Low Carbon Ukraine
Policy advice on low-carbon policies for Ukraine

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A deep dive into Ukraine's imports of critical energy equipment and fuels since Russia's invasion

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About Low Carbon Ukraine

Low Carbon Ukraine is a project that continuously supports the Ukrainian and Moldovan governments with demand-driven analyses and policy proposals to promote the transition towards a low-carbon economy.

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Executive summary

Since Russia's invasion of Ukraine in February 2022, Ukraine's energy infrastructure and power grid have been key targets of Russian attacks, aimed at weakening the country's resilience.

In response to the extensive damages, Ukraine's **imports of critical energy equipment surged**:

- The share of energy equipment imports within Ukraine's total imports **doubled from 1.4%** in **2021** to **2.7% in 2023.**
- The total value of monthly **energy equipment imports rose** from EUR 48 million in January 2021 to EUR 475 million in December 2022 as a response to Russian attacks on Ukrainian energy infrastructure, then decreased to EUR 120 million in December 2023, indicating a stabilization and partial restoration of domestic energy production. Imports surged again after March 2024 following the last wave of Russian attacks on Ukraine's energy infrastructure.

Legislative incentives by the Ukrainian government **helped bolster** equipment imports, exempting critical energy equipment from VAT and customs duties.

Key imports included **critical energy equipment** such as electricity generators (renewable and non-renewable), batteries, accumulators, and grid and transmission equipment.

- **Imports of non-renewable generation equipment** (diesel and semi-diesel generators, DC/AC generators, and combustion piston engines) saw the **largest increase**, from EUR 183 million in 2021 to EUR 732 million in 2023, reflecting the urgent demand for backup power generation following the Russian attacks.
- **Electricity storage equipment** imports peaked at EUR 106 million in December 2022 alone and reached an annual total of EUR 432 million in 2023, driven by the need to store electricity and provide reliable power during outages caused by intensified Russian attacks on energy infrastructure during that period.
- **Solar PV equipment**, while was essential for providing reliable power to homes, schools, and hospitals, saw a decline in imports from EUR 193 million in 2021 to EUR 52 million in 2022, before recovering to EUR 77 million in 2023. This drop in imports was primarily due to the halt of utility-scale projects. However, international partners have been coordinating the delivery of solar PV donations, which has played a crucial role in maintaining the supply of this vital equipment during the period of reduced imports.
- **Wind-powered generation equipment** imports, valued at EUR 79.2 million in January 2022 alone, dropped to zero by March 2022, except for minimal import activity up to May 2023, reflecting efforts to meet small-scale needs or partial revival of projects.

International partners have actively assisted in restoring Ukraine's energy infrastructure:

- Ukrainian energy assistance received 1,138 cargoes weighing about 15.5 thousand tons **(constituting around 5% of total equipment imports)**
- Ukraine Support Task Force facilitated 146 in-kind donations and delivered around **3,700 tons of energy-related equipment.**

Fuel imports fluctuated significantly, peaking at EUR 1.3 billion in January 2023, followed by a decline and a period of stabilization. The value of fuel imports remained significantly higher compared to critical energy equipment imports, totalling EUR 12 billion versus EUR 1.3 billion in 2022, and EUR 9.6 billion versus EUR 1.6 billion in 2023, respectively.

- There are sharp declines in natural gas (from 18.5 TWh to 0.22 TWh) and coal imports (from 12.4 TWh to 1.2 TWh) due to damaged or destroyed thermal power plants, and crude oil imports (to zero by June 2022) due to destroyed refinery capacity.

The share of renewable energy equipment imports in total energy equipment imports dropped from 38% in 2021 to 15% in 2023. Diesel generators were prioritized for their reliability during outages, while solar PV and wind projects lagged due to infrastructural challenges.

Both during the ongoing war and in the post-war reconstruction, a shift towards renewables is and will be essential for Ukraine’s long-term energy security and resilience.

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1 Introduction and background

The energy sector has been one of the key battlegrounds since Russia's invasion of Ukraine in February 2022. The explicit targeting of Ukraine's energy sector, part of a broader strategy to weaken Ukraine's resolve and capability, has had profound implications on the country's energy security and supply chains. From October 2022 to April 2023, Russia conducted over 1,200 missile and drone attacks, damaging 43 percent of Ukraine's main power grid network.[1] In March 2024, Russia launched its largest attack on Ukraine's energy infrastructure since the start of the full-scale invasion, leaving over a million people without electricity.[2] In Kyiv alone, 60 percent of transformers have been destroyed as a result of enemy air attacks, and the replacement of these have been difficult and time-consuming, complicated also by international supply chain shortages.[3] The most urgently needed energy equipment have been power transformers, generators, solar panels, and repair tools and equipment.

In response, the Ukrainian government launched various programmes to quickly bolster and diversify power supply. One such measure included the import of electricity enabled by the synchronization with ENTSO-E, although commercial capacity remains small and European electricity prices are higher than those in the domestic market.[4] Additionally, Ukraine introduced tax incentives and has simplified and reduced the cost of importing critical energy equipment by exempting gas generators, electric motors, electric generators, transformers, and other electrical appliances from VAT and customs duties since November 2022.[5] These tax benefits were temporary and ended in the spring of 2023. Diesel generators have become especially common in Ukrainian cities and commercial facilities, with hundreds of units shipped daily from international partners and benefactors.[6] Additionally, imports of electricity storage equipment, including primary cells and electric accumulators, surged in the last quarter of 2022 due to their critical role in ensuring a stable and reliable power supply. In July 2024, the Ukrainian Parliament (Verkhovna Rada) passed laws 3853-IX and 3854-IX which grant exemptions on duties and VAT for importing equipment into Ukraine's customs territory. This legislation applies to electric generators, wind and solar generation equipment, batteries (excluding low-power ones), demining equipment, and devices for countering technical intelligence.[7] The new exemptions for large capacity generators and batteries will remain effective until martial law concludes or until January 1, 2026.

[1] Just Security (2024). Russia's Attacks on Ukraine's Energy Infrastructure Imperil Healthcare Access. (Link)
[2] Meduza (2024). Russia has attacked Ukraine's energy infrastructure. (Link)
[3] Emerging Europe (2022). How generators became Ukraine's hottest commodity. (Link)
[4] Ibid.
[5] Cabinet of Ministers of Ukraine (2022). Statement by Prime Minister Denys Shmyhal at a Government session. (Link)
[6] Ministry of Economy of Ukraine (2022). Government exempts from VAT and import duties spare parts and components for the manufacture of electric generators, as well as satellite Internet equipment. (Link)
[7] Interfax Ukraine (2024). Zelenskyy signs laws on preferential import of energy equipment. (Link)

Besides commercial imports, international partners, private donors, and government institutions played a key role in aiding Ukraine's efforts to restore its damaged energy infrastructure during the war. Humanitarian efforts, coordinated by the Ministry of Energy of Ukraine, the Ukraine Support Task Force (USTF), and various donors, have facilitated the donation, procurement, and delivery of critical energy-related equipment.

This paper analyses the impact of Russia's targeted attacks on Ukrainian energy infrastructure by examining customs trade data related to critical energy equipment and fuels, identified as essential for understanding the impacts on Ukraine's energy sector amid the ongoing Russian aggression, and data on in-kind donations. Using this data as a proxy, insights are provided into how disruptions and damages to the energy infrastructure have influenced Ukraine's import patterns and overall energy security regarding the decentralization of energy infrastructure.

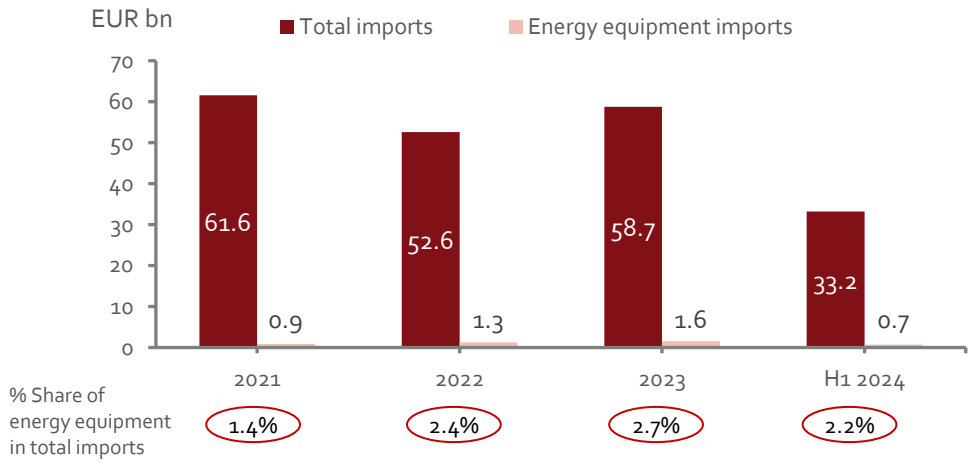
The paper begins with an overall examination of trends in energy equipment imports, followed by a detailed analysis of each equipment category. Next, it delves into the analysis of fuel imports and compare these findings with the trends in energy equipment imports, concluding with a summary of the findings and insights.

2 Imports of energy equipment

The primary energy components imported into Ukraine include fossil and renewable electricity generation equipment, grid and transmission equipment, and storage equipment.[8] These were selected due to their critical role in maintaining and restoring energy security and supply chains. The analysis focuses on the period following the Russian invasion that began in February 2022, with data up to July 2024, capturing the effect of the last wave of Russian attacks on energy infrastructure from October 2022 and March 2024.

In 2021, energy equipment accounted for only 1.4% of the total imports (EUR 0.9 billion out of EUR 61.6 billion). This share rose to 2.4% in 2022 (EUR 1.3 billion out of EUR 52.6 billion) and further to 2.7% in 2023 (EUR 1.6 billion out of EUR 58.7 billion), indicating efforts repair the energy infrastructure damaged by the ongoing Russian attacks and to meet energy demand. The share of energy equipment imports within the total imports were 2.2% in the first half of 2024 (Figure 1).

Figure 1. Ukraine total imports and energy equipment imports, in EUR billion



Source: Ukrstat data, authors' calculations

Imports of energy equipment to Ukraine saw a significant increase, rising from EUR 47.8 million in January 2021 to a peak of EUR 475 million total in December 2022. This surge was a direct response to the infrastructural damages inflicted by the ongoing war. The imports included generators, transformers, and other critical components necessary to repair and replace the damaged energy infrastructure. By December 2023, import figures had decreased to EUR 120 million, signalling a stabilization in the immediate crisis and a partial recovery of domestic energy production capacities with the help of imported energy equipment. However, this trend was reversed by a renewed increase in imports following the latest wave of Russian attacks from March 2024 onwards, reaching EUR 234 million in July 2024.

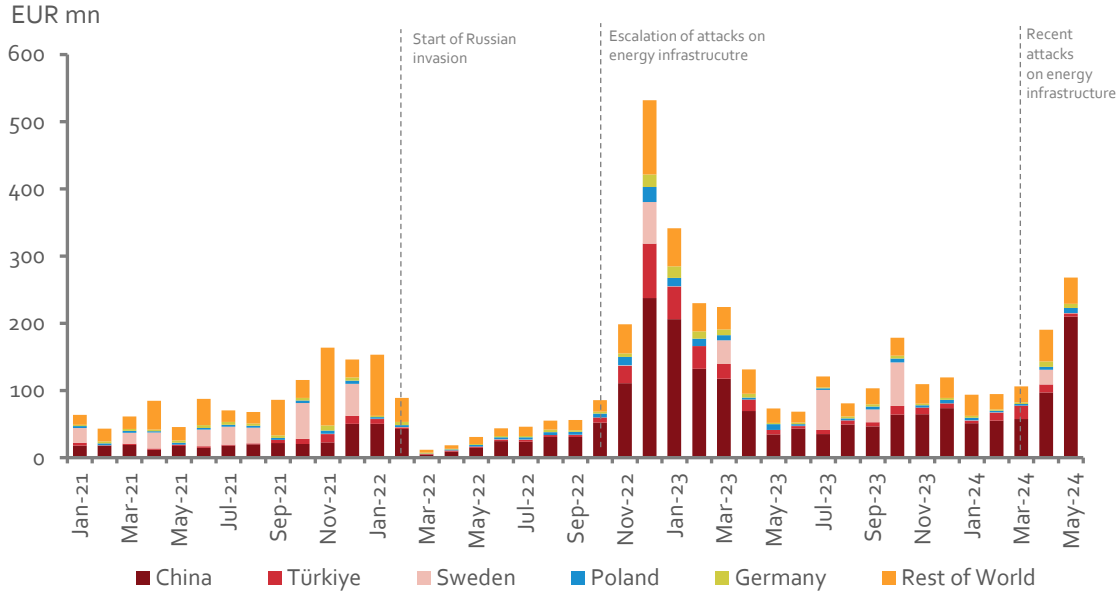
A large portion of the damage caused by Russian attacks was to the electricity transmission infrastructure. However, with the help of international organizations and governments,

[8] See Annex for a full list of equipment and fuels considered.

approximately 80% of the capacity was restored before the latest round of attacks. This assistance included the provision of generators and other support, which has been crucial in restoring electricity supply. Additionally, the electricity import capacity from the EU was increased from 500 MW to 1200 MW, further enhancing the energy supply.[9]

From January 2021 to mid-2022, Ukraine's energy equipment imports remained relatively stable at low levels. However, following the Russian attacks on Ukraine's energy infrastructure around October 2022, imports surged dramatically, peaking in December 2022. China led with EUR 234 million in imports, followed by Turkey at EUR 80 million and Sweden at EUR 62 million. This spike reflected the urgent need to restore energy capacities after the attacks. Notably, China's share of total imports increased significantly, especially after winter 2022. Import levels stabilized to lower levels in 2023 but increased again by mid-2024 in response to renewed Russian assaults on the energy grid (Figure 2).

Figure 2. Ukraine's imports of energy equipment by country, top 5 exporters, in EUR million



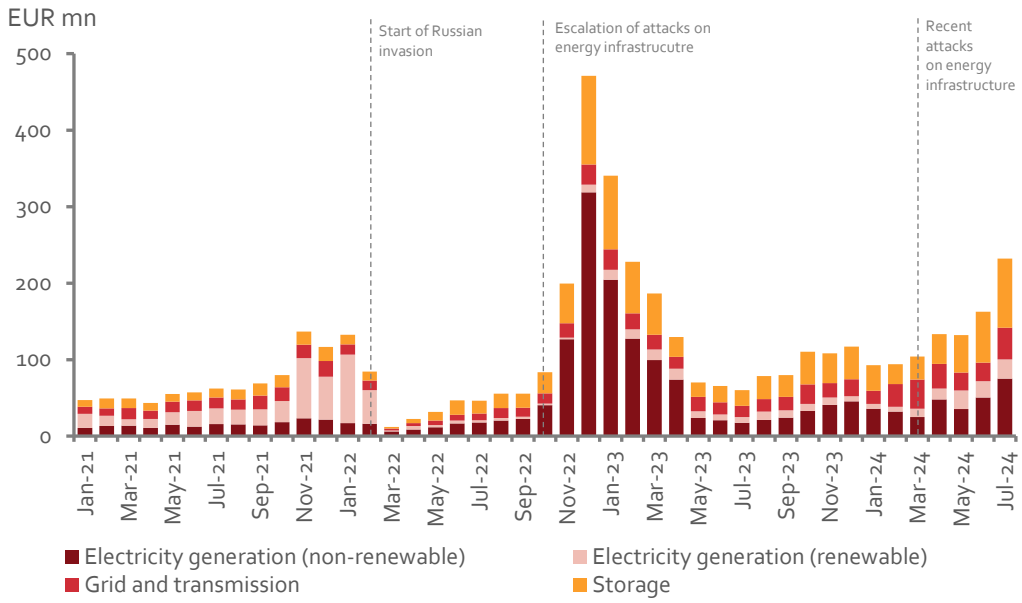
Source: ITC based on Ukrstat data, authors' calculations

Imports of non-renewable electricity generation equipment surged from EUR 183 million (22% of total energy equipment imports) in 2021 to EUR 621 million (50%) in 2022, and to EUR 732 million (46%) in 2023. In contrast, imports of renewable-based electricity generation equipment dropped from EUR 312 million (38%) in 2021 to EUR 123 million (15%) in 2023. This decline is largely due to the disruption of several utility-scale renewable projects caused by the war, although anecdotal evidence suggests that some projects were completed during the war. Additionally, solar panels were included in in-kind donations from international organizations and governments, aimed at meeting the energy needs of schools and hospitals as part of efforts to support social infrastructure. Meanwhile, imports

[9] Suspilne.media (2023). Prime Minister Denys Schmyhal on protection of energy facilities. (Link)

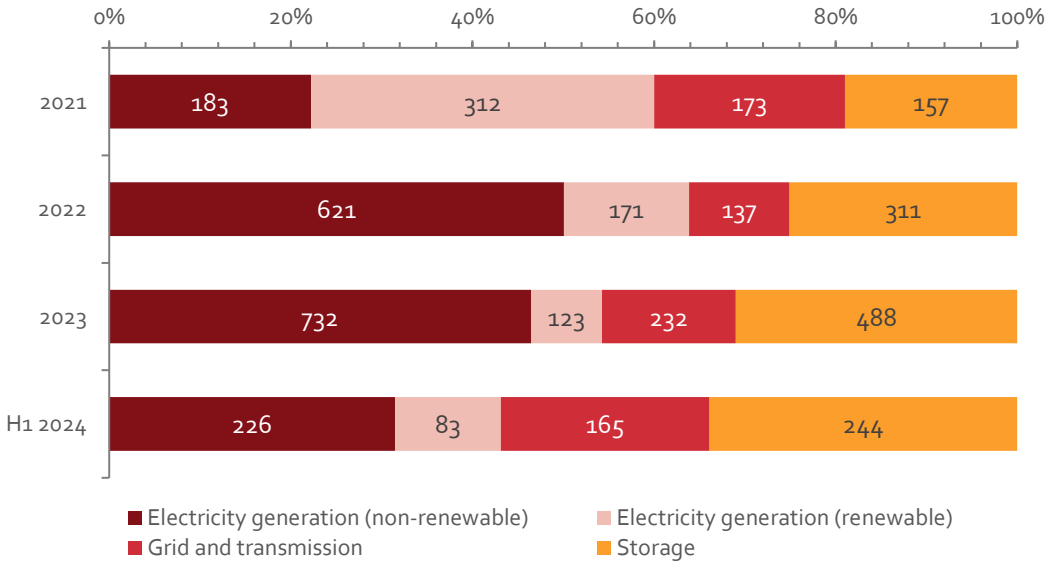
of energy storage and grid transmission equipment rose steadily, reflecting ongoing efforts to repair damaged energy infrastructure and ensure energy security (Figure 4).

Figure 3. Imports of energy equipment by category, in EUR million



Source: ITC based on Ukrstat data, authors' calculations

Figure 4. Share of critical energy equipment imported by category, annual total (2021-2023), in EUR million



Source: ITC based on Ukrstat data, authors' calculations

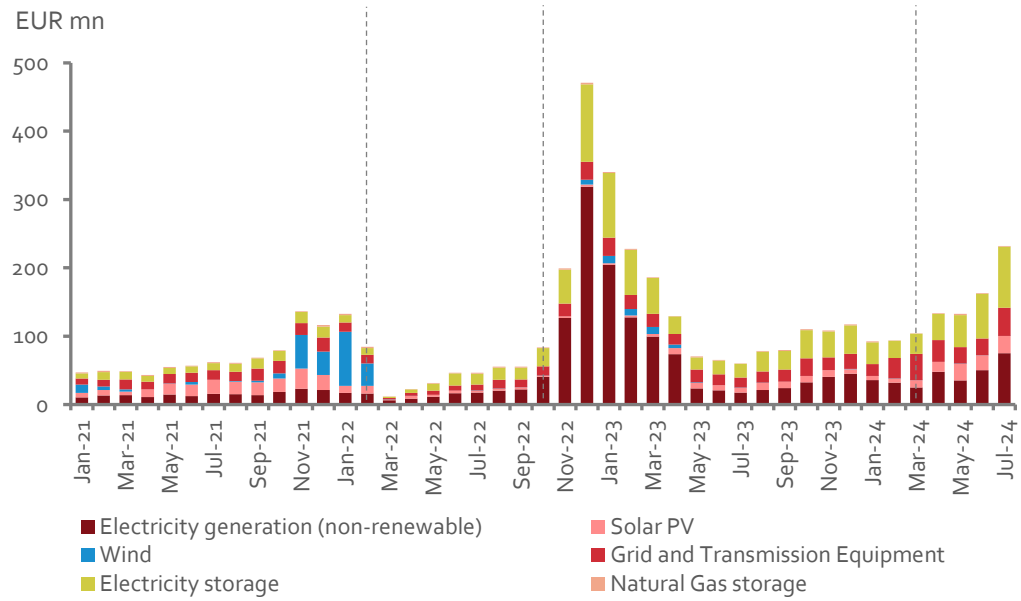
Besides commercial imports, international partners have been actively helping Ukraine restore its energy infrastructure. Between April 2022 and July 2024, the Ukraine Support Task Force (USTF) successfully facilitated the delivery of 146 in-kind donations of energy-related equipment totalling 3,700 tons to Ukraine, representing 1% of the total energy

equipment imports to Ukraine during this period.[10] In total, through the coordination by the Ministry of Energy of Ukraine, Ukrainian energy assistance has received 1,138 cargoes weighing about 15.5 thousand tons, constituting 5% of total equipment imports.[11] According to the external trade statistics from the National Bank of Ukraine, the share of humanitarian aid, based upon the United Nations Financial Monitoring Service for Humanitarian Aid (FTS) data, accounted for 6% of total imports of goods in 2022, 5% in 2023, and 3% in Q1 2024. Although the humanitarian aid statistics provided by the National Bank of Ukraine are not disaggregated into different product categories and include aid beyond the energy sector, the share within the total imports is comparable.

2.1 Imports by type of equipment

Figure 5 below shows the imports of various types of energy equipment to Ukraine from January 2021 to July 2024, ranked by total value in millions of euros. Imports of non-renewable generation equipment (diesel and semi-diesel generators, DC/AC generators, and combustion piston engines) saw the largest increase in the fourth quarter of 2022. These imports totalled EUR 732 million in 2023, a sharp rise from EUR 183 million in 2021. Notably, diesel engine imports surged to around EUR 198 million in December 2022, reflecting the urgent demand for backup power generation following the Russian attacks ahead of winter.

Figure 5. Imports of energy equipment by technology, in EUR million



Source: ITC based on Ukrstat data, authors' calculations

[10] Ukraine Support Task Force (2024). (Link)
[11] Ministry of Energy of Ukraine (2024). (Link)

The second-largest import category was electricity storage equipment, with a total import value of EUR 106 million in December 2022. Overall, imports of this equipment reached EUR 432 million in 2023, a significant increase from EUR 112 million in 2021.

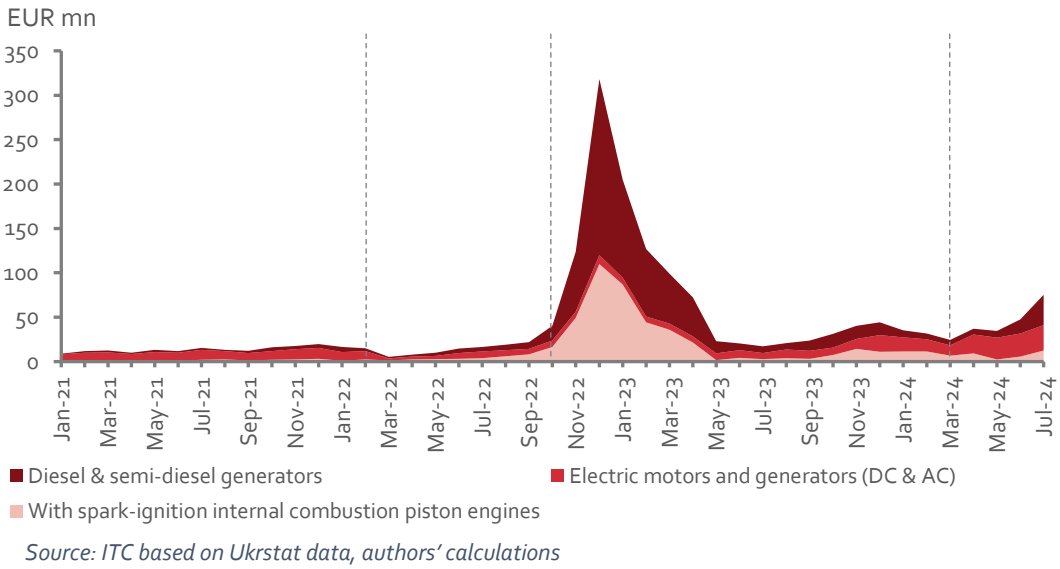
Compared to the pre-war period, solar PV equipment imports declined from EUR 193 million in 2021 to EUR 52 million in 2022. However, there was a recovery in 2023, with imports rising to EUR 77 million. In the first half of 2024, imports had already reached EUR 75 million, driven by the latest wave of Russian attacks from March 2024. Wind-powered electric generation equipment imports to Ukraine dropped from EUR 79.2 million in January 2022 to effectively zero by March 2022 due to the war. Limited import activity resumed in late 2022 to early 2023, reflecting small-scale needs or the partial revival of projects, but no significant recovery followed.

Since the onset of Russian aggression in February 2022, imports of grid and transmission equipment have steadily increased, reaching EUR 232 million in 2023, up from EUR 137 million in 2022. This equipment plays a crucial role in stabilizing Ukraine's energy supply by enabling the integration of different energy sources and battery storage into the grid, as well as facilitating power conversion to ensure compatibility with existing systems, particularly in older installations and off-grid solutions. These equipment are vital in maintaining energy resilience in response to the ongoing infrastructure challenges.

2.1.1 Non-renewable electricity generation equipment

Non-renewable electricity generation equipment has been crucial for backup generation in ensuring continuous energy supply during grid failures or peak demand. The import of diesel or semi-diesel engines had a notable peak in the 2022-2023 autumn and winter period as a result of continued missile attacks by Russia on energy infrastructure. In November 2022, Khmelnytskyi NPP and Rivne NPP had to shut down, explaining the import peak around December 2022.

Figure 6. Imports of electricity generation equipment, in EUR million



Source: ITC based on Ukrstat data, authors' calculations

The highest imports were the smaller size engines with an output smaller than 75 kVA. This has been crucial in meeting the electricity needs of critical facilities and public 'points of resilience,' enabling people to access essential services such as phone charging, internet connectivity, heating, and lighting.[12] Following the peak period, imports of these types of equipment gradually declined and stabilized at lower levels by February 2024, before increasing again following the new wave of Russian attacks in March 2024. Spark ignition internal combustion engines also experienced a significant import peak around December 2022, due to heightened infrastructural needs during the period. Compared to the pre-war levels (EUR 19.3 million in 2021), imports of combustion engine generators increased by 1130% to total EUR 237 million in 2023. Between April and July 2024, there was a resurgence in the import of these generation equipment, particularly in July 2024. However, these imports did not reach the peak levels seen in December 2022. (Figure 6).

These trends indicate continued efforts to meet the growing energy demand, and the immediate effects of the VAT and customs duties exemption legislation passed by the Ukrainian parliament. In 2024, the Ukraine Support Task Force (USTF), established in early March 2022 to aid Ukraine with door-to-door delivery of specialized energy equipment, announced the delivery of a 16.5 kVA diesel generator to Ukraine by a Norwegian electrical services provider. Norwegian grid companies and power producers have been making in-kind contributions to restore Ukraine's energy sector through USTF's coordination.[13]

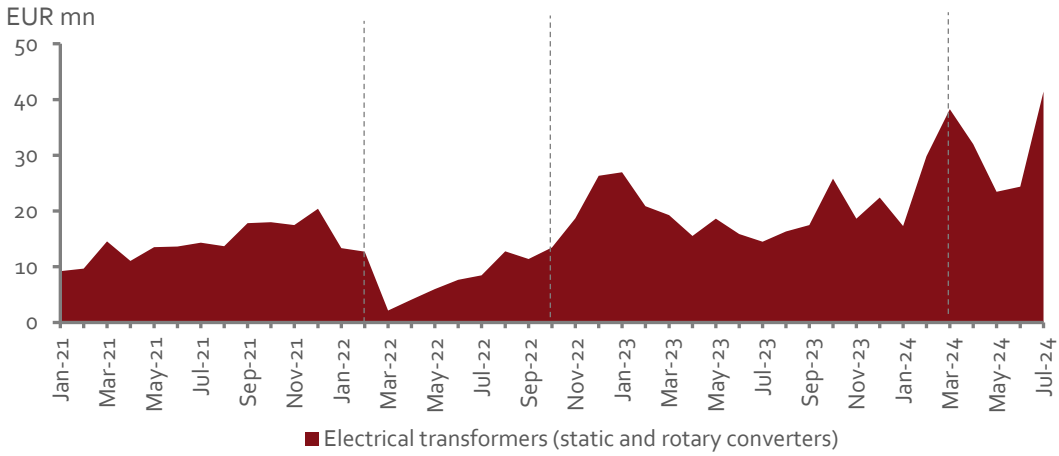
2.1.2 Grid and transmission equipment

Figure 7 below shows the monthly imports of grid and transmission equipment in Ukraine, notably electrical transformers. These components are essential for maintaining Ukraine's energy infrastructure, with smaller transformers (under 650 kVA) used in local power restoration while larger transformers (exceeding 10,000 kVA) used for restoring substations and high-voltage transmission networks to ensure reliable power delivery across the country.

Following the Russian invasion in February 2022, imports initially declined due to disrupted supply chains and logistical challenges. However, by mid-2022, imports began to recover and steadily increased, reflecting efforts to restore the damaged infrastructure. By late 2022 and throughout 2023 import levels exceeded pre-war levels, with EUR 232 million in 2023 compared to EUR 137 million in 2022.

[12] Ecoaction (2023). Solar to the rescue: photovoltaic energy systems can support Ukrainian communities and cities during the emergency response and in the longer term. (Link)
[13] Energy Community (2024). Ukraine Support Task Force assists the delivery of Diesel generator to Ukraine in collaboration with Norwegian partners. (Link)

Figure 7. Imports of grid and transmission equipment, in EUR million

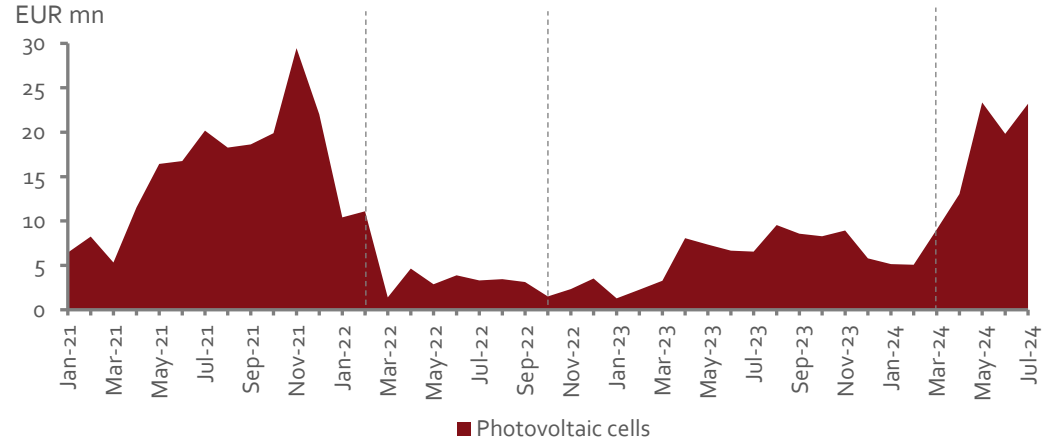


Source: ITC based on Ukrstat data, authors' calculations

2.1.3 Solar PV equipment

Solar PV provides increased resilience and security against targeted attacks due to its decentralized nature, which is vital for maintaining electricity supply in Ukraine. The installation of small-scale solar PV systems in homes, schools, and hospitals ensured clean and reliable power even during shut-downs of power plants due to Russian attacks. In 2021, solar PV imports totalled EUR 193 million but fell sharply to EUR 52 million in 2022 due to the war. However, a small recovery followed, with imports rising to EUR 77 million in 2023, and by the first half of 2024, imports had already reached EUR 75 million, increasing especially after the last wave of Russian attacks. Additionally, the EU Civil Protection Mechanism has coordinated the delivery of over 15,000 solar panels to Ukraine.[14] This resurgence highlights the growing importance of solar PV in decentralizing Ukraine's energy supply and reducing reliance on traditional power sources and the damaged infrastructure.

Figure 8. Imports of solar PV equipment, in EUR million



Source: ITC based on Ukrstat data, The State Customs Service of Ukraine, authors' calculations

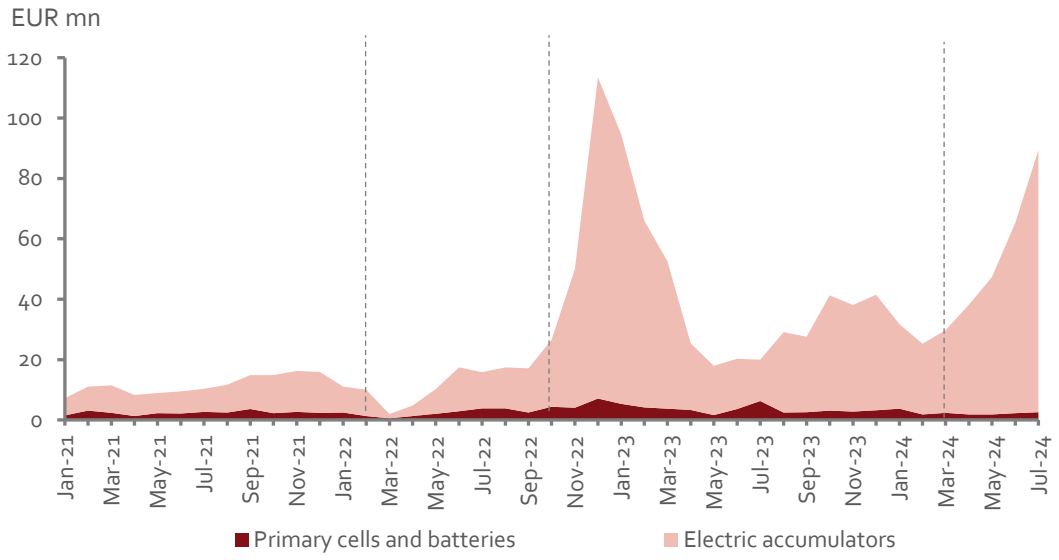
[14] European Commission (2024). News article. (Link)

2.1.4 Electricity storage equipment

Electricity storage equipment, including primary cells and electric accumulators, are vital for stabilizing the grid, storing excess energy, and providing reliable power during outages or fluctuations. Electric accumulators, especially those with higher capacity and energy density, are essential for Ukraine's efforts to restore and stabilize its energy supply by storing renewable energy and ensuring a continuous electricity flow in areas affected by grid damage. These systems are also critical for providing backup power to hospitals and communication systems, which are essential during the war. Primary cell and batteries, though non-rechargeable, play a key role in providing reliable temporary power for small-scale applications such as off-grid lighting and emergency backup for critical communication devices.

Ukraine saw a sharp increase in electricity storage equipment imports in the last quarter of 2022, peaking at EUR 113 million in December 2022, driven by the need for backup power following the Russian attacks around October. This surge was further supported by VAT and customs duty exemptions passed by the Ukrainian parliament, reducing the cost of importing critical energy equipment and facilitating efforts to reinforce energy security across the country (Figure 9).

Figure 9. Imports of electricity storage equipment, in EUR million

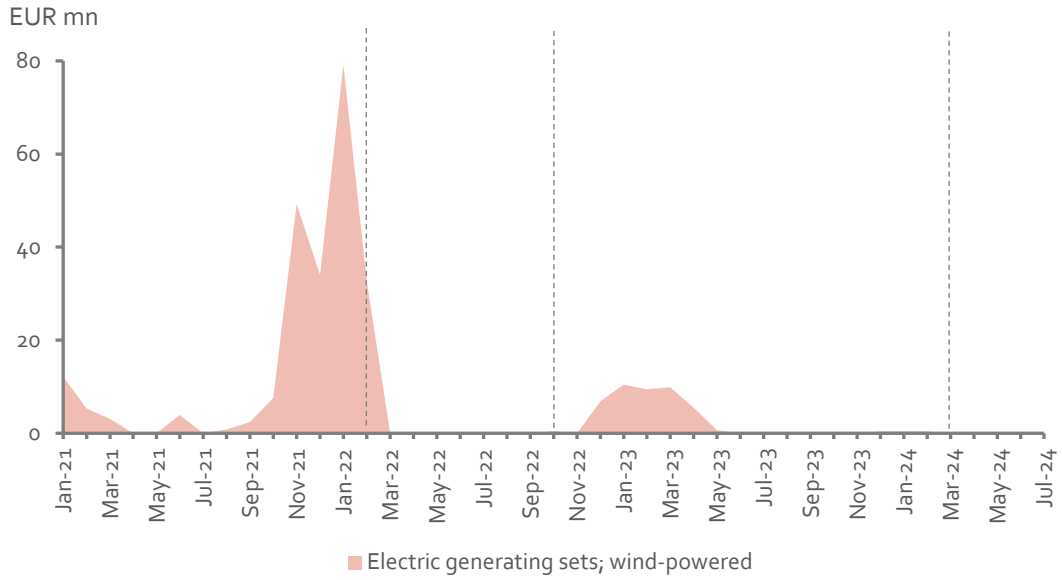


Source: ITC based on Ukrstat data, authors' calculations

2.1.5 Wind-powered generation equipment

Figure 10 below shows the monthly imports of wind-powered electric generation sets to Ukraine. Before the war, in January 2022, imports reached a total of EUR 79 million. At the onset of the Russian invasion of Ukraine in February 2022, the import value dropped significantly to EUR 33 million, and by March 2022 imports dropped to zero. Before the war, the high import values at the beginning of 2022 were related to the substantial deployment and investment in wind energy projects across Ukraine, with a sharp decline in imports from February 2022 as the construction of new wind energy projects was halted. The import activities from November 2022 to May 2023 indicate efforts to fulfil small-scale needs or revive some projects, such as the restarting of the construction of the Tyligulska wind power project by DTEK Renewables.[15] The first phase of the project was launched in the spring of 2023 with a capacity of 114 MW.[16] The absence of imports from June 2023 onwards suggests that wind energy projects did not significantly recover or that large-scale deployments did not resume.

Figure 10. Imports of wind powered electric generation sets, in EUR million



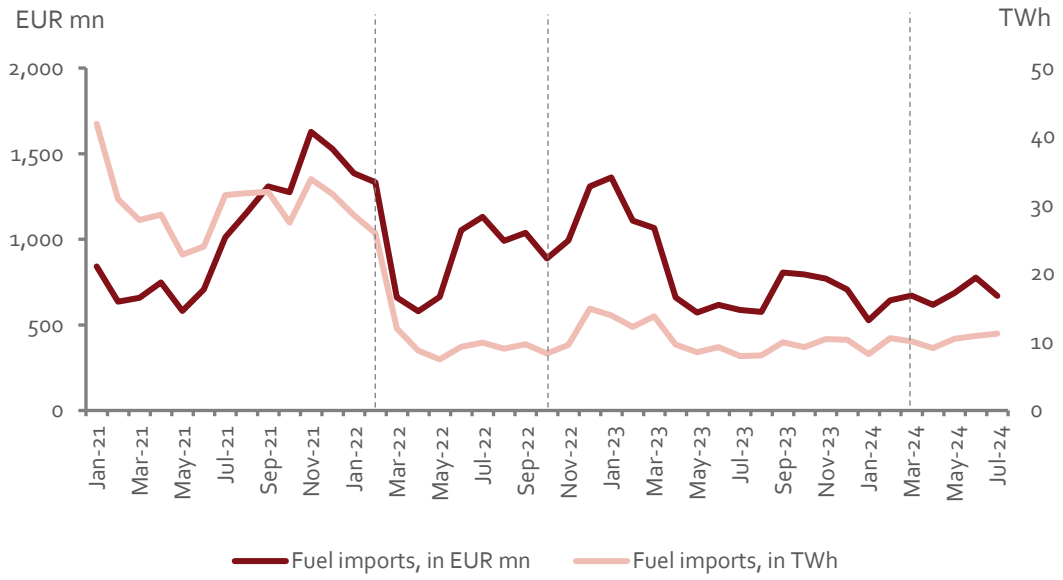
Source: ITC based on Ukrstat data, authors' calculations

[15] PEI (2023). Ukraine's DTEK commissions wind project despite war. (Link)
[16] DTEK (2023). Press Release. (Link)

3 Fuel imports

Fuel imports to Ukraine have shown fluctuations in value. The higher volatility in import values can be attributed to changes in global fuel prices. The initial shock of the Russian aggression led to a sharp decline in imports from EUR 1.6 billion in November 2021 to EUR 580 million by April 2022, which followed by a period of fluctuation and gradual stabilization. A sharp increase in the last months of 2022 occurred to meet the increased energy demand during the winter period. The small early 2024 recovery in both value and volume imply strategic adjustments by Ukraine in response to market conditions or anticipated future needs before the winter (Figure 11).

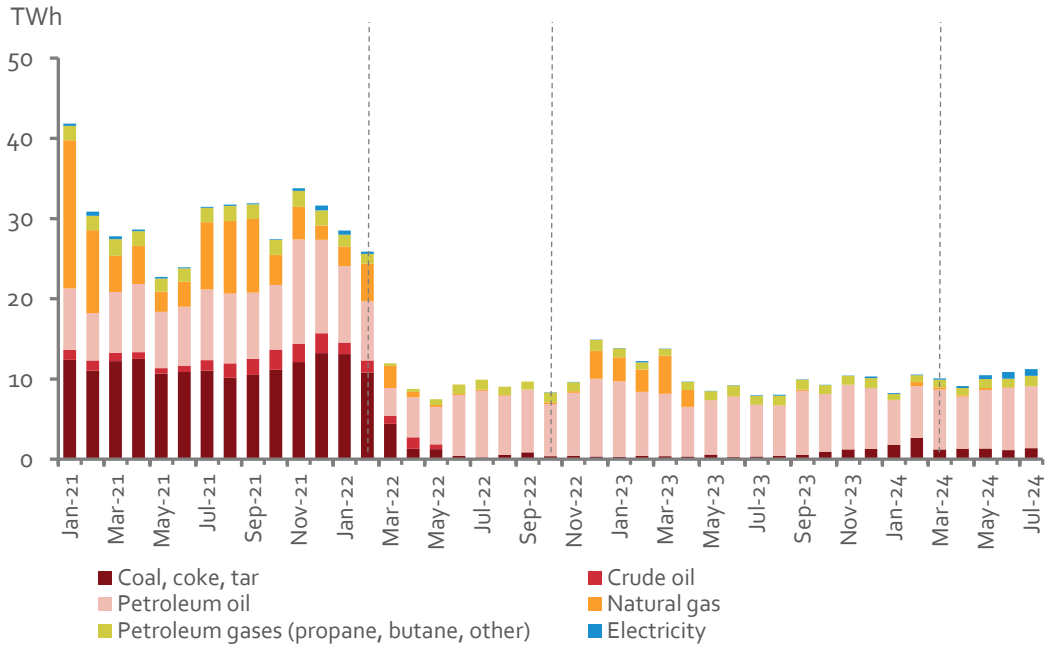
Figure 11. Fuel imports to Ukraine from World, value vs volume



Source: ITC based on Ukrstat data, authors' calculations

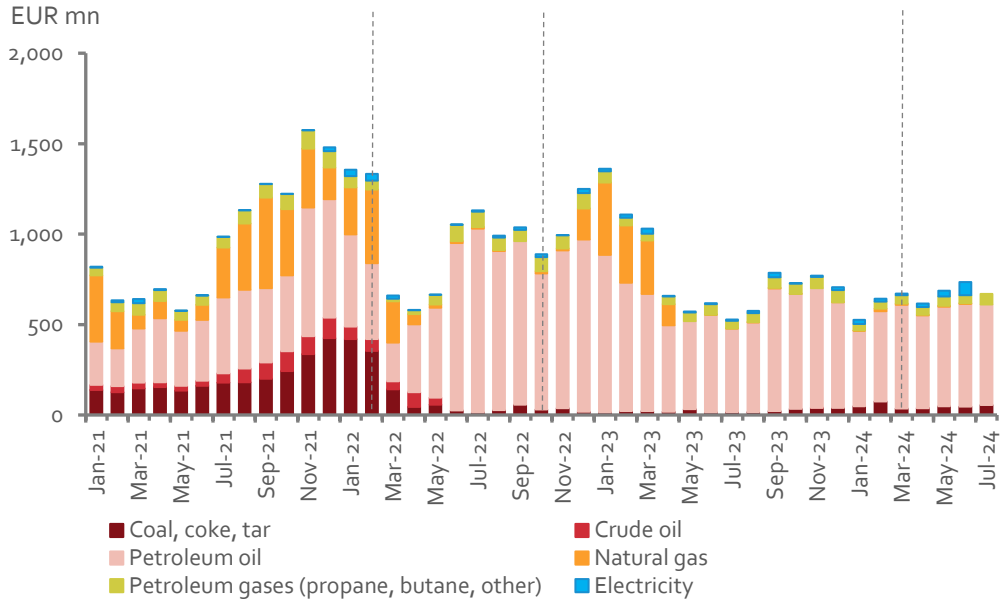
The sharp drop in total fuel import volume from 41.9 TWh in January 2021 to 7.5 TWh in May 2022 was mainly caused by the decrease in natural gas, crude oil, and coal and coke imports. Natural gas imports fell from 18.5 TWh to 0.22 TWh during the same period and reached near-zero levels in the second half of 2023. Coal and coke imports experienced a similar sharp decline, dropping from 12.4 TWh to 1.2 TWh over the same period (Figure 12). This can be attributed to damaged and destroyed thermal power plant capacity, reducing the need for coal and natural gas imports. Additionally, the sharp decline in crude oil imports to zero by June 2022 is due to the total loss of refinery capacity following the destruction of the last operating refinery, the "Kremenchuk Oil Refinery", in April 2022, which eliminated the need for imported crude oil. The remaining production now relies on locally extracted oil, as evidenced by the absence of crude oil exports.

Figure 12. Imports of fuels by type, in TWh [17]



Source: ITC based on Ukrstat data, ENTSO-E, authors' calculations

Figure 13. Imports of fuels by type, in EUR million



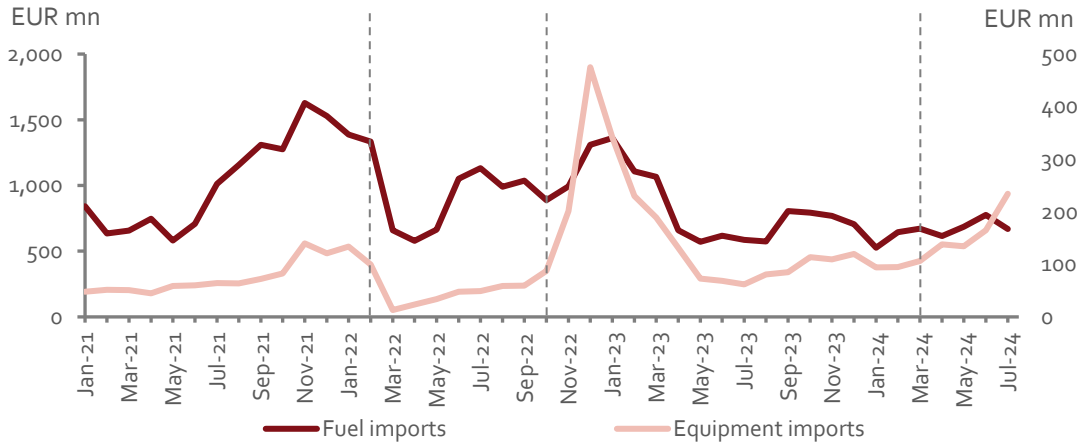
Source: ITC based on Ukrstat data, authors' calculations

[17] Electricity imports are based on ENTSO-E data for incoming scheduled commercial exchanges to Ukraine from its neighbouring countries, with the total for all border countries provided monthly from January 2021 to July 2024.

3.1 Comparison of fuel and equipment imports

Fuel and energy equipment imports followed a similar trend in the year preceding the war. Following the Russian invasion in February 2022, there was sharp decline in both, followed by a period of recovery, with a significant spike for energy equipment imports in the last quarter of 2022 due to increased need to rebuild the energy infrastructure and secure energy supply in response to damages to the energy infrastructure caused by the Russian attacks. Energy equipment imports rebounded by the end of the first half of 2024, following the latest wave of attacks in March 2024 (Figure 14).

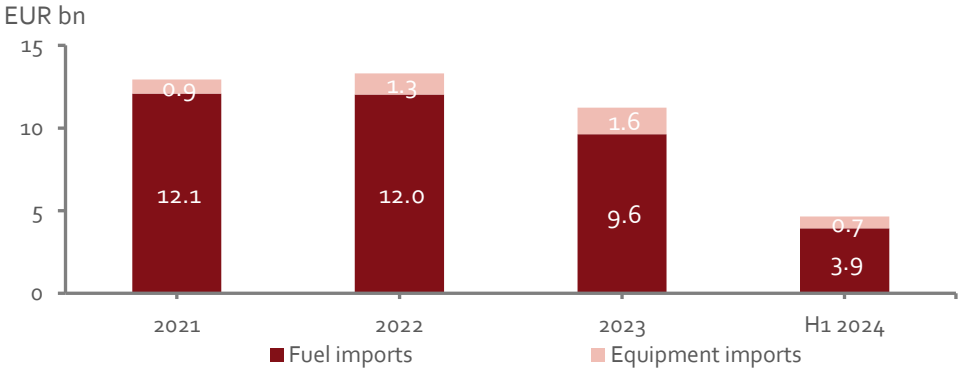
Figure 14. Imports of fuel (left axis) and energy equipment (right axis) to Ukraine, in EUR million



Source: ITC based on Ukrstat data, authors' calculations

Fuel imports remained stable in value terms initially but dropped significantly by 2023. In contrast, energy equipment imports increased steadily, reflecting a shift towards investing in critical energy infrastructure to ensure a reliable supply during the war (Figure 15). After a dip in energy equipment imports in the summer of 2023, concerns about potential Russian attacks in the winter of 2023/2024 led to a surge in demand for energy equipment. However, as no major targeted attacks on energy infrastructure materialized at that point in time, the demand subsequently decreased.

Figure 15. Imports of fuel and energy equipment to Ukraine, in EUR billion



Source: ITC based on Ukrstat data, authors' calculations

4 Analysis and additional considerations

While many highly interesting patterns emerge from the findings of the trade analysis, the most pertinent one is the significant decline in renewable energy sources (RES) within Ukraine's total energy equipment imports: from 38% in 2021 to 15% in 2023. While not entirely unsurprising given the ongoing war context, the declining share of renewable imports runs at odds with many of the narratives and ongoing strategies to ensure the continued greening of the energy system both during and after the war.

Diesel generators have been prioritized due to their perceived reliability and fast deployment during outages, whereas solar PV and wind projects, which require more stable infrastructure, have lagged behind. The drop in wind-powered generation equipment imports, dropping effectively to zero by March 2022, reflects the exposure of large-scale projects to the war. Solar PV imports, after a sharp decline, have shown recovery with smaller-scale applications in both residential and public sector buildings. Batteries, however, have played a critical role across both conventional and renewable energy sources, highlighting their future importance in stabilizing the electricity grid.

Currently, the roll-out of all types of generating capacity in Ukraine (both renewable and non-renewable) at both the utility and small-scale is undoubtedly desperately needed. Concurrently, the comparatively smaller share of renewables within energy equipment imports may however also still signal that consumers are either cautious or unaware of the benefits that, for example, small-scale distributed solar PV and battery storage may provide. These include factors such as reliability and costs reductions, with possible benefits maximised especially in times of grid outages.[18] At the same time, large-scale reliance of diesel-powered generators may impose significant risks. Given the destruction of Ukraine's domestic oil refining capacities, all oil products must be imported from abroad, and while the risk of supply disruption is not high, price volatility may pose significant economic risks. The process of the deployment of small-scale solar PV (often in tandem with battery storage) has been driven across all sections of society in Ukraine but has most prominently been led by various civil society organisations but also several municipalities, which are choosing to reconstruct their cities and ensure resilience through small-scale renewables.

As Ukraine rebuilds the energy sector, there is a role for conventional fossil-fuel powered technologies (such as highly flexible CCGTs and gas pistons), but a primary focus has to be on renewable-based generation. This is important at both the small- and utility-scales, especially to prevent long-term lock-ins and path dependencies. Legislative efforts are crucial in driving the future growth of renewables. In July 2023, Ukraine enacted Law No. 3220-IX, titled "On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine", which introduced measures to simplify and accelerate the connection of renewable energy generation facilities to the power grid, aiming to support the development of green energy and reducing reliance on traditional

[18] Saparova, D., Stubbe, R., Bilek, P. (2023). *Keeping the lights on in times of grid outages. Solar PV panels, battery storage systems and diesel generators*. Low Carbon Ukraine (Link)

sources. Furthermore, in July 2024, the government launched a 0% interest loan program for households to purchase and install renewable energy generation units and energy storage systems, further promoting the adoption of renewable energy solutions.[19] Both of these may play a positive role in the expansion of renewables in the current context and in the post-war recovery period.

This however also means progressing further with important energy market reforms to enable Ukraine's full potential and support the reconstruction effort. The wholesale electricity market needs to be liberalized by removing price caps and floors, which currently distort price signals and hinder investments in renewables, but also flexible generation and storage capacities. Addressing the high levels of debt across the energy system, particularly within the renewable energy and balancing markets, is also essential to restore investor confidence. The establishment of a reliable payment mechanism for renewable energy producers, replacing the "Green Tariff" system is another critical step. Additionally, reducing the high cost of capital by implementing de-risking measures, such as loan guarantees and interest subsidies, will make investments in renewables more attractive. Many of these measures are already being implemented (see above), but further steps may be necessary. Additionally, programmes aimed at up-skilling workers and preparing them for jobs in the renewables sector are highly needed, with a specific focus on integrating more women, veterans, and workers from communities heavily dependent on the fossil fuel economy (e.g. coal mining regions).[20] Finally, fostering the development of decentralized energy systems by supporting prosumers and ensuring robust regulatory frameworks will further strengthen the market and drive the growth of renewable energy in Ukraine.

5 Conclusion

Since Russia's invasion of Ukraine in February 2022, Ukraine's energy infrastructure and power grid have been key targets of Russian attacks, aimed at weakening the country's resilience. The import of critical energy equipment to Ukraine significantly increased in response to the extensive damage caused by the ongoing Russian invasion, which domestic production alone could not meet. Monthly imports rose from EUR 48 million in January 2021 to a peak of EUR 475 million in December 2022, primarily driven by the urgent need to repair and replace damaged energy infrastructure. This surge included essential equipment such as renewable and non-renewable electricity generators (diesel & semi-diesel generators, solar PV), accumulators, grid and transmission equipment.

Notably, imports of non-renewable generation equipment, including diesel and semi-diesel generators, and electricity storage equipment saw the most significant increases. Imports of non-renewable generation equipment totalled EUR 732 million by the end of 2023, reflecting the urgent demand for backup power generation following the Russian

[19] Ukraine Government Portal (2024). News release. (Link)
[20] Bilek, P., Stubbe, R. Weser, H. (2024). A Solar Marshall Plan for Ukraine. Empowering Ukraine's brighter future: bottlenecks and key policy reforms needed to boost solar PV deployment. Greenpeace, Berlin Economics (Link).

attacks ahead of winter. Electricity storage and grid and transmission equipment imports rose steadily, reflecting ongoing efforts to repair damaged energy infrastructure and meet energy demand. In addition, solar PV equipment imports, which declined from EUR 193 million in 2021 to EUR 52 million in 2022, rebounded in 2023 to EUR 77 million. By the first half of 2024, imports reached EUR 75 million, driven by the latest wave of Russian attacks that started in March 2024.

International partners have also played a crucial role in supporting the restoration of Ukraine's energy infrastructure. Coordinated by the Ministry of Energy, Ukraine received 1,138 cargoes, totalling approximately 15.5 thousand tons, which accounted for 5% of total equipment imports during this period. The Ukraine Support Task Force also facilitated significant in-kind donations, delivering around 3,700 tons of energy equipment, emphasizing the critical role of international assistance in bolstering Ukraine's energy resilience.

Moving forward, the maintenance and reconstruction of Ukraine’s energy system has to enable the integration of conventional energy sources, but increasingly also renewable energy sources at both the small-scale and utility-scale. In order to do so, significant market reforms and support will be needed, but a greener transformation of the energy sector is fundamental for Ukraine’s resilience, long-term economic competitiveness and obligations, especially in light of its future within the European Union.

Annex

Table 1. List of equipment and fuels included in the analysis

HS Code	Description	Category
2701	**Coal; briquettes, ovoids and similar solid fuels manufactured from coal**	
270111	Coal, Anthracite, whether or not pulverised, non-agglomerated	Fuel
270112	Coal, Bituminous coal, whether or not pulverised, non-agglomerated	Fuel
270119	Coal, whether or not pulverised, non-agglomerated (excl. anthracite and bituminous coal)	Fuel
2704	**Coke and semi-coke; of coal, lignite or peat, whether or not agglomerated; retort carbon**	Fuel
2706	**Tar distilled from coal, from lignite, peat and other mineral tars**	Fuel
2709	**Petroleum oils and oils obtained from bituminous minerals, crude**	Fuel
2710	**Petroleum oils and oils from bituminous minerals, not crude; preparations n.e.c**	
271012	Petroleum oils and oils obtained from bituminous minerals (other than crude) and preparations not elsewhere specified or included, containing by weight 70 % or more of petroleum oils or of oils obtained from bituminous minerals, these oils being the basic constituents of the preparations, other than those containing biodiesel and other than waste oils; Light oils and preparations	Fuel
271019	Petroleum oils and oils obtained from bituminous minerals (other than crude) and preparations not elsewhere specified or included, containing by weight 70 % or more of petroleum oils or of oils obtained from bituminous minerals; not light oils and preparations	Fuel
271020	Petroleum oils and oils obtained from bituminous minerals (other than crude) and preparations not elsewhere specified or included, containing by weight 70 % or more of petroleum oils or of oils obtained from bituminous minerals, these oils being the basic constituents of the preparations, containing biodiesel, other than waste oils	Fuel
2711	**Petroleum gases and other gaseous hydrocarbons**	
271112	Propane, liquefied	Fuel
271113	Butanes, liquefied (excl. of a purity of >= 95% of N-butane or isobutane)	Fuel
271119	Gaseous hydrocarbons, liquefied, n.e.c. in heading no. 2711	Fuel
271121	Natural gas in gaseous state	Fuel
271129	Hydrocarbons in gaseous state, n.e.s. (excl. natural gas)	Fuel
2716	**Electrical energy**	Fuel
7311	**Containers for compressed or liquefied gas, of iron or steel**	Equipment
7613	**Aluminium; containers for compressed or liquefied gas**	Equipment
8411	**Turbo-jets, turbo-propellers and other gas turbines.**	
841181	Gas turbines of a power <= 5.000 kW (excl. turbojets and turbopropellers)	Equipment
841182	Gas turbines of a power > 5.000 kW (excl. turbojets and turbopropellers)	Equipment
841199	Parts of gas turbines, n.e.s.	Equipment
8416	**Furnace burners for liquid fuel, for pulverised solid fuel or for gas**	
841610	Furnace burners for liquid fuel	Equipment
8501	**Electric motors and generators (excluding generating sets)**	
850110	Electric motors and generators (excluding generating sets); motors of an output not exceeding 37.5W	Equipment
850131	Electric motors and generators (excluding generating sets; other DC motors; other than photovoltaic generators; of an output not exceeding 750W	Equipment

850132	Electric motors and generators (excluding generating sets; other DC motors; other than photovoltaic generators; of an output exceeding 750W but not 75kW	Equipment
850133	Electric motors and generators (excluding generating sets; other DC motors; other than photovoltaic generators; of an output exceeding 75kW but not 375kW	Equipment
850134	Electric motors and generators (excluding generating sets; other DC motors; other than photovoltaic generators; of an output exceeding 375kW	Equipment
850140	Electric motors and generators (excluding generating sets); other AC motors, single-phase	Equipment
850151	Electric motors and generators (excluding generating sets); other AC motors, multi-phase; of an output not exceeding 750W	Equipment
850152	Electric motors and generators (excluding generating sets); other AC motors, multi-phase; of an output exceeding 750W but not 75kW	Equipment
850153	Electric motors and generators (excluding generating sets); other AC motors, multi-phase; of an output exceeding 75kW	Equipment
850161	Electric motors and generators (excluding generating sets); AC generators (alternators), other than photovoltaic generators; of an output not exceeding 75 kVA	Equipment
850162	Electric motors and generators (excluding generating sets); AC generators (alternators), other than photovoltaic generators; of an output exceeding 75 kVA but not 375 kVA	Equipment
850163	Electric motors and generators (excluding generating sets); AC generators (alternators), other than photovoltaic generators; of an output exceeding 375 kVA but not 750 kVA	Equipment
850164	Electric generators; AC generators, (alternators), of an output exceeding 750kVA	Equipment
850171	Electric motors and generators (excluding generating sets); Photovoltaic DC generators; of an output not exceeding 50 W	Equipment
850172	Electric motors and generators (excluding generating sets); Photovoltaic DC generators; of an output exceeding 50 W	Equipment
850180	Electric motors and generators (excluding generating sets); Photovoltaic AC generators	Equipment
8502	**Electric generating sets and rotary converters.**	
850211	Generating sets with compression-ignition internal combustion piston engine "diesel or semi-diesel engines: Of an output not exceeding 75 kVA	Equipment
850212	Generating sets with compression-ignition internal combustion piston engine "diesel or semi-diesel engines: Of an output exceeding 75 kVA but not exceeding 375 kVA	Equipment
850213	Generating sets with compression-ignition internal combustion piston engine "diesel or semi-diesel engines): Of an output exceeding 375 kVA	Equipment
850220	Generating sets with spark-ignition internal combustion piston engine	Equipment
850231	Generating sets, wind-powered	Equipment
8504	**Electrical transformers, static converters (for example, rectifiers) and inductors.**	
850410	Ballasts for discharge lamps or tubes	Equipment
850421	Liquid dielectric transformers, having a power handling capacity <= 650 kVA	Equipment
850422	Liquid dielectric transformers, having a power handling capacity > 650 kVA but <= 10.000 kVA	Equipment
850423	Liquid dielectric transformers, having a power handling capacity > 10.000 kVA	Equipment
850431	Transformers having a power handling capacity <= 1 kVA (excl. liquid dielectric transformers)	Equipment
850432	Transformers, having a power handling capacity > 1 kVA but <= 16 kVA (excl. liquid dielectric ...	Equipment
850433	Transformers having a power handling capacity > 16 kVA but <= 500 kVA (excl. liquid dielectric ...	Equipment
850434	Transformers having a power handling capacity > 500 kVA (excl. liquid dielectric transformers)	Equipment

850440	Static converters	Equipment
850490	Electrical transformers, static converters and inductors; parts thereof	
8506	**Primary cells and primary batteries**	
850610	Manganese dioxide cells and batteries (excl. spent)	Equipment
850630	Primary cells and primary batteries; Mercuric oxide	Equipment
850640	Primary cells and primary batteries; Silver oxide	Equipment
850650	Lithium cells and batteries (excl. spent)	Equipment
850660	Primary cells and primary batteries; Air-zinc	Equipment
850680	Primary cells and primary batteries, electric (excl. spent, and those of silver oxide, mercuric ...	Equipment
850690	Cells and batteries; primary, parts thereof	
8507	**Electric accumulators, including separators therefor, whether or not rectangular**	
850710	Lead-acid accumulators of a kind used for starting piston engine "starter batteries"; including separators	Equipment
850720	Lead acid accumulators (excl. spent and starter batteries)	Equipment
850730	Nickel-cadmium accumulators (excl. spent)	Equipment
850750	Nickel-metal hydride accumulators (excl. spent)	Equipment
850760	Lithium-ion accumulators (excl. spent)	Equipment
850780	Electric accumulators, other, including separators, whether or not rectangular	Equipment
850790	Plates, separators and other parts of electric accumulators, n.e.s.	Equipment
8541	**Semiconductor devices; photosensitive semiconductor devices**	
854142	Photovoltaic cells not assembled in modules or made up into panels	Equipment
854143	Photovoltaic cells assembled in modules or made up into panels	Equipment