UNIT 12 INDUSTRY

Structure

12.1 INTRODUCTION

Industrial processes are highly energy intensive. Industry accounted for approximately 30% of global final energy consumption in 2014 (IEA 2016). Industrial processes and technologies are driven by energy. Further, industrial processes such as "metal smelting" and chemicals' manufacturing unit in addition to using enormous amount of energy, emit greenhouse gases like methane, nitrous oxide, etc. Nevertheless, the certain industries like fertilizer plants, iron and steel industries, petroleum refining plants, cement factory, pulp and paper mill are important energy-consuming industries. It must be noted that socio-economic development drives energy consumption which is also symptomatic of rising production in industrial subsectors like iron and steel, pulp and paper mill, etc. In this decade, India experienced its highest growth rate in industrial energy consumption, while China experienced remarkable growth in industrial sector. In-depth study of industrial sectors would throw light on the "life cycle emissions", ways to reduce waste generation occurring during manufacturing and construction, and developing strategies to adopt circular economy-based industrial initiative. In this unit, we would be discussing the potential of industrial sector in climate change mitigation. Further, the need for promoting climate resilient industry would be elaborated.

12.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the potential of industrial sector to reduce GHG emissions;
- explain the energy efficiency, emission efficiency, material efficiency and measures to mitigate GHG; and
- explain the need to promote climate resilient industry.

12.3 OVERVIEW OF GHG EMISSION FROM INDUSTRIES

The industrial sector is very diverse: major energy-consuming industries include cement, chemicals and petrochemicals, iron and steel, aluminium, and pulp and paper. The greenhouse gases emissions from global industrial sector increased from 10 $GtCO_2eq$ in 1990 to 15 $GtCO_2eq$ in 2010. The global industrial sector contributed about 30% of global GHG emissions in 2010 (IPCC 2014). The GHG emissions from the industrial sectors primarily include "direct energy-related CO_2 emissions from industry", "indirect CO_2 emissions from production of electricity and heat for industry", "process CO_2 emissions", and "non-CO_2 GHG emissions" (Fischedick et al. 2014). The CO_2 emissions are from the activities that include but not limited to fossil fuel combustion for meeting energy needs of the industries; fossil fuel use in industries like cement, lime manufacturing units, chemical processing units and metal smelting, etc. It is reported that the "global demand for industrial products will increase by 45–60% by 2050 as compared to 2010 production levels". Nevertheless, according to the report "Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy Transition", jointly prepared by the International Renewable Energy Agency (IRENA) and the International Energy Agency (IEA) (IRENA, 2017a, b), global energy-related carbon dioxide (CO_2) emissions can be reduced by 70% by 2050 with a net positive economic outlook. However, the greenhouse gas emissions from the industrial sector can be minimized by adoption of energy and material efficiency measures. Industries can minimize the GHG emissions through factoring "lifecycle emissions", approaches to reduce waste generation occurring during manufacturing and construction, and developing strategies to adopt circular economy-based industrial initiative.

The growth experienced in energy and process efficiency in industry in the last few decades were remarkable. In fact, the growth was driven by increasing costs of energy. The need of the hour is to develop strategies to improve the "emissions efficiency", "material use efficiency", "product service efficiency", coupled with measures to reduce demand and increase the possibility of recycle and re-use of materials, and products. As regards the emission efficiency, the measures can be carbon dioxide capture and storage, fuel switching, etc. The material use efficiency can be augmented by adopting measures to reduce scrap and designing new products, which are efficient and sustainable. Due to the fact that industrial sector is the largest CO_2 emitter worldwide; improving industrial CO_2 emission efficiency plays a significant role to promote low-carbon development. Keeping above in view, the unit discusses potential of industrial sectors for reducing greenhouse gases by adopting various measures for energy efficiency, emission efficiency, material efficiency and production efficiency.

Box 12.1 : Definitions

'Industry', very broadly, refers to economic activity producing either goods or services. The term also refers to the secondary sector, covering production processes such as refining, manufacturing and construction. The industrial sector is largely made up of the primary production of materials such as iron and steel, non-ferrous metals, non-metallic minerals, chemicals and petrochemicals and pulp and paper. The residuum of the sector is made up of the manufacture and production of goods such as machinery and other equipment, food, tobacco, textiles and wood products. Mining and quarrying, petroleum use as feedstocks (raw materials) are also included.

Source: IEA's Energy Technology Perspectives, 2017.

12.4 POTENTIAL OF INDUSTRIAL SECTOR FOR REDUCING GHG EMISSIONS

The industrial sector has potential to reduce emissions of greenhouse gases. Nevertheless, the GHG reduction from the perspective of industrial sector demand innovative technologies and mitigation strategies. GHG mitigation can be achieved by adopting production-related and demand-related strategies. The former aims to improve the industrial process efficiencies and the latter aims at reducing the demand for the product. Nevertheless, it is reported that the demand for the materials like steel, cement, etc., would increase by 2050 to an extent of 45-60% as compared to the 2010 levels. Hence, in order to reduce GHG emissions from the industrial sector, measures should be way beyond the current practices. In this regard, it is pertinent to note that the approaches that aim towards "low-carbon industrial processes" include reliance on renewable energy sources and minimizing the process energy. The technology routes for CO_2 mitigation in industry can be addressed on the following routes.

- Energy efficiency
  1. Process specific
     - New process routes/reactor designs
     - Heat integration
  2. Industry-wide/cross-cutting • E.g. Motor and steam systems
- Fuel switching
  - Less carbon intensive fuels
- Life cycle changes
- Carbon capture and storage

Within the "Global Climate Action", industries are expected to adapt their business model in order to contribute to the achievement of the target of keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. As a consequence, industries are expected to:

- change their supply chain towards sustainability;
- cooperate with multi-stakeholders' initiatives aimed at GHGs emissions reduction;
- define emissions reduction targets by sector within 2050;
- setting GHGs emissions reduction targets or resilience improvement targets;
- encompassing climate change in business strategies and governance; and

- supporting the implementation of private and public policies aimed at tackling climate change and supporting the development of markets with low carbon dioxide (CO_2) emissions.

According to IPCC (2014), options for mitigation of GHG emissions from industry fall into the following categories:

- *"energy efficiency;*
- *emissions efficiency (including fuel and feedstock switching, carbon dioxide capture and storage);*
- *material efficiency (through reducing yield losses in production);*
- *re-use of materials and recycling of products; and*
- *more intensive and longer use of products, and reduced demand for product services".*

In the following sections, we will discuss all these measures in detail.

Box 12.2: Mitigation Strategies

1. Production-related strategies are mainly geared towards improving industrial process efficiencies. Three main strategies are:

   Emission efficiency: Reducing the amount of emissions per unit of energy used, generally by switching to low-carbon energy sources.

   Energy efficiency: Improving the ratio of energy consumption to production of materials.

   Material efficiency: Reducing the amount of raw material needed to create a product. One-tenth of paper, a quarter of steel and half of all aluminium produced is scrapped (mainly in downstream manufacturing) and internally recycled.

2. Demand-related strategies are focused on reducing the overall use of product material by changing the demand for industrial products. Strategies include increasing re-use and recycling, substitution with less energy- and GHG-intensive materials, and using materials more efficiently.

   Two main strategies in this regard are:

   Product-service efficiency: Using products for longer and more intensively can help reduce the amount of product created.

   Demand reduction: Reducing overall demand for new product, for example through re-use and recycling, will reduce emissions.

Source: (Fischedick et al. 2014).

12.4.1 Energy Efficiency

According to the World Energy Council, "*energy efficiency has a broader meaning than mere technological efficiency of equipment; it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic output (e.g. the energy used per unit of GDP) or to achieve* *a given level of comfort. Energy efficiency is associated with economic efficiency and includes technological, organizational and behavioural changes*". According to Agenda 21, "*reducing the amount of energy and materials used per unit in the production of goods and services can contribute both to the alleviation of environmental stress and to greater economic and industrial productivity and competitiveness*".

In the industries, energy is used to produce heat, to perform an activity/work or to run a chemical reactions. In fact, the chemical reactions are under the thermodynamic limits. The industrial process aspires to reach the technical limits. In this regard, industrial energy efficiency is significant. There is a huge scope to improve the energy efficiency and also there is variation in industrial efficiency among the industries and countries. It is reported that in the industries which demand less energy, there is scope for improvement in the domain of process and system-wide technologies. It is further reported that the "technical potential of energy efficiency measures" in the industrial sector is about 25%. The energy efficiency options are found in the industrial processes and also in the systems domain, which encompasses the electric motor systems, steam systems, and process heating systems. The electronic control system aid in optimizing the performance of instruments like steam combustion, compressors, motors, etc., and enhancing the economic and energy efficiency of the industrial plants leading to cost reduction, energy savings, and GHG emissions benefits also. Nevertheless, in small and marginal industrial units, the channeling of resources in efficiency enhancing technologies are meagre and hence the small and marginal industrial units has scant information about the advanced energy-efficiency technologies and options. In this respect, energy audit provide a pathway to remove the information barrier and subsequently leading to adoption of energy-efficient options (Fischedick et al.2014).

Energy Efficiency Measures

Energy efficiency measures can find place among the cross-cutting technologies. The cross-cutting technologies include pumping systems, compressed air systems, steam generation units, motor systems, etc. Innovations in cross-cutting technologies greatly improve overall energy use efficiency of industries. It is reported that isolated energy efficiency options provide savings only for a certain period of time. So, it is advisable for the industrial units to implement energy management system so that the energy performance of the industrial unit improves comprehensively. Further, adoption of energy management system also provides a framework for the industrial unit to improve efficiency, reduce cost, and sustainability of the industrial unit as well. There is a dire need to augment investments in the small and medium enterprises and also in the process, and sector specific related domain in order to capitalize the energy efficiency potential of the industrial sector. "Energy Management Systems are a collection of business processes, carried out at plants and firms, designed to encourage and facilitate systematic improvement in energy efficiency. The typical elements of Energy Management Systems include maintenance checklists, measurement processes, performance indicators and benchmarks, progress reporting, and on-site energy managers" (Fischedick et al.2014).

12.4.2 Emission Efficiency

It is projected that 30% of the industrial energy supply would be from coal and oil, 24 % from gas, and the residuum from electricity and direct use of renewable energy sources by 2035 (IEA, 2011). Reduced dependency on fossil fuels would reduce the emissions per unit of energy. In the industrial combined heat and power installations, use of natural gas aids in efficient use of energy. Of late, use of waste and biomass as a feedstock in energy industry is progressing markedly. For instance, cement industry is looking for options of using municipal solid waste and sewage sludge in the production process. Further, decarbonization of electricity generation can reduce GHG emissions and also result in spread of electrification. It is also reported that the potential available with solar thermal energy for washing, drying and evaporation should be sustainably harvested. The International Energy Agency (IEA) forecasts that carbon dioxide capture and storage can reduce greatly the methane emissions from industries even to the tune of 30 % by 2050) (IEA, 2009). Nevertheless, presently, "the industrial use of CO_2 was small, and further, the storage time of CO_2 in industrial products often short" (Fischedick et al.2014). The policies that aim at increasing energy efficiency also reduce the carbon dioxide intensity. The strategies as part of the emission efficiency policy include incentives, research and development initiatives, initiatives to reduce non-carbon dioxide greenhouse gases, fuel switching, etc.

12.4.3 Material Efficiency

The material intensity of an economy can be defined as "the total quantity of all raw materials consumed relative to total production, e.g. tons of raw materials consumed per unit of GDP". The quantity of material consumed is measured as "resource flows" or "total material requirement", a concept pioneered by the World Resources Institute (WRI). Material efficiency in industrial production can be defined as "the amount of a particular material needed to produce a particular product" (https://www.un.org/esa/sustdev/publications/industrial_development/3_2.pdf). The material efficiency can be increased by adopting either of the two strategies namely by reducing the amount of material that ends up as waste or by "lightweighting". As regards the resource efficiency in industry, recycling of products such as metals, plastics and paper can offer significant energy savings. The level of recycling, which can be achieved depends on the lifecycle of the product and material flows. Once manufactured, steel and aluminium can take around 100 years before becoming available as scrap. This is particularly relevant for developing countries, which are still building up their infrastructure and have not reached a steady state of material flow.

In effect, the production and processing of materials demand energy and hence the production process may release greenhouse gases. For instance, the energy-intensive industries such as iron and steel, cement industry release enormous amount of GHG. In this regard, the material efficiency can be achieved by fuel switching, reducing the amount of fuel consumed, reducing material losses and designing innovative products. Further, reuse and recycling greatly improves material efficiency and also cost benefits. In short, the material efficiency hinges on "lightweighting", "waste reduction" in the production process, waste recycling and reducing yield losses. Further, in addition to efficient product design and sustainable consumption, measures to reduce the demand for the products have an impact on industrial emissions.

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. What is energy efficiency?

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2. What are energy management systems?

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3. What is material efficiency?

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4. How to improve material efficiency?

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Table 12.1: Major GHG Emitting Industrial Sectors

Industry	Energy Efficiency	Emission Efficiency	Material Efficiency
Iron and steel	• Improved heat and energy recovery from process gases, products and waste streams; • Improved fuel delivery through pulverized coal injection; • Improved furnace designs and process controls; and	• Switching to gas-based direct reduced iron (DRI) and oil and natural gas injection, electric arc furnace (EAF) process; • Charcoal; • Use of biomass and waste plastics to displace coal.	• Smaller, lighter fuel efficient vehicles (FEVs), reuse and recycle.

	• Reduced number of temperature cycles through better process coupling such as in Endless Strip Production (ESP) and use of various energy efficiency technologies including coke dry quenching and top pressure recovery turbines.		
Cement	• Many options exist to improve the energy efficiency of cement manufacturing	• Fuel switching; • Use of biomass wastes; • Carbon Capture and Storage.	• Using less cement initially and reusing concrete components at end of first product life • Cement can be produced with lower ratios of clinker through use of additives such as blast furnace slag, fly ash from power plants, limestone, etc.
Chemicals (plastics / fertilizers / others)	• Upgrading all steam cracking plants to best practice; • Switching to a biomass-based route to avoid steam cracking	• Introduction of new N_2O emission reduction technologies in nitric acid production such as high temperature catalytic N_2O decomposition; • Fuel switching; etc.	• Reducing yield losses; • Waste reuse and recycling
Food processing	• Increased use of heat exchanger networks or heat pumps, combined heat and power, mechanical dewatering compared to rotary drying and thermal and mechanical vapour recompression in evaporation; • Savings in energy for refrigeration could be made with better insulation and reduced ventilation in fridges and freezers.	• Switching from heavy fuel oil to natural gas; • Using lower-emission modes of transport; • Anaerobic digestion processes to reduce landfill emissions	• Reducing food demand and food waste; • Demand for high-emission food such as meat and dairy products could be replaced by demand for other, lower-emission foods.

Source: Fischedick et al. 2014

12.5 PROMOTING CLIMATE RESILIENT INDUSTRY

From the perspective of climate change mitigation and Sustainable Development Goals, it is essential to decipher the interactions between different industries and also the relation between the industries and other economic sectors. Measures adopted in one sector may have an influence on another industry in terms of GHG emissions. Hence, systemic collaborative activities, if adopted within the industrial sector and also across the sector, would pave way for climate change mitigation.

The role of industry is rightly recognized by the 2030 Agenda for Sustainable Development, and particularly by SDG 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation". Additionally, shifting to low emission and climate resilient pathways falls neatly within SDG 13: "Take urgent action to combat climate change and its impacts". This emphasizes the need to transform industry to become climate resilient. Inclusive and sustainable industrialization has strong ramifications for most, if not all, other SDGs. The interrelated nature of the SDGs makes it imperative to promote industrialization patterns that are socially inclusive and reduce pollution and GHG emissions compared to traditional technologies and practices. Climate resilient industry builds on cleaner and resource-efficient production technologies and practices that de-couple economic growth from unsustainable resource consumption and environmental degradation. Pathways for climate resilient industry must ensure that climate change and actions to combat it do not jeopardize the development of countries or the welfare of their citizens. Climate resilient industrial development involves continued efforts to mitigate changes in the climate while at the same time prepare industry to adapt to its impacts. Apart from those related to extreme weather events, the impacts of climate variation on industry are not always obvious. Considering the heavy dependence of industry on various natural resources and raw materials, the productive capacity of manufacturing industry could be severely affected by climate change, if not addressed appropriately in a timely manner. It is becoming increasingly evident that certain mitigation measures could aggravate vulnerability in another location, while other approaches have clear mutual benefits towards improving resilience. Effective solutions to climate change require a holistic approach that recognizes the interlinkages and potential trade-offs of different approaches, and leverages the synergies between mitigation and adaptation measures. This can also bring additional benefits such as climate financing that could not have been leveraged if addressed separately.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. Explain the need for climate resilient industry.

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12.6 LET US SUM UP

Limiting industrial CO_2 emissions is crucial to reduce the risks of climate change, but this looks very challenging and warrants policy attention. Owing to energy intensive, fossil-fuel dependent processes, CO_2 emissions from heavy industries form a large segment of global emissions. Production and associated CO_2 emissions are predicted to continue to rise, as developing countries grow and seek to improve their standards of living. Reducing emissions from industry requires a sustained and focused effort. Through this unit, we have discussed the options for reducing industrial CO_2 emissions and also the energy efficiency, emission efficiency and material efficiency pertaining to the industrial sector. It can be categorically stated that industrial sector has potential to mitigate climate change and there is dire need to promote climate resilient industry so as to achieve the Sustainable Development Goals.

12.7 KEY WORDS

Primary Industry : It is defined as principally relying on the extraction of natural resources which are energy intensive such as mining, cement, iron, steel, chemicals, pulp, paper and non-ferrous metals.

Projection : A potential future evolution of a quantity or set of quantities, often computed by a model. Projections involve assumptions that may or may not be realised, and are therefore subject to substantial uncertainty; they are not predictions.

Renewable Energy : Any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use.

Resilience : The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure.

Transition Economy : An economy that is changing from a centrally planned economy to a free market.

12.8 SUGGESTED FURTHER READING/ REFERENCES

Worrell E, Allwood J, Gutowski T (2016). The Role of Material Efficiency in Environmental Stewardship. Annual Review of Environment and Resources 41:575-598. doi: 10.1146/annurev-environ-110615-085737

Hertwich E, Ali S, Ciacci L, Fishman T, Heeren N, Masanet E, Asghari F, Olivetti E, Pauliuk S, Tu Q, Wolfram P (2019) Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics-a review. Environmental Research Letters 14:043004. doi: 10.1088/1748-9326/ab0fe3

Fischedick M., J. Roy, A. Abdel-Aziz, A. Acquaye, J. M. Allwood, J.-P. Ceron, Y. Geng, H. Kheshgi, A. Lanza, D. Perczyk, L. Price, E. Santalla, C. Sheinbaum, and K. Tanaka, 2014: Industry. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IEA (International Energy Agency) (2016). World Energy Outlook 2016, OECD/IEA, Paris.

IRENA (2017a). Renewable Energy Prospects for India, a working paper based on REmap, International Renewable Energy Agency, Abu Dhabi. www.irena.org/remap.

IRENA (2017b). Synergies between renewable energy and energy efficiency, a working paper based on REmap, International Renewable Energy Agency (IRENA), Abu Dhabi, www.irena.org/remap

IEA (2017). Energy Technology Perspectives 2017, IEA/OECD, Paris www.iea.org/etp/.

IEA (2011). World Energy Outlook 2011 Special Report: Are We Entering a Golden Age of Gas? International Energy Agency, Paris. Available at: http: / / www.worldenergyoutlook.org/ goldenageofgas /

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Web Links

http://report.mitigation2014.org/drafts/final-draft-postplenary/ipcc_wg3_ar5_final-draft_postplenary_chapter10.pdf

https://www.un.org/esa/sustdev/publications/industrial_development/3_2.pdf

http://www.ipcc.ch/report/ar5/wg1/

http://www.ipcc.ch/report/ar5/wg2/

http://www.ipcc.ch/report/ar5/wg3/

http://www.ipcc.ch/report/ar5/syr/

https://www.ipcc.ch/sr15/

https://www.globalchange.gov/climate-change/glossary

https://health2016.globalchange.gov/glossary-and-acronyms

12.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. *"Energy efficiency encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic output (e.g. the energy used per unit of GDP) or to achieve a given level of comfort".*

2. *"Energy Management Systems are a collection of business processes, carried out at plants and firms, designed to encourage and facilitate systematic improvement in energy efficiency. The typical elements of Energy Management Systems include maintenance checklists, measurement processes, performance indicators and benchmarks, progress reporting, and on-site energy managers"*

3. Material efficiency in industrial production is defined as "the amount of a particular material needed to produce a particular product"

4. The material efficiency can be increased by adopting either of the two strategies namely by reducing the amount of material that ends up as waste or by "lightweighting". In effect, the material efficiency hinges on "lightweighting", "waste reduction" in the production process, waste recycling and reducing yield losses.

Check Your Progress 2

1. The Sustainable Development Goal 9 highlights the need to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. The SDG 9 and SDG 13 are closely related, which call for transforming industry into climate resilient. Further, climate resilient industry builds on cleaner and resource-efficient production technologies and practices that de-couple economic growth from unsustainable resource consumption and environmental degradation. Climate resilient industrial development aims not only on climate change mitigation, but also adapting industry to climate change. Holistic approach towards climate change management requires tapping the potential both mitigation and adaptation options.