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Industry 4.0, Sustainability, and Government Policies: Pathways to Achieving SDG 2030 and Viksit Bharat@2047

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Abstract

India's ambitious vision of becoming a developed nation by 2047, i.e. Viksit Bharat@2047, aligns with its commitment to global sustainability objectives, including the United Nations' Sustainable Development Goals (SDGs) for 2030. This paper explores the intersection of Industry 4.0 and Government of India policies, highlighting their role in driving sustainability and digital transformation in Indian industries. Through a qualitative review of policy documents, industry reports, and academic literature, this study examines the adoption of Industry 4.0 technologies and their alignment with initiatives such as 'Make in India', 'Digital India', 'Samarth Udyog 4.0. and others. The findings suggest that a strategic alignment of policies with Industry 4.0 initiatives can significantly contribute to India's sustainable development agenda. This paper also discusses challenges, opportunities, and future directions for sustainable industrial growth in India.

Keywords: Industry 4.0, Viksit Bharat 2047, sustainability, government policies, digital transformation

1. Introduction

The concept of Industry 4.0, which includes the integration of technologies such as IoT, artificial intelligence (AI), automation, and big data, represents the next phase in the evolution of manufacturing. For India, a nation that is rapidly progressing towards becoming a global industrial hub, the adoption of these technologies is key to driving economic prosperity, ensuring environmental sustainability, and fostering inclusive social development. Industry 4.0 can lead to green manufacturing practices, improve energy efficiency, and reduce environmental footprints, all contributing to India's long-term goals, including the SDGs (Sustainable Development Goals) and the Viksit Bharat 2047 vision. While sectors like automotive and electronics have begun integrating Industry 4.0 technologies, challenges such as limited infrastructure, skill gaps, and the need for substantial investment remain (trade.gov, 2023). This paper explores how India's government policies and initiatives, along with the country's adoption of Industry 4.0 technologies, can help achieve these goals.

2. Literature Review

The concept of Industry 4.0 emerged as a paradigm shift in global manufacturing, enabling smart factories and efficient resource utilization. It integrates technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data analytics, robotics, and cloud computing to enhance productivity, flexibility, and competitiveness (Kagermann et al., 2013). In India, Industry 4.0 adoption has become critical for bri-

dging the gap between traditional manufacturing practices and global standards.

2.1 Global Perspective on Industry 4.0

Globally, Industry 4.0 adoption has been driven by the need for operational excellence, customization, and sustainability. Countries like Germany and China have established frameworks such as Industrie 4.0 and Made in China 2025, which prioritize automation, digitalization, and smart manufacturing to achieve economic and technological leadership (Drath & Horch, 2014). Studies show that Industry 4.0 adoption can significantly improve resource efficiency, supply chain resilience, and innovation capabilities (Liao et al., 2017).

2.2 Industry 4.0 in India: Opportunities and Challenges

India's manufacturing sector is undergoing a transformation, with Industry 4.0 technologies being piloted in sectors such as automotive, pharmaceuticals, and electronics. The Make in India initiative, introduced in 2014, aims to increase manufacturing's contribution to the GDP from 17% to 25% (PIB, 2023). This initiative complements the Digital India program, which builds the digital infrastructure necessary for advanced manufacturing technologies (MeitY, 2024). Research indicates that Industry 4.0 technologies can significantly enhance sustainability by improving resource efficiency, reducing waste, and minimizing carbon footprints. For instance, IoT devices can optimize energy consumption in manufacturing processes, leading to lower emissions and operational costs (Kamble et al., 2020). The GoI has implemented several policies aimed at promoting Industry 4.0. Initiatives such as "Make in India" and "Digital India" emphasize the need for technological advancement and innovation in the manufacturing sector (Ministry of Commerce and Industry, 2015). These policies not only encourage investment in advanced technologies but also aim to create a skilled workforce capable of leveraging these innovations. However, challenges persist. Limited infrastructure, high capital investment, and a lack of skilled labor have hindered Industry 4.0 adoption in India. Studies emphasize the need for workforce upskilling and financial support to enable Small and Medium Enterprises (SMEs) to transition to advanced manufacturing. Furthermore, awareness about Industry 4.0 remains relatively low among Indian industries compared to global peers. (Jena et al.,2019)

2.3 Sustainability and Industry 4.0

The role of Industry 4.0 in promoting sustainability has been widely documented. By reducing waste, optimizing energy use, and enabling predictive maintenance, Industry 4.0 technologies contribute to the Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) (Birkel et al., 2019). In India, the adoption of Industry 4.0 technologies has been shown to significantly enhance environmental performance, particularly in high-emission industries such as steel and cement. For instance, implementing these technologies in manufacturing processes has led to a 9.33% reduction in specific energy consumption and carbon footprint. The National Green Hydrogen Mission, launched in 2023, highlights India's commitment to sustainable industrial development. It aims to decarbonize sectors such as chemicals, petrochemicals, and transportation, where Industry 4.0 technologies like IoT and AI can play a pivotal role (MNRE, 2024). The mapping of Industry 4.0 technologies to government policies highlights the interconnectedness between technological advancement and sustainability outcomes.

Table 1: Mapping Industry 4.0 Technologies to Policies and Sustainability Outcomes

Industry 4.0 Technologies	Government Policies	Sustainability Outcomes
IoT, Big Data	Digital India	Smart cities, resource efficiency
AI, Automation	Make in India	Green manufacturing practices
Hydrogen Technology	Green Hydrogen Mission	Renewable energy goals
Robotics, AI, Additive Manufacturing	National Policy on Electronics 2019	Sustainable electronics production
5G, IoT, AI	Skill India, National Skill Development Policy	Skilled workforce for green tech industries

Source: PIB, Reports

3. Government Policies Driving Industry 4.0 Adoption

3.1 Make in India

Launched in 2014, the "Make in India" initiative aims to transform India into a global manufacturing hub. On its 10th anniversary, the initiative was praised for boosting manufacturing, creating jobs, and enhancing ease of doing business. It has successfully positioned India as the world's second-largest mobile phone manufacturer and attracted significant investments (PIB, 2024). "Make in India" fosters Industry 4.0 by promoting smart manufacturing, automation, AI, and IoT integration in India's industries. It transforms traditional manufacturing into high-tech, competitive sectors, supporting digitalization and laying the foundation for the widespread adoption of Industry 4.0 technologies (PIB, 2024).

3.2 Digital India

Launched in 2015, the Digital India Mission aims to enhance India's digital infrastructure and empower citizens through technology. It plays a key role in advancing Industry 4.0 (I4.0) by promoting automation, data exchange, and smart technologies in manufacturing. The mission supports broadband connectivity, AI, IoT, and quantum computing, which are essential for Industry 4.0. It also strengthens digital public infrastructure like Aadhaar, UPI, and DigiLocker, facilitating efficient operations for industries adopting I4.0 solutions. Overall, Digital India accelerates India's transition to a technology-driven manufacturing sector. (PIB, 2023)

3.3 Skill India

Launched in 2015, Skill India aims to train millions of Indians in emerging technologies such as AI, robotics, data analytics, and IoT, preparing them for a technology-driven future. This initiative, aligned with the National Policy for Skill Development and Entrepreneurship, seeks to develop a workforce that can drive innovation and support industrial growth. Skill India plays a crucial role in fostering the development of a skilled workforce capable of operating and managing Industry 4.0 technologies. Training programs are designed to equip individuals with skills in areas like robotics, machine learning, and data science, directly contributing to the adoption and success of Industry 4.0 in India. By enabling workers to work with cutting-edge technologies, Skill India helps build the foundation for a competitive and innovative industrial ecosystem. (PIB, 2023)

3.4 The National Policy on Electronics

It was first introduced in 2012 to establish a competitive Electronics System Design and Manufacturing (ESDM) ecosystem in India. It laid the foundation for boosting domestic manufacturing, innovation, and

exports in the electronics sector. Building on this, the National Policy on Electronics 2019 (NPE 2019) aims to position India as a global hub for ESDM by fostering the development of core components like chipsets and enabling high-tech projects such as semiconductor and display fabrication.

NPE 2019 focuses on promoting Industry-led R&D in emerging technologies such as 5G, IoT, AI, robotics, and additive manufacturing while encouraging grassroots innovations and early-stage startups. It also emphasizes re-skilling the workforce, creating a trusted electronics value chain, and strengthening cybersecurity. The policy significantly contributes to Industry 4.0 by facilitating the production of IoT devices, sensors, and other smart systems essential for automation, robotics, and AI integration. By developing a robust ESDM ecosystem, it enhances India's readiness for smart manufacturing and digital transformation. (MeitY, 2019)

3.5 National Strategy for Additive Manufacturing Policy

Launched in 2022, this policy aims to boost India's global market share in 3D printing to 5% and add USD 1 billion to GDP by 2027. It targets the development of 50 India-specific technologies, the creation of 100 startups, and training 1 lakh skilled workers. Aligning with Make in India and Atmanirbhar Bharat, the policy seeks to foster self-reliance through technological innovation. 3D printing, or additive manufacturing, enables efficient, on-demand production with minimal capital investment, benefiting small and medium enterprises. However, challenges such as a lack of standardized certification, high initial equipment costs, and resistance to adoption remain (MeitY, 2022). To capitalize on the opportunities, India must strengthen research and development and offer government support for distributed manufacturing.

3.6 SAMARTH Udyog Bharat 4.0

The SAMARTH Udyog Bharat 4.0 Initiative is a program launched by the Ministry of Heavy Industry & Public Enterprises, Government of India, aimed at enhancing the competitiveness of the Indian capital goods sector. The initiative targets key stakeholders, including manufacturers, vendors, and customers, to promote the adoption of Industry 4.0 technologies. To spread awareness and provide hands-on experience, the government has established four Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) Centres across India: C4i4 Lab in Pune, IITD-AIA Foundation in Delhi, I-4.0 India at IISc Bengaluru, and Smart Manufacturing Demo & Development Cell at CMTI Bengaluru. These centres offer training, workshops, and consultancy in areas such as IoT, software development, and data analytics to industries, including MSMEs, helping them integrate Industry 4.0 solutions. However, it's important to note that no direct financial assistance is provided to industries to adopt these technologies. (Source: Ministry of Heavy Industries and Public Enterprises, heavyindustries.gov.in).

Table 2: Industry 4.0 Policies, Objectives, Contributions, and Responsible Ministries

Policy Initiative	Objective	Industry 4.0 Contribution	Ministry
Make in India	Promote innovation and boost manufacturing in India	Encourages the adoption of smart manufacturing technologies	Ministry of Commerce & Industry
Digital India	Digitally empower India through infrastructure development	Lays the groundwork for Industry 4.0 integration	Ministry of Electronics & IT

Skill India	Train individuals in emerging technologies	Ensures a skilled workforce for managing Industry 4.0 technologies	Ministry of Skill Development & Entrepreneurship
National Policy on Electronics	Foster electronics manufacturing, including IoT devices	Supports Industry 4.0 through IoT and sensor production	Ministry of Electronics & IT
National Strategy for Additive Manufacturing	Develop Additive Manufacturing capabilities	Supports advanced manufacturing techniques and customization in industries	Ministry of Electronics & IT
SAMARTH Udyog Bharat 4.0	Capacity building and technology adoption for MSMEs	Promotes Industry 4.0 adoption in MSMEs	Ministry of Heavy Industries & Public Enterprises

Source: PIB, Reports

These policies are strategically aligned with the Viksit Bharat 2047 vision and the SDG 2030 goals, setting the foundation for India's industrial transformation. By promoting economic development, environmental sustainability, and technological innovation, they support the country's ambition to lead in advanced manufacturing and digital industrialization. The integration of Industry 4.0 technologies within these frameworks is expected to contribute to inclusive growth and a sustainable future, positioning India to play a pivotal role in the global industrial landscape.

4. Alignment with Viksit Bharat@2047 Vision and SDG 2030 Goals

India's policies focused on Industry 4.0, digital transformation, and sustainable development are strategically aligned with the country's long-term vision of Viksit Bharat 2047 and the SDG 2030 goals, setting the foundation for India's industrial transformation. These policies are designed to foster industrial growth, technological innovation, and sustainability, laying the groundwork for a more inclusive, resilient, and sustainable economy by 2047. India's Vision 2047 envisions India as a developed nation by the time it celebrates its centenary of independence, characterized by robust infrastructure, sustainable industries, and a skilled workforce. Industry 4.0 plays a crucial role in achieving these objectives by enhancing productivity and sustainability in manufacturing. Simultaneously, these policies are aligned with the SDG 2030 goals, especially those related to Decent Work and Economic Growth (Goal 8), Industry, Innovation, and Infrastructure (Goal 9), and Responsible Consumption and Production (Goal 12). Industry 4.0 technologies help enhance productivity and create a sustainable industrial ecosystem by reducing resource consumption, minimizing waste, and increasing operational efficiency — key factors in meeting SDG 12. Additionally, advancing manufacturing capabilities through sustainable industrial practices supports clean energy and environmental responsibility, which aligns with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

4.1 How Policies and Industry 4.0 Will Achieve These Missions:

1. Economic Growth and Innovation: Policies such as Make in India, Skill India, and the National Policy on Electronics focus on fostering innovation, enabling infrastructure, and developing a skilled workforce. These efforts will stimulate the adoption of Industry 4.0 technologies across key sectors. The resulting automation, data-driven decision-making, and smart manufacturing will drive India's

industrial growth and economic resilience, directly contributing to both the Viksit Bharat 2047 vision and SDG 8 (Decent Work and Economic Growth).

2. Sustainability and Responsible Manufacturing: The integration of sustainable development principles with Industry 4.0 will enhance India's industrial processes by reducing emissions, minimizing waste, and promoting the circular economy. By adopting clean energy technologies and AI-driven resource optimization, India will make significant strides in SDG 12 (Responsible Consumption and Production), SDG 7 (Affordable and Clean Energy), and SDG 13 (Climate Action).
3. Infrastructure and Technological Advancements: Policies supporting the development of advanced infrastructure, including smart cities and industrial corridors, are critical for the success of Industry 4.0. The digital connectivity provided by Digital India and the focus on high-tech projects like 5G, AI, and IoT will create the foundation for smart manufacturing, making India a leader in advanced manufacturing and digital transformation, aligning with SDG 9 (Industry, Innovation, and Infrastructure).
4. Skilled Workforce for the Future: Skill India and other workforce development initiatives will ensure that the Indian workforce is prepared for the challenges of the digital economy. By equipping individuals with skills in AI, machine learning, robotics, and data science, these policies will create a workforce capable of driving Industry 4.0 adoption and ensuring inclusive growth — thus contributing to SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth).

5. Future Policy Suggestions and Reforms

To accelerate Industry 4.0 adoption and ensure sustainable industrial growth, the following policy reforms are recommended:

1. Incentivizing Green Technologies: Policies should promote the adoption of green technologies and clean energy solutions in manufacturing. Incentives can be provided to industries that reduce carbon footprints and adopt renewable energy sources.
2. Strengthening Data Infrastructure: India must invest in building robust data infrastructure to support the integration of IoT and AI technologies in manufacturing processes.
3. Promoting Collaboration between Academia and Industry: Universities and research institutions should collaborate with industries to promote the development of cutting-edge manufacturing technologies and solutions.
4. Creating more Industry 4.0 Hubs: Establish more Industry 4.0 innovation hubs apart from already existing Samarth 4.0 hubs, in key industrial regions to facilitate the testing and adoption of new technologies by Indian manufacturers.

6. Conclusion

Industry 4.0 technologies, combined with robust government policies, hold the key to transforming India's manufacturing sector and urban spaces into paragons of sustainability. Through initiatives such as "Make in India," Vision 2047, and the Smart Cities Mission, India is poised to become a global leader in sustainable industrialization. The integration of AI, IoT, automation, and blockchain provides the necessary tools for achieving these ambitious sustainability goals. However, challenges remain in the widespread adoption of these technologies, particularly in rural and underdeveloped areas. Continued investment in digital infrastructure, training, and policy reforms will be necessary to ensure that India remains on track to meet its sustainability objectives. Future research should explore the long-term impact

of Industry 4.0 on sustainability metrics, evaluating its effectiveness across different sectors and regions. By fostering collaboration between the government, industry stakeholders, and technology developers, India can realize its vision of a sustainable, technologically advanced future.

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