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Decarbonization of rail transport as an element of climate policy

Abstract: The aim of this article is to present the plans for the energy transformation of the Polish railway system in the context of the objectives of the European and national climate policy. After a short introduction and reference to the main sources, the author discusses modern methods of reducing pollutant emissions accompanying the use of traction energy on the railroad. The second part describes the steps of a specific plan with the goal of achieving zero emissions for this mode of transport. The whole is closed with a summary that indicates a general change in the priorities of the European transport policy and the resulting new opportunities and impulses for the development of railways.

Keywords: Sustainable transport; Railway; Climate policy; Emissions reduction

Introduction

The year 2021 has been declared the "Year of Railways" in the European Union. An initiative launched by European railway companies aims to highlight the growing role of environmental factors in decision-making relating to transport development. In the sectoral dimension, it is also to emphasize the role of railways in the green transformation, which has been recognized as the foundation of future social and economic development.

For decades, railways have been a pillar of long-distance and mass road transport. This situation has changed with the development of road transport and better and better infrastructure increasing its range and competitiveness. The almost unlimited availability and flexibility of cars allowed them to dominate the global transport market. This has led to a situation where the car is today, on the one hand, an integral part of social and economic activity, and, on the other hand, one of the main threats to the environment and the health and life of citizens. As a result, the degree of use and emissions from this particular mode of transport today determine the overall environmental impact of the entire sector.

Both in Europe and in Poland, the only alternative to cars is currently rail transport. By taking over large flows of passengers and cargo, it significantly reduces the unit demand for energy, and consequently also the level of air pollution and the related climate changes. At the same time, it also contributes to reducing the number of accidents, noise, and congestion. As a result, it is the least burdensome for the environment and society. Therefore, the development of railways is becoming an increasingly important element of the policy of decarbonizing the economy and an instrument of energy transformation.

The method and scope of the analysis

This article has been prepared on the basis of two reports that were published in 2021. The first one entitled "Railroad for climate - climate for railways" was prepared by the Foundation "Pro Kolej" at the 14th International Railway Fair TRAKO2021, the second, "Green railway in Poland - climate, energy, transport" was created as a result of a framework agreement

under the patronage of the Ministry of Development and Technology, as a result of work on the implementation of the UN sustainable development goals in Poland. In addition, the material uses information from other scientific studies, current literature on the subject as well as data from the Central Statistical Office, the National Center for Emission Management and Balancing, and Eurostat.

Reduction of emissions from the railway sector

Decarbonization and ensuring energy efficiency are challenges that virtually every sector of the economy has to face. This is also true of transport - including railways. Although it is the branch with the lowest emissivity, its final level of environmental impact, taking into account indirect emissions, depends to a large extent on the structure of energy production and consumption. In the case of power supply to railways, the sector's emissions are determined both by the proportions of individual types of traction - electric and diesel - as well as the structure of fuel consumption in the commercial power industry and production methods - i.e. energy mix (Fasiecka, Marek 2018, Sowiński 2020).

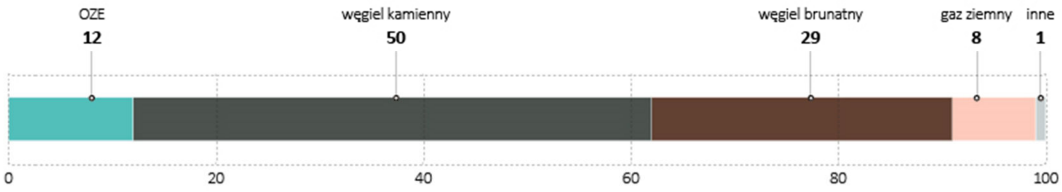
Tab. 1. Emissivity of electricity used on railways

Type of emission	Carbon dioxide [CO_2]	Sulfur oxides [SO_x]	Nitrogen oxides [$N0_x$]	Dusts [$PM_{10/2,5}$]
Współczynnik emisji	731 [kg/MWh]	0,60 [kg/MWh]	0,53 [kg/MWh]	0,14 [kg/MWh]

Source: Information on the impact of electricity on the environment in terms of emissions for individual fuels and other primary energy carriers used to generate electricity PKP Energetyka S.A. in 2019

In Poland, i.e. a country where electricity production is largely based on fossil fuels (see Fig. **1**), powering the railways is not an issue that is neutral from the point of view of climate policy. Of course, the mere transfer of passenger and freight transport to rail leads to a reduction in CO2 emissions and other air pollutants. However, it does not allow to fully reduce the negative impact of transport activities on the environment. The solution to this problem would be the energy transformation of the rail sector based on two main pillars:

- replacing power sources with energy from renewable sources;
- systemic reduction of energy demand.



1. Sources of electricity used on the railroad (2019)
Source: PKP Energetyka S.A.

The first of the above-mentioned areas requires the independence of the railway supply structure from the general *energy mix* of the country. It means the need to prepare new, clean energy sources, which are an alternative to conventional energy - that is, to build a network of renewable energy sources (RES) with an appropriate potential, and with it to construct a stable and effective power supply system that:

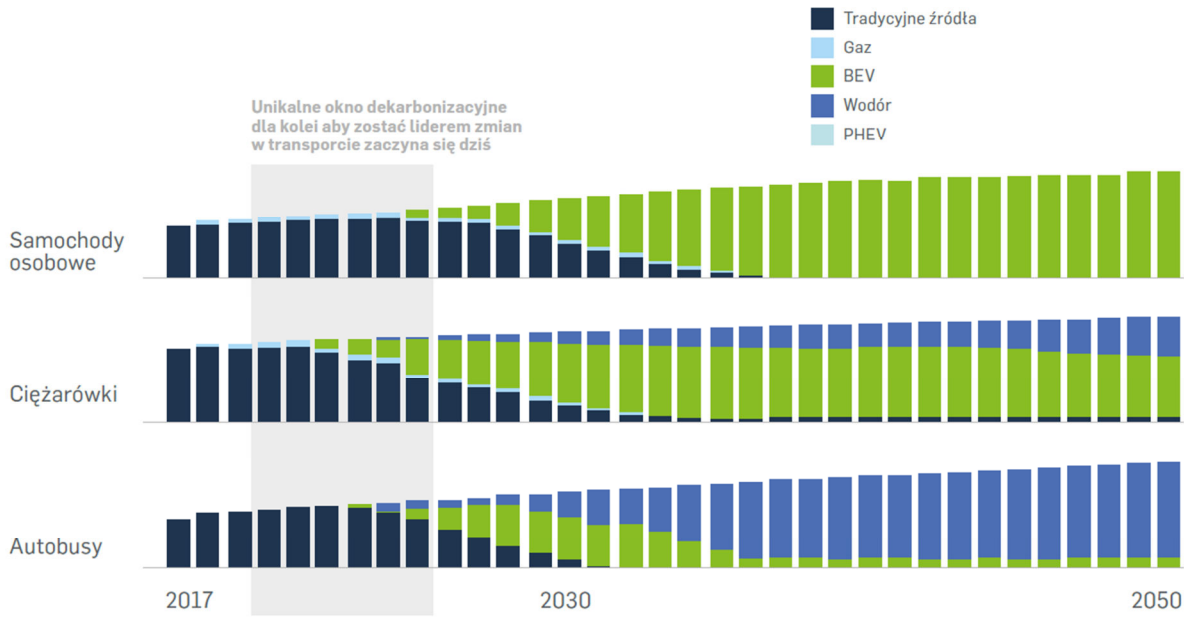
- guarantees the balancing of production and consumption in the form of appropriate energy storage systems,

- provides backup sources and diversified flow directions,
- enables the management of power grids with a large number of distributed sources.

The described investments require a very large scale. Therefore, their basis must be the long-term commitment and cooperation of many entities - the more that the specificity and requirements of the energy sector in many respects exceed the scale typical of even railways.

It is not a simple task, but a transformation in this area is in the interest of both entities from the railway industry and a wide range of its recipients and partners - including logistics operators, the rolling stock industry, infrastructure companies, manufacturers of devices, and equipment for the sector and current users. It is also an additional opportunity that allows you to secure risks not only at the investor level but also for a large group of recipients or even for entities operating in this mode of transport.

The described process is economically justified because the formation of energy prices depends to an increasing extent on the sources of its production. In this respect, energy from fossil sources is becoming more and more expensive, because apart from the costs of fuel and production, it is additionally burdened with the rapidly growing costs of CO_2 emission allowances. In mid-March 2021, the prices of emission allowances on the European Energy Exchange increased to a record level of EUR 40 per ton. The market forecasts assume a further dynamic increase in prices to approx. EUR 70-80 in 2030, which will have an impact on the competitiveness of the domestic power sector and industry, which are largely based on coal. Moreover, an increase in the burden is also caused by the systematically raised thresholds of environmental standards. They require more and more advanced treatment or emission reduction systems, and thus additional investments. On the one hand, for this reason, and on the other because of the clear environmental pressure, financial institutions avoid crediting investments in conventional energy sources, and difficulties in obtaining capital for development or modernization increase energy prices.



2. The period of "decarbonization window" for railways

Source: McKinsey Decarbonization Model for Poland, for: McKinsey & Company, Can zero-emission emissions contribute to the renaissance of railways?, Kongres Kolejowy, November 2020.

In the case of the rail sector, the time for transformation is not unlimited. The chances in this respect are determined by the so-called "decarbonization window" (see Fig. **2**), i.e. the period in which it is possible to permanently increase the competitiveness against other modes of transport. The decarbonization window is a term that refers to the period of around 5-10 years during which most modes of transport will become low or zero-emission, and thus more competitive in terms of delivering green transport solutions. Alternative sectors are also working on building their own environmentally friendly solutions and ecological arguments in favor of railways may gradually lose their importance (Wolański 2021).

As mentioned, the second pillar of the pro-ecological transformation of the railway sector is a radical increase in the energy efficiency of the transport system. In this case, the tool for implementing changes should be activities such as:

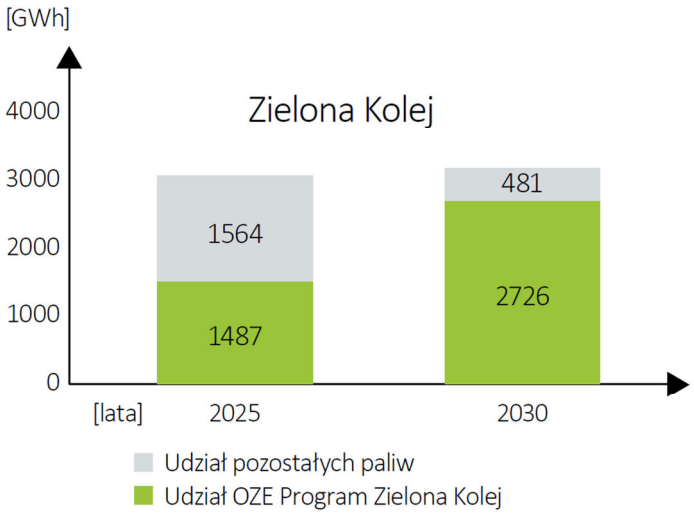
- replacement and modernization of rolling stock, thus increasing the energy efficiency of traction vehicles,
- use of recuperation,
- *eco-driving*.

The first issue is related to technological progress and more and more advanced and energy-efficient vehicle power systems. The second area - the recovery of energy generated during braking - means the conversion of energy and its reuse for traction or non-traction needs. Traction needs can be realized in the form of powering another vehicle through the grid or energy storage which is then used to accelerate the same vehicle. Non-traction needs include lighting, heating, and air conditioning. According to the estimates of the Railway Energy Efficiency Center, energy consumption savings due to recuperation in regional or agglomeration transport can reach a value of about 25%. The last instrument mentioned above to reduce the demand for traction energy is the optimization of driving techniques, i.e. *eco-driving*, which reduces energy consumption with virtually no investment. It is estimated that eco-driving will allow you to generate energy savings of 7%.

"Green Railway" as an example of a comprehensive program

The direction of changes, determined first by the European Green Deal, and then specified in detail by the Sustainable and Intelligent Mobility Strategy published at the end of 2020. The Sustainable and Intelligent Mobility Strategy requires that the energy transformation in transport should move from the sphere of plans to implementation. A tool for this purpose should be sectoral programs that have a high replication potential and with each subsequent implementation improve efficiency and reduce costs thanks to economies of scale (UN Global Compact Network Poland 2021).

An example of such a comprehensive plan is the "Green Railway" program, prepared by the Railway Energy Efficiency Center (CEEK). It is an industry initiative that assumes a systemic change in power sources for the sector, which by 2030 will use 85% of energy from renewable sources, and by 2050 in 100% (cf. Fig. **3**).



3. Expected energy transformation of the railway sector
Source: Railway Energy Efficiency Center, 2020

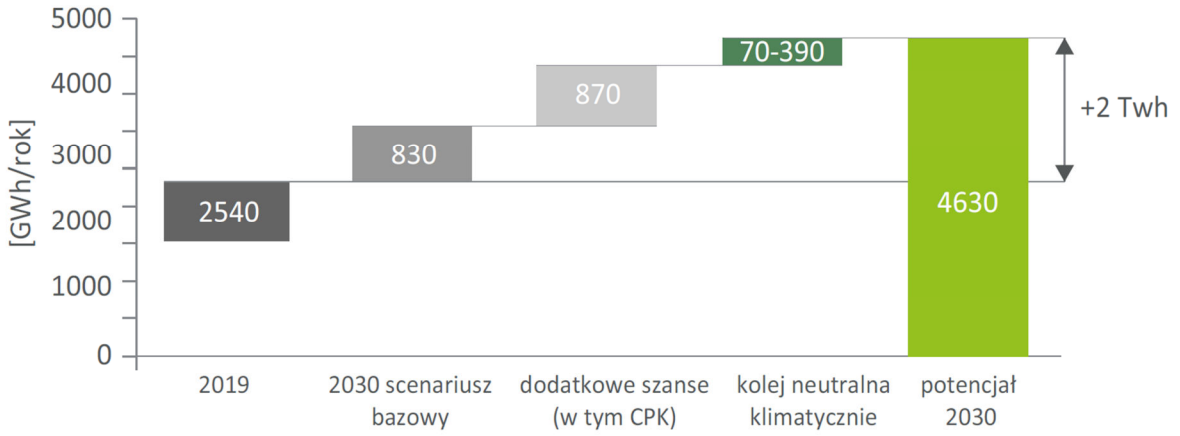
To implement the above assumptions, it is necessary to invest in energy generation infrastructure, including the creation of a renewable energy investment program dedicated to supplying the traction network. At the same time, installations with lower power intended to supply the railway undertakings themselves, become a complementary element. In both cases, production can use railway areas and facilities, including the roofs of railway stations and technical backup facilities, platform shelters, and workshop buildings. As a result, the distance between the place where energy is generated and received is shortened. And this means an additional effect in the form of reduction of transmission losses.

In the described model, a large, reliable, institutional recipient - rail transport - guarantees an appropriate scale of demand, and thus constitutes the basis for the preparation of long-term contracts for new producers. Those, in turn, having a stable partner, can obtain low-cost financing and prepare a cost-competitive production system. The basis of the program are investments estimated at PLN 6 to 10 billion and the commissioning of several hundred small and several dozen large photovoltaic farms and wind sources. Their effect is to be the generation of approx. 1.8 GW of new power from a "virtual power plant" dedicated to the railways (this amount corresponds to the assumption of an 85% share of renewable energy in 2030 in relation to the current energy demand).

The economic basis of the "Green Railway" program is the coordination of all available tools for obtaining and saving energy and creating the conditions for the required investments through:

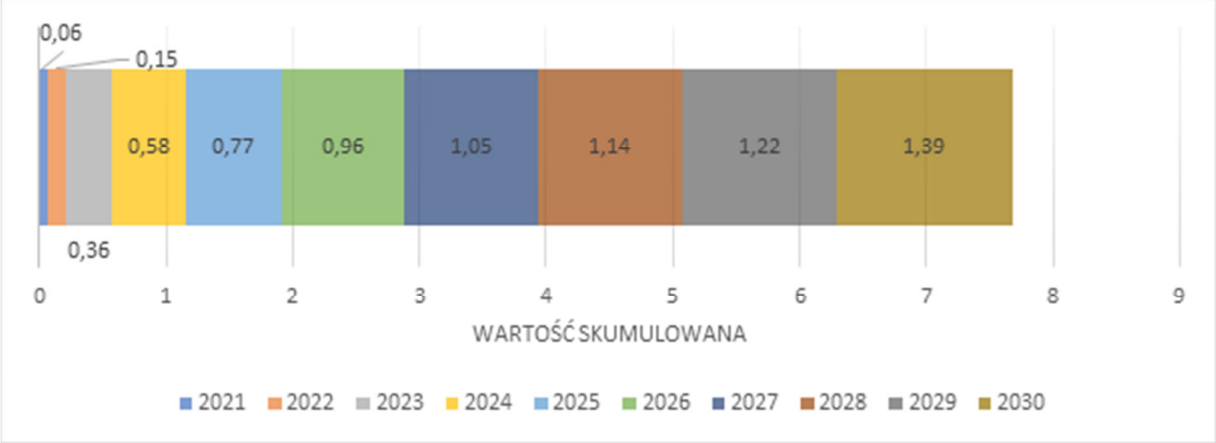
- determining the amount and technology of connecting renewable energy sources in appropriate locations (creating supply),
- guaranteeing long-term demand, thanks to the scale of operations and contracts with carriers and other rail recipients (creating demand),
- management of distributed generation in the railway network,
- aggregation of sources dispersed in time and allocation to the needs of railways.

The "Green Railway" program assumes that the infrastructure and rolling stock investments currently implemented in Poland will lead to a significant increase in the transport of both passengers and goods. As a consequence, increased demand for traction energy can be expected (see Fig. **4**).



4. A scenario of increasing demand for traction energy for railways in Poland
Source: Railway Energy Efficiency Center, 2020

In the interests of its ecological advantages, the industry must independently ensure that the forecast increase in transport does not generate new environmental burdens. Therefore, part of the development scenarios must include both involvements in renewable energy and pro-efficiency tools. Only the compilation of these two elements makes it possible to reduce the consumption of energy produced from conventional fuels (cf. Fig. **5**).



5. CO_2 emissions eliminated in the "Green Railway" program [Cumulative value]
Source: Railway Energy Efficiency Center, 2020

From the point of view of rail transport, the benefits of implementing the Green Railway Program may be felt on three levels. The first is fast decarbonization and specific eliminated emissions. Rail transport is privileged in this case because it has already passed the electrification stage. The second is the image-related benefits that may contribute to the generation of new passenger and freight traffic, which, thanks to ecological arguments, will go to the railway system instead of the roads. Consumers aware of climate change declare readiness to change their choices and behavior in order to reduce the impact on the natural environment. This means that, with similar prices, they are willing to choose transport solutions that contribute to environmental and climate protection (Wolański 2021). The third one is the possibility of obtaining additional sources of financing for the development of the industry - including EU financing. The program complies with the increasingly restrictive environmental criteria that are followed by both financial and European institutions - especially in the case of granting grants and settling competition procedures.

Summary
In order to reduce the harmful impact of transport on our health and the surrounding environment, it is necessary to use the widest possible spectrum of organizational and technological solutions. Wherever possible, the economy and social relations should be developed so as not to increase the demand for transport. In a situation where resignation from transport is not possible, the solution is to change the division of transport tasks and preferences for the means of transport with the lowest emissions of pollutants.

Despite such recommendations and current environmental advantages, the railway sector will not avoid challenges related to the necessity of its own energy transformation. This will be a difficult task, as it requires the involvement of the entire industry and support from decision-making centers at the local and central levels, including appropriate incentives and reliefs. However, due to the infrastructural possibilities and the limited number of market participants, it is a development opportunity. Rail has an advantage over other transport segments and can complete the transformation faster than other modes of transport. Thanks to this, the industry can become a leader in changes in the implementation of the postulates of a low-emission economy, and ultimately zero-emission. Especially since no other branch of transport can offer eighty percent electromobility today and the prospect of just a decade to reach 85% of the share of power from renewable sources.

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