worldsteel ASSOCIATION

FACT SHEET

Addressing climate change through technology transfer and research

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

The steel industry has made significant improvements in energy use and efficiency in the last two decades thereby reducing CO_2 emissions. As an industry at the forefront of tackling the challenges of climate change, it recognises that breakthrough technologies are needed to further reduce carbon emissions.

A majority of modern steel plants are operating at the limits of energy efficiency and intensity by the laws of thermodynamics. Employing advanced technologies maximises energy efficiency which minimises emissions of CO_2.

The CO_2 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_2 emissions through emission trading schemes (for example: EU and South Korea), carbon taxes or energy efficiency initiatives.

Technology transfer

worldsteel member companies see technology and best practice transfer as part of the solution – bringing all the major steel-producing companies up to the best in class as quickly as possible. The objective is to disseminate best practices without compromising competitiveness.

worldsteel members regularly exchanges information through projects, workshops, as well as meetings of expert groups and committees on safety and health, innovation, technology, environment, raw materials quality improvement and product sustainability. There are online benchmarking tools available for worldsteel members as a drive to optimise safety and health improvement, energy intensity, emission intensity, reliability performance, process yields and sustainability performance. These systems can be used by members for internal benchmarking or compare themselves with peer companies or sites. These are powerful tools to transfer knowledge and practice across the industry.[1]

worldsteel regularly produces technical reports on major subjects impacting the steel industry. These reports are aimed at improving the economic and environmental performance of the steel industry and form the basis for internal online benchmarking systems.

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_2 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_2 emissions are not possible with the available technologies. The targets set out by governments and international bodies require breakthrough technologies via innovation and exploration of new production technologies.

worldsteel facilitates a global technology innovation forum and has set up an expert group from its membership. 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_2 emissions. Feasibility studies 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_2 produced captured and stored. The approach is similar to the power industry's effort to cut emissions from fossil fuel-based power plants; although the steel production solutions propose pure oxygen-based operation and in-process CO_2 capture. This is in contrast to oxy-fuel combustion and pre- or post-combustion capture. In this context the ironmaking solutions range from the blast furnace with integrated CCS as in the HIsarna programme, which is a re-designed smelting reduction process.
- 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 needs 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 steel making process.
- 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.

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_2 by burning without nitrogen content and the chemical absorption pilot plant which seeks to further decrease energy consumption per unit of CO_2 captured. Additionally, academic cooperation projects in CSC include BOF slag carbonation and microalgae carbon fixation.	(1) CO_2 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_2 separation, capture and storage; (3) CO_2 fixation by plants and its effective use; (4) Hydrogen reduction has been tested with interesting results, limits have also been identified.
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 coke oven gas 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.
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 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_2 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_2 emissions. These programmes received large support from the Australian government.	(1) CO_2 emissions decrease through the use of biomass and by-products.
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_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) Advanced direct reduction with CCS; (3) Electrolysis.

- **CCS** – carbon capture and storage technology (CCS) is a necessary technology at present to achieve the large shift in emissions to atmosphere and to store it or use it for other purposes. 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). Process gas from steel production differs from that of other industries by its CO_2 and dust content, 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_2 have also been developed such as gaseous cement used as reef replacement or building water barriers. Emirates Steel in the United Arab Emirates is currently taking part in a project, whose aim is to capture, and use the CO_2 for enhanced oil recovery and store 800,000 tonnes of carbon dioxide (CO_2) from its steel plant annually[2]. The project is scheduled to be completed by 2016.

The various exploratory breakthrough programmes have identified over 40 technologies of which seven show promise. The more ambitious projects in terms of CO_2 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 are probably in the intermediate future. Hydrogen-based steelmaking is up-coming but the energy sources are an issue if not carbon free. Funding of the projects has been difficult in the short term as economic realities have hit most regions over the past eight 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.

Energy intensity project

worldsteel completed the energy intensity project in 2013. This landmark project included a global survey of 190 energy-efficient technologies that are used in the steel industry. Some of these technologies are mature and widely used while the others are still under development. 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. Further addition of new technologies would not create additional energy savings[3].

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 to ore 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[4].

Importance of 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_2 and overall greenhouse gases.

By sector, global steel recovery rates are estimated at 85% for construction, 85% for automotive (reaching close to 100% in the US), 90% for machinery, and 50% for electrical and domestic appliances.

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 from recycled material. The average life for steel products is 45 year approximately. The time to recycling can vary from a few weeks in the case of steel packaging, to vehicles which may last up to 15 - 20 years or infrastructure and buildings which may last up to 50 - 100 years.

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.

Steel: the permanent material in the circular economy

The steel industry supports the circular economy by promoting 4Rs, Reduce – Reuse – Remanufacture – Recycle.[5]

Reduce - Decreasing the amount of material, energy and other resources used to create steel and reducing the amount of steel used in products.

Reuse – Reuse is using an object or material again, either for its original purpose or for a similar purpose, without significantly altering the physical form of the object or material.

Remanufacture – The process of restoring durable used steel products to as-new condition.

Recycle – Melting steel products at the end of their useful life to create new steels. Recycling alters the physical form of the steel object so that a new application can be created from the recycled material.

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Footnotes:

1. worldsteel.org, Steel by topic section, Technology category, http://www.worldsteel.org/steel-by-topic/technology.html.
2. Success stories: Reducing the Carbon Footprint, www.esi-steel.com.
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