approximately 30%, reducing the energy intensity from 1.64 to 1.15 tonnes of CO<sub>2</sub> per tonne of crude steel produced (IEA, 2009). The aim is for the technologies to be "established" by 2030 and "industrialized and transferred" by 2050, although it is not made clear what year the project hopes to begin realizing these emissions savings on a national basis (JISF, n.d.).

The plan consists of three stages: the first two, lasting until just before 2030, aiming to develop technologies, and the third intended to be for implementation and diffusion. The project is currently in step one of phase one, which lasts from 2008-2012 and has a budget of ¥10 billion (US\$ 119,000). The second and final step of phase one has a proposed budget of ¥15 billion (US\$ 179,000) and appears to last from 2012 until 2016 or 2018, although COURSE 50's dedicated website does not confirm the precise end-date. Actors under contract from NEDO currently conducting R&D for step one of phase one are: Kobe Steel Ltd., JFE Steel Corporation, Nippon Steel Corporation, Nippon Steel Engineering Co. Ltd., Sumitomo Metal Industries Ltd. and Nisshin Steel Co. Ltd. (JISF, n.d.)

COURSE 50 is exploring two general routes for reducing CO<sub>2</sub> emissions in the steelmaking process:

- Hydrogen reduction of iron ore
- Capture and recovery of CO<sub>2</sub> from blast furnace gases

#### *1. Hydrogen reduction of iron ore:*

In order to be 'reduced', iron needs to be separated from the oxygen molecules that are naturally bound to it. In traditional steelmaking, this is done by combusting coke, which releases carbon monoxide (CO). The carbon monoxide reacts with the oxygen in the iron ore, eventually resulting in pig iron and carbon dioxide (CO<sub>2</sub>) off-gas. It is chemically possible to bring about a similar reaction with hydrogen (H<sub>2</sub> reacts with the oxygen in the iron ore to form pig iron and water (H<sub>2</sub>O)) but blast furnaces do not reduce iron ore with hydrogen alone because the gas cannot be obtained at low enough costs. (JISF, n.d.) Plants can, however, take the gases that are formed when coke is produced – a mixture of hydrogen (55%), carbon monoxide (6%) and methane (28%) – and inject it into the blast furnace, such that the hydrogen content contributes towards iron ore reduction and allows for a reduction in the amount of coke that is used. COURSE 50 proposes to increase the hydrogen composition of the coke oven gas, with official documentation referring to both 60% and 67% shares of hydrogen being aimed for (JISF, n.d.), allowing for a further reduction in the use of coke and thus a reduction in the amount of CO<sub>2</sub> generated.

This project involves two main R&D challenges:

**i. Technology to increase the hydrogen composition of coke oven gas:** in order to produce additional hydrogen, it is necessary to develop "process technology" that can reform the tar contained in the coke oven gas. COURSE 50 claims that this can be done using "unused energy within the steel plant" and a catalyst. (JISF, n.d.)

**ii. Technology to make coke stronger and more reactive:** according to the COURSE 50, "high strength coke is required to maintain the gas permeability necessary for the reduction reaction of iron ore under reduced coke feeding rates" and a side-effect of hydrogen reduction is to lower temperatures in the blast furnace. The project is currently exploring the use of a "high performance caking additive (HPC)", a substance that packs more tightly together the coal particles in coke, resulting in a stronger and more reactive product. (JISF, n.d.)

COURSE 50 does not state how much CO<sub>2</sub> emissions can expect to be saved through this avenue of research. It is also not clear how significant it is to have increased the share of hydrogen from 50% to 60% or 67% of the coke oven gases. The COURSE 50 website claims, however, that coke oven gas is currently "utilized effectively as the fuel for reheating furnaces within steel plants", so it is possible that simply using coke oven gases in blast furnaces at all might offer meaningful CO<sub>2</sub> reductions. It is not estimated how much the use of coke oven gases in blast furnaces would cost, neither in terms of up-

front investments or the opportunity cost of using the gases for something other than their current application.

It should be noted that the IEA states: "As the amount of waste heat from coke ovens is limited, this is a niche option that will generate less than 0.5 GJ additional H<sub>2</sub> per tonne of steel. Coke oven gas is rich in H<sub>2</sub> and can be used for iron-making, but the quantities are limited, typically 2 GJ/t iron produced in a conventional blast furnace." (IEA, 2009)

## 2. Capture and recovery of CO<sub>2</sub> from blast furnace gases

As stated previously, using coke to reduce iron ore results in the production of CO<sub>2</sub>, which exits the blast furnace as one part of a mixture of off-gases. COURSE 50's second research project aims to find ways that this CO<sub>2</sub> can be captured. It should be noted, however, that in every instance the word 'capture' appears, the project's dedicated website uses parenthetical dashes to emphasize that this means "separate and recover", implying that there is no 'sequestration' stage in the project. Without this, there are presumably no CO<sub>2</sub> emission reductions to be made and COURSE 50 does not mention any non-sequestration-related ways for CO<sub>2</sub> emissions to be avoided. This suggests that the 30% reduction in CO<sub>2</sub> aimed for by COURSE 50 as a whole is may be based entirely on the partial substitution of coke with hydrogen in blast furnaces. On the one hand, this makes sense, given that successful CCS in steel-making would allow for theoretical CO<sub>2</sub> emission reductions of up to 70%, significantly more than those aimed for by the initiative; on the other hand, it is not clear that the partial use of hydrogen in the blast furnace could offer reductions as dramatic as 30%.

This project involves a number of R&D challenges:

**i. Technology for chemical absorption:** one route for carbon separation and recovery would be to pass blast furnace gases through an 'absorption tower', where a special substance would absorb only the carbon content of the gases. This could then be sent to a 'regeneration tower' and undergo a process that would re-release the CO<sub>2</sub>. According to COURSE 50's website, the focus of this research will be on developing new absorbent solutions that require little energy to power the process and quantifying the effects of CO<sub>2</sub> capturing technologies on steel-making. It notes that research in this area will involve the operation of a pilot plant capable of processing 30 tonnes of CO<sub>2</sub> per day. (JISF, n.d.)

**ii. Technology for chemical adsorption:** adsorption refers to a process where molecules of a gas, liquid or dissolved solid are made to stick to the surface of a substance. It differs from absorption because the substance – the adsorbent – is not permeated by the molecules. According to COURSE 50's website, the 'separation' step would take place by passing the blast furnace gas over the absorbent under pressure, and the 'recovery' of the CO<sub>2</sub> would be done by simply moving the absorbent to a depressurized location. Research in this area is focused on developing a low-energy method for carbon adsorption, also involving a pilot plant, this time with the capacity to process 3 tonnes of CO<sub>2</sub> per day. (JISF, n.d.)

**iii. Technology to capture currently unused waste heat from steel-making processes:** In its overview of prospective low-carbon technologies for the iron and steel sector, the IEA dismisses the use of CCS based on chemical absorption of CO<sub>2</sub> on the grounds that, "insufficient waste heat is available. Separate combined heat and power (CHP) units would be needed to provide additional heat." (IEA, 2009) It is presumably for this reason that COURSE 50 is pursuing four innovative ways to capture "conventionally unused waste heat" from steelmaking processes, summarized below. It should be noted, however, that COURSE 50 provides no estimate of how much unused heat might be captured by each of the following innovations, nor the likelihood that the total, realistic sum of aggregate heat that could be captured would be enough to power chemical-absorption-based carbon separation and recovery.

- **Technology for sensible heat recovery from steelmaking slag:** when iron is separated from ore and then turned into steel, a by-product also emerges, called 'slag', made up of the non-iron bits of the ore. Slag is then sold as a product in its own right, often used in road construction. (National Slag Association, n.d.) 'Sensible heat recovery' means capturing the heat that comes off the slag when it is cooling. COURSE 50's research is focused on how to do this at

the point where molten slag, at a temperature of around 1200-1600°C, is shaped into product. (JISF, n.d.)

- **Phase Change Materials (PCM):** phase change materials (PCMs) are special substances that can store medium-to-low-temperature waste heat “with high density” via their “latent heat of melting and solidification”. They then be transported to a separate location to discharge the heat. The focus of COURSE 50’s research is to develop technologies for expanding the useful temperature range for high-output PCMs and for their transportation. (JISF, n.d.)
- **Heat pumps:** heat pumps are devices that move heat from one place to another. A typical design involves a fluid that absorbs heat in one place, evaporating, and is then condensed in another place, where it gives off heat and returns to the original location to be evaporated again. COURSE 50’s research is focused on using heat-activated heat pumps to transfer low temperature waste heat from the steelmaking process to carbon capture and sequestration. (JISF, n.d.)
- **Kalina cycle power generation technology:** the “Kalina cycle” is an existing technology that uses recovered waste heat at temperatures of around 100°C to generate power. Currently, its waste heat recovery is relatively inefficient and equipment costs are high. The goal of COURSE 50’s research is to increase the waste heat recovery “through the exploration of a suitable low-boiling point medium to be used for low-temperature-heat power generation systems”, and to reduce the size and cost of power generation equipment. (JISF, n.d.)

- **Ultra-Low CO<sub>2</sub> Steel-making (ULCOS)**

ULCOS is a cooperative R&D program investigating innovative technologies for the reduction of carbon emissions in steelmaking. It was begun in 2004 and is run by a consortium of 48 European companies and organisations from 15 European countries, supported by the European Commission (EC). Within this are a small number of ‘core members’, which contribute to the budget beyond their own work: steel companies ArcelorMittal (the project coordinator), Saarstahl, VoestAlpine, Dillinger Hütte GTS, Corus [which became Tata Steel Europe as of September 2010], Riva, SSAB and RUUKKI; high-tech minerals group LKAB; and sustainable materials and technology group ThyssenKrupp.

ULCOS’s goal is to cut carbon dioxide emissions by at least 50% in comparison to today’s cleanest steelmaking routes. Although its website does not specify a particular date by which this should be achieved (ULCOS, n.d.), documentation elsewhere states that the timescale foresees commercial implementation by around 2025–2030 (Birat, et al., 2008).

The program consists of three stages. The first of these, ULCOS I, was scheduled to run from 2004 to 2010. It was subdivided into two sub-stages, a ‘research phase’ and a ‘pilot phase’. The research phase explored seventy different steelmaking processes, which were mapped out and compared on the basis of energy consumption, CO<sub>2</sub> emissions and cost. The pilot phase, completed in March 2009, focused on five of these processes specifically (for more information, see the description of ULCOS technologies below) (Birat, et al., 2008). The second phase is due to run from 2010 to 2015 and is described as a ‘demonstration’ phase. Following this, ULCOS III is anticipated, with a focus on implementation, although it is not clear if it will commence immediately after the expected end-date of ULCOS II. (ULCOS, n.d.)

The partners in the ULCOS consortium pay 60% of the total cost, with the remaining 40% being contributed by the European Commission. The budget for the six-year lifetime of ULCOS I was €75 million (around US\$ 105 million) (ULCOS, n.d.). The estimated budget announced for ULCOS II was considerably larger, in the range of €700–800 million (around US\$ 1.0–1.1 billion) (ULCOS, 2009). It is unclear if this cost was shared between the consortium and the EC in the same proportion as the first phase.

ULCOS is exploring four general routes for reducing CO<sub>2</sub> emissions in the steelmaking process.

- A top gas recycling blast furnace (potentially combined with CCS or biocoke)

- HISarna, a combination of a melting cyclone and iron ore smelter (potentially combined with CCS or biocoke)
- A low-cost process for the direct reduction of iron (DRI) using natural gas, in a project called ULCORED (potentially combined with CCS)
- Electrolysis, in two projects called 'ULCOWIN' and 'ULCOLYSIS'

As implied, this also involves research into CCS and biocoke.

### *1. Top Gas Recycling Blast Furnace (TGR-BF)*

The core concept behind this innovation is that the gases exiting the top of the blast furnace can be separated into useful and non-useful parts. The useful parts can then be recycled back into the furnace as reducing agents, such that less coke is needed. The process also introduces oxygen to replace the heated air that is normally injected into the blast furnace. This helps make the off-gas CCS-ready, by removing unwanted nitrogen. (ULCOS, n.d.)

According to modeling and laboratory and bench-scale experiments, a top-gas recycling gas furnace could reduce CO<sub>2</sub> emissions by 15%. If combined with CCS, emissions could be reduced by 65% (Birat, et al., 2008).

The TGR-BF is reported to be the breakthrough technology that is nearest to deployment in the ULCOS program. Pilot tests have been conducted at 1.5 t/h and a demonstration phase was launched in 2010 (Birat, Steel and CCS, 2010). This will take place in two steps: the first, scaling up a pilot TGR-BF to the size of a small production blast furnace; and second, scaling up to a larger blast furnace, with roughly double the production volume, and in combination with a CO<sub>2</sub> storage test-site in a nearby deep saline aquifer. The demonstration phase will cost €310 (around US\$ 430 million) and it is envisaged that deployment could begin by 2020 (Birat, ULCOS II has been shaping up..., 2009). According to the United Nations Industrial Development Organisation (UNIDO), the TGR-BF technology can be retrofitted.

### *2. HISarna*

HISarna is a combination of three separate technologies: coal preheating and partial pyrolysis; the use of a 'melting cyclone' to melt the iron ore; and a smelter vessel for reduction.

The reduction process would begin by firing the iron ore into the top of the furnace, where it would be melted by a cyclone of hot gases. The melted ore would then flow down the walls of the furnace and be partially reduced by its contact with carbon monoxide and hydrogen (H<sub>2</sub>) rising from a reactor at the base called a converter. This converter, containing a liquid slag layer on top of a hot metal bath, is fed with pre-heated coal and injected with oxygen. The fact that the coal has been preheated means that the whole process has higher thermal efficiency than usual and, by corollary, less coal is needed. As well as reducing the iron, the hot gases from the converter rise up the furnace into the cyclone at the top and help melt the ore. The off-gases from the furnace are concentrated CO<sub>2</sub>. (ULCOS, n.d.)

Like the top gas recycling blast furnace, HISarna offers two avenues for CO<sub>2</sub> emission reductions: reducing the need for coal in the reduction process, and creating off-gas that is CCS-ready. The exact amount of emissions reductions that could be achieved is not stated on the ULCOS website but it is implied that the total possible savings are substantially larger than the TGR-BF (ULCOS, n.d.). According to the IEA, however, experiments with HISMelt indicate that it could reduce coal-usage by 20% - which, assuming the blast furnace stage of production contributes 70% of emissions from the total steel-making process, would equate to roughly a 14% overall reduction in CO<sub>2</sub>. Once equipped with CCS, the IEA report that HISMelt could reduce overall steelmaking emissions by 70% (IEA, 2009).

The current program of research on HISarna foresees the construction of a pilot plant capable of producing 8 t/h to start up in 2010. (Birat, 2009) Estimates for the construction of a demonstration plant and the beginning of deployment range from around 2012 and 2025 (Birat, 2009) to 2020 and 2030 (Birat, 2010), respectively. This makes it the third among the four technologies in terms of maturity and likely date of deployment.

### *3. Low-cost gas-based DRI (ULCORED)*

The aim of ULCORED is to make costs lower for gas-based direct reduced iron – one of the main current barriers to this method of production. This will be done by developing a new method to prepare the gas for reduction of the ore, a process known as 'reforming'. The new method will use less expensive capital and allow for a reduction in the amount of natural gas required per tonne of iron produced. It will also result in an off-gas that is sufficiently pure for CCS.

The ULCOS website does not state how much CO<sub>2</sub> could be reduced by this innovation. It is estimated that a pilot and demonstration plant will be constructed during ULCOS II and that the technology may be ready for deployment by just after 2020, making it the second-nearest ULCOS project to deployment. (Birat, ULCOS II has been shaping up..., 2009)

#### *4. Electrolysis (ULCOWIN and ULCOLYSIS)*

The reduction of iron ore via electrolysis would see the ore placed in an alkaline solution through which an electric current would pass between two electrical conductors, a cathode to an anode. This would cause the oxygen to become a negatively charged, and to separate from the particles of iron in order to move toward the positively-charged anode.

ULCOS is currently exploring two possible routes for electrolysis. ULCOWIN, the more advanced of the projects, would use a solution of sodium hydroxide at a temperature of 110°C and a proposal has been made to test the technology by creating a pilot plant able to produce 5 kg/day. ULCOLYSIS would use a solution of molten oxide mixture at a temperature of 1600°C in order to melt the iron metal.

As electrolysis reduces iron ore without the need for any carbon reducing agent, it could theoretically reduce CO<sub>2</sub> emissions to zero, but only if it is powered by zero-carbon electricity generation.

- **World Steel Association CO<sub>2</sub> Breakthrough Program**

This is a platform to exchange information.

- **United States Department of Energy's Intensive Processes Initiative**

This initiative has made eight awards to recipients investigating breakthrough processes such as electrical steel-making.

## Annex C: World Steel Association activities

### The World Steel Association (WSA)

The World Steel Association (WSA), formerly The International Iron and Steel Institute (IISI), was founded in 1967. It is an industry association that represents approximately 180 steel producers, including 19 of the world's 20 largest companies, which together account for around 85% of the world's steel production. Its purpose is "[to provide] global leadership on all major strategic issues affecting the industry" and "[to promote] steel and the steel industry to consumers, the industry, media and the general public". (WSA, n.d.) Its activities include monitoring the global steel industry, lobbying, conducting research and sharing information between members.

### The WSA's commitment to sustainability

WSA members established a policy on sustainable development in 2002 that committed to seven key focus areas. It remains today the agreement that shapes the organisation's activities regarding sustainability and is reproduced in the box below. So far as environmental sustainability is concerned, the key commitment is to optimise the resource and energy efficiency of steel-making and steel products.

#### BOX C1: The World Steel Association's Policy Statement on Sustainable Development

##### Vision

The Member Companies of IISI are committed to a vision where steel is valued as a major foundation of a sustainable world. This is achieved by a financially sound industry, taking leadership in environmental, social and economic sustainability.

##### Sustainable Development Commitments

The Member Companies of IISI seek to develop sustainably and are committed to:

**I.** Operate their businesses in an efficient and financially sustainable way in order to supply steel products and solutions that satisfy their customer's needs and provide value to their stakeholders.

**II.** Optimise the eco-efficiency of their products through the product life-cycle, including increased resource and energy efficiency in the production of steel and during the use of steel products. They are committed to the promotion of the recovery, reuse and recycling of steel.

*Source: (IISI, 2005)*

**III.** Foster the well-being of employees in the steel industry and provide them with a healthy and safe working environment.

**IV.** Demonstrate social responsibility by promoting values and initiatives that show respect for the people and communities associated with their businesses.

**V.** Conduct their business with high ethical standards in their dealings with employees, customers, suppliers and the community.

**VI.** Engage their stakeholders and independent third parties in constructive dialogue to help fulfil their sustainable development commitments.

**VII.** Build on their knowledge of sustainability and willingly share it with others. They will be open and active in their communications and help steel companies and organisations in the supply chain to implement sustainable practices.

It has been up to members to pursue these commitments themselves, with the WSA taking on the role of reporting on how the global steel industry as a whole has performed according to a number of indicators, which measure environmental, social and economic sustainability. The results of this data-gathering are summarized on the following page, alongside a number of notes that identify where gaps exist or changes took place in either in the collection of data or calculation of indicators between different years.

There are many positive things about the WSA's indicators that deserve congratulation. They represent a broad interpretation of sustainability, including health and safety statistics, as well as environmental and

economic issues. They also mark a significant, voluntary step on behalf of an industry towards increased accountability and in this sense they are an important model.

They also exhibit some weaknesses however. Most fundamentally, they are not representative of the global steel sector. Respondents have only ever represented between 33%-42% of the world's steel production. In addition, the data behind this are not made readily apparent, so it is not possible to tell if particular production methods, countries or regions are under- or over-represented, although limited information shows that this is clearly the case – for example, in 2004 and 2005, the WSA noted that respondent companies were biased towards the use of integrated steel-making, a more energy-intensive, and thus CO<sub>2</sub>-intensive production method. This lack of coverage combined with a lack of transparency greatly detracts from the reliability of the indicators as a true 'global' assessment.

It is also not clear why indicators have not been disaggregated according to production method, given their substantially different environmental impacts, and problems of inconsistency prevent any meaningful tracking of progress between different years. For example, the fact that different groups of companies might report data each year makes it impossible to determine if fluctuations in performance are due to improvements in sustainability or the inclusion or exclusion of particular members. The WSA also appears to have changed the definition of its indicators a number of times. After 2004, for example, measures of energy-intensity, CO<sub>2</sub>-intensity and material efficiency were changed to include the finishing and operations parts of steel production. The WSA's 2005 Sustainability Report states that the data were 'weighted' but does not explain how; no other report, however, makes reference to weighting. The language used to describe indicators has changed several times – measuring greenhouse gas emissions according to steel "produced" and then steel "cast", and changing "value added" into "economic value distributed" – without any explanation of whether this involved a change in the data being collected.

More broadly, a number of questions might be asked about the data fields that have been chosen to give a 'full picture' of the sector's efforts concerning sustainability. The measurement of 'material efficiency', for example, is somewhat lacking in use-value, given that in the first year of reporting the average percentage of by-products being re-used was 96.8% and in the latest figures has moved up to 98.1%, suggesting that there is little progress to measure. Similarly, although the industry has clearly expressed its aversion to *targets* regarding absolute CO<sub>2</sub> emissions, it seems misleading not to at least measure this as an *indicator*, as increases in absolute CO<sub>2</sub> emissions are, ultimately, the concern. No analysis of the relationship between indicators and world market trends is also disappointing – for example, a market boom might significantly boost levels of investment and economic value distributed.

<b>WSA Sustainability Indicators: 2004 – 2008</b>								
<b>Indicator</b>	<b>Unit<sup>a</sup></b>	<b>2003</b>	<b>2004<sup>b</sup></b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	
<b>Environmental sustainability<sup>d</sup></b>								
<b>1</b>	Greenhouse gas emissions	Tonnes CO <sub>2</sub> /tonne steel cast <sup>e</sup>	1.6	1.7	n.d.	1.7 <sup>f</sup>	1.9	1.9
<b>2</b>	Energy intensity	GJ/tonne steel cast <sup>e</sup>	19.0	19.1	n.d.	20.6 <sup>f</sup>	18	18
<b>3</b>	Material efficiency	% of by-products re-used	96.8	95.6	n.d.	97.2 <sup>f</sup>	98.0	98.1
<b>4</b>	Steel recycling	% of crude steel produced	42.3	42.7	n.d.			
<b>5</b>	Environmental management systems (EMS)	% of employees and contractors in EMS-registered production facilities	85	90.7	n.d.	85.5	85.1	86.6
<b>Social sustainability</b>								
<b>6</b>	Lost time injury frequency rate	Injuries/million hours worked	7.8	6.6	n.d.	8.8	3.0	3.6
<b>7</b>	Employee training	Training days/employee and year	6.3	9.9	n.d.	10.5	6.9	5.1
<b>Economic sustainability</b>								
<b>8</b>	Investment in new processes and products	% of revenue	6.0	6.2	n.d.	7.7	7.9	9.0
<b>9</b>	Economic value distributed <sup>g</sup>	Billion US\$	-	-	n.d.	-	323.9	308.3
		% of revenue <sup>h</sup>	2.6 <sup>i</sup>	11.7	n.d.	7.6	84.1	70.4
<b>Metadata</b>								
<b>No. of companies reporting</b>			42 <sup>j</sup>	45 <sup>k</sup>	n.d.		33 <sup>l</sup>	33 <sup>m</sup>
<b>% of world steel production represented</b>			33		n.d.	42	35	35
<b>No. of countries operated in by reporting companies</b>			30		n.d.			

**Notes:**

- a. All indicators represent the average of reporting companies, with the exception of "Steel Recycling". This is based on the WSA's annually published statistics on the steel sector globally.
- b. According to WSA's 2005 Sustainability Report, the data for this year are "weighted averages". It is not clear if data from the other years are weighted and – if so – how this weighting is conducted.
- c. No data appears to have been collected for 2005.
- d. According to the WSA's 2004 and 2005 Sustainability Reports, reporting companies over-represented the use of integrated steel production technology. This means that rates of CO<sub>2</sub> emissions and energy intensity per tonne of steel produced/cast may be overstated for the global sector as a whole.
- e. Before 2007, this indicator was called measured per "tonne steel produced".
- f. As of 2004, greenhouse gas emissions, energy intensity and material efficiency were "based on an extended system boundary that includes finishing and operations (for example, hot rolling, cold rolling and galvanising)". (IISI, 2005) As of 2007, the methodology used to calculate greenhouse gas emissions and energy intensity estimates was "slightly revised". (WSA, 2010b)
- g. 'Economic value distributed' was first measured in absolute terms for 2007.
- h. In 2003 and 2004 data reporting, this indicator was called "Value Added".
- i. The 2003 indicator for value-added was revised in the WSA 2005 Sustainability report, from 3.2% to 2.6%, based on more consistent reporting of Return on Capital Employed among all reporting companies.
- j. In 2004, data for environmental and social indicators also included the 55 companies that make up the Japan Iron and Steel Federation (JISF).
- k. This number is derived from the WSA's 2005 Sustainability Report. The report does not state how many companies reported but notes that "there are 5 new companies reporting" and that "HADEED and YUSCO" were the only companies that did not participate again".
- l. In 2007, only 24 companies reported data for the indicator 'economic value distributed'.
- m. In 2008, only 25 companies reported data for the indicator 'economic value distributed'.

**Sources: compiled and adapted from (WSA, 2010a; IISI, 2005; IISI, 2004)**

## WSA's activities, priorities and positions

WSA's activities, priorities and positions can be understood from its policy statements and position papers. In **May 2007**, the steel industry released a policy statement that included the proposal of a global sectoral approach. (WSA, 2007a). It proposed:

- A global, voluntary, technology-focused and intensity-based agreement should be reached. The steel industry will show its commitment to this by taking actions including:
  - Expand the use of current efficient technologies to minimize CO<sub>2</sub> emissions.
  - Undertake research and development of new technologies that can radically reduce CO<sub>2</sub> emissions. To be coordinated by the WSA with universities, research institutes and other industries. Timescale 15-20 years.
  - Maximize the potential to recycle scrap steel.
  - "Facilitate the use of" new-generation steels to improve end-product energy-efficiency. Includes the development of new steels.
  - "Adopt common and verified reporting procedures that account for and report progress towards achieving CO<sub>2</sub> emission reductions."
  - "Adoption of a global sector-specific approach." The WSA launched a task force to develop a global sector-specific approach for CO<sub>2</sub> reductions post-Kyoto.
- The WSA also call on governments to show their own commitments to the idea, namely by:
  - Doing away with cap and trade. Policies that "allow the most efficient steel companies in terms of CO<sub>2</sub> emissions to expand and the least efficient to decline" are encouraged.
  - Develop a sectoral framework including all major steel producing countries.
  - Establish recycling programs.
  - Encourage the closure and replacement of the least efficient plants.
  - Support long-term research for radical technologies.
  - Engage with the industry to develop robust CO<sub>2</sub> emissions indicators.
- They argue that new-generation, by being both light-weight and strong, can increase the energy-efficiency of end-products.
- Mention is made of the WSA's "CO<sub>2</sub> Breakthrough Programme" that is "taking a multiphase approach to radically reduce CO<sub>2</sub> emissions". This seems to be focused on technology development.

In **December 2007**, the WSA released a "position paper" reiterating and expanding these ideas, including a global sectoral approach for the industry. It noted: (WSA, 2007b)

- Steel can contribute to climate change mitigation by:
  - Being used in the construction of renewable energy technologies. New-generation steel can reduce emissions in the use of steel end-products, e.g. lighter weight cars.
  - The steel industry is "involved in many programmes" to help technology transfer. They have "projects and working groups" who "regularly exchange information".
  - The steel industry has started the CO<sub>2</sub> Breakthrough Programme, "a long-term research project investigating new processes for steel production that will substantially decrease CO<sub>2</sub> emissions".
- The WSA opposes the European ETS on the basis that it:
  - distorts competition (because allocation is "arbitrary" and not based on individual plant performance)
  - fails to effectively reduce emissions (because of leakage)
  - fails to reward improvements ("does not allow the most efficient steel companies to expand and the least efficient to decline")
  - leads to "huge and unjustified inflation" in electricity prices
- It reports that the WSA announced a "new global steel sector approach" at the annual worldsteel conference in Berlin in October 2007. This includes:
  - beginning with the collection and reporting of CO<sub>2</sub> "emissions data" by "steel plants in all the major steel producing countries".
  - this will lead to the benchmarking of improvements
  - this will lead to setting commitments on a national or regional basis for implementation post-Kyoto

- The WSA claims that China's steel companies approve of this plan, making it workable (China accounts for roughly 50% of steel emissions). More generally, members from developed and developing countries are said to approve.
- They note their ongoing work to cooperate with the Asia-Pacific Partnership on Clean Development and Climate (APP).
- They summarize by saying "The steel sector is asking for a new emissions regulatory regime that takes a global steel sector approach, is intensity based, verifiable and finally is technology driven."
- They ask governments to:
  - work closely with them in the design of a sector-specific framework.
  - support the expansion of efficient steel companies.
  - help worldsteel develop its methodology to measure emissions.
  - help invest in next-generation technology to reduce CO<sub>2</sub> emissions in steel-making.

In **2010**, the WSA again stressed its progress: (WSA, 2010b)

- Technology is key to reducing CO<sub>2</sub> emissions, especially CCS and CO<sub>2</sub>-lean electricity.
- They coordinate an expert group on CO<sub>2</sub> breakthrough technologies, with research taking place in the EU, US, Canada, South America, Japan, Korea, China, Taiwan and Australia.
- In 2008, the WSA set up a CO<sub>2</sub> emissions data collection programme "enabling every steel producing company in the world to submit their CO<sub>2</sub> emissions using a standardized methodology", "from now on, consistency [in sustainability indicators measured by the WSA] is assured by the worldsteel data collection programme".

In **2011**, the WSA's references to sectoral approaches were dropped from the worldsteel position paper "Steel's Contribution to a Low Carbon Future" (WSA, 2011). This paper stresses at several points the need for a "sustainable life cycle approach", and notes the contribution steel makes to the production of various downstream emissions reduction technologies and processes. WSA offers its database of life cycle inventory data for the production of a whole range of steel products. WSA's priorities regarding governments revolve around working in partnership:

1. governments should "work actively with the industry and our customers" in "maximising the collection and recycling of end-of-life steel products";
2. governments should use a life cycle approach "if they create regulations and standards to energy efficiencies in domestic appliances, passenger cars, building codes, etc.";
3. "the steel industry cannot, on its own, be expected to fund the long term research and development of new technologies to radically reduce steel's emissions".

## **Annex D: Asia-Pacific Partnership (APP)/Global Superior Energy Performance Partnership (GSEP) activities**

### **The Asia-Pacific Partnership on Clean Development and Climate (APP)**

The Asia-Pacific Partnership on Clean Development and Climate (APP) was announced on 28 July 2005 at the Twelfth Meeting of the ASEAN Regional Forum (ARF) in Vientiane, Laos, five months after the Kyoto Protocol entered into force. It was formally launched at a Ministerial Meeting in Sydney, Australia, on 12 January 2006. (APP, n.d.) Its members originally consisted of Australia, China, India, Japan, the Republic of Korea and the United States, with Canada joining as the seventh member at the APP's Second Ministerial Meeting in 2007. Together, the group is responsible for more than half of the world's economy, population and energy use, and more than 60% of the world's steel production. (APP, n.d.)

At the time of the APP's inception, Japan was the only member that had also committed to achieve a target level of CO<sub>2</sub> emissions by 2012 under the Kyoto Protocol.<sup>31</sup> (UNFCCC, 2009) Japan is said to have joined the APP only at 'the last minute', due to the United States' concerns that it would push for emissions reduction targets. From the beginning, it emphasized the attitude that the APP is complementary to the Kyoto Protocol, although more generally "there has been debate over the extent to which it actually was formed to become an alternative to the legally binding framework under the Protocol". (van Asselt, Kanie, & Iguchi, 2009).

It is thought that Japan became party to both international agreements in order to uphold its reputation as a leader in environmental diplomacy at the same time as maintaining its long-standing relationship with the United States, and engaging its largest trade partner, China, in climate change mitigation. It also positions Japan in its traditional role as a mediator between more strident advocates of commitments to combat climate change, such as the EU, and more conservative parties, such as the US. (van Asselt, Kanie, & Iguchi, 2009) It is also true that, in its basic structure, the APP is the realization of what Japan has advocated for some time in UNFCCC negotiations: a sectoral-based agreement among a small number of countries who represent a large proportion of the world's CO<sub>2</sub> emissions.

### **The APP's sectoral approach**

The APP has no overarching goals or timelines other than to "meet... our increased energy needs and associated challenges, including those related to air pollution, energy security, and greenhouse gas intensities". Its activities focus on two rough areas: the development and diffusion of existing, emerging and future technologies that are cleaner or more efficient than those in use today; and sharing information about national policy approaches to development, energy, environment and climate change issues. (APP, n.d.)

It was agreed at the launch of the partnership that work would be conducted on eight key sectors by public-private Task Forces, focusing on: cleaner fossil energy; renewable energy and distributed generation; power generation and transmission; steel; aluminium; cement; coal mining; and buildings. Each Task Force then developed an Action Plan, containing a number of individual projects and activities, which were endorsed at a meeting in October 2006, and have been being implemented since that time. (APP, n.d.; APP, 2008)

### **The Steel Task Force's Action Plan**

Given that energy is responsible for up to 40% of the costs of steel production, the Action Plan developed by the Steel Task Force concluded that the most cost-effective way to improve the steel sector's environmental performance would be to increase its energy-efficiency. Although the document which sets out the Action Plan is somewhat confused – identifying 'primary opportunities' in the steel sector, as well as barriers,

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<sup>31</sup> Australia and the United States had not ratified the Protocol, and China, India and the Republic of Korea, also among the world's top fifteen emitters of CO<sub>2</sub>, were not subject to binding targets. Australia did, however, ratify the Kyoto Protocol in 2007. (UNFCCC, 2009; United Nations Statistics Division, n.d.)

objectives and projects and milestones, all of which fail to coherently map onto one other, and are in some cases defined in vague 'political speak' – the real meat of the Task Force's intentions appears to lie in the six projects it has established, which form the backbone of its on-going activities. (APP, 2008) Stripped down to their essentials, the six projects cover five major areas, summarized below:

1. The first project focuses on promoting information-sharing between APP members, committing them to attend annual APP Steel Workshops in partner countries, hosted on a rotating basis. These Technical Workshops consist of presentations by country experts about some aspect of climate change, energy efficiency or iron and steel production. To date, they have always been held alongside the Steel Task Force's regular meetings. The Steel Task Force has also coincided one of its meetings with an industry 'showcase' event, where technology suppliers presented their wares and were available to discuss them with industry representatives.
2. The second and third projects, led by Japan and Korea, are deeply interrelated and can be summarized in three steps: first, to review the current performance of the steel industry with respect to energy and the environment in different APP countries; second, to agree quantitative indicators that can be used to benchmark and measure changes in the steel sector's use of energy and its impact on the environment; and third, for each partner country to set "ambitious but realistic milestones" to "guide" their efforts in improving the steel sector's energy- and environment-related performance domestically. Essentially, they create the foundation for agreeing targets and measuring progress.

Since this work began, it was decided that a third-party organisation would be chosen to increase the perceived credibility and reliability of the projects' outputs: HATCH, a Canadian technical and project consultancy service for the mining, metallurgical, energy and infrastructure industries. (Kakudo, 2009c) It was also originally intended for the two projects to be merged into a single, combined project in 2009, although it is unclear if this has taken place.<sup>32</sup> (APP, 2008)

The Steel Task Force has published very little information about its work to overview the status of the steel sector, agree on common indicators and set milestones. Descriptions of the projects are often vague and difficult to connect to one another – it is not even known exactly what indicators are to be measured. Summaries of the Steel Task Force's annual meetings suggest that APP member countries continue to disagree with one another about exactly what should be included. The following facts are clear:

- In 2005 a data-collection exercise took place consisting of two surveys, one called an "Energy Intensity Survey", and another a "Technology Diffusion Survey". (Kakudo, 2009a)
- In 2007 an 'Expert Group' was set up in order to review the data for accuracy and consistency and to consider data-confidentiality guidelines. (Tateishi, 2007)
- In 2008 it was agreed that data related to CO<sub>2</sub> emissions and energy should 'observe commonality' with formats and guidelines followed by the World Steel Association (WSA) [formerly known as the International Iron and Steel Institute (IISI)]. (Tateishi J. , 2008b) At a second meeting, later in the year, it becomes clear that a third survey has also been disseminated, on "barriers to installation of abatement facilities" [presumably abatement of CO<sub>2</sub> emissions, but it is not stated]. (Kakudo, 2008)
- In a second meeting in 2008, Japan presented a discussion paper on a methodology for target setting. Although not publically available, the paper appears to have presented a number of options, including: setting a common target or country-specific targets; setting targets for energy intensity (either absolute values or percentage reductions), implementation of technologies or 'others'; and setting a target year of 2020 or 2030. (Tateishi, 2008a)
- In 2009, the original surveys on energy intensity and technology diffusion were reviewed by HATCH, which recommended a number of changes. It was commissioned to integrate them into a single survey, to be ready for dissemination by 2010. It is unclear if the survey on barriers to the implementation of abatement technologies was also reviewed. (Kakudo, 2009a)

<sup>32</sup> NB. In the Steel Task Force's 5<sup>th</sup> meeting in October 2007, it was agreed that all members would support a 'new' "Flagship Project under the title 'Establishment of a Common Methodology to Identify Reduction Potential and Performance Benchmarking' to be jointly led by Japan and Korea, which had two components, STF-06-02 and STF-06-03. [Steel Task Force projects two and three]" However, this decision is not reflected anywhere else in the Steel Task Force's publically available documentation about its projects and the Action Plan, which continues to describe them as two separate projects, was published after this meeting took place, in 2008. (Tateishi, 2007)

- Despite this decision to amend the surveys, the Steel Task Force used the data collected in 2005 to perform some preliminary calculations. It estimated that, given the implementation of ten major technologies, the APP members could collectively reduce CO<sub>2</sub> emissions by 129 tonnes per year; SO<sub>x</sub> emissions by 0.67 tonnes per year; and NO<sub>x</sub> emissions by 0.29 tonnes per year.<sup>33</sup> (Kakudo, 2009b)
- Between 2008 and 2009, the Steel Task Force also discussed mid-term targets for the steel industry, but had different opinions on scope, timing and methodology. This resulted in the “St. Louis Agreement”, which agreed to: (Kakudo, 2009c)
  - report energy intensity and “complete surveys”;
  - “use the HATCH reports to understand opportunities for improvement”
  - “make improvements according to company and government policy”
  - give steel sectors the option to set targets for energy intensity improvement

Different APP attitudes towards target-setting are summarized in the table below:

<b>Australia</b>	<b>Canada</b>	<b>China</b>	<b>India</b>	<b>Japan</b>	<b>Korea</b>	<b>United States</b>
Targets should be consistent with national policy and COP negotiations, i.e. 5-15% reduction of CO <sub>2</sub> emissions from 2000 levels by 2020.	Targets should be consistent with national policy and COP negotiations, i.e. 20% reduction of CO <sub>2</sub> emissions from 2006 levels by 2020.	Targets should be based on plans to restructure the steel industry, i.e. improve energy efficiency by 20% from 2005 levels by 2010. A timeframe of 2020 is too long for China to set a target.	It should be optional to set a target.	Targets should be set for each kind of steel-making process (e.g. BF-BOF, EAF etc.) in each country.	Targets should be set for each kind of steel-making process (e.g. BF-BOF, EAF etc.) in each country, taking into account countries’ development status.	A single, national average should be set for each country. Targets should not be set for each kind of steel-making process.

Source: (Kakudo, 2009b)

- In 2010, Hatch delivered a presentation to the Steel Task Force on the preliminary results of “the modified survey on energy, technology diffusion and barriers”. This was not made public. (Kakudo, 2010)
3. The fourth project, also led by Japan, consists of experts visiting steel plants in order to perform a ‘diagnosis’ of their potential to improve energy-efficiency and environmental performance through best practices and clean technologies. Japanese experts have visited a number of steel plants in India and China. As of 2009, it was reported that the energy efficiency of these plants could be improved by between 2–17%. (Tateishi, 2009)
  4. The fifth project, led by the United States, was to identify the best available technologies to “provide steel decision makers in APP countries with access to attractive environmental/process technology options to support their capital improvement projects”. This resulted in the State-of-the-Art Clean Technologies (SOACT) Steelmaking Handbook, published in December 2007. (APP, 2007) The United States is currently coordinating the second edition of the Handbook, which will include between 25 to 30 new technologies, as well as information about several technologies’ costs and benefits. (Kakudo, 2009c) According to the project’s status report, the SOACT Handbook is intended to be a “living

<sup>33</sup> This so-called ‘theoretical reduction potential’ covers all seven APP countries. Although Canada was not a member of when the original surveys were conducted, it submitted data in order for up-to-date estimates to be calculated. (Kakudo, Progress Report: APP Steel Task Force, 2009b)

document", that will continue to have periodic updates throughout the life of the Steel Task Force. (APP, 2009)

5. The sixth project, led by Australia, is called 'Technology Deployment' and its purpose has been under contestation among Task Force members. The purpose described by the Action Plan is to "develop detailed practical projects to deploy State-of-the-Art Clean Technologies". As such, this would be the logical final step in the projects described so far: first, establishing the status quo; then setting indicators and agreeing targets; diagnosing opportunities for improvement; and finally, implementing the necessary technologies to take advantage of those improvements.

In 2007, however, it was stated that the project was "intended to promote new technology development, rather than simply fund the installation of fully proven and readily available technologies", and Australia asked for clarification – which was not ultimately resolved – on the specific role it was supposed to play. (Tateishi J. , 2007) In a later meeting, it was agreed that Australia's role should be to "facilitate project implementation actions", after which Australia drafted a document called Guidelines for Technology Deployment. This was not made publically available and seems to have consisted of setting out a process by which energy- or environment-related performance improvement projects could be identified, as opposed to actually being implemented. (Tateishi J. , 2008b; Kakudo, 2008)

A year later, however, it was decided to temporarily halt the project. Although the reasoning is not clearly explained, it appears to be due to a lack of funding to actually implement technology improvement projects. (Kakudo, 2009c) The APP appears unable to provide any funding itself, and all subsequent work to date on the project reported at Steel Task Force meetings has consisted of countries identifying various international funds which might be willing to finance technology deployment. (Kakudo, 2009a; Kakudo, 2010)

## Future prospects

The APP Steel Task Force is currently being wound down with a replacement Steel Working Group set up under the GSEP, and to be hosted at the IEA in Paris. This working group will build upon the work of the APP Steel Task Force (Clean Energy Ministerial, 2010).

It is difficult to determine the future prospects of the Steel Task Force's activities in the Asia-Pacific Partnership on Clean Development and Climate, given the organisation's lack of transparency about its activities. It can be speculated, however, that regardless of original intentions, the APP in its current state does not offer an alternative to the Kyoto protocol – its members are unable to agree on even non-binding targets for improvements in energy efficiency and appear to be unable to fund the projects that they themselves recommend, despite early commitments to set "concrete quantitative indicators" and "set ambitious but realistic milestones". (APP, 2008) Moreover, there is a fundamental disconnect between the Steel Task Force's activities and any attempt to take into account global efforts to mitigate climate change – in order to achieve various targets for maximum temperature increases, how much *should* the steel sector be trying to reduce, and how does that compare with the APP's theoretical potential?

In the publically available meeting summaries, there is a sense that momentum has been lost. The only product to have resulted from the Steel Task Force's activities is the SOACT Handbook which, while a useful technical manual, is a far cry from meaningful climate change mitigation. Japan appears to have been the driving force behind most other projects, with little contribution from other members. China has failed to attend four out of a total of nine meetings since the group's inception.

As a sectoral approach, a number of elements appear to be missing from the APP's strategy. There is no indication that the steel sector from each respective country is closely involved in negotiations, nor under pressure – as was the case for the Nippon Keidanren in 1997 – to arrive at some form of domestic agreement or be threatened with national regulation. The lack of transparency regarding the Steel Task Force's activities is also a great failing. Although this may have been one of the conditions that made it possible for China, India and the United States to form a partnership, it also cripples the organisation's credibility and legitimacy, as well as taking away the potential for countries to be under pressure follow through on their commitments.

## Annex E: Potential for CCS development in Japan

### Context

Projections show that the Japanese steel industry is likely to rely heavily on carbon capture and storage (CCS) to reduce their future emission of greenhouse gases. CCS is one of the two pillars of the COURSE50 breakthrough technology research program, which aims to deliver a 30% reduction in emissions from the industry by 2050. The three elements of the CCS chain, namely, capture, transport and sequestration of CO<sub>2</sub>, must be integrated to deliver this pillar's share of the overall reduction goal.

As of the end of 2010, the industry has focused almost exclusively on the capture of greenhouse gas emissions from blast furnaces. A pilot capture project at Nippon Steel's Kimitsu works has proven sufficiently successful to warrant scaling up of the capture rate from 1 to 30 tons of CO<sub>2</sub> per day (Takagi, 2010). However, this captured CO<sub>2</sub> does not equate to avoided or mitigated emissions, since it is not subsequently sequestered so to prevent release to the atmosphere. While the COURSE50 program does allude to sequestration, the industry has yet to engage directly in transport of capture CO<sub>2</sub> or geological sequestration.

The capture stage is clearly an important element of the CCS chain, since it comprises approximately 70% of the total cost of CCS, imposes energy consumption and operational efficiency penalties on CCS-equipped facilities, and requires special design features or retrofits in industry facilities (McKinsey, 2009). Industry may choose to focus on capture because they perceive capture cost to be the most pressing impediment to CCS, or they may wish to avoid bearing costs for transport and storage, which they believe to be the responsibility of government. Nevertheless, without the integration of transportation infrastructure to deliver pressurized CO<sub>2</sub> to a geological storage site, and the injection and long-term storage of that CO<sub>2</sub>, CCS cannot deliver emissions reductions. Industry claims about emissions reduction potential from CCS lack credibility without demonstrating the viability of integrated CCS, from capture, through transport, to safe and secure long-term storage of CO<sub>2</sub> within geological formations. Given significant uncertainties about overall storage capacity in Japan, and proximity of that capacity to major point sources,<sup>34</sup> industry furthermore cannot dismiss the need to explore and confirm that there will be sufficient geological capacity to sequester emissions to meet their 30% reduction target. This section provides background on the transport and storage elements of the CCS chain, discusses progress on transport and storage within Japan, and proposes strategies to increase steel industry involvement in transport and storage.

### CCS Economics: Transport and Storage

The cost of integrated CCS comprises three main elements: capture, transport and storage.<sup>35</sup> Transport and storage typically account for 30% of the cost of a ton of sequestered carbon, while capture accounts for 70% (McKinsey 2009).<sup>36</sup>

*Capture* of greenhouse gas emissions requires upfront capital expenditure, either for a retrofit to existing plant, or for an additional element of a new build, as well as ongoing operating expenditure including energy consumption and operational efficiency penalties.

*Transport* is typically most economical by pipeline, but other modes of CO<sub>2</sub> transport such as container ship or truck have been considered (McKinsey, 2009). Pipeline transport cost varies according to the distance between the point source and the injection site, and whether the pipeline is onshore or offshore. Pipeline lengths over 250km increase overall cost due to greater CO<sub>2</sub> pressurization requirements (McKinsey, 2009), and pipelines that include offshore elements are generally more expensive, as submarine pipelines must link to an offshore platform or subsea wellhead (Takagi, 2007).

<sup>34</sup> RITE estimates suggest that storage capacity is between 5.2 and 146 billion tons of CO<sub>2</sub> (Takagi, 2010).

<sup>35</sup> Storage cost can be further disaggregated into three cost elements, CO<sub>2</sub> injection cost, Geological survey cost, and long-term monitoring cost (Akimoto, 2006).

<sup>36</sup> The cost of CCS is typically listed in dollars/tonne sequestered. This cost includes normalized CAPEX and OPEX values, capitalized over periods of up to twenty years. There is significant uncertainty in actual costs, and this is part of the challenge facing CCS demonstration and deployment.

*Storage* costs can be disaggregated into three elements: injection cost, geological survey cost and monitoring cost (Akimoto, 2006). Each of these cost elements will vary according to the availability, type and location of geological storage sites. There are a number of different geological formations that may serve as storage sites, including saline aquifers, depleted oil and gas fields, and coal seams, both onshore and offshore. The injection cost element for each of these sites would depend on the maximum permissible injection rate, which in turn depends on the well penetration rate (Nakagawa, 2008). Offshore injection cost is higher due to greater upfront capital expenditure requirements, for construction of an offshore platform or subsea wellhead, or in the form of extended reach drilling to access subsea formations (Takagi, 2007; Nakagawa, 2008). However, offshore monitoring costs may be lower relative to onshore monitoring, due to lower risk to human health and safety from CO<sub>2</sub> leakage at offshore sites. Geological survey cost and monitoring cost depend on the state of pre-existing knowledge about particular storage sites, for example, in the form of data generated from previous extraction activity at a particular site. The cost of monitoring is highly uncertain, as monitoring needs may extend hundreds of years into the future to ensure that CO<sub>2</sub> remains sequestered and avoids contributing to climate change.

Estimates of *transport* and *storage* cost in Japan run counter to these norms in several respects. First, onshore pipelines in Japan are more costly than offshore pipelines, and transport in general is more expensive than elsewhere in the world (Akimoto, 2006; Takagi, 2007). Onshore pipeline cost is high due to population density and limited landmass in Japan, and the lack of pipeline 'right-of-way' legislation, which would necessitate negotiations with multiple landowners for pipeline siting, or the construction of pipelines under public roads (Takagi, 2007; Terada, 2010). Second, a scarcity of onshore storage sites, and proven storage capacity proximate to large point source increases both transport and storage costs, since pipelines must extend longer distances and offshore. An RITE survey<sup>37</sup> of major emission sources, including iron and steel facilities, relative to proven geological storage capacity, has shown that there is lack of proven storage sites (and geological data for areas) nearby many emission source concentrations (Nakagawa, 2008). Third, low penetration rates at known Japanese storage sites would allow only low injection rates, and increase storage costs (Takagi, 2007). These points underscore the need to conduct additional studies, drilling and seismic surveys, and storage demonstrations in Japan, so to locate storage sites with higher penetration rates, at closer proximity to large point sources (Nakagawa, 2008; Takagi, 2010). Given these factors, transport and storage costs in Japan may be significantly higher than the 30% estimate, and may comprise a major portion of an investment decision in CCS. The Japanese steel industry should consider the cost of transport and storage, and not only focus on efforts to reduce capture cost.

## CCS Policy and Regulatory Environment

The integration of the capture, transport and storage elements of the CCS chain requires an enabling regulatory and legal environment. In particular, law and policy may render long-term geological storage of CO<sub>2</sub> feasible, and allow for economically viable transport. Legislation related to, *inter alia*, subsurface resource extraction activities (for oil and natural gas wells, as well as for minerals extraction), pipeline siting 'right of way' legislation, long-term environmental liability legislation (nuisance and toxic discharges, contamination of groundwater, human health and the environment), public health and safety and environmental protection legislation (including water legislation), and international ocean law (London Convention), is relevant in this context.

Certain jurisdictions have advanced regulatory and legal environments in this context.<sup>38</sup> In many cases, existing regulations and legislation for natural resource and mineral extraction can be applied or adapted with modification to CCS.<sup>39</sup> However, a central issue that exists in all jurisdictions, regardless of existing legislation, is how to manage long-term liability for sequestered carbon. The significant time period that injected CO<sub>2</sub> would need to remain sequestered, potentially hundreds of years, is widely understood to be an unmanageable environmental (financial) liability for private entities (Wilson et al., 2007). Instead, it is suggested that liability for long-term storage and monitoring be transferred from private entities to government at some point following a successful sequestration demonstration period. Finally, fostering public acceptance of CCS is an important component for ensuring the integration of the transport and

<sup>37</sup> RITE (2006), 'Report on the development of carbon dioxide geological storage' (in Japanese). Cited in Nakagawa, 2008.

<sup>38</sup> For example, the Canadian Province of Alberta regulates subsurface resource extraction through a series of regulations developed by the Alberta Energy and Resources Conservation Board (ERCB), covering injection, well completion, abandonment, and monitoring.

<sup>39</sup> Again turning to Alberta, existing ERCB regulation for the injection and storage of acid gas (in the process of natural gas extraction and refinement) provide a solid basis of CCS regulation in that jurisdiction (de Figueiredo, 2007).

storage, which in part flows from the deployment of successful demonstration projects (McDaniels and Bowen, 2010).

Japan has little to no domestic experience with fossil fuel extraction, and thus lacks this regulatory and legal background. Without this framework, significant legal and regulatory clarification would be required to enable private demonstration projects to go ahead. For example, pipeline 'right of way' legislation would greatly facilitate the transport element of the CCS chain, and elaboration of long-term environmental liability arrangements would make industry investment in CCS more attractive. Although the Japanese government will likely be heavily involved in demonstration of integrated CCS (see below), regulation is still important for providing guidance to private participation in projects. Firms engaging in integrated CCS projects face a range of risks, including, financial risk (from capital and operating expenditure), regulatory and liability risk, and reputational risk (from an unsuccessful project, imposing additional financial risk), and legal and regulatory clarification will reduce the magnitude of risks and promote deployment (Birat, 2009).

## Japanese Integrated CCS Demonstrations

Japan has yet to host a fully integrated CCS demonstration project, from industrial capture through to geological storage. Nonetheless, the Japanese government has been heavily involved in promoting demonstration of different elements of the CCS chain. In particular, METI and NEDO have funded a number of small-scale demonstration projects and CCS related research. The Nagaoka Pilot (sponsored by METI and overseen by RITE) successfully injected and stored approximately 10,000 tCO<sub>2</sub> (purchased from a commercial source) in an onshore saline aquifer between 2003 and 2005, and monitored storage for three years subsequent (Nakagawa, 2008). There have been several successful industrial capture projects held in partnership between government, and utilities and heavy industry. With respect to steel, NEDO commissioned a bench scale capture project at Nippon Steel's Kimitsu works, which is currently being scaled up from 1 tCO<sub>2</sub> to 30 tCO<sub>2</sub> captured per day (Nippon Steel Engineering, 2010; Takagi, 2010).

There are a number of ongoing and planned demonstration projects, which should generate the first Japan integrated CCS project in coming years. Two METI projects; 'Demonstration of CO<sub>2</sub> Reduction Technologies', and 'Development of Assessment Technologies and Site Screening', and one NEDO project; 'Feasibility Study – CCS Total System, CO<sub>2</sub> capture at IGCC (integrated gasification combined cycle) and storage at an offshore depleted gas field' are the main initiatives behind these future projects (Abe, 2010). The latter NEDO project is engaged in developing the first integrated Japanese CCS project, linking the Nakoso IGCC power plant and the depleted offshore Iwaki-Oki gas field (Abe, 2010). Capture tests occurred between 2008 and 2010, and injection is scheduled for 2015 (Terada, 2010). This project is being undertaken in partnership with the Japan CCS Company, a consortium of 37 Japanese firms (including 3 iron and steel group firms)<sup>40</sup> with an interest in CCS development. The METI projects have also commissioned studies by the Japan CCS Company on potential storage sites. These studies have highlighted the Tomakomai offshore aquifer as a promising site, which could be accessed from shore through extended reach drilling (Abe, 2010; Terada, 2010). Additional notable initiatives with respect to geological sequestration are the 'Coolgen'<sup>41</sup> project and the 'Innovative Zero-emissions Coal-fired Power Generation'. Coolgen seeks to sequester CO<sub>2</sub> captured from a J-Power IGCC plant in an aquifer beneath the inland Seto Sea, while the ambitious latter project aims to transport CO<sub>2</sub> captured in Japan by ship to overseas storage sites (Oshumi, 2009; Takagi, 2010).

## Next Steps

As noted above, Japanese electricity companies are leading the way with integrated CCS demonstration. J-Power, for example, is taking initiative with Chugoku Electric to develop the Coolgen project, and is also a partner in the Australian Callide Oxyfuel Project, which aims to be the world's first operational integrated CCS system at a commercial scale power plant.<sup>42</sup> Whether this is due to the Japanese government or Japan CCS Company choosing to focus integrated CCS demonstration efforts on electricity applications, nonetheless the steel industry has shown little initiative in developing the transport and sequestration portions of their CCS ambition.

<sup>40</sup> The three firms are: JFE Engineering Corporation, Nippon Steel Engineering, and JFE Steel Corporation.  
[http://www.japanccs.com/en\\_japanccs/index.html](http://www.japanccs.com/en_japanccs/index.html)

<sup>41</sup> <http://www.jpowers.co.jp/english/ir/pdf/2010-11.pdf>

<sup>42</sup> <http://www.jpowers.co.jp/english/ir/pdf/2010-11.pdf>

However, there are good reasons for the Japanese steel industry to become involved in CO<sub>2</sub> transport and storage. The high cost attached to transport and storage in Japan is the first reason. The two most promising storage sites identified by METI and NEDO (see above) are relatively distant from the bulk of iron and steel emission sources, most of which concentrated in the Tokyo Bay, Osaka Bay, and Seto Inland Sea areas (Nakagawa, 2008). If the steel industry hopes to use CCS as a future mitigation option, it will need to identify storage sites at close proximity to its point sources to make CCS economical (Takagi, 2010). The first step in this regard is drilling and seismic surveys, followed by injection tests to demonstrate permanence of storage, which the steel industry could promote and fund (Nakagawa, 2008; Takagi, 2010). The second reason for the industry to demonstrate integrated CCS is to solidify their position as global technological leaders. The EU steel industry is currently leading the global development of integrated CCS due to the efforts of ArcelorMittal, and could take the top position as technological leaders above Japan. Given the importance of technological leadership to the Japanese steel industry brand and reputation, they may want to ensure that they do not fall behind their European counterparts in CCS.

There may be some opportunities for the steel industry to piggyback on other transport and storage projects, by linking up to those projects' infrastructure. Investment by the steel industry in projects that could potentially be accessible to their emission sources, such as the Coolgen project in the Seto Sea, could be one interim solution prior to developing steel industry specific demonstration projects.

Finally, it is important to note the role of government in next steps to promoting CCS demonstration by the steel industry. First, the level of ambition signalled by government will affect the willingness of industry to participate, and in this respect the Japanese government has not given particularly clear or ambitious signals. The year 2020 has been identified as a goal for deploying CCS, but the exact terms of this deployment and the overall goal have yet to be determined by the Japanese cabinet (Terada, 2010). In addition, and as mentioned above, the Japanese government can play a constructive role in moving CCS forward through the development of a supportive legal and regulatory environment.

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Climate Strategies is an international organisation that convenes networks of leading academic experts around specific climate change policy challenges. From this it offers rigorous, independent research to governments and the full range of stakeholders, in Europe and beyond. We provide a bridge between research and international policy challenges. Our aim is to help government decision makers manage the complexities both of assessing the options, and of securing stakeholder and public consensus around them. Our reports and publications have a record of major impact with policy-makers and business.

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