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SUSTAINABLE MANUFACTURING: REDUCING CARBON FOOTPRINT IN MANUFACTURING – OPTIMIZATION OF RESOURCE UTILIZATION, RECOVERY OF WASTAGES AND USE OF RENEWABLE ENERGY: - BEING LEAN AND GOING GREEN

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Abstract: Sustainability has been Point of Global Focus and a fast acquiring center stage for all process Industries, Manufacturing firms and Business organizations. Being caught in a vicious circle of Environmental Regulations, Sustainable performance, and climate change resiliency, manufacturers must secure their operation and trade licenses so that they can co-exist in the circular economy. The alarming rate at which the focus of investors on social, environmental, and governance (ESG) performance and higher market valuation for sustainable products, adds to this burgeoning need for greener , safer and sustainable future. The risk is enormous, but opportunities are abundant while Innovation remains the key driver which is why it's widely accepted among Environmental Activists, industry professionals, statutory bodies. This is due to the fact that sustainable development is a need of the hour that requires prompt action and abrupt changes from statutory Bodies, Manufacturing and Industry professional, and society as whole, it's finally the same world we all build together. Holistically we should view sustainability as a strategic function which is way beyond meeting statutory requirements and compliances which promises new business opportunities, Cost Benefits and reduction of cost over the life cycle of Systems and This research paper shall review the literature on technological Advancements- and innovations in system Design which will contribute to reduction of carbon footprint, Improvement System Efficiency , and lead to Zero Emissions discharge to the environment which in turn will lead to transformations in individuals, organizations, supply chains, and communities towards a sustainable future. In this Although many of the articles explored in this review report on existing urgent social, environmental ,Health and financial issues, their findings, recommendations, and contributions are encouraging as we make progress toward a sustainable society through innovation and use of alternative methods for generation of resources . This article reviews the diversity of innovation for Sustainable Development in the literature, proposes a typology of such a phenomenon, provides an overview of key articles based on the primary subjects they address, and identifies a series of recommendations for the future development of the field.

Keywords: Sustainability, Manufacturing, Business, Regulations, Carbon footprint, Circular economy.

I. INTRODUCTION

While Every Living and Non Living Matter on earth contributes towards impact on environment humans beings have caused devastating and tremendous negative impact on the environment. Pollution is simply the introduction of hazardous contaminants into the environment which would be chemical, Physical, Biological or even inform of noise or light which causes ecological unbalance in the system. It has been estimated that about 400 million metric tons of pollution is produced annually, of which the United States alone produces 250 million metric tons, having only 5% of the global population US alone produce quarter of carbon emissions across the globe and the impact is simply devastating. "Climate change is already affecting every inhabited region across the globe," affirms the first instalment of the IPCC AR6. Prepared by 234 scientists from 66 countries, this report examines the extent to which changes are occurring on Earth's land, oceans, and atmosphere – its biosphere. Their conclusions deem it "unequivocal" that human influence has contributed to global warming, finding

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that approximately 1.1 degrees Celsius warming can be attributed to emissions of GHGs from human activities. Based on observational data of historical warming from 1850 to 2020, global temperature will reach or exceed 1.5 degrees Celsius warming in the coming decades. The report mentions that emissions of carbon dioxide (CO2), a GHG and main driver of climate change, are also negatively impacting coastal areas and oceans. Coastal areas will continue to experience sea level rise during this century, contributing to flooding and coastal erosion. The authors state that oceans are also experiencing warming, acidification, and reduced oxygen levels largely due to increasing global temperature and increased absorption of CO2.

Increasing Carbon Emissions and unstructured policies has led to dramatic effect on the environment. Rapid Ramping up of Production in Manufacturing Facilities and fast growing economies have further contributed to unsustainable development of frameworks which have further stirred up alarming Environmental crises stemming from ever increasing Greenhouse gases , Industrial wastes and contaminants and Natural resource Depletion. As a result, reducing carbon emissions has become absolute necessity which has further geared up a need for an imperative tool – Zero Emission systems and waste management in this long lasting battle against climate change, ecological balance, Economic Environmental and health disruptions.

Sustainability Brings Enormous and promising Advantages, It brings forth strategic and competitive opportunities thus meeting consumer and investor demands which is way beyond just addressing Social, Economics, Statutory or new evolving regulations. Evidently, the need to drive strategic outcomes for a competitive edge, improved returns, investor attraction, enhanced brand image, and economic multiplier effects (see Figure 1: Reference: Enterprises reaping profits through sustainability practices) has emerged as a lever for adopting sustainability initiatives.

Figure 1: Enterprises reaping profits through sustainability practices

[1] Business Wire; Morgan Stanley Sustainable Reality Report Reveals U.S. Sustainable Funds Outperformed Traditional Funds by 4.3% in 2020; February 24, 2021; https://www.businesswire.com/news/home/20210224005399/en/Morgan-Stanley-Sustainable-Reality-Report-Reveals-U.S.-Sustainable-Funds-Outperformed-Traditional-Funds-by-4.3-in-2020

[2] RBC Global Asset Management; ESG Adoption Increases Globally, While COVID-19 Impacts How Investors Look at Social Factors, RBC Global Asset Management Survey Finds; October 14, 2020; https://www.rbcgam.com/en/ca/about-us/news-release/esg-adoption-increases-globally-while-covid-19-impacts-how-investors-look-at-social-factors-rbc-global-asset-management-survey-finds/detail

[3] World Economic Forum; How can businesses accelerate the transition to a circular economy?; January 20, 2020; https://www.weforum.org/agenda/2020/01/how-can-we-accelerate-the-transition-to-a-circular-economy/

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Sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs, (World Commission on Environment and Development, 1987). In the extensive discussion and use of the concept since then (see e.g. Holmberg, 1992; Reed, 1997; Harris et al., 2001), there has been a growing recognition of three essential aspects of sustainable development, which are Economic, Environmental, and Social aspects.

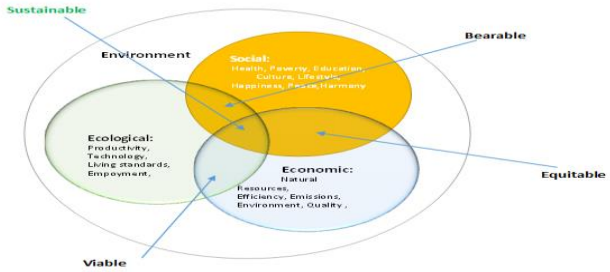

Figure 2 : 3 Pillars of Sustainability bounded by the environment.

Manufacturing and increasing devastating effects on Environment and Climate are turning points, where sustainability converges into a need for better technology, Humanity and innovation, thereby altering the way business would take place in the future. Manufacturing businesses must focus on dynamic economic growth, environmental, and social risk management. Becoming sustainable by design will automatically oblige the statutory bodies, meet investor and customer centric goals and deliver the required criteria for operational and trade licenses. Thus it is pertinent to re-examine the role of manufacturing as a driver for growth and its contribution towards sustainability in developing countries and plan for sustainable Methods and design systems for more efficiency and cleaner and safer environment.

II. OBJECTIVES OF THE STUDY

Manufacturing industries account for a significant part of the world's consumption of resources and generation of waste. Worldwide, the energy consumption of manufacturing industries grew by 61% from 1971 to 2004 and accounts for nearly a third of today's global energy usage. Likewise, they are responsible for 36% of global carbon dioxide (CO2) emissions (IEA, 2007). The Main Objectives of this research is to minimize wastages of resources, Improve overall System efficiency without compromising the current capabilities of the system.

1. Improving Resource Efficiency and Multilevel Optimization of Manufacturing Process – Lean usage of resources.
2. Design of Manufacturing Systems for Circular Economy throughout the lifecycle of the product across the complete - Reduce, Reuse, Repair, and Remanufacture.

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3. Improvement of System Efficiency and recovery of Energy, Products and raw material thus retain the value of the system- Resource Recovery Systems.
4. Looking for Alternative Energy Sources in Manufacturing Facilities and Industrial Estates.
5. Multi-Level Energy Management System – To develop guidelines for Material, Energy and Waste (MEW) process flow modelling to support the pursuit of sustainable manufacturing.
6. Reduction of Carbon Emissions across Various Industrial and Commercial sectors thus reducing impact on the Environment.
7. Development of System Design Framework for sustainability.
8. Understand the Economic Impact and determine the drivers for sustainability.
9. Dynamic Risk Management of Manufacturing as a Business while on journey towards sustainability.
10. Decarburization of extended Supply chain.
11. To Study the life Cycle emission efficiency of manufacturing systems and optimize consumption over the life cycle.
12. Building Process and new Technologies for sustainable Manufacturing.
13. Building Next Generation sustainable Target operating Model.
14. Change Management and Value Driven approach for sustainable Manufacturing systems.
15. To establish a core sustainability purpose well integrated with business goals and agenda.

III. RESEARCH QUESTIONS OR HYPOTHESES

Development of sustainable capabilities will cohesively accelerate the potential payoff by embracing the same quality output with increased transparency and focus on traceability to resolve the issues. In this research we would be studying about various available technological innovations to recover waste, Optimize our resources and look for alternatives sources for resources also we would see how different production systems can be integrated and how the holistic control on carbon emissions reduction can be achieved leading to lean and sustainable Manufacturing System Design. The journey towards sustainable Manufacturing is a long way through and the following questions arise:

1. Are customers and investors willing to invest their time and finances and will the improvement in utilization resources help to minimize wastages and in turn reduce the carbon emissions?
2. Is Design for Sustainability possible? Are there any system inefficiencies? Will it contribute to circular economy and realize the cost benefits? How do we implement sustainability in Business and manufacturing?
3. What's the current strategy? Will it establish a core sustainability purpose well integrated with business goals and agenda?
4. What are the current Sources of Energy? Are Alternatives available? If Yes, Is it renewable? If yes, is Technology available to harness the power from such sources? If yes how would we implement the transition of energy sources?
5. What's Mass Energy Balance or Material Energy Waste (MEW) balance? Are there wastages in the system? Are there wastages in the Manufacturing System? How do we maintain the balance and minimize wastages?? What are the technologies to recover materials and energy from waste?
6. Will Managing Waste reduce carbon footprint? Will it realize the benefit to the end customer? Does it contribute to sustainability? Does it improve economic Multipliers?
7. How to become a sustainability leader in the manufacturing industry? Does it demand for a complete redesign of the touch points where sustainability concerns are typically raised across the extended value chain? Are there any frameworks available? Is it possible to apply system driven approaches which addresses the comprehensive needs from design to usage and further reuse, repurposing, or remanufacturing..?
8. What are the drivers for sustainability? How do they have a negative impact? Can we determine the factors and drivers for sustainable manufacturing??
9. What are the new technologies available? What are the recovery methods?
10. What are the capabilities and what are the benefits of fully integrated sustainable manufacturing system and do we achieve the desired results for sustainability by Design?

IV. RESEARCH METHODOLOGY AND APPLIED CONCEPTS:

A) Numerous Frameworks, Methodologies and capabilities work concurrently to expedite the potential returns of embracing the sustainable by design model. Undivided focus on transparency and visibility across the value chain and complete life cycle of the product across the supply chain can support the traceability of existing sustainability data, materials, and events. In simple terms digitization of the complete system is necessary. This paves the path for an integrated sustainability data model, powered by cohesion and Artificial intelligence that can generate insights and provide proactive responses to anomalies in the system and control the system ambiguously. These data, along with digital sustainability Performance reporting systems, can bring sustainability aspects in line with the key business decisions. Manufacturing business in to ponder upon

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investing in product and process innovation technologies leading to circular product designs and sustainable manufacturing initiatives, eventually supporting their decarburization goals. Such decarburization levers support an organization's carbon neutrality goals coinciding with region specific goals however when we focus on circular economy we apply sustainability principles to evenly balance out the system across the whole globe. Furthermore, with connected value chains and circular ecosystems, organizations need to use technologies to weave in the right amount of agility and flexibility with decisions made at the edges of the network. Ecosystem-level decisions are based on seamless data collaboration and insights. Such a connected, cognitive, and collaborative ecosystem built using this approach can facilitate ecosystem orchestration for new or alternate business models

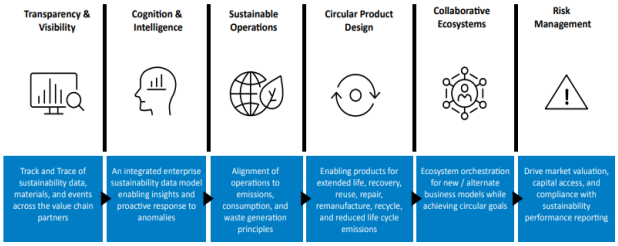

Figure 3: Capabilities of a sustainable by design enterprise- TCS Paper Reference Neural Manufacturing TM

On the other hand opportunities and sustainability governs business survival thus bringing risks and continuity through aspects such as access to finances, Uncertainties, product valuation, and statutory requirements. Manufacturers require to remain focused to mitigate the compounding risks, govern the policies effectively and communicate their sustainability strategy and performance to their business stakeholders.

B) From the technological point of view and specialist aspects we shall be using the following systems to reduce carbon emissions:

1. Renewable Energy and Energy Management Systems.
1.1 Wind Energy
1.2 Solar Energy – Concentrated Solar Power systems for heat and light, Solar Heaters and Photo Voltaic Cells.
1.3 Geothermal Energy.
1.4 Tidal Energy – Air Derivative turbine System.
1.5 Advanced thermal conversation form sewage and effluent treatment plant.
1.6 Solid State Fuel Cells and Hydrogen Generation from sea water using other sources of renewable energy.
1.7 Digitization- Control, Monitoring and Analysis of complete Energy.
1.8 Cross flow and Energy Management.
1.9 Peltier Effect – Heat Recovery Devices.
1.10 Volatile Liquid Boilers and Low temperature energy recovery.
2. Waste Management Systems.
1.1 Waste Energy recovery.
1.2 Waste Heat Recovery from Compressor and HVAC systems.
1.3 Using VAM chillers with process waste heat.
1.4 Waste Heat utilization for Vacuum distillation System.
1.5 Optimized operation and different systems in network.
1.6 Alternative Long lasting material – Bio Degradable.
1.7 Zero Liquid Discharge system.
1.8 Sewage Treatment Plants and Methodologies.
1.9 Effluent Treatment Plants.
1.10 Energy efficient Motion control systems.
1.11 Hybrid system to minimize losses.
1.12 High Voltage Power Distribution systems.
1.13 Waste Management and Process systems.
1.14 Incinerator for Energy recovery from waste oil.
1.15 Radiant and Hybrid cooling systems for District Heating and Cooling systems.

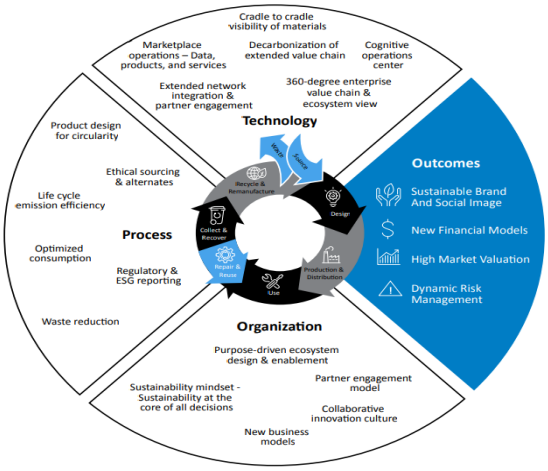

Figure 4: Building the next-gen sustainable target operating model- Reference TCS Neural Manufacturing TM

C). A focused approach encompassing organization, process, and technology change can foster such transformation for an organization. For sustainable Manufacturing we shall look at such models to determine the tangible and intangible factors thus integrating technology with process to enhance business for organization and deliver the potential goals of sustainable manufacturing. In this process we shall look at the complete life cycle of the product across the entire supply chain and then deliver the process map for adopting sustainability for any organization.

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D) System Integration to achieve Mass-Energy-waste (MEW) Balance across the system: Here we shall look at integrating all the systems in entire manufacturing facilities and have a cross transfer of energy from one system to another so that waste from one system can be utilized as a source to another system so that we convert our energy to most desirable form to be used and to be stored. We shall look at all power management systems and innovative methods to realize cost benefit and by storing and optimizing the use of energy.

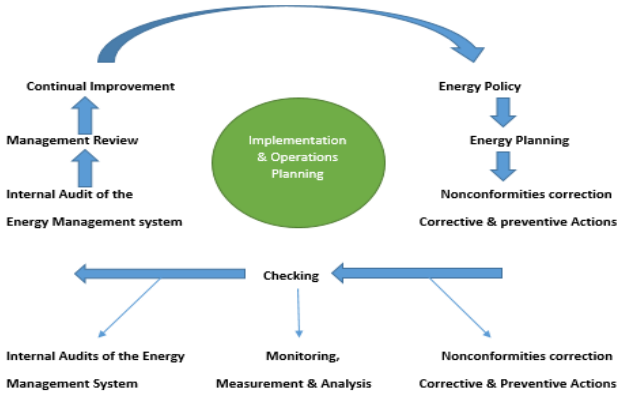
E) Design a concept for Energy Management System and Discuss various System integration techniques for digitization of the facilities and harness maximum productivity at Low cost, We shall also discuss and implement some of the methods of cost optimization and System maintenance by using advanced methods and IoT techniques to improve system performance and maximum utilization of facilities.

Energy is the most vital component of the Industries today. Managing resources well would help the industries and factories to increase their productivity, complete utilization of its existing resources, and in turn great profitability. Now let's speak about the standards which will guide us through the whole system ISO 50001:2018 – Energy **Management System ISO** 50001 is based on the **management system** model of continual improvement also used for other well-known **standards** such as **ISO** 9001 or **ISO** 14001. This makes it easier for organizations to integrate **energy management** into their overall efforts to improve quality and environmental **management**. Our Project would focus on study of such systems and use various techniques to recover waste energy from the industrial factories.

Process of building Energy Management System:

Understanding the Energy Use:

- In this Project I took my own plant as an example and we enlisted all the machinery which consumes and generates power and also displayed all the power parameters of the system in a tabulated Excel sheet.
- We generated an SLD of Complete electrical distribution system and looked out for points where we can improve and transfer energy in other forms other than electricity.
- We further mounted sensors and controllers to view and evaluate the system and started monitoring the energy consumption and control different components of the system.



- Plan: Understand the requirements, Seek Management Commitment, Set energy Goals, Structure Team to execute the task.
- Do: Know the energy consumers, Seek for possibilities, identify the energy 'Guzzlers'-Heavy consumers, List out Opportunities.
- Check- Bench Mark Energy Usage, List and check energy parameters, Check energy consumption and check billing for loopholes.
- Act – Review the data and conduct audits, Meeting requirements of the standards as per ISO 50001:2018 and other applicable standards, Prioritise energy upgrades based on financials of the organisation.

Why Energy Management??

- Effective Utilisation of resources- **More profitability**.
- **Branding**- Enhanced branding is always possible for an organisation as documented evidence is available.
- **Transparency** – It helps to identify critical points in system and optimise energy usage
- Improves energy balance/reduces co2 emissions and contributes to organisations **sustainability.**
- **Awareness**- Helps to monitor and understand the energy usage to encourage more efficient utilisation among people.
- **Unified Structure:** High level structure helps to obtain further certifications and helps to have better control on the facilities- e.g.. Documents available for audits

V. CONCLUSIONS AND RECOMMENDATIONS:

We have designed Subsystems so far which are capable and mapped the complete system in form of power distribution SLD.

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We have targeted some of the subsystems and identified the energy wastage and used some of engineering principals and transferred the waste energy to other Sub-systems and put to its use. We conclude that the energy savings is directly proportional to cost reduction, we have also calculated the return of investment for some of the systems which are future ready.
We progressed in development of IO summary and also decided the number of sensors and controllers to be used in the system. We made a BOQ of the complete system and built components future ready so that then can communicate on one single platform.
We also identified the energy consumers and followed the 5 steps as per ISO 50001:2018 energy management system standards;

By Building EMS (Energy Management system) we had: Better and effective use of existing Resources and Energy system.

- Conserving Energy and Driving Profitability.
- Improve productivity.
- Promote energy efficiency through entire supply chain and reduced overall costs.
- Provide integration of energy management system with other organisation management systems such as financial, facilities, sales, marketing, maintenance etc.

VI. OUTCOMES AND FUTURE WORK

1. Digitization in Manufacturing and Improving Process efficiency.
2. New revenue streams through circular business models:
3. Resilience to climate and linear business model risks:
Access to green finance and lower capital rates:
Cost and operational efficiency:
4. Resource Management and Resource Efficiency.
5. Waste Energy Management and sustainable Manufacturing Systems.
6. Sustainability and renewable Energy in manufacturing systems.
7. Business Models for Sustainable Manufacturing.
8. Design By sustainability for Sustainability.

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