American Journal of Materials Engineering and Technology, 2018, Vol. 6, No. 1, 8-13
Available online at http://pubs.sciepub.com/materials/6/1/2

DOI:10.12691/materials-6-1-2

Advances in Green Steel Making Technology - A Review

Jitesh Kumar Singh[1,*], Dr. Arun Kumar Rout[2]

[1]Department of Mechanical Engineering, O.P. Jindal University, Raigarh (CG), India
[2]Department of Production Engineering, VSS University of Technology, Odisha, India

*Corresponding author: jitesh.singh@opju.ac.in

Abstract The aim of this research work is to increase the quality, productivity of steel and to reduce the CO_2 emissions from the global manufacturing sector. On average, the production of one ton of steel generates about two tons of CO_2 emission. The main cause for energy inefficiency and environment pollution are outdated steel production technology in use. The green steel is a new steelmaking process lowers green house gas emission, cuts costs and improves the quality of steel. The new process is known as molten oxide electrolysis and the clever use of iron-chromium alloys. When we are using molten oxide electrolysis to create oxygen from the iron in lunar soil and steel was created as a byproduct of steel. This process is limiting carbon emissions. This concept is fundamental to the triple bottom line concept of sustainability, which focuses on the interplay between environmental, social and economic factors. The production of steel results in the generation of byproducts that can reduce CO_2 emissions by substituting resources in other industries. The implementation of green manufacturing focused on investigating the energy saving & CO_2 emission from producing steel & effective utilization of recycling of steel scrap as a way of sustainable development in steel industry.

Keywords: *emission, environment, electrolysis, byproduct, green steel, etc*

Cite This Article: Jitesh Kumar Singh, "Advances in Green Steel Making Technology - A Review." *American Journal of Materials Engineering and Technology*, vol. 6, no. 1 (2018): 8-13. doi: 10.12691/materials-6-1-2.

1. Introduction

Steel industries play a vital and crucial role in the development of a country. They increased the prosperity, employment and opportunities for livelihood. On the other hand they are accelerating the consumption of fossil fuels and releasing solid, liquid and gaseous pollutants in surroundings [1]. The emission of CO_2 is a big problem for steel industries. Increases the productivity through the adoption of efficient technology in production and manufacturing sector will be effective for environment and social development [2]. In this paper we discuss on the growth of productivity, reduced CO_2 emission and environmental change. This paper consolidates the available information on alternatives of emerging the iron making technologies and new emerging efficiency technology to guide the engineers, investors, iron and steel manufacturers, etc [3,4]. This paper helps to give the idea of utilizing green steel technology in iron and steel manufacturers and reducing the carbon emission in environment and increasing efficiency of process.

2. Literature Review

There are several valuable works have been identified that deal with carbon emissions measurements reduction prospects and industrial energy specifically regarding the iron and steel industry in relation with climate change [5]. The emission by iron and steel sectors are about 30% [6]. The several processes are used for making the steel. The main [7] processes are-

I. Coke production
II. Sinter production
III. Raw steel production
IV. Iron production
V. Continuous casting
VI. Hot and cold rolling
VII. Finally finished product preparation.

The secondary process for steel making, where the ferrous scraps is recycled by smelting and refining by an electric arc furnace [8]. The major units of a steel plants are-a. Sinter plants b. Blast furnace c. Coke pushing d. Non recovery cock oven battery combustion stack e. Basic oxygen furnace exhaust [9,10]. The primary combustion sources include the following-coke oven. The primary combustion sources of green houses gases include the cock oven battery combustion stack, blast furnace stove, process heater, reheat furnace, flame suppression system, annealing furnace, other miscellaneous combustion sources etc. for integrated steel making the primary sources of green house gases emissions are blast furnace stove (43%), miscellaneous combustion sources and process gases (30%), other process unit (15%), and indirect emission from electricity usage (12%) [11,12,13]. For coke facilities, the battery stack is the highest source with over 95 percent of the green house gas emission for byproduct coke plants and 99% of the green house gases emission from non recovery plants [14,15]. Industrial energy efficiency can be enhanced by informed management of the energy use by operation and processes [16].

3. Methodology

The various methods of steel making have been studied under this project for green steel manufacturing technology. This are-

I. Pulverized coal injection (PCI)
II. Continuous casting technology (CCT)
III. Coke dry quenching (CDQ)
IV. Coke dry cooling plant (CDCP)
V. Carbon capture and storage (CCS) technology in iron and steel industries

Pulverized Coal Injection- In this process involves blowing large volumes of fine coal granules into the blast furnace. This provides a supplemental carbon source to speed up the production of metallic iron and reducing the need for coke production. As a result, energy use and emission can be reduced. The amount of coal that can be injected will depend on the coke and coal quality, blast furnace geometry and practice of operations. The maximum level of coal that can be injected at the tuyere is around 0.27 t/tone hot metal. The use of oxy-coal enables around 20% increase in coal injection and helps to reduce the coke quantity accordingly. With 170-200 kg/ton hot metal and pulverized coal injection, coke consumption as low as286-320 kg/tone hot metal has been achived in modern blast furnace. Cost of pulverized coal injection plant largely depends of the size of blast furnace and the layout of the plant.

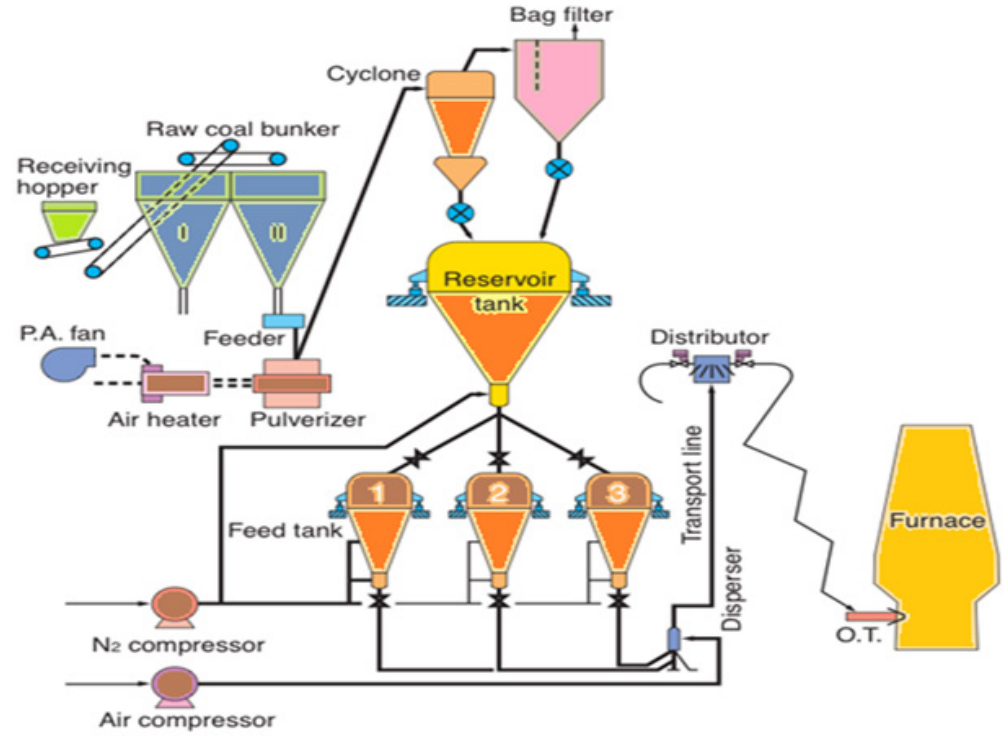

Figure 1. Pulverized Coal Injection

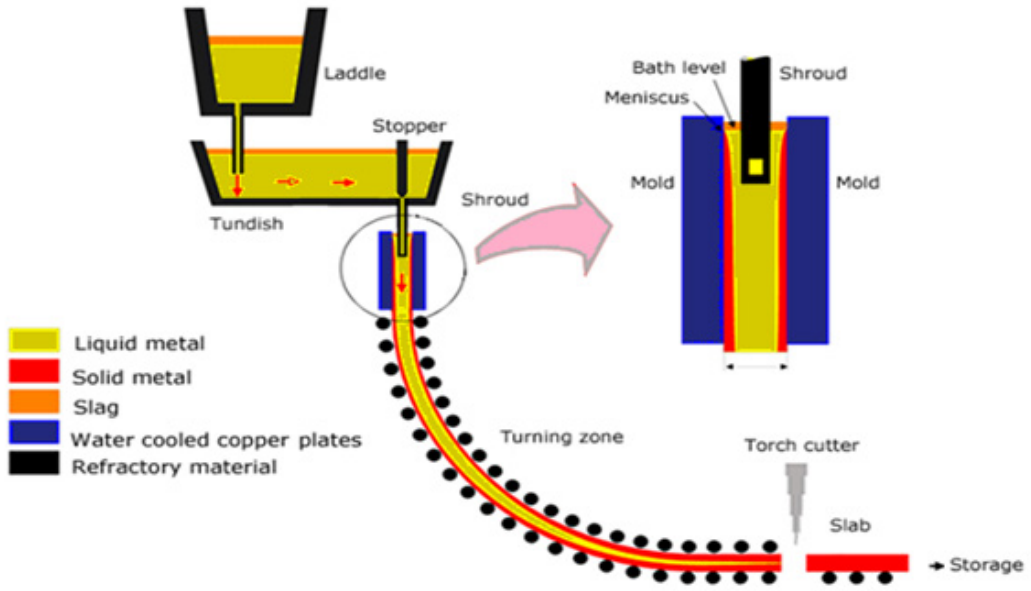

Figure 2. Continuous Casting Process

Continuous Casting Technology- In this process, liquid steel flows out of the ladle into the holding tank and then is fed into a water-cooled copper mold. Solidification begins in the mold and continues through the caster. The strand is straightened and discharge for intermediate storage. A considerable amount of energy is needed to reheat these cast items as part of the subsequent rolling processes for improving energy efficiency and productivity. The various range of continuously cast sections are-

- The cast machines are designed to be billet, bloom or slab caster.
- The conventional bloom casters cast sections above 200 x 200 mm. The bloom length can vary from 4 to 10 m.
- The billet caster cast smaller section sizes, such as below 200 mm square, with length up to 12 m long.
- Conventional beam like I-beams in cross-section vary from 1048 x 450 mm or 438 x 381 mm overall.

Coke Dry Quenching- It is a heat recovery system to quench red hot coke from a coke oven to a temperature appropriate for transportation. It is an energy saving system in which sensible heat of the red hot coke is recovered for power generation. The feature of coke dry quenching process are-

- It is a gradual coke quenching system and improves coke strength and coke size distribution.
- The coke dry quenching coke has lower moisture content than the coke wet quenching coke and the coke ratio of blast furnace can be reduced.
- A high annual operating ratio of 95% can be achived by combining the double flue technology through appropriate refractories and highly reliable equipments.

Coke dust and combustible component in circulating gas are burned by blowing air into gas so that the temperature of the circulating gas can be raised.

- Steam generation of 500 to 700 kg/ton coke and power generation of 140 to 185 kwh/ton coke can be obtained.
- The excellent feature realize the payback period of initial investment within three to five years.

The coke dry quenching is one of the excellent measures to global warming. Recovered heat by coke dry quench is used to generate the stem or electric power which leads to a reduction of fossil fuel usage at power plant. So we can reduce CO_2 emission in total.

Coke Dry Cooling Plant- The dry cooling of coke is known as coke dry quenching and is an alternative to the traditional wet quenching. During wet quenching of run of oven coke the sensible heat of the hot coke is dissipated into the atmosphere and is lost. In a coke dry cooling plant red hot coke is cooled by inert gases. The heat energy from the red coke is recovered in a waste heat boiler for use as steam, resulting the conservation as well as a reduction in coke particle emissions. Hot coke is brought from the battery to the coke dry cooling plant in bottom opening bucket kept on the quenching car. This bucket is lifted at the coke dry cooling plant by a charging device to the top of the coke dry cooling plant chamber and red hot coke is discharged in the chamber for cooling. Hot coke is cooled in the chamber by the inert gas.

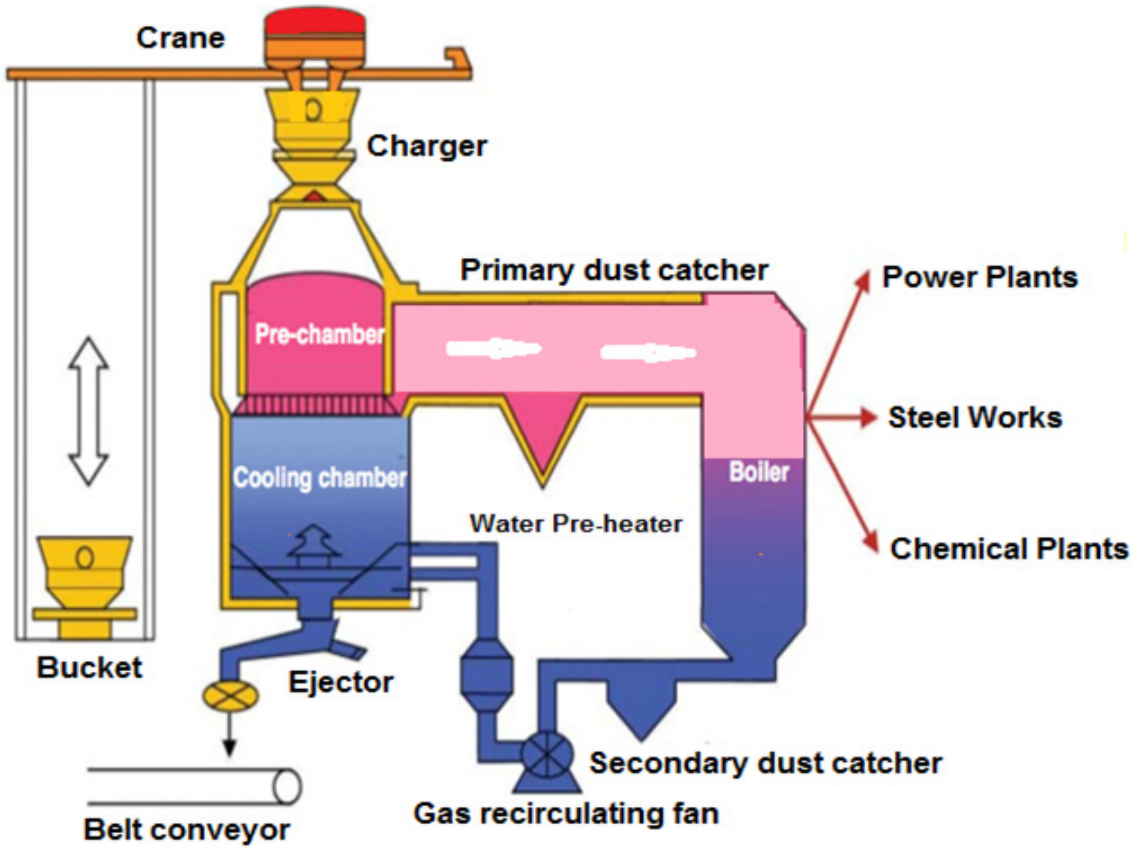

Figure 3. Coke Dry Cooling Plant Flow Process

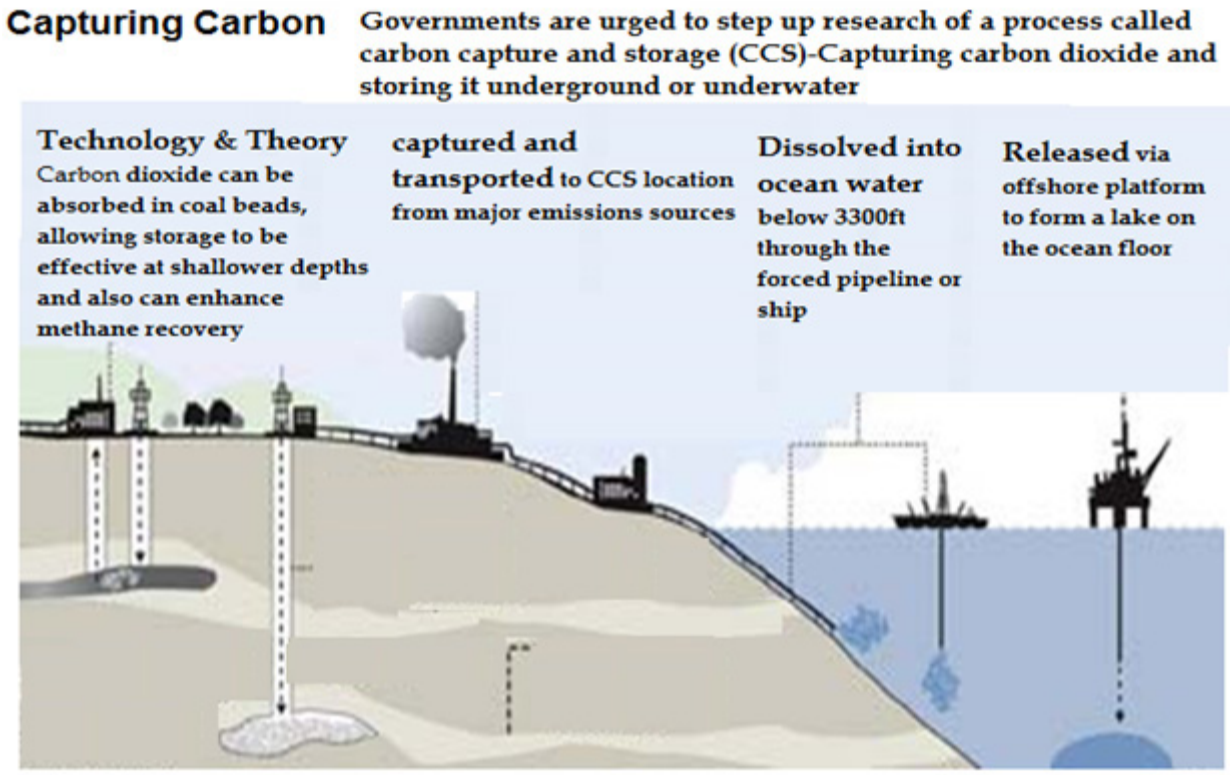

Figure 4. Carbon Capture & Storage (CCS)

In this chamber inert gas moves upwards while the coke moves downwards by the gravity. The coke is discharged at the bottom. The advantages of coke dry cooling are-

- The micron value of M 40 of the coke is improved by 3 to 8%.
- The value of CSR coke is improved by 2%.
- The hot coke is cooled gradually by inert gas so it is free from surface pore and internal cracks normally present in the wet quenched coke.
- Coke dry cooling is economical as compared to wet quenching and red coke is quenched by inert gas in a closed system and is equipped with efficient dust removing facilities, so its avoid the pollution of the atmosphere.
- Coke dry cooling generates from waste heat. Aprox 15-18 MW of power can be generated from a coke dry cooling plant having a capacity of more than 100 tons per hour.
- The moisture continent of coke produced by dry cooling is around 0.2% as compared to that of around 5% in wet quenched coke, so its help in reducing the coke rate in blast furnace.
- Coke dry cooling plant has better reliability and lower maintenance.

Carbon Capture and Storage (CCS) Technology- carbon capture and storage is the process of capturing waste carbon dioxide from large point sources such as fossil fuel power plant and transporting it to a storage site and deposit it where it will not enter the atmosphere, normally an underground geological formation. The aim is to prevent the release of large quantities of CO_2 into the atmosphere. Carbon capture and storage applied to a modern conventional power plant could reduce CO_2 emission to the atmosphere by approximately 80-90% compared to a plant without carbon capture storage. The intergovernmental panel on climate change estimate that the economic potential of carbon capture storage should be between 10% and 55% of the total carbon mitigation effort until year 2100.

Carbon Capture Technology- Carbon dioxide can be separated out of air or flue gas with absorption or membrane gas technology. Absorption or carbon scrubbing with amines is currently the dominant capture technology. Carbon dioxide absorbed to a metal-organic framework through chemisorptions based on the porosity and selectivity of the metal organic framework leaving behind a greenhouse gas poor gas stream that is more environments friendly. The carbon dioxide is then stripped off the metal organic frame work using temperature swing absorption so that metal organic framework can be used. After capturing, the CO_2 would have to be transported to suitable storage sites.

4. Conclusion

- The use of steel scrap reduces carbon emissions from steel life cycle. Reducing the amount of pre consumer scrap generated when steel products are transformed into final consumer goods would have a large impact.
- The production of steel results in the generation of by products that can reduce CO_2 emission by substituting resources in other industries.
- Keeping total global CO_2 emissions at the current level depends on the development and introduction of radical new steelmaking technologies with a lower carbon footprint, including reuse of CO_2. This process may prove successful and will help to lower the emission for the steel industry.

- The implementation of green manufacturing focused on investigating the energy saving & CO_2 emission from producing steel & effective utilization of recycling of steel scrap as a way of sustainable development in steel industry.
- Conducting independent studies and validation on the fundamentals development and operation of this emerging technology can be helpful to private and public sectors as well as academia.
- Analyzing the present situation of iron industry points were the world is now in a dilemma and increased wastage and pollution is default. Then analysis of the relationship between green manufacturing and wastage and pollution in iron industries is done.
- It is pointed out that adequate environment protection in a green iron and steel plant does not just mean an accepted disposal of pollutants emitted from its operation units to optimize the complete manufacturing process of the whole iron and steel plant.

5. Future Scope

- Green manufacturing process is used to improve and to maximize the yield and minimize the waste that is produced.
- Green manufacturing reduces green house gas reduction in iron and steel industries and providing a cleaner source of energy through use of new technology.
- Decreasing energy consumption in green manufacturing process by using energy saving technology and productive efficiency is improving the overall efficiency.
- Increase iron resource efficiency in the steel manufacturing process and emission mitigation of CO_2 by CO_2 capture technology is used.
- Converting pollutants and wastes into byproducts and promote their utilization and recycling along with the use of the product is the main aim of this process.
- Through the finding of this work, recycling of steel scrap is suggested as an alternative to boost the local content of steel production, reduce energy consumption and carbon dioxide emission.
- The implementation of green manufacturing focused on investigating the energy saving and CO_2 emission from producing steel and effective utilization of recycling of steel scrap as a way of sustainable development in steel industry.
- Finally, making the process much better for the environment and better use of the materials that are being used.

References

[1] Allam, R.J., Chiang, R., Hufton, J.R., Middleton, P., Weist, E.L., White, V., 2005. Development of the Sorption Enhanced Water Gas Shift Process, in: Thomas, D., (ed), 2005. Carbon Dioxide Capture for Storage in Deep Geologic Formations - Results from the CO Capture Project, Vol. 1: Capture and Separation of Carbon Dioxide from Combustion Sources, Elsevier Publishing, UK.

[2] Wu Xia and Kuang Xubo. (2008). "Developing Green Manufacturing and Promoting Sustainable Development of Machinery Manufacturing", Market Modernization, Vol. 2, p. 252.

[3] Kim Y, Worrell E. International comparison of CO2 emission trends in the iron and steel industry. Energy Policy 2002; 30(10): 827-38.

[4] Choi, G.N., Chu, R., Degen, B., Wen, H., Richen, P.L., Chinn, D., 2005. CO2 Removal from Power Plant Flue Gas – Cost Efficient Design and Integration Study, in:Thomas, D., (ed), 2005. Carbon Dioxide Capture for Storage in Deep Geologic Formations - Results from the CO2 Capture Project, Vol. 1: Capture and Separation of Carbon Dioxide from Combustion Sources, Elsevier Publishing, UK.

[5] Tang Jianwen (2006), "Green Manufacturing", Journal of Gangdong Plytechnic Nnormal University, Vol. 82.

[6] Ozawa L, Sheinbaum C, Martin N, Worrell E, Price L. Energy use and CO2 emissions in Mexico's iron and steel industry. Energy 2002; 27(3): 225-39.

[7] Benson, S.M., ed., 2005, Carbon Dioxide Capture for Storage in Deep Geologic Formations -Results from the CO Capture Project, Vol. 2: Geologic Storage of Carbon Dioxide with Monitoring and Verification, Elsevier Publishing, UK. 654 pp.

[8] Hurst, P. and Miracca, I., 2005. Chemical Looping Combustion (CLC) Oxyfuel Technology Summary, in: Thomas, D., (ed), 2005. Carbon Dioxide Capture for Storage in Deep Geologic Formations - Results from the CO2 Capture Project, Vol. 1: Capture and Separation of Carbon Dioxide from Combustion Sources, Elsevier Publishing, UK.

[9] Remus R., Aguado Monsonet M.A., Roudier S., Delgado Sancho L., Best Available Techniques (BAT) Reference Document for Iron and Steel Production, Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control); 2012.

[10] Pardo N., Moya J.A., Vatopoulos K., Prospective scenarios on energy efficiency and CO2 emissions in the Iron & Steel industry, Joint Research Centre, 2012.

[11] Yin Ruiyu (2002), "Energy-Saving, Clean Production, Green Manufacturing and Sustainable Development of Steel Industry", Iron and Steel, Vol. 3.

[12] World Steel Association (2013), "Steel's contribution to a low carbon future", World Steel Association Position Paper, Brussels, www.worldsteel.org/publications/position-papers.html.

[13] World Energy Council (WEC). Energy efficiency improvement utilising high technology, an assessment of energy use in industry and buildings. World Energy Council, London, UK: WEC, 1995.

[14] IEA/Unido (2011). Technology Roadmap Carbon Capture and Storage in Industrial Applications. OECD/International Energy Agency IEA and United Nations Industrial Development Organization UNIDO. Paris 2011.

[15] Beer, J., Worrell, E., Block, K., 1998. Future technologies for energy-efficient iron and steel making. Annu. Rev. Energy Environ. 23, 123-205

[16] Bhktavatslam MAK, Choudhury R. Specific energy consumption in the steel industry. Energy 1995; 20(12): 1247-50.

[17] Worrell E, Martin N, Price L. Energy efficiency and carbon dioxide emissions reduction opportunities in the U.S. iron and steel sector. Berkeley, CA: Lawrence Berkeley Nation 32. 2001; 26: 513-36.

[18] International Iron and Steel Institute (IISI). Steel statistics of developing countries, 1996 edition. Brussels: IISI, 1997.

[19] International Iron and Steel Institute (IISI). Energy use in the steel industry. Brussels: IISI, 1998.

[20] Ministry of Metallurgical Industry. Yearbook of iron and steel industry of China. Beijing: MMI, 2000.

[21] Energetics. Energy and environmental profile of the U.S. steel industry. Prepared for the U.S. DOE, Office of Industrial Technologies. Washington, DC: Energetics, 2000.

[22] International Energy Agency. Tracking industrial energy efficiency. 2007.

[23] Chatterjee A. The steel industry in India. Iron making and Steelmaking1996; 23(4): 293-302.

[24] Das B, Prakash S. An overview of utilization of slag and sludge from steel industries. Resour Conserv Recycl 2007; 50: 40-57.

[25] IEA (2013). World Energy Outlook 2013. International Energy Agency OECD/IEA, Paris 2013.

[26] Gordon, Y., Freislich, M., and Els, J., Iron making technology selection for site specific conditions, Proc. AISTech 2010, vol. 1, pp. 519-528.

[27] Overview of Steel Government of India, available at http://steel.gov.in/overview.

[28] Brimacombe, L., Shonfield, P., 2001. Sustainability and steel recycling. New Steel Construction 9 (2), 19-21.

[29] Battese GE, Coelli TJ. Prediction of farm-level technical efficiencies with a generalized frontier production functions and panel data. J Econometrics 1988; 38: 387-99.

[30] Aigner DJ, Lovell CAK, Schmidt P. Formulation and estimation of stochastic frontier production function models. J Econometrics 1977; 6: 21-37.

[31] Farla JCM, Blok K. The quality of energy intensity indicators for international comparisons in the iron and steel industry. Energy Policy 2001; 29: 523-543.

[32] G. Nardin, F. Dal Magro – "Scientific collaboration: Innovative devices for variance reduction of the thermal flux of waste gas characterized by high gradients of temperature" – University of Udine - Academic year 2011/2012.

[33] Kumar, S., Freislich, M., Mysko, D., Westfall, L.A., and Bachenheimer, S., Addressing climate change— a novel greenhouse gas carbon abatement process (G-CAPTM) for the iron and steel industry. Proc. AISTech 2010, vol. 1, pp. 227-248.

[34] Lall, S. (1992). Technological Capabilities and Industrialization, World Development, 20, 165-86.

[35] Nelson, R.R. (2007). The changing institutional requirements for technological and institutional catch up. International Journal of Technological Learning. Innovation and Development 1, 4-12.

[36] Price L, Levine MD, Zhou N, Fridley D, Aden N, Lu H, et al.. Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th five year plan. Energy Policy 2011; 39(4): 2165-78.

[37] Rasiah, R. (2008). Conclusions and implications: The role of multinationals in technological capa-bility building and localization in Asia. Asia Pacific Business Review 14, 165-169.

[38] Sinton JE. Accuracy and reliability of China's energy statistics. China Economic Review. Forthcoming.

[39] Worrell E, Laitner JA, Ruth M, Finman H. Productivity benefits of industrial energy efficiency measures. Energy 2003; 28: 1081-98.

[40] Worrell E, de Beer JG, Blok K. Energy conservation in the iron and steel industry, in: P.A. Pilavachi (ed), Energy efficiency in process technology, Elsevier Applied Sciences, Amsterdam/London, 1993.

[41] Wei YM, Liao H, Fan Y. An empirical analysis of energy efficiency in China's iron and steel sector. Energy 2007; 32(12): 2262-70.

[42] World Steel Association. World steel in figures, 2009.

[43] Wheeler, F., Twigge-Molecey, C., and McLean, L., Managing the risk of implementing new technologies, Proc. 36th Mechanical Working and Steel Processing Conference, Baltimore, Maryland, USA. 1994.

[44] Zhang J, Wang G. Energy saving technologies and productive efficiency in the Chinese iron and steel sector. Energy 2008; 33(4): 525-37.

[45] Debreu G. The coefficient of resource utilization. J Econometrica 1951; 19: 273-92. 3. Koopmans TC. Activity analysis of production and allocation. New York: Wiley; 1951.

[46] Energy and Climate Policy: Bending the Technological Trajectory, OECD Studies on Environmental Innovation, OECD Publishing, Paris.

[47] Gordon, Y., Freislich, M., and Brown, R., Selection of iron making technology for existing specific conditions of European part of Russian Federation, Proc. AISTech Conference, Atlanta, GA, USA. 2012.

[48] Huiting S, Forssberg E. An overview of recovery of metals from slag. Waste Manage 2003; 23: 933-49.

[49] WEF (2008). The Global Competitiveness Report 2008-2009: Full data edition. World Economic Forum, Geneva, 2008.

[50] International Iron and Steel Institute (IISI). IISI web site: http://www.worldsteel.org/steeldatacentre/lgcountry.htm. Brussels: IISI, 1999.

[51] Lutz C, Meyer B, Nathani C, Schleich J. Endogenous technological change and emissions: The case of the German steel industry. Energy Policy 2005; 33(9): 1143-54.

[52] Meeusen W, van den Broeck J. Efficiency estimation from Cobb–Douglas production functions with composed error. Int Econ Rev 1977; 18: 435-44.