# REDUCTION OF USE OF ENERGY FOR INDUSTRIAL PURPOSES TO MITIGATE $CO_2$ EMISSIONS

Role of Material science is important:

Introduction - Rising population and increasing wealth are fueling growing global demand for products, services, buildings, and public infrastructure. The industrial sector, which manufactures these products and structures, has many opportunities to make them using less energy and emitting less carbon dioxide ($CO_2$). Industry has a role in developing, producing, using, and recycling improved materials to manufacture products that consume less energy when used. Improved and modified materials should be stronger, lighter, better insulating, safer, better handling characteristics etc., than the earlier one.

Most industrial energy consumption occurs in industries that produce raw materials, such as chemicals and petrochemicals, iron and steel, nonmetallic minerals, and nonferrous metals. At present level, direct industrial $CO_2$ emissions (excluding emissions from electricity generation and heat use) amounted to more than 6 gigatons. Three sectors were responsible for nearly 70% of the direct industrial emissions: iron and steel, nonmetallic minerals (notably cement), and chemicals and petrochemicals (this does not include the emissions from the freight transportation involved in bringing raw materials to manufacturing facilities and delivering products made from them to consumers, which would add another 10–12 percentage points). Thus, between one-third and one-half of global $CO_2$ emissions are generated in activities related to materials and product supply.

Opportunities for energy efficiency vis-a-vis emissions - Globally, industry's energy consumption and direct $CO_2$ emissions have been growing. For the most part, growth in energy demand has been high in developing countries than in developed world. To some extent, growth in both energy demand and emissions has been mitigated by efficiency improvements in all sectors worldwide. However, these efficiency gains have not been geographically uniform. The rapid growth of production in less-efficient developing countries has contributed significantly to poverty alleviation, but it has also limited the average efficiency gains worldwide. Rapid growth in countries such as China and India has supported continuation of less-efficient heavy industry in some sectors that does not exist in developed countries. Small-scale manufacturing plants using outdated processes and low-quality fuels and feedstocks, as well as weaknesses in transportation infrastructure, contribute to industrial inefficiency in some emerging economies.

These overall energy and emissions trends can be mitigated through additional energy efficiency measures. Even though energy represents a manufacturing cost, to be managed and controlled like any other cost, industry is not always efficient in its energy use. Studies suggest that technical efficiency improvement potential of 18–26% for the manufacturing industry worldwide is possible if the best available technology were applied. Apart from savings, it reduces CO2 emissions substantially worldwide. Most of the underlying energy-saving measures would be cost-effective in the long term, but their implementation is hindered by the long remaining lifespan of the standing capital stock and the priority given to avoiding production disruptions that can be caused by new equipment or new procedures.

The realization of part of the potential for technical improvements would entail immediate significant costs because it would imply replacement of the existing capital stock before the end of its technical life. Over the longer term, however, these gains seem affordable. A key factor is the age of the capital stock. New plants tend to be more efficient than old ones, as more efficient technologies are developed and adopted. As a consequence, the most efficient industries can sometimes be found in emerging economies where production is expanding.

The discussion so far has focused only on technical potential, based on existing technology and current production volumes. Part of this potential will be realized by the market without new policy efforts. New CO2 policies might result in a greater uptake of these efficiency options, as well as in the use of further CO2 mitigation options that entail additional costs. In fact, incentive reflects a policy effort that can be based on a range of policy instruments such as taxes, subsidies, emissions trading schemes, sectoral agreements etc. A mix of CO2 emissions reduction incentives, efficiency regulations, and support measures would be needed. A range of new technologies plays a role in this scenario.

Discussion here focuses on three key materials industries—namely, iron and steel, cement, and chemicals and petrochemicals—providing some examples of the materials science, engineering, and management challenges of improving their energy efficiency and emissions performances.

a. Iron and steel – Steel is most important structural metal. Steel is used in a number of markets such as transportation equipment, infrastructure, machinery, buildings, and packaging. Taking into consideration the total world production of more than 1,3 billion tons of steel, the steel industry produces over two billion tons of CO2. In last three decades annual steel production grew more than 95%, while its energy use rose by about 30% and CO2 emissions increased by about 17% during the period.

Materials recycling reduce the energy needs and direct $CO_2$ emissions substantially, by a factor of 2 to 4. Total scrap recovery in steel production increased substantially. Even though the recycling rate is high, an expanding economy has meant that the total crude steel production is roughly twice the amount of scrap collected and used. Materials losses from the lifecycle of steel are small, so increased recycling is an improvement option of secondary importance.

Materials properties enhancements are an important element of the steel industry's effects on sustainability. Steel strength, quality, and other properties have a significant influence on how products made from steel use energy. For example, stronger steels allow for the use of thinner-gauge, and thus lighter-weight, product components. Reducing the weight of automobiles has received much attention and could yield 10– 15% fuel efficiency gains, provided that it is not offset by trends toward larger and higher performance vehicles. Improved collection and separation practices and processing technologies for scrap metal will allow further growth in the use of recycled steel in areas that have been the domain of virgin steel. In the case of coal-fired power plants, steel quality determines maximum operating efficiencies by limiting the temperatures and pressures in steam sections.

Not only steel quality but also coke quality is an issue that deserves attention. The impact of coke quality on coal and coke consumption in blast furnaces is still not well understood. Blast furnace operation is still largely based on engineering experience, and the impact of coal quality and ore quality on process operation cannot easily be transferred from one blast furnace to another. This limits the potential to translate the operating experiences of the best blast furnaces into a global improvement.

b. Cement – The cement industry contributes about 5% to global anthropogenic $CO_2$ emissions, making the cement industry an important sector for $CO_2$-emission mitigation strategies. Worldwide cement production is increasing with the vast majority of the production occurring in developing countries. China accounted for more than 47% of global cement production, whereas India, Thailand, Brazil, Turkey, Indonesia, Iran, Egypt, Vietnam, and Saudi Arabia together accounted for about 17%. Cement is a special case among major materials industries because more than half of its direct greenhouse gas (GHG) emissions emanate from process sources (the calcination of limestone during clinker production) rather than energy use, and these emissions cannot be reduced through changes in the process conditions.

Four approaches can be applied to increase the energy efficiency and reduce $CO_2$ emissions in the cement industry:

(i) increase the process energy efficiency,

(ii) use coal fuel substitutes,

(iii) capture and store $CO_2$ (an option for $CO_2$ reduction only; not yet commercialized),

(iv) develop new cement types that reduce the use of cement clinker.

c. Chemicals and Petrochemicals – In last decades energy use in chemicals and petrochemicals production rose by more than 210% and $CO_2$ emissions increased by about 160%. Certain inorganic chemicals such as fertilizers, chlorine, and soda have some energy relevance, but petrochemicals represent the bulk of the energy and feedstock use in this sector.

Materials substitution of biomass feedstocks for petroleum feedstocks holds great potential for reducing energy use in the petrochemicals industry. Interest in realizing this potential has risen, in tandem with the increased attention paid to the development of liquid biofuels stemming from surging oil prices, supply security considerations, environmental policies, and technological progress.

Detailed analyses show that bio- based chemicals offer substantial potential savings of nonrenewable energy and greenhouse gas (GHG) emissions. The bio-based chemical with the largest potential market is likely ethylene made from bioethanol. Bio-based ethylene can be used to produce bio-based polyethylene and all other bio-based ethylene derivatives such as ethylene oxide, ethylene glycol, or acetaldehyde; these, in turn, can be used for a wide range of chemicals such as polymers, solvents, antifreeze agents, and lubricants. It has been estimated that nonrenewable energy use and lifecycle GHG emissions can be reduced by more than one-third compared to petrochemical based approaches if ethylene is produced from bioethanol made from maize in a moderate climate and using the current level of technology. Using the same feedstock and more advanced fermentation and separation technology, the savings can be increased to 50%. Technically speaking, the overwhelming share of the total demand for organic chemicals and polymers could be covered from bio-based feedstocks.

Conclusions – Increasing the efficiency of industrial processes and the flows of materials through the economy is a slow transformation process that will take decades. In the short and medium term, it is important that new plants be built with the best available technology. Materials sciences will play a key role in the further development of emerging solutions for increased energy efficiency and reduced $CO_2$ emissions.

Efforts to achieve deep GHG emission reductions will have significant consequences for materials use. About 36% of all $CO_2$ emissions can be attributed to industry, mainly to materials production processes. Materials sciences can help to increase the efficiency of materials use and to develop new materials that allow for higher energy efficiency during product use.

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