TCExpression

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Editor's Note

Dear Readers,

Welcome to this edition of TCExpressions, where we explore the theme 'Building Tomorrow.' In these pages, you'll discover a wealth of insights and stories from our colleagues, showcasing the innovation and dedication that define Tata Consulting Engineers.

Our theme, 'Building Tomorrow,' captures the essence of our collective efforts to design and deliver solutions that shape a sustainable and prosperous future. This magazine highlights our technical achievements and the collaborative spirit and forward-thinking mindset that drive our success.

We hope you find inspiration in these stories and realise the significant role you play in our mission to build a better tomorrow. Your support and partnership are invaluable to us.

I would like to thank all our in-house writers for contributing to the content and Mr. Nikhil Kadam for the beautiful design. If you have any thoughts or feedback, please feel free to share them with us at tceconnect@tce.co.in.

Happy reading!

Best regards,
Alpna Singh

Reflections

Dear Colleagues,

I am immensely pleased to introduce this special edition of TCExpressions, centred around the theme 'Building Tomorrow.' This theme resonates deeply with our mission at Tata Consulting Engineers, where we strive to be at the forefront of innovation and excellence in consulting. Our goal is to contribute significantly to the advancement and prosperity of our nation while meeting the evolving needs of our clients and stakeholders.

In this edition, you will find a collection of inspiring articles penned by our talented employees. These articles reflect the passion, creativity, and dedication each of you brings to your work daily. From pioneering projects to innovative solutions, our team's contributions pave the way for a brighter, more sustainable future.

Our company's recent achievements, which we are proud to share, are a testament to the collective commitment and relentless pursuit of progress by our team. These stories of success, spanning various sectors, are a reflection of your hard work and dedication, and they underline our continued growth and impact.

As we set our sights on the future, it's crucial to acknowledge the driving forces behind our success-our collaborative spirit and shared vision. 'Building Tomorrow' is not just about the physical structures and systems we design; it's about fostering a culture of continuous learning, where we embrace new technologies and uphold the highest standards of integrity and professionalism.

I encourage you to delve into this edition of TCExpressions and draw inspiration from the remarkable stories within. Your role in these stories is crucial. Let us continue to innovate, collaborate, and lead the way in building a better tomorrow for all.

Thank you for your unwavering commitment and hard work. Together, we are shaping the future and making a lasting impact on the world.

Warm regards,

Amit Sharma

Managing Director & CEO

Building a Better Tomorrow

The global landscape is swiftly changing, with a growing focus on sustainability and innovation to address the urgent challenges of climate change and resource depletion. As the world moves towards a cleaner and more resilient future, the role of engineering in developing and deploying advanced technologies becomes crucial. The global community increasingly depends on innovative engineering solutions to create a sustainable and resilient future. Industries are striving to minimise environmental impact and transition to cleaner energy sources, making advanced technologies even more critical.

Green ammonia and green methanol represent additional frontiers in clean energy, offering versatile and sustainable solutions for energy storage and as alternative fuels. Green steel production, which aims to eliminate carbon emissions from the steelmaking process, exemplifies our commitment to transforming traditional industries into environmentally friendly operations. Lithium batteries are critical for energy storage solutions, enabling the integration of renewable energy sources into the grid and powering electric vehicles. On the other hand, semiconductors are the backbone of modern electronics, essential for advancing smart technologies and efficient energy management systems.

Beyond individual technologies, we are dedicated to building sustainable infrastructure that supports these innovations. This involves physically constructing energy-efficient buildings and transportation networks and developing smart cities that leverage technology to optimise resource use and enhance quality of life. Keeping pace with the global megatrends, TCE is actively engaged and taking the lead in the development and implementation of projects for making biofuels, green hydrogen, green ammonia, green methanol, and green steel —each playing a crucial role in reducing carbon footprints and enhancing energy efficiency.

TCE's multidisciplinary approach combines research and development, strategic partnerships, and practical implementation to deliver cutting-edge solutions that are economically viable and environmentally sustainable. By showcasing our capabilities and achievements in these technological areas, we aim to demonstrate our leadership in driving the clean energy transition and our unwavering commitment to engineering a sustainable future.

TCE is deeply invested in harnessing and advancing these technologies to engineer a better tomorrow and stands at the forefront of these innovations, leveraging its expertise to engineer solutions that meet current demands and anticipate future needs. By thoroughly examining these technologies and our strategic approach, we aim to demonstrate our capability to provide cutting-edge, sustainable solutions that drive progress and create a better world for future generations.

BIOFUELS

Biofuels are derived from renewable biological sources, such as plants, algae, and organic waste. They offer an alternative to fossil fuels and contribute to reducing greenhouse gas emissions. Biofuels can be categorised into different types, including ethanol, biodiesel, and renewable diesel. According to the International Energy Agency, global biofuel demand will grow by 41 billion litres by 2026. India recognises the critical role of biofuels in achieving net-zero emissions. Biofuels contribute to emission reduction, energy diversification, enhanced security, and a net-zero carbon economy. The global shift toward biofuels is essential for a sustainable energy future, and policies, technological advancements, and market dynamics will continue to shape this transition.

In 2018, India released its National Policy on Biofuels, which set blending targets for ethanol (20% blending by 2030) and biodiesel (5% by 2030). India benefits from abundant feedstocks, including agricultural waste, forestry residues, and urban garbage. These resources make biofuels a sustainable alternative to fossil fuels.

India's biofuel growth can contribute to global deployment. The country launched the Global Biofuels Alliance in 2023, collaborating with leaders from eight other nations. The alliance aims to develop new markets, accelerate technology deployment, and achieve consensus on sustainability assessments. India can further deploy bioenergy by replacing coal with solid biomass, adopting modern bioenergy forms, and increasing the transport of biofuels based on domestically available agricultural residues.

Transitioning from a fossil-based to a low-carbon economy is a critical global goal. It aims to reduce carbon intensity within a relatively short timeframe, typically one to two decades. This transition is driven by the need to limit global warming caused by greenhouse gas emissions, primarily from fossil fuels and, to a lesser extent, land-use changes. TCE is engineering India's first bioethanol plant based on 1G and 2G technologies. As a part of sustainable development, waste-to-energy projects are getting traction, and TCE is providing engineering solutions for such projects.

GREEN CHEMICALS: PIONEERING THE FUTURE OF SUSTAINABLE INDUSTRY

The chemical industry stands at a pivotal crossroads in pursuing a sustainable future. Traditional chemical production processes, reliant on fossil fuels, contribute significantly to global greenhouse gas emissions and environmental degradation. However, the advent of green chemicals—synthesised using renewable resources and environmentally benign processes—heralds a transformative shift. Among these, green ammonia, green methanol, green hydrogen, and sustainable aviation fuel are poised to play crucial roles in defining the future of sustainable industry. Green chemicals, including green ammonia, green methanol, green hydrogen, and sustainable aviation fuel, represent a promising frontier in sustainability. While the engineering challenges are substantial, the potential benefits for the environment, economy, and society are immense. By investing in research, innovation, and collaborative efforts, the chemical industry can pave the way towards a greener, more sustainable future. This section delves into the potential of these green chemicals, their engineering challenges, and their prospects in shaping a greener tomorrow.

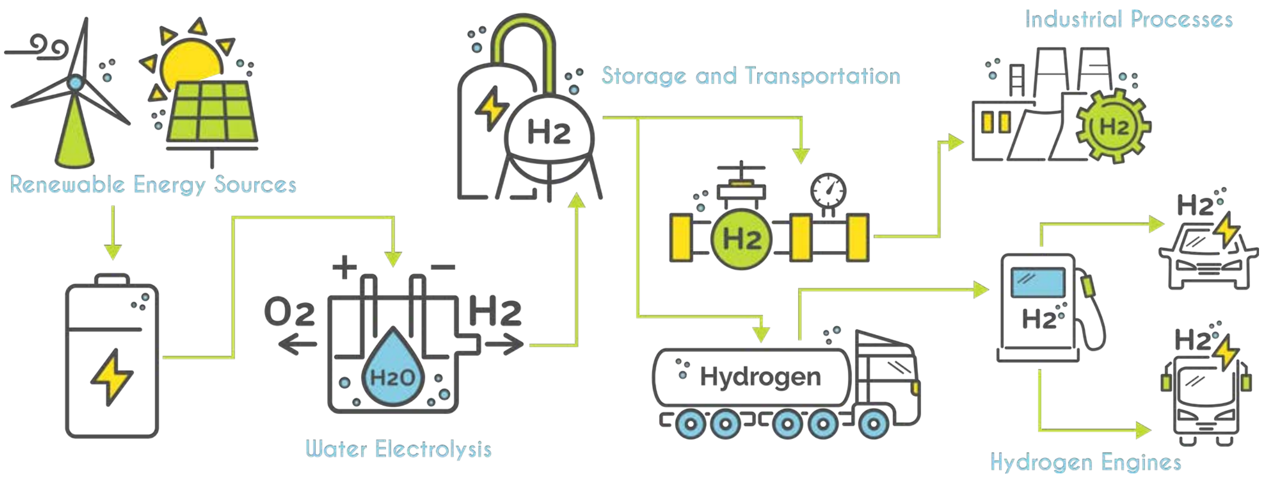
THE PROMISE OF GREEN AMMONIA

Ammonia is a corerstone of the agricultural industry, primarily used in fertilisers. Traditionally, ammonia is produced via the Haber-Bosch process, which is energy-intensive and heavily reliant on natural gas, a significant source of carbon emissions. On the other hand, green ammonia is produced using renewable energy sources such as wind, solar, or hydropower to electrolyse water and generate hydrogen, which is then combined with nitrogen from the air. The production of green ammonia involves two key steps:

- **Electrolysis:** Renewable electricity splits water into hydrogen and oxygen. Proton exchange membrane and alkaline electrolysis are standard methods.

- **Haber-Bosch Process:** The hydrogen produced is combined with nitrogen under high pressure and temperature in the presence of a catalyst to form ammonia.

Green ammonia production can potentially eliminate carbon emissions associated with traditional ammonia synthesis. As an energy-dense chemical, ammonia can store and transport renewable energy.
Green ammonia can be used directly as a carbon-free fuel in combustion engines and fuel cells, offering a clean alternative for shipping and heavy industry.
The primary challenge lies in reducing the cost of electrolysers and improving their efficiency. Current technologies are expensive and require significant capital investment. Scaling up green ammonia production to meet global demand requires advances in renewable energy generation and storage technologies. Existing infrastructure designed for fossil fuel-based ammonia may require substantial modifications to handle green ammonia safely and efficiently.



THE POTENTIAL OF GREEN METHANOL

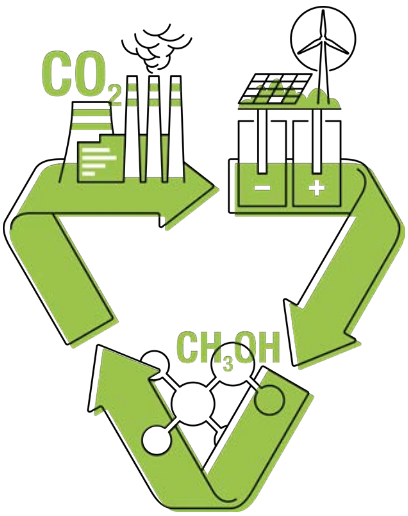
Methanol is a versatile chemical used in various industries, including fuel, pharmaceuticals, and plastics. Conventional methanol production relies on natural gas or coal, producing substantial carbon emissions. Green methanol, however, is produced using renewable feedstocks and sustainable processes, making it a promising candidate for a circular economy.

The production of green methanol typically involves:

- **Biomass Gasification:** Gasification converts Biomass into syngas (a mixture of hydrogen, carbon monoxide, and carbon dioxide).
- **Electrochemical Reduction:** Carbon dioxide captured from industrial emissions or directly from the air can be combined with green hydrogen to produce methanol.

Green methanol can achieve near-zero carbon emissions, mainly from captured CO_2. As a liquid fuel, methanol is more straightforward to store and transport than hydrogen, making it a suitable alternative for marine and road transportation. Green methanol can serve as a feedstock for producing various chemicals, promoting sustainable industrial practices. However, several engineering challenges must be resolved for the mass-scale adoption of green methanol and related technologies.

Sourcing sufficient biomass or capturing CO_2 at scale is challenging and requires technological and logistical advancements. Improving the efficiency of the production process, particularly in gasification and electrochemical reduction, is crucial for cost competitiveness. Like green ammonia, the high cost of renewable electricity and the capital-intensive nature of green methanol plants pose significant hurdles.



THE ROLE OF GREEN HYDROGEN

Hydrogen is a clean energy carrier with the potential to decarbonise various sectors, including transportation, industry, and power generation. Green hydrogen, produced through water electrolysis using renewable energy, offers a zero-emission alternative to grey hydrogen derived from natural gas. Green hydrogen, produced using renewable energy sources, is gaining traction across various industrial applications due to its potential to reduce carbon emissions significantly.

Green hydrogen can produce ammonia, a key component in fertilisers, without the associated carbon emissions of traditional methods. Hydrogen is essential in refining processes to upgrade heavy oil fractions and remove sulfur from fuels. Green hydrogen can replace conventional hydrogen to reduce the carbon footprint. Using green hydrogen instead of coke in steel production can drastically cut CO_2 emissions, making the industry more sustainable.

Surplus renewable energy can be converted into hydrogen, stored, and later converted back to electricity or used as a fuel. Hydrogen can help balance supply and demand in electricity grids with high renewable energy penetration. Green hydrogen is used in fuel cells for electric vehicles, particularly in heavy-duty transportation sectors like buses, trucks, trains, and ships. Industries that require high temperatures, such as cement and glass manufacturing, can use green hydrogen as a clean fuel alternative to natural gas or coal. Lastly, hydrogen is used in various processes, including producing semiconductors and electronic components, where green hydrogen can help reduce the industry's carbon footprint.

Green hydrogen production involves:

- **Electrolysis:** Renewable energy sources power electrolysers to split water into hydrogen and oxygen.
- **Storage and Distribution:** Hydrogen can be stored as a gas or liquid and transported via pipelines, tankers, or specially designed carriers.

Developing a green hydrogen economy is faced with several engineering challenges. The high cost of electrolysers and the need for abundant, low-cost renewable energy are significant barriers to widespread adoption. Developing a robust hydrogen infrastructure, including production facilities, storage systems, and distribution networks, is essential.

SUSTAINABLE AVIATION FUEL (SAF)

The aviation industry is a significant contributor to global carbon emissions. SAF derived from renewable resources such as biofuels, waste materials, or synthesised using green hydrogen and CO_2, offers a pathway to reduce the carbon footprint of air travel. India is making significant strides in developing its SAF market, aiming to position itself as a leader in this field. The country has set ambitious targets, with plans to blend 1% SAF with jet fuel by 2027 and 2% by 2028, initially targeting international flights. India's approach to SAF involves leveraging its abundant agricultural residues, used cooking oil, and other waste products as feedstocks. This initiative aligns with the global push for the aviation sector's decarbonisation, as SAF can be significantly less carbon-intensive than traditional jet fuel.

SAF can be produced through various methods, including:

- **Biomass-to-Liquid:** Converting biomass into liquid fuels through gasification & Fischer-Tropsch synthesis.
- **Hydroprocessed Esters and Fatty Acids (HEFA):** Waste oils and fats are used as feedstocks, processed through hydroprocessing to produce jet fuel.
- **Power-to-Liquid :** Combining green hydrogen with captured CO_2 to produce synthetic aviation fuel.

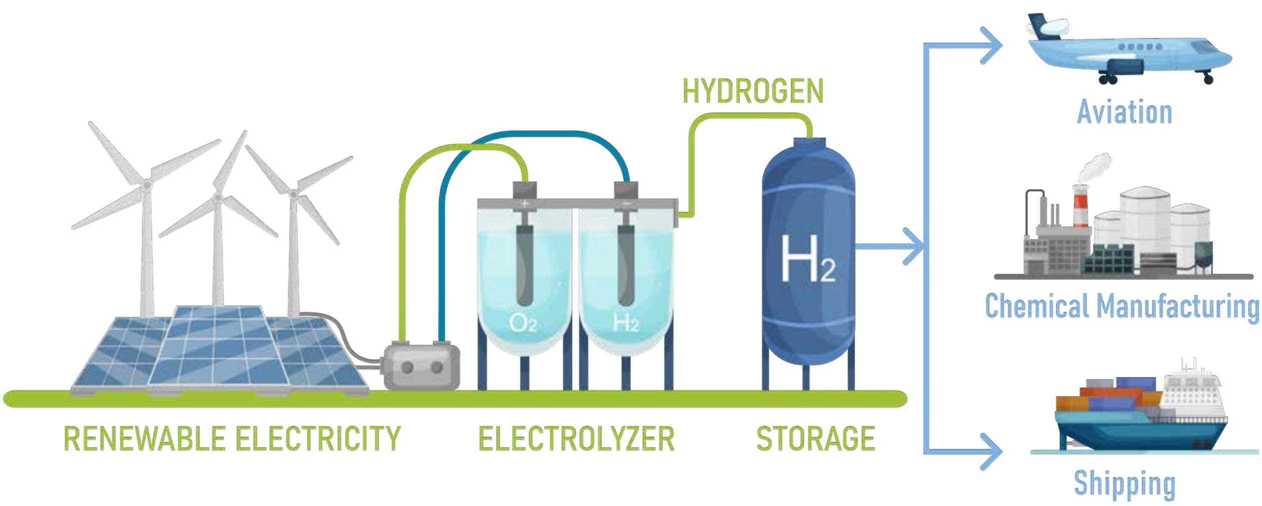
However, some challenges for SAF production include sourcing sufficient quantities of sustainable feedstocks and developing efficient conversion processes, which are critical. High production costs and limited economies of scale make SAF more expensive than conventional jet fuel. Ensuring SAF meets stringent safety and performance standards and scaling production to meet global demand are significant hurdles.

FUTURE OF GREEN CHEMICALS

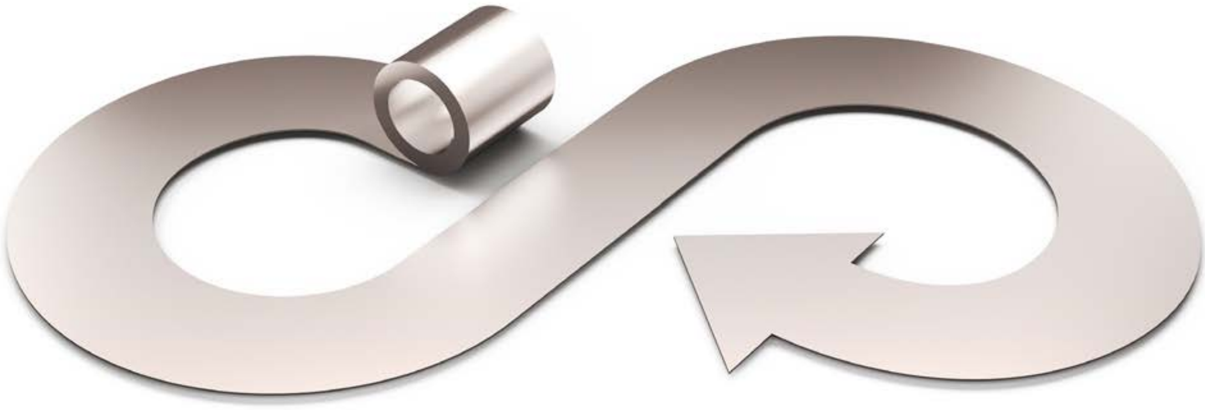
Green chemicals are poised to redefine the future of the chemical industry and beyond. They are driven by the urgent need to mitigate climate change and reduce environmental impact. Their successful integration into mainstream applications hinges on overcoming engineering challenges and achieving cost parity with conventional chemicals.

Continued research and innovation are vital to addressing the technical and economic barriers associated with green chemicals. Key areas of focus include:

- **Advanced Electrolysis:** Developing high-efficiency, low-cost electrolysers for green hydrogen and ammonia production.
- **Catalyst Development:** Designing more effective catalysts for chemical synthesis processes to operate at lower temperatures and pressures, reducing energy consumption and increasing yield.
- **Feedstock Optimisation:** Enhancing sustainable feedstocks' availability and processing efficiency for green methanol and SAF.
- **Process Integration:** Optimising the integration of renewable energy sources with chemical production processes to maximise efficiency and minimise costs.
- **Policy and Collaboration:** Policy support and collaboration across industries, academia, and governments are crucial to accelerating green chemical adoption. Initiatives such as carbon pricing, renewable energy subsidies, and research and development funding can drive the transition towards a sustainable chemical industry.



GREEN STEEL: TRANSFORMING THE STEEL INDUSTRY TOWARDS SUSTAINABILITY



Steel manufacturing is one of the most carbon-intensive industries, accounting for approximately 9-10 % of global CO_2 emissions. This is primarily due to the chemical reactions involved in traditional blast furnace operations, which rely heavily on coal and coke as reducing agents. However, as the world shifts towards more sustainable practices, the concept of "green steel" has emerged, aiming to drastically reduce carbon emissions through innovative technologies and alternative energy sources. The traditional steelmaking process involves the reduction of iron ore (Fe_2O_3) to iron (Fe) using carbon as a reducing agent in a blast furnace. This reaction generates a significant amount of CO_2. Given the fundamental chemistry, achieving zero-emission steel production is challenging.

However, hydrogen-based Direct Reduced Iron (DRI) technology advancements offer a promising alternative. Instead of using carbon as a reducing agent, this method employs hydrogen gas, producing water vapour instead of CO_2. The iron produced can then be processed in an Electric Arc Furnace (EAF) to make steel. Existing blast furnace-based steel plants can also transition to the DRI-EAF route. This involves:

- **Integration of Hydrogen Production:** Hydrogen production facilities should be established to ensure green hydrogen, preferably using renewable energy sources like wind or solar power.
- **Retrofitting Infrastructure:** Modifying existing BFs and establishing new DRI units compatible with hydrogen as a reducing agent.
- **EAF:** Shifting from traditional BFs to EAFs, which are more flexible and can be powered by renewable electricity, reducing overall emissions.

While transitioning to DRI-EAF is a long-term goal, there are interim measures to reduce emissions from existing blast furnaces. Utilising biomass or biochar as a partial replacement for coke can reduce net CO_2 emissions, as these materials are considered carbon-neutral.

Injecting methanol into blast furnaces can serve as a carbon source that partially offsets the need for coke, leading to lower CO_2 emissions. Directly injecting hydrogen into blast furnaces can complement the reduction process, reducing CO_2 output.

Transitioning to green steel, TCE is providing comprehensive engineering solutions, including roadmap studies and:

- **Hydrogen Production and Storage:** Efficient production, storage, and hydrogen transport are crucial. Electrolysis using renewable energy is a preferred method for producing green hydrogen.
- **Plant Retrofitting:** Upgrading existing plants to integrate new technologies without significant downtime or cost overruns.
- **Energy Management Systems:** Implementing advanced energy management systems to optimise energy usage and integrate renewable energy sources.

Significant capital investments are required for new technologies and for retrofitting existing plants. Scaling up green hydrogen production to meet the demands of the steel industry is again one of the main challenges for transitioning to green steel making. There is a need for supportive policies and regulations to facilitate the transition.

There is a need to increase the use of recycled steel scrap in EAFs, which will require significantly less energy to process than primary steel production. Powering EAFs with renewable electricity should be considered to reduce the carbon footprint further. Implementing CCUS technologies to capture CO_2 emissions from traditional blast furnaces and other processes would help decarbonise the steel industry.

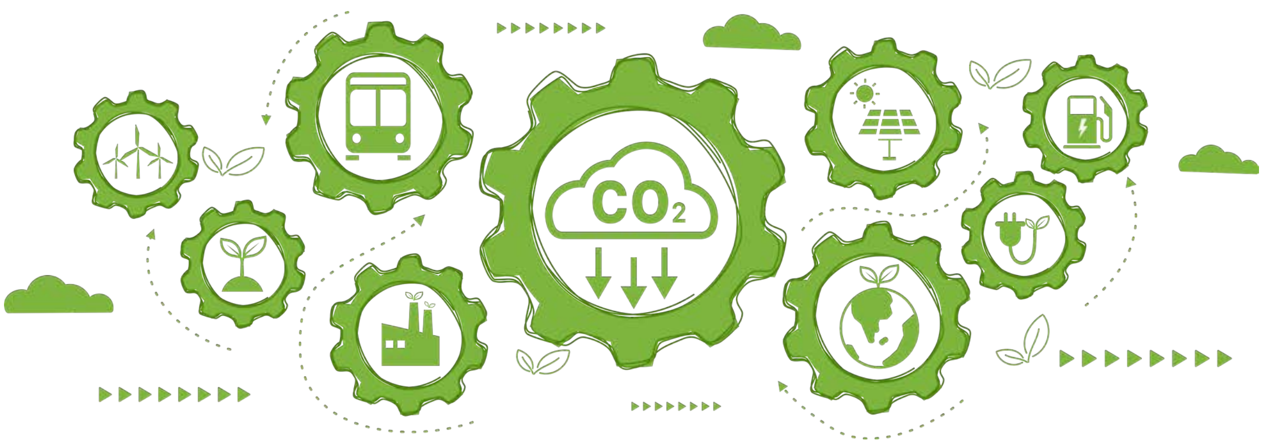
Green steel represents a transformative approach to steel manufacturing, aligning with global sustainability goals. While challenges exist, transitioning to hydrogen-based DRI and EAF and interim measures to reduce emissions in existing blast furnaces offer a viable path forward. Engineering a better tomorrow for green steel manufacturing involves several key strategies and technologies to reduce steel production's carbon footprint and environmental impact. With continued innovative solutions from TCE, the steel industry can significantly reduce its carbon footprint, contributing to a more sustainable future.

RENEWABLE ENERGY FOR DECARBONISING INDUSTRIAL SECTOR

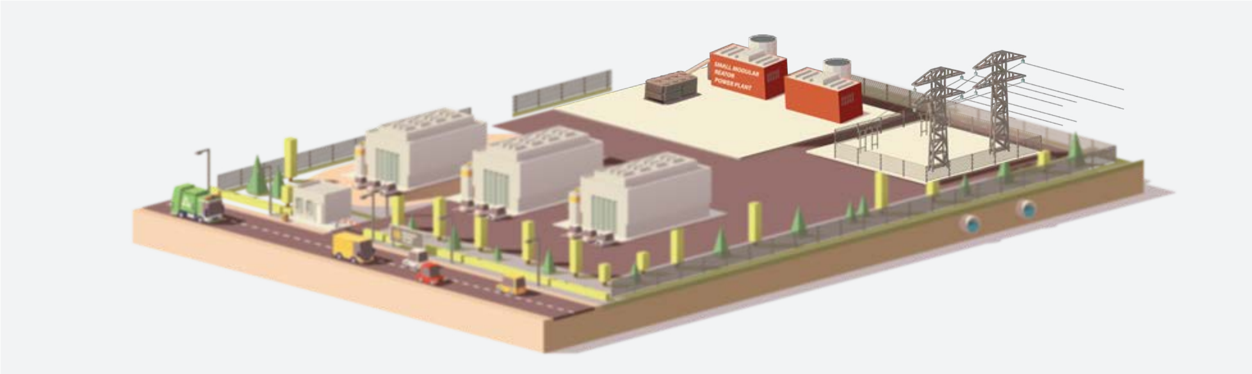
The global push towards sustainability has made renewable energy a critical component in decarbonising the industrial sector. As a developing country with burgeoning industrial activity, India has recognised the need to pivot towards renewable energy to meet its climate goals and ensure sustainable growth. India has set ambitious targets to enhance its renewable energy capacity. The country aims to achieve 450 GW by 2030. The strategy involves substantial investments in solar, wind, and hydroelectric power projects, supported by favourable policies and regulatory frameworks. This plan is critical for reducing greenhouse gas emissions, improving energy security, and reducing dependence on fossil fuels. India has made significant strides in solar energy generation. As of 2023, the country boasts over 50 GW of installed solar capacity, making it one of the largest solar markets globally. Key initiatives, such as the National Solar Mission and the implementation of solar parks, have propelled this growth. Due to their favourable geographical conditions, states like Rajasthan, Gujarat, and Tamil Nadu lead in solar power generation. Technological advancements in photovoltaic cells have enhanced efficiency and reduced costs. Innovations like bifacial solar panels, which capture sunlight from both sides and floating solar farms, which utilise water bodies, are gaining traction.

India's wind energy capacity is approximately 40 GW, with significant contributions from states like Tamil Nadu, Gujarat, and Karnataka. The country has leveraged its long coastline and favourable wind conditions to develop extensive onshore wind farms. The focus is now shifting towards offshore wind energy, with potential sites identified along the coasts of Gujarat and Tamil Nadu. Offshore wind farms can provide a more consistent and robust wind resource, although they come with higher initial costs and technical challenges.

Pumped hydro storage is a well-established technology for energy storage and balancing grid demands. India has an installed capacity of around 4.8 GW of pumped hydro storage. Projects like the Srisailam project in Andhra Pradesh and the Kadamparai project in Tamil Nadu are noteworthy examples. There is a renewed interest in expanding pumped hydro storage to support the increasing share of intermittent renewable energy sources. Modernisation of existing facilities and developing new projects are underway, aiming to enhance storage capacity and efficiency.



SMALL MODULAR NUCLEAR REACTORS FOR DECARBONISING INDUSTRIES



The industrial sector contributes to global greenhouse gas emissions, accounting for approximately 24% of global CO_2 emissions. Decarbonising this sector is critical to mitigating climate change. Nuclear energy, characterised by low lifecycle GHG emissions, presents a viable solution. However, large-scale nuclear reactors face high capital costs, long construction times, and public perception issues. Small Modular Reactors (SMRs) have emerged as an innovative solution, offering distinct advantages that make them suitable for industrial decarbonisation.

SMRs are designed to generate up to 300 MWe per unit, significantly smaller than traditional reactors. This smaller size allows for greater flexibility in deployment, making them suitable for various industrial applications. Additionally, SMRs can be manufactured in factories and transported to sites, facilitating faster and more efficient construction than conventional reactors. SMRs incorporate advanced safety features, such as passive safety systems that rely on natural circulation and gravity rather than active mechanical systems. This reduces the risk of accidents and simplifies the design.

The smaller reactor core and lower power output also decrease the potential impact of any incidents. The modular nature of SMRs allows for incremental investment, reducing the financial risk associated with enormous upfront capital costs. The potential for mass production of SMRs can lead to economies of scale, further driving down costs. Additionally, the shorter construction timelines translate to quicker returns on investment. One of the key innovations in SMR technology is the shift towards factory fabrication. This approach enhances quality control, reduces construction times, and lowers costs. Modules can be prefabricated and assembled on-site, minimising the complexity and risks associated with traditional on-site construction.

SMRs can be integrated into hybrid energy systems, which work with renewable energy sources such as wind and solar. This integration can provide a stable and reliable energy supply, balancing the intermittent nature of renewables and enhancing grid stability. India has recognised the potential of SMRs in meeting its energy needs and decarbonisation goals. The country has a robust nuclear energy program is actively exploring SMR technologies. The Department of Atomic Energy and Nuclear Power Corporation of India Limited are leading efforts to develop and deploy SMRs. India is developing indigenous SMR designs, leveraging its existing expertise in nuclear technology. These efforts aim to create cost-effective and locally suitable SMR solutions. SMRs represent a futuristic technology with transformative innovation in the nuclear energy sector, offering a viable solution for the decarbonising industry: flexibility, enhanced safety features, and economic advantages. TCE has extensive experience in engineering atomic facilities in India and is ready to take up the challenge of implementing SMRs shortly.

TCE is at the vanguard of engineering a better tomorrow by pioneering and implementing advanced technological solutions across various industry segments. We significantly contribute to the global effort to reduce carbon emissions and transition to clean energy sources through our commitment to biofuels, green hydrogen, green ammonia, green methanol, and green steel.

ENGINEERING SUSTAINABLE INFRASTRUCTURE

Sustainable infrastructure engineering is pivotal in addressing the challenges of rapid urbanisation, climate change, and resource depletion. The concept of sustainable infrastructure encompasses planning, designing, constructing, operating, and maintaining infrastructure systems to ensure economic efficiency, social equity, and environmental responsibility. As global populations continue to urbanise, the demand for resilient and sustainable infrastructure has become increasingly critical.

Environmental sustainability focuses on minimising the ecological footprint of infrastructure projects. Efficiently utilising materials and energy to reduce waste and pollution forms the core of sustainable solutions. Another important aspect is designing infrastructure to withstand and adapt to the effects of climate change, such as extreme weather events and sea-level rise. TCE's sustainable design and construction practices focus on minimising environmental impact and enhancing resource efficiency. Key practices include - Adhering to standards such as LEED (Leadership in Energy and Environmental Design) to ensure sustainable construction practices, Incorporating renewable energy sources, such as solar and wind power, into infrastructure projects and Using materials that are renewable, recyclable, and have a low environmental impact.

TCE uses smart technologies, which are crucial in enhancing infrastructure sustainability. TCE also employs BIM to optimise infrastructure projects' design, construction, and operation.

Engineering sustainable infrastructure is crucial for addressing the environmental, social, and economic challenges of the 21st century. By adhering to sustainable principles, employing advanced methodologies, and leveraging smart technologies, it is possible to create resilient, efficient, and equitable infrastructure systems. Through continued innovation and collaboration, sustainable infrastructure can pave the way for a more sustainable and prosperous future.

> TCE is one of the technological frontiers that define the future of engineering and sustainability. Join us as we chart a course towards a cleaner, greener, and more innovative world, leveraging our expertise to create lasting positive impacts across various industry segments.

LITHIUM-ION BATTERY MANUFACTURING PLANTS

Lithium-ion batteries have become the cornerstone of modern energy storage, playing a critical role in various sectors such as consumer electronics, renewable energy storage, and especially electric mobility. The surge in demand for electric vehicles has spurred significant growth in the lithium-ion battery manufacturing industry. India is emerging as an essential player in the global lithium-ion battery market. The country's growing emphasis on renewable energy and electric mobility drives the demand for lithium-ion batteries. The Indian government's initiatives, such as the National Electric Mobility Mission Plan (NEMMP) and the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, are pivotal in promoting the adoption of EVs and, consequently, the development of local battery manufacturing capabilities.

The Indian lithium-ion battery market is projected to grow by over 30% by 2026. Several factors contribute to this growth. The Indian government has proactively created a conducive environment for battery manufacturing through subsidies, tax benefits, and incentives for manufacturers and consumers. Numerous international battery manufacturers are entering the Indian market through joint ventures and collaborations with local companies. This influx of foreign capital and expertise is accelerating the development of battery manufacturing infrastructure. Initiatives like the Make in India campaign encourage domestic production of lithium-ion batteries, reducing dependence on imports and enhancing self-reliance.

The burgeoning EV sector is the primary driver of the lithium-ion battery market in India. With a target of achieving 30% electric vehicle penetration by 2030, India presents a substantial market for lithium-ion batteries. The two- and three-wheeler segments are expected to grow significantly, further boosting battery demand. Integrating renewable energy sources, such as solar and wind, into the grid necessitates efficient energy storage solutions. Lithium-ion batteries, with their high energy density and long cycle life, are well-suited for this purpose.

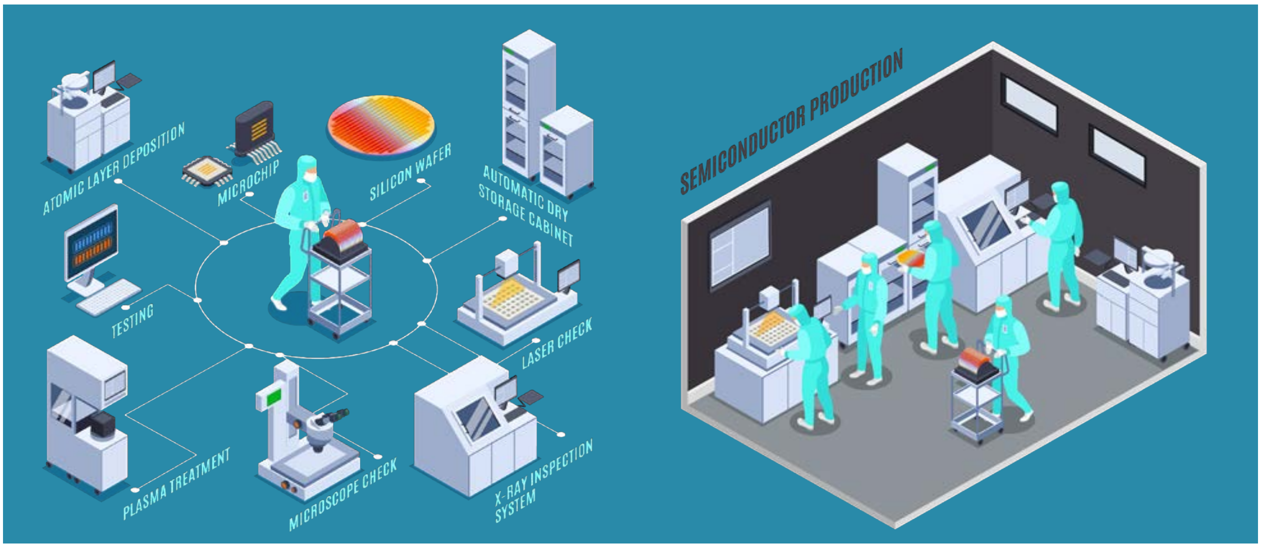
The Indian government's focus on increasing renewable energy capacity to 450 GW by 2030 will drive demand for lithium-ion batteries for grid storage applications. As the new horizon technology, several engineering Challenges must be addressed while setting Up battery plants. The availability of critical raw materials, such as lithium, cobalt, and nickel, poses a significant challenge. India lacks substantial reserves of these materials and relies heavily on imports. Developing a robust supply chain and exploring alternative sources and materials, such as lithium iron phosphate (LFP), are critical.

Setting up a lithium-ion battery plant requires substantial investment, including clean rooms, specialised machinery, and testing facilities. The precision and quality control required in battery manufacturing necessitates advanced technology and expertise, which can be a barrier for new entrants. Adhering to stringent environmental and safety regulations is crucial in battery manufacturing. Proper disposal and recycling of batteries, managing hazardous materials, and ensuring worker safety are paramount. Compliance with these regulations increases the complexity and cost of setting up manufacturing facilities.

Technology is progressing fast, and innovations such as automation and robotics are being implemented to enhance precision, reduce human error, and increase production efficiency. Automated assembly lines, robotic material handling, and advanced inspection systems are integral to modern battery plants. Integrating digital technologies and the Internet of Things (IoT) in battery manufacturing plants enables real-time monitoring, data collection, and analytics. This digital transformation enhances process optimisation, predictive maintenance, and quality control. One of the critical components in battery manufacturing is the dry room. Lithium-ion batteries are susceptible to moisture; even trace amounts of water can degrade battery performance and safety. A well-designed dry room with controlled humidity levels (typically below 1% relative humidity) is essential.

Advanced dehumidification systems are required to maintain deficient humidity levels. Desiccant-based dehumidifiers are commonly used. HEPA filters are necessary to ensure that the air within the dry room is accessible from particulates and contaminants. Specialised equipment for handling and storing sensitive materials within the dry room is necessary to prevent contamination and exposure to moisture. Ongoing research and development in battery chemistries are producing batteries with higher energy densities, longer lifespans, and improved safety profiles. Solid-state batteries, silicon anode batteries, and lithium-sulfur batteries are promising technologies being explored, and they could revolutionise the battery manufacturing landscape.

ADVANCED TECHNOLOGIES: SEMICONDUCTORS



Semiconductors form the backbone of modern technology, integral to everything from smartphones and computers to advanced automotive systems. With its burgeoning digital economy and a tech-savvy populace, India stands on the cusp of becoming a global semiconductor manufacturing hub. The importance of establishing a robust semiconductor manufacturing ecosystem in India cannot be overstated, as it promises to drive economic growth, enhance national security, and reduce dependency on imports. India's foray into semiconductor manufacturing is marked by significant capital expenditure (capex) investments. The country's first high-capex semiconductor project, with investments running into billions of dollars, is set to lay the foundation for a self-reliant semiconductor industry.

The integration of several specialised units supplied by Original Equipment Manufacturers (OEMs) is crucial for the success of the semiconductor manufacturing facility. OEMs are essential partners in the semiconductor value chain, providing the necessary specifications, market demand insights, and technical requirements. Collaboration with OEMs ensures that the manufactured semiconductors meet industry standards and are compatible with various end-use applications, such as consumer electronics, automotive systems, and industrial machinery. This requires extensive experience, and TCE leverages a strong record of executing large, complex, first-of-its-kind projects. Building a new semiconductor plant involves numerous project management challenges. Semiconductor plants, or fabs, are the most complex manufacturing facilities to design and build. They require cleanrooms, precision equipment, and sophisticated process control systems. Given the high capex involved, managing time and costs is critical. Delays and budget overruns can significantly impact the project's viability. Ensuring a steady supply of raw materials and advanced machinery from global suppliers involves intricate logistics and coordination. Recruiting and training a skilled workforce is essential, as semiconductor manufacturing requires specialised knowledge and expertise.

Innovative engineering solutions are vital for overcoming the challenges in semiconductor manufacturing. Modular design principles allow for scalable and flexible plant construction, enabling future expansions and upgrades with minimal disruption. Automation technologies, including robotics and AI-driven process controls, enhance precision, efficiency, and yield in semiconductor manufacturing. Integrating sustainable practices, such as recycling water and reducing energy consumption, helps minimise the environmental impact of semiconductor fabs. Utilising digital twin technology and collaborative platforms facilitates real-time monitoring and decision-making, ensuring optimal plant performance and maintenance.

The future of semiconductor manufacturing in India looks promising. With government support through initiatives like the Production Linked Incentive scheme and investments in infrastructure, India is poised to attract global semiconductor giants and foster domestic champions. Developing semiconductor clusters and research institutions will further enhance the ecosystem, driving innovation and technological advancement.

CONCLUDING REMARKS

TCE is at the vanguard of engineering a better tomorrow by pioneering and implementing advanced technological solutions across various industry segments. We significantly contribute to the global effort to reduce carbon emissions and transition to clean energy sources through our commitment to biofuels, green hydrogen, green ammonia, green methanol, and green steel. Our advancements in lithium battery technology and semiconductor manufacturing are essential for enabling the widespread adoption of renewable energy and enhancing the efficiency of modern infrastructure.

By integrating these cutting-edge technologies into diverse industry applications, we are addressing the immediate challenges of climate change and laying the groundwork for a sustainable and resilient future. Our comprehensive approach ensures that our solutions are scalable, economically viable, and environmentally friendly, meeting the needs of our customers and the broader society.

As we progress, TCE remains dedicated to innovation, sustainability, and excellence. We will continue to push the boundaries of what is possible, leveraging our expertise to engineer solutions that drive progress and create lasting positive impacts. Together, we are not just envisioning a better tomorrow—we are actively building it, one technological breakthrough at a time. By taking the lead in executing first-of-its-kind projects, TCE is one of the technological frontiers that define the future of engineering and sustainability. Join us as we chart a course towards a cleaner, greener, and more innovative world, leveraging our expertise to create lasting positive impacts across various industry segments.

Author

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Chief Technology Officer

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Architectural Paradigm Shift

Exploring Cutting-Edge Advances in Modular and Prefabricated Construction Technology

The construction industry is on the brink of a transformative era, driven by innovative technologies that promise to redefine how we build our world. Among these advancements, modular and prefabricated construction technology has emerged as a game-changer, offering a paradigm shift in traditional construction methods. This research article delves into the intricacies of modular and prefabricated construction, exploring its evolution, current state-of-the-art practices, and the potential implications for the future of the built environment.

Historically, construction projects have been synonymous with time-consuming, labour-intensive processes, often plagued by delays, cost overruns, and inefficiencies. Adopting modular and prefabricated construction represents a departure from this conventional approach, offering a more streamlined, efficient, and sustainable alternative. This methodology involves the assembly of building components off-site in controlled environments, subsequently transporting and assembling them on-site.

Various factors, including advancements in materials, computer-aided design, manufacturing processes, and a growing emphasis on sustainability and cost-effectiveness, propel the modular and prefabricated construction revolution. The ability to prefabricate entire building modules or components in a factory setting allows for meticulous quality control, reduced construction time, and minimised environmental impact.

This research article aims to provide an in-depth analysis of the key elements driving the adoption of modular and prefabricated construction technology. It will explore this innovative approach's technical aspects, economic implications, and environmental considerations. Additionally, the article will examine notable case studies and successful implementations of modular and prefabricated construction across different scales and building types.

Understanding and harnessing the potential of modular and prefabricated construction becomes imperative as we navigate the complexities of an ever-evolving urban landscape and face challenges such as population growth, resource constraints, and the need for sustainable infrastructure. This research article seeks to contribute to the ongoing discourse surrounding this transformative technology, offering insights that can inform industry professionals, researchers, and policymakers alike.

In the subsequent sections, we will delve into the historical context of modular construction, the technological advancements shaping its trajectory, and the socio-economic implications that make it a compelling choice for the future of construction. Through this exploration, we aim to shed light on the multifaceted dimensions of modular and prefabricated construction technology, paving the way for a more efficient, resilient, and sustainable built environment.

ADVANTAGES FOR ARCHITECTS

- **Speed and Efficiency:** Modular and prefabricated construction significantly reduces project timelines, allowing architects to meet tight deadlines and client expectations.
- **Cost-Effectiveness:** The controlled factory environment minimises waste, enhances resource efficiency, and often leads to cost savings compared to traditional construction methods.
- **Design Flexibility:** Contrary to misconceptions, modular construction offers architectural flexibility. Architects can still create unique and aesthetically pleasing designs while benefiting from the efficiency of off-site fabrication.
- **Sustainability**: The controlled manufacturing process enables better waste management, and the ability to use recycled materials makes modular construction an environmentally friendly choice.

MODULAR AND PREFABRICATED CONSTRUCTION TECHNOLOGY

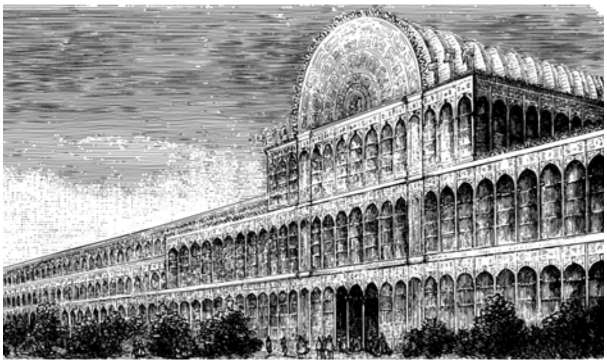
Today, at the forefront of this revolution, a profound transformation spurred by technological innovations that challenge traditional methodologies and reshape the landscape of how we build is the advent of modular and prefabricated construction technology. This dynamic approach redefines the essence of construction processes.

To understand the significance of modular and prefabricated construction, it is crucial to trace its historical evolution. The origins of prefabricated construction can be traced back to various historical points, with examples of early prefabrication practices found in different parts of the world. Here are some notable instances that highlight the historical roots of prefab construction:

- **Ancient Rome**: The Romans were known for their engineering prowess and employed prefabricated construction techniques in various structures. One notable example is the construction of villas and forts, where building components, such as columns and architectural elements, were mass-produced in workshops and transported to the construction site for assembly.

- **18th-Century England:** In the 18th century, England saw the emergence of prefabricated construction methods. One well-known example is the construction of early "kit" houses. Companies offered pre-cut building materials and components that could be shipped to the customer's location for assembly. These kits often included everything from timber to windows and doors.

- **1851 Crystal Palace, London:** A landmark event in the history of prefabricated construction was the Great Exhibition of 1851 in London, where Joseph Paxton designed and built the Crystal Palace. This iconic structure was a pioneering example of large-scale prefabrication, with standardised iron and glass components manufactured off-site and assembled locally.



- **Sears, Roebuck and Company Houses (20th Century):** In the early 20th century, Sears, Roebuck and Company in the United States offered mail-order houses as kits. Customers could choose a house design from a catalogue, and Sears would ship all the necessary materials, including precut lumber and detailed instructions, to the customer's location. This approach allowed for more affordable and accessible home ownership.

- **Post-World War II Housing:** After World War II, there was a pressing need for rapid housing construction to accommodate returning veterans and growing populations. Prefabricated construction gained popularity as a solution to this demand. Various countries, including the United States and the United Kingdom, embraced prefab techniques to assemble housing units quickly.

- **Soviet Union's Khrushchyovkas:** In the mid-20th century, the Soviet Union's Khrushchyovka housing program involved the mass production and assembly of standardised panel buildings. These prefab apartment buildings were crucial in addressing housing shortages in urban areas.

- **Modern Prefabrication (Late 20th Century - Present):** In recent decades, technological advancements, materials, and construction processes have led to a resurgence of interest in prefabricated construction. Modular construction, in particular, has gained prominence, with entire building modules being manufactured off-site and transported for assembly. This approach is being used for a wide range of structures, from residential buildings to commercial complexes.

The evolution of prefabricated construction reflects a continuous quest for more efficient, cost-effective, and scalable building methods throughout history. From ancient civilisations to the present day, the principles of prefabrication have shaped the built environment.

KEY COMPONENTS OF MODULAR CONSTRUCTION

Basically, Modular construction has two components:

- **Modules:** The building blocks of modular construction, these are factory-built components that can include entire rooms, walls, floors, or even facades.
- **Connectors:** Specialised connectors facilitate the assembly of modules on-site, ensuring structural integrity and efficient integration.

PREFABRICATION TECHNIQUES

There are primarily 3 broad kinds in which Modular construction is carried out.

- **Volumetric Construction:** Entire rooms or sections are manufactured as three-dimensional units, minimising on-site assembly.
- **Panelised Systems:** Walls, floors, and roofs are produced as panels and assembled on-site.
- **Hybrid Systems:** A combination of modular and traditional construction methods to maximise efficiency and design flexibility.

TECHNOLOGICAL CATALYSTS

Various technological catalysts have significantly influenced the adoption and evolution of modular and prefabricated construction technology. These catalysts have played a crucial role in transforming traditional construction practices and paving the way for more efficient, sustainable, and innovative building methods. Here are some critical technological catalysts driving the advancement of modular and prefabricated construction:

Computer-Aided Design (CAD): CAD technology has revolutionised the design phase of construction projects. Architects and engineers can create detailed and intricate 3D models, allowing for precise planning and visualisation of modular components. CAD facilitates efficient collaboration among design professionals, producing more accurate, sophisticated, prefabricated building designs.

Building Information Modeling (BIM): BIM is a collaborative digital process that integrates various aspects of a construction project, from design and planning to construction and maintenance. BIM enhances communication and coordination among stakeholders, providing a comprehensive digital representation of the building. This technology is instrumental in optimising the prefabrication process and ensuring seamless integration of modular components.

Advanced Materials and Composites: Technological advancements in materials science have introduced a range of high-performance and sustainable materials suitable for prefabricated construction. Lightweight yet durable materials, such as engineered wood products, advanced steel alloys, and composite materials, contribute to the strength and resilience of modular components while reducing overall weight and transportation costs.

Energy-Efficient Systems: Integrating energy-efficient systems, such as smart HVAC (Heating, Ventilation, and Air Conditioning) and lighting solutions, contributes to the overall sustainability of prefabricated buildings. These systems enhance occupant comfort while reducing energy consumption and operational costs.

Digital Fabrication Technologies: Digital fabrication technologies, including 3D printing and robotic fabrication, are increasingly employed in modular construction. These technologies enable the production of intricate and customised components with high precision. 3D printing, in particular, can revolutionise the construction industry by allowing on-site printing of building elements.

IoT (Internet of Things): IoT technologies are integrated into prefabricated construction to enhance functionality and efficiency. Smart building components with sensors and connectivity enable real-time monitoring and data collection. This information can be used for predictive maintenance, energy optimisation, and overall building performance enhancement.

Prefab Software Solutions: Dedicated software solutions tailored for prefabrication and modular construction streamline project management, logistics, and coordination. These tools enable better collaboration among project stakeholders, facilitating communication and ensuring all components align seamlessly during assembly.

Augmented Reality (AR) and Virtual Reality (VR): AR and VR technologies are utilised for design visualisation, construction planning, and worker training. These immersive technologies allow stakeholders to experience a virtual representation of the modular construction project, helping to identify potential issues and streamline decision-making before construction begins.

Drones for Site Inspection: Drones are increasingly used for site inspections, surveying, and monitoring during construction. They provide real-time data and imagery, allowing project managers to assess progress, identify potential challenges, and ensure that modular components are installed correctly.

Robotics and Automation: Integrating robotics and automation in manufacturing facilities has significantly improved the efficiency and precision of prefabrication processes. Automated machinery can perform repetitive tasks accurately, leading to consistent and high-quality modular components. Robotics also enhances worker safety by handling tasks that may be hazardous in traditional construction settings.

The convergence of these technological catalysts is driving the ongoing transformation of the construction industry, enabling modular and prefabricated construction to be at the forefront of innovation and efficiency. As these technologies evolve, the construction landscape will likely see further speed, precision, and sustainability advancements.

ARCHITECTURAL PRACTICES AT TCE

Using modular elements in design always contributes to cohesion, harmony, and a sense of unity within a visual composition. Consistency in design elements helps to create a more organised and visually pleasing outcome. Modular elements can save time and resources. Once a set of elements is established and proven effective, we replicate or modify them for future projects, promoting efficiency.

Prefab construction also often involves meticulous planning and coordination during the design and manufacturing stages. This can result in more efficient project management, reducing the likelihood of delays during the construction phase. Prefab construction minimises on-site disruption and noise, as most of the noisy and disruptive construction activities occur in the factory. This is particularly advantageous in urban areas with tight regulations on construction noise and disruption.

Prefab building elements often come as pre-engineered systems. This means that the structural and design considerations are integrated into the prefabricated components, reducing the need for extensive on-site engineering work.

In design projects that tell a story or convey a message, using consistent elements helps in weaving a cohesive narrative. Elements can be employed to evoke specific emotions or themes throughout the design.

Figure: Typical courses of each columns are produced and assembled at site

Having certain modular architectural elements, such as columns, arches, or materials, can assist in defining and organising spatial layouts. This creates a sense of order and hierarchy within the building. Consistent architectural elements can be employed to convey cultural symbolism or reflect the values and identity of a community. This helps in creating a building that resonates with its users and surroundings.

Figure: Modular Arches and Iconography providing a sence of cohesion and hierarchy to the entire space

Replicating and producing certain architectural elements off site can lead to cost savings in terms of design, manufacturing, and construction. Standardised elements often require less time and resources for planning and execution. Taking example from one of our projects (picture below), initially when the same scheme was conceptualised in stone, the cost was shooting immensely and in turn they were produced in GRC at a factory and installed on the façade. Adopting prefabricated GRC elements not only saved cost but also regulated quality and reduced time of finishing against when a manual stone clad façade was visualised.

Figure: Modular Cladding prefabricated in factory and installed on RCC columnar structure

When Prefab elements arrive at the construction site ready for assembly, it minimises the time spent on-site for tasks such as cutting, shaping, and assembling traditional elements, which is common in on-site construction.

Figure: Prefabricated Porta Cabins installed in a PEB Shed structure for Security scanning at the entry of a complex

Figure: Usage of Prefabricated Wall Panels for building enclosure

Figure: Interiors of the PEB Building

Standardising certain architectural elements, such as windows or roofing materials, can simplify production of drawings which are technically correct and have minimum error. This is especially relevant for large-scale projects or developments. We are imbibed in standardising all regular elements which enables us to deliver more efficiently in minimum time.

Our successful adoption of modular and prefabricated construction at TCE requires a strategic approach. Educating professionals, evaluating project suitability, collaborating with experts, and investing in technology and training are vital steps to seamlessly integrating this methodology into construction practices.

CONCLUSION

In conclusion, adopting modular and prefabricated construction technology represents a transformative journey for the construction industry, promising a future of efficiency, sustainability, and innovation. This paradigm shift is propelled by technological catalysts, changing industry mindsets, and a pressing need for more rapid and sustainable building solutions.

As the global population grows and urbanisation accelerates, modular and prefabricated construction offers a timely response to the demand for rapid, cost-effective, and sustainable building solutions. From residential housing to commercial structures, the diverse applications of modular construction underscore its adaptability and potential to address pressing challenges in the built environment.

Our successful adoption of modular and prefabricated construction at TCE requires a strategic approach. Educating professionals, evaluating project suitability, collaborating with experts, and investing in technology and training are vital steps to seamlessly integrating this methodology into construction practices. Furthermore, partnerships with modular construction specialists and a commitment to continuous improvement will ensure this transformative approach's ongoing success and evolution.

In essence, modular and prefabricated construction is not merely a construction method but a catalyst for positive change in the industry. By embracing this innovative approach, we at TCE have the opportunity to redefine efficiency, enhance sustainability, and contribute to the creation of resilient and forward-looking built environments. The journey towards a modular future is underway, and we, as practitioners, navigate this transformative landscape. We stand at the forefront of shaping the future of construction.

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Building Tomorrow: Steering to a Greener Future

Humanity is currently facing numerous global challenges of unprecedented scale and complexity, such as climate change, depletion of natural resources, social inequality, and economic fragility. To ensure our survival and prosperity, it is imperative that we work towards a sustainable, innovative, and inclusive future. This article explores the various strategies that can be employed to navigate these turbulent times and pave the way for a brighter, more resilient tomorrow.

Sustainability: Sustainability is the cornerstone of our vision for the future. Its importance goes beyond environmental conservation and encompasses a holistic approach that includes economic viability and social equity. Denmark and Japan are pioneers in this philosophy. Denmark's wind energy initiative demonstrates how renewable energy can power a nation and bring economic and social benefits. Japan's aggressive recycling mandates show how a circular economy can reduce waste, conserve resources, and create jobs.

In addition, the regeneration of urban spaces into green, energy-efficient environments presents another aspect of sustainable development. Cities like Singapore and Stockholm are leading the way with innovative city projects that integrate green roofs, efficient public transportation, and waste-to-energy systems, proving that urban areas can solve environmental challenges.

Technology: The impact of technological innovation on sustainability is revolutionary. Renewable energy technologies such as solar photovoltaic (PV) panels and offshore wind turbines are becoming more efficient and affordable, driving the transition towards a green economy. In addition, electric vehicles (EVs) and hydrogen fuel cells are paving the way for significantly reducing greenhouse gas emissions in transportation.

Blockchain technology is also showing potential to enhance transparency and efficiency in renewable energy markets, enabling peer-to-peer energy trading and improving supply chain sustainability. Technology also has the potential to address critical issues in the fight against climate change, such as geoengineering projects and carbon capture and storage (CCS) technologies.

Inclusiveness: Inclusiveness is a crucial pillar of sustainable development. An inclusive future means that every individual, regardless of their socioeconomic status, has access to the opportunities and benefits of development. Inclusivity extends beyond healthcare and education to encompass economic opportunities, digital inclusion, and participation in decision-making processes. Initiatives like microfinance and social entrepreneurship empower communities in developing countries by providing the resources needed to lift themselves out of poverty. Bridging the digital divide through affordable internet access and digital literacy programs is critical for ensuring that everyone can benefit from the digital economy. Inclusive policies and practices foster social cohesion and resilience, as exemplified by the global response to the COVID-19 pandemic, which highlighted the importance of solidarity and collective action.

Collaboration: National borders do not limit our challenges and require a unified response. International cooperation platforms like the United Nations, G20, and COP28 are essential in promoting collaboration among nations to address climate action, sustainable development, and crisis response. Collaboration is not limited to the governmental level only; public-private partnerships, cross-sector alliances, and community initiatives are crucial in driving sustainable innovation and implementing solutions.

The concept of resilience has become increasingly important in recent years, emphasised by the global upheaval caused by the COVID-19 pandemic.

Resilience: Building resilient societies involves strengthening healthcare systems and infrastructure and fostering economic stability, social cohesion, and environmental sustainability. Strategies such as developing green infrastructure, diversifying supply chains, and investing in renewable energy are critical in enhancing resilience.

In conclusion, a sustainable, innovative, and inclusive future is crucial to address the pressing challenges of our time. By embracing these principles, we can forge a future that is not only sustainable and innovative but also inclusive and resilient, ensuring the well-being and prosperity of future generations. Let us unite in this monumental task, for the decisions we make today will shape the world of tomorrow.

> The impact of technological innovation on sustainability is revolutionary. Renewable energy technologies such as solar photovoltaic (PV) panels and offshore wind turbines are becoming more efficient and affordable, driving the transition towards a green economy. In addition, electric vehicles (EVs) and hydrogen fuel cells are paving the way for significantly reducing greenhouse gas emissions in transportation.

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Significant Role of Activity-based Travel Modelling in Urban Planning & Mobility

The strategic use of data has become indispensable for advancing the planning and modelling of intricate urban services. Within this landscape, mobility emerges as a critical focal point, necessitating substantial improvements to address key challenges in urban areas effectively. A discernible global trend reveals increasing investments in mobility-related services, particularly noteworthy in densely populated nations such as India and China. The escalating toll of congestion and pollution on cities has propelled city agencies to pivot from traditional models to more forward-looking approaches, representing a paradigm shift from practices prevalent in the past decade.

TRIP MODELLING

Since their inception, traditional travel models, notably the widely employed trip-based models, have been pivotal in supporting regional, subregional, and project decision-making processes.

However, the dynamic nature of evolving travel demands, with increasing user expectations to have services at the time of need and with the comfort of private transport, necessitates a closer look.

"Within the transportation sector, decision-makers grapple with complex questions demanding judicious choices for investments in diverse shared transportation models."

Users prioritise convenience, shorter travel times, and fewer interchanges, emphasising the critical role of public transit in addressing these pain points. The on-demand shared mobility options become apparent in peak demand routes and timing, indicating the need to address both temporal and spatial factors.

Figure 1: On-demand shared mobility options must be a priority in all towns and cities with a rapid increase in share of private vehicle usage

CHALLENGES IN THE CURRENT MODEL

Traditional trip-based models face challenges in meeting these dynamic demands. Understanding trends and utilising advanced trip models are imperative to match service delivery with evolving travel needs.

The conventional trip model, rooted in the zones of trip production and termination, lacks the spatial-temporal relationship of each trip. Its broad aggregation based on zones and travel modes fails to support detailed trip modelling, which is essential for addressing dynamic demands requiring precise timing and spatial attributes.

Modern travel demands go beyond mere convenience; they demand a seamless and integrated network for the entire trip. Various surveys assessing the factors to improve the quality of public transportation highlight three significant criteria: frequency, reliability, and addressing service delivery gaps such as last-mile connectivity and intermediate connections. Tackling these criteria is crucial for a successful shift to public transportation modes.

Investments in transportation play a pivotal role in addressing the challenges of traffic congestion, pollution, and other mobility-related issues cities face. In response to these challenges, city agencies establish authorities to integrate various modes of transport into a unified transportation network.

A Unified Metropolitan Transport agency aims to consolidate all transportation services onto a single platform. This allows users to utilise a comprehensive ticket that covers all aspects of their trip, preventing overlapping services and eliminating duplicate coverage zones.

Tata Consulting Engineers has collaborated across diverse smart city and urban development projects with spatial planning agencies like CIDCO and Urban Local Bodies. This partnership involves continually evolving strategies tailored to meet specific project requirements. Backed by a comprehensive team comprising urban planners, designers, and a robust infrastructure support unit, TCE strategically positions itself to excel in town and urban planning projects.

SHIFTING TO AN ADVANCED MODEL

The Activity-Based Demand Model was developed in the late 20th century to solve the constraints of traditional trip models. This concept gained prominence in transportation planning and research during the 1980s and 1990s, driven by the study and evolution of activity-based models. Various researchers and practitioners in the transportation planning and modelling community contributed to this paradigm shift, recognising that many factors influence people's travel behaviour.

The Activity-Based Model aims to capture actual travel patterns and their complexities, considering dimensions such as time, duration, and scheduling constraints. Unlike most trip-based models, it provides person-level data, offering a more detailed perspective. This modelling approach acknowledges that travel demand originates from individuals' needs to engage in various activities.

This model is the foundation for behavioural theories related to travel decision-making, representing each activity and travel choice. Its data encompasses various decisions based on income, transit accessibility, travel times, etc.

These insights contribute to the development of trip modelling, which is highly accurate in determining when, where, and how trips should be assigned. Furthermore, it empowers users with greater freedom and choices, particularly in shared modes of transport, which are characterised by seamlessness, integration, and convenience. Adopting Activity-Based Travel Demand marks a transformative shift in transportation planning, offering a nuanced understanding of individual travel choices' intricate dynamics.

This shift to Activity-based modelling is considered a crucial development in the field, and researchers have explored various facets of activity-based travel demand models (ABTM) to enhance predictive capabilities and provide a more realistic depiction of travel behaviour.

Recent studies in activity-based trip modelling have brought significant advancements in transportation planning, challenging and surpassing the traditional trip-based models that dominated for nearly half a century. Some key critical points discussed in these studies are:

- **Role of activity schedules as vital inputs** shaping the model's predictions . Real-time data resources, facilitated by big data, have empowered new ABM models to capture mobility behaviour with unprecedented detail, incorporating sociodemographic, economic attributes, and travel characteristics.
- **Activity-based models depict realistic travel in a more intuitive, consistent, and behaviourally realistic way** . They use exogenous and endogenous data sources and exceptionally detailed data at the Traffic Analysis Zone (TAZ) scale for accurate modelling.
- **Activity-based demand modelling becomes** critical in crafting efficient demand management strategies tailored to the unique dynamics of developing country settings .
- **Simulation tools** can be used to generate a synthetic population in case detailed microdata is not available
- **Indispensability of big data** for efficient digestion, processing, and analysis within stringent timeframes.

A dynamic team of proficient data scientists, transport research analysts, and skilled software developers can collaboratively contribute to crafting a simulation model and presenting it to diverse cities and transport agencies.

A FORWARD-THINKING APPROACH TOWARDS ACTIVITY-BASED MODELLING

To formulate a comprehensive mobility plan integrating various transport modes, detailed data inputs down to the individual level and capturing trip specifics, including modal interchanges, are critical. Proposing a meticulous questionnaire, the article suggests conducting surveys at activity endpoints, such as workplaces or institutions, as an efficient means of data collection, providing insights into significant portions of commuting and travel demand patterns across the city.

Workplaces will be identified as pivotal sources for obtaining real-time individual-level data based on everyday commute patterns. A simple yet effective questionnaire will facilitate collecting data from workplace sources, highlighting the potential for workplace-centric strategies to shape travel behaviour.

The survey's output will help generate dynamic spatial-temporal maps to identify critical zones exhibiting higher demand for public transit, recognise service gaps within the shared transit network, pinpoint instances of increased private vehicle usage, and gain insights into potential traffic and rush hours in public transport services.

This data-driven approach also helps assess the available capacity of existing networks. Heat maps are a powerful tool for condensing complex data points into an easily interpretable colour-coded format. This visualisation method facilitates the identification of trends, patterns, and areas of interest within the data. As shown in the adjacent image, software tools helps simulate traffic models based on user data in spatiotemporal aspects.

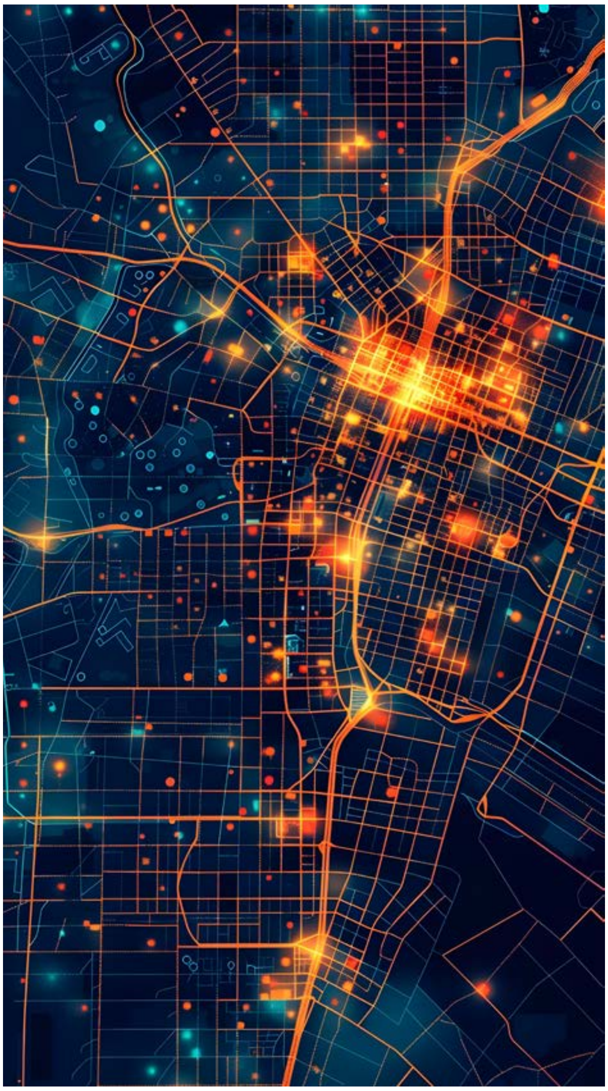

Figure 2: Dynamic Vibrant heat maps provide better insights to urban and transport planners

Robust infrastructure and planning team, TCE and the emerging DATOM framework structure are poised to gain an early advantage in spearheading a solid and unique value proposition for this pressing urban challenge. The approach and solution are designed to be highly scalable across cities and towns, offering a forward-thinking and adaptable solution to urban mobility challenges.

CONCLUSION

Tata Consulting Engineers has collaborated across diverse smart city and urban development projects with spatial planning agencies like CIDCO and Urban Local Bodies. This partnership involves continually evolving strategies tailored to meet specific project requirements. Backed by a comprehensive team comprising urban planners, designers, and a robust infrastructure support unit, TCE strategically positions itself to excel in town and urban planning projects.

The significance of new town development plans has escalated across India, as a proactive measure to alleviate city congestion. City ULBs are identified new towns as satellite cities, envisioning a future characterised by green, resilient, and sustainable urban development.

These project aims to elevate mobility standards and integrate land use planning within these new towns. In land use planning, there is a discerning acknowledgement that various facets of mobility often go unnoticed. These include multi-modal transportation, accessibility, the concept of complete streets, last-mile connectivity, and the promotion of transit-oriented development.

The landscape of commuting demands is rapidly evolving, necessitating a nuanced understanding of individual commute patterns within a city. While various technology companies actively engage in mobility, their solutions often adopt a piecemeal approach.

These solutions typically address challenges like last-mile connectivity, metro accessibility, and commuting through data on individual aspects. However, the required approach to tackle these challenges effectively involves adopting an activity-based model, offering a unique and comprehensive perspective.

A thorough analysis, encompassing a detailed network of routes for various public transit modes, is pivotal in rationalising routes across all modes and identifying service delivery gaps.

This approach becomes imperative for efficiently optimising available resources where needed. Shifting the focus towards workplaces and institutions as central hubs of activities is crucial for capturing data from most commuters, contributing to a more holistic understanding of the commuting landscape.

The imminent adoption of Activity-Based Demand modelling is set to become a prominent feature in cities. Real-time data on individual commute patterns from activity centres will facilitate dynamic traffic assignment and seamless service integration. In conclusion, a comprehensive study and implementation of these strategies will enhance the efficiency of commute systems and contribute significantly to the overall development of urban mobility.

With its robust infrastructure and planning team, TCE and the emerging DATOM framework structure are poised to gain an early advantage in spearheading a solid and unique value proposition for this pressing urban challenge. The approach and solution are designed to be highly scalable across cities and towns, offering a forward-thinking and adaptable solution to urban mobility challenges.

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TCE Awards

Masters of Risk in Real Estate and Infrastructure Sector Mid-Cap Category by India Risk Management Awards

Award for Use of Pathbreaking Construction Technology by Civil Engineering & Construction Review

Best Legal Team Award by Indian Achievers Forum

Leadership Development Award by Brandon Hall Group

Design Honour Award for Innovation and Design of AFLASS by Tata Innovista

Winner in the medium category for the Highest number of volunteering hours by Tata Engage

Winner in the medium category for the Highest number of volunteering hours during TVW 19 by Tata Engage

Winner in the medium category for the Highest number of volunteering hours during TVW 18 by Tata Engage

Top 25 Safest Workplaces in India by KelpHR

Best Digital Finance Team of the Year Award by CFO Confex & Awards

Best Finance Strategy & Execution Award by CFO Confex & Awards

Best Case Study Award by National Electrical Safety, Power Quality & Reliability Circle CII









Top 50 Innovative Companies in India by CII Industrial Innovation Award

Top Innovative Company in Services Large Segment by CII Industrial Innovation Award

Platinum Industry Excellence Award by the Institute of Engineers India (IEI)

National Award for Best Governed Company Unlisted Segment: Medium Category by ICSI

Engineering Innovation Award for Riverfront Development of Tunga in Shivamogga Smart City by CEAI National Awards

Best Tax Technology Implementation by Tax Strategy & Planning Summit and Awards

HR Excellence in Corporate Social Responsibility by CHRO Vision & Innovation Summit & Awards

HR Excellence in Effective Communication & Feedback Strategies by CHRO Vision & Innovation Summit & Awards

Tata Affirmative Action Programme (TAAP) Adoption Award by Tata Business Excellence Group

Gold Award for Excellence in Employee Retention Strategy by Economic Times Human Capital Awards

Innovative Product/Service Award for Retractable Arm for Satellite Launches by Golden Peacock Awards

Impactful Learning Program of the Year Award by L&D Confex & Awards











Client Testimonials

TCE's successful execution of multidimensional projects, such as sports infrastructure, Roads and street scaping, waterfront development, and Parks, has profoundly impacted our city. The dedication and professionalism of each team member have been instrumental in these achievements. Your collective efforts have transformed our city's roads, pathways, and cycle tracks into safe, efficient, and aesthetically pleasing spaces for our people. The recognition of our city's roads, pathways, and cycle tracks with a prestigious award is a testament to your meticulous planning, strategic implementation, and unwavering commitment to excellence. Your team's exceptional efforts have consistently exceeded expectations, and I am immensely proud of this accomplishment.

★★★★★

TCE looked after the mechanical piping and equipment erection, which included the erection of critical glass-lined columns and piping. They worked during the project's construction phase until its commissioning and startup (Jan 2022 to July 2023) and coordinated with all the disciplines to complete the project. TCE's technical know-how and communication skills are good, and their work as construction managers has been very satisfying.

★★★★★

For all the TCE employees to take valuable time from their homeland to come to the UK and want to be part of this project, I have the utmost admiration for you all. To be away from your family for a short period is hard enough, but to be for a number of years, you have my utmost respect. New learnings, especially for TCE employees, were developed, especially seeing how a Brownfield site operated within the UK, the challenges of merging with contractors and the Storming and norming Performing process; I am sure it was very challenging; however, both parties developed and worked well together.

★★★★★

We appreciate the TCE team for their support throughout the execution of the JUPC Drying Column Project. Engineering Package submissions were hassle-free, and we could meet our client's expectations. There was a lot of learning for both teams, which we believe will strengthen our future collaborations. We completed all the site activities a few weeks ahead of schedule, and now systems are handed over to the client for process commissioning. We thank the TCE team for their vital contribution to the success of this project.

★★★★★

Infrastructure Cluster

Gujarat's Robotic Gallery: A Blend of Education and Entertainment

The Gujarat Council of Science City (GCSC), an eminent body under the Department of Science & Technology, Government of Gujarat, has been a pivotal platform for science education and popularisation in the state and across India. In its latest endeavour, the GCSC, alongside Tata Consulting Engineers Limited (TCE), set the stage for a revolutionary Robotic Gallery in Science City, Ahmedabad, marking a significant milestone in the intersection of education and entertainment.

INTRODUCTION TO THE ROBOTIC GALLERY PROJECT

The Robotic Gallery project, conceptualised by the GCSC with TCE as the Design & Technical Agency (DTA), promises to be a sprawling centre dedicated to robotics. This gallery is designed to be an edutainment hub, merging educational activities with entertainment to spark curiosity and foster a scientific temper among visitors.

Spanning an area of 11,000 square meters, the G+2 building houses various thematic sections such as the History Gallery, Sport-o-mania, and Robo-Café, among others.

THE VISION AND EXPERTISE OF TATA CONSULTING ENGINEERS LIMITED

TCE's involvement in the project spans comprehensive engineering services across multiple disciplines, including architecture, civil and structural engineering, MEP, and more, aimed at bringing the Robotic Gallery to life. From conceptual design to construction supervision, TCE's role is critical in ensuring the gallery's success. Their specialised services for robotics have facilitated the creation of informative and highly engaging exhibits, offering hands-on experiences that promote innovative thinking.

UNVEILING THE ROBOTIC GALLERY'S FEATURES

The gallery is a marvel of modern architecture and engineering, featuring a central atrium covered by a steel structure and an interactive museum that presents robots in various applications, from art and sports to utility and education. Each exhibit, carefully designed and reviewed by TCE, offers visitors a unique insight into the potential and versatility of robotics in our society.

EDUCATIONAL AND ENTERTAINING EXHIBITS

Among the gallery's highlights are:

- **Celebots:** Reception robots and robot guides that greet and interact with visitors.
- **Sport-O-Mania:** Robots engaging in sports like soccer, badminton, and air hockey, showcasing their agility and coordination.
- **Botulity:** Robots designed for utility purposes, including search and rescue missions and industrial tasks, demonstrate robotics's practical applications in various fields.

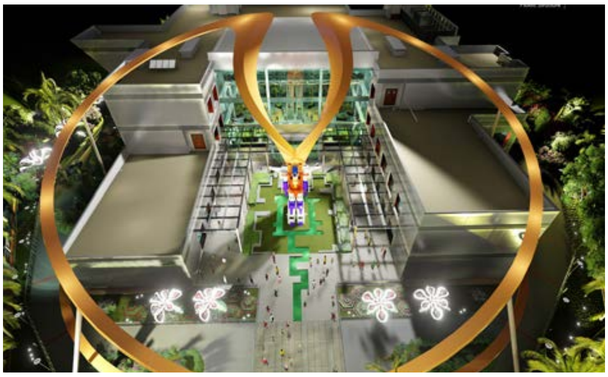
Moreover, the gallery features a Virtual Reality Gallery and a Robotics Workshop, emphasising hands-on learning and immersive experiences that make science and technology accessible and enjoyable for all ages.

INNOVATIVE STRUCTURES: FLUIDIC STRUCTURE AND CONNECTING BRIDGE

TCE brought significant innovation to the project through the gallery's fluidic structure and connecting bridge. These elements serve aesthetic purposes and represent engineering marvels in their own right.

THE FLUIDIC STRUCTURE

The fluidic structure’s flowy, non-linear design is a testament to architectural ingenuity and structural engineering excellence. Overcoming wind load methodology and structural modelling challenges, TCE employed advanced software to achieve the desired aesthetic without compromising safety or functionality. This structure is a visual focal point and symbol of technology and innovation's fluid and dynamic nature.



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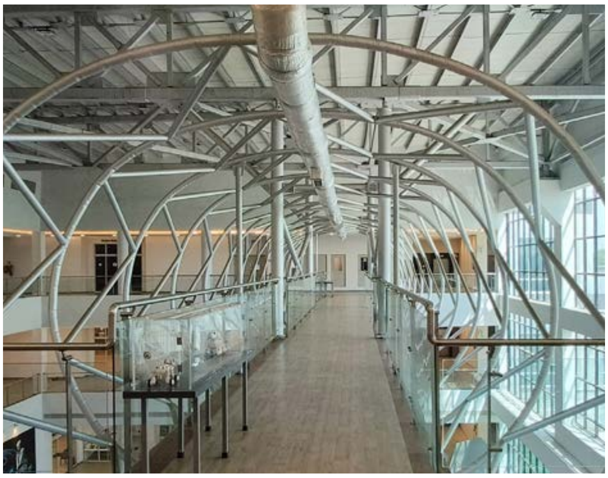
THE CONNECTING BRIDGE

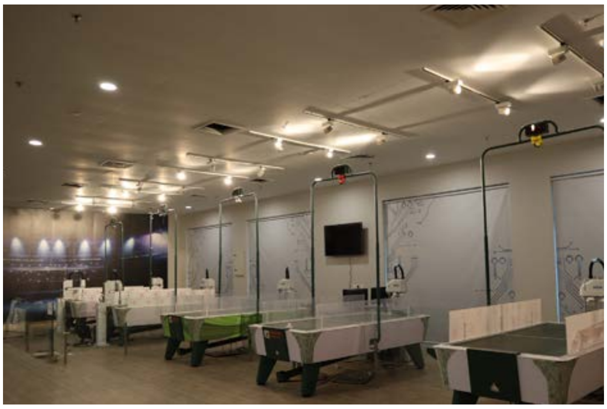
Similarly, the connecting bridge, spanning 27 meters without intermediate support, offers visitors a unique vantage point over the atrium below. This feature exemplifies TCE's ability to blend form and function, providing a seamless experience for visitors while maintaining the integrity of the building's design.



IMPACT AND LEGACY

The Robotic Gallery, inaugurated by Prime Minister Shri Narendra Modi, stands as a beacon of progress in science and technology education. It is expected to be a significant tourist attraction, contributing to the economy and inspiring future generations to explore and innovate in robotics. The collaboration between GCSC and TCE in bringing this vision to life underscores the potential for public-private partnerships to create educational spaces that are both informative and inspirational.

In conclusion, the Robotic Gallery in Gujarat's Science City is more than just a museum; it is a pioneering venture into the future of education and entertainment, where the wonders of robotics are made tangible and accessible. The meticulous planning and execution by the Gujarat Council of Science City and Tata Consulting Engineers Limited serve as a model for how science can be demystified and presented in an engaging way to the public.



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Transforming Research at IISc Bangalore

In the heart of India's premier research institution, the Indian Institute of Science (IISc) Bangalore, stands the newly inaugurated Interdisciplinary Research Centre (IDR Building), a testament to modern architectural brilliance and engineering innovation. This project, conceptualised with the support of the TCS Foundation, is a collaborative effort between IISc Bangalore, Venkataramanan Associates as the Concept Architect, and Tata Consulting Engineers Limited (TCE) as the Design and PMC Consultant. Spanning over 4 acres with a built-up area of approximately 220,000 sq.ft., the IDR Building embodies the fusion of multiple research domains under a single roof, promoting a multidisciplinary approach to scientific inquiry.

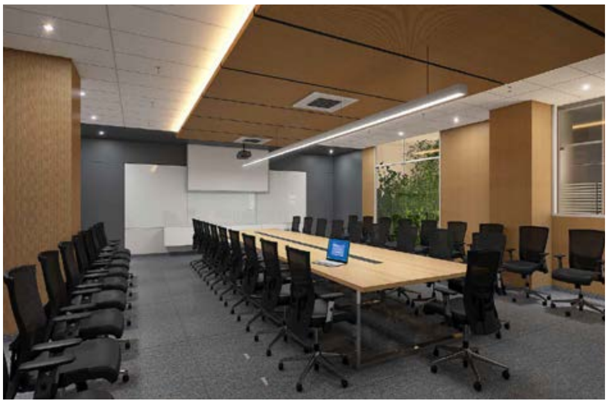
PROJECT OVERVIEW

Designed to house four major research centres - the Centre for Biosystems Science and Engineering (BSSE), Centre for Nano Science and Engineering (CeNSE), Centre for Infrastructure, Sustainable Transportation & Urban Planning (CiSTUP), and Robert Bosch Centre for Cyber-Physical Systems (RBCCPS) - the IDR Building is a marvel of collaborative design and engineering. Its strategic layout facilitates synergy among researchers from diverse fields, fostering innovation at the intersections of science and technology.

ARCHITECTURAL AND ENGINEERING EXCELLENCE

The building's configuration, with a Lower Ground Floor plus seven additional floors, is not just an architectural choice but a strategic one. It maintains the natural ground profile's level difference of approximately 5 meters. This design allows entry from two levels, enhancing accessibility while integrating seamlessly with the surrounding landscape.

TCE's scope of work encompassed comprehensive engineering services, including detailed architectural design, structural design, MEP design, procurement works, and construction supervision services. Each element of the project was meticulously planned and executed to ensure that the IDR Building serves its functional purpose and stands as a beacon of sustainability and innovation.



TCE's scope of work encompassed comprehensive engineering services, including detailed architectural design, structural design, MEP design, procurement works, and construction supervision services. Each element of the project was meticulously planned and executed to ensure that the IDR Building serves its functional purpose and stands as a beacon of sustainability and innovation.

INNOVATION AND COMPLEXITY

One of the hallmark features of the IDR Building is its adaptability to the natural terrain. It utilises retaining walls to maintain the earth and provides dual entry points to accommodate the ground profile's slope. The structural framing arrangement, a mix of beam-slab, flat slab, and grid floor systems, alongside the genuine ceiling concept, enhances the aesthetic appeal of the entrance and double-height areas.

A significant engineering feat within the building is the design of the CeNSE clean room, which required vibration isolation to protect sensitive research activities. This was achieved through a sophisticated trench system incorporating anti-vibration materials, showcasing TCE's attention to detail and commitment to providing tailored solutions for the building's unique requirements.

THE ATRIUM STAIRCASE: A DESIGN MARVEL

A standout innovation is the building's atrium staircase, designed without intermediate support to offer an unobstructed, aesthetically pleasing view.

TCE proposed two design options - a single stringer and a double stringer staircase, with the latter being chosen for its slim profile and cost-effectiveness, reducing construction costs significantly compared to conventional designs.

SUSTAINABILITY AND ENVIRONMENT

The IDR Building's design prioritises sustainability, aiming for a GRIHA Five Star rating. This ambition is evident in the building's efficient envelope, water management systems, and the integration of energy-efficient materials and technologies. In response to budget constraints and environmental considerations, the redesigned west facade illustrates TCE's innovative approach to balancing aesthetic, financial, and ecological demands, ultimately saving significant costs while achieving the desired environmental performance standards.

CONCLUSION

The IDR Building at IISc Bangalore, with Tata Consulting Engineers Limited at the helm of its design and project management, stands as a monument to interdisciplinary research and sustainable design. Its inauguration by Mr Natarajan Chandrasekaran, Chairman of the Board of Tata Sons, in 2023 marks a new chapter for IISc Bangalore, promoting innovation and collaboration among the brightest minds in science and engineering. Through this project, TCE has once again demonstrated its prowess in engineering and architectural excellence, contributing significantly to the advancement of research infrastructure in India.

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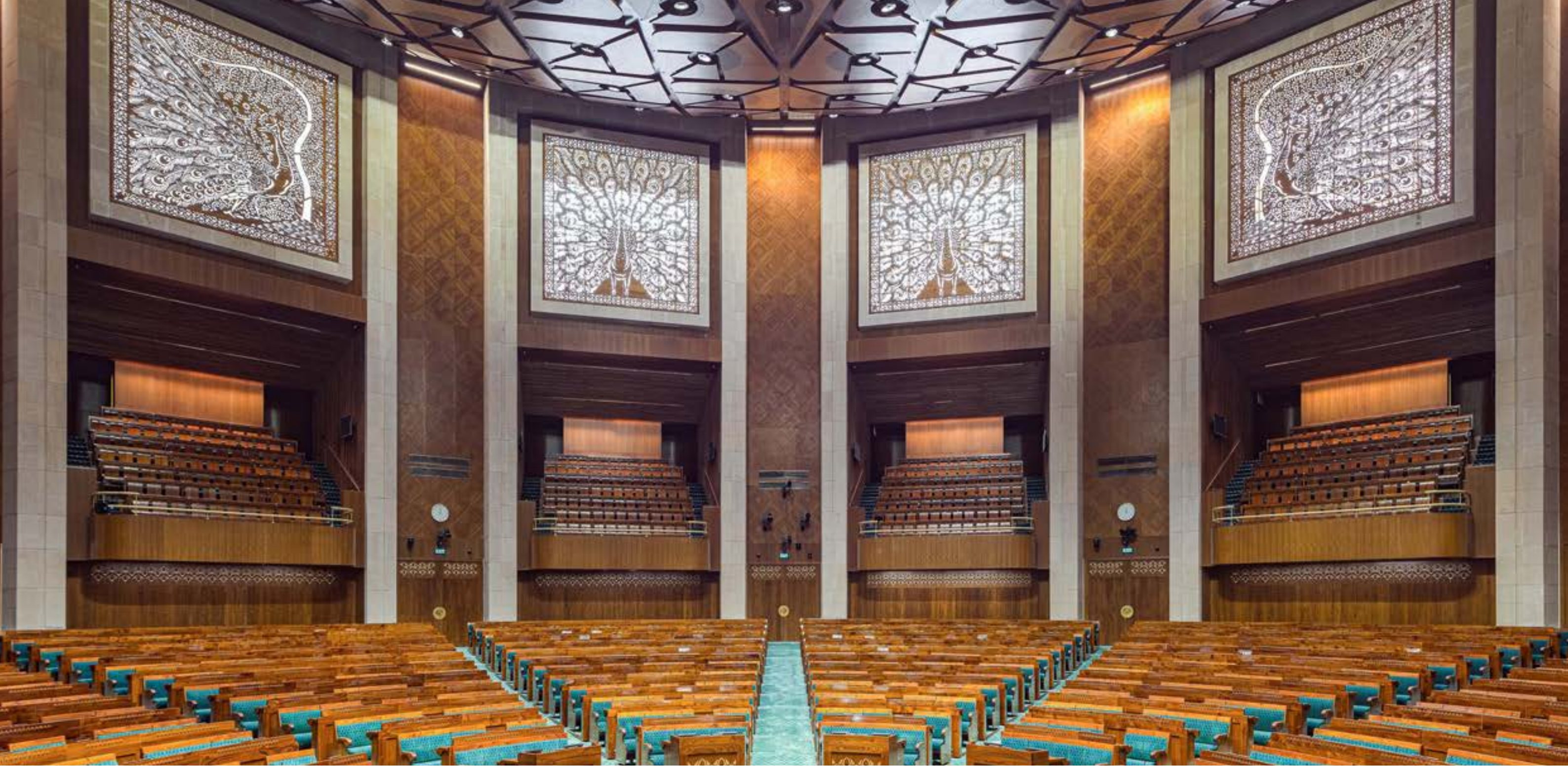
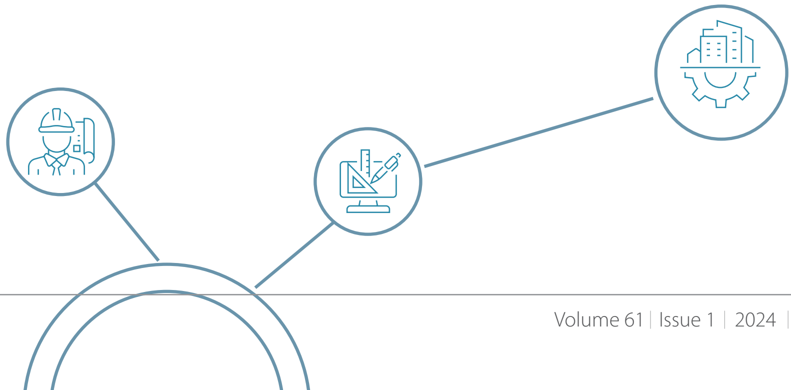


Design of an Air Conditioning System for a Large Assembly Hall

As society continues to industrialise and grow, challenges such as air pollution and global warming arise. To combat this, it is crucial to maintain a pollution-free environment in areas where people spend a significant amount of time, such as homes, offices, malls, supermarkets, auditoriums, theatres, hospitals, and more. Each location presents unique obstacles in controlling the indoor environment to ensure it remains healthy, comfortable, and safe.

One way to regulate indoor air quality is by installing an air conditioning system, allowing for precise control of the building's internal environment. The benefits of air-conditioned buildings, including the ability to regulate air temperature, relative humidity, air velocity, particulate count, oxygen levels, and more, make it necessary in many facilities worldwide.

This paper discusses our experience designing an air conditioning system for a spacious assembly hall with specific shape, area, height, and interior design requirements.

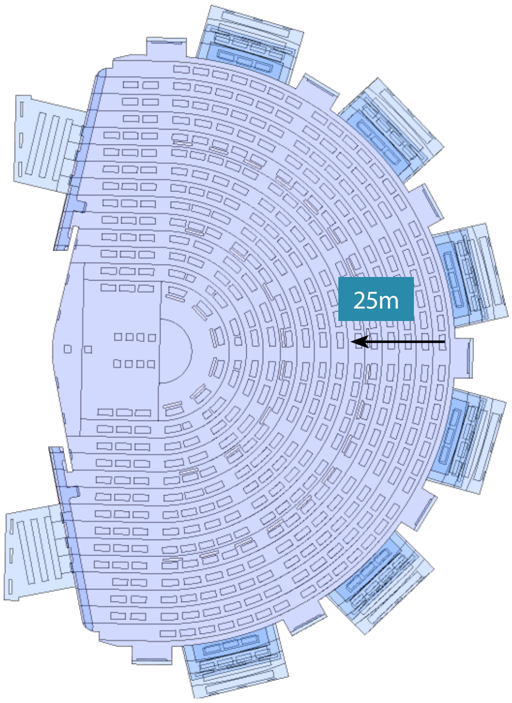


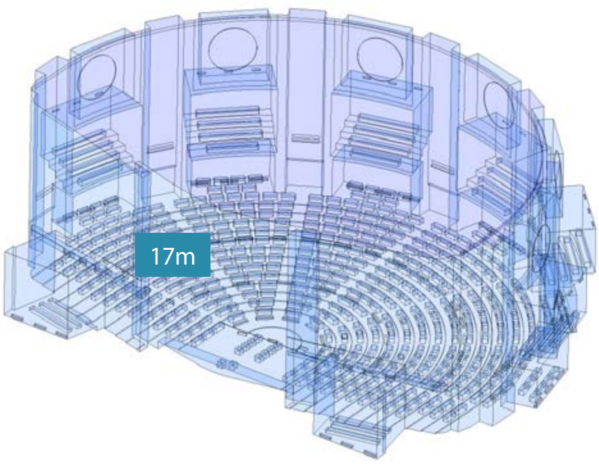
DESIGN CHALLENGES

The assembly hall is semi-circular, with a capacity of 1300 people, an area of 1486.449 sqm (16,000 sq ft), and a height of 17 meters.

The architectural design did not account for the air supply to come from the ceiling.

The images depict a plan and a perspective view of the Assembly Hall.





AIR DISTRIBUTION PHILOSOPHY FOR A LARGE AUDITORIUM

Designing air supply and exhaust distribution systems for large auditoriums presents many challenges due to their size and height. This particular auditorium posed additional difficulties as it had a semi-circular floor plan with a significant height and a sloping floor. Distributing cold supply air from the ceiling and taking warm return air from the side or ceiling is straightforward. However, in this case, air distribution from the ceiling was impossible due to interior design requirements. As a result, an alternative solution was devised. Seven vertical shafts were installed to accommodate supply air distribution ducts and grills. Return air grills were in the suspended assembly hall floor, with ducts in the void space below.

The cold air that had been treated was delivered through ducts installed within seven vertical shafts. Each vertical shaft had two supply air grills around 4-5 meters above the floor. These grills were angled differently, with the lower grill set at 45° to cool the nearest area and the upper grill set at 0° to cover the farthest area. This strategic positioning ensured that the cooling effect was uniform throughout the hall.

Air used was collected from the floor openings beneath a few desks and directed back to the Air Handling Units (AHUs) through return air ducts. Constant Air Volume (CAV) boxes were employed at each connection point to ensure that the designated AHU received the intended amount of return air. The CAV boxes helped balance the airflow during the commissioning stage. A flexible connection was utilised to accommodate gaps or variations between individual return air openings and the return air branch.

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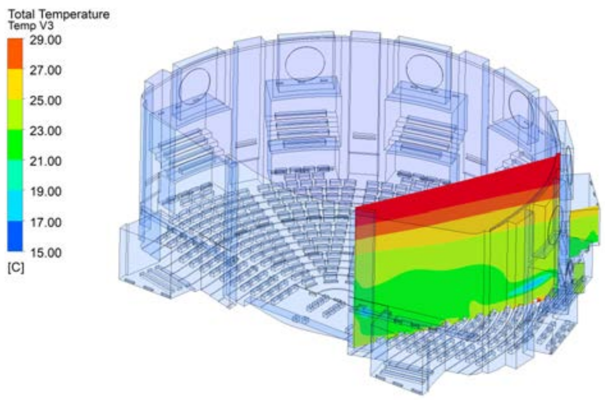
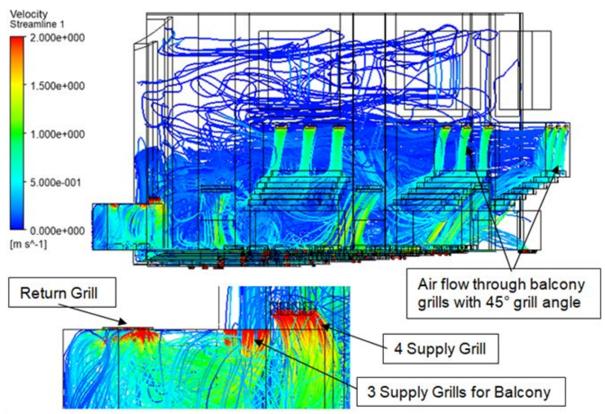
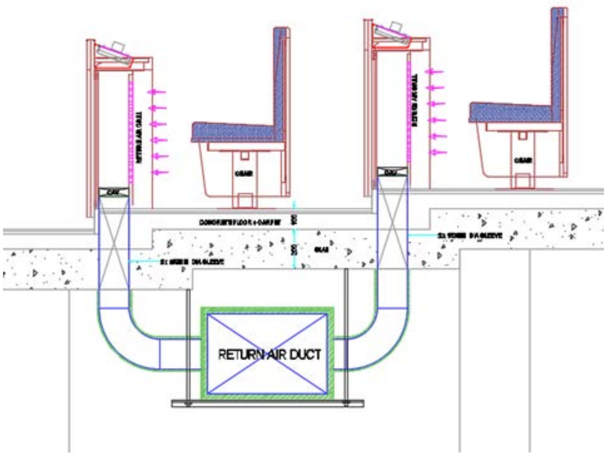


A CFD analysis was conducted to ensure the effectiveness of the designed system. This analysis simulated the airflow and thermal effects within the system, resulting in the identification of any hot spots. Based on preliminary CFD reports, corrective actions such as increasing airflow, deploying additional AHUs, and adjusting the angle of the supply grill were taken. Following these changes, the analysis was repeated to verify the results. Figures displaying the temperature and velocity profiles and a typical section of the Return Air Ducts were provided.



CONCLUSION

A well-designed air distribution system has been implemented in the assembly hall to ensure a comfortable environment. The system meets all the necessary design requirements, including the large area, shape, height, and interior design aesthetics, and it is currently functioning effectively.



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AI (Artificial Intelligence) Powered Engineering Consultancy Services in Chemical Industry

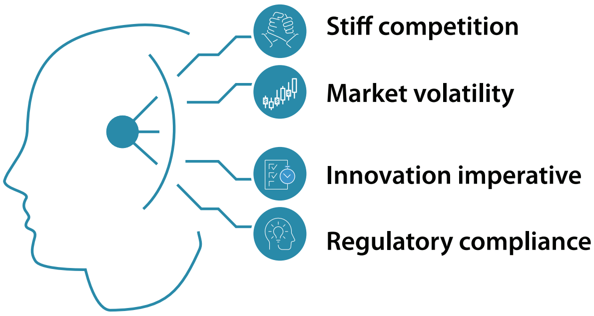
India's chemical industry is a dynamic sector that constantly grapples with evolving market demands, stringent regulations, intensified competition, increasing pressure to provide sustainable solutions, and resource scarcity. Traditional engineering consultancy services have long been a cornerstone for optimising operations, ensuring safety, and navigating technological advancements in this complex landscape. However, Artificial intelligence (AI) is emerging as a transformative force, potentially revolutionising the engineering services consultants provide and delivering more excellent value to customers.

This article explains the key applications of AI in engineering consultancy services in the chemical sector and its impact on efficiency, innovation, and sustainability.

Also, the potential challenges and opportunities associated with AI adoption are discussed, and recommendations for the successful integration of AI within the framework of consulting services are provided.

INTRODUCTION

The chemical industry is the backbone of modern economies, feeding various sectors such as food, pharmaceuticals, speciality chemicals, fertilisers, FMCG, agriculture, etc. However, it faces several challenges, as given below.



- **Stiff competition:** Globalised markets and technological advancements have intensified competition, needing cost optimisation and efficient operations.
- **Market volatility:** Agile decision-making and risk-mitigating strategies are needed to manage the increasing cost of energy, fluctuations in raw material costs, and consumer demands.
- **Regulatory compliance:** Stringent environmental and safety regulations demand systematic planning and proactive implementation or deployment of sustainability initiatives.
- **Innovation imperative:** The need for newer products/ services and processes to address evolving market needs and environmental concerns puts pressure on the delivery mechanism for continuous improvement through value-added services and innovation.

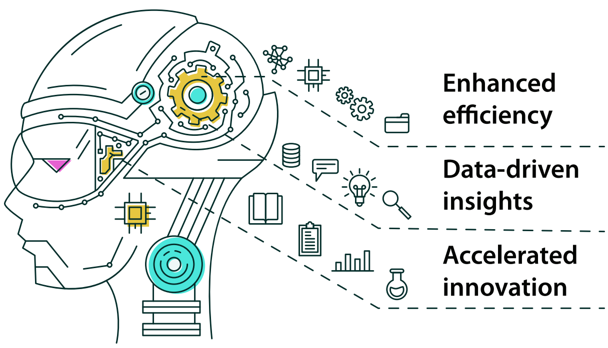
Traditional engineering consultancy services often need help to adapt to ever-changing challenges. Their reliance on manual data analysis, expert-driven insights, and time-consuming workflows limits their ability to provide flexible yet real-time solutions and embrace transformative change.

AI AS A GAME CHANGER

AI presents a transformative opportunity for engineering consultancy services in the chemical industry. Its core ability to analyse vast amounts of data, identify patterns, and automate complex tasks may enable the following:

- **Enhanced efficiency:** AI-powered solutions can streamline data collection, analysis, and reporting, automating routine tasks and allowing consultants to focus more on strategic areas.

  This, in turn, improves accuracy, reduces turnaround times, and optimises resources. Improved efficiency, optimised processes, and reduced downtime lead to significant cost savings and revenue growth.
- **Data-driven insights:** This data-driven approach empowers informed decision-making and proactive management of potential issues. AI algorithms can analyse vast amounts of data from sensors, equipment, and production processes, uncovering hidden patterns and anomalies that human experts might miss. This enables proactive maintenance, preventing costly equipment failures and optimising process parameters for improved efficiency and yield.
- **Accelerated innovation:** AI can aid in material take-offs, catalyst design, and process simulation, speeding up the development of products and processes. Generative models can explore vast chemical space, while optimisation algorithms can identify the most efficient process pathways and plant configurations. Virtual experimentation and accelerated design cycles lead to quicker development and commercialisation of new products and technologies. AI automates routine tasks, freeing valuable time for experts to focus on strategic decisions and client engagement.



Intelligent 3D modelling is an innovative approach that uses an AI engine with built-in intelligence to choose the correct material specification.

Imagine that every pipeline, pump, and vessel had a brain and could act according to its environment, which is nothing but operating parameters. By taking inspiration from the designers who modelled these products, we may construct brains for each of them. A piping brain will, therefore, ultimately understand its purpose and methodology.

After they have acquired knowledge, these brains may be shared by all the pipe items, enabling the 3D objects to make decisions based on their prior experiences.

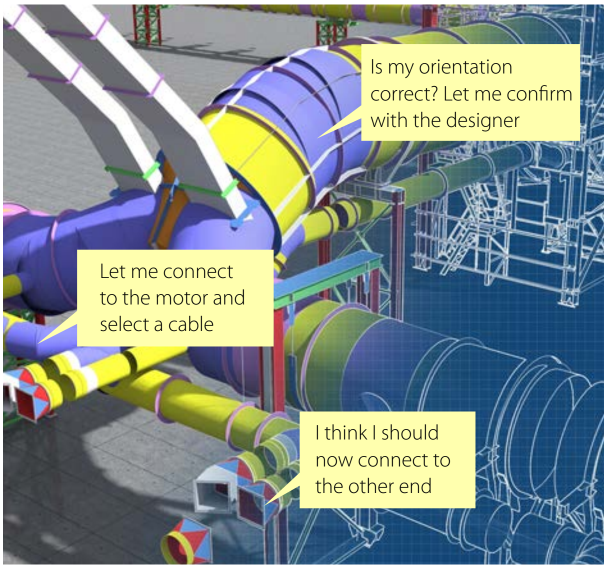
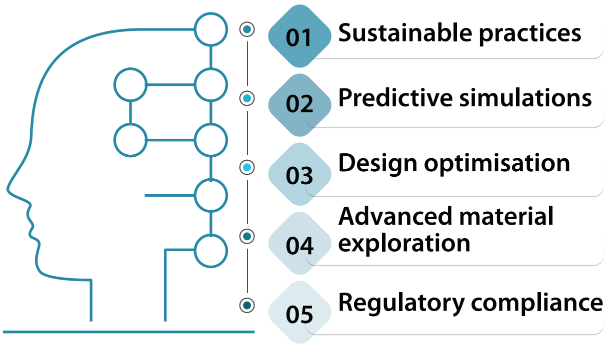


Figure: Artificial intelligence for 3D Models

A correctly placed pump may prompt a designer to ask, "Do you want me to connect to the motor and select the appropriate cable type?" There are infinite possibilities for building brains inside the 3D model for such collaborative communication, which can generate a 3D model with precise material specifications. Similarly, the Pipeline knows what parameters it has or needs so that it can adjust itself if there is a clash.

Just like the designers, the GAD or the P&ID (Piping and Instrumentation Diagram) will be the input for the intelligent 3D model. Such collaborative brains can generate new objects as and when needed. The collective data is managed by the central intelligence of the plant's 3D modelling tool. This reduces the mundane activity required by the designer and helps us focus on better quality and safety.

A structural analysis model shall have intelligence built-in to identify errors in geometrical modelling, load applications, boundary conditions, and design parameters so that the user is prompted to take corrective actions. Again, human intelligence is necessary to understand the suggestions and make corrections. One cannot expect an AI engine to fix the errors by itself.



- **Sustainable practices:** AI can be crucial in greening the chemical industry. It can optimise energy consumption, minimise waste generation, and develop sustainable production processes by analysing complex environmental data and predicting potential ecological impacts.

- **Predictive simulations:** AI-powered simulations can accurately model the behaviour of chemical reactions, equipment performance, and product properties under various conditions. This allows for virtual experimentation, reducing the need for physical prototypes and accelerating the development of new products and processes.

- **Design optimisation:** AI algorithms can automatically optimise plant designs, considering safety, energy consumption, and material costs. This results in more efficient, sustainable, cost-effective designs, greater competitiveness and reduced environmental impact.

- **Advanced material exploration:** AI can scan through massive databases of materials and their properties, suggesting new materials with desired characteristics for specific applications. This accelerates the development of novel catalysts, membranes, and other materials crucial for next-generation chemical processes.

- **Regulatory compliance:** AI can analyse complex regulations and guide companies through compliance, ensuring they adhere to environmental and safety standards. This mitigates risks and reduces the burden of regulatory compliance.

KEY APPLICATIONS

AI can be applied across the entire design process of the chemical industry value chain, including:

Front-end engineering: AI-powered tools can support feasibility studies, process design, and plant layout optimisation, reducing costs and improving project efficiency.

Process optimisation: AI algorithms can analyse real-time process data to identify areas for improvement, optimise operating parameters, and predict potential disruptions, ensuring smooth and efficient production.

Predictive maintenance: AI can analyse sensor data to predict equipment failures and schedule preventive maintenance, minimising downtime and production losses.

Safety and risk management: AI can analyse historical data and identify potential safety hazards, allowing consultants to develop proactive safety protocols and mitigate risks.

Supply chain optimisation: AI can help optimise coordination and inventory management, ensuring efficient raw material procurement and finished product distribution.

CHALLENGES AND OPPORTUNITIES

While AI promises significant benefits, its adoption comes with the following challenges:

Data availability and quality

Talent and expertise

Transparency and bias

- **Data availability and quality:** Access to relevant data is crucial for practical AI model training. To benefit from emerging technologies, chemical companies must invest in data infrastructure and establish data governance practices.

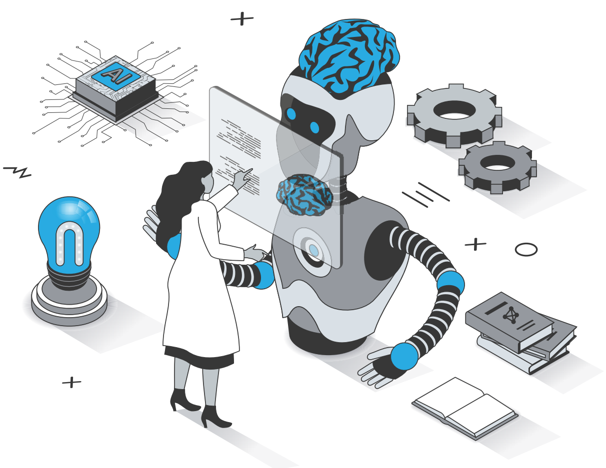
  AI is strong, but it is also limited in a few ways. Lack of proper data and an inability to accept various input data formats hinder many generative AI solutions. Though there is a dearth of P&IDs (Piping and Instrumentation Diagram) to learn from and a need for a better understanding of words related to chemical engineering, recent initiatives to create generative AI for P&ID automation have shown promise. More data is needed to properly create complicated chemical engineering models, which could be hard to come by.

- **Talent and expertise:** Integrating AI requires consultants with expertise in data science, machine learning, and domain knowledge. Companies must recruit and upskill their workforce to use AI effectively.

- **Transparency and bias:** Transparency and trust in AI-powered decisions are essential. Consultants must employ transparent models and mitigate potential biases to ensure ethical and reliable applications. Ethical considerations are critical in the use of AI in engineering. As AI advances, the responsibility and accountability of AI systems need to be fixed, and crucial aspects such as ethical use, algorithm error prevention, and human oversight need to be addressed.

AI algorithms, such as neural networks, are often called "black boxes" because they provide correct results but lack transparency in explaining how they are obtained. This lack of interpretability can be a concern when making critical decisions based on AI-generated outputs.

Despite these challenges, the opportunities outweigh the risks. By addressing them, chemical companies and engineering consultants can harness the power of AI to:



- **Strengthen their competitive edge:** Improved efficiency, innovation, and risk management enhance competitiveness in the global market.
- **Enhance client value:** Consultants can provide data-driven insights and tailored solutions, exceeding client expectations and building long-term partnerships.
- **Drive sustainable growth:** AI can promote more sustainable practices by optimising resource utilisation and minimising environmental impact.

Tata Consulting Engineers has over 60 years of consulting experience designing and commissioning many prestigious projects. This has provided us with a deeper understanding of the complexities and concepts and unique competencies to handle challenging assignments using innovative technologies.

CONCLUSION

By proactively addressing the above challenges and embracing AI holistically, engineering consultants can unlock a new era of unparalleled efficiency, innovation, and sustainability. This is not just a technological revolution; it's a paradigm shift, rewriting the script for the engineering consultancy's future. While AI may speed up the design engineering process, the output or results will need to be reviewed, analysed, and understood, and this can only be done with human intervention. If the AI generates an incorrect design at any stage, human intelligence must identify the AI output to re-train AI and develop further. So, AI certainly will not replace engineers' skills and expertise but will facilitate them to work with enhanced efficiency, greater flexibility, and higher productivity.

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Engineering Sustainable Systems

Sustainability refers to a system's capability to self-operate and generate the necessary resources to sustain its functioning. This concept is often linked to ecological systems that support human life. In biological systems, sustainability signifies the ability to maintain good health, support diversity, and remain productive over a long period. Over the past few decades, sustainability has been emphasised as the key to ensuring human life is balanced with the environment.

The United Nations' Brundtland Commission (March 20, 1987) defines sustainable development as meeting the needs of the present without sacrificing the ability of future generations to meet their own needs. The idea of sustainable development became prominent in the last two decades of the 20th century as concerns grew about environmental degradation, uneven development, poverty, population growth, and socioeconomic disparities. The negative impact of mass consumerism and one-sided development strategies on natural resources like water, land, and forest cover also became increasingly apparent, with disastrous consequences.

TENETS OF SUSTAINABILITY

A sustainable system or process is based on the following three foundational attributes:

- Changes caused to the environment can be easily reversed
- The system is viable in economic terms
- It should benefit society at large

Figure 1 illustrates the correlation among the three factors and their respective sub-factors. A system must effectively integrate these factors and generate a harmonious outcome to be sustainable. As the individual attributes interact, they create new combined factors that reflect the collective impact of their sub-factors toward achieving a common goal that benefits all stakeholders.

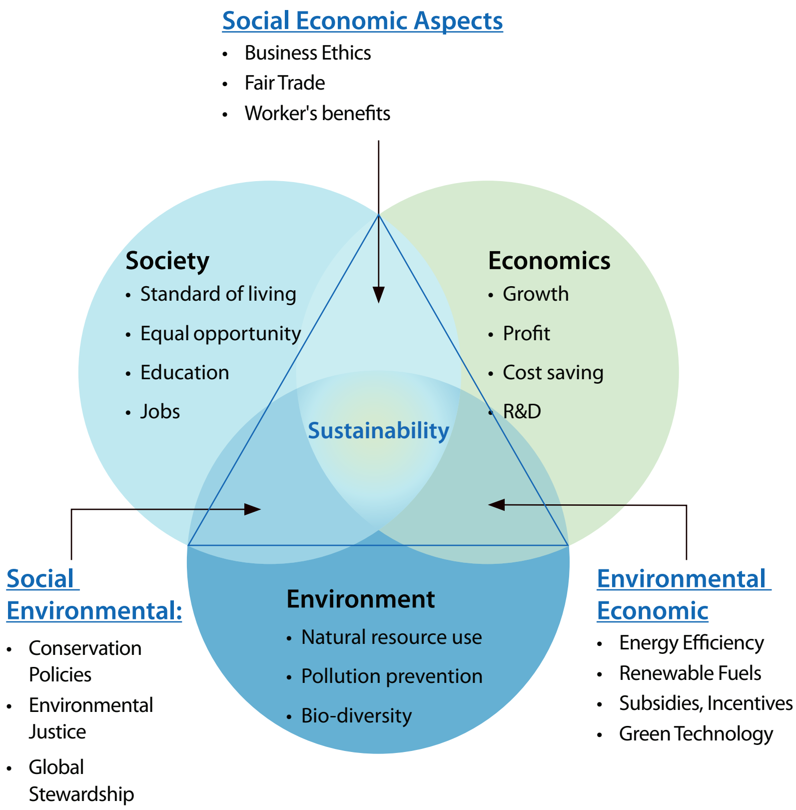

Figure 1: Interplay of three aspects of sustainable development

Sustainable development is based on three main aspects: environment, society, and economy. These aspects are represented by a prism of sustainability, as shown in **Figure 2**. The one-dimensional principles are positioned near the three corners of the prism, while the two-dimensional principles are placed in between. The principles strongly linked to a particular aspect are closer to that aspect's corner. The central pentagon contains the three-dimensional principles. Overall, each element is associated with two one-dimensional principles, two two-dimensional principles, and one three-dimensional principle, forming a pentagon structure.

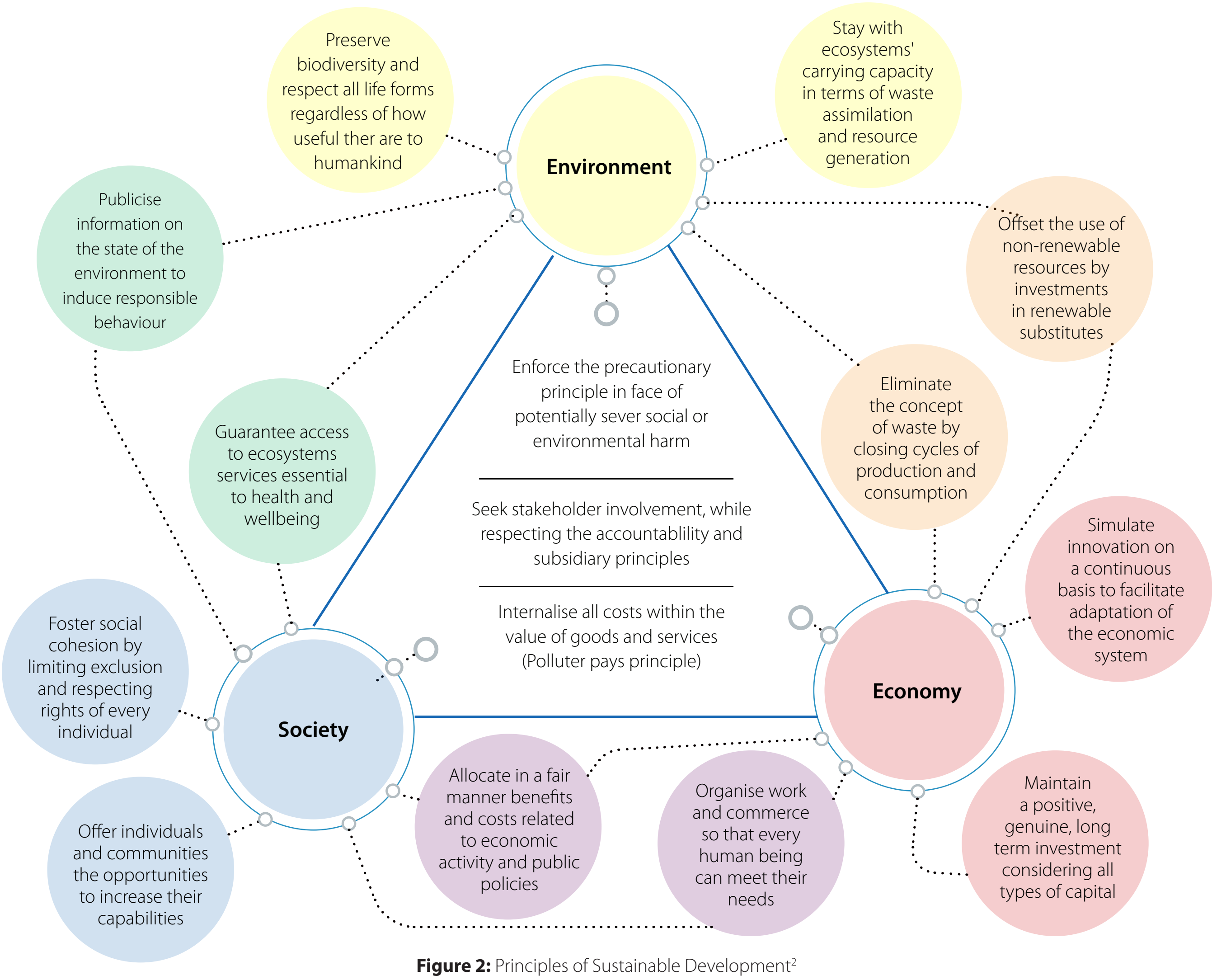

Figure 2: Principles of Sustainable Development[2]

SUSTAINABLE SYSTEMS

One common challenge faced by those who support sustainable systems is deciding how to balance economic growth with human-engineered systems. To create sustainable systems, different approaches are used, including:

The theory of a steady state economy, put forth by Herman E. Daly, is grounded in the idea that resources are finite, and growth will ultimately peak at a balance point. This balance point is achieved when consumption and supply are equal and growth reaches its highest value. According to the Daly Rules, renewable resources should be utilised at a rate that matches their regeneration rate, non-renewable resources should only be used at a pace renewable substitutes can be provided for, and waste generation should not exceed the rate of processing and recycling. Daly himself summarised the principles as follows:

It is not possible for resources to be produced out of thin air or for waste to disappear into nothingness. If this were possible, we could have an endless supply of resources to fuel the growth of the economy. However, the first law of thermodynamics states that this is not possible. Some suggest that we keep the economy growing by recycling matter and energy faster, as shown in economics textbooks' circular flow diagram. Unfortunately, this is also not possible according to the second law of thermodynamics. [Daly, 2009].

The theory of Oscillating Steady State, developed by Howard T. Odum and his team, posits that natural energy sources such as solar, geothermal and gravitational forces can drive continuous recycling and reorganisation of resources. These systems operate on feedback from the environment and can adapt to changes, allowing the system to run stably over time. To better comprehend the principle, one can consider the rapid depletion of slowly regenerating natural resources, resulting in a development slowdown, allowing the resources to be restored and start a new cycle.

According to Eric Ellis's Anthropology Ecology Theory, humans have used advanced techniques and technologies to manipulate ecosystems and overcome resource constraints. This ability to create and transform will eventually lead to a new balance in the biosphere that can be sustained indefinitely.

SUSTAINABLE DESIGN PRINCIPLES

Design activity aims to improve efficiency, aesthetics, and other desirable attributes of a system or product. William McDonough's sustainable design principles, known as "The Hannover Principles: Design for Sustainability," guide achieving this goal. The principles include:

- Healthy coexistence of nature and humanity
- Interdependence of human design and nature in many aspects
- Connection of human spirit and material world in multiple aspects of human settlement
- Accept responsibility for design decisions on human-nature coexistence
- Create products that are safe in long-run valuation
- Eliminate waste by utilising the life cycle value of products and processes
- Use natural energy flows in processes
- Nature-inspired design instead of external systems to control nature
- Continuous improvement through learning and knowledge sharing

Among these principles, waste management has the highest impact on health and the environment. Strategies for waste reduction include:

- Using materials that are non-toxic and produced or recycled with little energy
- Reduce energy in the manufacturing process
- Design products that create durable emotional relations with people
- Design products for 'afterlife' use
- Use biomimicry principles for design
- Sharing of use to reduce per capita resource consumption
- Source materials locally or from sustainably renewable processes

The following examples explain the application of sustainable principles in design.

Emotionally Durable Design

Jonathan Chapman, a professor at the University of Brighton in the UK, has developed a philosophy that aims to enhance consumers' emotional connection with a product. This prolonged attachment can decrease natural resource consumption and waste. Chapman believes that intricate emotional factors drive the act of consumption and go beyond mere mindless acquisition and disposal of newer items. To achieve emotional durability in a product, Chapman proposes the use of five key elements.

- **Narrative:** personal history that the user shares with the product
- **Consciousness:** The user feels that the product has an autonomous existence
- **Attachment:** The user has a strong emotional connection to the product
- **Fiction:** user and product share a relationship beyond the physical world
- **Surface:** the product assumes its character and existence with age

An emotionally durable design creates responsible tactile products to which users attach long-term value[1].

Biomimicry

The principle of biomimicry involves emulating the elements, models, and systems found in nature to solve technological challenges. Nature has already provided sustainable solutions to many engineering problems, which can be replicated in new technologies. From macro to nanoscale levels, biosystem prototypes have inspired the development of smart technologies with massive potential for sustainability. Some examples of biomimicry principles used in technology include:

- Many companies, such as Qualcomm, are using the design of butterfly wings to create coloured displays that consume low power. The scales on the wings are specially oriented to cause diffraction, interference, and scattering, resulting in vibrant colours.
- The efficient ventilation system found in termite mounds served as inspiration for the design of the Eastgate Centre office complex in Zimbabwe. Despite temperatures exceeding 40°C outside, the building manages to remain calm without the need for air conditioning, utilising only 10% of a traditional ventilation system.
- Did you know that the Biomimetic grazing principle, developed by Alan Savory, is based on the natural grazing patterns of herds that predatory animals control? Implementing an intelligent grazing plan that includes fences or barricades can prevent overgrazing of the same land. This method helps to rebuild the soil, increase biodiversity, and reverse desertification, ultimately expanding the grass-grazer ecosystem. Moreover, this process sequesters carbon and cools the planet.

- Did you know that wasps utilise cellulose and protein from their saliva to construct their nests? This material is not only water-resistant but also serves as a protective covering. Interestingly, the amount of protein used in this process varies depending on the humidity of the surrounding environment —more protein is used in rainy areas than in drier regions. This environmentally tuned design approach could be adapted to create non-toxic, biodegradable, and waterproof materials.

SUSTAINABLE ENGINEERING PRINCIPLES

The concept of sustainable engineering involves integrating sustainable development ideas into the technical design and implementation process. This means incorporating environmentally friendly practices during technology development, resulting in a sustainable full-scale implementation. The principles of sustainable engineering aim to provide a balanced solution to Environmental, Social, and Economic values.

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As Benoit Cushman-Roisin sums up, sustainable engineering is about engineering with a conscience for a finite planet and an indefinite future. To illustrate the differences between traditional and sustainable engineering principles, refer to Table 1 below.

Table 1: Sustainable Engineering approaches

Traditional Engineering	Sustainable Engineering
Focus solely on the object or process output	It encompasses a complete system and where the object or process is used
Based on solving only technical issues	The holistic approach considers the synergy of solutions to technical and non-technical issues.
Looks into the immediate problem	Looks for long-term solutions to the problem
Local context is only considered.	Reviews idea against global context
Refrain from considering the link between technical, political, ethical, and societal issues.	Recognises the association of multi-disciplinary expertise for holistic solutions to the problem
The solution is valid for a fixed set of input parameters	The solution can adapt to changing inputs from various external factors and evolve suitably

The principles of sustainable engineering align with the levels of the sustainability pyramid.

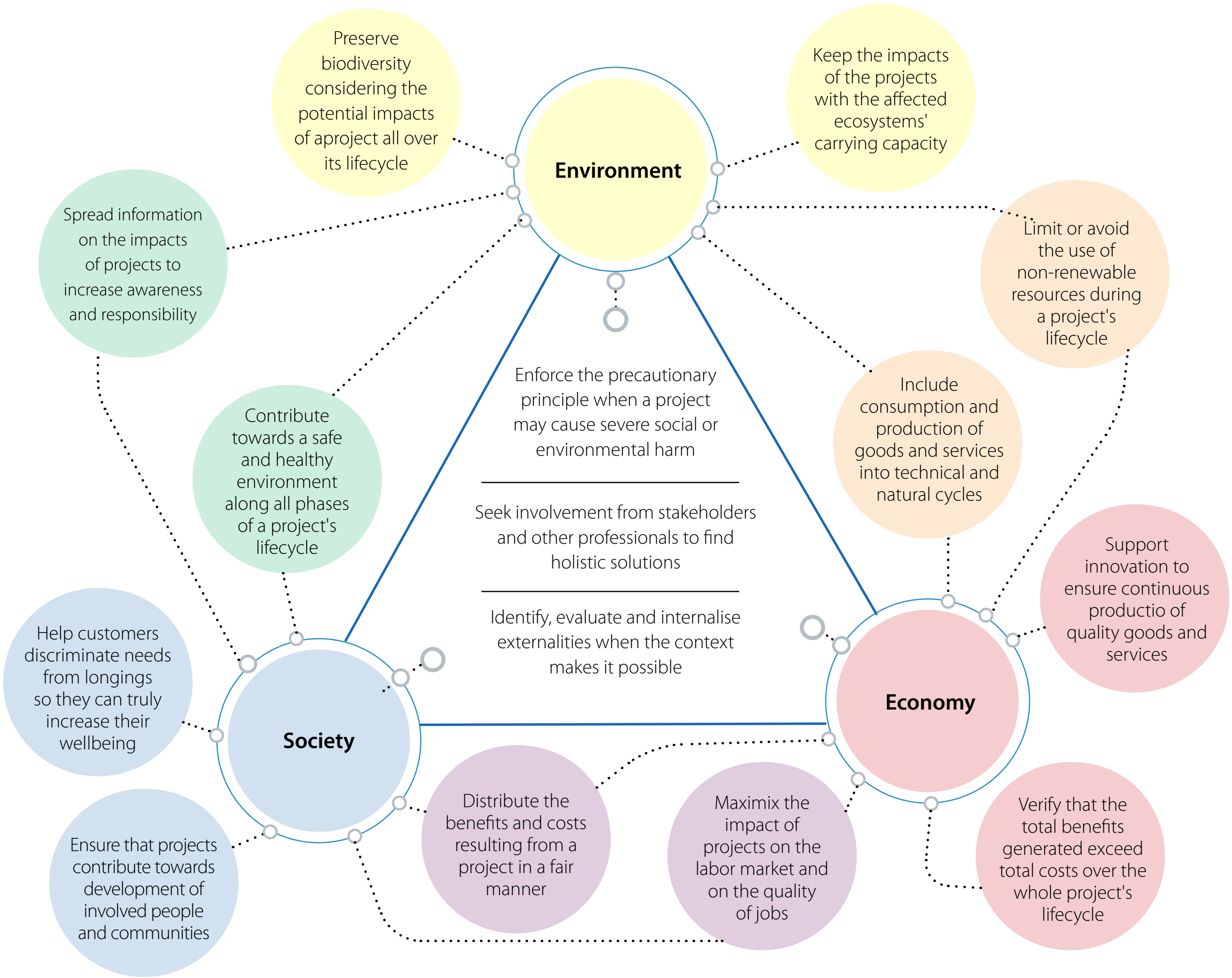

Figure 3: Principles of Sustainable Engineering[3]

These principles serve as general guidance for understanding how technology, ecosystems, individuals, and society interact. To effectively implement a project, the engineering team must develop specific criteria tailored to the project's context. Success can be measured using appropriate indicators, and the chosen solution should meet project requirements and sustainability goals without compromising one for the other.

TECHNOLOGY IN SUSTAINABLE ENGINEERING

Technology acts as the link between the development of an idea through design and engineering and the final products or services. **Figure 4** presents a hierarchical view of how sustainability is integrated into engineering, resulting in tangible benefits for society.

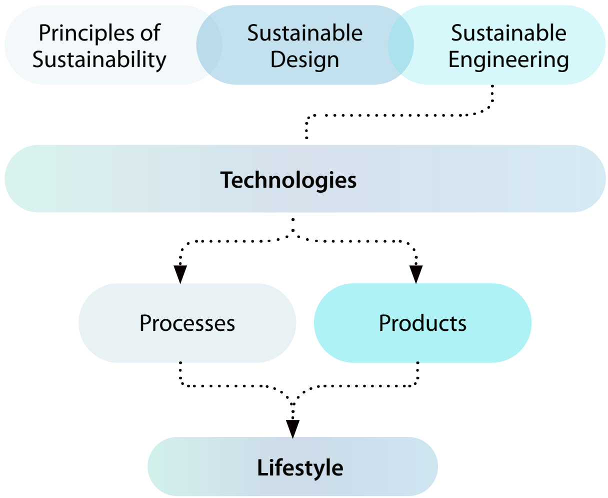

Figure 4: Hierarchy of Sustainability Guideline and Technology role[1]

The concept of sustainable design is based on the principles of sustainability. During this process, the design and functionality of the final product are determined with a focus on its entire lifecycle. The sustainable engineering stage involves the technical implementation of the design idea, with continuous adjustments to ensure that the design idea and engineering route converge and result in a process or product. Technology plays a crucial role in demonstrating the impact of sustainable design and engineering on people's lifestyles, as society is heavily reliant on it. Therefore, it is essential to incorporate sustainability principles in the design hierarchy to initiate new trends and societal changes.

STRATEGY DRIVERS

Adjusting national strategies to avoid the harmful development and growth paths pursued is essential. Instead, move towards sustainable paths that harmonise with nature and society. Additionally, the principles of diversity and inclusion must be considered to achieve balanced growth, which may require changes in international policy-making. Some crucial factors to consider when developing environment and development policies that incorporate sustainable principles are:

- revival of growth to benefit maximum population, enabling sustainable use of resources
- changes in the quality of growth, making it less material and energy-intensive
- meet essential needs for jobs, food, energy, water, and sanitation for all
- maintaining population at a sustainable level consistent with the regenerative capacity of the ecosystem
- conservation of natural resources and enhancing regeneration through balancing consumption to maintain reasonable standards of living
- reorientation of technologies and risk identification and management to suit environmental and societal factors
- inclusion of environmental and economic factors in decision-making in an integral manner and changing the objectives and attitudes at institutional levels

CONCLUSION

Sustainable development strategies aim to harmonise humanity's interaction with nature. Implementing such strategies requires changes to our current systems and processes:

- The political system should allow citizen participation in decision-making
- Economic system should generate surpluses and enhance technical knowhow in a self-reliant and sustained manner

- Inclusive social system that recognises diversity and reduces imbalanced development
- Production system should conserve the ecological base for development
- Technology system continuously searching and developing innovative solutions
- International policies favouring sustainable trade practices and finance
- Flexible administrative system with capability for introspection and self-correction

The United Nations has formulated seventeen sustainable development goals (SDGs) that act as guidelines for national and international action. Successfully implementing sustainable development requires the sincere pursuit of these principles and the effective correction of deviations. Engineering and technology will play critical roles in this transformation journey by providing sustainable solutions to the challenges. The sustainability engineer of the future should be a global citizen capable of critical thinking and problem-solving while taking into account environmental, economic, social, and cultural factors and their inter-relationships.

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Overview of Futuristic Engineering and Possibilities

The world is going through a challenging time when engineers and technologists have an essential role to play. Apart from political, social, and economic doldrums, threats of environmental catastrophe are looming large in the global community.

Climate change, depletion of natural resources and minerals, deforestation, etc., endangering the globe and leading to disaster. But better late than never - the world community has rightly woken up and recognised the need to fight against the causes behind the climate threats.

In the present scenario, mitigating climate change is not an option but a compulsion. United Nations Framework Convention on Climate Change (UNFCC), the entity to support the global response to climate change, is in place now, and conferences amongst almost all countries are held annually (COP) to discuss, review and commit towards the mitigation plans and targets. The Inter-Governmental Panel on Climate Change (IPCC), formed by the World Meteorological Organisation (WMO) and United Nations Environmental Programme (UNEP), undertake a thorough study of climate change and helps the COP to adopt mitigation targets and measures. According to an estimate , carbon dioxide (CO_2) contributes to more than fifty per cent of the total GHG emissions **(Figure 1)**, and Energy, Industry and Transportation contribute to seventy per cent of the global GHG emission **(Figure 2)** sector wise.

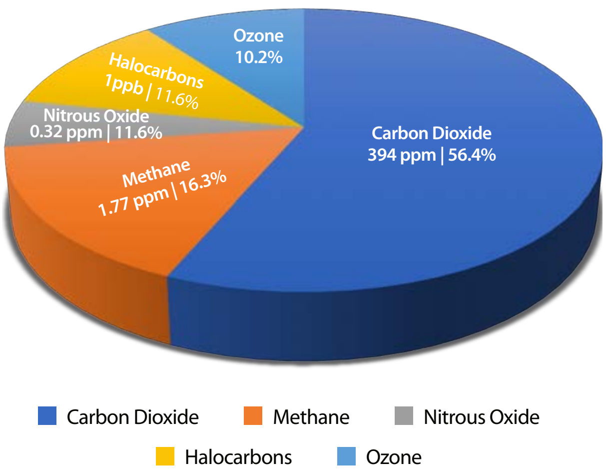


Figure 1

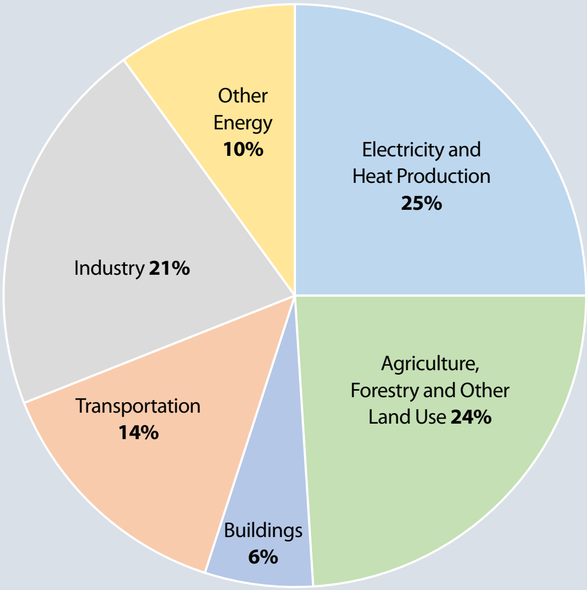


Figure 2

With this backdrop, the key challenge to Technologists and Engineers is to contain global warming within 2^0 C, preferably 1.5^0 C compared to the preindustrial level by the end of the century, as per the resolution of the COP21 (Paris agreement). Under these circumstances, Innovations and new technologies are of prime importance for global decarbonisation and will shape the future of engineering possibilities and business models.

EMERGING POSSIBILITIES

Along with the demand for sustainable engineering solutions, engineers must keep pace with the dynamic landscape in the technology domain. The pandemic has created an opportunity for remote working in the areas previously perceived to be worked upon physically. Ongoing advancements in computer hardware, communication, sensors, internet of Things (IoT), cloud computing, data analytics, Artificial Intelligence (AI), and Augmented/ Virtual/ Extended Realities (AR/VR/ER) have been shaping the way of working which will continue for the upcoming years and business models need to be aligned to leverage these technologies. Brief discussions on the technologies and future scope are summarised subsequently.

Hydrogen Infrastructure

Hydrogen is the next-generation fuel that will replace fossil fuels to decarbonise the world. Hydrogen can be used in electricity generation, transport, heating and cooling in buildings, apart from producing ammonia, methanol, and syngas. It is the most viable alternative fuel and is treated as green fuel as it can be made using energy from renewable sources. Research is underway to improve technology/ efficiency with the primary purpose of cost reduction. Report indicates green hydrogen may be cost-competitive to grey hydrogen by 2050 **(Figure 3)**.

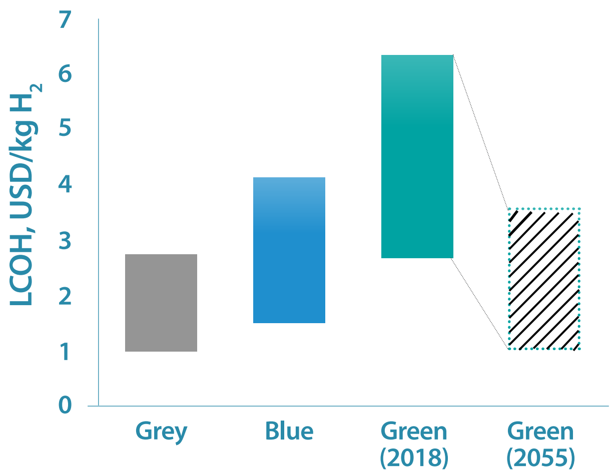


Figure 3

Along with production comes the technology for the storage and transport of hydrogen. We can reach the hydrogen world once the production, distribution, and transportation become green and cost-competitive in scaled production. Considering all these objectives and to achieve the climate goal, India has launched the National Hydrogen Mission. It aims to produce three-fourths of hydrogen from renewable sources by 2050.

Hydrogen is going to be the world's lifeline. During the next thirty years, there will be tremendous possibilities for engineering in Hydrogen Infrastructure, and engineers, consultants, and technologists will toil heavily to make the Hydrogen economy successful.

Additive Manufacturing

Additive manufacturing (AM) is an automated process of building an object by adding layers, - one at a time. It can be used to make exceptionally complex geometries precisely, and the chances of error are nil. It has further advantages of minimum human intervention and minimum wastage. 3D-printed, lightly loaded structures, like small buildings [3] and small pedestrian bridges , are being tried on a pilot basis internationally, and India is close behind, having made a 3D-printed small building at IIT, Madras . India has a large population, mostly in rural areas belonging to low-income brackets. Hence low-cost mass housing is necessary for the present and future. Such mass housing, disaster shelters, public toilet blocks, and small dispensaries are generally of simple shape and can be standardised in modules. The modules are ideally suited for 3D printing within a short time. Materials for 3D printing, when made from waste, add value immensely to sustainability. Considering the present and future demand and being a responsible corporate citizen, TCE has explored the infinite engineering possibilities of serving the nation through 3D printed structures and collaborating with academia.

Renewable Energy (RE)

Conformance to the COP21 goal of limiting global warming below 2^0 C by the end of the century is shifting power generation from fossil fuel to renewables. According to the report , gross power generation will almost double by 2050, with renewable energy contributing 85% of electricity. Solar and wind will share a significant part of about 60% of the renewables [8]. Under this scenario, engineering in the Renewable sector will have infinite possibilities and enormous business growth. In line with this, numerous innovations and patents are happening in floating solar and offshore wind power. TCE has been updating and building competencies to make adorable footprints in system engineering and structural design of hybrid wind towers, offshore wind, and floating solar along with conventional onshore solar plants, where TCE has created a footmark of leading consultant.

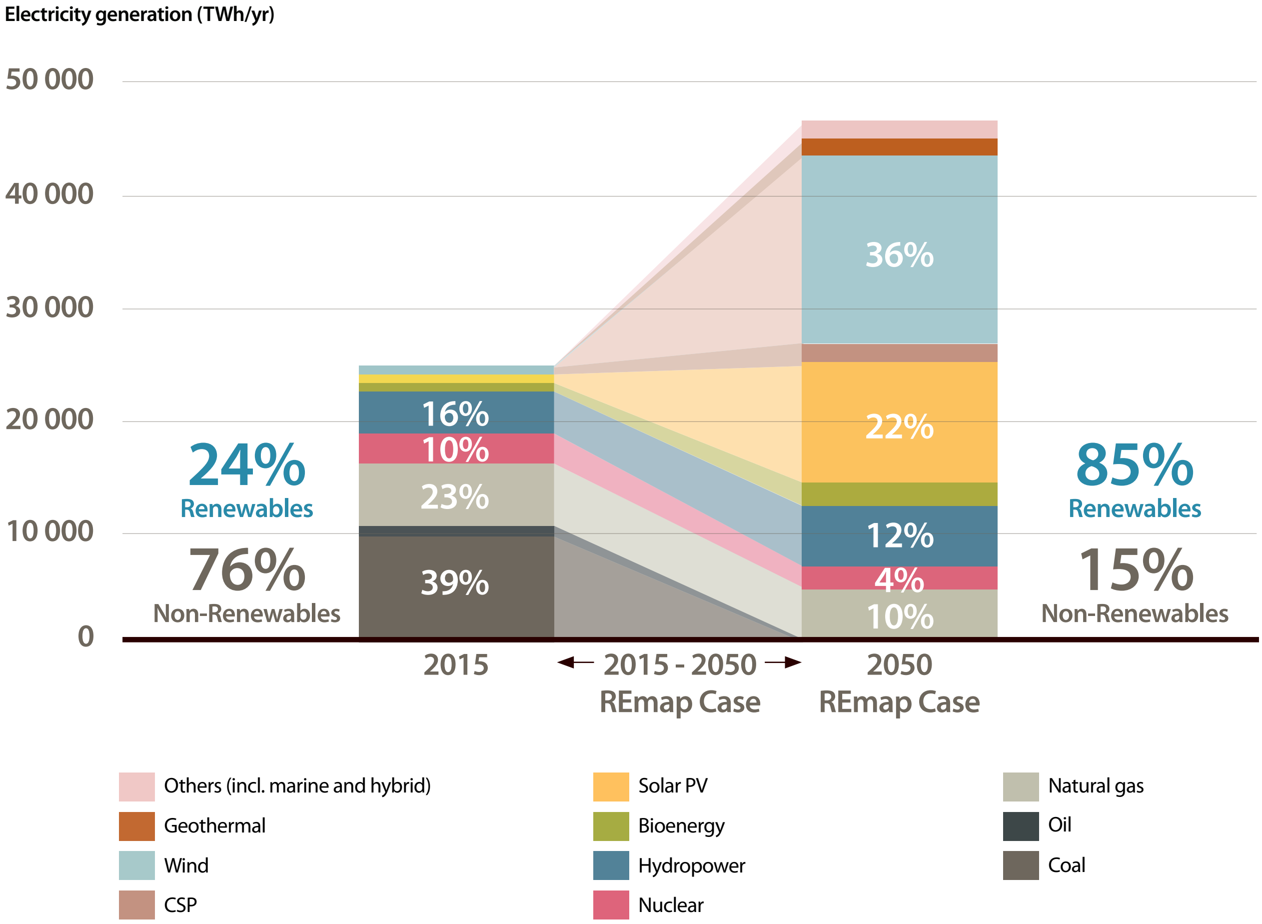


Figure 4

Renewables, being climate-dependent energy storage, is of prime importance for stable power supply and grid stability. Various new technologies are emerging and under research for energy storage. Ensuring power availability commensurate with the demand and transmission of power through the existing grids and keeping stability are the primary engineering challenges, bringing the concept of long-duration energy storage (LDES) to the forefront **(Figure 5)**. LDES technologies may be in thermal, mechanical, chemical, and electrochemical forms, and they can be used at scale and are cost-competitive for prolonged energy storage .

There are 4 kinds of novel LDES

All LDES allow energy to be stored when there is a generation surplus and released when there is a shortage.

Thermal

Thermal energy storage systems use thermal energy to store and release electricity and heat. E.g. heating a solid or liquid medium and then using heat to power generation at a later data.

- **Sensible heat**
- **Latent heat**
- **Thermochemical heat**

Mechanical

Mechanical LDES store potential or kinetic energy in systems for future use.
E.g. raising a weight with surplus energy and then dropping it when energy is needed.

- **Novel PSH**
- **Gravity based**
- **CAES**
- **LAES**
- **Liquid CO_2**

Electrochemical

Electrochemical LDES refers to battories of different chemistries that store energy.
E.g. air-metal batteries or electrochemical flow batteries.

- **Aqueous flow batteries**
- **Metal anode batteries**
- **Hybrid flow batteries**

Chemical

Chemical energy storage systems store electricity through the creation of chemical bonds.
E.g. using power to create syngases, which can subsequently be used to generate power.

- **Power-to-gas-to-power**

Figure 5

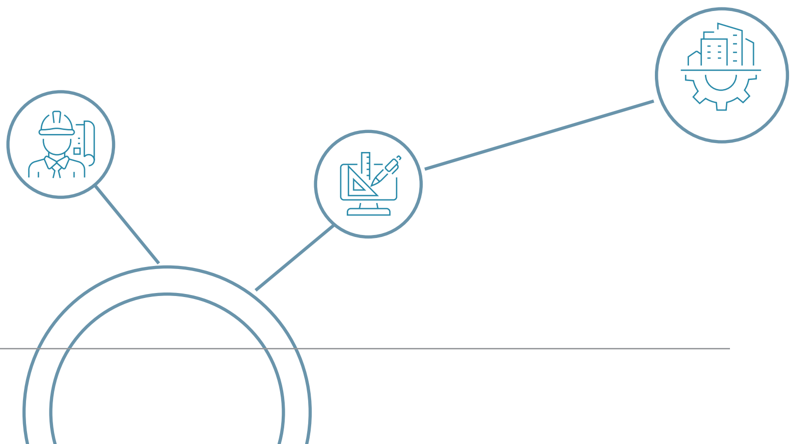
Countries aspiring to an ambitious climate target, plan to increase the share of renewables to 60 to 70 per cent in the power mix by 2035, accelerating the deployment of LDES as the lowest-cost flexibility solution [9].

Building Information Modelling (BIM)

According to WIKIPEDIA, building information modelling (BIM) is a process supported by various tools, technologies, and contracts that involves generating and managing digital representations of places' physical and functional characteristics. Though the concept is pretty old (1970), adoption and working worldwide on a large scale took a long time and an international standard, ISO 19650, could only be published in 2019. The BIM captures all the information during a project life cycle. It is a 3D platform catering to all the details from structure to equipment, utilities, electricals, etc, from concept to commissioning of the project and operation and maintenance during the plant life. These stages are termed as levels of detailing (LOD). The future of engineering is not limited to design offices only, but a collaboration of all the stakeholders, like the Owner, Consultant, Contractor, and Vendor, is necessary for successful construction and project management, given the resource and time constraints. BIM is the tool that fits all these requirements and enables virtual onboarding. TCE started to work on the BIM platform and gradually adopted 5D to 7D working methodology to fit future engineering possibilities.

Water Conservation and IoT

Natural water is treated for domestic and industrial purposes. Water is a very precious resource. The scarcity of potable/ usable water is a concern. Water demand is growing at a faster rate than population. Over the past 70 years, while the world's population has tripled, water demand has increased sixfold. About 900 million to 1.1 billion people worldwide are facing a lack of drinking water . The United Nations predicts that 5 billion of the world's 8 billion people will have water scarcity by 2025. A 2003 United Nations report states, "Across the globe, groundwater is being depleted by the demands of megacities and agriculture, while fertiliser runoff and pollution threaten water quality and public health."



Under the circumstances, water management for production and distribution is where much engineering is happening with the help of sensors, electronics, and IoT-based big data analytics. The primary aim is to make the whole system smart enough by using IoT-enabled methods to identify problems, leakages, wastages, and demand-supply gaps to maximise supply, prevent wastages, and enable rational water usage, resulting in water conservation. A typical schematic is shown in **Figure 6**.

IoT SMART WATER SOLUTION

Pipeline Monitoring
Locates leakage and reduces Non-Revenue Water

Pump Station Monitoring
Enables intelligent scheduling and monitors real-time device operation

District Metering area
Timely Controls the water distribution system and maximises the profit

User-Friendly
Simple technology solve the complex water problems

Water quality test
Ensures secure data and real-time water quality data

Cost-efficient
Low cost enabled solution helps in mass analysis

Figure 6

The water sector is TCE's strength area, with a well-established setup and competent resources. Engineering possibilities remain promising, and TCE can collaborate with academia and experts to develop IoT-based solutions.

Modularisation

Expansion and modernisation of plants is desirable rather than going for a new plant for economic, land, socio-political, and environmental reasons. Construction has to be done within various constraints, particularly in the limited spaces in these brownfield projects. Moreover, projects are often situated near the source of primary raw materials, which is remotely located, and the availability of equipment and skilled workforce at the project site is a big question. Modularisation in this context is gaining momentum when structural modules of suitable size and weight, complete with all fittings, equipment, utilities, etc, are made at the manufacturer's facilities and transported to the site to assemble and integrate. The availability of advanced technologies like BIM, VR, and AR are enablers for modularisation. Modularisation is already in place and shall continue, creating a high level of engineering possibilities where the contractor, consultants and vendors are the key players.

Figure 7

CONCLUSION

Given the technological advancements in the Internet, communications and cloud computing engineering is no longer a designer's choice but a collaborative exercise among all the stakeholders. Many digital tools are available and being developed to provide 3D visualisation and feel the realities through VR/AR. Armed with state-of-the-art technology and sophisticated tools, engineers are expected to deliver innovative and time-bound smart solutions. Apart from providing solutions, there is a rising horizon of infinite engineering opportunities and possibilities driven by climate challenges. Decarbonisation, circular economy and innovations are the pillars of future engineering, resulting in a vast landscape of Energy transition, Resource conservation, Renewables, Remote working and modularisation. Thus, Engineering Consultants find an infinite scope and possibilities in the future and need to prepare to be future fit.

Hydrogen is the next-generation fuel that will replace fossil fuels to decarbonise the world. Hydrogen can be used in electricity generation, transport, heating and cooling in buildings, apart from producing ammonia, methanol, and syngas.

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Architectural & Urban Resilience in the Face of Change

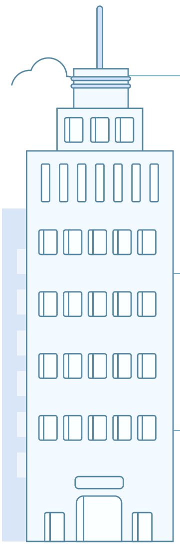
As life and nature evolves, so does demographics, which in turn leads to a dynamic scenario where designing and planning for spaces and cities have to continuously reinvent themselves and be constantly prepared to adapt for the extreme change.

In an era of rapid urbanisation, globalisation, climate change, and technological advancements, Architects and Urban Planners have become protagonists in creating spaces beyond aesthetically pleasing structures. As said by Heraclitus of Ephesus, a Greek philosopher, "The only constant in life Is change." It has been well witnessed in nature and reality over the ages. Change is the only inevitable and constant strata nature has given us as a disguise, which can often be chiselled into a blessing. Resilience can be portrayed as the ability to bounce back and recover from extreme and demanding change. We use the term "resilience" in referring to one's capacity to cope with changes and adapt.

Due to the resilient profile of earlier civilisations like the Indus- Valley, Greece and others, they went extinct as they were not equipped enough to adjust and cope-with natural calamities.

Thus, the more resilient buildings, cities, and infrastructure are in an ever-changing world, the better they will accommodate future unknown variables. A resilient community recovers from adversity after adapting and anticipating it beforehand. Therefore, the hour intends to find innovative solutions beyond survival to escalate architectural and urban resilience.

Architectural resilience creates dynamic and sustainable buildings that thrive in adversity. Each building has its specific requirements and functions for which it is designed. These should be well attended, and particular strategies and designs involving function and operation should be well curated. Some of the avenues involving physical character and surroundings include:



- a. Recognising the Role and function of the building
- b. Social Operations and Economic Importance of the Building and its association with any institution or business and stakeholders
- c. Environmental changes it poses from the structure and material used (reducing carbon footprint)
- d. Consequence of Building collapse and recovery in case of any calamity

TRENDS OF MODERN URBANISATION

Urban resilience today is based upon three converging trends: climate change, demographic growth, and globalisation. Cities should be considered holistically regarding their capacities through community engagement with society's most vulnerable members.

Climate change, pandemic, and political waves have created massive fault lines in social, economic, and environmental sections. These threats disproportionately impact the financially weaker sections, racially or ethnically marginalised groups, and women and older people. Therefore, the vision summarises designing a safe and inclusive environment for users and neighbours and a disaster management plan in case of particular exigencies or calamities. **Figure 1** illustrates the same, giving an insight into the standard arenas where adaptive and coping capacities can be explored.

Some of the significant methods and solutions of providing a base to design resilient solutions that can withstand unforeseen challenges have been listed below. These include the ones having the capacity to help sustain-

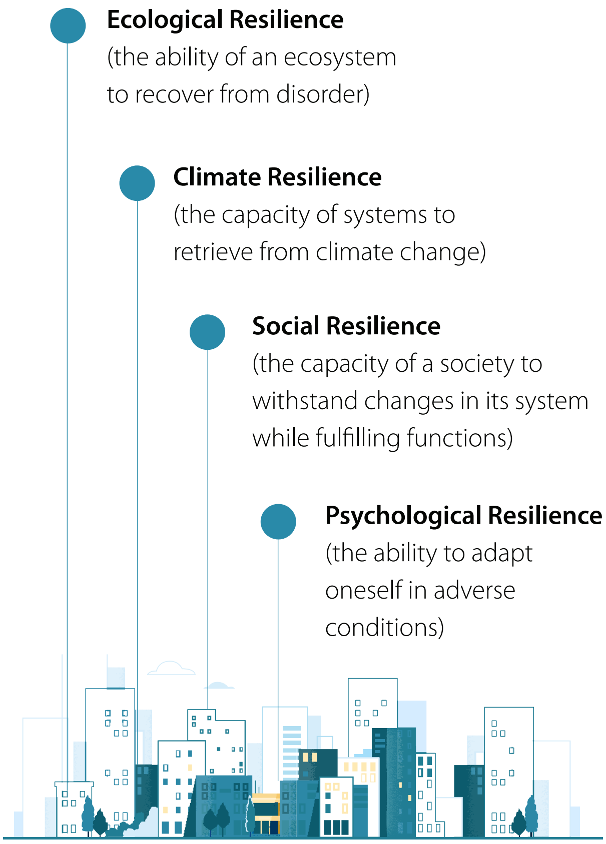


Figure 1: Basic Mechanism of Coping, Adjust & Transform in Resilience

Climate change, pandemic, and political waves have created massive fault lines in social, economic, and environmental sections. These threats disproportionately impact the financially weaker sections, racially or ethnically marginalised groups, and women and older people. Therefore, the vision summarises designing a safe and inclusive environment for users and neighbours and a disaster management plan in case of particular exigencies or calamities.

STRATEGIES FOR RESILIENT DESIGN

A. Embracing Sustainable Design

Sustainable design to minimise environmental impact is at the core of architectural and urban resilience. **Figure 2** shows it is a cradle-to-grave process for designing with nature.

Figure 2: Life-Cycle Assessment in Sustainable Design

Sustainable architecture and planning involve integrating natural elements into the built environment. Green roofs, vertical gardens, and urban forests are some of the components of Green Buildings, which help mitigate urban heat island effects, enhance air quality, promote water conservation, influence energy-efficient systems, and enhance biodiversity, as demarcated in **Figures 3** and **4**.

Figure 3: Bifurcation of Sustainable Planning Components

Sustainability seeks to reduce carbon footprints and promote resource conservation. EDGE (Excellence in Design for Greater Efficiencies), LEED (Leadership in Energy and Environmental Design) & GRIHA (Green Rating for Integrated Habitat Assessment) ratings are some of the major avenues that foster ratings for designing a certified green building.

Mapping through GIS and other software and recognising the most vulnerable areas requiring buffers, SEZs, and other belts help reduce the added stress on adjoining areas, leading to sustainable development with resilience and preparedness. Limiting the use of natural sources like water and fossil fuels and garnering the concept of reuse of water and use of renewable energy will add to resilience.

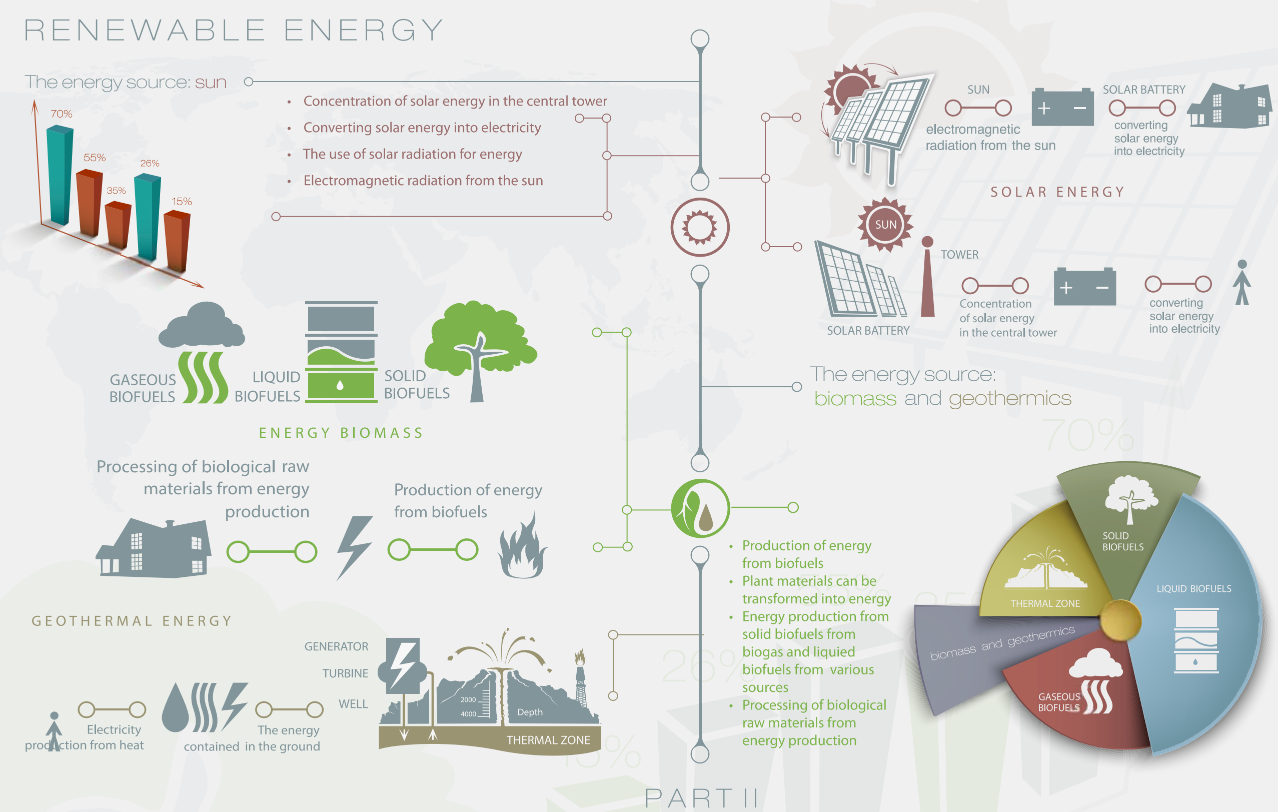


Figure 4: Measures to promote Sustainable Design at Micro- Level

B. Climate-Responsive Architecture

Climate change brings weather events, such as hurricanes, floods, and heat waves, posing significant challenges to urban infrastructures. Buildings with energy-efficient materials, efficient drainage systems, and elevated structures in flood-prone areas are strategies employed to fortify cities against climate-related threats.

The design of structures is preferably symmetrical with limited slenderness and uniform distribution of load-bearing members. Correction of diaphragm deficiencies, removing stressed members, and considering windward and leeward directions are vital ways of enhancing climate-responsive buildings. The design approach includes upgrading traditional construction practices, using vertical and horizontal reinforcements, using knee braces at beams to post junctions, and using deeper foundations.

At the urban level, developing and enforcing seismic-resistant construction techniques, analysing underlying geological conditions to determine safer sites, and removing unsafe buildings are key entities, as reflected in **Figure 5**. Land use control (zoning) and strict application of building codes and standards (mass-space relations, low-density development, coastal zoning regulations, green buffers, etc.) with a specialised disaster management unit are requisite for a solid infrastructure base to foster Resilience.

Figure 5: Climate Responsive components at Micro Level

C. Adapting to Technological Advancements

The current century is characterised by rapid technological advancements equipped with interconnected devices. The AI-driven systems offer opportunities for efficient resource management for enhanced urban experiences. Integrating smart technologies into simple designs while creating intelligent buildings and infrastructure can respond to dynamically changing urban needs.

Software like BIM, Big Data, Augmented, and Virtual Realities are adapted while designing. These help in quick analysis and give a binocular view of the practical considerations of environment and 3D that directly impact Buildings and Cities. This basic information can help prepare and develop coping mechanisms, as shown in **Figure 6**.

Figure 6: Digital Technology for Urban Solutions

Some of the typical outcomes using technological advancements include (also shown in **Figure 7**):

a. Preparing emergency communication systems through AI for health and safety.

b. Mapping of green areas to provide carbon sequestration to help curb air pollution.

c. Preparing plans on 2D & 3D alternative water supply transportation routes in case of vulnerability.

d. Safe spaces could be identified through GIS, and masses living in calamity-prone areas could be relocated.

e. Use of mixed reality to create and design buildings with increased efficiency.

TCE has designed a sustainable concept incorporating eco-friendly materials, reduced carbon footprint, and energy-efficient systems. BIM technology and other latest software in Projects, along with understanding various Green Ratings, are feathers in the cap.

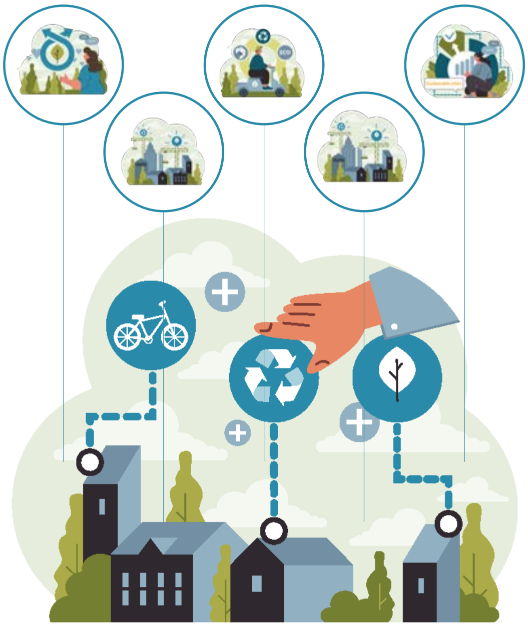


Figure 7: Smart Solutions using Digital Technology at Urban Level

D. Fostering Inclusivity and Community Engagement

Social Cohesion is also a part of resilience, apart from Physical Structures. It also includes the historical and current effects of traumas on individuals residing in a community that cannot be resilient.
Residents engage in the design process, ensuring that the spaces reflect the identities and cultures of the people they serve. As a sense of community ownership, the built environment can collectively overcome challenges. The first level of commitment requires stakeholders, government and policymakers to develop strategies, policies and programs. A comprehensive approach demarcates geographic zones and identifies vulnerable populations that could be made inclusive of a community. An extensive public awareness program will also accompany this.

This would also include training residents to conduct projects involving community engagement techniques. Developing community resilience would require stakeholders and communities to come together on one platform and shape their needs and challenges on a single page, with a social responsibility for collective action.

E. Designing for Flexibility and Adaptability

The concept of adaptability in designs and buildings with flexibility allows structures to be repurposed as per urban needs, which will evolve. Modular designs are mostly multi-functional spaces catering to changing demands and ensuring that cities remain agile while responsive to emerging challenges.

A second-level approach to creating a sense of adaptability is to form an awareness program, spreading awareness about natural and artificial hazards and what can be done to prevent a disaster. Vulnerable communities should be a significant part of such preparedness programs.

Architectural and urban resilience extends beyond individual buildings. It encompasses the entire urban landscape, including green and open spaces, pedestrian-friendly areas, and mixed-use developments that encourage sustainable living.

Prioritising walkability and connectivity also fosters social interaction, thus developing psychological resilience and building cities that can withstand the test of time.

F. Prevention is better than Cure

Preparedness includes public awareness and a responsive system to be captured in case of calamities. Police and Officials should be prepared to serve at their best. Teams should be trained beforehand for search and rescue operations, disaster assessment, and determining if structures are safe for re-occupancy.
These mitigation measures must be backed by the collection of background information. Seismic-resistant construction techniques, soil type, and geological structure analysis will determine safe construction sites. Measures to remove unsafe buildings and promote safer construction methods by implementing land-use control (zoning), standards and building codes are necessary.

These include favourable taxation, loans, subsidies, and land development incentives to prevent destruction after a disaster.

To make a site resilient, potential disaster-prone sites must be identified and restricted to construction, the dam capacity verified, and earthquake forces estimated.

TCE'S APPROACH TO RESILIENCE BUILDING

TCE has designed a sustainable concept incorporating eco-friendly materials, reduced carbon footprint, and energy-efficient systems. BIM technology and other latest software in Projects, along with understanding various Green Ratings, are feathers in the cap. TCE often associates itself with projects involving reviewing the structural soundness of facilities and guiding with necessary solutions.

TCE has always centred around people–inclusive architecture, considering the diverse needs of a community and its stakeholders. This concept has been applied to many rehabilitation projects under the CSR initiative.

To conclude, TCE always takes a strategic approach to building the foundation for a thriving and adaptable society. This symbolises resilience, echoing the strength and dynamism inherent in the human spirit.

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Project Management in Pictures

Inauguration

Millions of Safe Work Hours

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Plant Engineering & Design (PED) Cluster

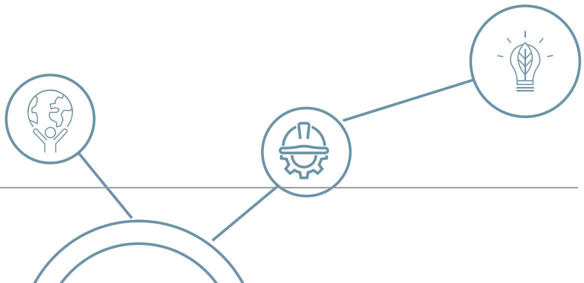
Harnessing Innovation in Engineering

This article delves into Tata Consulting Engineers (TCE) pivotal role in shaping the future through innovative engineering solutions, specifically focusing on Plant Operation Outsourcing. Aligned with TCE's Concept to Commissioning strategy and beyond, it aims to create a visible impact extending past the commissioning phase.

TCE's strategic approach involves preparing contracts for executing fixed-term outsourcing operations and facilitating the handover of plant operations to third parties. This comprehensive approach ensures a seamless transition through a training program initiated from the commissioning of the plant. This article not only explores the significance of TCE's involvement in plant engineering and managing the establishment of the plant but also highlights the importance of knowledge transfer and the development of sturdy operational frameworks tailored to plant-specific needs.

TCE has established itself as a significant contributor to the continuously evolving realm of engineering solutions, spearheading innovation and excellence in plant engineering. As profit margins are under pressure in capital-intensive industries, the emphasis on operational efficiency by deploying specialised partners at better economics has intensified, emerging as a pivotal driving force.

Based on their economic differences (the concept is grounded in David Ricardo's Comparative Advantage, whereby) two countries can benefit from trade even if one is less efficient in producing all goods than the other. To optimise costs and other liabilities, companies are adopting strategies of outsourcing operations even to specialised players; this was hard to visualise 8 to 10 years back.



While working on one of the projects, TCE's task was to prepare an operation and maintenance tender and its cost estimate for a six-year contract term for one Navaratna Oil PSU unit. This task introduced a new perspective on outsourcing business practices.

The team recognised the prevalence of Annual Maintenance Contracts (AMCs) and Operations and Maintenance (O&M) contracts in the market for various systems and packages, such as ETP (Effluent Treatment Plants), WTP (Water Treatment Plants), CPP (Combined Power and Process) plants. Additionally, infrastructure projects often employ contract awards based on the Build-Own-Operate (BOO) and Build-Operate-Transfer (BOT) frameworks. However, the O&M of a complete Oil dehydration and Storage plant, with nearly 450 crores in CAPEX and being outsourced to a single third party that neither built the asset nor owns it but is solely responsible for its operation and maintenance for a fixed term, represented a new paradigm. Furthermore, this marked a significant milestone, as it was the first time TCE outsourced the operation and maintenance of a process plant. Moving away from the traditional outsourcing of routine, low-end plant tasks marked a significant advancement for TCE.

STRATEGIC APPROACH TO PLANT OPERATION OUTSOURCING:

Drawing insights from the successful collaboration with the Oil Company, TCE has identified a forward-thinking strategy that involves scouting for similar opportunities across diverse process plants. This approach entails engaging third-party operators under fixed-term contracts. This move broadens the operational scope and injects specialisation and cost-efficiency previously unseen in the industry. By harnessing its engineering expertise, TCE facilitates a seamless transition of plant operations through comprehensive training programs tailored to equip third-party teams with the necessary knowledge and skills. This strategic manoeuvre allows client companies to redirect their focus towards their primary business objectives, thus optimising overall productivity and operational standards. More significantly, this strategy elevates TCE to a pivotal role in shaping the future of operational excellence as it adeptly navigates through the complexities of modern plant operations, offering a blueprint for efficiency, flexibility, and unparalleled expertise in the engineering domain.

SEAMLESS HANDOVER THROUGH COMPREHENSIVE TRAINING:

A critical element of TCE's approach to plant operation outsourcing lies in its meticulous handover process. Understanding the criticality of knowledge transfer, TCE dedicates substantial resources to developing in-depth training programs. These programs are meticulously designed to give third-party operators a robust foundation in plant engineering principles and practices. By doing so, TCE equips these operators with vital knowledge and ensures their readiness to manage plant operations smoothly, significantly reducing the risk of operational hiccups and boosting overall efficiency. Central to this strategy is the proactive involvement of the Operations and Maintenance (O&M) contractor right from the commissioning phase. TCE's early engagement is a strategic move to steepen the learning curve, offering a blend of theoretical knowledge and practical experience. Such comprehensive training ensures that the O&M contractor gains a nuanced understanding of the plant's operations right from the get-go. This deliberate and structured approach emphasises TCE's commitment to excellence in operational transition, setting a new industry standard for effective and efficient plant management.

> Tata Consulting Engineers is redefining its role from concept to commissioning and pioneering the future of plant operation outsourcing. By focusing on strategic integration, digital innovation, and a steadfast commitment to sustainability and regulatory compliance, TCE is setting new benchmarks for excellence in plant engineering management. As the industry continues to evolve, TCE stands ready to lead, fostering a more efficient, sustainable, and compliant future for the engineering sector.

CASE STUDY: OUTSOURCING OF OIL DEHYDRATION AND STORAGE PLANT OPERATIONS

The experience with a prestigious Navaratna Public Sector Undertaking (PSU) is a compelling case study showcasing TCE's efficient handover process. This project revolved around outsourcing an oil dehydration and storage facility, a significant venture with a capital expenditure (CAPEX) of 450 crores, to a third-party operator without transferring asset ownership.

A critical factor in the project's success was the meticulous preparation of the Operations and Maintenance (O&M) tender, which was carefully aligned with the client's specific requirements. This precision in alignment ensured its successful acceptance and passage through the rigorous scrutiny of the client's review committee. TCE's dedication to adhering to timelines was further exemplified by the strategic release of the tender well in advance, yielding a significant time savings of three months. This foresight proved invaluable, especially in the wake of the downturn in oil prices caused by the COVID-19 pandemic. Upon request from the client, TCE devised and implemented cost reduction strategies, achieving a notable overall savings of 6.6% on the proposed operational expenses (OPEX).

The project, which focused on constructing a Tank Farm in Northeast India, encountered several challenges, including the absence of a reference tender and incomplete details, mainly due to the bankruptcy of the Engineering, Procurement, and Construction (EPC) contractor.

TCE's adaptability and resilience in overcoming these obstacles ensured the project's success and earned appreciation from the client's review committee. This achievement has the potential to broaden TCE's range of service offerings, highlighting the company's capacity for adaptability, resilience, and commitment to delivering excellence under challenging circumstances.

SALIENT FEATURES OF INSTALLATIONS:

Under TCE's guidance, the project showcased extensive capabilities, emphasising the meticulous planning and execution of a complex oil processing facility. The critical components of this project included:

1. **Crude Oil Safe Storage Capacity:** An impressive 40 million litres, ensuring ample capacity for crude oil storage.

2. **Crude Oil Processing:** The facility specialises in dehydrating wet crude oil and efficiently transferring the processed dry crude oil to the Central Tank Farm (CTF).

3. **Water Management:** The project incorporated advanced treatment of formation water, prioritising environmental safety through the disposal of treated water.

> This report was subsequently submitted to the Ministry of Petroleum and Natural Gas, significantly enhancing TCE's credibility in the industry.

4. **Energy Resources:** The facility was equipped to receive natural gas alongside a sophisticated Captive Power Plant (CPP) with a formidable 4 x 1600 KVA capacity emphasised the project's self-sufficiency.

5. **Utility Systems:** Including a comprehensive utility system featuring raw water treatment, steam generation, and compressed air system.

6. **Safety Measures:** The project maintained safety by incorporating critical systems such as a flare header, and fire protection, among other essential safety components.

7. **Sustainability Initiative:** A state of art sewage/ sludge treatment system and an Effluent Treatment Plant with a capacity of 7020 kLPD, reflecting the project's commitment to sustainability.

Following the tendering phase, TCE's commitment extended to seamlessly integrating the Operations and Maintenance (O&M) contractor during the commissioning phase. This phase was marked by an innovative training program developed from scratch, a testament to TCE's dedication to excellence and innovation. The program was designed without precedent within TCE and explicitly tailored to the project's needs.

	Crude Oil Safe Storage Capacity
	Crude Oil Processing
	Water Management
	Energy Resources
	Utility Systems
	Safety Measures
	Sustainability Initiative

TRAINING PROGRAM HIGHLIGHTS:

- Comprehensive coverage of the overall process and specific plant systems, combining classroom instruction with practical, on-field training.
- Detailed modules on operating various systems and components, like the Main Plant, ETP, sophisticated gas engine-driven pumps and HVAC systems.
- A methodical approach to training, including classroom sessions, onsite training, assessments, and feedback mechanisms.

MODULES COVERED IN TRAINING:

- Brief description of the overall process
- Overall Process Training (Main Plant & ETP)
- Familiarisation of the GG System Installation at CPP & Load trial Run of GG-1/2/4
- 4 X 1440 kw GG system (Gas Genset) Load test, Maintenance and Operation training
- Operation of MOV field (Control room and field Training)
- Operation of ROSOV & Control Valves
- TFMS and Servo Gauge TFMS system
- Boiler (Classroom and field Training), including Boiler Control Panel Training
- ETP (Classroom and On Field Training)
- Electrical Substation
- Control Room (DCS, ESD and F&G System)
- Fire Water Network
- Dosing System
- Gas engine-driven pumps (DCODP)
- HVAC System
- ACS
- Air Compressor

- RWTP, STP
- Chemical Dosing System
- VFD Operation
- Air fin Fan Cooler (Through VFD operation and detailed briefing)
- IDBH, DBH & EET (Classroom and On-field Training)
- Plate type heat exchanger
- Cooling Tower & Cooling Water Pumps
- OWS Pump
- Effluent water transfer Pumps
- Clarified water dispatch pump

APPROACH FOR TRAINING:

Classroom Training
Onsite Training
Training Assessment Subjective Test
Obtaining Training Feedback from participants
One-time Retraining and Reassessment for lesser Assessment scores

This service innovation not only delighted the customer but also led to receiving an additional RFQ to provide similar training from the client.

The training program, systematically designed by TCE, concluded with examinations, interactive feedback sessions, and submitting a comprehensive report to the client. This demonstrated TCE's unwavering commitment to delivering high-quality service.

The **training initiative's success** was further validated through **organised assessments**, **valuable insights gained from evaluations**, **positive trainee feedback**, and the creation of a **detailed management report**.

This report was subsequently submitted to the Ministry of Petroleum and Natural Gas, significantly enhancing TCE's credibility in the industry.

This innovative service introduces a distinctive element to TCE's portfolio and strategically positions the company for prospective opportunities in EPCM and PMC jobs. The invaluable experience gained from this project fortifies TCE's competitive edge and underlines its capacity to pioneer new services tailored to evolving industry demands. The significance of this endeavour and its tangible impact is evident in the client's explicit request for additional training sessions. This affirmation solidifies TCE's standing as a trusted partner and leader in innovative engineering solutions.

MANAGING PLANT ENGINEERING ESTABLISHMENTS - WHAT MORE:

TCE distinguishes itself by transcending the traditional concept-to-commissioning approach, embracing holistic methodology, and spotlighting its commitment to sustainability, adherence to regulatory frameworks, and dedication to the long-term success of critical infrastructure projects.

ELEVATING SUSTAINABILITY PRACTICES

TCE sets the standard for incorporating sustainable practices into plant engineering. This commitment is manifested through:

- **Adoption of Green Technologies:** Leveraging the latest eco-friendly innovations to minimise environmental impact.
- **Energy Efficiency:** Streamlining processes to reduce energy consumption, capitalising on renewable energy sources whenever possible.
- **Waste Reduction:** Implementing strategies to diminish waste output, promoting recycling and reusability.

Adoption of Green Technologies
Energy Efficiency
Waste Reduction

By prioritising these areas, TCE contributes to a healthier planet and pioneers a movement towards a more sustainable industrial sector.

ENSURING COMPLIANCE AND REGULATORY INTEGRITY

Navigating the complex maze of regulatory requirements is a formidable task. TCE excels in this domain by:

- **Ensuring Local and International Compliance:** Staying abreast of and adhering to the myriad of standards governing plant operations.
- **Risk Management:** Identifying potential compliance risks early and devising strategies to mitigate them effectively.
- **Cultivating a Culture of Compliance:** Instilling a deep-rooted sense of regulatory adherence throughout all levels of operation.

Ensuring Local and International Compliance
Risk Management
Cultivating a Culture of Compliance

TCE's proactive approach safeguards against legal and financial repercussions and reinforces its reputation for reliability and trustworthiness.

ANTICIPATING AND SHAPING FUTURE TRENDS

As the landscape of plant operation outsourcing evolves, TCE is at the lead, ready to embrace and shape future trends. This foresight includes:

- **Artificial Intelligence (AI) and Smart Technologies:** AI can be utilised to predict and solve complex challenges, and smart technologies can be integrated to improve efficiency and reduce costs.
- **Sustainability and Efficiency:** Balancing the drive for innovation with the imperative of sustainability ensures that technological advancements contribute to greener operations.
- **Digital Transformation:** Incorporating digital technologies to optimise operations and enhance productivity.

TCE's forward-thinking strategy positions it as a leader in developing solutions that are not only technologically advanced but also sustainable and efficient.

Digital Transformation
Artificial Intelligence (AI) and Smart Technologies
Sustainability and Efficiency

CONCLUSION

Tata Consulting Engineers is redefining its role from concept to commissioning and pioneering the future of plant operation outsourcing. By focusing on strategic integration, digital innovation, and a steadfast commitment to sustainability and regulatory compliance, TCE is setting new benchmarks for excellence in plant engineering management. As the industry continues to evolve, TCE stands ready to lead, fostering a more efficient, sustainable, and compliant future for the engineering sector.

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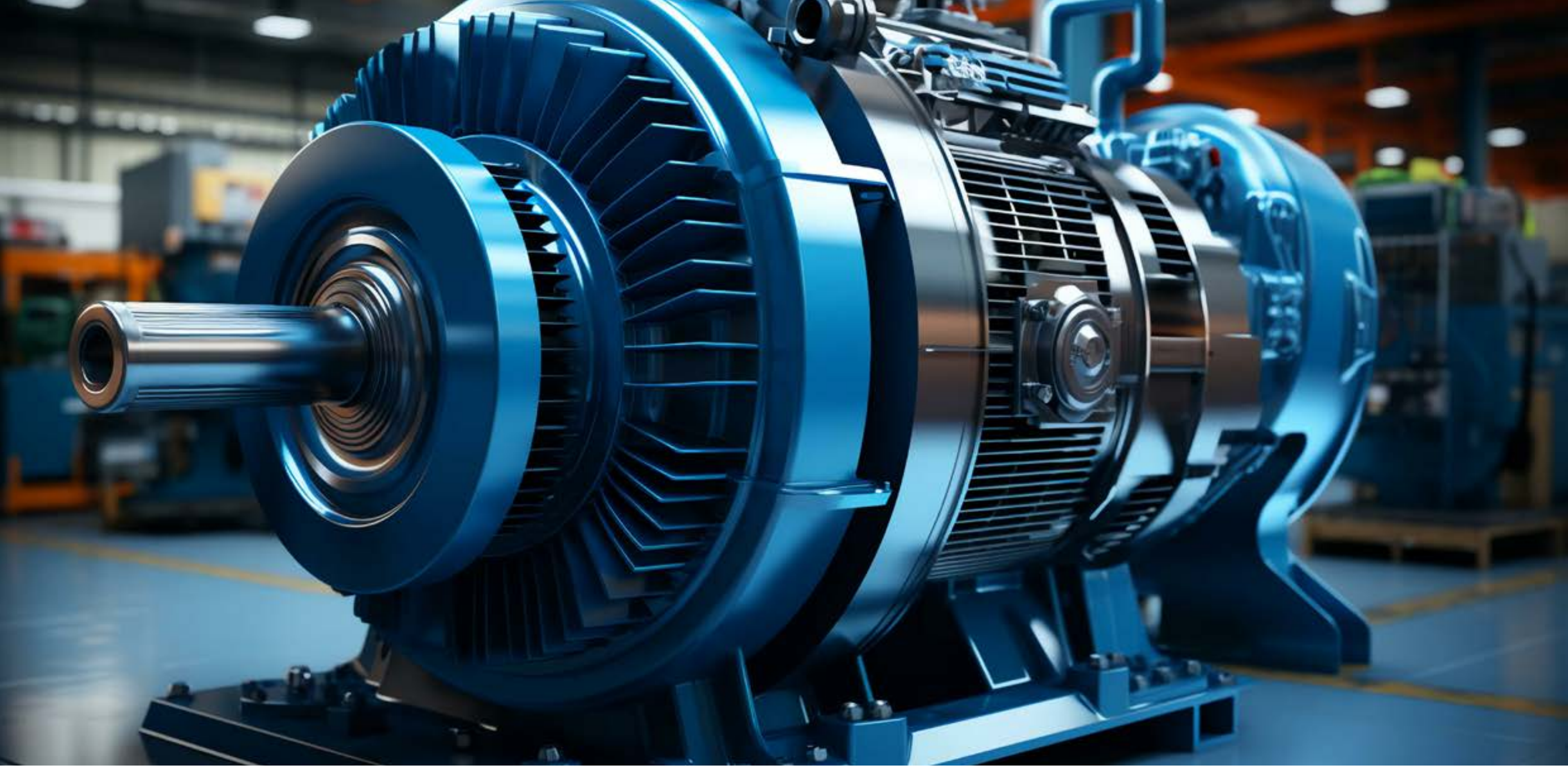

Alternative to Pressure Reducing Valve - A Turbine?

Almost all industrial complexes use low-pressure steam for various process applications as heating mediums. Low-pressure steam is preferred for heating applications because of its higher latent heat and, hence, the lower quantity of steam required. However, producing steam at low pressure in industries does not make economic sense. Thus, steam produced at higher than required pressure needs to be throttled to make it suitable for process application.

Pressure Reducing Valves (PRV) carry out this throttling or pressure reduction. In some industrial applications, de-superheating is required downstream of PRV to match required process parameters; in that case, the arrangement is called PRDS. Though PRV effectively reduces steam pressure, valuable energy is also drained.

This energy loss in PRV can be eliminated using a non-condensing or back-pressure steam turbine, which can perform the identical pressure reduction function and simultaneously generate electric power utilising steam energy.

In the steam turbine generator set, the steam pressure is converted to velocity head through nozzles, and high-velocity steam jets hit turbine rotor blades to turn the turbine at high rotational speed. The turbine, thus rotating at high rotational speed, drives the alternator to generate electrical power.

The steam turbine does not consume steam except for negligible steam loss through glands. It simply reduces the pressure of the steam from the inlet to the outlet through passages of nozzles, guiding vanes, and turbine blades, and it subsequently discharges exhaust steam into the process header.

MICRO STEAM TURBINE IN PLACE OF PRV

A single-stage backpressure steam turbine is suitable for dealing with saturated steam at low pressures. The pressure drop across the turbine is utilised to generate power via a geared or gearless turbo-generator set. The figure below shows a schematic diagram in which a backpressure steam turbine bypasses an existing PRV station to reduce incoming steam pressure to the required pressure as per process demand.

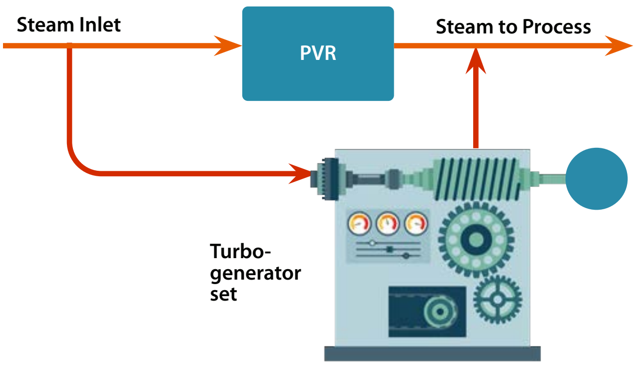

Figure 1: Schematic diagram showing steam turbine in by-pass to an existing PRV station

The type of electrical generator is usually either an induction or synchronous generator, depending on the owner's requirements and operational needs.

Installation of this kind of small backpressure turbine results in drastically reduced auxiliary power consumption, lower dependence on Grid power (in case of power import) or any other power source, and savings in power cost.

These small steam turbine generator sets have gear reducers, pressurised lubrication oil systems, and constant-speed mechanical governors. However, sets without gear reducers, lubrication oil systems, and speed governors are also available. These turbo-generator sets are available in the market in a wide capacity range, starting from 20 KW up to 1700 KW.

KEY FEATURES OF TURBO-GENERATOR SET

- Quick startup times
- Easy to retrofit in any existing layout
- Versatile, highly efficient, rugged and robust design
- Single disc, single row/double row Curtis type impulse wheels
- Compatibility with both induction and synchronous generators
- Complete automatic operation
- Short payback period
- PLC-based control panel with HMI screen (optional)
- Ability to operate efficiently with high exhaust steam pressures
- Ability to operate on the island as well as in synchronised mode

The features mentioned above/list of equipment may vary based on OEM's proven practice.

LAYOUT

Accommodating the footprint of a new installation in an existing layout can be challenging. Hence, the footprint of the proposed backpressure steam turbine set is of utmost concern in a bid to replace an existing PRV. The highly compact size of the steam turbine set also comes into play in this case.

Figure 2 below shows the footprint of a typical 500 KW turbo-generator set:

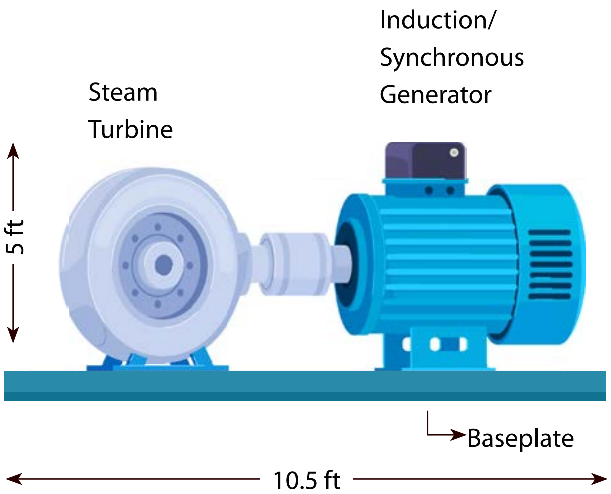

Figure 2

Fig. 2 shows the footprint of a typical 500 KW back pressure turbo-generator set.

Back-pressure turbines can be installed bypassing an existing PRV station. Though the turbine will remain in line to reduce steam pressure in green field installations, the PRV station must be parallel to it. In case of a turbine outage, the PRV station will operate to ensure a continuous supply of process steam.

The turbine generator set is a modular unit. A typical 3000 mm X 1850 mm X 2000 mm (LWH) unit weighs approximately 9.0 Tons and comes with standard forklift pockets. There is no specific requirement for a foundation; a level load-bearing surface of 3500 mm X 2500 mm will be adequate for the above set.

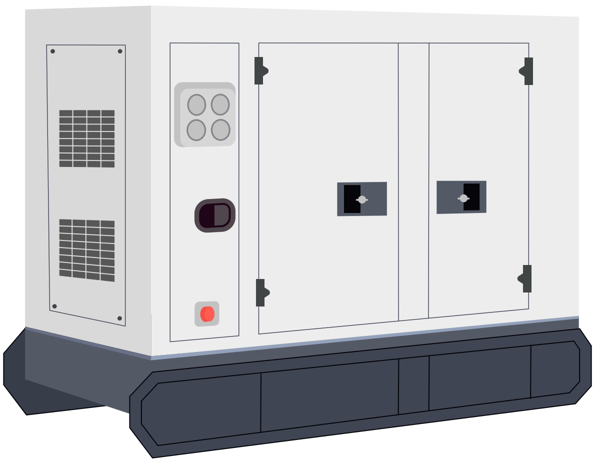

Figure 3: Typical turbo generator set

In the present era of energy transition and growing awareness about the evils of greenhouse gas emission, awareness for harnessing waste heat to produce valuable energy has gained momentum. PRVs are abundant across all process industries, which presents a massive opportunity for waste energy recovery.

POWER GENERATION POTENTIAL

The electrical Power generation potential of the back pressure turbine depends on inlet and outlet steam condition; pressure drop across the turbine, steam flow rate, etc. Electrical Power is generated in 415V, three ph+N, and can be fed to LT MCC incoming feeder to run miscellaneous auxiliary equipment in the plant. Typical power generation potential is given in tabular form (turbine isentropic efficiency considered 90%, other losses ignored):

Inlet Steam condition		Outlet Steam condition		Inlet Enthalpy	Outlet Enthalpy	Mass Flow rate	Isentropic Efficiency	Power Potential
Pressure in kg/ cm2(g)	Temp.in °c	Pressure in kg/ cm2(g)	Temp.in °c	kJ/kg	kJ/kg	kJ/hr	%	kW
15	200.5	3	143.2	2795	2738	8000	90%	108
10	183.3	3	143.2	2792	2738	6000	90%	81
18	208.9	10	183.2	2797	2738	8000	90%	118
12	190.8	6	164.4	2786	2762	10000	90%	60
55	272	22	219.8	2793	2681.6	5000	90%	139
25	225.1	15	200.5	2802	2792	10000	90%	25

Figure 4: Typical power generation potential of back pressure turbo-generator set

The above table considers inlet steam to be saturated only. If incoming steam is superheated, power potential will increase with the superheat and incremental enthalpy degree.

INSTALLATIONS

University of Missouri, Columbia, has installed a 300 KW back-pressure turbine to replace an existing PRV station in 2017. The PRV was used to reduce the steam pressure from 60 psig to 5 psig. The backpressure steam turbine's electricity helps save fuel and reduce emissions. The electricity generated by the turbo-generator set is estimated to be equivalent to annual benefits of:

- Savings of 1,550 tons of coal
- Reduction of 4,200 tons of CO_2.

In India, Amul Fed Dairy, Gandhinagar, has also installed a 90 KW back pressure turbine in bypass to existing PRV stations, which were installed to convert available steam at 21 kg/cm2(g) to 9 kg/cm2(g) to meet process demand. This microturbine is estimated to generate 5,18,400 kWh of electrical power annually and reduce 425.09 Tons of CO_2 emission annually. Payback for the turbine is estimated to be 16 months.

Different companies, such as Kessel Steam Turbine, IB Turbo Pvt. Ltd, TurboTech Precision Engineering Private Limited, and Heliex Power Ltd. have multiple microturbine installations across various industries in India and abroad.

PROJECT SCHEDULE

Project schedule plays a vital role in assessing the feasibility of any project. Many companies manufacture small back-pressure turbines indigenously. It does not involve the import of expensive and complex equipment from overseas. It can be completed within a year, from order placement to synchronisation and trial run. A typical project schedule is presented below:

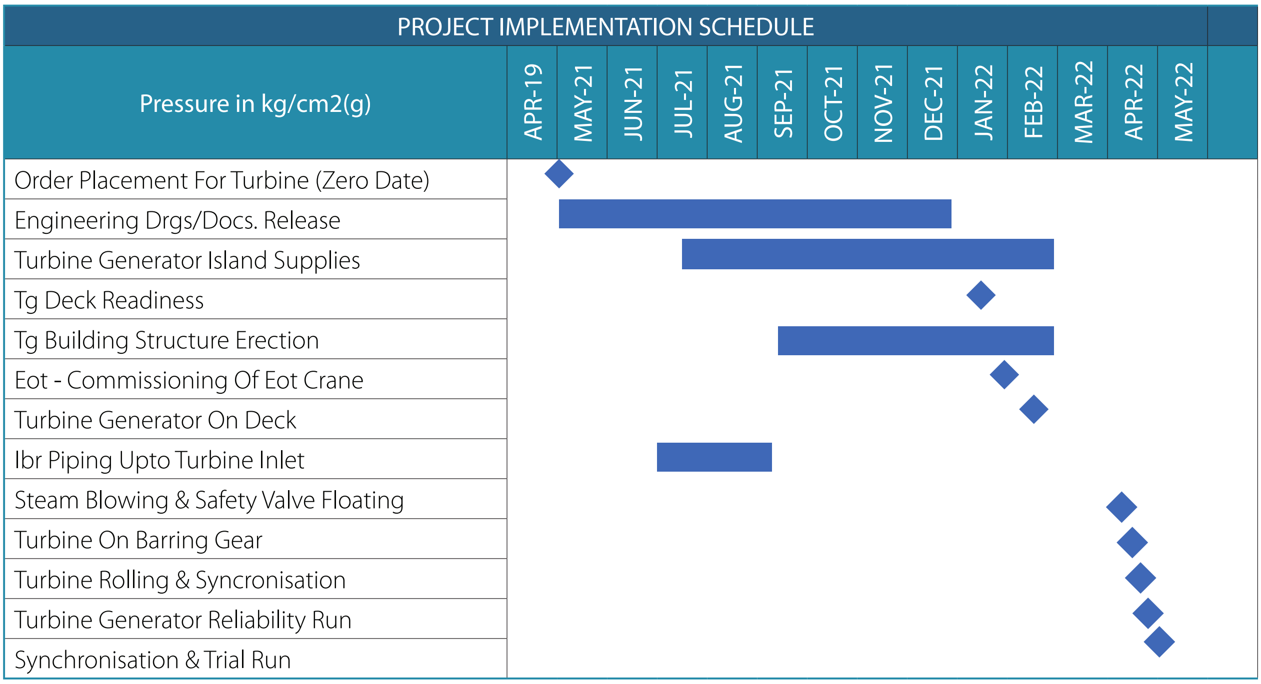

Figure 5: Typical project implementation schedule

RETURN ON INVESTMENT

Installing a back-pressure turbine bypassing PRV involves additional capital expenditure, so it is essential to evaluate the commercial parameters of this proposal. Let's calculate the simple payback period for a 100 KW back-pressure turbine.

Assumptions

a. Plant load factor – 80%

b. Seling value of per unit electricity – Rs. 8/kWhr.

c. Auxiliary power consumption – 10%. Net power generation – 90 KW.

The electrical energy generated by the back pressure turbine in a year = 90 X 365 X 24 X 80/100 = 630720 kWh.

The selling price of generated electrical energy = 630720 X 8 = Rs. 50,45,760.

The capital expenditure for procuring a 100 KW turbine is Rs. 51,00,000 (source: the website of IB Turbo Pvt. Ltd.).

Further, adding the cost of electrical equipment, installation, and total capital expenditure, the estimated amount is Rs. 71,40,000.

Since the turbine converts waste energy into useful electrical power, it involves no other input cost except initial capex. For simplicity, we are ignoring O&M costs and other minor consumable costs.

Hence, the payback period = 71,40,000/ 50,45,760 = 1.41 years or 15 months.

The above calculation envisages installing the turbine bypassing the existing PRV station. But in case of new installation, even if the turbine is installed for pressure reduction, a PRV station may still be required as a bypass for the turbine. In that case, the payback period will be higher. Carbon-di-oxide emission per electricity generation unit is estimated to be 0.91 to 0.95 kg/kWh for CO_2 (source-reference no. 6) in India. Hence, one unit of a 100 KW turbo-generator set will save approximately 574 metric tons of CO_2 emission each year.

The above calculation shows that though a backpressure turbine involves capital expenditure, it harnesses useful electrical power from waste energy without significant operating costs and can, as a result, offer a beautiful payback period.

Backpressure steam turbines are designed for a minimum service life of 20 years and are known for their high availability and low maintenance requirements.

CONCLUSION

In the present era of energy transition and growing awareness about the evils of greenhouse gas emission, awareness for harnessing waste heat to produce valuable energy has gained momentum. PRVs are abundant across all process industries, which presents a massive opportunity for waste energy recovery. Using a back pressure turbine for pressure reduction is an established technology and doesn't involve a considerable footprint or investment.

Back pressure turbines not only offer an attractive payback period but also offer the opportunity for a remarkable reduction in CO_2 emission. However, careful study of existing equipment, layout, selection of turbine, and integration with existing electrical system are critical to achieve successful alternatives to existing PRV stations.

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Tata Consulting Engineers Limited (TCE)

Technology Team Update

At TCE, we are committed to achieving engineering excellence and delivering innovative solutions that add value for our customers. As we set ourselves apart in a competitive market with our unique services, we must enhance our focus on "Building Tomorrow" with cutting-edge technologies, sustainable growth, innovation, and cost-effective solutions. Sustainability is at the core of our values, emphasising a circular economy through eco-friendly designs, renewable energy solutions, and resource-efficient projects. Our goal is to align ourselves to achieve Net Zero.

The technology team acts as a dedicated task force, leading the way in providing customers with the latest and most advanced technologies and innovations. Subject Matter Experts (SMEs) from various technology disciplines offer technical support to all Business Units.

Furthermore, the team actively collaborates with prestigious academic institutions such as IIT Bombay and IISc Bangalore to engage in research and development efforts to create new and sustainable technologies.

The technology team is also the primary catalyst for fostering the innovation culture in the organisation. Its goal is to provide innovative and value-added services to customers, which are documented in the Organisation's Value-Added and Innovation portal. The technology team is crucial in encouraging participation in Tata Innovista and guiding the teams at the pre-final and Final stages.

TECHNOLOGY TEAM DIMENSIONS

Technology Strategy & Offering

- BU Technology Strategy
- Emerging Technology Tracking
- Technology Adoption / Collaboration
- Develop Related New Service Offerings

Knowledge Management

- Standard Documents
- Efficiency & Quality Improvement
- Knowledge Capture and Dissemination

Academia Collaboration

- Program Partnership
- Funded Research Program

Promote Innovation Culture

- Value Adds and Innovation

Rhythm Tech Track

- Learning and Continuous Improvement

Technical Branding

- Publications & Conferences
- Panel Discussions
- BIS Committee

Business Enablement

- Technical Support to New and Emerging Technology Area Proposals
- Technical Training

Quality Control

- Error Free Critical Deliverables
- RCA and CAPA
- Competency Index

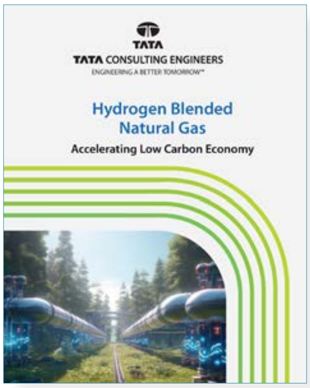
THOUGHT LEADERSHIP

The Technology group and subject matter experts author and facilitate the positioning of the organisation as a thought leader at various national and international platforms, including the TCE portal, which showcases unique designs. TCE's achievement in various brand-building efforts during FY24 is shown below.

- Paper Publications
- TCE Web Articles
- White Papers
- Conf./ Webinar Presentations
- Panel discussions

A BRIEF OVERVIEW OF RECENT EFFORTS AND INITIATIVES BY THE TECHNOLOGY TEAM IS PRESENTED BELOW:

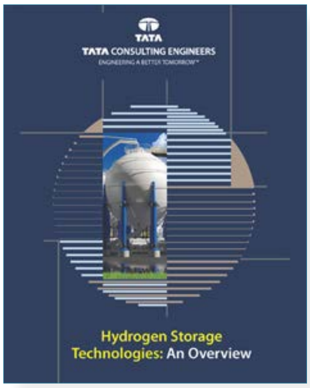
WHITEPAPERS: FY 2023 - 24



Hydrogen Blending with Natural Gas

Sakthivel S, Amit Sharma, Atul Choudhari

Hydrogen blending with natural gas is a global strategy to reduce CO_2 emissions. The hydrogen content typically ranges from 5% to 20% volume, but there is a move towards higher hydrogen content. However, increasing the hydrogen content raises concerns about the potential for transmission medium embrittlement. Various factors such as diffusion velocity, temperature, concentration, and material strength affect embrittlement, which creates operational challenges in upgrading infrastructure. Safety precautions against hydrogen's flammability are crucial, adding complexity to the supply chain. Additionally, the higher cost of hydrogen production underscores the need for supportive policies and market demand for cost-effective blending. Despite these challenges, hydrogen blending shows promise in reducing CO_2 emissions by utilising a clean fuel source and supporting renewable integration. Successful implementation requires careful planning, infrastructure upgrades, and collaborative policy development involving industry, governments, and stakeholders. Overcoming challenges depends on technological advances, economies of scale, and supportive policies to make hydrogen blending a sustainable energy solution.



Hydrogen Storage Technologies – An Overview

Sakthivel S, Shireesh S Swami, Amit Sharma, Atul Choudhari, Arnab Dandapath

Hydrogen storage plays a crucial role in the hydrogen economy, as it is essential for various applications such as power generation, transportation, and industrial processes. Despite hydrogen's high energy content per mass unit, its low density presents challenges, especially in volume-related applications. Researchers are actively developing storage technologies to improve the volumetric energy density while prioritising safety, reliability, and scalability. Advancements in storage methods are necessary to promote the widespread adoption of hydrogen across different sectors. This paper explores different hydrogen storage systems, focusing on compressed, cryo-compressed, cryo-supercritical H2, and liquid hydrogen storage. It discusses opportunities and challenges and outlines vital requirements and performance criteria for hydrogen storage tanks, contributing to the evolution and broader acceptance of hydrogen and fuel cell technologies.

Clearing the Air: Sustainable Aviation Fuel (SAF) for Transforming the Aviation Industry

Sakthivel S, Amit Sharma, Atul Choudhari

The increasing demand for SAF, driven by airlines and countries committed to reducing carbon emissions, has led to significant investments and advancements in SAF production technologies. This growth highlights SAF's economic potential and creates new opportunities in the aviation and biofuel industries. Additionally, regulatory support from governments worldwide is increasing, with incentives, mandates, and tax benefits being introduced to encourage SAF production and utilization, further solidifying its role in the aviation industry's sustainability efforts. The market potential for SAF is substantial, both in India and globally. SAF is essential to the aviation industry's strategy to reduce emissions and promote sustainability. Collaboration, innovation, and policy support will be key to realizing the full potential of SAF.

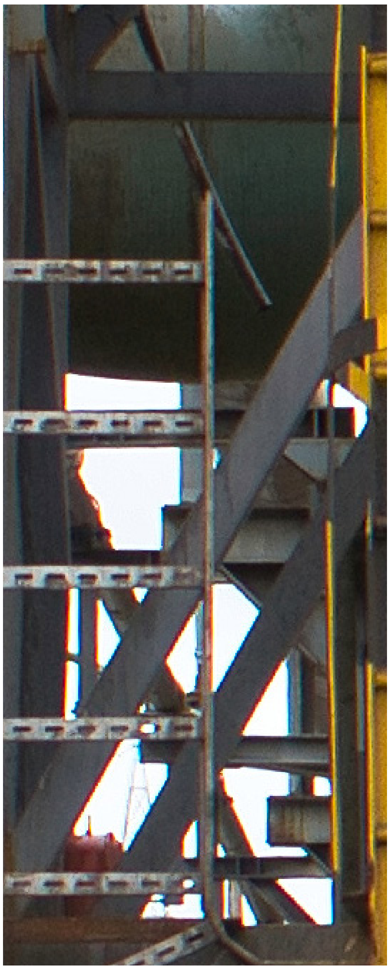
TECHNICAL PUBLICATIONS - FY24

5G Technology is a Game-Changer for Industry 4.0

C. Shailaja, Dr. Sakthivel S., Chemical New (Journal of the Indian Chemical Council), Volume XX, No.5, November 2023

The emergence of 5G technology represents a significant shift in connectivity set to revolutionise Industry 4.0 with millions of subscribers worldwide. Known for its minimal latency, ample bandwidth, and robust device connectivity, 5G can be applied to various industrial uses, seamlessly integrating with AI, IoT, big data analytics, cloud computing, and more. This alignment leads to the development of innovative applications, propelling industrial progress.

This article explores the crucial role of 5G in industrial automation, highlighting its speed, ultra-low latency, and extensive connectivity as game-changers for Industry 4.0. These features enable real-time data transfer, laying the foundation for smart factories and autonomous systems. Furthermore, it delves into the potential of 5G, examining advanced robotics, predictive maintenance, and supply chain optimisation. It also discusses the technology enablers necessary for successfully integrating 5G in industrial settings, providing insights into practical implementation strategies for deploying 5G in the industrial sector.

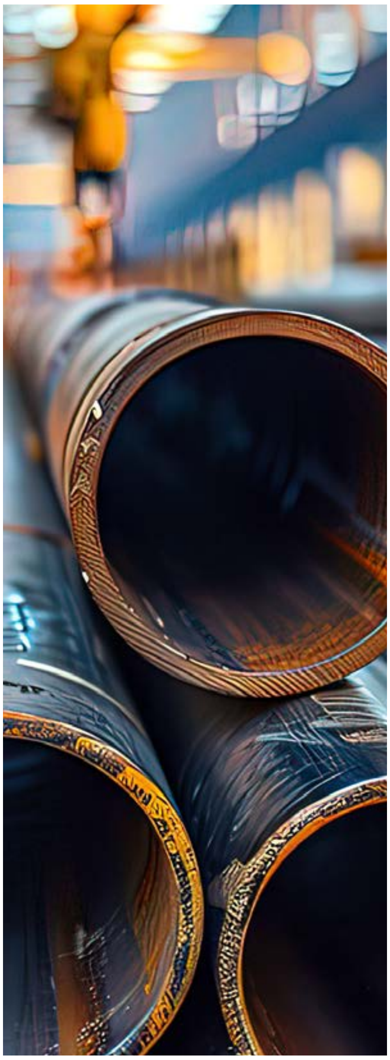


Risk Mitigating Strategic Approach to Asset Integrity Management [AIM]: A Case Study for the Replacement of a Junction House

Manikanta Kapaganti, Bhaswati Jha, Runu Dutta, Sayak Banerjee, Shalini Bandyopadhyay, Manos Kumar De, INSDAG Yearbook 2023, Sep 23

Asset Integrity Management (AIM) is transforming the construction engineering sector by addressing the challenge of repairing or replacing ageing assets in operational plants. In a specific case at an integrated steel plant, a critical Junction House showed significant structural damage, leading to a decision-making dilemma between incremental repairs and complete replacement. A health assessment revealed widespread damage, with 65% of structural members needing attention. This presented logistical challenges, safety hazards, and the potential for further corrosion, especially given the limited six-day shutdown window for the plant.

An alternative solution proposed the complete replacement of the Junction House. Cost analysis supported this option, as the cost of repairing 19.5 tons of steelwork was nearly equivalent to the price of a new 30-ton steel structure. The replacement strategy required careful planning, including stage-wise deconstruction, on-site support structures, and a detailed pre-shutdown and shutdown activities schedule. Despite initial complexities, the comprehensive replacement plan proved feasible and advantageous for structures with over 50% health defects. This addressed the immediate issues and eliminated uncertainties associated with extending the structure's service life. This case highlights the pivotal role of AIM in making optimal asset management decisions to improve safety, efficiency, and long-term reliability.



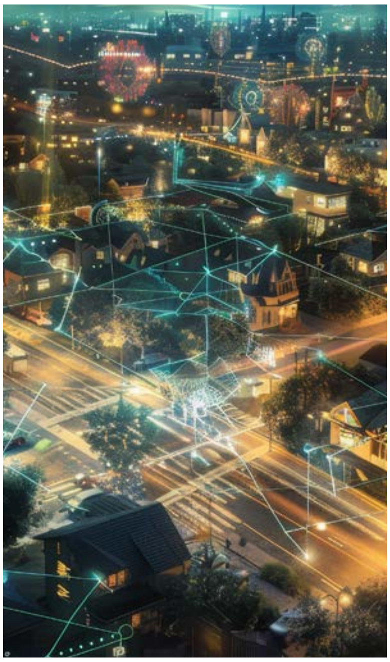
Case study on restoration work for critical plant supporting age-old asset in an integrated steel plant under site-specific process and acute space constraints

Bhaswati Jha, Manos Kumar De, Arpan Sarkar, Shalini Bandyopadhyay, Renewable Mirror, INSDAG Yearbook 2023, Sep 2023

In Asset Integrity Management (AIM), repurposing industrial steel structures provides an eco-friendly solution to extend asset life and reduce carbon footprint, avoiding the need for new construction and associated expenses. In a 60-year-old steel plant, an unused material handling structure exposed to corrosive conditions suffered significant damage while partially supporting process utilities. AIM adopted a systematic approach for structural restoration and repurposing, ensuring safety, operational continuity, and efficient resource utilisation.

The retrofit design thoroughly studied damages, utility details, load flow paths, and access planning. Key considerations included ensuring the lateral stability of transverse frames, a bottom-up deconstruction approach, and providing temporary support for live utilities during dismantling. An optimised arrangement of transverse frames, considering moment-connected and diagonal braced framing options, resulted in a cost-effective choice, saving INR 0.422 Cr.

The design included 45MT of new steel, 13MT of temporary structures, and 27 sqm of steel grating while reusing 50MT of steel sections. The dismantling process generated 150MT of structural steel and 250 sqm of sheeting scrap. The outcome was a 50-year asset life extension with reserve capacity and reclaimed space, demonstrating AIM's ability to enhance sustainability through intelligent structural repurposing.



Smart Street Lighting System in Smart City Infrastructure

Anupam Roy, Electrical Mirror, Oct 2023

The current trend in India is the development of smart city infrastructure focused on energy conservation and a sustainable environment. India has targeted transforming 100 cities into smart cities with improved living standards and amenities. One key aspect of smart city infrastructure is smart street lighting. Conventional streetlights are known for consuming high electricity due to poor luminous efficacy, especially in high-intensity discharge lamps, which are not controllable in terms of light intensity.

This inefficiency hurts the environment, leading to high carbon emissions. Smart street lighting systems use energy-efficient LED lamps and sensor-based automated controls to adjust light intensity based on ambient lighting, traffic, and pedestrian movements. These systems can also integrate Internet of Things (IoT) enabled devices to optimise power usage, improve operational efficiency, and monitor environmental air quality, traffic congestion, smart parking, and safety and security.

Smart Automation in Rural Development

Latha D S, Viewpoint, Oct 2023

The United Nations' Sustainable Development Goal (SDG-11) focuses on creating safe, inclusive, resilient, and sustainable cities and settlements worldwide. In recognition of the importance of rural development, India has initiated Smart and Model Village programs to address the specific needs of its 69% rural population living in approximately 640,930 villages. Rural development aims to strengthen physical and institutional infrastructure, meet the basic needs of all segments of the rural population, and incorporate the latest technologies for progressive settlements. The objective is to empower residents to live dignified lives, maximise their potential, and utilise technology. Consultancy in rural development is crucial due to diverse demands and infrastructure limitations. This article emphasises the role of SMART Automation, Information and Communication Technology (ICT) in rural development. These technologies streamline daily operations, enable remote monitoring and control, facilitate communication, enhance digital education, and impact critical sectors such as healthcare, agriculture, and water management. Technology integration aims to provide affordable drinking water and promote overall growth, economic development, and sustainable living in rural areas, aligning with the global goal of inclusive and resilient settlements

Role of CO_2 in Decarbonisation of Industries

Lakshmana Rao & NandaKishore Desapande, Chemical Industry Digest, Sep 2023

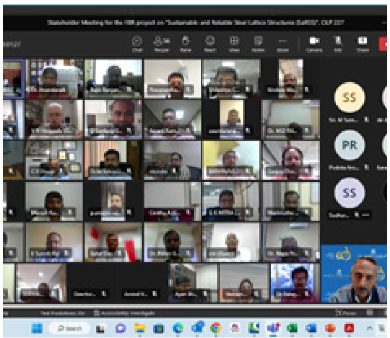
In energy-intensive industries such as cement, chemical and petroleum refining, and iron and steel production, waste heat is released at temperatures higher than the surrounding environment during thermal processes. There is a growing focus on capturing and utilising this waste heat to improve energy efficiency and implement decarbonisation strategies. Carbon dioxide (CO_2) has emerged as an efficient working fluid due to its favourable properties, including a low critical point, specific heat characteristics, high power density, thermal stability, non-toxicity, and low global warming potential.

With a critical point of 73.8 bar(a) and 31.1°C, CO_2 in a supercritical state is more manageable than steam, making it suitable for absorbing heat from low-temperature sources. CO_2 can efficiently recover heat from a broad temperature range (100°C to 650°C), making it an ideal working fluid for converting waste heat into power. This technology is commercially available in modular form, enabling waste heat recovery from low to medium-temperature sources, thereby contributing to power generation and supporting the decarbonisation of industries. Implementing CO_2 as a working fluid aligns with sustainable development goals by promoting energy efficiency and reducing the environmental impact of various thermal processes.

EXTERNAL REPRESENTATION FY24

At the FIDIC Asia Pacific 2023 Conference on **"Engineering towards Net Zero"**, **Mr Atul Choudhari** shared essential insights on achieving net zero. He emphasised the transformative potential of hydrogen in reaching net zero targets. Hydrogen, a versatile molecule, is a critical element of industrial decarbonisation, serving as both a feedstock and a clean fuel to expedite the transition to net zero. Mr. Choudhari's presentation thoroughly explored hydrogen's potential impact across industries such as chemicals, steel, aviation, cement, and transportation. He underscored the need for hydrogen infrastructure to support clean energy generation and transportation. Stressing the importance of global collaboration and policy support, he highlighted that these elements are crucial in overcoming technological barriers and accelerating the transition to net zero.

Mr. Shireesh Swami presented on **cybersecurity in CGD networks at the Annual CGD Conclave** organised by Deligentia. He highlighted the increasing digitalisation in CGD networks, including smart metering, ratio control for blending hydrogen and biogas, SAP, SCADA, and leak detection, all of which pose a severe risk of breaches.



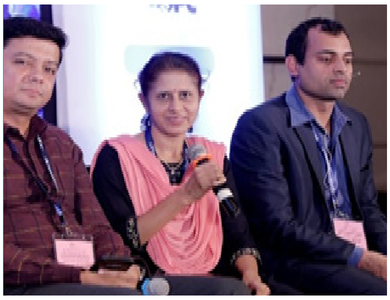
Mr. Manos De participated as a review panel member for the CSIR/SERC Focused Basic Research (FBR) Project on **Sustainable and Reliable Steel Lattice Structures (SaRSS)**. The project aims to develop design guidelines specific to HSS truss lattice structures at the material, component members, and associated welded/bolted connections level to avoid unsafe or uneconomical design solutions from conventional design methods. As a panel member, Manos De participated in discussions between academia and industry experts, providing views and suggestions on the project's effectiveness and increasing its relevance for industry use.

Ms. Latha D S delivered a presentation on **5G for Industrial Automation organised** by India Infrastructure Publishing Pvt. Ltd.

The presentation emphasised critical features of 5G communication networks for industrial automation, including 5G networking standards (Non-Standalone and Standalone), expanded networking spectrum, and innovations to enhance data transmission. It highlighted benefits such as faster speed (10-20 times that of 4G), high reliability with low latency, and the capacity to connect a million devices per square kilometre. Case studies showcasing potential 5G implementations in industrial automation were also discussed.

At the cemCCUS – 2023 conference organised by Mission Energy Foundation, **Mr Atul Choudhari** delivered a presentation on **technological pathways for carbon capture and utilisation in the cement industry**. He discussed various carbon capture technologies available to the cement industry, such as calcium looping, chilled ammonia, sky mine, membrane, and oxyfuel, which can produce valuable by-products during the capture process. For instance, captured CO_2 can produce methanol, urea, or sustainable aviation fuel. Mr Choudhari emphasised that as economies of scale increase, the viability gap for these value chains is expected to decrease soon. He suggested that with policy support and concurrent R&D efforts, now is the ideal time to create a phased roadmap for decarbonising the Indian cement industry.

Mr. Manos De presented on "Geotechnics: Recent Advancements in Research and Practices" at the invitation of the Indian Geotechnical Society, Kolkata Chapter. The presentation took place at a conference held on the campus of Jadavpur University, where he shared case studies related to industry practices in this field. Specifically, he covered two case studies: one focused on using 3D tools for geotechnical characterization at a brownfield site and the importance of employing geophysical exploration. The other case study delved into applying GISTM for tailing management from an Indian perspective.



Ms. Latha participated as a panel member for the topic **"Plant asset management enabling energy transition."** During the panel, she discussed the latest technology implementations and innovative solutions in progress. She emphasised the importance of advanced asset management by utilising available plant data, artificial intelligence, and predictive analytics to support effective decision-making. Ms. Latha highlighted how these technologies can reduce plant downtime and improve productivity, leading to uninterrupted renewable power as a reliable energy source.

Mr. B. B. Gharat presented **a paper on cost economics and revenue models for sewage management** at the ninth annual conference on sewage and wastewater treatment in India, organised by India Infrastructure.

Mr. Atul Choudhari participated in the 2nd International Conference on **Green Hydrogen** organised by the Central Board of Irrigation and Power (CBIP). He delivered a lecture on the role of hydrogen in decarbonising the industry.

He discussed the innovative industry pathways developed by TCE for various sectors, including hard-to-abate industries like cement and steel.

At the 3rd World Hydrogen Energy Summit the Energy and Environment Foundation organised, **Mr Atul Choudhari** emphasised the **potential of hydrogen and natural gas as high-energy gases for creating a low-carbon energy system**. He pointed out that hydrogen, mainly, shows promise for reducing carbon emissions in challenging sectors such as steel production. Mr Choudhari also discussed the potential of converting captured carbon into cleaner aviation fuel through hydrogenation. Additionally, he highlighted the possibility of blending hydrogen with natural gas and transporting it through existing natural gas pipelines without significant modifications, up to a 20% blending ratio. However, he stressed the importance of conducting in-depth studies on metal embrittlement and system safety integrity to determine the safe blending ratio of hydrogen with natural gas.

Mr. Manos Kumar De presented a paper at the One-day technical seminar on **"Geo-exploration: Advances and the Need for Standardisation"** organised by the Indian Geotechnical Society Jharkhand Chapter. He was invited to present case studies at a conference held at the campus of IIT-ISM Dhanbad. The case studies focused on industry practices related to the subject. Two case studies were presented: one on geophysical exploration methods for designing a coffer dam for a Pumped Hydro Storage project and another on geophysical exploration for analysing seepage problems from a tailing dam.

Mr. Shivnarayan Pareek presented a paper titled **"Decarbonisation-Impact and Opportunities For LNG Industry"** at the 9th LNG Summit 2023. During the conference, he discussed how the global energy landscape is changing due to the need to combat climate change. Decarbonising various industries, including liquefied natural gas (LNG), is crucial to this shift. Decarbonisation involves reducing carbon dioxide and other greenhouse gas emissions to create a more sustainable and environmentally friendly energy future.

PATENTING

Patenting intellectual property is vital for companies to safeguard their innovations, maintain their competitive edge, and foster economic growth. The technology team diligently monitors the patenting process. TCE holds seven patents listed below, including two granted in 2023.

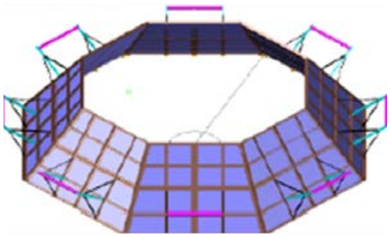
A SYSTEM TO REGULATE THE FLUE GAS EXIT VELOCITY FROM CHIMNEYS

Name of Innovators - *R L Dinesh, Anjan Bhattacharya, B B Gharat, M K Lokhande*

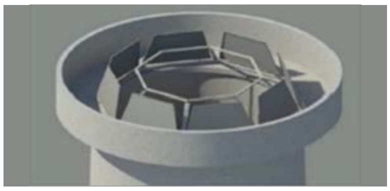
This innovation devised a system by which chimney flue gas exit velocity can be regulated with flue gas flow through the chimney, maintaining a desired level irrespective of plant operating conditions.

The proposed device aims to overcome the limitations of single and multiple-flue chimneys through the following features:

- Regulating the chimney flue gas exit velocity to accommodate varying boiler load conditions.
- Cost-effective design achieved by adopting a single flue chimney with a velocity regulating system that can serve multiple boilers.
- The device has built-in fail-safe measures to ensure uninterrupted operation in case of maintenance problems throughout the plant's life.
- The device can be operated from a platform under the chimney roof or ground-level control room, providing flexible operational options.



a. Closed view of Device

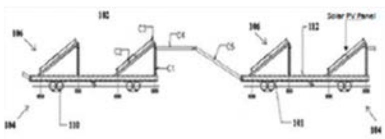


b. Top View of Chimney with device

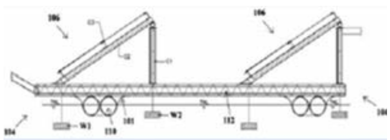
FLOATING SOLAR PHOTOVOLTAIC PLANT

Name of Innovators - *Anjan Bhattacharya, Sameer Kulkarni, Shibashish Pal, Bagmi Mushtaphi, Suman Dey, R L Dinesh*

The patent is for a floating solar block system that allows the blocks to be interconnected to create a floating solar energy generation system. The innovation lies in the solar panels' support arrangements and the blocks' interconnectivity. The unique feature of the solution is its broad flexibility of rotation (0 to 300 degrees) for the solar panels, resulting in higher efficiency and energy generation. Additionally, the use of a unique damping cum counterweight system eliminates the high cost of anchoring to the shore or bed, and the use of waste plastic adds to the sustainability of the system.



Elevation View of Connected Blocks



The technology team acts as a dedicated task force, leading the way in providing customers with the latest and most advanced technologies and innovations. Subject Matter Experts (SMEs) from various technology disciplines offer technical support to all Business Units.

TATA INNOVISTA WINNER FY23

Automated Film Loading and Stacking System (AFLASS)

AFLASS is an innovative, indigenously designed, and developed fully automated solution for carrying out Non-Destructive Testing (NDT), an X-ray radiography technique used for inspecting Solid Rocket Motors used in Space and defence applications.

Since its introduction, AFLASS has significantly reduced the efforts and time required to carry out the present manual NDT inspection with enhanced safety and accuracy by overcoming the inefficiencies and limitations of the present manual NDT inspection. AFLASS has reduced cycle time ~ by 70% (50 min to 9 min.) and improved productivity ~ by 300% (reduction of overall inspection time from 28 days to 8 days).

Thus, AFLASS has delivered precise benefits in terms of time efficiency, operational accuracy, safety improvements, flexibility in testing, and overall customer satisfaction, making it a valuable innovation in the field of NDT for critical defence applications.

VALUE ADDITION

- Reduced Cycle Time -70% (50 min to 9 min.)
- Improved Productivity - 300% (overall inspection time reduced from 28 days-8 days)
- Enhanced Accuracy-Improved inspection Quality-90%
- Safety-Reduced Human Exposure by 32 times

AFLASS SYSTEM

FOSTERING INNOVATION

Tata Innovista

TCE's ongoing engagement with Tata Innovista—an initiative celebrating innovation across the Tata Group—has been particularly fruitful. This year, our Automated Film Loading and Stacking System received the Design Honour Award, marking our project as a benchmark in industrial innovation. This accolade is a significant endorsement of our ability to leverage creative solutions for practical challenges, emphasising our broader commitment to technological excellence and innovation.

Pride Campaign

Value-added and innovative services form the DNA of our technically excellent offerings. We constantly focus on adding value to our esteemed customers by delivering on-time, best quality and cost-competitive solutions.

The PRIDE is an opportunity to showcase and share the value additions and innovations implemented in our projects and help foster a culture of learning and knowledge sharing. This unique platform is designed to recognise talent and reward our employees based on client accepted value additions.

Human Resource

Strengthening Foundations and Fostering Growth at TCE

At Tata Consulting Engineers (TCE), our dedication to fostering a thriving work environment remains unwavering. This year, we have made significant strides in building a culture that values innovation and recognition and prioritises career development for every TCE colleague.

Here's a closer look at our key initiatives and their impact:

TEAMWORK AND COLLABORATION

Recognising the importance of collaborative success, we introduced the Superstar Team Awards. These awards, celebrates teams across various business units that exemplify outstanding teamwork and achieve significant business results.

Our jury's rigorous evaluation highlighted teams that demonstrated exceptional synergy in enhancing business processes and delivering sustained outcomes, thereby reinforcing the value of collective effort within our corporate culture.

CULTIVATING A CULTURE OF INTRAPRENEURSHIP

We launched the iThink-Shark Tank edition this year, transforming our approach to innovation. This platform mimics the dynamic of a pitch competition, encouraging employees to devise and present solutions that align with add the goals, explicitly scaling TCE's financial growth and enhancing our workforce diversity by 2028. During the inaugural season, we attracted 54 innovative proposals, reflecting a robust engagement from our staff.

Participants presented their ideas through various funding stages— Pre-seed to going public—and received critical feedback from our seasoned panel of sharks. The initiative showcased our employees' creativity and commitment and reinforced our commitment to practical and scalable innovation.

LEARNING & DEVELOPMENT

Continuous learning and development are vital to our work culture, promoting collaboration, innovation, high performance, and agility. We have partnered with renowned institutions and new learning platforms to enhance upskilling and reskilling experiences.

Strategic Talent Advancement and Readiness Program (STAR): Our annual fast-track career advancement initiative identifies and nurtures high-performing and high-potential employees. Participants, selected through aptitude assessments, virtual assessment centres, and talent council interviews, embark on a 10-month intensive development program. This includes specialised courses from institutions like IIM-Kozhikode, IIM-Calcutta, IIT-Delhi, SP Jain Global, NMIMS, BITS-Pilani, and Tata Management Training Center (TMTC).

Leadership Excellence through Awareness and Practice (LEAP): Our flagship program aims to transform 75 transitioning managers into thought leaders. It promotes a growth mindset, strategic thinking, change management, diversity, equity, and inclusion. The journey includes peer-to-peer learning, speed coaching, action learning projects for real-time insights, and 360-degree feedback as part of the Manager Score Card for ongoing action planning.

EMPHASISING CORE VALUES

Our core values are integral to our identity at TCE. In 2023, we acknowledged 67 employees with the Value Awards for exemplifying these principles, mainly focusing on customer satisfaction, employee dignity, and societal responsibility. These awards recognise individual excellence and encourage our entire team to embody these values in their daily work, enhancing our corporate ethos and external reputation.

ENHANCING EMPLOYEE ENGAGEMENT AND WELLBEING

Our commitment to employee well-being is comprehensive, encompassing professional growth and personal health. Regular engagement activities, such as leadership talks, sports events, and cultural celebrations (including TCE Day and Engineer's Day), foster a sense of community and shared purpose. Health initiatives like the observance of World Heart Day with educational sessions on cardiovascular health underscore our commitment to employee wellness, which is fundamental to maintaining a productive and positive workplace.

TCE Day - Honoring Our Legacy and Values: TCE Day serves as a poignant reminder of our company's storied history, marked by decades of innovation in engineering across critical sectors like infrastructure, energy, and chemicals. This day allows us to reflect on our enduring values and ongoing sustainability and social responsibility efforts. It provides a platform for celebrating the diverse talents within our TCE family. Employees and their families come together to showcase their skills through various cultural events, including singing, dancing, and dramatic performances, enhancing our community spirit and shared commitment to excellence.

Engineer's Day - Inspiring the Next Generation of Innovators: Engineer's Day in India, celebrated on September 15th to honour the birthday of Sir Mokshagundam Visvesvaraya—a distinguished engineer and statesman—highlights the significant contributions of engineers to society. At TCE, this day was marked by engaging discussions led by thought leaders such as Dr Arun Kumar Nayak from the Department of Atomic Energy. The focus was on vital topics like climate change and the role of nuclear power in industry decarbonisation, aimed at celebrating our engineers' achievements and inspiring future innovations.

World Heart Day - Promoting Cardiovascular Health: World Heart Day at TCE underscores our commitment to global health awareness, specifically concerning cardiovascular wellness. Through informative sessions dedicated to heart health, we empower our employees to adopt heart-healthy habits, actively participate in the global fight against heart disease and stroke, and take charge of their cardiovascular health. These initiatives reflect our dedication to fostering a healthy work environment and promoting well-being among our staff.

Children's Day - Celebrating Potential and Joy: Children's Day is a joyous occasion that celebrates the innocence and potential of children globally. At TCE, this day is an opportunity to honour our youngest family members. We host a Children's Day Talent Show, which promotes children's well-being and happiness and allows them to display their talents in a supportive and festive environment. This event strengthens family bonds and highlights our commitment to nurturing the next generation.

Engagement Programs: In FY 2023-24, our Happiness Week initiative, designed to promote peer acknowledgement and gratitude, saw over 1,000 employees actively engage in recognition "drops" in person and on Yammer. This significantly enhanced professional relationships, workplace atmosphere, and overall happiness levels. Our commitment to wellness extends further with initiatives like the World Heart Day Medical Camp, International Yoga Day Celebration, and wellness sessions on mindful breathing techniques. We also organised the Lil'Champ Summer Camp and the Super-Mums and Superhero Father's Day, which celebrated the diversity of our workforce and fostered a sense of belonging within our extended TCE family.

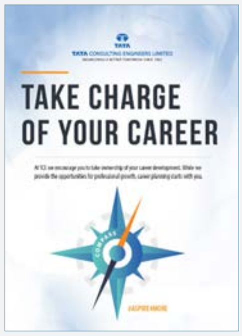
Celebrating Creativity: Colours of TCE, our annual art competition, has celebrated employee creativity for two decades. This year, during the Holi festival, the competition focused on "Sustainable Solutions for a Better Tomorrow", reflecting our commitment to environmental stewardship and social responsibility. We received 32 entries from various delivery centres, evaluated by a distinguished panel of four jury members. The winning artworks, showcasing the finest creativity and vision, were displayed across our locations and featured on custom greeting cards sent to employees on their birthdays.

Building a Culture of Intrapreneurship: To foster innovation and intrapreneurship, we introduced the iThink-Shark Tank edition, a dynamic platform for creative thinking, collaboration, and inventive problem-solving. This edition aimed to achieve two ambitious goals by 2028: doubling TCE's revenue from 1100 Crores to 2000 Crores and increasing diversity from 17% to 30%. The inaugural season saw 56 entries from teams and individuals across the organisation. Participants showcased their solutions through rigorous evaluation and mentoring stages: Pre-Seed, Seed, Series A, and Going Public. Participants engaged in captivating pitch battles, presenting their solution designs, delivery roadmaps, and financial impacts. Two winning teams emerged, distinguished by their innovative ideas, clear implementation roadmaps, scalability potential, and overall viability. Under the themes "Growth at Scale" and "Unity in Diversity," these teams challenged conventional thinking. They embraced inclusivity as a catalyst for change—their impassioned presentations and determination aimed to redefine innovation in today's evolving landscape.

FOSTERING CAREER DEVELOPMENT AND HIGH-PERFORMANCE CULTURE

Our performance management system is designed to thoroughly support our high-performance culture. Initiatives like the Career Fair and Mid-Term Assessment are pivotal in this regard, providing employees with clear insights into their career paths and performance. These programs ensure that personal achievements are aligned with our organisational goals, creating a cohesive and forward-looking workforce.

In conclusion, our performance management initiatives in the current financial year have been instrumental in creating a cohesive and growth-oriented work environment. The Career Fair, Mid-Term Assessment, Competency Assessment, and Quarterly Feedback collectively form a robust framework that nurtures individual development, aligns aspirations with organisational goals, and fosters a culture of continuous improvement. As we move forward, these initiatives will continue to be pivotal in shaping a workforce that is not only proficient in their roles but also strategically aligned with the evolving needs of the organisation.



CHAMPIONING INCLUSIVITY & EXCELLENCE THROUGH SPORTS

TCE Women's Cricket Tournament: In a landmark year for TCE Sports, the inaugural Women's Cricket Tournament was a resounding success. With ten teams and 105 participants, the tournament highlighted the talent and commitment within our organisation, promoting inclusivity and sporting excellence. Guided by the TCE Sports Committee, the best 15 players from each Delivery Centre formed our elite team, representing TCE in the prestigious Inter Tata Executive Cricket tournament. Our women's cricket team advanced to the Quarterfinals, a historic milestone reflecting our support for gender equality and women's empowerment.

Annual Sports Events and Championships: At TCE, we organise various sports events to promote wellness and team spirit. Our employees actively participate in both Intra-TCE and Inter-Tata Sports Championships, with events featuring cricket, futsal, carrom, and table tennis. The Futsal League, where CMC leaders build teams through an auction, fosters camaraderie and team bonding. Over 700 employees participate in various sports events throughout the year, cultivating a fitness, fun, and friendly competition culture.

Tata Mumbai Marathon 2024: Over 160 colleagues and family members enthusiastically participated in the Tata Mumbai Marathon 2024. This initiative promoted health, teamwork, and brand visibility.

Team TCE supported training, registrations, and goodies distribution, strengthening company culture and community presence.

REWARDS AND RECOGNITION

Acknowledging achievement is integral to TCE's commitment to excellence. We celebrate significant milestones and daily victories, fostering a culture of recognition.

Our digital instant recognition platform, Kudos, has seen a remarkable surge in usage, highlighting our appreciation for employees' relentless efforts. Alongside Kudos, our recognition programs, including Value Awards continuously empower employees to acknowledge their peers, promoting high performance and values alignment. This year, we introduced the inaugural Superstar Team Awards, recognising 48 high-performing teams across TCE. Teams were evaluated by an esteemed panel of 8 jury members against criteria such as Process Improvement, Sustained Business Results, Business Benefits, and Collaboration & Teamwork. These awards highlight the collaborative spirit and collective achievements within each Business Unit.

INDUSTRY RECOGNITIONS

TCE received the Gold award in Leadership Development from Brandon Hall Group's Human Capital Management Excellence Awards 2023 for the Leap Leadership Journeys with ProventusHR.

TCE was awarded the Impactful Learning Program of the Year at the L&D Confex & Awards 2024 for the STAR program and received the Gold award for Excellence in Employee Retention Strategies at the Economic Times Human Capital Awards 2024.

TCE also won two Excellence in Feedback and Communication Strategies awards at the 7th CHRO Vision and Innovation Awards 2024.

Cultivating Ethical Excellence through Communication and Training

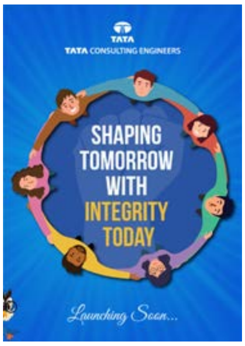
TCE prioritises ethics and integrity, positively impacting employee motivation and engagement. Training and communication programs, encompassing classroom and e-learning sessions, reinforce TCoC and related policies. Mandatory e-learning training programs on TCoC, POSH, ABAC, AML, and other policies ensure ongoing ethical education.

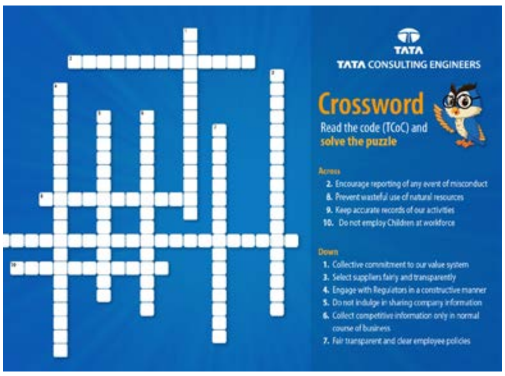
In FY 2023-24, TCE conducted over 17,610 person-hours of training on TCoC, POSH, and compliance. Our digital tool, "Ethos," available on TCE's intranet, is a comprehensive solution for ethics-related governance systems and processes. The Ethics webpage and Yammer's "Ethics: DecodeTheCode" enhance TCoC awareness.

Bi-annual Ethics Week celebrations, with themes like "Empowered Ethics" and "Ethics in the Digital Era," foster a culture of integrity and responsibility. Virtual awareness sessions and social media campaigns engage stakeholders, promoting ethical decision-making and accountability.

ETHICS WEEK CELEBRATION

Oct 2023





TCEndeavour

CSR INITIATIVE OF TATA CONSULTING ENGINEERS LIMITED

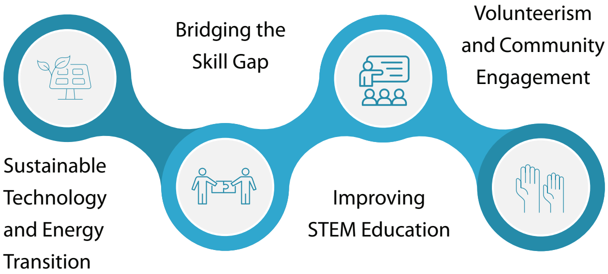
The Enduring Impact of Corporate Philanthropy in India

While a relatively recent term, corporate philanthropy in India has roots that stretch back over 150 years, primarily beginning with the visionary leadership of Jamshedji Tata, founder of the Tata Group, this article delves into how Tata and other corporations, following in its footsteps, have achieved business success and profoundly impacted social development through strategic philanthropy.

The Tata Group's philanthropic journey began when India grappled with the aftereffects of colonial rule. Under the guidance of Jamshedji Tata and, subsequently, leaders like Ratan Tata, the Group focused on uplifting the community, adhering to a strong ethos of "philanthropy with a purpose." This approach was about charity and meaningful change—helping India progress economically and socially.

In 2021, the EdelGive Hurun Philanthropists of the Century report highlighted the significance of Tata's contributions. Jamshedji Tata was recognised as the top philanthropist worldwide over the past century. His staggering contribution of $102.4 billion underscores the scale and impact of his commitment.

At TCE, the legacy of giving is an integral part of the corporate structure and philosophy. The focus here is not merely on charity but on creating systemic changes that are sustainable and transformative. This section explores critical areas of TCE's philanthropic efforts:



1. **Sustainable Technology and Energy Transition:** TCE is actively involved in developing affordable, indigenous sustainable technologies. Collaborating with premier research organisations like IIT Mumbai and IISC Bangalore, the aim is to accelerate India's transition to a net-zero future through projects focused on alternate feedstocks and industrial decarbonisation.

2. **Bridging the Skill Gap:** The Utkarsh Initiative: Since its inception, Utkarsh has been dedicated to enhancing the employability of youth from Diploma and ITI institutes through specialised training in engineering and drafting tools. In the current year alone, 162 students have been trained, with all participants completing the program.

3. **Improving STEM Education:** The Vigyaan Project: The Vigyaan project was launched in partnership with the Nehru Planetarium to elevate the quality of STEM education. The program equips teachers and students with low-cost, hands-on materials to better understand complex scientific and mathematical concepts, fostering a scientific temperament among students.

4. **Volunteerism and Community Engagement:** Beyond institutional efforts, TCE promotes a culture of volunteerism among its employees, known as 'Mentor Champions.' These volunteers undertake numerous initiatives, such as mentoring underprivileged adolescent girls and engaging in rural community projects focused on sustainable development. Testimonials from volunteers like Suraj P K and Neha Jain highlight these activities' personal satisfaction and transformative experiences, emphasising their involvement's profound, individual impact.

Tata's approach to philanthropy exemplifies how businesses can effectively contribute to societal progress while achieving corporate success. Jamshedji Tata's legacy lives on through continuous efforts in sustainable development, education, and volunteerism, showing that true corporate philanthropy goes beyond financial contributions—it builds brighter futures and nurtures hopeful communities.

By integrating corporate responsibility into its operations, TCE and the broader Tata Group continue to set benchmarks for others to follow, proving that doing well and doing good are not mutually exclusive but complementary facets of modern business philosophy.

OUR MENTOR CHAMPIONS VOLUNTEERS:

Our 7 Superstar Volunteers mentored adolescent girls from underprivileged backgrounds from Akshara Centre.

Suraj P K
General Manager, IMG ROW

Ramesh Thanalapati Saisampoornam
General Manager, Civil

Mahesh A Savant
General Manager, Civil

Ashwini Nimkar
General Manager, Civil

Chandra Bhushan Mishra
Sr. Structural Design Expert, Civil

Harinder Singh
Assistant General Manager, Civil

Paulomi Biswas
Assistant General Manager, Civil

TESTIMONIALS FROM VOLUNTEERS:

Dilip Sonwane

Along with my daughter Nidhi, I had multiple opportunities to interact with village/rural people in the Jawhar area through TCE CSR and NGOs through ProEngage. It was a very fulfilling, touching experience working with villagers, understanding their needs, and providing solutions on sustainable water management, livelihood, and health checkups.

Ganesh Jogi

Deputy General Manager, Process

It's a pleasure to participate in the STEM Workshop Vigyan Project. Mrs. Vrushali Sunil Madankar and I visited the school to monitor the progress made against the training given to the teachers. We stayed three nos of schools.

Ravi Bassi

Senior General Manager, Business Development

My engagement with kids during the volunteering sessions has been a fulfilling experience for me. Motivating young minds to envision their future is a rewarding aspect. Seeing their eyes light up with curiosity is the most heart-warming part of this journey. It is truly a joy to be a part of this inspiring exploration!!

Neha Jain

Assistant General Manager, Instrumentation and Control

Volunteering is indeed a rewarding experience that motivates you. Seeing the smiles on children's faces and those words, "When you all will come again," gives you a feeling of satisfaction.

Divya M Nanjappa

Manager, PMO

Contributing to volunteering activities is an enriching experience, and the satisfaction level is always high. It's always a pleasure to be associated with Society.

TCEndeavour

CSR INITIATIVE OF TATA CONSULTING ENGINEERS LIMITED

EMPLOYEE ENGAGEMENT THROUGH VOLUNTEERING

This year across, TVWs we able to reach total 4000 plus volunteers spent 17443 hours reaching 51000 plus beneficiaries across 10 states of India involving 66 NGO partners

25
Senior Leaders

25 senior leaders across geography participated in Volunteering activities

100
Volunteers

7000
Estimated Hours

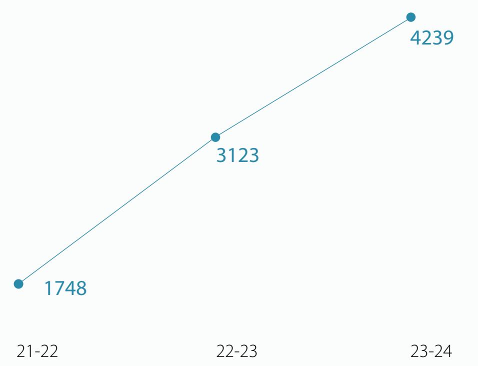
Addition to TVWs through CSR projects **100 volunteers** over the year were engaged spending **7000 estimated hours** across departments.

78
Volunteers

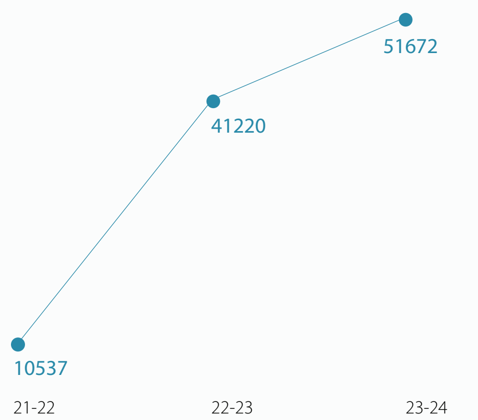
2604
Estimated Hours

Pro Engage (Group Driven Skill Based Volunteering Program) - **78 Volunteers** and **2604 Volunteering hours**

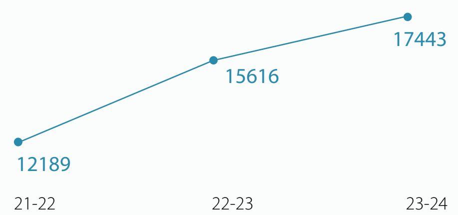
NO OF VOLUNTEERS



BENEFICIARIES REACHED



NO OF VOLUNTEERING HOURS



VIGYAAN

Tata Consulting Engineers Limited (TCE) has embarked on an exciting collaboration with the Nehru Planetarium to foster and enhance interest in STEM (Science, Technology, Engineering, and Mathematics) among both youth and educators. This strategic partnership aims to bring the wonders of India's space missions closer to the public through TCE's educational initiative, Vigyaan.

The Vigyaan initiative has already made a substantial impact, facilitating the engagement of over 600 students and 25 teachers under the leadership of Ms Aruna Yadav, Education Officer at NMMC. This initiative emphasises the excitement of activity-based learning and the satisfaction derived from unravelling scientific concepts.



STEM Education
to Empower Children


Lonar Crater & Lake






STEM Education
to Empower Children







TATA VOLUNTEERING WEEK 20

5th Sep - 7th Oct 2023

TEAM TWENTY 20 LEAGUE OF EXTRAORDINARY VOLUNTEERS

TATA VOLUNTEERING WEEK 21

3rd - 31st March 2024










SCORE A FOUR

OVERSTEP THE BOUNDARIES FOUR GOOD.

TATA CONSULTING ENGINEERS LIMITED

Engineering a Better Tomorrow™

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