

## FACT SHEET

### Climate change mitigation by technology, innovation and best practice transfer



Steelmakers are involved in many programmes to transfer technologies and best practices, thereby improving or replacing existing processes or reducing process steps. Steel producers are researching and investing in low carbon technologies that would radically reduce their environmental impact.

The steel industry has made significant improvements in efficiency in the last decade by reducing energy input and CO<sub>2</sub> emissions. The industry considers itself to be at the forefront of mitigating climate change, it has always recognised that a change in the type of technology used to make steel is needed to reduce carbon emissions to the level that will meet the two-degree scenario under the Paris agreement.

Modern steel plants operate at the limit of energy efficiency and intensity by the laws of thermodynamics using carbon. Employing the best practice and current technologies have provided the ability to maximise the energy efficiency process, which minimises emissions of CO<sub>2</sub>. The CO<sub>2</sub> generated in the steel industry results from the chemical reaction between coke and coal (carbon) and iron ore in a blast furnace. This process is called iron ore reduction and produces hot metal (near pure iron), which is subsequently converted into steel. Presently no large-scale volume production processes are available to replace the use of carbon in iron and steelmaking.

Modern integrated iron and steel plants recirculate all the process gases back into the production processes to recover energy from heat and generate electricity or use the heat for other processes, thus increasing efficiency, reducing the need for external energy and effectively reducing greenhouse gas emissions.

An increasing number of countries around the world are taking economic measures to reduce their CO<sub>2</sub> emissions through emission trading schemes (for example, the EU and South Korea), carbon taxes or energy efficiency initiatives.

#### Technology and best practice transfer

worldsteel member companies see technology and best practice transfer as part of the solution – bringing all the major steelmaking companies up to the best in class as quickly as possible. The objective is to disseminate best practices without compromising competitiveness. worldsteel members exchange information through projects, workshops, as well as participate in conferences for

expert groups and committee meetings on innovation, technology, environment, raw materials quality improvement product sustainability and safety and health. There are online benchmarking tools available for worldsteel members to enable optimisation of energy intensity, emission intensity, reliability performance, process yields, safety and health and sustainability performance. These systems can be used by members for internal benchmarking or to compare themselves with peer companies or sites. These are powerful processes to determine internally where the best practices are and ensure these are transferred within the company to reach the best operational level.<sup>1</sup> The data can also be used to see how their best performance measures with the rest of the industry. This enables the companies to transfer knowledge and practice by agreement.

worldsteel regularly produces technical reports on major issues or concerns that are impacting the steel industry. These reports are aimed at improving the operating and environmental performance of the steel industry and form the basis for the internal online benchmarking. Examples of topics in the recent technical publications are process yield, by-products, raw materials beneficiation, energy use, maintenance and reliability, air quality and water management in the steel industry. worldsteel is also recognised as a world leader in life cycle assessment, which uses the data from steel companies to determine the overall environmental impact of steel products at the time of making steel but also assessing its impact on the end product in the use phase.

#### The CO<sub>2</sub> breakthrough programme

Modern steel plants operate near the limits of practical thermodynamic efficiency using existing technologies. With most major energy savings already achieved, further large reductions in CO<sub>2</sub> emissions are not possible with the existing technologies. The targets set out by governments and international bodies require breakthrough technologies via innovation and exploration of new production processes.

Table 1: Breakthrough programmes (past or postponed programmes are highlighted in light blue in the table)

Programme	Involving	Purpose	Best results
Baosteel programme	Baosteel (China)	Objective is to reduce emissions from flares.	(1) Photovoltaic cells (2) Ethanol production from BOF gas (LanzaTech).
China Steel Corporation (CSC)	Taiwan CCS Alliance coordination (Taiwan)	The Alliance is focusing their research activities on two main technologies: the oxy fuel burner technology which aims at purifying CO <sub>2</sub> by burning without nitrogen content and the chemical absorption pilot plant which seeks to further decrease energy consumption per unit of CO <sub>2</sub> captured. Additionally, academic cooperation projects in CSC include BOF slag carbonation and microalgae carbon fixation.	(1) CO <sub>2</sub> purification; (2) Energy use reduction; (3) BOF slag carbonation and microalgae carbon fixation.
COURSE50	Japan 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 <sub>2</sub> separation, capture and storage; (3) CO <sub>2</sub> fixation by plants and its effective use; (4) Hydrogen reduction has been tested with interesting results, limits have also been identified.
POSCO CO <sub>2</sub> breakthrough framework	POSCO, RIST, POSLAB, POSTECH	Objective is to find new solutions for CO <sub>2</sub> 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 <sub>2</sub> absorption using ammonia solution, (3) Bio-slag utilisation for the restoration of marine environments, (4) Hydrogen production using coke oven gas and wastes, (5) Iron ore reduction using hydrogen-enriched syngas, and (6) Carbon-lean FINEX process.	(1) CO <sub>2</sub> absorption using ammonia solution; (2) Carbon-lean FINEX process.
Hlsarna ironmaking process	ArcelorMittal, Tata Steel, ThyssenKrupp and voestalpine	E-designed smelting reduction process. The Hlsarna ironmaking process has reached a sizeable pilot stage.	Potential reduction of approximately 20% of CO <sub>2</sub> per tonne of steel produced.
ULCOS Ultra-low carbon dioxide steelmaking (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 <sub>2</sub> ) emissions from steel production. Includes process science, engineering, economics and foresight studies in climate change. (more details on this project are available in the Carbon section below)	Top gas recycling blast furnace with CO <sub>2</sub> capture and storage (CCS); (2) Hlsarna with CCS; (3) Advanced direct reduction with CCS; (4) Electrolysis.
AISI Technology roadmap programme	Public-private partnership between AISI and the US Department of Energy (DOE), Office of Industrial Technology	Joint DOE/AISI collaborative programme designed to (1) increase energy efficiency, (2) increase competitiveness of the North American steel industry, (3) improve the environment. Different to other programmes because the steel programme is required to pay back the federal cost sharing.	(1) Suspension hydrogen reduction of Iron oxide concentrate; (2) Molten oxide electrolysis.
Australian programme	BlueScope Steel and OneSteel, CSIRO coordination (Australia)	CSIRO working with BlueScope and OneSteel on two projects aimed at cutting CO <sub>2</sub> emissions: biomass, which uses renewable carbon derived from biomass in steel manufacturing and heat recovery from molten slags through dry granulation, which captures the waste heat released from slag cooling, thus reducing CO <sub>2</sub> emissions. These programmes received large support from the Australian government.	(1) CO <sub>2</sub> emissions decrease through the use of biomass and by-products.

worldsteel facilitates a global technology innovation forum and has set up an expert group attended by its members. Initially, seven national and regional programmes on breakthrough technologies exchanged information on their projects, shared improvements and identified gaps or overlaps in research. This was already established early in 2000. Table 1 shows an overview of the programmes. The various regional programmes call on a range of industrial expertise from steel producers, energy generators, plant designers and equipment manufacturers. They also benefit through scientific expertise of research laboratories, universities and academic research institutions across the globe.

The programmes identify steelmaking technologies most likely to succeed in reducing CO<sub>2</sub> emissions. Feasibility studies are carried out on various scales – from lab work to small pilot plant, and eventually commercial-sized implementation or testing the improvement at an existing plant. Participants share updates annually to avoid unnecessary duplication and learn from each other, during the pre-competitive stage of the projects. There are no restrictions placed on the scope of the projects, and the output is intended to be aspirational and develop breakthrough technologies that can reduce the GHG emission to atmosphere by at least 50%, potentially revolutionising the way steel is made.

Each regional initiative explores the solutions that seem best suited to local constraints, energy generation sources and raw materials.

Four possible directions are under examination:

- Carbon** – will continue being used as a reducing agent but the CO<sub>2</sub> produced will need to be captured and stored. The approach is similar to the power industry's effort to cut emissions from fossil fuel-based power plants but the steel production solutions include maximum use of scrap, best practice operations and CO<sub>2</sub> capture for storage. This is in contrast to oxy-fuel combustion and pre- or post-combustion capture. In this context, the ironmaking solutions include the blast furnace with integrated CCS as in the Hlsarna programme, which is a re-designed smelting reduction process enabling a potential reduction of approximately 20% of CO<sub>2</sub> per tonne of steel produced.
- Hydrogen** – used as a reducing agent replacing carbon, as the reaction produces only water vapour. Hydrogen, either pure or as a synthesis gas (syngas) through reforming methane or natural gas, can be used in conventional direct-reduction reactors or in more futuristic flash reactors. The hydrogen will need to be produced using carbon-free energy hydro, nuclear, or renewable for the new processes such as water electrolysis or natural gas

reforming – which require high-pressure steam or carbon-free electricity - otherwise, it would defeat the purpose as the energy requirement is higher than using it directly in the steelmaking process. The energy used in a hydrogen reduction process is significantly higher than with carbon due to its cooling effect and may require 4-5 times the energy needed currently. This energy also needs to be generated from carbon-free sources to avoid shifting the emissions elsewhere.

- **Biomass** – can be used to generate the reducing agent (carbon), either from charcoal, for example, or syngas. Biomass in such a scheme would need to be grown effectively near the place of use and in sufficient quantities to make it economically viable and sustainable. Interest in biomass is strong in Brazil, Australia, Canada and Europe. Biomass can be added as charcoal in blast furnaces, to the coke oven charge, burned as fuel in steelmaking reactors or used in direct reduction as syngas etc. A balance needs to be considered in the amount of land area used to grow the biomass and the volume of steel required in the region.
- **CCS** – carbon capture and storage technology (CCS) is a necessary process to achieve the large shift in emissions to the atmosphere, it requires storing the CO<sub>2</sub> or using it for other purposes. Storage can be in deep saline aquifers, depleted oil or gas fields, compensate for existing gasfield extraction or enhanced oil/gas recovery and used in coal mines as geological storage, or turned back into carbonates (mineralogical storage). Process gas from steel production differs from that of other industries by its CO<sub>2</sub> and dust content, the composition of minor gases, temperature and pressure. Specific projects have been completed over the past decades in the EU, Japan, China and USA. Many uses for the CO<sub>2</sub> have also been developed such as gaseous cement used as reef replacement or building water barriers. Emirates Steel in the United Arab Emirates is involved in a project, whose aim is to capture, and use the CO<sub>2</sub> for enhanced oil recovery (EOR) and store 800,000 tonnes of CO<sub>2</sub> from its steel plant annually<sup>2</sup>. The project was completed in 2016.

The breakthrough programmes have identified over 40 technologies of which seven show promise. The most promising projects in terms of CO<sub>2</sub> reduction are now going through various stages with few technologies progressing from laboratory stage to pilot plant and their potential, constraints and technical limits are being evaluated.

The most likely to succeed are still carbon-based ironmaking technologies coupled with CCS. Biomass solutions may be an intermediate future. Hydrogen-based steelmaking is upcoming but the energy sources are an issue if they are not carbon-free. Funding of the projects has been difficult in the short-term as economic realities have hit most regions over the past ten years, from the seven projects only four are being actively continued (see table 1), research being postponed or test facilities being deferred over years rather than months. Funding is needed to drive the innovation as quickly as it is needed to meet the two-degree scenario.

New avenues of research are being considered such as integration of steelmaking with renewable energy storage technologies and next-generation nuclear power plants etc. Power generation solutions are not yet part of the ongoing programmes, but may be added in the near future.

worldsteel completed the energy intensity project in 2013. This landmark project also included a global survey of 190 energy-efficient technologies that are available to the steel industry. Some of these technologies are mature and widely used while the others are showing less promise. Among the technologies reviewed, a pattern was identified that energy savings were the most practical in only 30% of the commonly used technologies. These, when fully and reliably utilised, allow steel producers to reach the best in class. Adding further technologies will not create additional energy savings and in fact, may cause a waste of energy<sup>3</sup>.

### Importance of raw materials

The quality of raw materials strongly influences the energy consumption and emissions in iron and steelmaking and high-quality raw materials at an economic level are necessary for an efficient operation. Good quality iron ore has an iron content of 63-68% and low levels of contaminants. Iron ore beneficiation at the mine is the most efficient and significantly less capital intensive and can supply higher quality raw material economically. The quality of coal is equally important and can be achieved through beneficiation in a similar way at the mine.

Beneficiating ore and coal at the mine allows for energy efficient production of raw materials and providing a return of the unusable material back into the mine as well as minimising transportation of materials. Such improvements in the supply chain can significantly reduce the use of coal, energy or generated by-products at the steelmaking site<sup>4</sup>

### Steel: the permanent material in the circular economy<sup>5</sup>

The steel industry supports the circular economy by ensuring the maximum value of resources through **reducing** the amount of material, energy and other resources used; **recovery and reuse**; **remanufacturing**; and **recycling**.

Steel is a material which is 100% recyclable and can be reused indefinitely. This recyclability goes hand in hand with sustainability as the need for virgin resources is reduced significantly. Recycled steel also entails much lower energy consumption – manufacturing steel from scrap requires about a third of the energy needed in comparison to producing it from iron ore, resulting in decreases in CO<sub>2</sub> and overall greenhouse gases.

Due to the long life of steel products and the high demand for steel, there is not enough scrap available to meet all the demand for recycled material. The economics of collection, recovery and recycling is usually governed by the relative price of virgin raw materials. If ore prices are low, the balance shifts towards primary sources; similarly, if scrap is in abundance, it becomes more economically viable. The industry must continuously balance overall energy optimisation and costs with the use of iron ore, coal, and scrap in order to deliver the best quality material to suit the customers' demand.

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1. worldsteel.org, Steel by topic section, Technology category, <http://www.worldsteel.org/steel-by-topic/technology.html>.
2. CO2 Capture Project: <https://www.emiratessteel.com/index.php/en/corporate-responsibility/environmental/co2-capture-project>
3. Energy use in the steel industry report, worldsteel.org, 2014, 2015.
4. Raw materials improvement report, worldsteel.org, 2013.
5. Steel - The permanent material in the circular economy, worldsteel, 2016