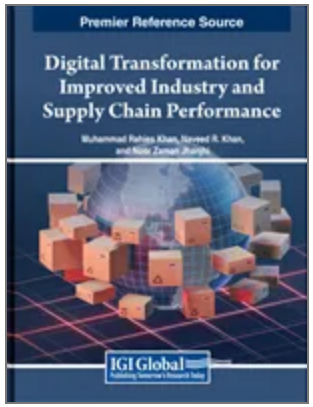

Smart Factories Greener Future: A Synergy of Industry 4.0 and Sustainability

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Abstract

The integration of Industry 4.0 and sustainability has paved the way for transformative practices in manufacturing, leading to the development of smart factories with a focus on greener futures. This chapter explores the synergy of Industry 4.0 technologies and sustainability. It emphasizes the collective potential of the two paradigms for the optimization of production processes, energy efficiency, and waste management. The integration of Industry 4.0 technologies including artificial intelligence, internet of things, big data analytics, robotics, and automation is playing a pivotal role in transforming the manufacturing processes and enabling the environmentally sustainable operations. The development of smart factories aligning with the sustainability goals has led to eco-efficiency and greener futures. In this chapter, responsible sourcing, circular economy, and energy management have been investigated along with the implementation opportunities and challenges.

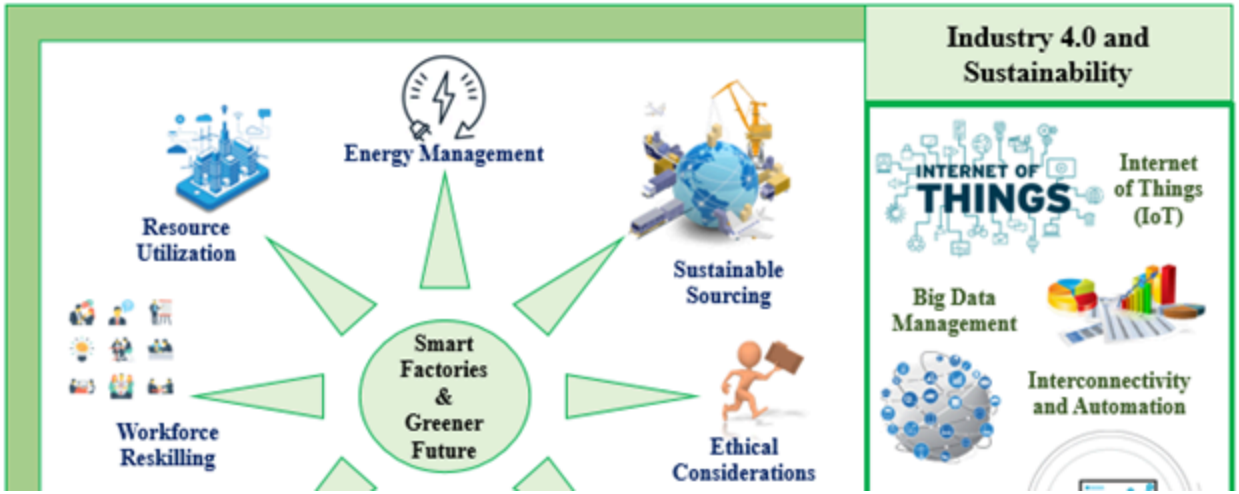
Full Text Preview

Introduction

The industrial landscape has been remodeled with the integration of Industry 4.0 technologies including Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, blockchain, robotics and automation (Jamwal et al., 2021) (Almusaylim & Zaman, 2019; Piccarozzi et al., 2018). Meanwhile, the importance of sustainability has being highlighted in various global platforms to deal with eco-friendly operations and resource management in diverse sectors. The mutual potential of sustainability and Industry 4.0 has led to the optimization of several smart factory operations, such as energy efficiency, waste reduction, and production process optimization. In Industry 4.0, the interconnectivity of several smart devices has been introduced by the IoT (Alex et al., 2022) (Siddiqui et al., 2022). The exponential increase in the number of smart devices has led to the real-time collection and dissemination of huge amounts of data through sensors (Bilal et al., 2020). Similarly, big data technologies enable real-time data analytics, thus assisting in promoting sustainable practices via informed decisions. Moreover, the blockchain technology, robotics, and automation have been integrated in smart factories and play a vital role in enabling the processes for sustainability (Enyoghasi & Badurdeen, 2021).

For, the intelligent, automated, and interconnected industrial ecosystem, advanced technologies under the umbrella of Industry 4.0 have been leveraged. The transformation of smart factories for sustainability has been only possible by integrating the technologies like big data analytics, machine learning, AI, IoT, and cyber physical systems (Mughal et al., 2024). The enhancement of productivity, adaptability, and operational efficiency while retaining the greener futures goals are the main objective of the synergy of Industry 4.0 and sustainability. Similarly, sustainability goals and practices have become global issues to enhance the processes of resource consumption, waste management, human, ecological, and economic wellbeing. Hence, the synergetic relationship of sustainability and Industry 4.0 technologies has enabled the smart and eco-efficient manufacturing and production processes, leading to the smart factories for greener futures. This has been enabled primarily by real-time data collection by leveraging IoT, automation, and real time data analysis for informed decision making powered by big data technologies and artificial intelligence. This phenomenon reduce waste generation, energy and resource consumption ultimately influencing the overall environmental footprint.

Figure 1. Synergy of Industry 4.0 technologies and sustainability for smart factories



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Supply chain management is also influenced significantly by the advanced technologies and the concept of smart factories (Telukdarie & Bag, 2018). However, certain aspects need to be considered for sustainable industrial trends, such as, societal impact, rules and regulations, standards and policies, and generally the support from the top stakeholders and industrial partners (Harikannan et al., 2021). As a vital part of Industry 4.0 revolution, the blockchain has the potential to increase the sustainability particularly in supply chain management by leveraging its trustworthy properties including the transparency, immutability, accountability, and credibility, which can ultimately impact the energy, data, and resource management at large scale (Esmaeilian et al., 2020). Several researchers have highlighted the role of interconnectivity, automation, robotics, big data analytics and blockchain technology as fundamental concepts in the realm of Industry 4.0 technologies and their role to attain sustainability practices (Jamwal et al., 2021). Figure 1 depicts an overview of the sustainability practices in smart factories and how this effort of sustainability is supported by its synergetic relations with the Industry 4.0 technologies.

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References

Follow Reference — Alex, S. A. S, P., R, A. T., Jhanjhi, N. Z., & Tayyab, M. (2022). Machine Learning-Based Wearable Devices for Smart Healthcare Application With Risk Factor Monitoring. In *Empowering Sustainable Industrial 4.0 Systems With Machine Intelligence* (pp. 174–185). IGI Global. 10.4018/978-1-7998-9201-4.ch009

Follow Reference — Almusaylim Z. A. Zaman N. (2019). A review on smart home present state and challenges: Linked to context-awareness internet of things (IoT).Wireless Networks, 25(6), 3193–3204. 10.1007/s11276-018-1712-5

Follow Reference — Alves Filho S. E. Filgueira Burlamaqui A. M. Aroca R. V. Goncalves L. M. G. De Lima Sa S. T. (2018). Green Robotics: Concepts, challenges, and strategies.Revista IEEE América Latina, 16(4), 1042–1050. 10.1109/TLA.2018.8362135

Follow Reference Astill J. Dara R. A. Campbell M. Farber J. M. Fraser E. D. G. Sharif S. Yada R. Y. (2019). Transparency in food supply chains: A review of enabling technology solutions.Trends in Food Science & Technology, 91, 240–247. 10.1016/j.tifs.2019.07.024

Follow Reference Bilal M. Usmani R. S. A. Tayyab M. Mahmoud A. A. Abdalla R. M. Marjani M. Pillai T. R. Targio Hashem I. A. (2020). Smart Cities Data: Framework, Applications, and Challenges. In AugustoJ. C. (Ed.), Handbook of Smart Cities (pp. 1–29). Springer International Publishing. 10.1007/978-3-030-15145-4_6-1

Follow Reference Bogue R. (2022). The role of robots in the green economy.The Industrial Robot, 49(1), 6–10. 10.1108/IR-10-2021-0230

Follow Reference Byun D. H. (2016). Trend of Smart Factory and Model Factory Cases.The E-Business Studies, 17(4), 211. 10.20462/TeBS.2016.08.17.4.211

Follow Reference Davis J. Edgar T. Porter J. Bernaden J. Sarli M. (2012). Smart manufacturing, manufacturing intelligence and demand-dynamic performance.Computers & Chemical Engineering, 47, 145–156. 10.1016/j.compchemeng.2012.06.037

Follow Reference Despeisse M. Chari A. González Chávez C. A. Monteiro H. Machado C. G. Johansson B. (2022). A systematic review of empirical studies on green manufacturing: Eight propositions and a research framework for digitalized sustainable manufacturing.Production & Manufacturing Research, 10(1), 727–759. 10.1080/21693277.2022.2127428

Follow Reference Drozdova A. P. Molchanova S. M. Samoylov A. V. (2020). CLOSED-LOOP BUSINESS MODELS AS A MODERN APPROACH TO THE PROBLEM OF SUSTAINABLE ECONOMIC DEVELOPMENT. *EKONOMIKA I UPRAVLENIE*. PROBLEMY, RESHENIYA, 2(11), 133–139. 10.36871/ek.up.p.r.2020.11.02.018

Follow Reference Ebinger F. Omondi B. (2020). Leveraging Digital Approaches for Transparency in Sustainable Supply Chains: A Conceptual Paper.Sustainability (Basel), 12(15), 6129. 10.3390/su12156129

Follow Reference Enyoghasi C. Badurdeen F. (2021). Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels.Resources, Conservation and Recycling, 166, 105362. 10.1016/j.resconrec.2020.105362

Follow Reference Esmaeilian B. Sarkis J. Lewis K. Behdad S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0.Resources, Conservation and Recycling, 163, 105064. 10.1016/j.resconrec.2020.105064

Follow Reference Ghadimi P. Kara S. Kornfeld B. (2015). Renewable energy integration into factories: Real-time control of on-site energy systems.CIRP Annals, 64(1), 443–446. 10.1016/j.cirp.2015.04.114

Gigafactory Nevada. (n.d.). Tesla. https://www.tesla.com/en_my/giga-nevada (https://www.tesla.com/en_my/giga-nevada)

Follow Reference Gregori F. Papetti A. Pandolfi M. Peruzzini M. Germani M. (2017). Digital Manufacturing Systems: A Framework to Improve Social Sustainability of a Production Site.Procedia CIRP, 63, 436–442. 10.1016/j.procir.2017.03.113

Follow Reference Gupta H. Kumar A. Wasan P. (2021). Industry 4.0, cleaner production and circular economy: An integrative framework for evaluating ethical and sustainable business performance of manufacturing organizations.Journal of Cleaner Production, 295, 126253. 10.1016/j.jclepro.2021.126253

Follow Reference Haanstra W. Toxopeus M. E. Van Gerrevink M. R. (2017). Product Life Cycle Planning for Sustainable Manufacturing: Translating Theory into Business Opportunities.Procedia CIRP, 61, 46–51. 10.1016/j.procir.2016.12.005

Follow Reference Harikannan N. Vinodh S. Gurumurthy A. (2021). Sustainable industry 4.0 – an exploratory study for uncovering the drivers for integration.Journal of Modelling in Management, 16(1), 357–376. 10.1108/JM2-11-2019-0269

Follow Reference Humayun M. Niazi M. Jhanjhi N. Alshayeb M. Mahmood S. (2020). Cyber Security Threats and Vulnerabilities: A Systematic Mapping Study.Arabian Journal for Science and Engineering, 45(4), 3171–3189. 10.1007/s13369-019-04319-2

Follow Reference Jamwal A. Agrawal R. Sharma M. Giallanza A. (2021). Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions.Applied Sciences (Basel, Switzerland), 11(12), 12. 10.3390/app11125725

Follow Reference Kayikci Y. (2018). Sustainability impact of digitization in logistics.Procedia Manufacturing, 21, 782–789. 10.1016/j.promfg.2018.02.184

Follow Reference Kim H. Quan Y.-J. Jung G. Lee K.-W. Jeong S. Yun W.-J. Park S. Ahn S.-H. (2023). Smart Factory Transformation Using Industry 4.0 toward ESG Perspective: A Critical Review and Future Direction.International Journal of Precision Engineering and Manufacturing-Smart Technology, 1(2), 165–185. 10.57062/ijpem-st.2022.0073

Follow Reference Kopnina H. (2019). Green-washing or best case practices? Using circular economy and Cradle to Cradle case studies in business education.Journal of Cleaner Production, 219, 613–621. 10.1016/j.jclepro.2019.02.005

Follow Reference Kumar M. Shenbagaraman V. M. Shaw R. N. Ghosh A. (2021). In FavorskayaM. N.MekhilefS.PandeyR. K.SinghN. (Eds.), Predictive Data Analysis for Energy Management of a Smart Factory Leading to Sustainability (Vol. 661, pp. 765–773). Springer Singapore. 10.1007/978-981-15-4692-1_58

Follow Reference Kumar N. Kumar G. Singh R. K. (2021). Big data analytics application for sustainable manufacturing operations: Analysis of strategic factors.Clean Technologies and Environmental Policy, 23(3), 965–989. 10.1007/s10098-020-02008-5

Follow Reference Lieder M. Asif F. M. A. Rashid A. Mihelič A. Kotnik S. (2017). Towards circular economy implementation in manufacturing systems using a multi-method simulation approach to link design and business strategy.International Journal of Advanced Manufacturing Technology, 93(5–8), 1953–1970. 10.1007/s00170-017-0610-9

Follow Reference Liu B. De Giovanni P. (2019). Green process innovation through Industry 4.0 technologies and supply chain coordination.Annals of Operations Research. 10.1007/s10479-019-03498-3

Follow Reference Lucke D. Constantinescu C. Westkämper E. (2008). In MitsuishiM.UedaK.KimuraF. (Eds.), Smart Factory—A Step towards the Next Generation of Manufacturing (pp. 115–118). Springer London. 10.1007/978-1-84800-267-8_23

Follow Reference Ma S. Zhang Y. Lv J. Yang H. Wu J. (2019). Energy-cyber-physical system enabled management for energy-intensive manufacturing industries.Journal of Cleaner Production, 226, 892–903. 10.1016/j.jclepro.2019.04.134

Follow Reference Ma S. Zhang Y. Ren S. Yang H. Zhu Z. (2021). A case-practice-theory-based method of implementing energy management in a manufacturing factory.International Journal of Computer Integrated Manufacturing, 34(7–8), 829–843. 10.1080/0951192X.2020.1757154

Follow Reference Maasmann, J., Bocker, S., Rettberg, F., Wietfeld, C., & Rehtanz, C. (2014). Renewable energies in smart factories with electric vehicle fleets. *2014 49th International Universities Power Engineering Conference (UPEC)*, (pp. 1–6). IEEE. 10.1109/UPEC.2014.6934778

Follow Reference Mahadevappa, P., Muzammal, S. M., & Murugesan, R. K. (2021). *A Comparative Analysis of Machine Learning Algorithms for Intrusion Detection in Edge-Enabled IoT Networks* (arXiv:2111.01383). arXiv. https://doi.org//arXiv.2111.0138310.48550

Follow Reference Maier A. Schriegel S. Niggemann O. (2017). In JeschkeS.BrecherC.SongH.RawatD. B. (Eds.), Big Data and Machine Learning for the Smart Factory—Solutions for Condition Monitoring, Diagnosis and Optimization (pp. 473–485). Springer International Publishing. 10.1007/978-3-319-42559-7_18

Follow Reference Matsunaga F. Zytkowski V. Valle P. Deschamps F. (2022). Optimization of Energy Efficiency in Smart Manufacturing Through the Application of Cyber–Physical Systems and Industry 4.0 Technologies.Journal of Energy Resources Technology, 144(10), 102104. 10.1115/1.4053868

Follow Reference McGrath P. McCarthy L. Marshall D. Rehme J. (2021). Tools and Technologies of Transparency in Sustainable Global Supply Chains.California Management Review, 64(1), 67–89. 10.1177/00081256211045993

Follow Reference Mohamed N. Al-Jaroodi J. Lazarova-Molnar S. (2019a). Industry 4.0: Opportunities for Enhancing Energy Efficiency in Smart Factories.2019 IEEE International Systems Conference (SysCon), (pp. 1–7). IEEE. 10.1109/SYSCON.2019.8836751

Follow Reference Mohamed N. Al-Jaroodi J. Lazarova-Molnar S. (2019b). Leveraging the Capabilities of Industry 4.0 for Improving Energy Efficiency in Smart Factories.IEEE Access : Practical Innovations, Open Solutions, 7, 18008–18020. 10.1109/ACCESS.2019.2897045

Follow Reference Mughal M. A. Ullah A. Cheema M. A. Z. Yu X. Jhanjhi N. Z. (2024). An intelligent channel assignment algorithm for cognitive radio networks using a tree-centric approach in IoT.Alexandria Engineering Journal, 91, 152–160. 10.1016/j.aej.2024.01.071

Follow Reference Muzammal, S. M., & Ali Shah, M. (2016). ScreenStealer: Addressing Screenshot attacks on Android devices. *2016 22nd International Conference on Automation and Computing (ICAC)*, (pp. 336–341). IEEE. 10.1109/IConAC.2016.7604942

Follow Reference Muzammal S. M. Murugesan R. K. (2018). A Study on Leveraging Blockchain Technology for IoT Security Enhancement.2018 Fourth International Conference on Advances in Computing, Communication & Automation (ICACCA), (pp. 1–6). IEEE. 10.1109/ICACCAF.2018.8776806

Follow Reference Muzammal S. M. Murugesan R. K. (2020). A Study on Secured Authentication and Authorization in Internet of Things: Potential of Blockchain Technology. In AnbarM.AbdullahN.ManickamS. (Eds.), Advances in Cyber Security (pp. 18–32). Springer. 10.1007/978-981-15-2693-0_2

Follow Reference Muzammal S. M. Murugesan R. K. (2021). Enhanced authentication and access control in Internet of Things: A potential blockchain-based method.International Journal of Grid and Utility Computing, 12(5–6), 469–485. 10.1504/IJGUC.2021.120090

New, S. (2010). The Transparent Supply Chain. *Harvard Business Review*. https://www.semanticscholar.org/paper/The-Transparent-Supply-Chain-New/0036c71ce3964f4dfff5354609d7c85b40c786df (https://www.semanticscholar.org/paper/The-Transparent-Supply-Chain-New/0036c71ce3964f4dfff5354609d7c85b40c786df)

Follow Reference Ogbemhe J. Mpofu K. Tlale N. S. (2017). Achieving Sustainability in Manufacturing Using Robotic Methodologies.Procedia Manufacturing, 8, 440–446. 10.1016/j.promfg.2017.02.056

Follow Reference Okeme P. A. Skakun A. D. Muzalevskii A. R. (2021). Transformation of Factory to Smart Factory.2021 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus), (pp. 1499–1503). IEEE. 10.1109/ElConRus51938.2021.9396278

Follow Reference Piccarozzi M. Aquilani B. Gatti C. (2018). Industry 4.0 in Management Studies: A Systematic Literature Review.Sustainability (Basel), 10(10), 10. 10.3390/su10103821

Follow Reference Raut R. D. Mangla S. K. Narwane V. S. Gardas B. B. Priyadarshinee P. Narkhede B. E. (2019). Linking big data analytics and operational sustainability practices for sustainable business management.Journal of Cleaner Production, 224, 10–24. 10.1016/j.jclepro.2019.03.181

Follow Reference Rejeb A. Keogh J. G. Treiblmaier H. (2019). Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management.Future Internet, 11(7), 161. 10.3390/fi11070161

Follow Reference Ren S. Zhang Y. Liu Y. Sakao T. Huisingh D. Almeida C. M. V. B. (2019). A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: A framework, challenges and future research directions.Journal of Cleaner Production, 210, 1343–1365. 10.1016/j.jclepro.2018.11.025

Follow Reference Roblek, V. Meško, M., & Meško Štok, Z. (2016). Digital Sustainability in the Fourth Industrial Revolution. SSRN *Electronic Journal*. 10.2139/ssrn.3282290

Follow Reference Rosso R. S. U. Jr Tsuzuki M. D. S. G. Barari A. Macchi M. (2022). Transition towards Smart Factories.International Journal of Computer Integrated Manufacturing, 35(4–5), 341–344. 10.1080/0951192X.2022.2080451

Follow Reference Sama N. U. Jhanjhi N. Z. Humayun M. Rahman A. U. (2024). Digital twin evolution, application areas and enabling technology.AIP Conference Proceedings, 2729(1), 070003. 10.1063/5.0168361

Follow Reference Samoylov A. V. Drozdova A. P. Molchanova S. M. (2020). IMPLEMENTATION OF THE ECONOMIC CONCEPT OF A CLOSED CYCLE. *EKONOMIKA I UPRAVLENIE*. PROBLEMY, RESHENIYA, 2(10), 4–10. 10.36871/ek.up.p.r.2020.10.02.001

Follow Reference Schulze C. Blume S. Siemon L. Herrmann C. Thiede S. (2019). Towards energy flexible and energy self-sufficient manufacturing systems.Procedia CIRP, 81, 683–688. 10.1016/j.procir.2019.03.176

Follow Reference Shang C. You F. (2019). Data Analytics and Machine Learning for Smart Process Manufacturing: Recent Advances and Perspectives in the Big Data Era.Engineering (Beijing), 5(6), 1010–1016. 10.1016/j.eng.2019.01.019

Follow Reference Shin S.-J. Woo J. Seo W. (2016). Developing a Big Data Analytics Platform Architecture for Smart Factory.Journal of Korea Multimedia Society, 19(8), 1516–1529. 10.9717/kmms.2016.19.8.1516

Follow Reference Siddiqui M. U. A. Qamar F. Tayyab M. Hindia M. N. Nguyen Q. N. Hassan R. (2022). Mobility Management Issues and Solutions in 5G-and-Beyond Networks: A Comprehensive Review.Electronics (Basel), 11(9), 9. 10.3390/electronics11091366

Follow Reference Sjödin D. R. Parida V. Leksell M. Petrovic A. (2018). Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing *Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies.*Research Technology Management, 61(5), 22–31. 10.1080/08956308.2018.1471277

Follow Reference Sujatha R. Chatterjee J. M. Jhanjhi N. Brohi S. N. (2021). Performance of deep learning vs machine learning in plant leaf disease detection.Microprocessors and Microsystems, 80, 103615. 10.1016/j.micpro.2020.103615

Telukdarie A. Bag S. (2018). A Review on Industry 4.0 and Supply Chain Sustainability.Proceedings of the International Conference on Industrial Engineering and Operations. Management. IEEE.

Follow Reference Thiede S. (2021). Digital technologies, methods and tools towards sustainable manufacturing: Does Industry 4.0 support to reach environmental targets?Procedia CIRP, 98, 1–6. 10.1016/j.procir.2021.02.001

Follow Reference Wang L. Mohammed A. Wang X. V. Schmidt B. (2018). Energy-efficient robot applications towards sustainable manufacturing.International Journal of Computer Integrated Manufacturing, 31(8), 692–700. 10.1080/0951192X.2017.1379099

Follow Reference

Winkler H. (2011). Closed-loop production systems—A sustainable supply chain approach.CIRP Journal of Manufacturing Science and Technology, 4(3), 243–246. 10.1016/j.cirpj.2011.05.001