Lean Green – Integration of Lean Manufacturing and Sustainable Development in the Light of the Pursuit of Economically and Environmentally Efficient Operations

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Abstract

The concept of Lean Manufacturing is a set of techniques, methods and tools, whose application in manufacturing processes is expected to eliminate wastes and improve their economic efficiency. The challenges of Sustainable Development determine a new approach to conducting manufacturing activities. Issues related to caring for the environment and the social aspects of the business are becoming crucial from the point of view of business stakeholders. The article attempts to juxtapose the classical approach to Lean Manufacturing, presenting its main principles. The authors also highlighted the key legal and formal requirements that determine a different approach to Lean Manufacturing. The main sources of green wastage were then presented and possible ways of correlating the Lean Manufacturing (classical) concept with Lean Manufacturing seen in the light of Sustainability challenges were analysed. This combination was presented as Lean Green, thus indicating the possible relationship between Lean Manufacturing and Sustainability, in its environmental part. Using examples of specific companies, the potential benefits of implementing a Lean Manufacturing concept oriented not only on economic aspects, but above all on environmental benefits, are summarised. A review of the Polish and world literature, an analysis of available sources and the authors' own experience were used.

Keywords: *lean manufacturing, lean green, sustainability, environment, efficiency*

1. Introduction

For years, manufacturing (production) processes have been largely profit-oriented only, doing so by, among other things, minimizing the unit cost of production. The concept of Lean Manufacturing, derived from the Japanese Toyota Production System (TPS), which is one of the strategies for efficient management and organisation of processes, has introduced significant changes in the perception of added value seen from the perspective of the end user, i.e. the customer. In the process of value creation, in addition to profit maximisation, quality embedded in the process, employee involvement in building the organisational culture, elimination of waste and continuous improvement have started to play an important role, with a consequent contribution to the company's flexibility and further improvement of its economic efficiency.

However, in recent times, particular emphasis has been placed on organising manufacturing processes in such a way that their negative impact on environmental, social and employee welfare aspects is also minimized. The measure of the attractiveness of the company, assessed from the point of view of its stakeholders, i.e. end users, suppliers, contractors, etc., it seen through specific actions aimed at carrying out such activities so that they are in line with the idea of Sustainable Development. A strong determinant in the conduct of sustainable activities is the European Union, which, in terms of the European Green Deal strategy and the planned achievement of climate neutrality by 2050, is constructing its legislation since 2019, which in a way, forces operators to focus their attention, mainly on environmental issues. This, in turn, results in the mutual organization of processes in such a way that they are economically optimal, but at the same time environmentally sustainable. Hence, seen over the years, the need to adapt the Lean Manufacturing methodology to these realities is starting to become even greater. An extension of the Lean Manufacturing methodology in this way has become the Lean Green concept, which using lean tools, seeks to develop models for conscious action to improve environmental performance.

This paper, based on the literature review and the authors' own experience, presents the main principles and assumptions of the Lean Green concept. The legal background to the need for integration measures is also outlined. Ways of integrating Lean Manufacturing and sustainable development into the Lean Green concept, for improving both economic and environmental efficiency are analysed and discussed. The environmental benefits of implementing selected Lean Manufacturing tools were also pointed out, indicating in the final conclusions the need to develop the issue in further empirical research.

2. Lean Manufacturing as a Concept Aimed at Improving Economic Efficiency

The concept of Lean Manufacturing was developed and first used by scholars at the Massachussets Institute of Technology. In the mid-1990s, D. Roos, J.P. Womack and D.T. Jones published the book "The Machine That Changed the World" in

Tab. 1. Principles of Lean Manufacturing. Source: own elaboration based on [13]
Tab. 1. Zasady Lean Manufacturing. Źródło: opracowanie własne na podstawie [13]

Criterion of principle	Description
Value	Defining what value is, defined only from the point of view of the end customer. The value should be expressed in terms of a specific product, good or service that will satisfy the customer's needs at a specific price and at a specific time.
Value stream	Identify the value stream. This stream is the set of all activities required to produce a specific product in a process composed of the three most important (in management) tasks, such as: product design, information flow management and physical production execution.
Flow	Creating a flow of value-creating activities - changing the way of thinking.
Pulling	Retrieved from, a 'sucking' system. In such a system, it is the customers who, according to their own needs, "pull" the product from the manufacturers according to their expectations. This avoids a situation in which manufacturers "push", often unwanted, products to customers.
Excellence	The implementation of the preceding actions allows those involved in the process to realise that there is no end to the process of reducing inputs, shortening time, limiting space, reducing costs and eliminating errors has no end, which in the understanding of the concept of Lean Management is at the central point and is referred to, as continuous improvement, from Japanese word "Kaizen".

Tab. 2. Integration of Lean and Green. Source: own elaboration based on [15]
Tab. 2. Integracja Lean oraz Green. Źródło: opracowanie własne na podstawie [15]

Approach	The relationship between Lean and Green	Example
Conflict	The lean approach means less green.	Frequent deliveries increase emissions and emission reduction reduce productivity.
Mild	Lean and Green coexist, but do not complement each other.	The Lean team pursues economic goals, the Green team independently pursues environmental objectives.
Synergistic	Use of tools and techniques lean manafacturing, which aims to eliminate waste in the economically, but inadvertently benefit the environment.	Reducing product waste reduces environmental impact at the same time. Improving economic efficiency in energy consumption translates into environmental benefits.
Symbiotic	Lean and Green are implemented as part of the same strategy as part of a continuous improving of the organisation.	A strategy to reduce environmental losses borne by society during the entire product cycle.

which they compared the parameters of results and expenditures in American, European and Japanese companies. Toyota Motor Production was recognised there as a leader with its Toyota Production System [4]. Many definitions can be found in the literature that attempt to explain the essence of the Lean Manufacturing concept. One of these defines Lean as a method of improving the operation of a company that optimises the creation and flow of value throughout the manufacturing process through the continuous elimination of waste. It aims to build quality into the manufacturing process while embracing the principle of cost reduction [7]. Lean Management is a management methodology, that creates a work culture in an organisation that makes all participants in the organisation interested in continuously reducing costs, increasing quality levels and shortening the delivery cycle. All this is done in order to maximise customer expectations and to adapt seamlessly to the environment [9]. In relation to manufacturing processes, i.e. the company's operational activities, we detail the concept of Lean Manufacturing, which places particular emphasis on the elimination of wastes, as this has a direct impact on an organisation's production efficiency. Sources of wastage are common unproductive losses, such as [6]:

- production of products not ordered by the customer, resulting in increased stocks finished products,
- idle waiting of machines and people for deliveries, that are delayed or for the next steps in the process, which is caused by poor work organisation,
- unnecessary transport of the materials in question between the areas they operate, which refers to unnecessary movement of machinery, as well as the movement of products and raw materials,
- too long to perform certain operations due to poor design of tools and products, rapid wear and tear of equipment, breakdowns, contamination, quality defects,
- excessively high material stocks, which freeze money for the purchase of packaging or raw materials, increase the risk of damage and make it difficult to control the quality control of stored products,
- moving workers around during work to find parts, instructions, tools or aids, refers to poor work organisation and poorly designed workstations,
- deficiencies or errors that need to be corrected or repaired, refers to the cost of scrapping defective products, the disruption of production and the time taken for complaints.

Conducting activities with the use of Lean tools makes it possible to eliminate both the described process "muda", but also overloading or inequalities occurring in processes. The basis for the implementing Lean tools is to rely on the basic principles of Lean Manufacturing, defined by the main criterion that determines each of them. The main principles by criterion of each are shown in table 1.

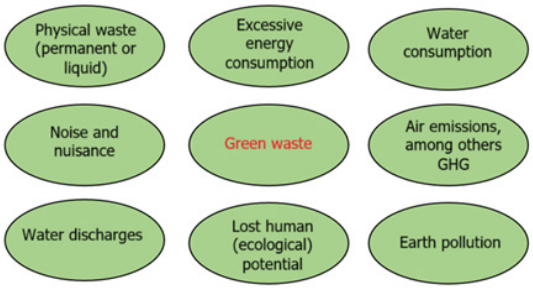

Fig. 1. Sources of green waste. Source: own elaboration based on [15]
Rys. 1. Źródła zielonych marnotrawstw. Źródło: opracowanie własne na podstawie [15]

The key element for implementing Lean Manufacturing in a company is to build awareness and employee culture at all levels of the organisation, so that everyone is involved in the improvement process and is aware of the benefits and tasks resulting from the adopted Lean strategy of efficient operation. Only then can one begin to implement Lean methods and tools, such as 5S, TPM, SMED, Kaizen, visual management, VSM, standardisation work and many others.

3. Sustainable Development and the European Green Deal – a Context for the Conemporary Adaptation of the Lean Manufacturing Methodology

The concept of Sustainable Development is becoming increasingly important for the activities of manufacturing companies operating in European and global value chains. Sustainable development is defined as development, that meets the needs of people today without compromising the ability of future generations to meet their own needs. In order to achieve sustainable development, three key elements need to be coherent: economic growth, social inclusion and environmental protection [20]. In the context of the goals referred to as SDGs (Sustainable Development Goals), included in the "2030 Agenda for Sustainable Development" of the United Nations, it is becoming crucial to work toward responsible production leading to economic growth, while protecting the natural environment and combating climate change. These goals and related targets are global in nature and can be implemented worldwide, taking into account the different conditions of individual countries, their capacities and level of development, and their compatibility with national strategies and priorities [16]. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU with regard to corporate sustainability reporting, referred to as the Corporate Sustainability Reporting Directive (CSRD). According to it, all large entities and small and medium-sized listed companies will already provide information on: environmental, social and human rights issues and corporate governance in their management report in 2024. This information will be reported according to the common European Sustainability Reporting Standards (the so-called ESRS) [17]. Undoubtedly, individual countries, or communities of countries around the world are pursuing the main objectives, thereby placing a focus on sustainable development. Thus, the European Union is a party to the 2015 Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCC). The Paris Agreement commits to reducing greenhouses gases (GHG) emissions in such a way that the increase in average global temperature compared to pre-industrial levels does not exceed 2°C. In addition, parties are to aim to limit this increase to 1.5°C. According to emission models put forward by the scientific community, including the Intergovernmental Panel on Climate Change (IPCC), this implies a halt to global emissions growth around 2030, followed by a successive reduction so as to reduce global emissions to zero in the second half of the century [19]. Recognised by researchers for years, the need for responsible consumption and production, rising GHG emissions leading to climate change, increasing energy consumption and the finiteness of the earth's resources are among the most serious challenges and dilemmas facing the world. Sustainability, the European Union's existing climate policy and the listed environmental challenges gave rise in December 2019 to the European Green Deal Strategy – a set of initiatives with the overarching goal of achieving climate neutrality by 2050 for all Member States. European Green Deal is also designed to enable a fair energy transition, enable the supply of clean, cheap and secure energy, support among others: the protection of biodiversity, efforts towards a circular economy, promote and support green investments as well as provide their financing.

A tool to support the transition is the EU Taxonomy, which sets out the criteria that an activity must meet to be considered environmentally sustainable (and thus to be able to attract additional funding to carry it out). The EU taxonomy identifies key environmental aspects, referred to as environmental objectives, such as [10]:

- combating and adapting to climate change (reducing CO_2 emissions and improving energy efficiency),
- water management,
- activities for the Circular Economy,
- non-GHG emissions,
- protection of biodiversity.

The EU Taxonomy therefore constitutes a requirement, but also an incentive for economic actors to target their activities to improve environmental performance in terms of the environmental impact of a given activity and thus to obtain 'green fund'.

4. The Concept of Lean Green as a Combination of Lean Manufacturing and Sustainable Development

Lean Green is a manufacturing method that minimizes wastes and maximize environmental protection (first of all minimizing emissions to air, water and soil) through proper process and product design, with sustainability as its main objective [8]. Environmental management tools such as LCA

Tab. 3. The impact of selected Lean Manufacturing tools on environmental added value. Source: own elaboration based on [11] [12]
Tab. 3. Wpływ wybranych narzędzie Lean Manufacturing na środowiskową wartość dodaną. Źródło: opracowanie własne na podstawie [11] [12]

Lean tool	Impact on environmental added value
VSM	Reducing waste, reducing the distance travelled by materials, products, finished goods
5S	Segregation of waste according to label codes, increase in training raising the environmental awareness of employees
TPM	Energy savings, improvement of OEE indicators
SMED	Energy savings resulting from reduced machine changeover time

Tab. 4. Selected environmental benefits and activities in the field of Lean and Green application in the world. Source: own elaboration based on [18] [21]
Tab. 4. Wybrane korzyści środowiskowe oraz działania w kierunku wdrożenia „zielonej i szczupłej" organizacji/produkcji na świecie. Źródło: opracowanie własne na podstawie [18] [21]

Company	Action	Benefit
DuPont	Elimination of landfilling of production waste according to the DMAIC (Lean SixSigma) approach.	The amount of waste landfilled so far has been reduced from 37,000 tonnes to zero. It generated $2.2 million in by-product sales and saved $400,000.
General Electric	Applying the Lean approach to the organization of more than 200 actions searching for opportunities to save energy.	This reduced greenhouse gas emissions by 250,000 tonnes and saved $70 million in energy purchase costs.
3M	Application of Lean, Six Sigma and the 3P (Pollution, Prevention, Pays) pollution prevention program.	Emissions of pollutants into the air were reduced per unit of sale by 61% and the amount of waste generated by 30%, and energy efficiency improved by 27%.
LSI Logic Corporation	Implementation of Lean Green.	By reusing water in the production facility, the manufacturing process need 63 percent less water than it did before.

(Life Cycle Assessment) analysis, the ISO 14001 Environmental Management System, the EMAS Eco-Management and Audit Scheme [1], the ISO 50001 Energy Management System and many others are also tools, that aim to minimize environmental losses. In the Lean Green approach, it is important to also relate it to existing management systems and environmental methods. Lean Green is a specific response to the rising costs of energy procurement, the possible risk of unstable supplies and the accelerating pace of regulatory and/or governmental changes. It is a concept that involves minimization the negative environmental aspects occurring or likely to occur within all types of waste identified in the lean structure of the organisation [5]:

- overproduction, generates more energy consumption than required, related to the infrastructure used to handle redundant products,
- inventory, result in an increase in energy requirements for storage (the need to heat, cool or light warehouses),
- transport requires energy to transport of goods (particularly CO_2 emissions),
- expectation, determines the power consumption during standstill,
- unnecessary movement, increases the need to have space for semi-finished products and work in progress products,
- deficiencies, force additional energy expenditures due to the necessity of corrective actions for production non-conformities (repairs, alterations, reclassification or scrapping),
- errors in the process, result in additional energy use.

Waste resulting from poor environmental performance have been referred to as 'green' wastes. Their main types are shown in figure 1.

The aim of integrating the concept of Lean Manufacturing and sustainable development into the Lean Green approach should be to achieve economic profit and the smallest possible environmental footprint, also referred to as an ecological footprint (minimization the harmful impact of operations on the environment). This combination makes it possible to meet the expectations of sustainable development, but also in the requirements of classically understood economic value. The ways of achieving lean and green maturity when applying the methodologies listed, together with the relationships that may exist between them, are presented in table 2.

The Lean Manufacturing concept is a stimulator for responsible business, so companies applying Lean focus mainly on reducing production time and costs. From the Green point of view, consumer satisfaction is higher the higher the environmental status of a product. By investing in new environmental products, excessive costs are reduced, which are usually incomparable to the benefits that an organisation can gain by implementing green practices [14]. Attempts to date to link and integrate the concepts of Lean Manufacturing and sustainable development in Lean Green involve the definition of so-called environmental added value. It expresses the impact of the use of Lean tools in production processes for selected environmental aspects. In other words, it provides a measure of the environmental benefits of applying the tools of Lean Manufacturing methodology. Table 3. describes how the application of Lean tools can influence the building of environmental added value and thus the environmental management system.

Companies around the world approach the application of Lean Manufacturing tools oriented toward improving environmental performance in different ways. Very often this application is unconscious - oriented towards process optimisation brings economic benefits while having a more or less positive impact on the environment. The environmental benefits could be greater if this started to be done in a systemic and more deliberate way, as shown by the selected examples of Lean and Green application worldwide, summarised in table 4.

Lean Green has applications in various industries. Also in the mining industry its application is possible, but the number of these implementations is so far small and the environmental benefits are seen "incidentally", which requires systematisation and the application of a conscious approach to the development of Lean Green in the mining industry. An example of the implementation of a Lean tool for the mining industry is the introduction of TPM (Total Productive Maintenance) at KGHM Polska Miedź and the consequent elimination of the tube-and-chain conveyor of the crusher dust removal system, thereby achieving zero failure rates and improving energy efficiency by saving 6 kW of energy per shift [22]. Thus, not only an economic benefit but also an environmental benefit (in the spirit of Lean Green) was observed. The mining industry's self-awareness of sustainability is steadily increasing. Not insignificant is also the awareness and expectations of industry stakeholders [23], who determine actions on the part of mining companies towards improving the environmental performance of the processes carried out there.

5. Conclusions

The overriding aim of applying the Lean Manufacturing methodology becomes the pursuit of improving environmental (in addition to economic) efficiency. The analysis of the principles, tools and techniques of Lean Manufacturing juxtaposed with the requirements of sustainable development indicates the need to adapt the methodology and consciously use it to improve the environmental performance of manufacturing processes carried out, as well as a rationale for presenting it as Lean Green. Legal determinants, such as the European Green Deal Strategy and the resulting legal instruments, which place particular emphasis on the prevention of negative climate change, its protection, the creation a circular economy, actions to protect the environment, are a concrete premise for organising manufacturing processes in such a way that they not only bring economic profit, but are continuously improved towards improving environmental efficiency, and thus the impact of these processes on the aforementioned ecological aspects. Of the Lean and Green approaches presented, a symbiotic approach, in which Lean and Green are implemented as part of the same strategy as part of the continuous improvement of the organisation, will yield the best results. The possibilities seen in the literature and previous research to apply selected Lean Manufacturing tools towards building a good environmental impact of manufacturing processes provide excellent material for specific implementations and tests in different industries, as evidenced by examples of Lean and Green implementations applied in companies with different industry specialisations. Increasingly the need to adapt Lean and Green to specific production conditions is becoming apparent, pointing to the need for further empirical research into the adaptability of Lean Manufacturing tools through the lens of environmentally conscious benefits.

Literatura – References

1. Bąk J. (2021), Environmental engineering, Zarządzanie środowiskiem i zarządzenie środowiskowe, Wydawnictwo PK, Kraków, p. 53.
2. Deloitte, Non-financial Reporting 2014, Vol. 6, Pages 348-364, https://www2.deloitte.com/content/dam/Deloitte/lv/Documents/strategy/Nonfinancial_reporting_2015.pdf
3. Corporate Sustainability Reporting Directive European Parliament legislative resolution of 10 November 2022 on the proposal for a directive of the European Parliament and of the Council amending Directive 2013/34/EU, Directive 2004/109/EC, Directive 2006/43/EC and Regulation (EU) No 537/2014 as regards corporate sustainability reporting.
4. Horzela A., Semrau J. (2020) Koncepcja Lean Manufacturing jako narzędzie doskonalenia procesów produkcyjnych 2020 s. 37-49
5. Krzyczkowski M. (2012) Ekologistyka a transport „Logistyka Odzysku" No. 1 (2), p. 14.
6. Liker J.K., Meier D.P. (2011), Droga Toyoty. Fieldbook. Praktyczny przewodnik wdrażania 4P Toyoty, MTBiznes, Warszawa, s.63
7. Lisiński M., Ostrowski B. (2006) Lean management w restrukturyzacji przedsiębiorstwa, Kraków-Kluczbork: Antykwa; Za: J. Czekaj. „Wybrane metody etatyzacji jako instrumenty lean administration". A. Stabryla (red.) (2010) Koncepcja zarządzania współczesnym przedsiębiorstwem. Kraków: Fundacja Uniwersytetu Ekonomicznego w Krakowie.
8. Maruthi, G. D., Rashimi, R. (2015) Green Manufacturing: It's Tools and Techniques that can be implemented in Manufacturing Sectors. Materials Today: Proceedings 2, 3351.
9. Pawłowski, E., Pawłowski, K., & Trzcieliński, S. (2010). Metody i narzędzia Lean Manufacturing, Wydawnictwo Politechniki Poznańskiej, Poznań, s.13.
10. Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment (hereinafter: "Taxonomy" or "Regulation").
11. Wirkus M., Chmielarz A. (2012) Środowiskowe aspekty wdrażania Lean Manufacturing, w: Materiały konferencyjne: Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane, s. 169-176.
12. Wirkus M., Chmielarz A. (2011). Value stream mapping as a tool to improve environmental management system. Inżynieria Produkcji : Innowacje i Technologie przyszłości - Production Engineering ; Innovations and Technologies of the Future, pp. 405-409.
13. Womack P. James, Jones T. Daniel (2012), Lean Thinking. Eliminating waste and creating value, ProdPublishing, Wrocław, ed. 2. pp. 20-40.
14. Wronka A. (2014) Integracja aspektów wyszczuplonego i zielonego zarządzania - Lean Green, Logistyka Odzysku 1/2014(10), Łódź.
15. Zokaei K., Lovins H., Wood A., Hines P. (2013) Creating a Lean and Green Business System. Techniques for Improving Profits and Sustainability, CRC Press Taylor & Francis Group. Boca Raton, London, New York, pp. 46, 56.
16. Dokument elektroniczny: Ministerstwo Rozwoju: Agenda 2030 na rzecz zrównoważonego rozwoju - implementacja w Polsce: https://www.gov.pl/web/rozwoj-technologia/agenda-2030 (access: 20.05.2023).
17. Dyrektywa o sprawozdawczości przedsiębiorstw w zakresie zrównoważonego rozwoju: https://www.gov.pl/web/finanse/dyrektywa-o-sprawozdawczosci-przedsiebiorstw-w-zakresie-zrownowazonego-rozwoju-juz-opublikowana (access: 10.05.2023).
18. Lean Center: https://leancenter.pl/bazawiedzy/lean-green (access: 25.05.2023).
19. Sobolewski M. (2020) Europejski Zielony Ład - w stronę neutralności klimatycznej: http://orka.sejm.gov.pl/WydBAS.nsf/0/5A874F6E5DAB64DCC12585AC002A3997/$file/Infos_275.pdf (access: 10.05.2023).
20. Zrównoważony rozwój i Cele Zrównoważonego Rozwoju: https://www.unic.un.org.pl/strony-2011-2015/zrownowazony-rozwoj-i-celezrownowazonego-rozwoju/2860 (access: 19.05.2023).
21. Gordon J. Pamela (2001) Lean and Green. Profit for your workplace and the environment, Berrett-Koehler Publishers, San Francisco, California, p. XV.
22. Migza M., Bogacz P. (2015) Możliwość wykorzystania narzędzi Lean Management w przedsiębiorstwach sektora górnictwa podziemnego w Polsce, Possibility of using Lean Management tools in underground mining companies in Poland, Przegląd Górniczy, ISSN 0033-216X-2015 t. 71 nr 8, s. 58-61.
23. Bogusz K. (2020) Branża wydobywcza w obliczu wyzwań niesionych przez ideę zrównoważonego rozwoju . Inżynieria Mineralna, 1(1), 131-138. https://doi.org/10.29227/IM-2020-01-21

Lean Green – integracja Lean Manufacturing i zrównoważonego rozwoju w świetle dążenia do prowadzenia działalności efektywnej ekonomicznie i środowiskowo

Koncepcja Lean Manufacturing to zestaw technik, metod i narzędzi, których zastosowanie w procesach produkcyjnych (wytwórczych) ma wyeliminować marnotrawstwo i poprawić efektywność ekonomiczną tychże procesów. Wyzwania zrównoważonego rozwoju determinują nowe podejście do prowadzenia działalności produkcyjnej. Kwestie związane z dbałością o środowisko i społeczne aspekty działalności przedsiębiorstw stają się kluczowe z punktu widzenia interesariuszy biznesowych. W artykule podjęto próbę zestawienia klasycznego pojęcia Lean Manufacturing, prezentując główne zasady i założenia tejże koncepcji. Autorzy zwrócili uwagę na kluczowe wymogi prawne i formalne, które determinują potrzebę odmiennego podejścia do Lean Manufacturing. Przeanalizowano możliwe sposoby korelacji koncepcji Lean Manufacturing (rozumianej klasycznie i zorientowanej na efektywność ekonomiczną) z Lean, widzianym w świetle wyzwań zrównoważonego rozwoju. Połączenie to zostało przedstawione jako Lean Green, wskazując tym samym na możliwy związek między Lean Manufacturing a zrównoważonym rozwojem, w jego części środowiskowej. Zaprezentowano także główne źródła „zielonych marnotrawstw", które można wyeliminować dzięki Lean Green. Na przykładach konkretnych firm zestawiono potencjalne korzyści z wdrożenia koncepcji Lean Manufacturing zorientowanej nie tylko na aspekty ekonomiczne, ale przede wszystkim na korzyści środowiskowe. Wykorzystano przegląd literatury polskiej i światowej, analizę dostępnych źródeł oraz własne doświadczenia autorów.

Słowa kluczowe: *szczupła produkcja, lean green, zrównoważony rozwój, środowisko, efektywność*