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LEGAL ASPECTS OF INDUSTRIAL SYMBIOSIS IN THE TRANSPORT SECTOR

Abstract

Transport has a significant harmful impact on the environment, contributing to air, water and soil pollution, greenhouse gas emissions, and climate change. Burning fossil fuels in transportation means releases large amounts of CO_2 and other pollutants, degrading air quality and contributing to global warming. Transport also causes noise pollution and habitat destruction due to infrastructure development like roads and highways. On the other hand, sustainable transport seeks to minimise these negative effects by promoting cleaner technologies, such as electric and hydrogen-powered vehicles, and improving fuel efficiency. Industrial symbiosis in the transport sector refers to collaborative efforts between companies to optimise resources, reduce waste, and improve energy efficiency. Industrial symbiosis in the transport sector can include recycling vehicles and their parts, using alternative fuels, sharing infrastructure, etc. There are several successful practical examples of industrial symbiosis in the transport sector. While no single legal framework is dedicated solely to industrial symbiosis in transport, the legal aspects of this concept are covered through broader regulations related to sustainability, the circular economy, and emissions reduction. These legal frameworks include European Union directives and Member States' national laws as well as international treaties and rules of most important international organisations dealing with transport. At the European Union level, the European Green Deal is a key policy initiative to achieve climate neutrality by 2050. It encourages emissions reduction in the transport sector by promoting energy efficiency, vehicle electrification, and circular economy principles - key components of industrial symbiosis. Within the Green Deal, the Circular Economy Action Plan promotes recycling, waste reduction, and the sharing of resources across industries, which is fundamental to industrial symbiosis. Industrial symbiosis also includes legal aspects related to waste management (Waste Framework Directive), alternative fuels and energy regulations (Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Regulation (EU) 2019/631 setting CO_2 emission performance standards for new

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passenger cars and for new light commercial vehicles), legislation on the use of shared infrastructure, etc. However, inadequate legislation (regulation) is very often mentioned as a type of industrial symbiosis barrier.

The paper lists various issues and regulations that regulate sustainability in transport. The paper presents the most important provisions of European regulations aimed at reducing environmental pollution, especially those related to transport and those that mention industrial symbiosis as a form of environmentally friendly production and activity.

Key words: transport, sustainable transport, industrial symbiosis, European regulation, legal regulation

I. Introduction

Environmental pollution problems are a key topic of the modern era, and finding solutions to reduce environmental pollution and its protection are imperative for the authorities. The European Union has recognised the importance and urgency of taking various measures to prevent or reduce environmental pollution. For this purpose, it passed over a thousand different directives.[1] The environment is most affected by CO_2 in sectors like energy industries, industry, and transport.[2] In 2021, transport accounted for 29.2%[3] of the European Union's total CO_2 emissions, with road transport contributing 76.3%, total navigation 14.8%, total civil aviation 8.1% and railways 0.5% of that figure.[4]

Transport is a complex system that affects various aspects of society and the natural environment. It encompasses not only the physical movement of people and goods but also involves infrastructural, economic, environmental, technological, and social dimensions. It is key to economic development because it enables trade, connects markets and supports production and distribution chains. Additionally, it shapes urban spaces and settlements, affecting the population's mobility. Technological advancements significantly enhance transportation by improving its efficiency, safety, and sustainability.

Industry in general, also has a great impact on the environment. The industry's negative impact on the environment worldwide is recognised as a serious problem. Circular economy and industrial symbiosis are possible ways to reduce

[1] Zorpas, A. A., "Strategy development in the framework of waste management," *Science of The Total Environment,* 716 (2020): 2. https://doi.org/10.1016/j.scitotenv.2020.137088.
[2] European Commission, EU Transport in Figures - Statistical Pocketbook 2023, Publications Office, 2023: 143, https://op.europa.eu/en/publication-detail/-/publication/493b2403-7157-11ee-9220-01aa75ed71a1/language-en.
[3] *Ibid*., p. 143.
[4] *Ibid*., p. 151.

waste and environmental pollution. The circular economy promotes the responsible use of materials, which contributes to preserving natural resources for future generations. Circular economy "is an economy in which materials are used sustainably, moving away from a linear ('take–make–dispose') economy into a circular one."[5] It is based on the idea that the value of materials is maintained in the economy for as long as possible. Defined by Chertow, industrial symbiosis, as a part of industrial ecology, "engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity."[6]

The topic of environmental protection is complex. The European Union's environmental goals are ambitious and a large number of regulations have been adopted regarding this matter. The paper lists various issues and sources of law that regulate sustainability in transport. The paper analyses the most important provisions of European regulations aimed at reducing environmental pollution, especially those related to transport and those that mention industrial symbiosis as a form of environmentally friendly production and activity. It tries to answer the question of whether the legal regulation of industrial symbiosis is adequate and what are the problems related to this topic.

II. Sustainable transport

As climate change impacts grow, sustainable transport is vital. The European Green Deal[7] sets a goal for Europe to achieve climate neutrality by 2050. This strategy promotes reducing transport emissions through sustainable mobility, alternative fuels, and integrated transport systems. The European Climate Law[8] makes emissions reduction and climate neutrality legally binding, ensuring transport sector sustainability.[9]

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[5] De Römph, T. J. and Cramer J. M., "How to improve the EU legal framework in view of the circular economy," *Journal of Energy & Natural Resources Law* 38, no. 3 (2020): 246. https://www.tandfonline.com/doi/pdf/10.1080/02646811.2020.1770961.

[6] Chertow, M. R., "Industrial Symbiosis: Literature and taxonomy," *Annual Review of Energy and the Environment* 25, no. 1 (2000): 314, https://www.annualreviews.org/content/journals/10.1146/annurev.energy.25.1.313.

[7] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions (The European Green Deal), COM/2019/640 final.

[8] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (European Climate Law), OJ L 243, 9. 7. 2021, p. 1–17.

[9] Činčurak Erceg, B., "Pravna regulacija zaštite okoliša od štetnih utjecaja prometa," In *Zakonodavstvo zaštite okoliša i održivi ekonomski razvoj u EU*, edited by Duić, D. and Ćemalović, U. Sveučilište Josipa Jurja Strossmayera u Osijeku, Pravni fakultet Osijek, Osijek, 2022: 119,

Sustainable development is a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[10] Environmentally sustainable transport refers to a system that does not endanger public health and ecosystems while fulfilling access needs. It achieves this by ensuring that renewable resources are used at rates below their natural regeneration and that non-renewable resources are utilised at rates lower than the development of renewable alternatives.[11]

The transport sector, which significantly contributes to greenhouse gas emissions and fossil fuel consumption, is recognised as a key area for the implementation of sustainable and circular solutions.

The European Union's transport policy aims to promote sustainable development by balancing social and environmental objectives. Over the years, the European Union has adopted numerous documents to guide action in the transport sector, including the White Paper 'European transport policy for 2010: time to decide'[12] of 2001 and the White Paper 'Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system'[13] of 2011. White Paper - European transport policy for 2010: time to decide emphasises that transport is a key factor in modern economies. The White Paper proposes around 60 measures aimed at creating a balanced transport system. These measures focus on revitalising the railways, improving quality in the road transport sector, promoting sea and inland waterway transport, striking a balance between growth in air transport and the environment, putting research and technology at the service of clean, efficient transport, etc.

White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system aims at reducing by 60% greenhouse gas emissions from transport by 2050, measured with respect to 1990 levels and calls for reducing the oil dependence of transport. It is stated that the transport industry represents an important part of the economy: in the European

https://www.pravos.unios.hr/wp-content/uploads/2022/11/zakonodavstvo-zastite-okolisa-i-odrzivi-ekonomski-razvoj-u-eu.pdf.

[10] World Commission on Environment and Development, Our Common Future, https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf, accessed 20. 12. 2024.

[11] Vasilj, A.; Činčurak Erceg, B. "Through changes to legislation to modern urban mobility, In *Book of Proceedings: 11th International Scientific Symposium "Region, Entrepreneurship, Development, RED 2022* edited by Leko Šimić, M., Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business in Osijek, Osijek, 2022: 801–819. https://www.efos.unios.hr/wp-content/uploads/2023/06/RED-2022-Proceedings.pdf.

[12] White Paper - European transport policy for 2010: time to decide, COM/2001/0370 final.

[13] White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM/2011/0144 final.

Union it directly employs about 10 million people and accounts for about 5% of GDP. It also states that technological innovation can drive a quicker and more cost-effective shift toward a more efficient and sustainable European transport system by focusing on three key areas: enhancing vehicle efficiency with advanced engines, materials, and designs; promoting cleaner energy through alternative fuels and propulsion methods; and optimising network usage and improving safety with advanced information and communication systems. These initiatives laid the groundwork for a sustainable and integrated European transport network.

In 2019 the European Commission introduced Communication "The European Green Deal"[14] that highlights the urgency of advancing the transition to sustainable and intelligent mobility. The European Green Deal emphasises the need for a 90% reduction in transport-related emissions by 2050 and highlights the importance of increasing the production and use of sustainable alternative fuels. Furthermore, it advocates for efficient resource use by transitioning to a clean, circular economy.

At the end of 2020, the European Union introduced the Sustainable and Smart Mobility Strategy,[15] which emphasises the primary challenges facing the transport sector: achieving a significant reduction in emissions and enhancing sustainability. The Strategy outlines the framework for the green and digital transformation of the transport system and identifies measures to cut emissions from the sector by 90% by 2050, in line with the goals of the European Green Deal.

Building on these ambitions, the 2021 Communication "'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality,"[16] stresses that the European Union is committed to definitely establish a path towards a green, competitive, inclusive, circular economy. 'Fit for 55' includes a number of proposals for revising European Union legislation, including transport, in order to achieve the climate goals from the European Green Deal and includes new requirements for industry to decarbonise production processes.

[14] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions (The European Green Deal), COM/2019/640 final.

[15] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Sustainable and Smart Mobility Strategy – putting European transport on track for the future, COM/2020/789 final.

[16] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM/2021/550 final.

Regulation (EU) 2021/1119, the 'European Climate Law',[17] establishes a framework for achieving climate neutrality in the European Union by 2050. This Regulation transforms climate neutrality from a political objective into a legally binding goal, requiring European Union institutions and Member States to adopt measures to meet the established targets. It repeats that climate action in the European Union should be an opportunity for all economic sectors to strengthen global industrial leadership in innovation. To achieve the 2050 climate neutrality target, contributions are required from sectors such as energy, industry, transport, buildings, agriculture, waste, and forestry.

Complementing these main policies, several specific regulations address emissions and infrastructure in the transport sector. These include: Regulation (EU) 2019/631 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles;[18] Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU;[19] Regulation (EU) 2019/1242 setting CO_2 emission performance standards for new heavy-duty vehicles;[20] Regulation (EC) No 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI);[21] Regulation (EC) No 715/2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles

[17] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (European Climate Law), OJ L 243, 9. 7. 2021, p. 1–17.

[18] Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (recast), OJ L 111, 25. 4. 2019, p. 13–53. This Regulation establishes CO_2 emissions performance requirements for new passenger cars and for new light commercial vehicles in order to contribute to achie Union's target of reducing its greenhouse gas emissions and the objectives of the Paris Agreement.

[19] Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, OJ L 234, 22. 9. 2023, p. 1–47. It sets mandatory national targets for EU Member States to deploy publicly accessible alternative fuels infrastructure (in particular for electricity and hydrogen) for road vehicles, vessels moored at the quayside and stationary aircraft.

[20] Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO_2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC, OJ L 198, 25. 7. 2019, p. 202–240. Regulation sets out the EU's first CO_2 emissions standards for heavy-duty vehicles. Together with Regulation (EU) 2019/631, it sets emission reduction targets for the road transport sector in the EU.

[21] Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/, OJ L 188, 18. 7. 2009, pp. 1–13.

(Euro 5 and Euro 6) and on access to vehicle repair and maintenance information;[22] Regulation (EU) 2024/1257 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7),[23] Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles,[24] Directive 2018/2001 on the promotion of the use of energy from renewable sources,[25] etc.

Together, these policies and regulations create a striking framework for transforming the European Union's transport sector, aiming to ensure that they contribute to achieving climate neutrality by 2050.

III. Industrial symbiosis

The most well-known definition of industrial symbiosis, the one cited by Chertow: industrial symbiosis "engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity".[26] Three primary opportunities for resource exchange are: by-product reuse,

[22] Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, OJ L 171, 29. 6. 2007, pp. 1–16.

[23] Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7), amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 of the European Parliament and of the Council, Commission Regulation (EU) No 582/2011, Commission Regulation (EU) 2017/1151, Commission Regulation (EU) 2017/2400 and Commission Implementing Regulation (EU) 2022/1362, OJ L, 2024/1257, 8. 5. 2024.

[24] Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles, OJ L 188, 12. 7. 2019, pp. 116–130.

[25] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), OJ L 328, 21. 12. 2018, pp. 82–209.

[26] Chertow, M. *op. cit*. (note 6), p. 314. However, there are also broader definitions. See Mirata, M.; Emtairah, T., "Industrial Symbiosis Networks and the contribution to environmental innovation: The case of Landskrona industrial symbiosis programme," *Journal of Cleaner Production* 13, no. 10-11 (2005): 994, https://doi.org/10.1016/j.jclepro.2004.12.010.

utility/infrastructure sharing and joint provision of services (e. g. fire suppression, transportation, and food provision).[27] Chertow states that "at least three different entities must be involved in exchanging at least two different resources to be counted as a basic type of industrial symbiosis."[28]

In 2018, the European Committee for Standardisation (CEN) began efforts to establish a clear definition of Industrial Symbiosis. In a workshop held later that year, Industrial symbiosis has been defined "as the use by one company or sector of underutilised resources broadly defined (including wastes, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) from another, with the result of keeping resources in productive use for longer."[29]

Based on the elements that link or generate synergy between different industrial entities Castellet-Viciano *et al.* distinguished three groups of industrial symbiosis:

1. Mutuality synergies: there is no flow of materials or products, but these synergies involve sharing services, facilities, or infrastructures. (e. g., energy supply or waste treatment, emergency planning, training, logistics, and transport),

2. Substitution synergies: these are transfers of products where the waste of one company or industrial process is part of the resource flow of another (e. g., exchange of by-products, waste, waste heat, etc.),

3. Genesis synergies: involve creating an original activity to satisfy the reuse requirement of any flow or company.[30]

There are numerous examples of Industrial symbiosis, in different sectors all over the world,[31] but in fact it is still underused.

Unlike the circular economy, Industrial symbiosis is a more specific concept focusing on the cooperation between different industries or companies. Here the

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[27] Chertow, M. R., ""Uncovering" Industrial Symbiosis," *Journal of Industrial Ecology* 11, no. 1 (2008): 12. https://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.1110

[28] *Ibid*.

[29] Erceg, A.; Krzeminski, P.; Jonaitiene, V.; Munoz Marti, M.; Dunjić, B.; Szilagyi, A.; Burmaoglu, S.; Činčurak Erceg, B.; Giacomi, E.; Anastasovski, A.; Ryan, Y.; Skolou, V.; Chrabak, P.; Refalo, P.; Borg, M.; Dosoretz, C.; Plaza, J. P.; Hurtado Ruiz, A. M.; Özcan Kilcan, C.; Tkaczyk, A. H.; Godina, R.; Neves, A., *State-of-the-art report on Industrial Symbiosis topic and its different sub-areas (settling the basis for further improvements and their introduction in the industry)*, 2024: 4. https://www.liaise-action.eu/publication/d1-1-state-of-the-art-report-on-industrial-symbiosis-topic-and-its-different-subareas/.

[30] Castellet-Viciano, L.; Hernández-Chover, V.; BellverDomingo, Á.; Hernández-Sancho, F., "Industrial Symbiosis: A Mechanism to Guarantee the Implementation of Circular Economy Practices," *Sustainability* 14, (2022): 5. https://www.mdpi.com/2071-1050/14/23/15872.

[31] Erceg, A., *et al.*, *op. cit.* (note 29), p. 68. See also Neves, A.; Godina, R.; Azevedo, S. G.; Matias, J. C.O. "A comprehensive review of industrial symbiosis.", *Journal of Cleaner Production* 247, (2020):119113. https://doi.org/10.1016/j.jclepro.2019.119113.

waste or by-products of one industry can be used as raw materials or inputs for another industry, thus reducing waste and improving resource efficiency. Waste as defined in Waste Framework Directive is "any substance or object which the holder discards or intends or is required to discard."[32] By-product is "substance or object resulting from a production process the primary aim of which is not the production of that substance or object is considered not to be waste but the following conditions must be obtained: a) further use of the substance or object is certain; b) the substance or object can be used directly without any further processing other than normal industrial practice; c) the substance or object is produced as an integral part of a production process; and d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.[33] Waste/by products regulations are a huge barrier to Industrial symbiosis actions. Therefore, to overcome this problem, it is necessary to increase the actions and accelerate activities of the regulators.

When discussing political frameworks and initiatives regarding Industrial symbiosis some authors systematise them on those of the United Nations, the OECD and the European Union. The United Nations Environment Programme "supports Industrial symbiosis with a focus on resource efficiency, circular economy and sustainable consumption and production".[34] The Organisation for Economic Co-operation and Development (OECD) states that "a resource efficient economy is important for achieving green growth and that better policies are needed to support circular economic initiatives".[35]

Industrial symbiosis is commonly associated to Industrial Ecology and constitutes a strategy to promote circular economy.[36] Industrial ecology seeks to establish sustainable closed-loop systems through a combination of industrial ecosystems, industrial symbiosis, industrial metabolism, and environmental laws and regulations. Industrial symbiosis is therefore a means and a subset to achieving this, and thus to achieving the general goals of 'industrial ecology'.[37]

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[32] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22. 11. 2008, p. 3–30, Art. 3, point 1.
[33] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22.11.2008, p. 3–30, Art. 5(1).
[34] Lybæk, R.; Christensen, T. B.; Thomsen, T. P., "Enhancing policies for deployment of Industrial symbiosis – What are the obstacles, drivers and future way forward?," *Journal of Cleaner Production* 280, no. 2 (2021): 7. https://doi.org/10.1016/j.jclepro.2020.124351.
[35] *Ibid*.
[36] Henriques, J.; Ferrão, P.; Castro, R.; Azevedo, J., "Industrial Symbiosis: A Sectoral Analysis on Enablers and Barriers," *Sustainability*, 13 (2021): 1723. https://www.mdpi.com/2071-1050/13/4/1723.
[37] Lybæk, R. *et al.*, *op. cit.* (note 34), p. 2.

Industrial symbiosis is rarely directly mentioned in European Union legislation. The concept of industrial symbiosis is incorporated into the European Union's regulations on the circular economy and resource management. European Union regulation encourages industries to move towards circular and sustainable practices, in which Industrial symbiosis plays an increasingly significant role. As was stated in SCALER's Report on EU-wide Industrial symbiosis regulatory measures, the European Union has been supporting Industrial symbiosis directly or indirectly for more than 30 years, and the European Union is recognising Industrial Symbiosis as a core element in "Roadmap to a Resource Efficient Europe".[38] According to the mentioned Report the is around 50 documents (directives, strategies, decisions, communications, opinions, action plans) related to Industrial symbiosis. In the European Union, Industrial symbiosis is promoted through action plans and strategies such as: Communication „A New Industrial Strategy for Europe",[39] and Communication „A new Circular Economy Action Plan for a cleaner and more competitive Europe".[40]

However, there are different drivers and barriers to Industrial Symbiosis such as 1. financial/economic, 2. technological, 3. regulatory and 4. institutional but also social, management, geographical, intermediaries.[41] Professional and scientific literature, as well as various reports, highlight the problem of regulatory barriers as one of the most important. Regulatory barriers are related to conflicting

[38] SCALER, "Report on EU-wide industrial symbiosis regulatory measures, regulatory gaps and need for deployment," 2020, https://www.scalerproject.eu/wp-content/uploads/2020/09/D4.4_SCALER_Policies-Report_v1.0.pdf.

[39] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – „A New Industrial Strategy for Europe", COM/2020/102 final.

[40] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – „A new Circular Economy Action Plan For a cleaner and more competitive Europe", COM/2020/98 final.

[41] Compare: Domenech Aparisi, T. A., "Social Aspects of Industrial Symbiosis Networks" (Thesis submitted in fulfilment of the Degree of Doctor of Philosophy, Bartlett school of Graduate Studies, University College London, 2010), https://core.ac.uk/download/pdf/1674444.pdf; Rahman M. F.; Islam K.; Islam K. N. "Industrial Symbiosis: A Review on Uncovering Approaches, Opportunities, Barriers and Policies." *Journal of Civil Engineering and Environmental Sciences* 2(1), (2016): 11-19. https://www.engineegroup.us/Civil-Engineering-Environmental-Sciences/JCEES-2-109.php; Golev, A.; Corder, G. D.; Giurco, D. P. "Barriers to Industrial Symbiosis: Insights from the Use of a Maturity Grid." *Journal of Industrial Ecology* 9, no. 1 (2014): 141–154. https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12159; 4. Herath, P.; Dissanayake, P.; Thisakya, G. "The potential of industrial symbiosis: An analysis of barriers to its implementation for better waste management in industrial zones in Sri Lanka". In: *Proceedings of the 11th World Construction Symposium*, edited by Sandanayake, Y. G.; Waidyasekara, K. G. A. S.; Ramachandra, T.; Ranadewa, K. A. T. O., Sri Lanka, 2023: 1064–1078. https://doi.org/10.31705/WCS.2023.85.

regulations, restrictive regulations for establishment and operation, lack of regulatory incentives, difficult approval processes.[42]

IV. Industrial symbiosis in transport

As explained, Industrial symbiosis refers to the collaboration between industries that exchange materials, energy, water, waste, and by-products, as well as share services or facilities to promote resource efficiency. For Industrial symbiosis to succeed, identifying potential exchanges and synergies is crucial. Key types of resources available for symbiosis include:

a) raw materials (spare raw materials, such as metals, chemicals, or timber can be used by other companies),

b) by-products (secondary outputs from production processes, like waste or side materials that can be repurposed as inputs for other companies),

c) energy resources (additional energy, such as heat or steam, from one company can be shared with neighbouring businesses),

d) water (treated wastewater can be reused for e. g. irrigation or cooling),

e) shared infrastructure (companies can share utilities, infrastructure, and services),

f) logistics services (collaborative logistics, including shared transportation and warehousing),

g) expertise, skills and specialised knowledge (companies can exchange technical knowledge and best practices to improve processes and innovate sustainably).[43]

Industrial symbiosis in the transport sector aims to enhance sustainability, lower costs, and deliver economic and environmental advantages for all stakeholders. Types of resources available for synergies under Industrial symbiosis, adapted to the transport sector, or collaboration can take several forms:

a) raw materials,

b) by-product utilisation (e. g. using biomass or agricultural waste for biofuel production),

c) energy symbiosis (electric vehicles utilise surplus energy),

d) water,

e) infrastructure sharing (sharing warehouses, ports, and terminals), including vehicle maintenance and recycling **(**sharing maintenance services, recycling parts, and sharing vehicles),

[42] Herath, P. *et al.*, *op. cit.* (note 41), p. 1067.
[43] Erceg, A., *et al.*, *op. cit.* (note 29), p. 5–6.

f) logistics optimisation (sharing routes or vehicles, reducing trips, and costs),
g) expertise, skills and specialised knowledge.

All these models of collaboration can have a positive impact on business by reducing costs and pollution. However, as previously mentioned, there are no direct regulations specifically governing industrial symbiosis, so the regulation of these forms of collaboration involves a wide range of different rules that govern other relations and processes across various branches of law. In principle, the concept of industrial symbiosis is incorporated into the European Union regulations on the circular economy, resource management, it is part of the regulations related to sustainable development, waste management and environmental protection in general. Below, we will outline some of them, which in a broader sense can be related to Industrial symbiosis.

It has already been said that Industrial symbiosis most often implies that one industry's waste becomes a resource for another, so regulations related to waste management are key to regulating this process. Waste management was underlined as a priority in the first European Union Environmental Action Plan, adopted in 1972 and since then it has continued to be one of the priority areas.[44] The Waste Framework Directive, adopted in 2008, establishes fundamental concepts and definitions for waste management, including waste,[45] recycling, and recovery. It clarifies waste transitions into a secondary raw material and how to differentiate between waste and by-products. It also outlines the waste hierarchy: waste prevention, preparing for reuse, recycling, recovery and disposal (Art. 4(1)). It sets quantity-based targets for the preparation of reuse and recycling for specific waste streams. Waste Framework Directive was amended in 2018.[46] As part of the circular economy package, Directive (EU) 2018/851,[47] which amends Directive 2008/98/EC, strengthens waste prevention measures and broadens the scope to emphasise reducing waste generation and promoting the transition to a circular economy. Notably, Point 16 of the Preamble introduces Industrial symbiosis, absent from the original Directive 2008/98/EC. It recommends that Member States

[44] Erceg, A.; Činčurak Erceg, B.; Božić, A., "Toward Circular Economy – Impact and Legal Regulation – Example of Croatian Plastic Packaging Producer," In *Book of Proceedings: 6th International Scientific Symposium - Economy of Eastern Croatia - Vision and Growth*, edited by Mašek Tonković, A., Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business in Osijek, Osijek, 2017: 477. https://www.efos.unios.hr/wp-content/uploads/2023/06/GIH-Zbornik-2017.pdf.
[45] According to Art. 3(1) of the Waste Framework Directive, waste "means any substance or object which the holder discards or intends or is required to discard".
[46] Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste, OJ L 150, 14. 6. 2018, pp. 109–140.
[47] Henriques, J. *et al.*, *op. cit*. (note 36), p. 7.

facilitate the recognition of by-products from production processes that are not primarily aimed at producing those substances, provided EU-level harmonised conditions are met. The Commission should be empowered to adopt implementing acts to establish detailed criteria for by-product status, prioritising replicable Industrial symbiosis practices.

Each year, more than six million[48] vehicles in Europe are discarded as waste once they reach the end of their life. Improper management of end-of-life vehicles can lead to environmental issues and result in significant losses of valuable materials for the European economy. The automotive manufacturing sector is one of the largest consumers of raw materials like steel, aluminium, copper, and plastics but relies very little on recycled materials. While the recycling rates of materials from end-of-life vehicles are generally high, the scrap metal quality is often low, and only small quantities of plastic are recycled.[49] The maintenance of vehicles during their lifetime continually generates waste products. Some types of waste can be reused or recycled. "Car wrecks consist of up to 80% of recyclable materials, usable as secondary raw materials, e.g. metals or plastic."[50] So, automotive and heavy-duty and off-road vehicles manufacturers have a direct interest in a more sustainable management of their components, materials and products, to stay competitive.[51]

Directive 2000/53/EC on end-of life vehicles[52] sets out measures to prevent and limit waste from end-of-life vehicles and their components by ensuring their reuse, recycling and recovery. The scope of the Directive 2000/53/EC is limited to passenger cars and light commercial vehicles. Unfortunately, for the heavy-duty and off-road sector there are no regulations and directives regarding the end-of-life.[53] The Directive 2000/EC/53 sets automobile recycling targets (Art. 7(2)).[54] Therefore, Member States are required to take measures to encourage the reuse and recovery of vehicle components, with a preference for recycling when environmentally viable, while maintaining safety and environmental standards. It

[48] European Commission, End-of-Life Vehicles, https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en, accessed 4. 2. 2025.
[49] *Ibid*.
[50] Ličbinský, R. and Adamec, V., "The Unfavorable Influence of Transport on the Environment," *Transactions on Transport Sciences*, 4, no. 2 (2011): 106. https://tots.upol.cz/pdfs/tot/2011/02/05.pdf.
[51] Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F., "Heavy vehicles on the road towards the circular economy: Analysis and comparison with the automotive industry," *Resources, Conservation and Recycling*, 135 (2018): 108–122. https://doi.org/10.1016/j.resconrec.2017.06.017.
[52] Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements, OJ L 269, 21. 10. 2000, pp. 34–43.
[53] Saidani, M. *et al.*, *op. cit*. (note 51), p. 113.
[54] Economic operators have to ensure that all end-of life vehicles are reuseble and recoverable to a minimum of 95 % by an average weight per vehicle and year and that they are reusable and recyclable to a minimum of 85 % by an average weight per vehicle and year.

is also necessary to take into account the provisions of the Regulation (EU) 2023/1542 concerning batteries and waste batteries,[55] that aims to reduce reliance on raw materials from outside the Europan Union ensure that future batteries are collected, reused, and recycled broadly within the Europan Union.

Industrial symbiosis often involves the use of by-products of other industries as alternative fuels or energy sources in the transport sector. The relevant regulations are Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources.[56] It promotes the use of renewable energy sources in transport, including biofuels and hydrogen produced from industrial by-products. According to Fraccascia *et al.*, bioenergy production might create the following environmental benefits: a lower amount of (bio)waste disposed of in landfills, a lower amount of energy produced from conventional sources, and a reduction in greenhouse gases emissions.[57]

Additionally, we refer to Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU[58] that establishes mandatory national targets leading to the deployment of sufficient alternative fuels infrastructure in the European Union for road vehicles, trains, vessels and stationary aircraft as well as technical specifications and requirements on user information, data provision and payment requirements for alternative fuels infrastructure (Art. 1). Regulations related to alternative fuels contribute to the establishment of Industrial symbiosis since, for example, by-products from one sector (e.g. agricultural waste) can be used to produce biofuels or hydrogen, which contributes to the reduction of emissions in transport.

Regulations limiting emissions in the transport sector are also important. Emissions for vehicles are regulated using Euro standards. The Euro 5 and Euro 6 standards regulate the highest permitted emissions from light passenger and

[55] Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, OJ L 191, 28. 7. 2023, pp. 1–117.

[56] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), OJ L 328, 21. 12. 2018, pp. 82–209.

[57] Fraccascia, L.; Yazdanpanah, V.; van Capelleveen, G.; Yazan, D. M. "Energy-based industrial symbiosis: a literature review for circular energy transition." Environment, Development and Sustainability 23 (2021): 4801. https://link.springer.com/article/10.1007/s10668-020-00840-9.

[58] Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, OJ L 234, 22. 9. 2023, pp. 1–47.

commercial vehicles,[59] and Euro VI[60] for heavy duty vehicles. However, new Euro 7[61] standards have been adopted in 2024, with different dates of application depending on vehicle categories. It aims to further reduce pollutants. Euro 7 covers cars, vans and heavy-duty vehicles in one legal act. Compared to Euro 6, it introduces stricter limits, broader testing conditions, and durability requirements, ensuring emissions stay low throughout a vehicle's lifetime. The Euro 7 standard also regulates brake emissions and tyre abrasion. These vehicle emissions standards may encourage the use of more environmentally friendly alternative fuels from other industries.

Industrial symbiosis offers numerous benefits in the transport sector, from environmental sustainability, resource efficiency, and cost reduction to fostering innovation. Ultimately, it creates a more environmentally friendly transportation system. Industrial symbiosis helps transport companies meet strict emission standards while adapting to evolving environmental policies. As shown in the paper, no direct legal regulations regulate Industrial symbiosis, especially not in the transport sector. Nevertheless, certain rules can be drawn from the broader provisions on environmental protection.

As stated by Golev *et al.*, uncertainties in environmental regulations and challenges in obtaining approvals for waste reuse projects from regulatory authorities can pose barriers to potential synergies. Conversely, mandatory recycling regulations for certain materials, increased waste disposal taxes, and similar measures act as driving forces for synergy projects.[62] Golev *et al.* point out that recycling and waste reuse issues are an integral part of current regulation, but there is still a lack of legislation incentives and guidance for the best environmental outcomes. „Legislation should recognise not only well-known, but also potential

[59] Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, OJ L 171, 29. 6. 2007, pp. 1–16. REgulation was amended several times.

[60] Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC, OJ L 188, 18. 7. 2009, pp. 1–13. Euro VI were amended several times.

[61] Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7), amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 of the European Parliament and of the Council, Commission Regulation (EU) No 582/2011, Commission Regulation (EU) 2017/1151, Commission Regulation (EU) 2017/2400 and Commission Implementing Regulation (EU) 2022/1362, OJ L, 2024/1257, 8. 5. 2024.

[62] Golev, A. *et al*., *op. cit.* (note 41), p. 143.

waste reuse options. A continuous review of the regulation barriers (in close collaboration with industry partners) is necessary. There has to be a clear promotion from a regulatory side for the best-known practices in waste reuse and recycling."[63] Enhancing compliance with laws and enforcement is also a key driver for industries to explore alternative pollution prevention methods, which may become more cost-effective as the expenses associated with end-of-pipe disposal solutions rise.[64]

V. Conclusion

The rapid expansion of transport in the 20th century, particularly in the 21st century, mainly in road transport, has greatly intensified negative impacts on the environment and human health. Environmental pollution, especially from sectors like energy, industry, and transport, has become a pressing issue for the European Union, which has enacted over a thousand directives to address it. In 2021, transport accounted for 29.2% of the EU's total CO_2 emissions, with road transport being the largest contributor. Transport is vital for economic development but also poses significant environmental challenges, requiring technological advancements for greater sustainability. The European Union has adopted numerous strategies to promote sustainable transport, such as the European Green Deal and the Sustainable and Smart Mobility Strategy, both aiming to reduce emissions by 90% by 2050. Additionally, circular economy concepts and Industrial symbiosis are being encouraged to reduce waste and environmental damage in industrial sectors. Regulations like the European Climate Law and other transport-specific policies are designed to align the European Union's transport sector with its climate goals, supporting the transition to a sustainable, green economy by 2050.

Industrial symbiosis promotes resource efficiency and sustainability by facilitating exchanges of materials, energy, water, waste, and shared services among industries. In relation to transport it offers several key advantages. By sharing resources like energy, materials, and logistics infrastructure, companies can reduce operational costs and improve efficiency in transportation. It helps minimise waste by repurposing by-products from one industry, such as biofuels or recycled materials, to power vehicles or build transport infrastructure. Industrial symbiosis also reduces greenhouse gas emissions and fuel consumption by optimising routes and avoiding unnecessary transport, which leads to fewer empty or inefficient trips. Additionally, it promotes collaboration between industries, fostering innovation in sustainable transport solutions. Overall, it contributes to a more circular and eco-friendly transport system.

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[63] *Ibid*., p. 150.

[64] Sakr, D.; Baas, B.; El-Haggar, S.; Huisingh, D., "Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context," *Journal of Cleaner Production* 19, no. 11 (2011): 1168. https://doi.org/10.1016/j.jclepro.2011.01.001.

The problem of researching this topic is the lack of appropriate legislation that regulates industrial symbiosis, especially the one that is even more specific and refers to transport. Also, there is a lack of literature related to the legal regulation of Industrial symbiosis.

Although no specific legal framework exclusively deals with Industrial symbiosis in transport, the legal aspects of this concept are covered through wider legislative frameworks related to sustainability, circular economy and emission reduction. These legal frameworks include regulations at the European Union level, as well as the national laws of the Member States.

The Industrial Symbiosis is gaining importance due to growing recognition of its environmental and economic benefits. However, its full potential is hindered by regulatory barriers, lack of financial incentives, and limited stakeholder awareness. In this sense, it is necessary to encourage cooperation with the academic community and innovation centres, to conduct education and inform the industry about the benefits of symbiosis, and to encourage all relevant stakeholders (governments, legislators, companies, research institutions, and specialised facilitators) to create favourable conditions for Industrial symbiosis and its implementation in practice. The future of Industrial symbiosis is promising, driven by global sustainability goals and initiatives like the European Union's Circular Economy package. For the Industrial symbiosis to succeed, it's essential to adopt appropriate legislation as well as various incentive measures.

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Bibliography:

1. Castellet-Viciano, L.; Hernández-Chover, V.; BellverDomingo, Á.; Hernández-Sancho, F. "Industrial Symbiosis: A Mechanism to Guarantee the Implementation of Circular Economy Practices." *Sustainability* 14, (2022): 15872. https://www.mdpi.com/2071-1050/14/23/15872.

2. Chertow, M. R. ""Uncovering" Industrial Symbiosis." *Journal of Industrial Ecology* 11, no. 1 (2008): 11–30. https://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.1110.

3. Chertow, M. R. "Industrial Symbiosis: Literature and taxonomy." *Annual Review of Energy and the Environment* 25, no. 1 (2000): 313–337. https://www.annualreviews.org/content/journals/10.1146/annurev.energy.25.1.313.

4. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions (The European Green Deal), COM/2019/640 final.
5. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Sustainable and Smart Mobility Strategy – putting European transport on track for the future, COM/2020/789 final.
6. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM/2021/550 final.
7. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – „A New Industrial Strategy for Europe", COM/2020/102 final.
8. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – „A new Circular Economy Action Plan For a cleaner and more competitive Europe", COM/2020/98 final.
9. Činčurak Erceg, B. "Pravna regulacija zaštite okoliša od štetnih utjecaja prometa." In *Zakonodavstvo zaštite okoliša i održivi ekonomski razvoj u EU*, edited by Duić, D. and Ćemalović, U. Sveučilište Josipa Jurja Strossmayera u Osijeku, Pravni fakultet Osijek, Osijek, 2022: 110–161, https://www.pravos.unios.hr/wp-content/uploads/2022/11/zakonodavstvo-zastite-okolisa-i-odrzivi-ekonomski-razvoj-u-eu.pdf.
10. De Römph, T. J. and Cramer J. M. "How to improve the EU legal framework in view of the circular economy." *Journal of Energy & Natural Resources Law* 38, no. 3 (2020): 245–260. https://www.tandfonline.com/doi/pdf/10.1080/02646811.2020.1770961.
11. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), OJ L 328, 21. 12. 2018, pp. 82–209.
12. Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste, OJ L 150, 14. 6. 2018, pp. 109–140.
13. Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles, OJ L 188, 12. 7. 2019, pp. 116–130.
14. Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements, OJ L 269, 21. 10. 2000, pp. 34–43.
15. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312, 22. 11. 2008, pp. 3–30.
16. Domenech Aparisi, T. A., "Social Aspects of Industrial Symbiosis Networks" (Thesis submitted in fulfilment of the Degree of Doctor of Philosophy, Bartlett

school of Graduate Studies, University College London, 2010), https://core.ac.uk/download/pdf/1674444.pdf.

17. Erceg, A.; Činčurak Erceg, B.; Božić, A. "Toward Circular Economy – Impact and Legal Regulation – Example of Croatian Plastic Packaging Producer." In *Book of Proceedings: 6th International Scientific Symposium - Economy of Eastern Croatia - Vision and Growth*, edited by Mašek Tonković, A., Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business in Osijek, Osijek, 2017: 465–475. https://www.efos.unios.hr/wp-content/uploads/2023/06/GIH-Zbornik-2017.pdf.

18. Erceg, A.; Krzeminski, P.; Jonaitiene, V.; Munoz Marti, M.; Dunjić, B.; Szilagyi, A.; Burmaoglu, S.; Činčurak Erceg, B.; Giacomi, E.; Anastasovski, A.; Ryan, Y.; Skolou, V.; Chrabak, P.; Refalo, P.; Borg, M.; Dosoretz, C.; Plaza, J. P.; Hurtado Ruiz, A. M.; Özcan Kilcan, C.; Tkaczyk, A. H.; Godina, R.; Neves, A., *State-of-the-art report on Industrial Symbiosis topic and its different sub-areas (settling the basis for further improvements and their introduction in the industry)*, 2024, https://www.liaise-action.eu/publication/d1-1-state-of-the-art-report-on-industrial-symbiosis-topic-and-its-different-subareas/.

19. European Commission, End-of-Life Vehicles, https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en. Accessed 4. 2. 2025.

20. European Commission, *EU Transport in Figures - Statistical Pocketbook 2023*, Publications Office, 2023, https://op.europa.eu/en/publication-detail/-/publication/493b2403-7157-11ee-9220-01aa75ed71a1/language-en.

21. Fraccascia, L.; Yazdanpanah, V.; van Capelleveen, G.; Yazan, D. M. "Energy-based industrial symbiosis: a literature review for circular energy transition." *Environment, Development and Sustainability* 23 (2021): 4791–4825. https://link.springer.com/article/10.1007/s10668-020-00840-9.

22. Golev, A.; Corder, G. D.; Giurco, D. P. "Barriers to Industrial Symbiosis: Insights from the Use of a Maturity Grid." Journal of Industrial Ecology 9, no. 1 (2014): 141–154. https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12159.

23. Henriques, J.; Ferrão, P.; Castro, R.; Azevedo, J. "Industrial Symbiosis: A Sectoral Analysis on Enablers and Barriers." *Sustainability*, 13 (2021): 1723. https://www.mdpi.com/2071-1050/13/4/1723.

24. Herath, P.; Dissanayake, P.; Thisakya, G. "The potential of industrial symbiosis: An analysis of barriers to its implementation for better waste management in industrial zones in Sri Lanka". In: *Proceedings of the 11th World Construction Symposium*, edited by Sandanayake, Y. G.; Waidyasekara, K. G. A. S.; Ramachandra, T.; Ranadewa, K. A. T. O., Sri Lanka, 2023: 1064–1078. https://doi.org/10.31705/WCS.2023.85.

25. Ličbinský, R. and Adamec, V. "The Unfavorable Influence of Transport on the Environment." *Transactions on Transport Sciences* 4, no. 2 (2011): 91-112. https://tots.upol.cz/pdfs/tot/2011/02/05.pdf.

26. Lybæk, R.; Christensen, T. B.; Thomsen, T. P. "Enhancing policies for deployment of Industrial symbiosis – What are the obstacles, drivers and future way forward?." *Journal of Cleaner Production* 280, no. 2 (2021). https://doi.org/10.1016/j.jclepro.2020.124351.

27. Mirata, M.; Emtairah, T. “Industrial Symbiosis Networks and the contribution to environmental innovation: The case of Landskrona industrial symbiosis programme.” *Journal of Cleaner Production* 13, no. 10-11 (2005): 993–1002. https://doi.org/10.1016/j.jclepro.2004.12.010.

28. Neves, A.; Godina, R.; Azevedo, S. G.; Matias, J. C.O. “A comprehensive review of industrial symbiosis.” *Journal of Cleaner Production* 247, (2020):119113. https://doi.org/10.1016/j.jclepro.2019.119113.

29. Rahman M. F.; Islam K.; Islam K. N. “Industrial Symbiosis: A Review on Uncovering Approaches, Opportunities, Barriers and Policies.” *Journal of Civil Engineering and Environmental Sciences* 2(1), (2016): 11-19. https://www.engineegroup.us/Civil-Engineering-Environmental-Sciences/JCEES-2-109.php.

30. Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/, OJ L 188, 18. 7. 2009, pp. 1–13.

31. Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, OJ L 171, 29. 6. 2007, pp. 1–16.

32. Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO_2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC, OJ L 198, 25. 7. 2019, pp. 202–240.

33. Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (recast), OJ L 111, 25. 4. 2019, pp. 13–53.

34. Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (European Climate Law), OJ L 243, 9. 7. 2021, pp. 1–17.

35. Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, OJ L 191, 28. 7. 2023, pp. 1–117.

36. Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, OJ L 234, 22. 9. 2023, pp. 1–47.

37. Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their

emissions and battery durability (Euro 7), amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 of the European Parliament and of the Council, Commission Regulation (EU) No 582/2011, Commission Regulation (EU) 2017/1151, Commission Regulation (EU) 2017/2400 and Commission Implementing Regulation (EU) 2022/1362, OJ L, 2024/1257, 8. 5. 2024.

38. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F. "Heavy vehicles on the road towards the circular economy: Analysis and comparison with the automotive industry." *Resources, Conservation and Recycling*, 135 (2018): 108–122. https://doi.org/10.1016/j.resconrec.2017.06.017.

39. Sakr, D.; Baas, B.; El-Haggar, S.; Huisingh, D. "Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context." *Journal of Cleaner Production* 19, no. 11 (2011): 1158–1169. https://doi.org/10.1016/j.jclepro.2011.01.001.

40. SCALER, "Report on EU-wide industrial symbiosis regulatory measures, regulatory gaps and need for deployment." 2020, https://www.scalerproject.eu/wp-content/uploads/2020/09/D4.4_SCALER_Policies-Report_v1.0.pdf.

41. Vasilj, A.; Činčurak Erceg, B. "Through changes to legislation to modern urban mobility, In *Book of Proceedings: 11th International Scientific Symposium "Region, Entrepreneurship, Development, RED 2022* edited by Leko Šimić, M., Josip Juraj Strossmayer University of Osijek, Faculty of Economics and Business in Osijek, Osijek, 2022: 801–819. https://www.efos.unios.hr/wp-content/uploads/2023/06/RED-2022-Proceedings.pdf.

42. White Paper - European transport policy for 2010: time to decide, COM/2001/0370 final.

43. White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM/2011/0144 final.

44. World Commission on Environment and Development, Our Common Future, https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf. Accessed 20. 12. 2024

45. Zorpas, A. A. "Strategy development in the framework of waste management." *Science of The Total Environment*, 716 (2020): 137088. https://doi.org/10.1016/j.scitotenv.2020.137088.