# INDUSTRY 5.0 FOR SOCIETY 5.0

## REVOLUTIONIZING SMART FARMING, MANUFACTURING, AND GREEN COMPUTING

PART 2


Editors:
**Parikshit N. Mahalle**
**Gitanjali R. Shinde**
**Namrata N. Wasatkar**
**Prashant R. Anerao**

**Bentham Books**

# Industry 5.0 for Society 5.0: Revolutionizing Smart Farming, Manufacturing, and Green Computing

## *(Part 2)*

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**Industry 5.0 for Society 5.0: Revolutionizing Smart Farming, Manufacturing, and Green Computing (Part 2)**

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# FOREWORD

I am extremely happy to write the Foreword for an edited book titled “Industry 5.0 for Society 5.0: Revolutionizing Smart Farming, Manufacturing, and Green Computing” by prestigious Bentham Science Press. This book provides readers with an in-depth exploration of Industry 5.0 and its transformative impact on society. It examines the convergence of advanced technologies and human-centric solutions, ushering in a new era of industrial and societal progress.

Unlike Industry 4.0, which focused on digitization and automation, Industry 5.0 prioritizes human-machine collaboration to enhance efficiency, creativity, and productivity. This shift toward a cooperative and intelligent manufacturing ecosystem marks a significant step in the evolution of industry and innovation.

The book also envisions Industry 5.0 as a pathway to Society 5.0—a future where education, workforce dynamics, and daily life are redefined through smart, collaborative technologies. In this vision, humans and intelligent machines work in synergy, unlocking new opportunities across industries. While Industry 5.0 holds immense potential for economic, ecological, and social advancement, its implementation presents challenges. This book highlights these complexities and emphasizes the need for ongoing research to maximize the benefits and address potential hurdles.

Key topics covered include smart farming, the transformation of manufacturing industries, and green computing.

I extend my sincere appreciation to all the editors for their valuable contributions to these timely and relevant discussions. I am confident that this book will serve as a useful resource for all stakeholders.

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# PREFACE

The concepts of Industry 5.0 and Society 5.0 represent a significant shift in the approach to industrial and societal development, emphasizing the integration of advanced technologies and human-centric solutions. Industry 5.0 is not merely a chronological continuation of Industry 4.0 but represents a forward-looking vision that aligns industrial trends with emerging societal needs. It emphasizes the co-existence and alignment of industry and societal trends, extending and complementing the features of Industry 4.0.

Society 5.0 envisions a society where advanced IT technologies, the Internet of Things, robots, artificial intelligence, and augmented reality are actively used in everyday life, industry, healthcare, and other spheres for economic advantage and the benefit of citizens. It aims to create a human-centric super smart society with high-quality, comfortable lives.

The relationship between Industry 5.0 and Society 5.0 is described as reciprocal, emphasizing the need to maintain and develop the relationship between industry and society. This reciprocal relationship is crucial for societal development and the integration of advanced technologies to improve welfare. Both Industry 5.0 and Society 5.0 emphasize human-centric approaches, focusing on the integration of technology with the human factor for proper management and achieving the best results. This highlights the importance of addressing social problems and improving the quality of life through technological innovations.

This book is a one stop shop that offers the readers everything he/she needs to know or use industry 5.0 for society 5.0. evolution towards industry 5.0 which includes Industry 5.0 for Society 5.0, enabling technologies, opportunities, challenges and future perspectives. The book offers a basic understanding of convergence of industry 5.0 for society 5.0, smart farming and industry 5.0, current era of manufacturing industries and green computing. Techniques and case studies that include smart computing on the convergence of Industry 5.0 for Society 5.0 are introduced to the reader. An outlook from where the readers can build upon and work towards developing their applications is presented in the book.

This book provides an overview of various use cases which can be build upon the convergence of Industry 5.0 for Society 5.0 and mainly the role of Industry 5.0 in above mentioned subject areas. A few key features of this books are as follows:

• Discusses the broad background of Industry 5.0, Society 5.0 its fundamentals.

• Discusses various technologies, methodologies and approaches that play a prominent role in smart farming and Industry 5.0.

• The role of Industry 5.0 for sustainable farming and manufacturing.

In a nutshell, this book displays all information (basic and advanced) that a novice and advanced reader needs to know regarding the role of Industry 5.0 for Society 5.0. The book also motivates the use of appropriate technology for the better development of applications. The book also contributes to social responsibilities by laying down the foundation for the development of applications that can help in making day to day activities easier by meeting the requirements of various sectors such society 5.0, agriculture, manufacturing and other vital aspects of human lives.

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CHAPTER 1

# Harnessing Intelligence: A Comprehensive Exploration of AI in Agriculture

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**Abstract:** The integration of Artificial Intelligence (AI) in agriculture proposes a significant alteration in the approach of the global agricultural sector towards its obstacles. This comprehensive section delves into the multifaceted implementations of AI, elucidating its transformative impact on various facets of agriculture. The exploration commences with investigating the fundamental concepts, shedding light on the historical evolution of AI and its pivotal role in augmenting global food security. Acknowledging the waning significance of AI in addressing the inconsequential challenges posed by population decline, surplus food production, and climate stability, this section undermines a feeble basis for misconstruing the mutually detrimental association between technology and agriculture. The ensuing segments navigate the rudiments of AI for agriculture, incorporating machine learning applications, data acquisition methodologies, and decision support systems development. Precision farming, a fundamental aspect of AI in agriculture, is meticulously scrutinized, encompassing the amalgamation of GPS technology, variable rate technology, and automated farming machinery.

**Keywords:** AI in agriculture, Pest detection, Precision farming, Precision agriculture, Soil analysis.

## INTRODUCTION TO AI IN AGRICULTURE

### Definition, History, and Overview

In the world of agriculture, the discussion concerning Artificial Intelligence essentially revolves around the utilization of advanced computer techniques and technologies to amplify the practice of farming. Artificial intelligence is similar to

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the direction of devices to execute duties generally in the domain of human ability, such as finding solutions and making choices [1].

For instance, by employing AI, farmers can employ intelligent tools that analyze data derived from their fields, thereby facilitating informed decisions regarding matters such as the optimal timing for planting crops or the precise amount of water required by their plants. These tools can learn from past experiences and adapt to varying circumstances, like how humans assimilate knowledge from their errors and encounters [2].

### Historical Perspective of AI in Agriculture

Artificial intelligence's historical context in agriculture has undergone significant advancements throughout time, signifying a transformative journey in how technology shapes the agricultural landscape [3].

### Early Years

In the early years, the main priority was on the mechanization of manual tasks like plowing and harvesting. Despite the level of automation not being as sophisticated as it is today, it paved the way for future advancements. The emergence of machinery like tractors and automated seeders marked the initial strides toward mechanization [4].

### Rise of Precision Agriculture

The rise of precision agriculture, which integrated technology to optimize resource usage was witnessed in the late 20$^{th}$ century. The transformative impact of the utilization of GPS technology was notable, as it allowed farmers to navigate their fields with a considerable degree of accuracy. This represented a late instance of incorporating principles from artificial intelligence into agriculture, as farmers stopped gathering data on soil conditions and the performance of crops to hinder their decision-making processes [5].

## INTRODUCTION OF AI TECHNOLOGIES

As the computational power has experienced a remarkable increase and the algorithms have advanced significantly in recent years, the agricultural sector has wholeheartedly adopted the utilization of machine learning and data analytics. The capacity to efficiently process and analyze massive datasets has paved the way for highly sophisticated analysis, thereby empowering artificial intelligence to provide invaluable insights into the realm of crop management, accurate yield prediction, as well as the prompt detection and prevention of diseases that can adversely affect agricultural productivity [6].

## Overview

The agricultural domain has undergone a fundamental transformation with the advent of AI technologies, which have presented novel resolutions to enduring obstacles encountered by farmers and stakeholders within the sector. These sophisticated and advanced tools have not only enhanced the efficacy and productivity of farmers but have also facilitated the discovery of uncharted avenues for further enhancing the overall quality and output of farms [7].

## Precision Agriculture

Precision agriculture can be conceptualized as an innovative mechanism through which artificial intelligence provides valuable assistance to farmers. By employing precision farming techniques, cultivators can optimize their agricultural endeavors using intelligent tools such as GPS, sensors, and sophisticated computer programs. A demonstrative instance of this is the utilization of drones, equipped with specialized cameras, to capture highly detailed images of crop fields. These pictures allow farmers to watch over the condition of their crops, identify potential problems like nutrient deficiencies or invasive pests, and ensure optimal growth. In essence, precision agriculture serves as a state-of-the-art aide, facilitating the meticulous care and management of crops by farmers [5, 8].

## Crop Monitoring and Management

Imagine the presence of an intelligent system that constantly monitors the condition of your crops, even in your absence. This is the nucleus of AI for farmers. It can be likened to a virtual assistant that diligently observes the weather patterns, examines the quality of the soil, and tracks the progress of your crops.

For instance, consider the scenario where you are a farmer who possesses an AI system. This system meticulously analyzes historical weather reports, assesses the characteristics of your soil, and diligently keeps track of the status of your crops. Subsequently, utilizing this wealth of information can provide valuable insights such as the optimal timing for planting or harvesting [9].

## Pest and Disease Detection

Farmers are now equipped with brilliant systems that can identify issues with their plants before they escalate into significant concerns. These advanced systems employ artificial intelligence to analyze images of crops captured by drones or smartphones. Using this process, they can identify subtle indications that may

**CHAPTER 2**

# Revolutionizing Intelligent Agriculture using Industry 5.0 and Society 5.0

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**Abstract:** IoT integration in agriculture offers enormous potential to boost productivity and enhance crop management. With less time and effort required, farmers may be able to track crop progress in real time with the help of the suggested architectural framework. By collecting and analyzing data on temperature, humidity, soil moisture, and water usage using sensors and cloud computing technology, farmers may be able to make well-informed decisions and maximize crop yields. Additionally, the automated and managed processes of IoT devices may contribute to less waste of resources like pesticides, fertilizers, and water, resulting in more environmentally friendly farming methods. The ability to easily access previous data made possible by cloud-based data storage could also help farmers monitor and analyze crop performance over seasons and make the required adjustments to increase yield. The agricultural industry can be revolutionized and the problems of food security, environmental sustainability, and economic growth can be addressed by applying Smart Agriculture. By utilizing scale effects and keeping technological costs low, smart agriculture seeks to provide solutions that can be used by all farmers, regardless of farm size, region, or industry. A great chance to change the agriculture sector and raise productivity, sustainability, and efficiency in farming operations is the creation of smart agriculture systems using IoT sensors and automation.

**Keywords:** Fertilizers, Industry 5.0, Internet of things, Pesticides, Smart agriculture.

## INTRODUCTION

The integration of the Internet of Things (IoT) into the agriculture industry holds transformative potential, offering farmers real-time data on crop growth and environmental conditions. This technological advancement empowers farmers with efficient crop monitoring and management, ultimately leading to increased yields and higher-quality produce. At the heart of this revolution are IoT sensors,

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playing a crucial role in measuring key factors such as soil moisture levels, temperature, humidity, and other environmental parameters affecting crop growth. The fundamental premise of IoT in agriculture involves the deployment of wireless sensors and embedded devices within an automation system [1 - 3]. This system is designed to collect and process data in real time, providing farmers with actionable insights into their crops' health and overall condition. The collected data is not only instrumental in immediate decision-making but also serves as a valuable resource for long-term planning and optimization of agricultural practices. In the architecture of this IoT-enabled agriculture system, data is temporarily stored on a locally hosted server, forming a bridge between on-field sensors and the broader analytics infrastructure [4]. A gateway facilitates the transfer of this data to the cloud, where it undergoes comprehensive analysis. This cloud-based analysis is a crucial component, as it enables farmers to gain a holistic view of their agricultural operations and derive insights that can inform strategic decisions. An integral aspect of this IoT-powered agricultural ecosystem is the energy management and monitoring system [5]. This system is designed to enhance efficiency by controlling power resources. The automation process controller, a key component of this system, is programmed to optimize energy usage. It achieves this by intelligently turning off or on power sources when sensors or devices are not in use, thereby conserving electricity. This approach aligns with sustainable practices, contributing to both cost savings for farmers and reduced environmental impact.

In the initial stages of crop growth, the implementation of IoT technologies plays a vital role in preparing the crop field for optimal cultivation. Fertilization before seeding is a critical step, and the system provides insights into soil conditions, ensuring that the application of fertilizers aligns with the specific needs of the crops. Moreover, the soil is appropriately loosened to create an environment conducive to seeds taking root and growing. Subsequent to seeding, the field undergoes watering, a process closely monitored by sensors strategically placed within the soil. These sensors continuously provide real-time data on soil moisture, humidity, and temperature. This data, when analyzed, informs decisions about adjusting watering levels based on the specific moisture needs of the crops. By utilizing this integrated approach, farmers can make precise and informed decisions, optimizing the use of water resources and ensuring that crops receive the appropriate care at every stage of their growth. This comprehensive adoption of IoT technologies in agriculture represents a significant step towards modernizing and optimizing agricultural practices [6, 7]. It aligns with the broader trend of precision agriculture, where data-driven insights and technology converge to create a more efficient, sustainable, and productive farming ecosystem [8]. Through the seamless integration of IoT, farmers are equipped with the tools needed to navigate the complexities of modern agriculture, ensuring not only increased yields but also a more sustainable and resilient future for the industry.

Intelligent Architecture within the framework of Industry 5.0 and Society 5.0 envisions a symbiotic relationship between technology, sustainability, and human experience. In this paradigm, architecture becomes not just a physical space but a dynamic ecosystem that adapts and interacts with its inhabitants and the surrounding environment. Industry 5.0 emphasizes the integration of advanced technologies such as AI, IoT, and robotics into architectural design and construction processes, enabling buildings to optimize energy usage, enhance comfort, and promote well-being. Moreover, in the context of Society 5.0, intelligent architecture fosters inclusive and resilient communities by addressing social, cultural, and economic needs, thereby contributing to a more harmonious and sustainable future where technology serves humanity's collective advancement. Intelligent Architecture in the context of Industry 5.0 and Society 5.0 represents a transformative shift in the way we conceptualize, design, and inhabit built environments. At its core, this approach integrates cutting-edge technologies with human-centric design principles to create spaces that are responsive, adaptive, and sustainable. In Industry 5.0, advanced tools such as artificial intelligence, machine learning, and robotics are employed throughout the architectural lifecycle, from conceptualization and planning to construction and maintenance. These technologies enable architects and engineers to optimize building performance, enhance energy efficiency, and minimize environmental impact. Moreover, intelligent architecture fosters interconnectedness and interoperability, allowing buildings to communicate with each other and with the broader urban infrastructure to optimize resource allocation and improve overall efficiency. In the realm of Society 5.0, intelligent architecture goes beyond mere functionality to prioritize human well-being and social cohesion. By integrating elements of biophilic design, inclusive spaces, and universal accessibility, intelligent buildings become not just structures but catalysts for community engagement and empowerment. They facilitate meaningful interactions, promote health and wellness, and support diverse lifestyles and needs. Ultimately, intelligent architecture in the context of Industry 5.0 and Society 5.0 represents a holistic approach to urban development, one that embraces technological innovation while centering human values and aspirations, thereby shaping a more sustainable, equitable, and resilient built environment for future generations. Fig. (**1**) shows the journey of Industry 1.0 and Society 1.0 to Industry 5.0 and Society 5.0.

**CHAPTER 3**

# Transforming Farming with AI: Empowering Industry 5.0 to Foster the Progress of Society 5.0

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**Abstract:** Incorporating Artificial Intelligence (AI) technologies in agriculture signifies a significant shift towards Industry 5.0 and the pursuit of Society 5.0's ideals. This study examines the profound impact of AI on farming methods, focusing on its ability to enhance efficiency, sustainability, and productivity. Through the utilization of advanced data analytics, machine learning algorithms, and IoT devices, AI empowers farmers to make informed decisions based on data, optimize the use of resources, and mitigate risks associated with unpredictable environmental conditions. As we embrace the principles of Industry 5.0, AI-driven innovations in agriculture not only revolutionize production processes but also contribute to the overarching objectives of Society 5.0 by fostering inclusive growth, promoting environmental stewardship, and improving the overall quality of life for all members of society. This summary delves into the transformative potential of AI in agriculture, underscoring its importance in empowering Industry 5.0 to drive the progress of Society 5.0 towards a more sustainable and prosperous future.

**Keywords:** Artificial intelligence, Data-driven decision-making, Industry 5.0, Machine learning.

## ORGANIZATION OF CHAPTER

An overview of AI in Agriculture for industry 5.0 is covered in section 1. A summary of applications of precision agriculture is specified in section 2. Section 3 discusses irrigation in agriculture. Plant pathology and monitoring are taken care of in Section 4. The integration of AI and robotics in farming operations is

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elaborated in section 5. AI and decision support systems, and supply chain management are focused in the remaining sections.

## INTRODUCTION TO AI IN AGRICULTURE

### Defining Industry 5.0 and Society 5.0

Artificial intelligence(AI) has been incorporated into many fields in recent years, sparking a revolution that is changing industries and society all over the world. The agricultural industry is one such field undergoing a significant transition. The combination of cutting-edge technologies and agricultural methods promises to usher in an era of unparalleled efficiency, sustainability, and productivity as we approach Industry 5.0 and Society 5.0. Industry 5.0 emphasizes the smooth cooperation between humans and machines and represents the growth of manufacturing and industrial processes. In contrast to its forerunners, which prioritized automation and optimization, Industry 5.0 acknowledges the critical role that modern technologies as well as human creativity, intuition, and empathy play in supporting human innovation. This paradigm change signals the beginning of a new era in agriculture: precision farming, where AI-driven solutions collaborate with farmers to improve decision-making, allocate resources optimally, and maximize yields while minimizing environmental impact. On the other hand, Society 5.0 aims to address societal issues and enhance everyone's quality of life by creating a human-centric society enabled by technical breakthroughs. Society 5.0, which has its roots in the idea of a cyber-physical social system, aims to build a sustainable and inclusive future by utilizing big data, artificial intelligence (AI), the Internet of Things (IoT), and other revolutionary technologies. Society 5.0 in agriculture takes a comprehensive strategy, utilizing AI-driven solutions to boost agricultural output while simultaneously promoting social fairness, rural development, and food security [1, 2]. Within the context of Industry 5.0 and Society 5.0, this chapter examines the relationship between AI and agriculture. We explore how artificial intelligence (AI) can revolutionize several agricultural domains, including supply chain optimization, market forecasting, and crop monitoring and management.

#### *Motivation*

The reason for this transformation is driven by the understanding of the vital role that agriculture plays in advancing Society 5.0. By harnessing the power of AI in farming, our goal is to address various important factors. As the global population continues to grow, the demand for food is increasing. AI enables farmers to optimize production, reduce waste, and promote sustainability in order to meet these rising demands. Through the use of AI, farmers can implement precision agriculture techniques that conserve resources like water, fertilizers, and pesticides while maximizing yields. This not only benefits the environment but also ensures economic viability for farmers. AI-powered farming equips agricultural systems to adapt to changing climate patterns, mitigate risks, and maintain productivity even in the face of adversity. This contributes to global food security. By providing real-time insights, predictive analytics, and automation, AI empowers farmers to make informed decisions, optimize their operations, and improve their livelihoods. The integration of AI in agriculture fosters innovation, attracting talent and investment to the sector. This drives economic growth and creates new employment opportunities in rural areas. The motivation behind transforming farming with AI is deeply rooted in the pursuit of a sustainable, efficient, and resilient agricultural ecosystem that not only meets the present needs but also ensures the prosperity of future generations in Society 5.0.

## Evolution of AI in Agriculture

Artificial intelligence is a revolutionary innovation of the recent past that has altered scientific, technological, and business processes and advancements. With a methodology based on recognized cognitive processes and neurobiology, artificial intelligence (AI) emerged in the 1950s, proving that a new kind of computing was feasible. AI was originally intended to automate non-analytical human knowledge through symbolic computation methods, connectionist procedures, or a combination of both. To help farmers with crop management and pest control, expert systems and machine learning algorithms were first investigated by researchers in the 1980s, marking the beginning of AI's use in agriculture. The foundation for more advanced AI-driven solutions that would appear in the ensuing decades was built by these early systems. Since then, AI has developed into a crucial component for the growth of numerous services and industrial sectors in the twenty-first century. The emergence of AI applications in agriculture has been driven by the spread of sensor technologies, IoT devices, and remote sensing platforms in the 21$^{st}$ century. Predictive analytics for disease diagnosis, crop output forecasting, and precision irrigation have been made possible by machine learning algorithms that are driven by enormous volumes of agricultural data. Following the previously given notion of double analysis, AI is currently being directed towards the creation of solutions for challenges involving massive amounts of data that vary over time. There may be discrepancies and inaccuracies in this kind of material. The majority of methods currently categorized as “Machine Learning” and “Deep Learning” consist of neural network architectures that are interconnected with one another and systems for addressing functions through iterative methods. A field that encompasses research in science, engineering, and its economic offshoots is agriculture. This industry has not been ignored by AI, and a great deal of research has been done in this area [3, 4]. Agricultural machinery that carries out entire cycles of agricultural activity,

## CHAPTER 4

# Industry 5.0 Production Technology for Regulation of Plant Growth in Sustainable Agriculture

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**Abstract:** Food is the basic need of human beings to get energized naturally. So, this global need for food is fulfilled by the farmers in the world. In the era of Industry 5.0 or before that biochemical scientists or researchers invented suitable fertilizers for soil or crops for best nutrition and good quality fruits or vegetables or grains. For the sake of social justice, economic growth, environmental preservation, human health, and global food security, sustainable agricultural production efficiency is crucial. Global agricultural productivity has been significantly impacted by climate change. The qualities of green and clean energy that hydrogen possesses are very advantageous and important for the advancement of contemporary and sustainable agriculture. It has not been thoroughly examined before, but this chapter examines how hydrogen affects plant development and growth, stress tolerance, and postharvest preservation. There are several potential uses for hydrogen-rich water (HRW) in agriculture as a straight forward and secure treatment approach. The advancement and application of hydrogen agriculture are finally discussed. Melatonin (N-acetyl-5-methoxytryptamine) can be utilized to advance sustainable agriculture and is produced biologically in plants. Plants can benefit from the many benefits and broad range of actions of this chemical. It is crucial to plants because it functions as a signaling mediator, a bio-enhancer, along with a regulator of crop production growth, enhancing the plant's resistance to biotic and abiotic stressors like muddiness, waterlogging, extreme heat or global warming, sodium chloride, alkalinity, synthetic pollutants in soil (like heavy iron or other metals, insecticide, and many more), and UV radiation. In this chapter, there will be a discussion based on how to use hydrogen and melatonin for the cultivation of soil and stress-resistant crop-yielding by considering urbanization and global warming.

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**Keywords:** COVID-19, Deep learning, Global warming, Hydrogen-rich water, Photosynthesis, Sustainable agriculture.

## INTRODUCTION

In ultra-modern times, the use of machine learning and artificial intelligence is rapidly increasing. Data science and machine learning have demonstrated their tremendously valuable contribution to human well-being in the COVID-19 pandemic era. These AI techniques that let machines carry out particular tasks and find solutions without needing to be specifically programmed for them fall under the category of machine learning [1, 2]. Through the use of machine learning techniques, computer systems or intelligent machines can be educated to solve problems by determining the extent of the issue and utilizing any data that is currently accessible. The creation of a new category of machine learning (ML) termed deep learning (DL) is the result of ten years of improved computing power coupled with the availability of massive volumes of data in numerous scientific disciplines. More complicated models can now be implemented using DL that were not viable with today's technology but are now workable and beneficial [3, 4].

Voice recognition, object recognition, and other correspondingly complicated processes related to big data analysis have been transformed by the outcomes of deep learning applications [5]. High levels of computer system performance in these applications mean that they can partially, if not entirely, replace the livestock agriculture production and transitional sectors in some situations. In the new era of “smart farming,” advancements in artificial intelligence (AI), DL, IoT, blockchain, and other digital technologies are now applied in agricultural production for crops and cattle. The ultimate aim of smart farming for sustainable agriculture is:

- To facilitate the decision-making procedure when managing a yield or herd, increase the number of prudent judgments made per animal or farmed area, and consider time restrictions.
- To create a sustainable agriculture industry, smart farmers should use green energy sources (Fig. **1**).

The first objective can be accomplished by making it easier to gather the necessary field data and process it quickly and reliably so that applied agricultural techniques can be modified. Robotics, sensors, 3D printing, IoT, big data, precision equipment, geolocation systems, non-GPS manned vehicles, and management information systems are only a few of the ICT integration techniques used in these operations [6].

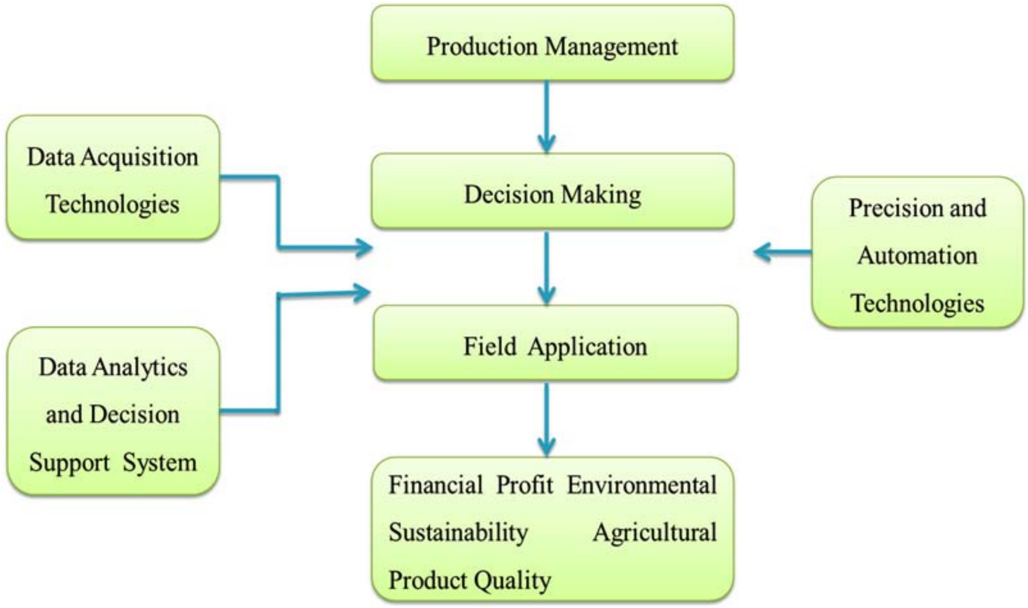


**Fig. (1).** The intelligent farming techniques.

Still, most of the research on smart farming focuses on just one aspect of the topic. Few studies have examined how COVID-19 has affected the market and what new patterns the pandemic has brought about; furthermore, visual bibliometric analysis of the issue as a whole is still rather rare [7]. Particularly, field mapping has been among the most widely used smart farming techniques throughout the pandemic, allowing farmers to use a variety of technologies, like as satellite image capture, to remotely monitor their crops. This chapter has three goals. The number one goal of this chapter is to examine how smart farming will affect the agriculture sector between 2017 and 2021. Encouragement of a smart farming route can assist agricultural practitioners worldwide in lowering their environmental impact while increasing their productivity and competitiveness. The second goal of this document is to illustrate the novel developments in smart farming that resulted from the COVID-19 epidemic. Finally, the third goal of this chapter is that this study adds to the ongoing and updated conversation about the tactics agricultural practitioners should devise in light of the major developments in industry 5.0 technologies in the post-pandemic environment [8, 9].

Integrating new energy sources is the second objective of smart farming, which will result in the growth of a sustainable agriculture industry. Most agricultural machinery is powered by fossil fuels, both of which exacerbate climate change and increase greenhouse gas emissions. Renewable energy sources, however, can lessen the aforementioned problems. The agricultural industry can benefit greatly

# CHAPTER 5

# Empowering Indian Agriculture with the Internet of Things

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**Abstract:** The Internet of Things (IoT) can significantly increase the efficiency and effectiveness of yield in agriculture. India's farmers face several difficulties, such as trade, technological, and environmental restrictions that lower production. With the use of IoT-enabled agricultural equipment that provides real-time monitoring of temperature, soil moisture, and many other tasks becomes easy. The IoT has the potential to transform agriculture by enabling farmers to make data-driven decisions, optimize resource utilization, and improve overall efficiency. IoT in agriculture empowers farmers with real-time data and automation capabilities, enabling them to make informed decisions, increase productivity, reduce costs, and contribute to more sustainable and environmentally responsible farming practices. Smart farming has a substantial contribution to the Indian economy and contributes handsomely to the Gross Domestic Product.

**Keywords:** Agriculture automation, Cloud computing, Data driven decisions, Internet of things, Industry 5.0, Smart agriculture.

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**Parikshit N. Mahalle, Gitanjali R. Shinde, Namrata N. Wasatkar & Prashant R. Anerao (Eds.)**

## INTRODUCTION

The agriculture sector plays a vital role in India's economy and society. Agriculture is the largest employer in India, providing livelihoods to a significant portion of the population, particularly in rural areas [1]. It is the primary source of income for millions of households, supporting both farmers and laborers. Agriculture is the backbone of India's food security. It provides the nation with a diverse range of crops and staples, ensuring a stable food supply for its vast and growing population [2]. It helps prevent food shortages and price fluctuations. Agriculture has a significant contribution to India's GDP share. Major agricultural exports from India include rice, wheat, spices, fruits, and vegetables [3]. Exports of agricultural commodities contribute significantly to the country's foreign exchange earnings. Agriculture supplies raw materials to various industries, including textiles, food processing, and agriculture-based industries [4].

Farmers' suicides have been a persistent issue in India. These suicides are primarily linked to the agrarian crisis in the country, which has been characterized by a combination of factors, including financial distress, crop failures, and debt burdens [5]. To address this concern, a sustainable solution must be provided. Many farmers in India practice traditional and sustainable farming methods, preserving biodiversity and taking care of the environment. Sustainable agricultural practices are essential for long-term environmental conservation. A significant proportion of the rural population in India lives below the poverty line. Sustaining and enhancing the role of agriculture in the Indian economy requires modernization, innovation, and sustainable practices to meet the evolving needs of the country's growing population and changing economic landscape [6].

Global farming techniques have undergone a transformation in the last several years due to the convergence of agriculture and technology. Through the evolution of Artificial Intelligence (AI) technology and its applications in agriculture, there have been several generations of AI in agriculture. The revolution of traditional agriculture to smart agriculture is shown in Fig. (**1**). Agriculture 1.0 *i.e.* traditional agriculture was featured by humans, animal power, and using simple tools for basic needs of farming tasks. Mainly wood and iron-based simple tools were used and later those were replaced by machines in Agriculture 2.0. Those machines were powered by steam and coal. It helped with mass production along with the use of chemicals and composts. Agriculture 3.0 was the age of automatic electric motors, petroleum, thermal hydro-power, and nuclear-powered engines. It helped to improve the level of agricultural mechanization through information technology. IoT, AI, and computerized programs that support Machine Learning (ML) and intelligence are the hallmarks of Agriculture 4.0.

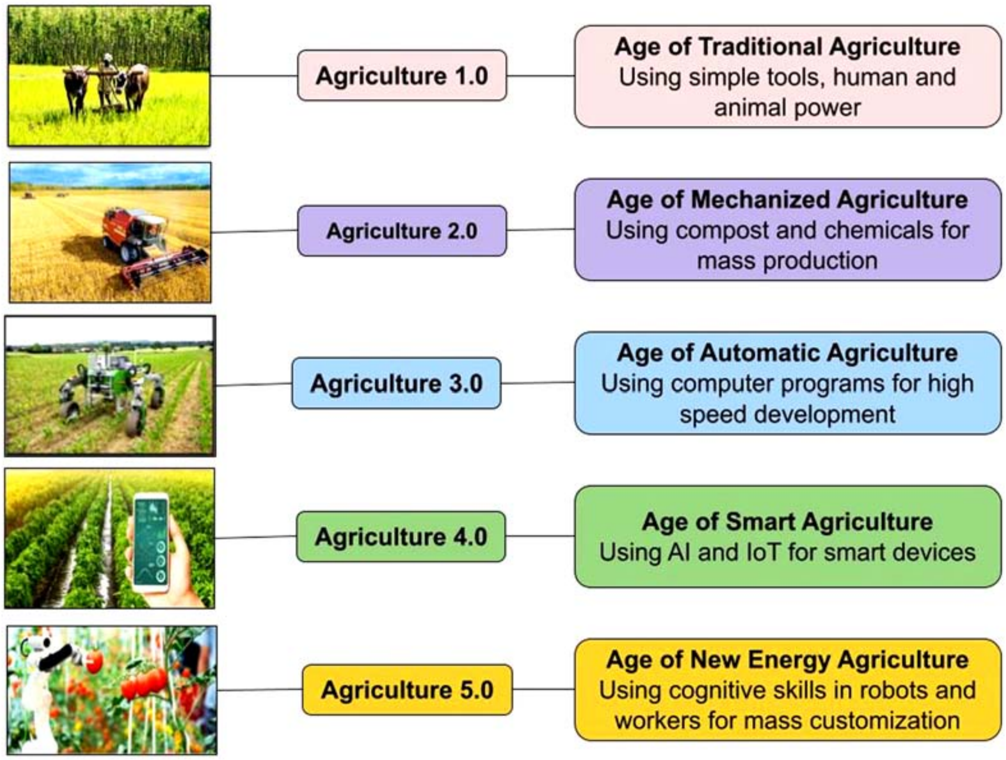


**Fig. (1).** Revolution of agriculture from Agriculture 1.0 to 5.0.

Industry 5.0 based agriculture 5.0 is the age of new renewable energy resources such as solar energy, and wind power along with recent trendy technologies. As human intelligence coexists peacefully with cognitive computing, it is more concerned with human-machine cooperation. Collaborative robots and workers are enabling value-added operations in manufacturing that result in bulk customization and client personalization. With each generation of AI in agriculture, advances are made in the way agricultural tasks are performed, resulting in a reduction in costs, a greater availability of food, and a greater sustainability of the industry.

India, with its vast and diverse agricultural landscape, has been quick to recognize the potential of these technological advancements in enhancing agricultural productivity, sustainability, and overall food security. At the forefront of this digital agricultural transformation is the IoT [6]. IoT is a network of interconnected devices and sensors that collect real-time data and exchange data to enable smarter decision-making. The IoT has emerged as a powerful tool that holds the promise of addressing critical challenges faced by Indian farmers, such

# CHAPTER 6

# Artificial Intelligence-Based Predictive Maintenance Approaches for Vehicle Condition Monitoring and On-Board Diagnostic Systems to Enhance Automotive Industries

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**Abstract:** Integration of Artificial Intelligence (AI) into the automobile sector represents a transformative force reshaping the automotive industry landscape. Al is catalyzing a paradigm shift in streamlining manufacturing processes and predictive maintenance of autonomous vehicles. The synthesis of AI and automotive technologies is not merely a luxury but a strategic necessity, asserting itself as an indispensable driver for progress and competitiveness in the evolving automotive landscape. Increasing vehicle system intelligence, allowing vehicles to detect pedestrians, identify lanes and stop signs, and make judgments using algorithmic analysis of information from cameras and sensors are some of their main goals. Large-scale assessments are made possible using Logged Vehicle Data (LVD) without the need for further measuring tools. Because of its intuitive interface, On-Board Diagnostic (OBD II) systems are becoming increasingly popular. OBD II, in contrast to prior iterations, monitors every emission-related component on any kind of vehicle.

The second-generation OBD-II system's combination of cloud computing, wireless networks, and cloud computation technologies allows for the real-time monitoring of critical data. This comprises dynamic data points, fault codes, coolant temperature, engine RPM, and vehicle speed. The in-house OBD scanning technology proves to be a useful tool in the automotive industry's quest to improve vehicle condition monitoring *via* AI-driven predictive maintenance strategies. AI currently plays and the anticipated future contributions within the industry and its intricate supply chains. This paper will meticulously unravel the specific domains where AI interventions are proving pivotal, such as enhancing vehicle safety, optimizing supply chain logistics, and revolutionizing the user experience. This paper also aims to underscore the critical significance of integrating Artificial Intelligence (AI) within the automobile industry. Furthermore, a comprehensive exploration of Al's expected trajectory and its influence on decision-making processes, fostering innovation, and bolstering overall operational efficiency in

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the automobile industry is discussed. Through a thorough examination of the current state and prospects, this paper endeavors to compellingly demonstrate the imperativeness of AI implementation in the automobile industry.

**Keywords:** Artificial intelligence, Automotive industries, On-board diagnostic system, Predictive maintenance, Vehicle condition monitoring.

## INTRODUCTION

### Predictive Maintenance 2.0: The Next Revolution

A Predictive Maintenance (PdM) program's primary goal is to detect probable defects or failures in a system early on, followed by the timely implementation of maintenance procedures. PdM data serves a dual role, providing diagnostic insights into current difficulties as well as predictive information about future occurrences. This data not only identifies the kind and location of problems, but it also explains the underlying reasons, distinguishing between minor flaws and impending failures, and even forecasting the time of failures. Leveraging such detailed information obtained from PdM data allows for a change toward proactive maintenance tactics, which improves the overall efficacy and efficiency of maintenance operations. Implementing Predictive Maintenance (PdM) is complex for enterprises, requiring meticulous planning for hardware, software, personnel, and training. As maintenance difficulties increase, outsourcing to specialist businesses becomes a viable alternative [1]. Internally managing PdM necessitates tough decisions, particularly about technology, software, personnel, and training.

The initial step involves identifying crucial elements for monitoring and pinpointing specific parameters indicative of degradation. Selecting suitable Predictive Maintenance (PdM) methodologies requires careful consideration, and referencing a relevant guide, such as Table **1**, can aid in this decision-making process. Deciding on the optimal placement of sensors is pivotal, as is establishing critical thresholds for each variable. Determining the inspection frequency involves options such as continuous monitoring, condition-based intervals, or regular intervals based on expert opinion, manufacturer recommendations, or historical performance. Finally, selecting an appropriate Computerized Maintenance Management System (CMMS) to administer the maintenance program is crucial.

**Table 1. Challenges and futuristic roadmaps in Predictive Maintenance.**

| S. No. | Key Findings | Challenges and Future Directions |
|---|---|---|
| 1 | Deep learning's role in autonomous driving. | Integration with advanced infrastructure like IoT, cloud, and blockchain technologies. |
| 2 | Taxonomy for self-driving vehicles, hybrid human-AI architecture. | Safety standards, data security and privacy using blockchain, performance with 5G networks. |
| 3 | The utilization of autonomous systems such as drones. | Detailed connections between drones and autonomous vehicles. |
| 4 | Configuration, elements, and functionalities for self-driving cars, intelligent unmanned aerial vehicles (UAVs), and drones; security concerns related to AI-based attacks [2] | In-depth discussions on technological aspects of autonomous vehicles and systems. |

## Predictive Maintenance Benefits

The benefits of Predictive Maintenance (PdM) are extensive and highly rated, encompassing enhanced worker safety and environmental protection, which receive top ratings for their critical importance. The increased dependability of equipment is highly valued, leading to improved operational uptime. Quality of products sees a significant boost, often rated highly by manufacturers. PdM also leads to notable reductions in expenses associated with parts and labor, receiving strong financial ratings. Moreover, it minimizes the wastage of raw materials and consumables, including lubricants, which are highly rated for sustainability. Energy conservation through optimized machinery, such as alignment improvements yielding 3%-5% savings and balancing enhancements providing 1%-2% efficiency gains, also garners high ratings for its positive impact on operational efficiency [1, 3].

## ARCHITECTURE OF IOT-BASED PREDICTIVE MAINTENANCE SYSTEM

The structure of an IoT-driven predictive maintenance system is intricately designed, drawing upon a network of interconnected devices, sophisticated data analytics, and advanced machine learning algorithms:

The core of the system is built upon a network of IoT devices, each housing a variety of sensors strategically placed throughout the equipment. These sensors work incessantly to collect live data, covering essential metrics such as temperature, vibration, pressure, and humidity [4]. Fig. (**1**). shows the architecture of the IoT-based predictive maintenance system and the data transfer and storage in the IoT-based predictive maintenance system. Data harvested by sensors

# CHAPTER 7

# Transforming Industry 5.0: Navigating the Future of Manufacturing Industries

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**Abstract:** This chapter examines the main features, trends, and consequential consequences of the Industrial Revolution in manufacturing industries as one of the industries 5.0 symbolises the beginning of a new age replete with progressive change and improvement. In this chapter, there are very detailed descriptions regarding the major forces, and impacts relating to this industrial revolution. In addition to the foundations that have been set by Industry 4.0, Industry 5.0 focuses on the partnership of human beings with artificial intelligence and other innovations. In this chapter, we examine what can be considered as the defining features of Industry 5.0 such as customization, flexibility, and cipher physical integration into one process. During the discussion of the findings, technological enablers including artificial intelligence, the Internet of Things, blockchain, and augmented reality will be discussed to explain how they are set to empower Industry 5.0 forward. By adapting them, companies can make a transition by enhancing efficiency, innovation, and competitiveness as was illustrated by case studies. This article expands the discussion to the concerns on workforce readiness, security, and ethical perspective pertaining to this shift. Accordingly, this chapter examines the consequences and transformation of manufacturing environments globally with respect to Industry 5.0 and presents the difficulties and prospects that may occur in connection with the change. At the end of the chapter, some forecasts are made concerning the development of the industry and the appeal to carry out proactive research and remodeling of industries that are in the process of development all the time. It is also an industry guide that transforms the industry Transforming Industry 6. Hence, 0 offers a prognosis, solution, and a futuristic assessment of today's manufacturing industries and the cardinal symptoms of Industry 5.

**Keywords:** Artificial intelligence, Fourth industrial revolution, Industries, Industrial internet of things, Robot sensing systems, Service robots, Surveys.

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## INTRODUCTION

A phenomenon known as Industry 4.0, also called Industry 4.0 or the fourth industrial revolution, describes how digital technology is incorporated into the production process for various products. There has been a shift away from a more traditional industrial model to one with greater interconnectedness, greater automation, and an increased reliance on data. There has been a change in the arsenal. Industrial 4.0 refers to the use of digital technology in manufacturing and production processes and is associated with the fourth industrial revolution. They incorporate cyber-physical systems, the Internet of Things, big data, artificial intelligence, and automation, leading to smart factories. As a result of these technologies, discrete machines, systems, and processes can communicate and collaborate with one another so they can evaluate data and make decisions independently, resulting in a higher level of manufacturing efficiency, flexibility, and customization [1-3]. An integral part of Industry 4.0 is a shift from a traditional industrial predicament to one that is digitally advanced, networked, and increasingly networked, in conjunction with manufacturing. An important aspect of the industry is shown in Fig. (**1**).

- **Cyber-Physical Systems (CPS):** The operations that fall under this category are those in which the physical processes are described, controlled, and directed by computerized algorithms, which provide a direct relationship between the cyber and the physical entities. There are some of them that are smart factories, which entail the integration and linking of various production assets such as machinery and equipment [4].
- **Internet of Things:** The Internet of Things (IoT) refers to the technological capability of connecting physical objects to the Internet, so transforming them into intelligent devices that are able to collect and transmit data. When considering Industry 4.0, it is important to note that the Internet of Things (IoT) also involves the connection between machines and sensors, and these devices make it easier to integrate production processes [5].
- **Big Data and Analytics:** Data from interconnected devices and systems, which are created in large quantities, is being processed and used for a variety of reasons, including to improve decision making, improve a variety of processes, and determine when it is most appropriate to address a variety of failures.
- **Automation and Robotics:** The term "Industry 4.0" refers to the employment of robotic systems and automation in order to carry out activities that were previously carried out in a conventional manner. It is general knowledge that these technologies improve the speed, accuracy, and efficiency of production while simultaneously reducing the role of human hands and, as a result, the cost of labor [6].
- **Artificial Intelligence & Machine Learning:** The analysis of data, the

prediction of outcomes, and the optimization of industrial processes are all handled by AI and ML algorithms. They make it possible for robots to learn from data and make decisions with significantly less involvement from humans [7].

- **Smart Factories:** A smart factory can be described as an advanced production plant where CT, IoT, AI, and automation are integrated to enhance production. Some of the features and capabilities that smart factories are able to provide include automatic fine-tuning of performance, real-time fault and failure anticipation as well as dynamic reconfiguration based on new situations [8].
- **Cloud Computing:** Cloud technology provides the infrastructure for storing and processing large amounts of data generated by Industry 4.0 technologies. It allows for scalable computing resources, enabling companies to manage their operations more efficiently [9].
- **Augmented Reality (AR):** AR is employed to expand the workers' competencies through registering digital info on top of physical environments. The areas of application of AR in manufacturing are for example assembly, maintenance, and quality assurance since it can provide real-time information and instructions [10].

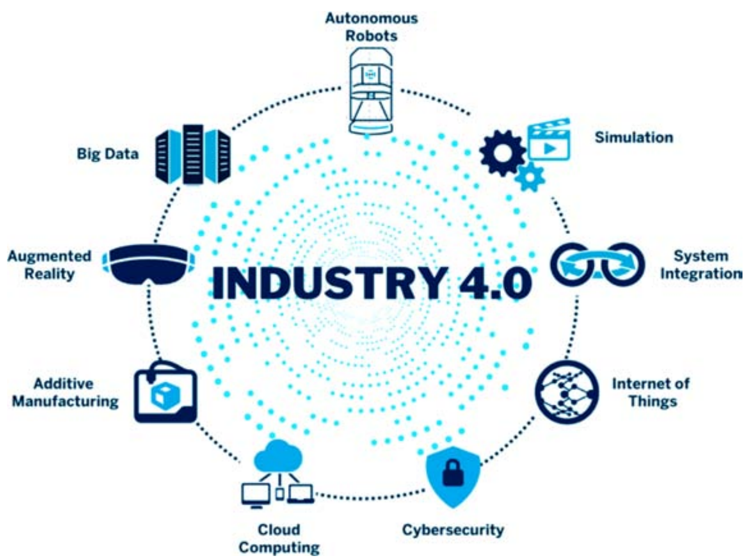


**Fig. (1).** Industries 4.0.

**Impact of Industry 4.0:** Industry 4.0 is the sequence that has brought a dramatic change to manufacturing through effective, adaptable, and customer-oriented production-cycle strategies. It has also led to the concept of mass customization whereby goods can be made in large quantities but designed in smaller private batches to match the customers' characteristics [11, 12]. Furthermore, Industry

**CHAPTER 8**

# Green Computing and Sustainable Practices for Renewable Energy Systems for Enhancing Energy Sectors Performance Optimization - An Extended Overview

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**Abstract:** The industry's extensive energy use and contribution to carbon emissions underscore the need for sustainable solutions. While green computing endeavors to enhance energy efficiency in computer systems, a more impactful strategy involves integrating renewable energy sources. This holistic approach, incorporating solar, wind, hydro, geothermal, and biomass power into IT infrastructure, can substantially decrease the industry's carbon footprint. The focus is on the creation of sustainable data centers, intelligent power systems, and energy-aware algorithms, all of which contribute to a more ecologically responsible computing ecosystem. Such integration not only aids in climate change mitigation but also fosters the IT sector's autonomy, reducing reliance on fossil fuels. Furthermore, the synergy between green computing and renewable energy systems creates a positive feedback loop, enhancing the energy efficiency of computer systems through the consumption of renewable, clean energy sources. In essence, this complete approach positions the IT industry for a greener, more resilient future, linking it with worldwide efforts to battle global warming and create a more ecologically friendly world. This holistic strategy sets the path for a cleaner and more environmentally friendly future for the IT sector, aligning it with global efforts to combat climate change. This chapter explores the collaborative potential of green computing and renewable energy systems in addressing environmental challenges stemming from the rapid expansion of the information technology sector. The current study will assist people in realizing and taking some measures to save a significant quantity of power that is now being squandered on a massive scale in the computer and electronics business.

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**Keywords:** Collaborative potential, Green computing, Information technology, Renewable energy systems, Rapid expansion, Sustainable development.

## INTRODUCTION

Green computing is the activity of designing, producing, utilizing, and disposing of computers and other electronic equipment in an ecologically responsible manner. In the present digital age, the exponential advancement of information technology has transformed practically every area of human life. Our reliance on computing systems is ubiquitous, spanning communication and commerce, entertainment, and education. Cloud computing is increasingly being used in various fields, necessitating a shift towards green computing to reduce power consumption and $CO_2$ emissions. Large amounts of power are needed to run the servers, coolant fans, consoles, monitors, internet accessories, lighting, and ventilation systems in these hundreds to thousands of square-foot data centers [1]. However, this rapid proliferation comes at a cost: the escalating demand for energy consumption and the associated environmental impact. As concerns over climate change intensify, the imperative to mitigate these effects has become increasingly urgent. As a result, the combination of clean energy and green computing has become a source of hope, providing a route towards sustainable technological progress. Companies may drastically lower their operational expenses and carbon footprint by putting environmentally friendly computing principles like cloud computing, server synthesis, and energy-efficient technology into practice. Additionally, utilizing renewable energy sources such as solar or wind power can further decrease the environmental impact of these data centers. As technology advances, it is critical that organizations and individuals prioritize sustainability to lessen the consequences of climate change and secure a more greener future. As more businesses and individuals adopt green computing practices and invest in renewable energy solutions, we get closer to creating a more sustainable future for everyone.

This chapter conducts an in-depth investigation of the symbiotic link between green computing and renewable energy in the information technology sector. By investigating the crossing areas of technology and sustainability, we hope to expose the revolutionary potential of this synergy and its implications for computing's future. Through a comprehensive analysis of case studies and industry trends, we aim to highlight the tangible benefits of integrating green computing practices with renewable energy sources. By exploring the potential cost savings, environmental impact reductions, and operational efficiencies that can be achieved through this integration, we seek to inspire greater adoption of sustainable IT solutions across the industry. Additionally, we will examine the challenges and barriers that currently hinder the widespread implementation of green computing and renewable energy solutions and propose strategies for overcoming these obstacles. Finally, we hope to create a road map for businesses and individuals to move to a more sustainable and ecologically responsible future using green computing and renewable energy. By emphasizing the benefits and possible obstacles of these solutions, we want to drive wider adoption and build a more sustainable world for future generations.

The Electronic Products Environmental Assessment Tool (EPEAT), provided by the Green Electronics Council, helps customers choose ecologically conscious computer equipment. This tool evaluates computer equipment based on 28 factors, including product efficiency and sustainability. The information and communication technology (ICT) industry currently consumes 3% of global energy, with a projected double-digit increase by 2030. In response, computer companies are increasingly supporting environmental initiatives. Employing the Environmental Computing Phase, which addresses tactics, architecture, implementation, procedures, and constant enhancement, organizations can create and apply green computing solutions. Green data centers, virtualization, cloud computing, power optimization, and grid computing are the five main green computing technologies that the Green Computing Initiative (GCI) supports. These technologies aim to reduce energy consumption, carbon emissions, and electronic waste. Green data centers employ energy-efficient servers and cooling systems to minimize environmental impact. Virtualization reduces the demand for servers and saves energy by allowing multiple OSes to run on only one physical server. Cloud computing facilitates resource access and sharing over the internet, leading to reduced energy consumption and carbon emissions. Power optimization maximizes energy efficiency in computing systems, while grid computing distributes computing tasks across multiple computers to increase efficiency and decrease electrical usage. Organizations can save money in the long run and contribute to a more environmentally friendly future by adopting these green computing technologies.

The ICT sector significantly contributes to global carbon emissions, with data centers alone consuming 0.3% of global electricity demand. In 2020, the ICT sector's carbon emissions amounted to 1.8 to 2.8% of global emissions, highlighting the urgency of adopting greener computing practices. The entire internet was responsible for about 3.7% of global carbon emissions in 2018, underscoring the need for sustainable computing practices to mitigate environmental impacts [3]. Through initiatives focused on energy efficiency optimization, renewable energy adoption, and sustainable design integration, the ICT sector can substantially reduce its environmental impact. Data centers and computer infrastructure are increasingly being powered by sources of clean

# CHAPTER 9

# Green Computing Application Development with Deep Learning towards Sustainable Development

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**Abstract:** The convergence of deep learning technology and green application development marks a transformative era for both Industry 5.0 and Society 5.0. This abstract explores the dynamic synergy between deep learning algorithms and sustainable practices, with the goal of driving industries towards greater ecological consciousness while fostering societal advancement. Deep learning, a subset of artificial intelligence, possesses unparalleled capabilities in processing vast datasets and extracting intricate patterns, making it a powerful tool for optimizing green applications across various sectors. Within this abstract, we delve into the symbiotic relationship between deep learning and green development, shedding light on its multifaceted implications for Industry 5.0 and Society 5.0. This study analyzes how deep learning enhances renewable energy systems, optimizes resource management, and revolutionizes sustainable manufacturing processes. Additionally, this study examines the integration of deep learning-enabled decision-making and fuels innovation in green technologies, thereby facilitating the transition towards more environmentally responsible practices. Beyond industry, this abstract investigates the societal impacts of deep learning-enabled green application development, including improved quality of life, equitable access to sustainable resources, and the cultivation of eco-conscious communities. By highlighting the potential of deep learning to catalyze sustainable progress within the framework of Industry 5.0 and Society 5.0. The proposed research emphasizes the importance of embracing technological innovation as a catalyst for global sustainability and societal well-being. Green application development and deep learning are two distinct fields that have recently gained significant attention in the technology industry. Green application development focuses on creating software and systems with minimal environmental impact, while deep learning involves training complex neural networks to perform tasks that traditionally require human intelligence. The intersection of these fields is crucial for addressing the environmental concerns associated with the energy consumption and carbon emissions of deep learning models.

**Keywords:** Deep Learning, Energy efficiency, Green Computing, Sustainable development.

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## ORGANIZATION OF CHAPTER

An overview of green computing and its importance in sustainable development is covered in section 1. A summary of deep learning algorithms and architectures as well as applications of deep learning in energy optimization and sustainability is covered in section 2. Deep learning models and algorithms for eco-friendly and sustainable applications are covered in section 3. Section 4 describes more about case studies and applications of deep learning in environment monitoring. Future trends and challenges are mentioned in section 5.

## INTRODUCTION

Green deep learning is an increasingly hot research field that aims to reduce the energy consumption and environmental impact of deep learning models. This involves the development of energy-efficient training strategies, compact networks, and other technologies to achieve state-of-the-art results with reduced computational resources [1, 2]. The AI community must aim to reduce energy consumption when building deep learning models, as the computations required by state-of-the-art models have been increasing at an alarming rate [3]. The intersection of green application development and deep learning is essential for achieving sustainability in AI and technology innovation. It involves the pursuit of energy-efficient deep learning solutions, such as neuromorphic computing, to reduce the environmental impact of AI systems [4]. Deep learning is being applied to optimize innovative waste management and create smart environmental solutions, demonstrating the potential for deep learning to contribute to green application development [5].

Precisely, the intersection of green application development and deep learning is driving the development of energy-efficient deep learning technologies, with a focus on reducing the environmental impact of AI systems and promoting sustainability in technology innovation. This area of research is critical for addressing the energy consumption and carbon emissions associated with deep learning models and advancing the development of green AI solutions. Industry 5.0 is a paradigm that emphasizes cooperation, long-term sustainability, and human-robot interaction with AI, which aims to create a manufacturing environment that is both efficient and innovative. These contribute to the society *via* various applications addressing the following aspects of human-robotic interactions, circular economy, human-centric approach and many more training a single AI model or deep learning model can result in a substantial carbon footprint, emitting up to 626,155 pounds of $CO_2$, which is approximately equal to the total lifetime carbon footprints of five cars as depicted in fig. (**1**). This is primarily due to the significant energy consumption involved in the training process, which can amount to 656,347-kilowatt hours of energy. The environmental impact of training AI models is a growing concern, and efforts are being made to address this issue. For instance, researchers have recommended the use of renewable energy to power data centers and the development of efficient algorithms to reduce the energy needed for training AI models. While the carbon footprint of AI training is significant, there are ongoing efforts to minimize its environmental impact [6, 7]. Sustainable deep learning applications are important in the context of Industry 5.0, which can solve necessary problems of society 5.0. By embracing these technologies, it can create a more inclusive, efficient, and sustainable manufacturing environment that would not cause any harm and benefit everyone.

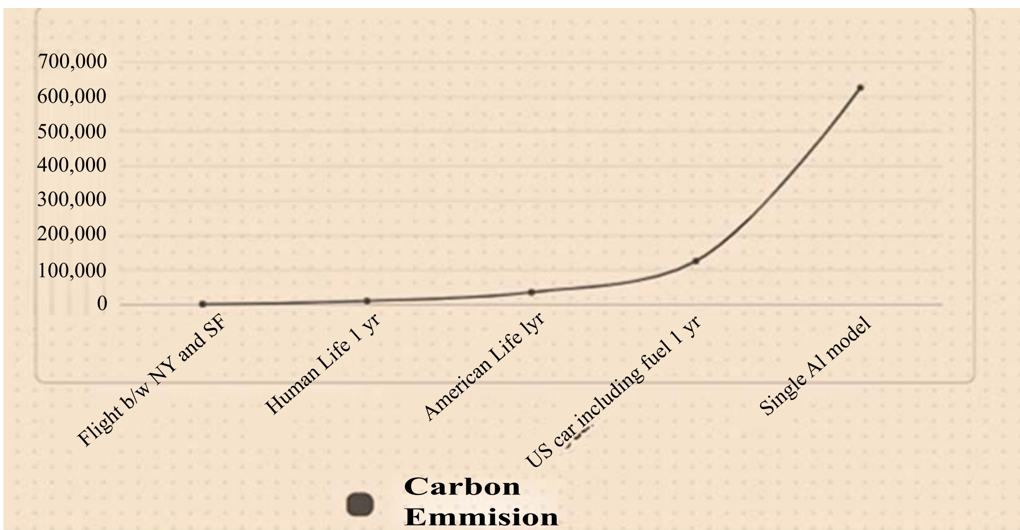


**Fig. (1).** Carbon emission analysis.

## MOTIVATION

Deep Learning plays a crucial role in advancing sustainable development through various key factors. In light of the pressing issues surrounding climate change and environmental degradation, the adoption of sustainable practices across all industries, including computing, is imperative. Green Computing is essential for minimizing the environmental impact of technology and achieving long-term sustainability objectives. The Power of Deep Learning: Deep Learning has proven to be a valuable tool in different fields, such as energy optimization and environmental monitoring. By harnessing Deep Learning techniques, we can create intelligent solutions that not only enhance efficiency but also contribute to a more eco-friendly and sustainable future. The energy consumption of computing infrastructure is substantial, resulting in carbon emissions and environmental

# SUBJECT INDEX

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Prof. Parikshit is a senior member IEEE and a professor, Dean Academics at Vishwakarma Institute of Technology, Pune, India. He did Ph.D. from Aalborg University, Denmark in 2013, and completed post-doctoral research at CMI, Copenhagen, Denmark. He has 25 years of teaching and research experience. He has 52 patents, more than 400 research publications including 69 books. Besides, his Google Scholar citations are 4000 plus, H index-28 and Scopus Citations are 2000 plus with H index -21, Web of Science citations are 545 with H index - 11). He is editor in chief of Research Journal of Computer Systems and Engineering (RJCSE), associate editor for IGI Global - Journal of Affective Computing and Human Interfaces (JACHI), etc. His research interests are machine learning, data science, algorithms, internet of Things, identity management and security. He is guiding 8 Ph.D. students in the area of IoT and machine learning. He is also the recipient of "Best Faculty Award" by Sinhgad Institutes and Cognizant Technologies Solutions.

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## Namrata N. Wasatkar

Prof. Namrata N Wasatkar has overall 11 years of experience, presently working as assistant professor, Associate Dean Academics at Vishwakarma Institute of Technology, Pune, India. She did Ph.D. in in 2022 in computer engineering from Savitribai Phule Pune University, Pune, India on Research Problem Statement "Rule based Machine translation of simple Marathi sentences to English sentences". She has received research funding for the project "SPPU online chatbot" by SPPU, Pune. She has published more than 20 papers in the national, international conferences and journals.

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Prof. Prashant R. Anerao is an assistant professor in the Department of Mechanical Engineering at the Vishwakarma Institute of Technology, Pune. He did M. Tech. in mechanical engineering, specializing in manufacturing engineering, from the Indian Institute of Technology, Bombay, in 2009. He is currently pursuing Ph.D. from Savitribai Phule Pune University. His research encompasses additive manufacturing of biocomposite and the application of artificial intelligence & machine learning in 3D printing. He has published 17 research papers in peer-reviewed journals, contributed 2 book chapters, and presented 13 findings at national and international conferences. He has been granted 8 patents. He has extensive experience collaborating with a range of prominent industries and also has approximately 15 years of teaching experience.