worldsteel
ASSOCIATION

FACT SHEET
Breakthrough technologies

Breaking through the technology barriers

Steel producers are researching new production technologies that would radically reduce their environmental footprint.

The steel industry has identified climate change as a major challenge for more than two decades. Long before the findings of the Intergovernmental Panel on Climate Change (IPCC) 2007, major steel producers recognised that solutions are needed to tackle CO_2 emissions. They have been highly proactive in improving energy use and reducing greenhouse gas emissions, and are now operating close to the limits set by steel production technologies.

The best steel mills are now limited by the laws of thermodynamics in how much they can still improve their energy efficiency. With most major energy savings already achieved, further large reductions in CO_2 emissions are not possible using present technologies. The kind of further reductions being called for by governments and international bodies require the invention and implementation of radical new production technologies.

The CO_2 Breakthrough Programme

A set of breakthrough technologies is needed; the kind of paradigm shift in industrial production that can change the way steelmakers around the world operate. In 2003, the World Steel Association (worldsteel) launched the 'CO_2 Breakthrough Programme', an initiative to exchange information on regional activities all over the world.

Research is taking place in:

- the EU (ultra-low CO_2 steelmaking, or ULCOS 1)
- the US (the American Iron and Steel Institute)
- Canada (the Canadian Steel Producers Association)
- South America (ArcelorMittal Brazil)
- Japan (Japanese Iron and Steel Federation)
- Korea (POSCO)
- China (Baosteel) and Taiwan (China Steel) and
- Australia (Bluescope/One Steel and HIsmelt).

The various regional programmes call on a range of industrial expertise from steel producers, energy generators, plant designers and equipment manufacturers. They also call on scientific expertise from labs and academic institutions the world over.

The programmes identify steelmaking technologies that hold the promise of large reductions in CO_2 emissions. They explore their feasibility at various scales, from lab work to pilot plant development and eventually commercial implementation. At the worldsteel CO_2 Breakthrough Programme, participants keep each other updated to avoid unnecessary duplication and to learn from each other.

There are no restrictions placed on the scope of the projects, and the output is intended to be breakthrough technologies that can completely revolutionise the way steel is made. Each regional initiative explores the solutions that seem best fitted to local constraints and cultures.

Five key directions

Five possible directions are under examination:

- **Coal** – would continue to be used as a reducing agent but the ensuing CO_2 would have to be captured and stored. The approach is similar to the power industry's effort to cut emissions from fossil fuel power plants, although the steel production solutions propose oxygen operation and in-process CO_2 capture rather than oxyfuel combustion and pre- or post-combustion capture. Ironmaking solutions range from the blast furnace, deeply modified to accommodate CCS (the new field of carbon capture and storage) as in the ULCOS 'top gas recycling blast furnace', to smelting reduction processes such as Isarna, HIsmelt, Finex, etc., also similarly re-designed.

- **Hydrogen** – could be used as a reducing agent, as its oxidation produces only water. Hydrogen, either pure, as a synthesis gas (syngas) produced by reforming methane or as natural gas, can be used in conventional direct-reduction reactors or in more futuristic flash reactors. Th is hydrogen needs to be produced using carbon-lean processes: water electrolysis or natural gas reforming. Both may include CCS at their own level. This research direction is closely related to the model of the Hydrogen Society.

- **Electrons** – could also be used as reducing agents. They can be provided by electricity, for which the corresponding process is the electrolysis of iron ore, or by bacteria. The EU and the US are exploring only the first path, as bacteria that fully reduce ore to metallic iron have not been identified. Electricity in this case would be produced using carbon-lean technologies.

- **Biomass** – can be used to generate the reducing agent, either from charcoal for example or syngas. Biomass in such a scheme would need to be grown in a sustainable way, but can originate from plantations in tropical countries or from agriculture or forestry residues in more temperate climes. Interest in biomass is strong in Brazil, Australia, Canada and Europe. Biomass can be used in charcoal-based blast furnaces, added to the coke oven charge, burned as fuels in steelmaking reactors or used in direct reduction as syngas, etc.

- **CCS** – use of carbon capture and storage technology is a necessary precondition to the continued use of fossil fuel based reducing agents in steel production. This emerging technology could be based on various capture and storage options, some of which only need to be adapted to the steelmaking context, while others still need basic research. Storage can be in deep saline aquifers, depleted oil or gas fields, in coal mines as geological storage, or turned back into carbonates (mineralogical storage). Waste-gas from steel production differs from that of other industries by its CO_2 content (usually higher), dust content, composition of minor gases (CO_2, CO, etc.), temperature and pressure. Specific studies are therefore actively being carried out in the various initiatives.

Over 100 new technologies identified

All these avenues are being explored in parallel, as solutions for Europe's steel industry may not fit Japan's or Australia's needs. This is why a diversity of research pathways is necessary.

The various exploratory programmes have already identified more than 100 new technologies, and classified them in terms of the CO_2 reduction they could achieve. Some technologies are ready to use but would deliver only a small reduction in CO_2 emissions. The more ambitious projects in terms of CO_2 reduction are now going through various steps of scaling up from lab to commercial reality.

The coal-based ironmaking technologies associated with CCS are the most likely candidates for early maturity. Hydrogen and electrolysis are further into the future, as these technologies will require deeper re-engineering of steel production and the development of new processes from first principles. Biomass solutions are probably in the intermediate future.

In the even longer term, new avenues of research are likely to emerge. These include the integration of steelmaking with solar power generation, with new energy technologies and with new, fourth or even fifth generation nuclear power plants. Such solutions are not yet part of the ongoing programme, but could be added in the near future.

Programme	Involving	Purpose	Best results
AISI - technology roadmap programme[1] (US)	Public private partnership between AISI and the US Department of Energy's (Doe), Office of Industrial Technology	Joint DOE/AISI collaborative programme designed to (1) increase energy efficiency, (2) increase competitiveness of North American steel industry, (3) improve the environment. Different to other programmes because steel programme is required to pay back the federal cost sharing.	(1) Suspension Hydrogen Reduction of Iron Oxide Concentrate; (2) Molten Oxide Electrolysis
POSCO CO_2 Breakthrough Framework	POSCO, RIST, POSLAB, POSTECH	Objective is to find new solutions for CO_2 emission reduction in the steel industry, and climate change adaptation using steelmaking by-products. The framework consists of six projects: (1) Pre-reduction & heat recovery of hot sinter, (2) CO_2 absorption using ammonia solution, (3) Bio-slag utilisation for the restoration of marine environments, (4) Hydrogen production using COG and wastes, (5) Iron ore reduction using hydrogen-enriched syngas, and (6) Carbon-lean FINEX process.	(1) CO_2 absorption using ammonia solution, (2) Carbon-lean FINEX process
COURSE50 (Japan)	Japanese Iron and Steel Federation (JISF), Japanese Ministry of Economy, Trade and Industry	Objective is to develop innovative technologies to help solve global environmental problems. Includes R&D projects, public relations activities and promotes industry/ institute cooperation.	(1) Scenario-making for global warming mitigation; (2) CO_2 separation, capture and storage; (3) CO_2 fixation by plants and its effective use
ULCOS - Ultra-Low Carbon dioxide Steelmaking[2] (EU)	All major EU steel companies, energy and engineering partners, research institutes and universities. Also supported by the European Commission	Cooperative R&D initiative to research radical reductions in Carbon Dioxide (CO_2) emissions from steel production. Includes process science, engineering, economics and foresight studies in climate change.	(1) Top Gas Recycling Blast Furnace with CO_2 Capture and Storage (CCS); (2) ISARNA with CCS; (3) Advanced Direct Reduction with CCS; (4) Electrolysis

Last updated: December 2009

Footnotes:

1. www.steel-trp.org
2. www.ulcos.org