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# Design concept of information control systems for green manufacturing industries with IoT-based energy efficiency and productivity

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**Abstract**

In today's and future industrial competition, IoT and the Fourth Industrial Revolution are unavoidable. Indonesia must be prepared to compete globally in an increasingly efficient and integrated industry, including efficient energy use and renewable energy. This issue has received little strategic and scientific thought, particularly in Indonesia. This study purposes to create a conceptual model of an information control system in the industry, which will include operational performance. The method involves four steps. Firstly, the process flow within the industry is comprehensively analyzed, including the input, process, and output (IPO) aspects. Secondly, all information pertaining to each production process is integrated into the information system. Thirdly, a management control system (MCS) is proposed, incorporating key performance indicators (KPIs), allowing real-time monitoring by management. Lastly, real-time information data on resource sharing is submitted to the information sharing control system within similar industrial clusters. This enables related business parties to optimize their resource utilization based on the provided information. The results show that green manufacturing can be initiated by controlling energy-saving and productivity-related KPIs. The concept of IoT green manufacturing depends on active involvement from the government, industry and the public. A crucial aspect of this system is how the industry effectively manages production performance through shop floor control (SFC).



## 1. Introduction

Modern society faces serious challenges related to energy use. Global energy consumption has doubled over the past 40 years and is projected to increase again over the next decade [1]. The manufacturing industry is the main electricity user compared to the other largest consumer groups. Nearly a third of all energy used in the world is consumed by the manufacturing sector [2]. For this reason, the use and demand for energy in the manufacturing industry sector must be reduced logically without having to disrupt the supply of products needed by the market. The industry as a producer has an important role in meeting this demand. That means the industry has to reduce energy consumption while still meeting the required output. With a modern industrial model, it is hoped that it will accelerate efficient and productive manufacturing with lower costs and higher output. To achieve this goal, it is important for the industry to improve energy efficiency. In other words, how to reduce energy demand by reducing energy consumption per unit output. In addition, speed and accuracy have become an obligation for the industry in the era of technological disruption and the 4$^{th}$ industrial revolution (TD4IR).

To be sustainable, the industry must be able to beat the competition in todays and rapidly changing future. The key is how to master the data during operation. The modern industrial world cannot be separated from data [3]. This is an opportunity despite the challenges that must be faced. Data consists of information about the interaction between the industry and the outside world, such as customers, suppliers, industrial communities, etc., as well as information from within the industry itself, such as; production process, maintenance, logistics, quality, energy supply system, etc. [4]. With the development of new applications, the data is used to analyze how to improve the industry's efficiency and productivity and its relevance to other related industries and society.

All countries must prepare themselves to face global industrial competition. Efficient, complex, and integrated industry competition will be more intense. In addition, the pressure to use more efficient energy and renewable energy will certainly increase [5]. Efficiency programs will be clearer to achieve if the production process operates normally, without any shortage of workload constraints. However, the real challenge for certain industries is the fluctuation of inputs to production due to seasonal factors and market conditions locally and globally. This situation often leads to a waste of resources, especially not implementing proper technology, management systems, and data analysis.

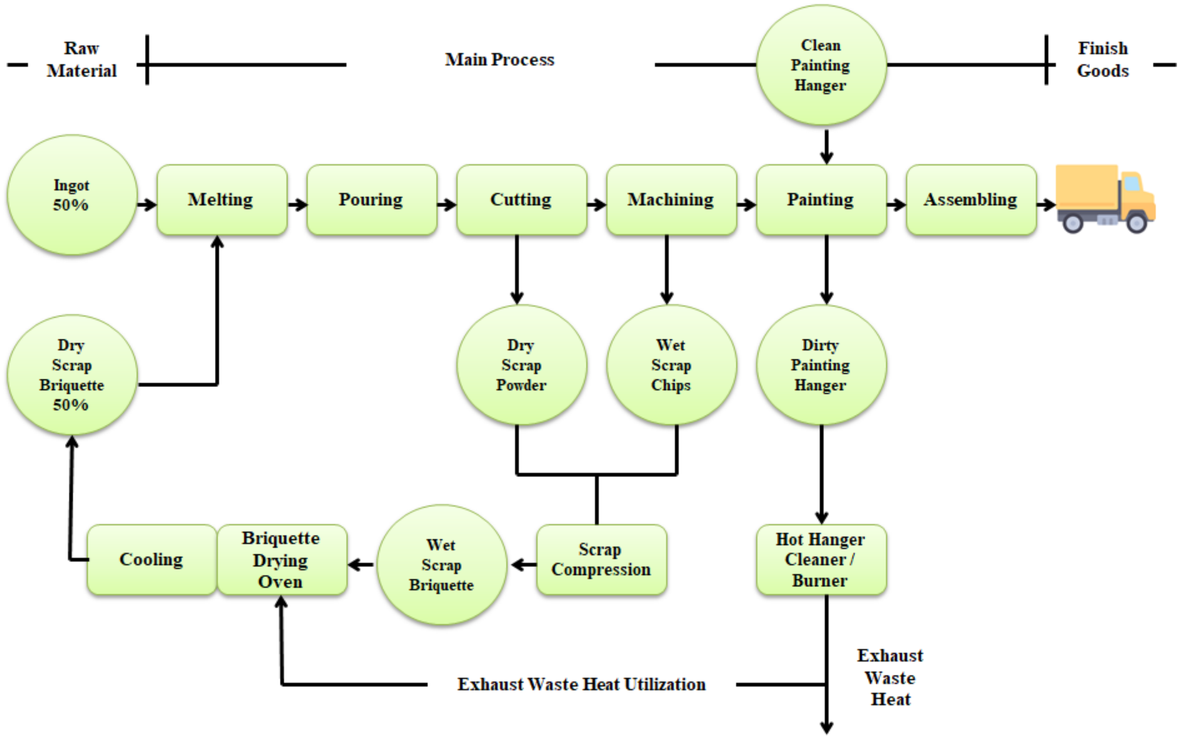
The concept of modern green and efficient industrial manufacturing with IoT facing the TD4IR era is an exciting topic for researchers worldwide today. Publications on the topic of green and sustainable manufacturing with IoT-based energy efficiency and productivity are quite numerous and varied with several reviews, such as; energy saving strategies in industrial sector [2], energy-efficient scheduling in intelligent production systems [6], internet of things (IoT) embedded sustainable supply chain for industry 4.0 requirements [7], methods of energy performance improvement towards sustainable manufacturing from perspectives of energy monitoring, evaluation, optimization and benchmarking [8, 9], control and monitoring for sustainable manufacturing in the industry 4.0 [10], cyber-physical systems architectures for industrial internet of things applications in industry 4.0 [11], lean and green manufacturing on its applications and impacts [12], lean-green manufacturing practices and their link with sustainability [12], smart manufacturing systems and applied industrial technologies for a sustainable industry [13], energy efficiency of manufacturing systems with energy assessment methods and tools [14], industry 4.0 technologies for manufacturing sustainability and future research directions [15], application of industry 4.0 technological constituents for sustainable manufacturing [16], influence of smart manufacturing towards energy conservation [17].

Based on the review paper above, it seems there has not been much strategic-scientific thinking regarding the implementation concept of green manufacturing industries with IoT-based energy efficiency and productivity, especially in Indonesia. In addition, the discussion on how the management control system (MCS) provides energy savings and productivity in the industry is not clear yet [18]. This research purposes to design a concept model of an information control system in the industry, involving: operational performance ranging from marketing, planning and materials, engineering & utility, field operations, quality control, and delivery, so that the information can be understood in real-time by management according to their needs. For high-level users, information can be presented on the dashboard. Information on resource availability in the industry from high to low utilization, such as the utilization of production machines and possibly utilities (steam, compressed air, hot air, clean water, etc.) by being raised to the level of similar local and regional industrial clusters. This system provides the information to the other business actors to utilize the capacity more efficiently (make-loan process). Then, there must be some kind of local/regional information system controlled by a certain party, such as the Ministry of Industry or the association of a cluster/industrial sector.

**2. Materials and Methods**

To achieve the objectives of this research, the following steps were carried out;

- Analyze process flow (business process) integrally, such as IPO (input – process – output) in an industry [18]. One of the goals of process flow analysis is to understand more clearly the industry being analyzed. For more details, the process flow analysis needs to be confirmed by direct observation on the floor, supported by validated data. Here, the analysis must clearly distinguish which one is the production and which one is supporting production. Each process in production and production support that produces important information is considered a




- **Figure 1.** Typical process flow of aluminum automotive parts [18].

Work Station (WS). Figure 1 shows the typical process flow of automotive parts from aluminum by utilizing wasted heat to recycle aluminum scrap.

- Thoroughly review all information related to each production process to be integrated into the information system. Ideally, once input from the beginning of the process into the system will be directly received by each related WS. Execution in each WS must be designed with a minimum or zero manual data input. Everything has been done with barcode sensors, counters, etc., with an informative log book as shop floor control (SFC). In every WS, there should be a production target to be controlled periodically with several key performance indicators such as; Productivity of production $P_p$, which is the ratio of the production output $O_p$ to the production input hour $H_p$ spent by operators/humans and machines.

$$P_p = O_p/H_p \tag{1}$$

and the effectiveness of energy consumption, which is the ratio of production output to the total energy input $E_{tot}$ [19],

$$E_{ec} = O_p/E_{tot} \tag{2}$$

$$E_{tot} = \sum_{1}^{n} E_n \tag{3}$$

where $n$ are the various types of energy with the equivalent factor referring to one type of energy, for example, electricity with kWh. Furthermore, the process cost of each WS $C_p$ is calculated from the total cost $C_{tot}$ of the production output of each WS.

$$C_p = C_{tot}/O_p \tag{4}$$

$$C_{tot} = E_{tot} + M_{tot} + A_{tot} \tag{5}$$

where; $M_{tot}$ is the total material cost and $A_{tot}$ another total cost, which can be more detailed by the accounting department.

- Propose a management control system (MCS) with the key performance indicators (KPI) to facilitate the information system, which the management can monitor in real-time [20]. Here, management levels are divided into executive, middle managers, and supervisory levels. Figure 2 shows the system concept in an MCS. Consisting of Goal, Plan, Assign, and Follow-up/Report. Plans should refer to Goals at each level with assignments and follow-up on achievements. If there is a variance, or the achievement is lower than planned, then corrective action must be taken immediately. The information provided by MCS will help them to take the necessary actions at any time, quickly and accurately, according to their responsibilities.

- Submitting information data regarding resource sharing to the information sharing control system in similar industrial [21] clusters in real-time to provide utilization to related business parties in optimizing their use. In real-time or periodically, productivity performance and energy efficiency in the internal industry as well as in industrial clusters can be monitored at any time in order to have an efficiency impact on the company's internal as well as regionally/nationally.

The IoT refers to a network of interconnected devices, sensors and systems that can collect, exchange and analyze data. In the scenario described, IoT devices can be deployed within industrial clusters to capture and transmit various types of information data. These devices may include sensors placed on machinery, equipment, or infrastructure within the industry.

The IoT devices in the industrial clusters are integrated with an information sharing control system. This control system acts as a central hub that receives and processes data from the IoT devices. It ensures that the information is accurately captured, aggregated, and made available to relevant stakeholders in real time. This real-time aspect is crucial as it enables immediate access to valuable insights for decision-making.

The information data collected by the IoT devices includes resource sharing details within the industrial cluster. This could encompass information about available resources, such as raw materials, equipment, or human resources, and their current utilization status. By submitting this data to the information sharing control system, the relevant business parties within the industrial cluster can access and analyze the information in order to optimize their resource usage.

The utilization of real-time data facilitates continuous monitoring of productivity performance and energy efficiency within the internal industry and the wider industrial cluster. IoT devices can capture relevant performance metrics, such as production output, energy consumption, and operational efficiency. These metrics are then transmitted to the information sharing control system, allowing stakeholders to monitor them at any time.

With the ability to monitor productivity performance and energy efficiency in real-time or periodically, the industrial cluster can identify areas for improvement and implement necessary measures efficiently. This enables businesses within the cluster to achieve higher levels of efficiency, both at the internal company level and in the regional or national context.

That is why, the IoT plays a crucial role in the described scenario by enabling real-time information sharing, resource utilization optimization, and continuous monitoring of productivity and energy efficiency within industrial clusters. By leveraging IoT technologies and the data they provide, businesses can make informed decisions to enhance their operational efficiency and contribute to the overall development of the region or nation.


**Figure 2.** System concept for management control system [20].

### 3. Results and Discussions

Figure 3 illustrates the block concept of information systems specifically designed for green manufacturing industries with an IoT-based approach. The primary focus of this concept is to enhance energy efficiency and productivity within these industries. In this system, the government plays a central role by acting as both a regulator and a data center. As a regulator, the government establishes guidelines and policies to promote and monitor energy efficiency and productivity within the manufacturing sector. As a data center, it collects and manages the data related to energy efficiency and productivity submitted by the industry. The industry generates data by utilizing SFC as a set of tools and processes used to manage and control the manufacturing operations at the shop floor level. The SFC system, integrated with IoT devices, captures data from various workstations (WS) within the manufacturing facility. These IoT devices could include sensors, meters, and other monitoring devices that collect real-time data on energy consumption, production rates, and other relevant parameters. The data collected from the WS through the SFC then transmitted to the management level through the Management Report. This report provides a comprehensive overview of the industry's performance in terms of energy efficiency and productivity. The integration of IoT allows management to access this performance data remotely through a dashboard interface. This means that management can monitor and analyze their company's performance from anywhere, facilitating quick decision-making and optimization of operations.

In addition to internal use by the industry, the data collected can also be used by the public or business society based on their specific needs. This includes stakeholders such as business societies, startups,

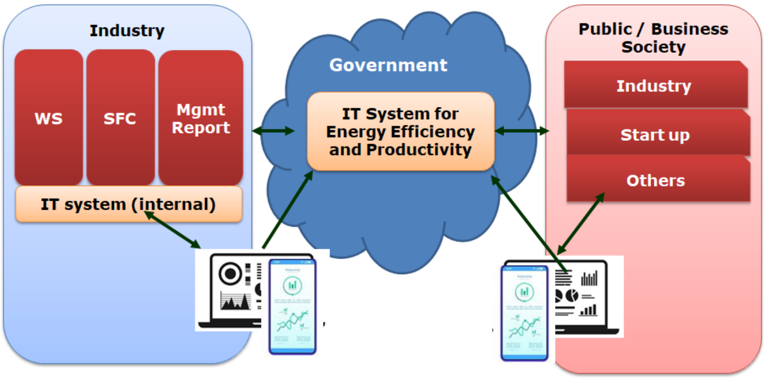



**Figure 3.** Block concept of information system for green manufacturing.

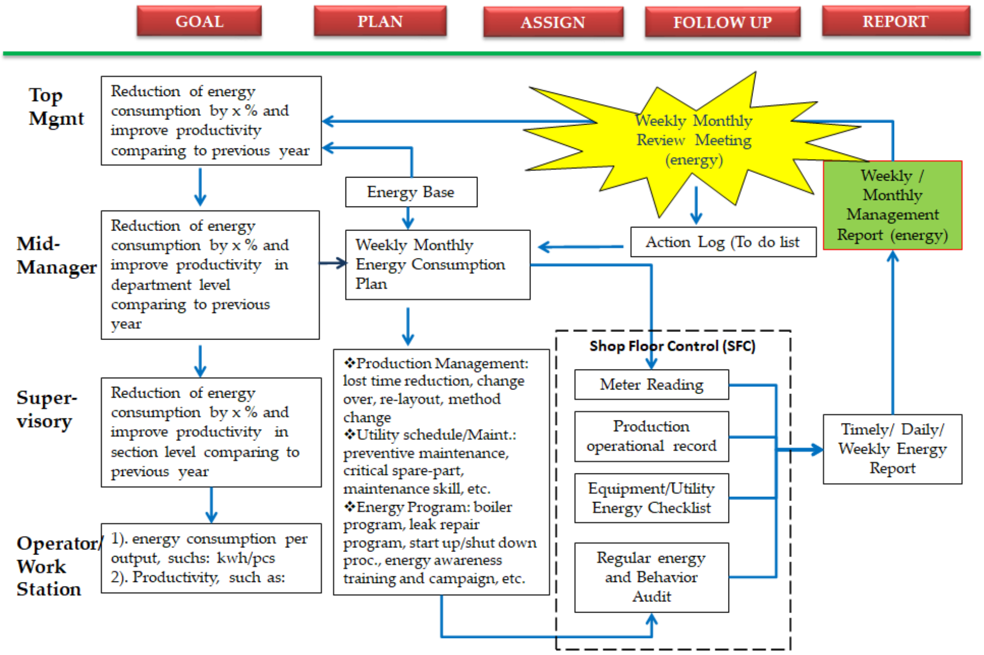



**Figure 4.** Production and energy management control system.

researchers, and other entities interested in utilizing the data for various purposes, such as benchmarking, research, or developing innovative solutions. The subsequent paragraphs and Figure 4 provide more detailed information about the industry, specifically focusing on energy and productivity management control systems. These systems utilize the data collected through IoT devices to effectively monitor and control energy consumption and optimize productivity levels within the manufacturing process. By leveraging IoT-based information systems, green manufacturing industries can gain valuable insights into their energy usage patterns, identify areas for improvement, and implement energy-saving measures. Similarly, productivity management control systems enable industries to monitor and optimize their production processes, leading to enhanced efficiency, reduced waste, and improved overall performance. The government's role as a regulator and data center, the utilization of IoT devices for data collection from workstations through the SFC system, the accessibility of management reports through remote dashboards, and the usage of data by the public or business society all contribute to promoting energy efficiency and productivity within the manufacturing sector.

Figure 4 illustrates the detailed flow of internal information systems within a Management Control System (MCS), building upon the system concept presented in Figure 2. The main objective of this flow is to effectively manage and optimize energy consumption while increasing productivity within the organization. The goals of reducing energy consumption and increasing productivity are derived from various levels within the organizational hierarchy, starting from the top management, mid-management, supervisors, and finally reaching the operator level. Each level contributes to defining specific and objectives that align with the overall

**Table 1.** KPI's related to the information system provided by MCS.

| Area and KPI | | | Distribution | | |
|---|---|---|---|---|---|
| | | | Internal | Government | Business |
| Production | Productivity | Pcs/manhour | √ | √ | |
| | Energy consumption | kWh/pcs | √ | √ | |
| | Labor efficiency | % | √ | √ | |
| | Machine efficiency | % | √ | √ | |
| | Reject rate | % | √ | √ | |
| | Downtime rate | % | √ | √ | |
| | Loading capacity | % | √ | √ | |
| Utility | Cost of electricity | IDR/kWH | √ | √ | √ |
| | Cost of steam | IDR/ton | √ | √ | √ |
| | Cost of clean water | IDR/M3 | √ | √ | √ |
| | Cost of waste water | IDR/M3 | √ | √ | √ |
| | Cost of compressed air | IDR/M3 | √ | √ | √ |
| | Utility consumption rate | % | √ | √ | √ |

targets of the organization. To ensure alignment and coordination, the planning process is adjusted by referring to the goals at each level. This ensures that the plans developed are consistent with the desired outcomes and objectives set by the higher management levels. This alignment helps create a cohesive and integrated approach towards achieving the energy consumption and productivity goals.

SFC plays a vital role as a follow-up tool in the field to ensure that the plans are implemented effectively and the targets are being achieved. SFC involves the use of real-time monitoring and control mechanisms to track and assess the progress of operations on the shop floor. The frequency of follow-up at the operator level can be adjusted based on the prevailing conditions in the field. For example, it can be done every hour or based on the time required to produce a certain quantity. The primary purpose of this follow-up process is to identify any variances between the planned and actual performance. If any variances are detected, immediate corrective action must be taken to address the deviations and bring the performance back in line with the plan. The data obtained from the SFC, including shift, daily, or weekly performance information, is collected and consolidated to form valid Key Performance Indicators (KPIs) within the Management Report, represented by the green box. These KPIs serve as quantifiable measures of the organization's performance in terms of energy consumption and productivity. They provide valuable insights into the effectiveness of the strategies implemented and help assess the progress made towards achieving the goals.

To evaluate the performance of the organization, weekly performance meetings, represented by the yellow cloud, are held. These meetings involve discussions based on the Management Report, where management reviews and analyzes the performance of the organization in the previous week. The purpose of these meetings is to assess the progress, identify any challenges or deviations, and make informed decisions to further enhance the organization's performance in reducing energy consumption and increasing productivity. The derivation of goals at different levels, the adjustment of planning to ensure alignment, the use of SFC for follow-up and corrective action, the generation of valid KPIs in the Management Report, and the evaluation through performance meetings all contribute to effectively managing and optimizing energy consumption while increasing productivity within the organization. Table 1 shows the KPI's related to the information system provided by MCS. As shown, there are several KPIs in Production and Utility with the customized distribution of information such as; internal, government, and business. As previously explained, the distribution of internal information aims to stimulate a culture of efficiency and productivity in the industry. For the government, the objective is to monitor and develop future policies, including incentives and benchmarking programs, both locally and nationally. As for the business community, how to use this information to share the production process so that the capacity and utility in the industry become more optimal and efficient.

Table 1 presented in the context represents the KPIs associated with the information system provided by the MCS. The table showcases various KPIs in the domains of Production and Utility, and these KPIs are distributed in a customized manner to different recipients, including internal stakeholders, government entities, and the business community. The KPIs listed under Production and Utility categories provide measurable indicators of performance and effectiveness within these areas. Scientifically, KPIs serve as quantifiable metrics that allow organizations to assess their progress towards specific goals and objectives. In this case, the KPIs are likely designed to capture the crucial aspects of production processes and utility optimization within the industry.

The distribution of information associated with these KPIs is tailored to three main recipients: internal stakeholders, government, and the business community. The objective of distributing internal information is to foster a culture of efficiency and productivity within the industry. This indicates a scientific approach to enhancing organizational performance by ensuring that relevant information is accessible to the internal workforce. By providing employees and managers with access to specific KPIs related to production and utility, the MCS promotes informed decision-making and the implementation of strategies to improve efficiency and productivity.

In terms of the government's involvement, the objective of information distribution is to monitor and develop future policies. The government aims to utilize the data provided by the MCS to gain insights into the industry's performance and guide policy-making processes. This scientific approach aligns with evidence-based policy-making principles, where data-driven decisions are made to address challenges and optimize outcomes. By monitoring the KPIs related to production and utility, the government can identify areas that require attention, develop appropriate policies, and design incentives and benchmarking programs at both local and national levels.

For the business community, the information distributed through the MCS can be leveraged to share production processes and increase industry capacity and utility. Scientifically, this suggests the importance of collaboration and knowledge sharing among businesses for achieving optimal efficiency and effectiveness. By accessing the relevant information on production processes provided by the MCS, businesses can identify opportunities for improvement, share best practices, and optimize their own operations. This collaborative approach aligns with scientific research highlighting the benefits of knowledge transfer, innovation, and increased competitiveness within industries.

Based on the concept described above, three interesting points need to be discussed. First, how the government creates clustering of similar industrial areas or industries with the same production system and facility support. With this system, the resource-sharing system will be easier to achieve for adjacent industries. Second, how the government provides incentives to efficient industries with programs made by the government. The industry must be open in reporting its performance to the business community and the public. Third, how can this information be used to provoke the emergence of new startups so that even without having a factory, they can still open temporary small manufacturing businesses at competitive costs.

Based on the concept described above, three interesting points need to be discussed. These points revolve around the government's role in fostering industrial development and utilizing the information provided to stimulate resource-sharing, incentivize efficient industries, and promote the emergence of new startups. Scientifically, these points touch upon important aspects of industrial policy, incentives, and entrepreneurial opportunities.

The first point raised is how the government can create clustering of similar industrial areas or industries with the same production system and facility support [22]. From a scientific perspective, this concept aligns with the idea of industrial agglomeration and spatial clustering. By strategically locating industries with similar production systems and providing them with shared infrastructure and support, the government can create synergies and economies of scale. This clustering facilitates resource-sharing among adjacent industries, leading to improved efficiency and competitiveness. Scientific research supports the notion that clustering can promote knowledge exchange, innovation, and specialization, ultimately benefiting the industries involved.

The second point discusses how the government can provide incentives to efficient industries through programs and initiatives. Incentivizing efficient industries is a common approach in industrial policy, aimed at promoting sustainable economic growth and competitiveness [23]. Scientifically, this aligns with the concept of performance-based incentives. By encouraging industries to report their performance and making it transparent to the business community and the public, the government can create accountability and motivate industries to improve their efficiency. Research suggests that well-designed incentive programs can drive productivity enhancements and encourage industries to adopt sustainable practices, ultimately benefiting both the industry and the overall economy.

The third point focuses on utilizing the provided information to stimulate the emergence of new startups [24]. Specifically, it discusses how aspiring entrepreneurs can open temporary small manufacturing businesses at competitive costs, even without owning a factory. Scientifically, this concept relates to the idea of distributed manufacturing and the sharing economy. The availability of information on production processes, capacity, and utility can empower entrepreneurs to identify niche opportunities and leverage existing manufacturing infrastructure. This approach can lower barriers to entry, promote entrepreneurship, and foster innovation. Scientific research indicates that leveraging shared resources and technologies can lead to cost savings, flexibility, and increased access to manufacturing capabilities for startups.

In conclusion, the scientific discussion in the manuscript highlights the government's role in promoting industrial development through strategic clustering, incentivizing efficiency, and stimulating entrepreneurial opportunities. These points align with established concepts in the fields of industrial policy, incentive design, and entrepreneurship. By utilizing these approaches, governments can foster sustainable economic growth, promote innovation, and enhance the competitiveness of industries.

The practical application of this concept extends beyond achieving a green manufacturing industry focused on energy efficiency and productivity; it can also be applied to other Key Performance Indicators (KPIs) in a general context. This suggests that the concept has broader applicability and can be adapted to different industries and performance metrics. This research makes an important contribution by providing insights into the implementation of sustainable energy savings and productivity programs. Scientifically, it offers valuable guidance and understanding on how to effectively design and carry out initiatives that promote energy efficiency and productivity in a sustainable manner. Future research endeavors are expected to focus on the development of user-friendly applications that are simple and easy to use, catering to both the industry and the general public. From a scientific standpoint, these applications should be designed to facilitate the adoption of sustainable practices and promote wider participation, fostering a collective effort towards achieving sustainability goals.

## 4. Conclusions

The design concept of an information system for the green manufacturing industry with IoT-based energy efficiency and productivity has been discussed with important notes, such as;

- Green manufacturing can be started by focusing on controlling KPIs related to energy savings and increased productivity.
- The concept of IoT green manufacturing requires a central role from the government by involving industry and the public.
- The key to this system is how the industry controls in more detail the production performance using shop floor control (SFC).

Future research endeavors are anticipated to focus on devising effective strategies and methodologies to transform this concept into a highly accessible application accessible from any location. This research will likely explore technological advancements, user interface design, and system optimization to enable seamless access and utilization of the concept, facilitating its widespread adoption and implementation.

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## References

1. Kober, T., Schiffer, H. W., Densing, M., Panos, E. (2020). Global energy perspectives to 2060 – WEC's World Energy Scenarios 2019, *Energy Strategy Reviews*, Vol. 31, No. July, 100523. doi:10.1016/j.esr.2020.100523
2. Abdelaziz, E. a., Saidur, R., Mekhilef, S. (2011). A review on energy saving strategies in industrial sector, *Renewable and Sustainable Energy Reviews*, Vol. 15, No. 1, 150–168. doi:10.1016/j.rser.2010.09.003
3. ur Rehman, M. H., Yaqoob, I., Salah, K., Imran, M., Jayaraman, P. P., Perera, C. (2019). The role of big data analytics in industrial Internet of Things, *Future Generation Computer Systems*, Vol. 99, 247–259. doi:10.1016/j.future.2019.04.020
4. Enyoghasi, C., Badurdeen, F. (2021). Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels, *Resources, Conservation and Recycling*, Vol. 166, No. September 2020, 105362. doi:10.1016/j.resconrec.2020.105362
5. Helwani, Z., Amraini, S. Z., Asmura, J., Siregar, T. N., Triwahyuni, V. E., Abd, A. A. (2023). Palm Frond Waste as a Carbon Source in the Synthesis of CaO/Biochar Catalysts for the Biodiesel Production Process, *Heca Journal of Applied Sciences*, Vol. 1, No. 1, 8–13. doi:10.60084/hjas.v1i1.9
6. Gao, K., Huang, Y., Sadollah, A., Wang, L. (2020). A review of energy-efficient scheduling in intelligent production systems, *Complex and Intelligent Systems*, Vol. 6, No. 2, 237–249. doi:10.1007/s40747-019-00122-6
7. Manavalan, E., Jayakrishna, K. (2019). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements, *Computers and Industrial Engineering*, Vol. 127, No. November 2018, 925–953. doi:10.1016/j.cie.2018.11.030
8. Cai, W., Wang, L., Li, L., Xie, J., Jia, S., Zhang, X., Jiang, Z., Lai, K. hung. (2022). A review on methods of energy performance improvement towards sustainable manufacturing from perspectives of energy monitoring, evaluation, optimization and

benchmarking, *Renewable and Sustainable Energy Reviews*, Vol. 159, No. June 2021. doi:10.1016/j.rser.2022.112227

9. Malek, J., Desai, T. N. (2020). A systematic literature review to map literature focus of sustainable manufacturing, *Journal of Cleaner Production*, Vol. 256, 120345. doi:10.1016/j.jclepro.2020.120345

10. Henao-Hernández, I., Solano-Charris, E. L., Muñoz-Villamizar, A., Santos, J., Henríquez-Machado, R. (2019). Control and monitoring for sustainable manufacturing in the Industry 4.0: A literature review, *IFAC-PapersOnLine*, Vol. 52, No. 10, 195–200. doi:10.1016/j.ifacol.2019.10.022

11. Pivoto, D. G. S., de Almeida, L. F. F., da Rosa Righi, R., Rodrigues, J. J. P. C., Lugli, A. B., Alberti, A. M. (2021). Cyber-physical systems architectures for industrial internet of things applications in Industry 4.0: A literature review, *Journal of Manufacturing Systems*, Vol. 58, No. PA, 176–192. doi:10.1016/j.jmsy.2020.11.017

12. Abualfaraa, W., Salonitis, K., Al-Ashaab, A., Ala'raj, M. (2020). Lean-green manufacturing practices and their link with sustainability: A critical review, *Sustainability (Switzerland)*, Vol. 12, No. 3, 1–21. doi:10.3390/su12030981

13. Cioffi, R., Travaglioni, M., Piscitelli, G., Petrillo, A., Parmentola, A. (2020). Smart manufacturing systems and applied industrial technologies for a sustainable industry: A systematic literature review, *Applied Sciences (Switzerland)*, Vol. 10, No. 8. doi:10.3390/APP10082897

14. Menghi, R., Papetti, A., Germani, M., Marconi, M. (2019). Energy efficiency of manufacturing systems: A review of energy assessment methods and tools, *Journal of Cleaner Production*, Vol. 240, 118276. doi:10.1016/j.jclepro.2019.118276

15. 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 (Switzerland)*, Vol. 11, No. 12. doi:10.3390/app11125725

16. Ng, T. C., Lau, S. Y., Ghobakhloo, M., Fathi, M., Liang, M. S. (2022). The Application of Industry 4.0 Technological Constituents for Sustainable Manufacturing: A Content-Centric Review, *Sustainability (Switzerland)*, Vol. 14, No. 7. doi:10.3390/su14074327

17. Terry, S., Lu, H., Fidan, I., Zhang, Y., Tantawi, K., Guo, T., Asiabanpour, B. (2020). The Influence of Smart Manufacturing towards Energy Conservation: A Review, *Technologies*, Vol. 8, No. 2, 31. doi:10.3390/technologies8020031

18. Yandri, E., Pramudito, P., Ronald, R., Ardiani, Y., Ariati, R., Setyobudi, R. H., Widodo, W., Zahoor, M., Zekker, I., Lomi, A. (2021). Technical Design of Aluminium Scrap Processing Machines by Utilization of Direct Exhaust Air using Conveyor Drying System, *Proceedings of the Estonian Academy of Sciences*, Vol. 30, No. 4, 9–11

19. Yandri, E., Ariati, R., Uyun, A. S., Setyobudi, R. H. (2020). Potential Energy Efficiency and Solar Energy Applications in a Small Industrial Laundry : A Practical Study of Energy Audit, *E3S Web of Conferences*, Vol. 00008

20. Yandri, E., Ariati, R., Uyun, A. S., Setyobudi, R. H., Anne, O., Susanto, H., Vincevica-Gaile, Z. (2020). Implementation of walk-through audits for designing energy management system: A first step towards an efficient campus, *IOP Conference Series: Earth and Environmental Science*, Vol. 490, No. 1. doi:10.1088/1755-1315/490/1/012005

21. de Matos, E., Tiburski, R. T., Moratelli, C. R., Johann Filho, S., Amaral, L. A., Ramachandran, G., Krishnamachari, B., Hessel, F. (2020). Context information sharing for the Internet of Things: A survey, *Computer Networks*, Vol. 166, 106988. doi:10.1016/j.comnet.2019.106988

22. Lee, C., Lim, C. (2021). From technological development to social advance: A review of Industry 4.0 through machine learning, *Technological Forecasting and Social Change*, Vol. 167, No. February, 120653. doi:10.1016/j.techfore.2021.120653

23. Aiginger, K., Rodrik, D. (2020). Rebirth of Industrial Policy and an Agenda for the Twenty-First Century, *Journal of Industry, Competition and Trade*, Vol. 20, No. 2, 189–207. doi:10.1007/s10842-019-00322-3

24. Pustovrh, A., Rangus, K., Drnovšek, M. (2020). The role of open innovation in developing an entrepreneurial support ecosystem, *Technological Forecasting and Social Change*, Vol. 152, No. October 2018. doi:10.1016/j.techfore.2019.119892