COMPARISON OF ENERGY STATUS IN PORTUGAL AND IN SLOVAKIA

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Abstract

Portugal and Slovakia, like other European countries, face the critical challenge of transforming their energy sectors to meet the EU's goal of climate neutrality by 2050. Achieving this target requires a comprehensive strategy involving new policies, advanced technologies, and sufficient financial investment to drive emission reductions and support a shift to more sustainable energy systems. While the overarching goal is the same across Europe, each country's approach is shaped by its specific conditions—such as geography, climate, natural resources, political priorities, and social factors. Therefore, national energy and climate strategies differ in scope and ambition. This paper focuses on the scale of transformation required in the energy sector, examining what Portugal and Slovakia must do to meet their 2050 climate targets. It analyzes their current energy systems, key challenges, and progress toward decarbonization. By comparing these two countries, the paper highlights how geographical and demographic differences influence their respective energy profiles. Portugal, with abundant renewable resources, and Slovakia, with a strong nuclear component, offer contrasting but instructive examples of the diverse paths European nations are taking toward a low-carbon future. The comparison helps illustrate the broader complexity of Europe's energy transition and the importance of tailored national strategies.

Key words

Energy, renewable energy sources, sustainable energy, energy sector.

Introduction

Energy plays a vital role in the development and functioning of every country. However, multiple challenges associated with energy production and consumption need to be addressed to ensure sustainability and resilience. Some of these challenges are economic in nature, including high energy prices, price volatility, and dependence on energy imports [1,2]. Others are environmental, contributing to climate change, human toxicity, acidification, and other ecological impacts [3,4]. In addition, energy access represents a significant social issue, as it should be both available and affordable for all segments of the population [5,6].

Addressing the energy challenge requires a comprehensive approach that considers various key sectors, including electricity generation, transportation [7], industry [8], and residential and service buildings [9,10]. Each of these sectors presents unique issues in terms of energy consumption patterns and environmental impacts and thus requires tailored solutions to promote efficiency and reduce emissions.

Given the diverse geographic, economic, and social contexts across Europe, individual countries may adopt different strategies to address their specific energy challenges [11,12]. In this study, the current and future energy outlooks of two European Union member state, Portugal and

Slovakia, are examined. The analysis aims to highlight their distinct approaches and progress toward achieving a more sustainable and secure energy future.

1. Present Status

Portugal and Slovakia are located in distinctly different regions of Europe, which leads to significant variations in their natural energy resources, climate conditions, and energy systems. Portugal is situated in the southwest of Europe, bordered by the Atlantic Ocean. It benefits from a Mediterranean climate, characterized by mild, wet winters and hot, dry summers. These climatic conditions offer a strong potential for solar energy generation, as Portugal receives a high number of sunshine hours per year. Additionally, its extensive coastline allows for the exploration of wind and marine energy sources. The country's diverse topography, including mountain ranges and river systems, also supports hydropower development.

Slovakia, in contrast, is a landlocked country located in Central Europe. It has a continental climate, with cold winters and warm summers, and experiences more seasonal variation than Portugal. Slovakia's terrain is largely mountainous, particularly in the northern and central regions, due to the Carpathian Mountains. These conditions are less favourable for large-scale solar energy, but the country has historically relied on other sources such as hydropower and nuclear energy, which are well-suited to its geographic and geological profile.

One of the key differences between the two countries is population size—Slovakia has approximately half the population of Portugal. This difference directly influences both energy supply and consumption patterns. However, as shown in Fig. 1, Portugal's total energy supply is higher than that of Slovakia, though not strictly proportional to the population difference. Other contributing factors include the countries' climates, economic structures, energy demand for heating or cooling, and national energy policies.

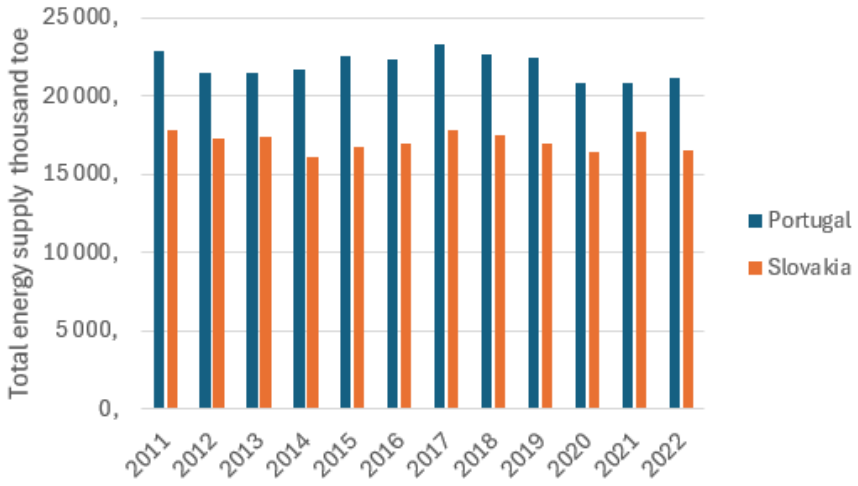

Fig. 1 Total energy supply for Portugal and Slovakia
Source: Osei Opoku, E.E.; Acheampong, A.O.; Dogah, K.E.; Koomson, I. Energy innovation investment and renewable energy in OECD countries. Energy Strateg. Rev. 2024, 54, 101462, doi:10.1016/j.esr.2024.101462

When analyzing energy supply by source, it becomes evident that Portugal and Slovakia follow different strategies shaped by their natural conditions. Portugal places a strong emphasis on renewable energy, particularly electricity from solar, wind, hydro, and biofuels. Nevertheless,

it continues to rely significantly on oil and petroleum products (excluding the biofuel portion) and natural gas, as illustrated in Fig. 2.

Slovakia, by contrast, has traditionally depended on nuclear energy, as well as natural gas, oil, and solid fossil fuels. Electricity supply from renewables is relatively lower than in Portugal (Fig. 2). However, a major development occurred in late 2023, when Slovakia shut down all coal-fired power plants, ending both coal mining and coal-based electricity generation. This marked a significant milestone in the country's shift toward cleaner and more sustainable energy sources.

In recent years, electricity production in Portugal has relied significantly on renewable energy sources, particularly wind and hydropower. These two sources have played a central role in the country's energy mix. In addition, photovoltaic (solar) energy is gaining momentum, with new policies and incentives being implemented to accelerate its adoption and integration into the national grid.

In contrast, Slovakia continues to rely heavily on nuclear power, which forms the backbone of its electricity generation. Among renewable sources, hydropower remains the most significant, though it contributes a smaller share compared to Portugal. Other renewable sources, such as solar and wind, currently represent only a minor fraction of Slovakia's energy production.

When examining energy consumption by sector, noticeable differences between the two countries emerge. In Portugal, the transport sector accounts for a higher share of total energy consumption, likely due to the country's geographic spread and limited rail infrastructure. In Slovakia, the residential sector shows a higher percentage of energy use. This can be partly attributed to the colder climate, especially during winter months, which increases energy demand for heating. Meanwhile, the industry, commercial, and public services sectors show relatively similar consumption levels in both countries, reflecting comparable patterns in economic activity and infrastructure.

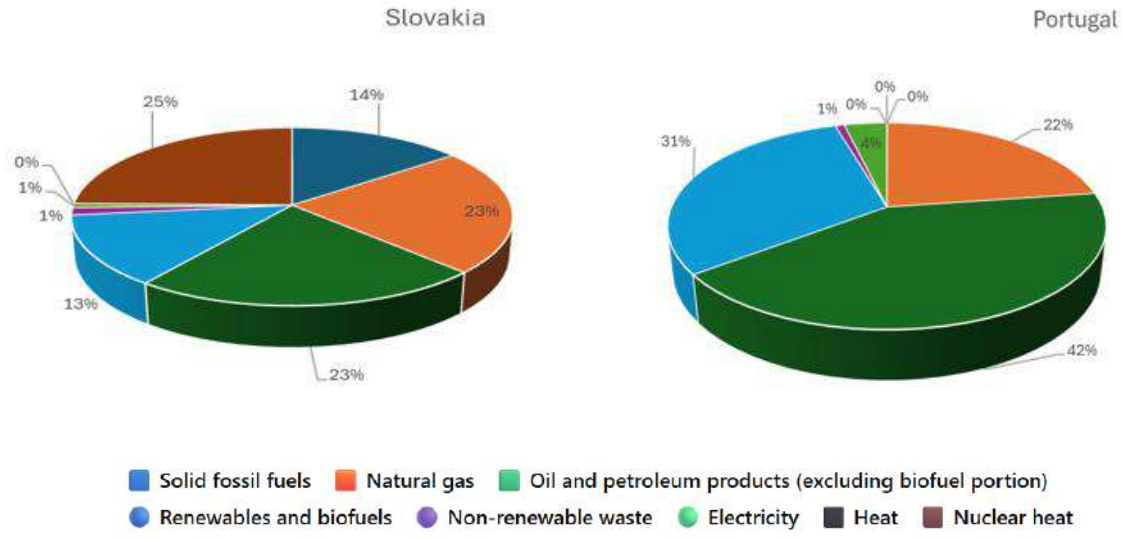

Fig. 2 Energy supply in Portugal and Slovakia by sources
Source: Osei Opoku, E.E.; Acheampong, A.O.; Dogah, K.E.; Koomson, I. Energy innovation investment and renewable energy in OECD countries. Energy Strateg. Rev. 2024, 54, 101462, doi:10.1016/j.esr.2024.101462.

2. Future status

These two countries should meet their goals, especially the ones set for the long term such as 2050. It is important to have affordable energy for the population while reducing greenhouse gas emissions and other negative environmental impacts. Since these two countries have different characteristics, they may follow different pathways to achieve their goals.
In the Portuguese roadmap for carbon neutrality is clear the pathway drawn. For photovoltaics installed power will reach 26 GW by 2050, between centralised and decentralised options. Onshore wind energy will also increase as well as offshore.
However, these technologies pose challenges that must considered to guarantee the security of supply. Batteries and pumped water in hydro facilities will continue to play a crucial role in the power system. Another measure is decentralisation of electricity generation which will contribute to a reduction of energy losses in the grid.
In the transport sector (Fig. 4), the incorporation of renewables will be done. In light passenger transport, diesel and petrol vehicles will be replaced by electric ones. Biofuels and hydrogen are considered to become important drivers. In industry (Fig. 4), energy and resource efficiency will assume great importance as well as electrification. Solar heating and biomass use are also significant measures in this sector. Biorefineries, industrial symbioses, and resource reuse are taught to be meaningful strategies to address the energy and climate change problems.
In residential or service building, a reduction of energy intensity is foreseen to be achieved by using high-performance electrical equipment for lighting and equipment of higher energetic efficiency classes [15].

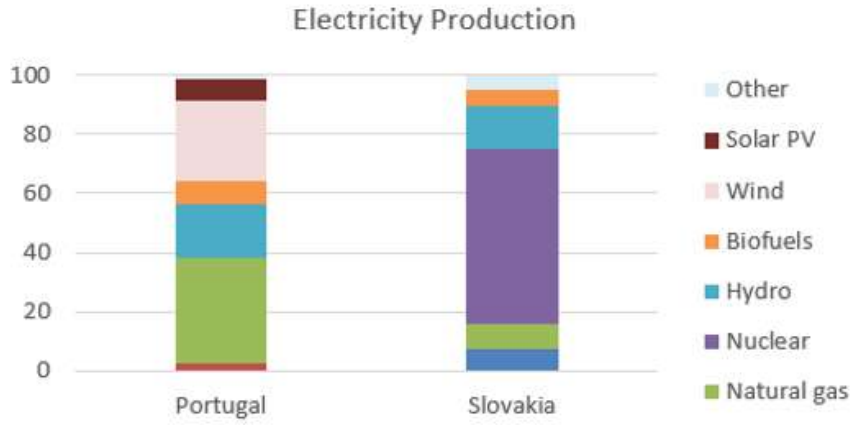

Fig. 3 ***Electricity production in Portugal and in Slovakia by sources***
Source: IEA, https://www.iea.org/ [accessed 26 Aug. 2024].

Slovakia, as well as Portugal, faces significant energy and climate challenges, in relation to the objective of achieving climate neutrality by 2050. The energy sector, which includes transport and emissions from extraction and fuel consumption, remains a key source of CO_2 emissions in Slovakia. Although measures to reduce emissions are already in place, current projections show that without further intensification of efforts, Slovakia will not meet its climate targets. The Slovak Republic has chosen its targets for energy efficiency at 30.3% and for renewable sources at 19.2% (from the current 15.4% in 2023).

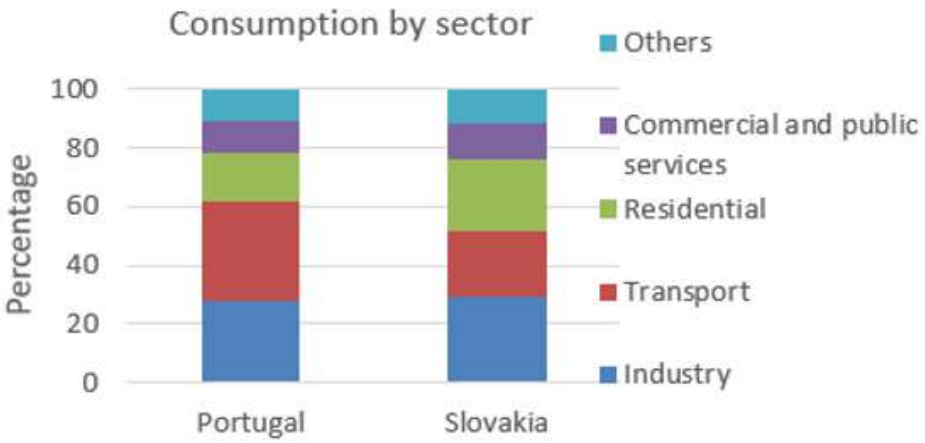

Fig. 4 Electricity production in Portugal and in Slovakia by sectors
Source: IEA, https://www.iea.org/ [accessed 26 Aug. 2024].

The main challenges to reach those targets are removing barriers to the use of renewable energy sources and supporting projects that can replace fossil fuels while ensuring the reliability and cost-effectiveness of electricity and heat generation. Because of climate conditions in Slovakia (especially in winter), there is a strong need to increase energy efficiency, especially in the building sector, where old inefficient heating systems need to be replaced with modern and combination of renewable sources and high-efficiency heat and power generation. Biomass has the largest energy potential among RES in Slovakia and biomass was co-combustioned in both coal power plants in the last years. The importance of promoting technologies to enable the integration of renewables into existing gas infrastructure and increasing the share of hydrogen in natural gas is also significant

Table 1 Summarizes the measures to be implemented in the future (2050) in selected sectors in Portugal and Slovakia

	Portugal	Slovakia
Power system	Increase photovoltaics installed power	Decommissioning of solid fuel power plants
	Increase wind installed power	Decarbonisation of electricity generation after 2020 thanks to RES and the development of nuclear energy
	Use of batteries	RES support for electricity generation, an increase of solar photovoltaics, onshore wind turbines, biogas/biomethane, and biomass
	Use of pumped water in hydro facilities	
	Decentralisation of electricity generation	
Transport	Incorporation of renewables	Subsidies to support alternative-fuel vehicles
	In light passenger transport replacement of diesel and petrol vehicles with electric ones	Electrification of transport
	Use of hydrogen technology	Use of hydrogen technology
Industry	Promotion of energy and resource efficiency	Increasing the energy use of waste, waste gases and waste heat

	Use of solar heating and biomass	Transform fossil-fuel power plants, based on a combination of renewable sources and high-efficiency heat and electricity production
	Promotion of biorefineries, industrial symbioses and resource reuse	
Residental or service buildings	Use of high-performance electrical equipment for lighting	Optimization of district heating systems
	Use of equipment of higher energetic efficiency classes	Decommissioning of solid fuel heating systems
		Development of heating installations with local development concepts in the field of thermal energy
		Increase energy efficiency in the building sector, by replacing old inefficient and non-ecological solid fuel heating installations with modern installations (including RES) in combination with thermal insulation

Conclusion

Portugal relies on renewable energy sources like wind and hydroelectric power and will continue to increase the use of renewables, while Slovakia depends more on nuclear energy and fossil fuels, although it is phasing out coal plants and biomass is seen as a potential alternative to contribute to solve the energy problem. Both countries face challenges in reducing greenhouse gas emissions, improving energy efficiency, and transitioning to sustainable energy systems. The article also outlines specific measures each country plans to implement by 2050, including increased use of renewables, energy efficiency improvements, and decarbonization of the energy sector.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-20-0157.
This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I04-03-V02-00033.

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62-049.8(062)
004-049.8(062)

МЕЃУНАРОДНА конференција ЕТИМА (3 ; 2025 ; Штип)
Зборник на трудови [Електронски извор] / Трета меѓународна конференција ЕТИМА 2025, 24-25 септември 2025 ; [главен и одговорен уредник Сашо Гелев] = Conference proceedings / Third international conference, 24-25 September 2025 ; [editor in chief Saso Gelev]. - Текст во PDF формат, содржи 357 стр., илустр. - Штип : Универзитет "Гоце Делчев", Електротехнички факултет ; Stip : "Goce Delchev" University, Faculty of Electrical engineering, 2025

Начин на пристапување (URL): https://js.ugd.edu.mk/index.php/etima/en. - Наслов преземен од екранот. - Опис на изворот на ден 30.10.2025. - Трудови на мак. и англ. јазик. - Библиографија кон трудовите

ISBN 978-608-277-128-1

а) Електротехника -- Примена -- Собири б) Машинство -- Примена -- Собири
в) Автоматика -- Примена -- Собири г) Инфоматика -- Примена -- Собири

COBISS.MK-ID 67297029