



Importance of Fossil Fuels in Finland's Energy Mix

Tadeusz OLKUSKI¹⁾*, Partrycja ZUBIEN²⁾

¹⁾ PhD Eng., Associate Professor of AGH University, AGH University of Krakow; ORCID: 0000-0002-6256-9628

²⁾ Eng., President of the „Nova Energia” Student Research Group, AGH University of Krakow; ORCID: 0009-0008-0358-6701

* Corresponding author: olkuski@agh.edu.pl

<http://doi.org/10.29227/IM-2024-01-109>

Submission date: 09-05-2024 | Review date: 20-06-2024

Abstract

The article presents the energy situation of Finland, with particular emphasis on energy resources. The introduction describes the geographical location of Finland, the population, the political system, and the wealth of Finnish society against the background of the European Union. Attention is paid to relatively low total and per capita carbon dioxide emissions. The energy mix, which is overwhelmingly based on renewable energy sources and nuclear power, especially for electricity generation, is also presented. Despite the fact that Finland has been focusing on increasing the share of renewables in its energy mix for years, as well as developing nuclear power plants, to ensure a continuous supply of energy, it is necessary to import both electricity itself and energy raw materials, with a particular focus on fossil fuels. The main part of the article focuses on presenting the consumption of crude oil, natural gas, and coal in the years 1980–2022. The directions of imports of these energy sources, which have changed after Russia's invasion of Ukraine, are also shown. Ensuring a continuous supply of energy resources from economically and politically stable countries will ensure Finland's energy security and development opportunities in the coming years.

Keywords: coal, oil, gas, wood, energy resources

Introduction

Finland is located in the northern part of Europe. It has a population of 5.6 million [18], and its capital and largest city is Helsinki. Finland is a democratic, parliamentary republic. The Finnish Parliament has 200 elected members and exercises legislative power. The prime minister is appointed by the president, who is elected by a direct vote for a term of six years. Energy matters are handled by the Ministry of Economic Affairs and Employment. The ministry's main tasks include developing energy markets and security of supply, promoting renewable energy and energy efficiency, and regulating nuclear power. The ministry is also tasked with implementing emissions trading and coordinating national climate policy preparation and implementation [23]. Finland is one of the richest countries in Europe, with a high quality of life. Finland ranks ninth in the European Union in terms of GDP per capita. This indicator is EUR 39,000 and is well above the EU average (EUR 35,500 thousand). Finland's share in the EU GDP is 1.8% [10]. Finland's energy policy plays a key role in the country's pursuit of sustainable development, economic competitiveness, and minimizing its impact on the environment, with a particular emphasis on carbon neutrality. In 2022, carbon dioxide emissions in Finland amounted to 34.1 million tonnes [1], which is 6.09 tonnes per capita. It is worth mentioning that in 2003 CO₂ emissions amounted to 74.9 million tons [1]. Coal-fired power generation is responsible for more than 50% of Finland's emissions, which accounts for less than 5% of total electricity generation [5].

The most important branches of the Finnish economy are the industry, mainly electronics, mechanical, and metal industries, as well as the wood, chemical, and petrochemical industries [27]. The wood industry has been one of the

basic industries in this country for years. Forests cover more than 75% of Finland. There are 20.3 million hectares of forest land suitable for timber production and 2.5 million hectares of scrub. According to the Natural Resources Institute Finland, the total annual tree felling in 2023 amounted to about 82 million cubic meters, of which 14% was energy wood, i.e. forest chips for heating and power plants and firewood for single-family houses [21]. The growth of Finnish forests exceeds the annual deforestation, so forest resources are constantly increasing. Therefore, the amount of carbon dioxide sequestered in forests is increasing [15].

Figure 1 shows the location of Finland on the map.

Energy mix

The Finnish energy mix is diverse, however, it is renewable sources together with nuclear energy that are of fundamental importance in this country. Figure 2 shows the percentage share of individual energy sources in 2021 in Finland. It is clear that renewable energy sources account for almost half of the Finnish energy mix. Nuclear power comes second, followed by crude oil, and coal.

Figure 3 shows the percentage share of individual sources in electricity generation in 2021. In this infographic, the most important role is played by renewable raw materials such as biofuels and biomass, mainly forest biomass. Nuclear power comes second, followed by solid fossil fuels, and then natural gas.

Wind energy in the context of renewable energy is one of the fastest growing sectors – the location of the analyzed country offers significant potential in this area. At the end of 2022, 1,393 wind turbines with a total capacity of 5,677 MW were installed. They generated 14.1% of Finland's electricity



Fig. 1. Finland's place on the map of Europe. Source: [3]
Rys. 1. Miejsce Finlandii na mapie Europy. Źródło: [3]

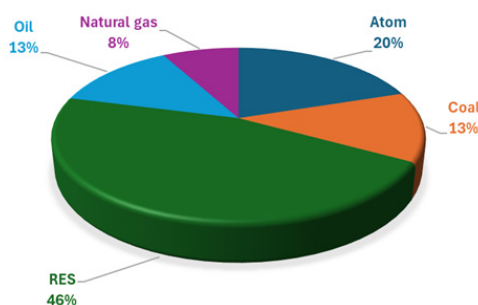


Fig. 2. Finnish energy mix in 2021. Source: own work based on [12]
Rys. 2. Fiński mikś energetyczny w 2021 roku. Źródło: praca własna na podstawie [12]

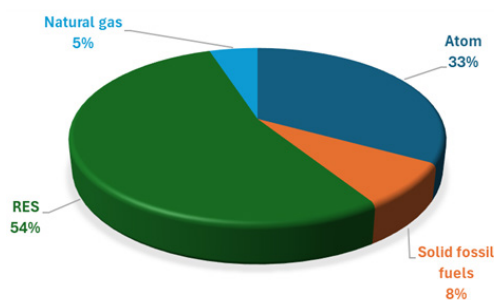


Fig. 3. Finnish electricity mix in 2021. Source: own work based on [12]
Rys. 3. Fiński mikś energii elektrycznej w 2021 roku. Źródło: praca własna na podstawie [12]

consumption in 2022. [25]. Hydropower is also crucial to Finland's location due to numerous floods.

Nuclear power also plays a crucial role, accounting for as much as 20% of the country's energy mix in 2021. Currently, there is an increase in interest in this area of energy. This is confirmed by the construction of the first nuclear reactor in Europe in over 15 years in Finland, which began commercial operation in April this year. Moreover, Finland is the first country in the world to conduct activities involving the final disposal of radioactive waste, which is one of the main problems regarding nuclear energy.

Despite Finland's long-standing focus on increasing the share of renewable energy sources in its energy mix, or developing nuclear-based power generation, to ensure continuous energy supplies, it was necessary to import both electricity and energy resources, with particular emphasis on fossil fuels. Figure 4 shows the electricity demand in 2022 by generation source and including imports.

The electricity demand indicated above in 2022 shows that energy imports covered more than 40% of the total demand. In the previous year, i.e. 2021, the total electricity consumption was 1,357 PJ, or as much as 245 GJ/person per year [8].

Energy security

Energy security indicators are very important for a country's energy policy, especially considering the question of energy imports. The analysis of these indicators is accompanied by several benefits. First, it is the ability to assess and manage risks and threats to the energy sector by identifying potential problems – the risk of dependence on energy imports, instability of energy markets, or threats to energy infrastructure. Strategic planning is also an equally important aspect, e.g. in the area of diversification of energy sources, investments related to energy infrastructure, or the issue of energy efficiency itself. All of the above factors strive for the energy security of a given country and the stability of the economy.

Based on publicly available figures, it is possible to present various indicators concerning energy security, depending on the development of the energy sector in a given country.

Considering domestic energy production, energy source, and domestic energy consumption, it is possible to obtain a percentage of the energy independence index, which is a measure of the degree of a country's dependence on energy imports. The higher the value of the energy independence ratio (index), the more self-sufficient the country is in terms of

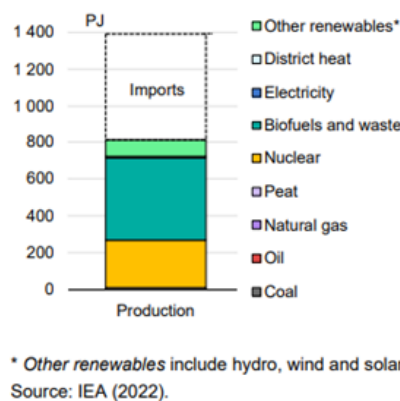


Fig. 4. Electricity demand in 2022, including generating sources and electricity imports. Source: [11]

Rys. 4. Zapotrzebowanie na energię elektryczną w 2022 roku z uwzględnieniem źródeł wytwórczych oraz importu energii elektrycznej. Źródło: [11]

| Fuel | 2000 | 2010 | 2019 | 2020 |
|-------------------------------|--------|--------|--------|--------|
| Import Dependency [%] | 56.6% | 49.1% | 42.5% | 42.4% |
| of Solid fossil fuels | 97.6% | 86.3% | 98.9% | 92.2% |
| of Hard Coal | 97.7% | 85.5% | 96.1% | 90.0% |
| of Oil and petroleum products | 111.5% | 94.2% | 98.9% | 106.4% |
| of Crude and NGL | 101.5% | 101.1% | 99.0% | 99.7% |
| of Natural Gas | 100.0% | 100.0% | 100.6% | 100.4% |

Source: EU energy statistical pocketbook and country datasheets based on Eurostat

Fig. 5. Import dependency ratio for Finland by fuel type in individual years. Source: [12]

Rys. 5. Wskaźnik zależności importowej dla Finlandii z podziałem na rodzaj paliwa w poszczególnych latach. Źródło: [12]

| | Gas | Oil | Coal |
|------|-----|-----|------|
| EU27 | 44% | 26% | 54% |
| FI | 67% | 84% | 55% |

Source: Eurostat (nrg_ti_sff, nrg_ti_oil, and nrg_ti_gas)

Fig. 6. Tabular presentation of import dependency ratios on Russian fuels for the European Union and Finland broken down by fuel type. Source: [12]

Rys. 6. Tabela przedstawienie wskaźników zależności importowej dla Unii Europejskiej oraz Finlandii od rosyjskich paliw z podziałem na typ paliwa. Źródło [12]

energy and less dependent on energy supplies from external sources. In Finland, in 2021, it was 58.5% [6], which means that 58.5% of the country's total energy demand was met by domestic power generation, while the remaining 41.5% had to be imported from other suppliers.

One of the most important energy security indicators, closely related to the energy independence ratio, is the import dependence ratio. Its value is calculated based on data such as import, export, and consumption of the energy source. Figure 5 illustrates in tabular form Finland's import dependencies for individual fuels in the years: 2000, 2010, 2019, and 2020.

In 2020, Finland recorded one of the lowest levels of this indicator among EU countries. This value was 42.4% at that time, which indicates a high level of energy security in the supply of energy resources [2, 12, 26]. Therefore, comparing 2022 with 2000, when this value was at the level of 56.6%, one can notice a significant, positive decrease in this area [12].

An equally important indicator is the one showing the share of renewable energy sources in final energy consumption, which in 2020 for Finland was also one of the highest in the EU and amounted to 27.2% [2]. This figure shows the extent to which Finland is diversifying its energy sources, thus becoming independent of coal or gas supplies from unpredictable countries.

Currently, all of the above indicators have changed positively, unfortunately only as a result of the 2022 Russian invasion of Ukraine. For years, the European Union, including

Finland, has underestimated the threats from Russia, even though the security of energy supplies and energy resources is of great importance. Figure 6 shows the import dependency ratios on Russian fuels for the European Union and Finland broken down by fuel type: natural gas, oil, and coal.

Natural gas

Natural gas does not play a significant role in the country's energy policy, as it accounted for only 5% of the primary energy supply in 2021, and in 2022 its share decreased to 3%. Until Russia's invasion of Ukraine, most of the gas was brought in by pipeline from Russia through the Imatra interconnection point. Russia cut off gas supplies in 2022, as state-owned supplier Gasum rejected Gazprom's demand for payment in Russian rubles. However, Finland has not been completely cut off from gas, as the Balticconnector gas pipeline connecting Finland with Estonia was put into operation in 2020 [7]. It allowed gas to be sent from a storage facility in Latvia and from Lithuania from the Klaipeda gas terminal. In 2021, gas imported via the Balticconnector met 23% of the country's needs (Finland 2023) [11]. However, in October 2023, namely on October 8, the gas pipeline was damaged. Initially, the cause of the accident was unknown, but the authorities of Finland, Estonia, and most European Union countries suspected sabotage. As claimed, it could have been an action by Russia against NATO countries [20]. It was later determined that the damage was caused by the Chinese ship Newnew Polar Bear,

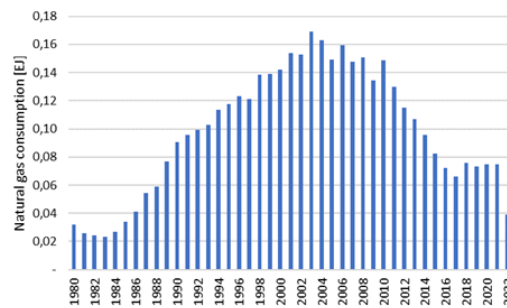


Fig. 7. Natural gas consumption. Source: own work based on [1]
Rys. 7. Zużycie gazu ziemnego. Źródło: praca własna na podstawie [1]

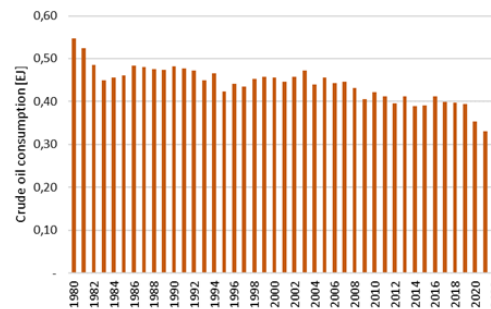


Fig. 8. Crude oil consumption. Source: own work based on [1]
Rys. 8. Zużycie ropy naftowej. Źródło: praca własna na podstawie [1]

flying the flag of Hong Kong, when its anchor hit the gas pipeline. [13, 17]. In April 2024, the repair of the gas pipeline was completed [14, 24]. In addition to the pipeline, three small LNG terminals are also used, and since this year the Floating Storage Regasification Unit has begun operating, allowing for the import of 5 billion m³ of gas per year. This is a remarkable number for such a sparsely populated country, so there are plans to supply gas to neighboring countries such as Lithuania, Latvia Estonia, and perhaps also Poland [9]. Finland has no problem with access to natural gas.

Fig. 7 shows the consumption of natural gas in the years 1980–2022.

Natural gas consumption has been systematically decreasing for twenty years, so Finland has not and will not have any problem meeting its gas needs in the near future.

Crude oil

Since the end of the 1970s, oil consumption has been steadily decreasing. However, the decline is not as spectacular as in the case of natural gas. Oil is used in transport, and although there are ambitious plans to replace it with biofuels, hydrogen, or to increase the electrification of transport, it is still of great importance to the Finnish economy.

The oil consumption in the years 1980–2022 is presented in Fig. 8.

For many years, Finland imported oil from the Soviet Union and then from Russia. In 2021, imports from Russia accounted for 84% of Finland's oil imports. In 2022, the situation changed dramatically. Imports from Russia amounted to only 17% [19]. Since mid-2022, Finland has completely stopped importing oil from Russia. Currently, crude oil is imported mainly from Norway, but also from the United Kingdom, the United States of America, and Denmark.

Coal

After World War II, coal was one of the primary energy resources not only in Finland but also in other European countries and the United States of America. In the case of Finland, the peak of its consumption fell in 2003. Later, its importance began to decrease, which is related to the energy policy of Finland and the entire European Union.

Figure 9 shows the coal consumption in Finland between 1980 and 2022.

It is clear that the demand for coal is declining, and policies aimed at climate neutrality are further accelerating this process.

Fig. 10 presents a comparison of fossil fuel consumption in Finland in the years 1980–2022. The charts show that the consumption of all fossil fuels is decreasing, but the consumption of natural gas and coal is decreasing the most.

Conclusions

The share of fossil fuels in Finland's energy mix is steadily decreasing. The presented data shows that Finland has not been very severely affected by the lack of energy supplies from Russia. Some of the raw materials have been replaced by supplies from other countries, but in general, Finland has already decided to move away from fossil fuels and replace them with renewables and low-carbon nuclear energy. The consumption of natural gas, oil, and coal is steadily decreasing, which is a result of the government's policy aimed at achieving climate neutrality by 2035. This is more ambitious than the European Union's goal of achieving climate neutrality in 2050 but looking at the direction and pace of change in the country's energy policy, it is quite achievable. Based on the Climate Change Act [22], updated on July 1, 2022, it has become a legal obligation to promote a sustainable economy and protect biodiversi-

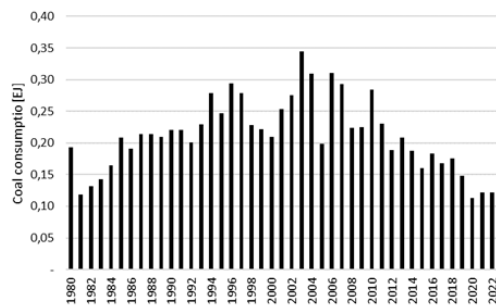


Fig. 9. Coal consumption. Source: own work based on [1]
Rys. 9. Zużycie węgla. Źródło: praca własna na podstawie [1]

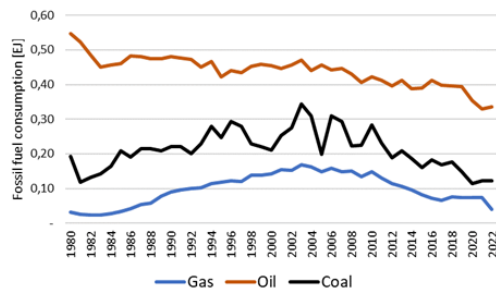


Fig. 10. Comparison of fossil fuel consumption. Source: own work based on [1]
Rys. 10. Porównanie zużycia paliw kopalnych. Źródło: praca własna na podstawie [1]

ty; this can only be achieved by implementing green energy sources that do not negatively impact the environment. This goal was set in the document “Carbon Neutral Finland 2035 - National Climate and Energy Strategy,” [4], placing particular emphasis on carbon neutrality, increasing energy efficiency, implementing a national hydrogen strategy, and incorporat-

ing new nuclear technologies, with a particular focus on small and modular SMRs (Small Modular Reactors).

Source of financing

The publication of the article was financed by the AGH University of Krakow research subvention no 16.16.210.476.

Literatura – References

1. BP Energy Institute Statistical Review of World Energy 2023
2. BRAUN J., 2023 – Analysis of Poland’s Energy Security in Comparison with the Other European Union Countries with the Use of Selected Economic Indicators of Energy Security, OPTIMUM. ECONOMIC STUDIES NR 1 (111) 2023, Maria Curie-Skłodowska University in Lublin
3. Britannica, 2023 – <https://www.britannica.com/place/Finland> ; accessed on 26.06.2023 r.
4. Carbon neutral Finland 2035 – national climate and energy strategy.
5. Electricitymaps 2023 – <https://app.electricitymaps.com/zone/FI> - accessed on 26.06.2023
6. Enerdata, 2023 – <https://www.enerdata.net/estore/energy-market/finland/> ; accessed on 26.06.2023 r.
7. Energiavirasto 2023 ; [https://energiavirasto.fi/maakaasumarkkinat#:~:text=Maakaasua%20on%20saatavilla%20noin%2040%20paikkakunnalla%20Suomessa.%20Suomessa,Suomessa%20tuotettua%20biokaasua%20sy%C3%B6tet%C3%A4%C3%A4n%20maakaasuverkkoon%20verrattain%20v%C3%A4h%C3%A4isi%C3%A4%20m%C3%A4%C3%A4ri%C3%A4](https://energiavirasto.fi/maakaasumarkkinat#:~:text=Maakaasua%20on%20saatavilla%20noin%2040%20paikkakunnalla%20Suomessa.%20Suomessa,Suomessa%20tuotettua%20biokaasua%20sy%C3%B6tet%C3%A4%C3%A4n%20maakaasuverkkoon%20verrattain%20v%C3%A4h%C3%A4isi%C3%A4%20m%C3%A4%C3%A4ri%C3%A4;); accessed on: 26.07.2023

8. Energy in Finland 2022, Statistics Finland
9. Euronews 2022 – <https://www.euronews.com/2022/12/28/finland-opens-floating-liquified-natural-gas-terminal-to-replace-russian-supply> ;accessed on: 5.08.2023
10. European-Union 2024 ; https://european-union.europa.eu/principles-countries-history/eu-countries/finland_pl#:~:text=Trade%20i%20economy%20Finland%20occupies%20division%C4%85th%20location%20w,Finland%20w%20ca%C5%82co%20PKB%20UE%20wynosi%201%20C8%20proc ; accessed on: 24.05.2024
11. Finland 2023 Energy Policy Review, International Energy Agency
12. FINLAND Energy Snapshot, European Commission 2023
13. Ilka-Pohjalainen 2023 – Poliisi selvittää kiinalaisen aluksen liikkeitä Balticconnector-kaasuputken vaurion yhteydessä – merenpohjasta löytyi möykky <https://ilkkapohjalainen.fi/ulkomaat/poliisi-selvittaa-kiinalaisen-aluksen-liikkeitä-balticconnector-kaasuputken-vaurion-yhteydessa> ; accessed on: 24.05.2024
14. Kamiński R., 2024 – Finał prac naprawczych Balticconnector. Operator zapowiada uruchomienie rurociągu <https://www.gospodarkamorska.pl/final-prac-naprawczych-balticconnector-operator-zapowiada-uruchomienie-rurociagu-77327> ; accessed on: 24.05.2024
15. Metsateollisuus – <https://www.metsateollisuus.fi/uutishuone/metsavarat> ; accessed on: 24.05.2024
16. Metsävarat ja metsänomistus – <https://forest.fi/fi/artikkeli/tiesitko-taman-euroopan-metsista-metsapinta-ala-puuston-maara-ja-hakkuut-ja-myos-suojeluala-ovat-jatkuvassa-kasvussa/#7680f393> ; accessed on: 24.05.2024
17. POLITICO 2023 – Everything indicates Chinese ship damaged Baltic pipeline on purpose, Finland says. <https://www.politico.eu/article/balticconnector-damage-likely-to-be-intentional-finnish-minister-says-china-estonia/> ; accessed on: 24.05.2024
18. Population, 2023 – <https://www.populationof.net/pl/finland/> ; accessed on 30.07.2023
19. Reuters 2023 – <https://www.reuters.com/business/energy/finland-replaces-russian-urals-with-oil-norway-uk-us-2023-03-15/> ; accessed on: 02.08.2023
20. Rzeczpospolita 2023 – <https://www.rp.pl/polityka/art39255441-uszkodzenie-gazociagu-balticconnector-sabotaz-na-dnie-baltyku-przeciw-nato> ; accessed on: 24.05.2024
21. Suomen metsävarat 2023 – <https://mmm.fi/metsat/suomen-metsavarat> ; accessed on: 24.05.2024
22. SUOMEN SÄÄDÖSKOKOELMA, 423/2022, Julkaistu Helsingissä 14 päivänä kesäkuuta 2022, The Finnish Climate Act, 14.06.2022
23. Tem.fi ; <https://tem.fi/en/energy#:~:text=The%20principal%20tasks%20of%20the%20Ministry%20of%20Economic,energy%20and%20energy%20efficiency%2C%20and%20regulate%20nuclear%20energy> ; accessed on 11.08.2023
24. Trusewicz I., 2024 – Balticconnector znów działa. Chińczycy bezkarni. <https://energia.rp.pl/gaz/art40118341-balticconnector-znow-dziala-chinczycy-bezkarni> ; accessed on: 24.05.2024
25. Tuulivoimayhdistys 2023 – <https://tuulivoimayhdistys.fi/en/wind-power-in-finland-2/wind-power-in-finland/about-wind-power-in-finland> ; accessed on 11.08.2023
26. Visualcapitalist, 2023 – <https://www.visualcapitalist.com/visualizing-the-eus-energy-dependency/> ; accessed on 26.06.2023 r.
27. Zieliński M., 2019 – Finlandia Informacja o sytuacji gospodarczej i stosunkach gospodarczych z Polską (Finland Information on the economic situation and economic relations with Poland, in Polish). Ministry of Entrepreneurship and Technology

Znaczenie paliw kopalnych w miksie energetycznym Finlandii

W artykule przedstawiono sytuację energetyczną Finlandii szczególny nacisk kładąc na surowce energetyczne. We wstępie opisano położenie geograficzne Finlandii, ludność, system polityczny oraz zamożność społeczeństwa fińskiego na tle Unii Europejskiej. Zwrócono uwagę na stosunkowo niską emisję dwutlenku węgla zarówno ogólną jak i przeliczoną na mieszkańca. Pokazano mikś energetyczny, który w zdecydowanej większości bazuje na odnawialnych źródłach energii oraz na energetyce jądrowej, zwłaszcza w zakresie wytwarzania energii elektrycznej. Pomimo tego, że Finlandia od lat koncentruje się na zwiększaniu udziału odnawialnych źródeł energii w swoim miksie energetycznym, a także rozwija elektrownie jądrowe, w celu zapewnienia ciągłych dostaw energii, konieczny jest zarówno import samej energii elektrycznej jak i surowców energetycznych, ze szczególnym uwzględnieniem paliw kopalnych. Właśnie temu zagadnieniu poświęcono dużą część artykułu przedstawiając zużycie ropy naftowej, gazu ziemnego oraz węgla w latach 1980–2022. Pokazano też kierunki importu tych surowców, które uległy zmianie po napaści Rosji na Ukrainę. Zapewnienie ciągłych dostaw surowców energetycznych z państw stabilnych gospodarczo i politycznie zapewni Finlandii bezpieczeństwo energetyczne i możliwość rozwoju w kolejnych latach.

Słowa kluczowe: węgiel, ropa, gaz, drewno, surowce energetyczne