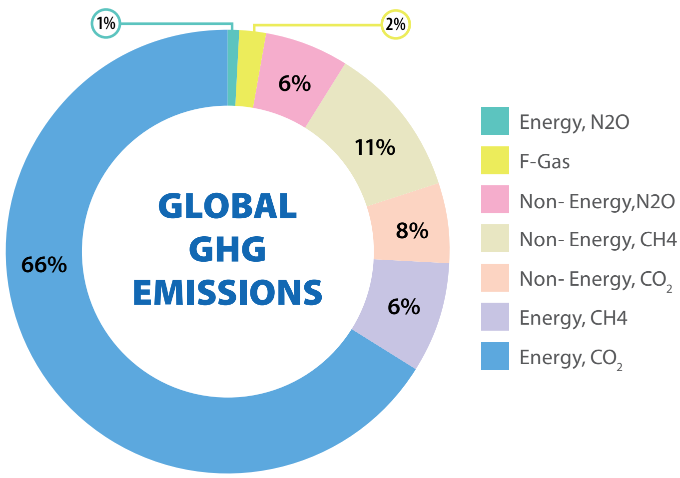
ROLE OF INDUSTRY 4.0 IN ENERGY TRANSITION

The energy industry is going through a significant transformation with Decarbonisation, Decentralisation and Digitalisation (3Ds) as central themes around this transition. It is touching every entity in the value chain; from energy-producing companies to the last mile consumers. The clean energy drive originates from the efforts to contain GHG emissions as part of the global climate change initiative. Digitalisation complements this drive by technologically enabling the transition. Decentralised production and energy consumption would significantly help reduce transmission losses and improve access to quality energy. The change is visible in energy production, consumption and the way it is transmitted and distributed. Digitalisation would accelerate each step of the transition by making them more efficient, flexible and reliable. Industry 4.0 technologies, Internet of Things (IoT) and Artificial Intelligence (AI) /Machine Learning (ML) can improve the efficiency of plants/industries and reduce fossil fuel consumption. This article covers the impact of Industry 4.0 technologies and digitalisation on energy transition.

Decarbonisation for Existence of Humanity

The Intergovernmental Panel on Climate Change (IPCC) of UN estimated that the human activities are responsible for about 1°C of global warming by 2030 w.r.t the pre-industrial levels and are likely to reach 1.5° C by 2050 if the current activity levels continue. Global warming effects are visible in the past couple of years with many unpredicted, devastating climate events worldwide. Considering the need for firm action to limit global warming, Paris summit on Climate Change in 2015 reaffirmed the global warming target of 1.5°C w.r.t base reference and legally binding agreement came into existence with acceptance of 195 countries.



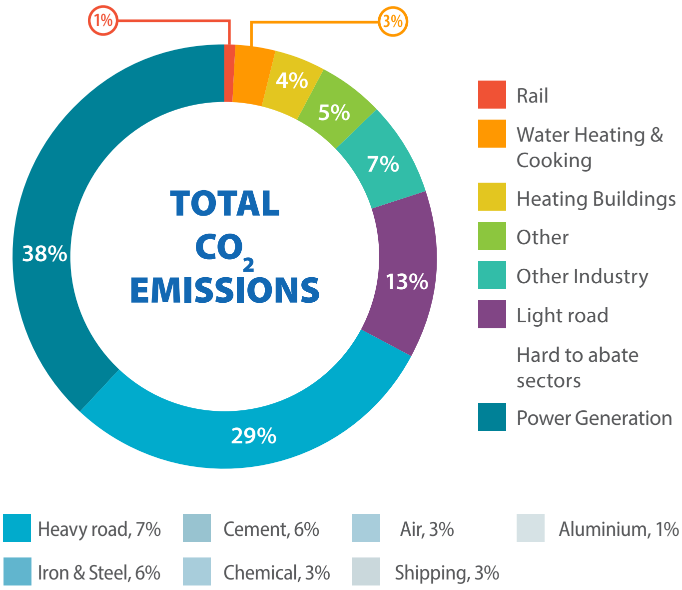
Source: WEF, Energy Transition 101, July 2020

Fig. 1

Significant technological and policy-related interventions are in various implementation stages to reduce emission levels and achieve carbon neutrality by 2050. The energy sector is the major contributor to GHG emissions. It corresponds to about 73% of the overall GHG emissions globally. Hence, a continued focus on the energy sector is essential to reduce emission levels. And about 66% of it is CO2 emissions. Refer Fig. -1.

In Energy Sector, a significant share is from power generation, contributing about 38% of the total GHG emissions per 2014 statistics.

The clean energy drive has picked up considerable momentum in this background, and measurable decarbonisation targets and monitoring mechanisms are in place for the countries and institutions. Carbon neutrality is targeted by 2050, and about 45% reduction in CO2 emissions than 2010 levels is required to achieve this goal.



Source: WEF, Energy Transition 101, July 2020

Fig. 2

Broadly, to meet the climate targets related to GHG emissions, there shall be a continuous reduction in usage of fossil fuels and an increase in dependency on renewable energy sources. The curtailment of fossil fuel can be achieved by shifting to renewable sources or improving fossil fuel-based plants/industries. The strategies that are being adopted for decarbonisation are aligned in this direction and major ones briefed below.

Use of Alternative, Low-Carbon Energy

The dependency on natural energy sources like solar, wind, tide, geothermal shall be increased instead of fossil fuels like coal, oil, natural gas etc. Hydrogen is also an alternative clean fuel. The energy production from these sources is also becoming cost-competitive due to scaling. IEA, in its 2020 report mentioned that the cost of capital for solar power is lower compared to coal-based power by about 2.6-5.0% in Europe and the US, 4.4-5.5% in China and 8.8-10.0% in India, mainly as a result of policies designed to reduce the risk of renewable investments. As per the report, solar electricity can be generated "at or below" $20 per megawatt-hour (MWh) in the best locations and with necessary policy and financial support.

Switching from fossil fuel to electricity in all transportation means can significantly reduce emissions. An average electric car and plug-in hybrid electric car using electricity emit less GHGs than a global average internal combustion engine driven car using gasoline over their life cycle. (Considering current global average carbon intensity of 518g of carbon dioxide equivalent per kWh). The alternative means for powering transportation would involve new materials (say for battery internals, motor winding etc.) and end processing. The GHG emissions generated in the life cycle of such new materials shall also be accounted while evaluating an alternative mean for mechanical power production in place of conventional fossil fuel-based engines.

Enhance Energy Efficiency

About 67% of the energy produced is lost on an average due to the inefficiencies in electricity generation, transport, heavy industry and buildings. For example, subcritical thermal power units have efficiencies between 33% and 37%; i.e. between 33% and 37% of the coal's energy is converted into electricity. Efficiencies for supercritical coal plants range from 37% to 40%. In ultra-supercritical units., generating efficiency ranges from 44-46% and the world's most efficient combined-cycle power plant in operation today, having an efficiency of about 63.08%. There is ample room for increasing the plants and processes' energy efficiency to use less fossil fuel for the same power generated. The fossil fuels still form about 84% of the global energy mix, and a small increment inefficiency can result in a significant reduction in CO2 emission.

Building energy management systems also plays a crucial role in reducing global CO2 emissions because of the scale at which it can influence. Efficient, smart, IOT powered building management systems can reduce energy consumption by about 20-30% in the longer run.

Further, there are "Hard to Abate "sectors wherein the CO2 emission is unavoidable due to the nature of the process adopted like in Steel industry. These sectors' emission contributes to about 29% of the total CO2 generated globally (Fig-02). These plants shall aim to increase the efficiency of the process to mitigate the emission levels.

Capture the Carbon

This measure is typically implemented when other options are not viable, either due to the limitation of process or higher cost. The present carbon capture & storage technologies can capture about 80-90% of the CO2 emitted from conventional coal-based thermal plants. Carbon capture and storage facilities are becoming popular in Europe. However, it would still need policy support for implementation at scale. A nature-based approach, like reforestation, has also been adopted for carbon capture.

Decentralisation for Reducing T&D Loss and Improving Access

As per Energy Progress Report, 2019 published by UN, about 13% of the global population lack access to modern electricity. They are either far away from the power grids, or the modern grids are not affordable for specific regions. The growth of RE power and its decentralised nature ensures more sustained electrification, improving electricity's access rate.

The world average T&D losses stand at about 8.3% in 2014. In India, the Aggregate Technical and Commercial (AT&C) losses stand at 19.89% which is more than twice the world average. Longer distances between the power generation and load centres would add to the T&D infrastructure cost and AT&C losses. The decentralised nature of renewable energy generation and distribution will minimise the cost, AT&C losses and increase the power system's efficiency. Mini/ microgrids connecting RE power with battery storage or pumped storages are proven decentralised options for electrification.

Digitalisation can help achieve a more stable operation of such grids. Such decentralised, stable mini/micro girds would reduce blackouts' risk and improve quality power access. The decentralised RE dominated mini-grids can also support EV charging stations in remote, inaccessible locations

Digitalisation - Driving force for Decarbonisation& Decentralisation

Digitalisation enables and catalyses the energy transition by making it more efficient, flexible and reliable. It would be interesting to analyse in detail about how digitalisation helps decarbonisation and decentralisation of energy.

Digitalisation for Decarbonisation

Digitalisation plays a vital role in all three significant steps that are being undertaken towards decarbonisation. Switching to low carbon RE has a considerable challenge of managing the variability from RE sources. Accurate forecasting of the RE power, load management in short intervals of fluctuations, and electricity grid stability during unpredicted weather conditions are possible only using digital tools. Smart grids help manage RE sources' variability through demand-side management using smart meters and big data tools. AI/ML algorithms and big data tools are successfully being adopted worldwide to manage modern RE dominated grids.

In the Power sector, the digitalised process optimisation can lead to a 5% increase in the electricity output per unit of fuel input for all subcritical and supercritical coal-fired power plants. Further, about 5% reduction in O&M costs in power generation and electricity networks can be achieved from digitalisation as per IEA report of 2017. Digital tools are proven to be reliable means for Real-Time Analysis and Optimisation. This is a low hanging fruit to reduce emissions in the energy transition journey. Policymakers can explore incentivising the first digital tool deployments in the plants to accelerate such digital tools.

Most industrial plants are instrumented adequately and generate a large amount of digital data related to the complex processes. Analog to Digital Converters (ADC) is used to get the data converted to a digital format in analogue signals. The digital tools analyse the data quickly and provide the operator with useful insights and actionable information into the processes that otherwise would not be available to the plant operator. The digital tools can streamline the data ingestion of structured or unstructured data on a real-time basis using the Machine Learning (ML) pipelines. The performance optimisation/ improvement tools use AI/ ML-based hybrid algorithms and advanced analytics to yield desired results.

A plantwide performance optimisation covering all critical equipment and process is generally planned though a digital platform capable of customising process/ equipment, interfacing and data ingestion, data analytics and visualisation. Plant/ Fleetwide digital transformations are typically implemented through such digital platforms.

There are micro/ point solutions that run on open architecture and focus on specific process or equipment issues. Such point solutions can be implemented quickly and independently as required in a plant to take advantage of time and cost. Most of such point solutions are cloud or edge deployable and are offered in Software as a Service (SaaS) model.

An example of a point solution related to pump performance monitoring and diagnostics is given below (Fig-03). This digital tool can help the operator monitor the pump performance and analyse multiple influencing parameters in near real-time to ensure optimal performance levels throughout plant operation.

Courtesy : Tata Consulting Engineers Ltd

Fig. 3 Digital Point Solution for Pumps

Few of the capabilities of the digital tool on Real-Time Monitoring and Diagnostics of Pumps are listed below

- Anomaly detection based on historical behaviour
- Recognise deviated parameter and provide early warning alerts
- Predict the pump performance for different load conditions
- Provide insights into pump failures and factors influencing pump performance
- Help plan the maintenance actions

Digitalisation for Decentralisation

Decentralised energy generation and distribution would be sustainable only if stable quality power supply can be ensured. The variability in generation and demand, continuous monitoring requirement, lack of technical skill, etc. are challenging such decentralised mini-grids' stability. The digital tools are handy to manage this situation. Remote monitoring through cellular communication, smart sensors, AI/ML-based self-diagnostic features and correction features etc. are promising technologies that are being explored to ensure stable, quality power supply from the decentralised RE dominated grids.

Digitalisation – Key Enabler for Energy Transition

A fast-paced energy transition is the need of the hour, and it is possible only with digital intervention. "Design for Digitalisation" is becoming the norm for the industry which involves 'sensorising' critical processes to help build accurate digital twins, provision for big data ingestion, and process and data-based interventions for process optimisation. The challenges of EV dominated future transportation system can be well managed through the digitalisation of the vehicles and charging infrastructure. Smart grids become an essential component of managing the variability from RE sources and new types of consumers like EV. Building energy management systems is also becoming more intelligent, efficient, and deployed at scale to aid energy transition effort. In a nutshell, digitalisation is the most effective enabler in the journey towards a greener planet.

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