ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20240928204313

Subject review
Received: 2024-09-28, Accepted: 2025-02-07

Fuelling Logistics from Refinery to Retail: Case Study of the Romanian Oil Supply Chain

Attila Turi

Abstract: The purpose of this paper was to examine how EU sanctions on Russia impacted Romania and how its refineries managed to continue operating with alternative suppliers. Production performance dynamics and their share in total output of refined petroleum products in the last 5 years (2019-2023) are analyzed using descriptive statistics. Own empirical research is used to study the supply chains of the Petrobrazi, Petrotel and Petromidia refineries and provide an overview of their role on the domestic fuel market by mapping out their fuel storage locations and network of filling stations. Findings underpin the importance of an interconnected infrastructure network (pipelines, railways and ports) and using it to its full extent to balance out onshore and offshore imports, as well as downstream deliveries. Study replicability is affected by the limited extent to which the collected data can be revealed, whilst future research can study sustainability of non-Russian oil sourcing alternatives.

Keywords: fuel distribution; fuel storage network; intermodal transportation; pipeline transportation; oil supply chain; refinery logistics

1 INTRODUCTION

Romania is the EU's third oil producer (after Italy and Denmark) and ranks fifth in Europe, Norway and the United Kingdom being the largest, according to Eurostat (2023). It also ranks in the top 10 producers of petroleum products in the EU with yearly refined volumes of over 10 million tonnes (2023) and has one of the lowest (68%, 2024) oil import dependency rates [1, 2], compared to the average 92% at EU level [3] and even less of Russian crude oil sourcing (18%, 2022), according to the International Energy Agency. Its other main import countries are Kazakhstan (KMG), Azerbaijan and Turkey (SOCAR), several other EU countries (mainly Bulgaria, Hungary and Austria) and Serbia [4] for refined oil products (Trading Economics, 2023 report). Oil products have a 5.6% share in Romania's exports and an overall 6.5% share in GDP (National Institute of Statistics, 2023 report), making it one of the most important drivers of economic growth in addition to being one of the country's strategic resources [5].

The 3 operational refineries ensure 32.1% of its domestic oil consumption needs (2022) and are owned by multinational oil companies from Austria, Russia and Kazakhstan (OMV, Lukoil and KazMunayGas). Prior to the invasion of Ukraine (2022), Novorossiysk's onshore terminal supplied Russian crude oil to all Romanian refineries (Lukoil's Petrotel having a higher share), whilst its offshore terminal still supplies Kazakh crude oil through the Caspian Pipeline Consortium (CPC), mainly to KMG's Midia Marine Terminal [6, 7]. Romania's fuel supply is uneven: a net exporter of gasoline and a net importer of diesel fuel due to its predominant domestic diesel consumption. In 2021, 30% of diesel fuels were imported from Russia, the majority of which (up to 90-95%) via Constanta's Oil Terminal [8-10].

Purchasing, importing and transferring seaborne crude oil (since December 2022) and certain petroleum products (since February 2023) from Russia to the EU are prohibited [11, 12]. Some temporary exemptions were made for landlocked (Hungary, Slovakia) or highly dependent countries (Germany), with others already having found alternative sourcing options (Bulgaria, Poland, Czech Republic) to fully align with the EU's restrictive policy [13-15]. A deal (1 year contract) for transport and storage of 2.9 million tonnes of crude oil was signed (May 2023) to supply MOL's refineries in Hungary and Slovakia via the Croatian pipeline, based on rigorous feasibility, technical and operational analyses [16, 17]. Hungary is still opposing shifting away from (cheaper) Russian oil imports and sourcing from Croatia via the Adria pipeline (operated by JANAF), claiming logistics costs are too high [18] and transport capacities from Omisalj are too low for its needs, despite reassurance from its southwest neighbor [19]. Slovakia has a similar position (Slovnaft), whilst Croatia has little leverage since INA is also owned by Hungarian MOL. Overall, Russia's share in extra-EU imports of oil products plummeted from 24.8% (Q4, 2021) to 1.2% (Q2, 2024) after its invasion of Ukraine and subsequent EU sanctions, according to recent data released by Eurostat.

By leveraging their distribution channels [20, 21], domestically refined fuels (Petrom, OMV [22], Lukoil and Rompetrol), in addition to import brands (MOL, SOCAR and Gazprom) and independent stations ensure the supply of fuel products [23] to their network of filling stations across Romania [24].

This article is organized in the following sections: Chapter 1 introduces background information and data on Romania's oil refining industry, its share of crude oil imports from Russia and provides EU neighboring context. Chapter 2 presents a synthesis of related scientific articles, outlining their contributions and identifying the gap this study intends to fill. Chapter 3 provides the research design, including a description of the data collection methods and analytical techniques utilized in this study. Chapter 4 reveals and summarizes the main research findings, followed by their interpretation and implications for future research in Chapter 5. Finally, Chapter 6 concludes the paper by summarizing its key findings, expressing their importance, limitations and initiates an outlook for further exploration of the topic.

2 LITERATURE REVIEW

The existing literature on oil refining and its logistics primarily focuses on macro-level analyses of fuel supply chains, with limited attention to the micro-level challenges and optimization opportunities within specific regions or even countries, as is the case of Romania in this article. The main reason for this research gap is the lack of accessible and/or aggregated data, as well as challenges regarding publishing due to high data sensitivity and confidentiality.

Seeking correlations between oil production and an array of other economic data provides mixed results, as is noted by [25]. Nevertheless refineries do have a strong influence on a country's economic activity, both direct (technical support, maintenance work) and indirect (transportation, logistics), despite lower returns to scale. This is also confirmed by [26], who show that oil refining is positively correlated with a country' global competitiveness index (GCI) and despite price volatility affecting cost competitiveness, a net oil exporter will bear less risk than a net oil importer. The closer oil refining capacities are to their demand market, the more cost-efficient they are and the more effective they are in reducing the impact of price fluctuations [27].

Optimization of fuel distribution networks is another recurring theme and mostly relies on analyzing, modeling and conducting matching scenarios between supply and demand with direct or indirect cost reduction-related targets.

Deterministic approaches such as the one undertaken by [28] highlight the complexities of managing a network of ships, tanks, pipelines to supply crude oil to refineries. More refined models provide more feasible decisions, but also increase the expected cost and are still subject to improvement. Supply chain management flow strategies are most often studied in countries where oil refining is an underlying economic sector, as proven by [29]'s approach which sources good solutions in reasonable time spans for both cost and time-related parameters. The narrow margins of refineries are balanced out by consistency in delivering volumes and maximizing oil trade decision-making, as shown for Europe's leading independent crude oil facilities (Petroineos) in Lavéra (France), Grangemouth (Scotland) and the largest European refinery site (Shell) in Pernis, The Netherlands by [30].

While these approaches require a more in-depth analysis of a specific regional setting, they still have limited practical applicability. This is due to the typical high sensitivity and reactivity of the oil market to various external factors (production levels, geopolitical events, economic sanctions, OPEC decisions, natural disasters), which source a rather unpredictable, volatile and dynamic pricing pattern, which alters supply decisions.

Other authors [31] outline decision-making challenges of the real world as being ambiguous or vague. Their proposed model employs a pentagonal fuzzy number to minimize the cost along the refineries' supply chain (depots, multimodal transportation and demand nodes), provides improved larger-scale results and reduces the optimality gap, despite uncertainty being factored in.

Therefore while simulating routes is nevertheless useful to analyze and redesign certain supply choices, its rather static assumptions and constraints modeled on historical data might become suboptimal, unrealistic or even impossible in certain real life conditions.

Inconsistent use and implementation of EDI systems across filling stations, with mostly short loop communication systems, even in the case of multinational brands' supply chains alters operations management effectiveness and hinders appropriate fast-response logistics, as also outlined by [32]. Significant differences also exist between individual filling stations' supply chains, especially in case of a lower concentration of fuel providers within that specific region.

This article's role is to contribute to the research field by providing a granular analysis of the Romanian fuel supply chain, considering local production, depot storage locations, distribution system and its mix of alternative sourcing locations within the specific logistical challenges of the Balkans. Previous research has not explored the impact of redesigning upstream crude oil supply on country basis in the context of Russian sanctions, a gap this study aims to fill. Effective decision-making relies on high-quality data: real-time, accurate and consistent data enables a more focused analysis, which in turn leads to a greater impact on overall productivity and operational performance.

3 MATERIALS AND METHODS

The current research paper uses primary and secondary data about the oil industry in Romania (production, capacity utilization, alternative sourcing options, storage facilities, distribution network and intermodal logistics systems), its main multinational competitors and their domestic market shares.

Raw and primary data is sourced through own empirical research by conducting on-site fieldwork and observational study (at refineries, port and intermodal terminals). Certain parts of gathered data (mainly from the refineries and port terminal operators) are subject to consented NDAs' strict terms, prior to gaining access to specific operational, financial, customer and supplier data. Secondary data (statistics databases, industry reports and official releases) is cross-referenced with each refinery's and intermodal terminal's records, with some marginal data cleaning being required to eliminate inconsistencies and validate findings. The paper's collated data is consented for publication and adheres to all contracted stipulations of the NDAs.

Descriptive statistics is applied to investigate the evolution of the 3 refineries' time-series data (2019-2023) on operational performance metrics. Year-to-year percentage variations and relative share in total output of refined fuels are analyzed to contextualize production dynamics. Qualitative and quantitative methods are used to exhibit relevance of empirical data by mapping and compiling fuel storage locations, the distribution network and their connectivity to main intermodal transportation terminals, thus offering a holistic approach to the case study.

4 RESULTS' ANALYSIS

Romania's 3 operational refineries (Petrobrazi, Petrotel and Petromidia) are owned by multinational oil companies: OMV (Austria), Lukoil (Russian Federation) and KMG International/KazMunayGas (Kazakhstan). Over 80% of total output is provided by the Petrobrazi (OMV) and Petromidia (KMG) facilities, the latter being Romania's most modern refinery with the highest capacity utilization rate (CUR), as shown in Tab. 1. Petrotel's productivity has been decreasing in recent years (by 45% since 2019), despite

Lukoil having the closest alternative refinery (Neftohim Burgas) in Bulgaria. In view of the economic context after invading the Ukraine, Russia's Gazprom transferred its operations to Serbian multinational company Naftna Industrija Srbije (NIS) Petrol, thus legally avoiding sanctions imposed on Russian oil imports since Serbia is a non-EU member state. Lukoil uses a similar approach, importing its crude oil through intermediate companies outside of the Russian Federation (e.g. Turkey or via pipelines) and then using its Petrotel processing facility in Ploiesti (Romania) to refine it, thus also avoiding sanctions. OMV and MOL also use this loophole, in addition to other major European companies (BP, Shell, TotalEnergies or ENI). Tab. 1 presents an overview of oil companies' production volumes, Capacity Utilization Rate (CUR), year-to-year variations (2019-2023) and share of total refined petroleum products in Romania.

Table 1 Romania – main refineries' performance metrics

Refinery	KPI	2019	2020	2021	2022	2023
OMV Petrobrazi Brazi (South)	Output (MTPA)	4.54	4.05	3.83	4.56	3.84
	CUR (%)	0.94	0.84	0.79	0.95	0.80
	Dynamic (%)	1.02	0.89	0.94	1.19	0.84
	Share (%)	0.37	0.39	0.38	0.40	0.37
Lukoil Petrotel Ploiesti (South)	Output (MTPA)	2.49	1.88	1.93	2.22	1.37
	CUR (%)	0.92	0.69	0.71	0.82	0.50
	Dynamic (%)	1.03	0.75	1.02	1.15	0.61
	Share (%)	0.20	0.18	0.19	0.19	0.13
KMG Petromidia Navodari (East)	Output (MTPA)	4.97	4.29	4.16	4.51	5.01
	CUR (%)	0.97	0.83	0.81	0.88	0.97
	Dynamic (%)	1.03	0.86	0.97	1.08	1.11
	Share (%)	0.41	0.42	0.41	0.39	0.49
Total	Output (MTPA)	12.00	10.22	9.92	11.29	10.22
	CUR (%)	0.95	0.81	0.78	0.89	0.81
	Dynamic (%)	1.03	0.85	0.97	1.13	0.90

OMV-owned Petrobrazi refinery (sourcing Petrom and OMV fuel brands) covers almost 40% of Romania's total refining capacity, with a record output of 4.56 million tonnes of petroleum products, 19% year-on-year increase and 95% CUR (2021). After buying the refinery from Petrom (51.1% of shares since 2004), OMV has invested over 2 billion euros in modernization projects at its Petrobrazi location in South Romania. Planned shutdowns for routine maintenance and equipment upgrades of the country's oldest operating refinery (2021, 2023) and the first pandemic year (2020) caused its CUR indicator to fall below 90%. Its 2023 planned shutdown (for environmental compliance) reduced its output by 0.72 million tonnes (16% compared to 2022) and CUR to only 80%.

In 2019, Lukoil boasted sourcing Romania's highest gasoline quality at its Petrotel refinery, according to some independent reports. Lukoil owns 99.76% of Petrotel's shares (since 1998) through Litasco, its own oil trading company based in Switzerland, and invested almost 500 million euros in modernization projects at its Ploiesti refining unit (2004-2015). With a share of only 20% of the country's refined petroleum products and a focus on competitive pricing, its investments slowly decreased, as did its CUR metric (around 70% in 2019 and 2020). EU sanctions against imports from the Russian Federation after invading Ukraine, combined with reduced alternative crude oil sourcing options further curtailed its refining output to around 50% of its total capacity (yield of 1.37 million tonnes), in 2023. Tax evasion lawsuits and undisclosed operations (crude oil sourcing, processed amount and downstream distribution) lead to Lukoil losing its trading license (temporarily), shortly after Petrotel suspended its operations for overhaul (November 2023).

Last year, KMG's (KazMunayGas) Petromidia refinery (owned with 54.63% of shares), produced a record 5.01 million tonnes of petroleum products (Rompetrol fuel brands), an 11% year-on-year increase and 49% overall domestic refining share (2023) supported by its 97% CUR. KMG also owns Vega, a smaller refinery (capacity: 0.4 million tonnes/year and 98.5% CUR/year) in Ploiesti, that operates in an integrated system with its main refinery from Navodari. A fire interrupted activity for 83 days (July 2021) before repairs allowed regular operations to restart in September 2021, whereas refining capacity was fully restored only in April 2022. Petromidia produces Romania's highest amount of petroleum products, with one exception: 2 months of general overhaul reduced its CUR (88%) and output (4.51 million tonnes) in 2022, being overtaken by its competitor, OMV Petrom (4.56 million tonnes).

In 2019 Romania's refineries had a combined output of 12 million tonnes of petrol and diesel fuels, before 2 consecutive years of dwindle caused by the Covid-19 pandemic. Yearly volumes of petrol and diesel fuels declined by 1.78 million tonnes (15% in 2020) and a further 0.3 million tonnes (3% in 2021), before recovering in 2022 (11.29 million tonnes). 2023 marked another 10% descend (to 10.22 million tonnes), mostly due to Petrotel's ownership issues: 0.85 million tonnes less yield (39% year-on-year decrease) and OMV Petrom's planned general turnaround: 0.72 million tonnes less refined products (16% year-on-year decrease). Around 60% of refined products (petrol and diesel fuel) are sourced locally by the refineries: Petrobrazi (66%), Petromidia (58%) and Lukoil (50%). The rest is mainly imported from Hungary (MOL), Bulgaria (Lukoil), Serbia (NIS) and offshore facilities through tankers via the port of Constanta and then distributed locally (storage facilities and gas stations). Crude oil and refined petroleum products (petrol and diesel fuel) are also sourced from Asia (30%) and the United States (20%), but 80% of imports from the Caspian Sea (KMG and SOCAR) pass through Russia's pipelines before being shipped to Romania's Black Sea gateway. Imported oil products come at higher prices due to extra shipping and insurance costs and arrive at Constanta Port's Oil Terminal. MOL (Hungary) is the most important import brand, but its main refinery near Budapest is also an important supplier for the West of Romania, in addition to its controlled facilities in Slovakia (Slovnaft) and Croatia (INA).

A map of Romania's refineries, their domestic fuel depots and main alternative sourcing (import) locations is presented in Fig. 1.

Figure 1 Romania – domestic refineries' production units, storage and alternative sourcing locations (2024)

MOL's Danube refinery in Szazhalombatta (Hungary) is one of the 10 largest in Central and Eastern Europe (CEE) with its 165,000 barrels/day and/or 8.1 million tonnes/year refining capacity. MOL also owns neighboring Slovnaft (Bratislava, 6.1 million tonnes/year) and INA (Rijeka, 4.5 million tonnes/year) refineries. In the CEE region, Austria (Schwechat, OMV), Poland (Plock and Gdansk, Orlen) and Germany (7 refineries) have higher capacity refineries. MOL fuels are distributed towards Romania via the Danube River (between Regensburg and Giurgiu ports), railway (rail tank cars) and/or road (tankers), the latter being mostly used to supply the Western region (Timisoara, Arad, Oradea).

Bulgaria's Lukoil Neftohim Burgas refinery is only 250 km away from the border with Romania, being the closest neighboring unit from the south of the country, where all Romanian refineries are located. As of 2024 the refinery has ceased receiving Russian-produced oil, tax rate increased to 60% and Lukoil's concession contract to run the Rosenets Oil Terminal near the Black Sea port of Burgas was terminated. Alternative sourcing is currently supplied to the refinery from Kazakhstan, Iraq and Tunisia and new ownership is expected.

Serbia's NIS Petrol (owned by Gazprom from Russia) operates the largest network of filling stations (324 units) in Serbia (total of 1,529 units) and runs its 2 oil refineries, with a combined capacity of 7.4 million tonnes/year in the province of Vojvodina (Novi Sad and Pancevo), both within 100 km of Romania's Western border crossings. Gazprom Neft transferred some of its shares to avoid EU sanctions (May 2022), but the supply of Russian crude oil through the Adria oil pipeline from Omisalj's Oil Terminal (Croatia) ceased 6 months later. NIS Petrol mainly sources its crude oil imports from Iraq (53%), Russian Federation (46%) and Romania (as of 2022).

The Schwechat refinery (Austria) is one of Europe's top 10 units by capacity (9.6 million tonnes/year), accounts for 52% of OMV's refined output and is located approximately 450 km from the Romanian border. The Austrian refinery near Vienna is supplied by AWP (Adria-Wien-Pipeline) from the oil terminal in Trieste (Italy), being a branch connection of the Transalpine Oil Pipeline (TAL) which connects Italy, Austria and Germany. Despite important ties in the energy sector, OMV decided to cease all further investments in Russia (March 2022) and currently sources its crude oil needs from the nearby CEE area, North Sea (mainly Norway) and North Africa regions (mainly through Algeria's port of Bejaia). Between 10-15 tankers (600,000 barrels/tanker) arrive every month at the port of Trieste, after a journey of 4-5 days, and are unloaded in 24 hours before being sent to Schwechat through the AWP and TAL pipeline systems (throughout time: 48-72 hours).

Rompetrol is KMG's fuel brand in Romania, but its distribution extends to its neighboring Black Sea countries (Bulgaria, Moldova, Turkey, Georgia) and Western Europe (France, Spain) under the same or different brands (dyneff). Since KMG took over Petromidia (2007), in addition to its local sourcing, up to 60-75% of total processed crude oil was imported from Kazakhstan via its offshore terminal.

Table 2 Romania – Overview of fuel distribution sourcing and storage units (2024)

Brand(s)	Main refinery Location	Domestic capacity	Distribution stations	Fuel depots
OMV (Petrom)	Petrobrazi (Brazi, RO)	4.8/18.2 (RO) (26.37%)	586 units (25.57%)	6 units (13.95%)
Lukoil	Petrotel (Ploiesti, RO)	2.7/64.5 (RO) (4.18%)	319 units (13.92%)	7 units (16.27%)
KazMunayGas (Rompetrol)	Petromidia (Navodari, RO)	5.1/10.6 (RO) (48.11%)	401 units (17.50%)	6 units (13.95%)
MOL (Slovnaft) (INA)	Szazhalombatta (Hungary)	0/18.7 (HU) (imported)	238 units (10.38%)	2 units (4.65%)
SOCAR	Aliaga (Turkey)	0/16.4 (AZ) (imported)	75 units (3.27%)	4 units (9.30%)
Gazprom (NIS Petrol)	Pancevo (Serbia)	0/7.4 (RS) (imported)	19 units (0.82%)	N/A
independent gas stations	petroleum wholesalers	0/12.6 (RO) (sourced)	653 units (28.50%)	18 units (41.86%)
7 brands and independents	3 domestic and 5 adjacent (A, HU, RS, BG)	12.6/135.8 (RO) (9.27%)	2291 stations (100%)	43 units (100%)

Over 70% of Romania's gas stations (2,291 total units, as of 2024) are owned by the brands listed in Tab. 2. More than half (57%) are owned by the 3 brands operating refineries in the South-East of the country (1,306 units) while the number of independent gas stations (653 units) is less than a third (28%). An outline of oil companies' and independent brands' distribution networks (sourcing, storage and stations) is presented in Tab. 2, whilst brand ownership of all 43 fuel depots in Romania is mapped out in Fig. 3.

Petrobrazi accounts for over a quarter (26.37%) of OMV's total refining capacities and supplies petroleum products for both its fuel brands (Petrom, OMV) in Romania. OMV also covers more than a quarter (25.25%) of all Romanian filling stations with its 586 units, around 30% being high-end ones (OMV brand).

Lukoil's refining capacity at Petrotel represents less than 5% of the Russian group's output volumes, whilst its focus on competitive pricing and recent EU sanctions will further add challenges to its operations in Ploiesti. Despite having the highest number of fuel depots (7) across the country, Lukoil's network of petrol stations has been steadily decreasing since 2019 and now only adds up to 319 units (13.92% of total).

The Petromidia refinery in Navodari has an almost 50% share of KazMunayGas' overall refined output capacity and distributes its fuels in Romania under the Rompetrol brand. Rompetrol's network of filling stations (401 units) is the second largest and its fuel depot locations are the most balanced, being distributed among all regions in Romania.

MOL is Romania's third most important fuel brand (after OMV and Rompetrol), despite it having to import its petrol and diesel fuels, with the fourth largest domestic distribution network (238 filling stations and/or 10% of total) and only 2 fuel depots.

Other brands that import their petroleum products are SOCAR with 4 fuel depots and 75 filling stations (less than 5% of total) and Gazprom with less than 1% of the total fuel distribution network (only 19 stations and no fuel depots).

Independent gas stations are supplied by the petroleum wholesalers' distribution network, have seen their overall share being reduced in the last decade, but still account for almost 30% of all filling stations (653 units) and 40% of fuel depots (18 units) in Romania, as of 2023. OSCAR Downstream is the largest independent Romanian fuel distribution company and ranked in the top 5 players on the downstream market (after OMV, KMG, MOL and Lukoil). 7 fuel depots (38% share of all independent units) and 115 stations (17% share of all independent filling stations) are part of OSCAR's distribution network.

Smart Diesel (SD) is another important independent fuel company in Romania and has partnered with DKV Mobility (since 2021). The SD Group operates 36 own gas stations in Romania (5% of all independents), its own SD card (more than 3,000 active customer companies) is accepted in around 2,000 partner gas stations abroad (2023), offering bulk fuel, toll payment solutions, VAT recovery services, telematics and roadside assistance for trucks to over 13,000 B2B customers.

The Black Sea handles oil imports from the Caspian Sea (Azerbaijan and Kazakhstan) through its dedicated terminals (Oil Terminal, Midia Marine Terminal) and port pipe system (50 km) in Constanta, as shown in Fig. 2.

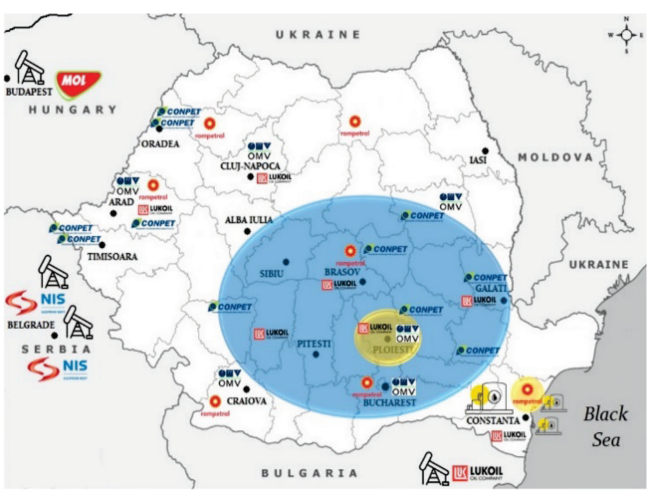

Figure 2 Romania – map of national pipeline coverage, Black Sea terminals (2024)

All Black Sea oil terminals (Oil, JT and MMT) are connected to the 3,809 km of national pipeline network, operated by Conpet across 24/41 counties, including the 3 Romanian refineries. Oil tankers dock at the specialized terminals where they unload the crude oil into storage tanks through large pipes. Constanta's Oil Terminal handles import of crude oil and gasoline, as well as export of refined and/or unrefined petroleum products and other liquid chemical products. Crude oil is pumped from storage tanks through underground pipelines to the 3 refineries in Romania or to one of 24 other export terminals (of which 11 are Conpet's own fuel depots) across the country. Almost 70% of all fuel depots (30/43) are owned by Conpet or the 3 domestic refineries. Petroleum products refined from crude oil are distributed in Romania through gas station networks and other industrial users.

Conpet's allocated storage capacity for domestic crude oil is 3 times higher than for imported crude oil. The crude oil national transport pipeline system's throughput is 200 million barrels/year (or 27.43 million tonnes/year), around 75% is used for imported oil, but is currently only used at a third of its capacity, 37% as of 2023 (in 1990 there were 10 operational refineries). Some of the refined petroleum products are also exported from Romania through pipelines, tankers and other means of transport.

Oil Terminal is the largest operator of petroleum products in the Port of Constanta, where it owns a developed network of high-capacity pipelines and tanks (storage capacity: 10 million barrels). Its terminal in the port operates 7 berths where it also stores over 70% of its capacities, the rest is deposited in an underground central storage facility in the center of Constanta. Oil Terminal inaugurated a new storage tank for crude oil and/or diesel (capacity: 55,000 cbm) in its terminal at the Constanta Port (January 2024), the largest built after 1989.

Midia Marine Terminal (MMT) is an offshore marine terminal supplying a tank farm (capacity: 390,000 cbm) and the Petromidia refinery through pipelines (onshore and offshore), located 8.6 km East off the Black Sea. MMT is operated by Rompetrol Logistics (KMG International Group), with an unloading rate of more than 600,000 barrels/day, and was built to reduce distance (by 30 km) travelled by tankers (60,000-165,000 DWT) to unload oil at Constanta Port. 32 million barrels (or 4.37 million tonnes) of crude oil, mainly from Kazakhstan, were unloaded at the MMT offshore terminal from 53 vessels (2023). Rompetrol also operates 7/14 berths at Midia's onshore oil and gas terminals, but this port's depth only allows smaller ships (10,000-20,000 DWT) to enter. Larger vessels (165,000 DWT tankers) could have been unloaded only in Constanta Port, an alternative meaning oil reached the refinery through long pipelines and with various losses along the way. On average, 2 million tonnes of additional oil products are imported and exported by 550 KMG tankers in Midia Port every year.

The newest and most modern terminal for liquid petroleum products (duty-free diesel fuel) in the Port of Constanta is operated by JT Terminal. JT Terminal offers storage and handling spaces for specific products (diesel, biodiesel, bitumen and other liquid products) prior to their distribution on the market (domestic or export). JT Grup Oil is also a regional fuel distributor for the South-East of Romania with its own fleet (11 tankers with a 40,000 liter/tanker capacity) and more than 250 storage tanks across its distribution network. The terminal has 8 storage tanks (total capacity: 33,000 tonnes) and operates barges with different capacities (from 3,000-9,000 tonnes), trains (up to 16 wagons at the same time on 2 parallel railway lines) and tankers (up to 20 at a time in its dedicated loading/unloading area). JT Terminal's handling capacity is 700-1,000 tonnes/hour (for ships), 300-700 tonnes/hour (for trains) and 40-80 tonnes/hour (for tankers).

Figure 3 Romania – map of oil companies' storage and distribution centers (2024)

An overview of Romania's 43 fuel depots' regional distribution (per brand) is highlighted in Fig. 3, with additional details (exact locations and delivery alternatives) being provided in Tab. 3.

Conpet's national pipeline system connects to 11 fuel depots (25% of all Romanian fuel depots), half in the West and the other half around the refineries in the South-East, with free access being leased to all domestic-operating oil companies. Lukoil and Oscar Downstream each own 7 of Romania's 43 fuel depots (and 32% combined), with an almost identical spread across the country, but different fuel sourcing: Lukoil's throughput is mostly domestic (Petrotel refinery), whilst Oscar Downstream only handles imported fuels. OMV and KMG own over 25% of fuel depots (6 units each) with similar regional distribution, while Rompetrol's fuel depot in Vatra Dornei is the only one in the Northern area. Since SOCAR imports its petroleum products from Azerbaijan through the Black Sea, its fuel depot network (4 units) is scattered in the South-East, with Hungarian MOL locating its units in the West (by rail and/or road) and South (by Danube River, through the Giurgiu port).

Romania's precise fuel storage locations, their regional coverage and network access is provided in Tab. 3.

Romania's branded filling stations (multinational oil companies' petrol and diesel fuels) are supplied by a total of 18 main locations: 3 domestic refineries (16%), 8 nearby onshore (44%) and 7 offshore locations (38%). Petrobrazi is the only domestic refinery supplying 2 different brands (standard Petrom and premium OMV fuels). Petrotel has the highest sourcing choice (6 sites, 33% of total): in addition to its domestic Ploiesti refinery it can also import fuels from neighboring onshore Burgas refinery (Lukoil, Bulgaria) or its 4 locations in Russia, currently subject to EU sanctions. Hungarian MOL is Romania's third most important brand, its 3 onshore refineries providing fuels for its neighboring CEE markets (Slovakia, Slovenia, Croatia, Serbia). The 4 nearest onshore locations are Lukoil (Bulgaria), NIS Petrol (Pancevo and Novi Sad, Serbia) and MOL (Hungary), whilst the other 4 locations (OMV and MOL refineries) are further away (Austria, Slovakia, Germany, Croatia). Only 3 of the 7 offshore locations are currently able to supply crude oil to Romania (KMG from Kazakhstan and SOCAR's 2 sites in Turkey and Azerbaijan), as Lukoil's offshore sites are all in Russia. OSCAR Downstream operates the highest number of domestic own fuel depots (7 units), despite only importing its fuels from international traders via offshore locations. All brands operating in Romania have access to Conpet's national pipeline system (3,809 km) and extensive fuel depot network (11 units, 25% of total).

Most fuel depots (30%) are located in the South (13 units), mainly around the 3 refineries, due to the proximity to the Romanian capital, Bucharest, and the manufacturing plants of Dacia and Ford, with OMV having a 23% share with its 3 units (Brazi, Jilava and Isalnita). Conpet holds the highest concentration of storage facilities both in the West (50%) and East (30%). Automotive industry is the main economic growth driver in the Western region (Timisoara and Arad), whereas the Black Sea's Port of Constanta shipping activity fuels the business stimulus in the East. Lukoil, KMG and Oscar Downstream share two thirds of fuel depots (2 fuel depots each) in the Centre, Romania's Transylvania region. The region is fuelled by Cluj's competitive IT sector and automotive industry suppliers (Mercedes Benz). Northern Romania only has 1 fuel depot (KMG), mostly due to the lack of supporting infrastructure, a local economy focused on agriculture and the shutdown of one of Romania's main nearby refineries (RAFO Onesti).

Arad is the county with the highest number of fuel depots (5 units or 11% of total), mostly due to its geographic position (border with Hungary and gateway to Western Europe) and excellent high speed road (A1) and railway (M200) connections. Bucharest has 4 nearby depots (Jilava, Mogosoaia, Fundulea and Giurgiu) and connects to all major economic drivers: Constanta Port and Petromidia refinery via A2 (road) and M800 (rail), carmakers Dacia and Ford via A1 (road) and DEx12 expressway (road) and Prahova refineries (Petrobrazi and Petrotel) via A3 (road). Over 40% of storage units (3 fuel depots each) are located in the counties of the following 6 big cities: Oradea (logistics hub for the Western Area, connecting Cluj to the Hungarian border), Brasov (Selgros grocery wholesaler's headquarters, automotive electronics suppliers, TotalEnergies lubricants factory) in the Centre, Bacau (connecting Iasi, the Dornesti railway and transshipment terminals (DRT, DTT) to the sea and river port of Galati), in addition to Constanta (port and Petromidia refinery), Craiova (Ford, Pirelli and power electronics manufacturers) and Ploiesti (Petrobrazi, Petrotel and Vega refineries, main grocery retailers' logistics hub).

Table 3 Romania – Storage locations for fuel distribution (2024)

Brand(s)	Main fuel sourcing locations	Regional coverage (units)	Fuel depot locations	Intermodal connections
OMV (Petrom)	Petrobrazi (Brazi, RO) Schwechat (Austria) Burghausen (Germany)	West (1) Center (1) North (0) East (1) South (3)	Arad Cluj Brazi Isalnita Jilava Bacau	A3 (road) M200 (rail) M300 (rail) M500 (rail)
Lukoil	Petrotel (Ploiesti, RO) Burgas (Bulgaria) Kstovo, Perm, Ukhta, Volvograd (Russia)	West (1) Center (2) North (0) East (2) South (2)	Arad Cluj Rm. Valcea Brasov Ploiesti Galati Constanta	A3 (road) M200 (rail) M300 (rail) M500 (rail) ROCND (sea)
MOL (Slovnaft) (INA)	Szazhalombatta (Hungary) Bratislava (Slovakia) Rijeka (Croatia)	West (1) Center (0) North (0) East (0) South (1)	Tileagd Giurgiu	M43-A1 (road) 120-M200 (rail) RODTS (river)
KMG (KazMunayGas) (Rompetrol)	Petromidia (Navodari, RO) Atyrau (Kazakhstan)	West (1) Center (2) North (1) East (0) South (2)	Arad Craiova Mogosoaia Simleu Silvaniei Vatra Dornei Zarnesti	A4, A2 (road) M800 (rail) ROCND (sea)
SOCAR	Aliaga (Turkey) Baku (Azerbaijan)	West (0) Center (1) North (0) East (2) South (1)	Teius Ploiesti Onesti Constanta	ROCND (sea) ROGAL (river)
Gazprom Neft (NIS Petrol)	Pancevo (Serbia) Novi Sad (Serbia)	West (0) Center (0) North (0) East (0) South (0)	N/A	A1-E70 (road) RODTS (river)
Conpet national pipeline system (mainly OMV Petrom, Lukoil, KMG Rompetrol)	Petrobrazi (Brazi, RO) Petrotel (Ploiesti, RO) Petromidia (Navodari, RO) KMG Atyrau (Kazakhstan) SOCAR Aliaga (Turkey)	West (5) Center (1) North (0) East (3) South (2)	Biled Valcani Pecica Marghita Suplacu de Barcau Barbatesti Imeci Berca Moinesti Independenta Ciresu	ROCND (sea) Conpet network (refineries, fuel depots) A4, A2, A3 (road) M800 (rail) M200 (rail) M300 (rail) M500 (rail)
Oscar Downstream	Szazhalombatta (Hungary) Pancevo (Serbia) Novi Sad (Serbia) other (import)	West (1) Center (2) North (0) East (2) South (2)	Fundulea Sercaia Craiova Zadareni Ocna Mures Roman Constanta	ROCND (sea) A4, A2, A1 (road) M800 (rail) M200 (rail) M500 (rail)
7 major brands 1 main wholesaler and national pipeline system	3 domestic refineries 8 onshore and 7 offshore locations	West (10) Center (9) North (1) East (10) South (13)	West (23%) Center (21%) North (2%) East (23%) South (30%)	

Fig. 4 highlights fuel distribution alternatives to the 5 regions across Romania. Refineries use a mix of pipelines and tank wagons (rail) to supply their specific regional fuel depots for longer domestic hauls, tankers for imported petroleum products via Black Sea and Danube River ports (Constanta, Galati and Giurgiu) and fuel trucks (road) for supplying their network of filling stations.

Over 60% of Petrobrazi's refined products (3.84 million tonnes, 2023) were diesel fuels. Petrom and OMV-branded fuels are distributed downstream through Conpet pipelines, tank wagons and fuel trucks. The Oltenia region is mainly supplied through pipelines (Conpet) leading to its fuel depot located in Isalnita. West and Center fuel depots (Arad, Cluj) usually receive their products by rail (M200 and M300): 2-3 trains/day with 36-38 wagons (over 50 tonnes of fuel each), on average. Most of the total length (50 km) of the 4 operational railway lines within the Petrobrazi refinery was modernized in the past decade (around 75%). Over 50,000 railway cars loaded with petroleum products (Petrom and OMV brands) are dispatched annually from the Petrobrazi refinery to supply OMV's domestic fuel depot network. The North of Romania is mainly supplied by fuel trucks (up to 28 million liters of fuel/truck) that can carry 4 different fuel types (standard and/or premium petrol and/or diesel) on a single trip (each divided into 4,000, 8,000, 10,000 and 14,000 liters per compartment) to the fuel depot in Bacau. The Republic of Moldova (a network of 69 Petrom filling stations) is also supplied directly from the Petrobrazi refinery with fuel trucks through its own Petrom storage facility in Chisinau, 450 km away. Up to 990 fuel trucks/week transit Romania's roads with fuels supplying Petrom and OMV's 586 filling stations. OMV uses tankers from Galati, Constanta (Black Sea shipments) and Giurgiu port (via the Danube River) to supply its stations in Bulgaria (92 units) and Serbia (64 units), in addition to regular fuel truck deliveries.

Figure 4 Romania – oil companies' intermodal transportation alternatives (2024)

In addition to domestic sources, Petrotel refines Russian crude oil at its Ploiesti site, before having to find alternative suppliers after EU sanctions (2022) impeded the inflow of Lukoil's regular sources. Gradual restrictions allowed for a surge of consecutive monthly imports of Russian crude oil (up to 3-5 times higher than regular deliveries) through Constanta's Oil Terminal and hedge its storage in Lukoil's own fuel depots, as well as additional storage capacities rented from Oil Terminal and Conpet, before the embargo. Lukoil is a major fuel supplier for the Romanian public sector, despite low transparency of its operations' data, continuous net operating loss and tax evasion suspicions. Landlocked CEE countries (Czech Republic, Slovakia and Hungary) were exempt and continue to receive deliveries of (cheaper) Russian oil. Since its regular EU markets ceased imports, Russia is now shipping (more) oil to new markets (China, India, Turkey, North Africa, South America), that now act as an intermediary in petroleum products sale. India is clearly benefiting from selling refined products to the EU (20/27 countries), at full price, but from cut-price Russian-originated oil imports. India's top 3 markets (2023) are the Netherlands (24%), France (23%) and Romania (12%). As of 2024 the Czech Republic has also fully complied to EU sanctions, having found alternative options, but Hungary's MOL (who also owns Slovnaft from Slovakia) continues to favor cheaper Russian imports, despite having alternative sourcing nearby. The Adria pipeline from Omisalj (Croatia) considered more expensive, has higher technical risks, logistics costs and Russian imports would still be necessary to supplement oil deliveries from Croatia (up to 80% of total refining needs), according to Hungary (MOL). After Ukraine blocked all Lukoil transit shipments (via the Druzhba pipeline), Hungary's MOL found Tatneft as an alternative provider. Russia also uses a shadow fleet (600-2,000 rented tankers, some being in an advanced state of degradation) for 80% of its crude oil shipments to Kaliningrad and/or other destinations through the Baltic Sea, bypassing the Swedish island of Gotland.

Every year more than two thirds of Rompetrol's refined products (3.5 million tonnes of fuel products & LPG) are shipped from Petromidia Navodari (9 intermodal terminals) and Vega Ploiesti (6 intermodal terminals) with an average of 60,000 tank wagons (rail) and 35,000 fuel trucks (road), in addition to pipeline transportation (Conpet's network). Petromidia uses up to 10,000 tank wagons/month (75% of total Rompetrol rail shipments, M800) to transport petrol and diesel fuels from Navodari to its 6 storage depots across Romania. Mogosoaia is Rompetrol's largest fuel depot (capacity: 13,000 tonnes), around 120 trucks supplying it daily with premium products. Fuel trucks then handle downstream deliveries to its network of filling stations (regular and new premium-branded "hei" concept stations). MMT enables both import (crude oil from Kazakhstan) and export (refined products mainly towards subsidiaries in Moldova, Bulgaria, Georgia) through its onshore and offshore terminals at the Black Sea port. With its 3 terminals, berth 9 is the most modern and allows transiting of 350,000 tonnes/month finished products (fuel products, ethylene and LPG), in addition to the other 4 berths (for crude oil) at Midia Port.

MOL uses trains for deliveries to the intermodal hub at Curtici Cargo Center (West) and ships on the Danube River to connect to Giurgiu port (South) which act as DCs for final deliveries, mostly by fuel trucks, to its network of 238 filling stations. KMG uses 2 routes: from Atyrau through the CPC pipeline (Tengiz-Novorossiysk Black Sea Marine Terminal) for regular shipments and through the BTC pipeline (Aktau-Baku-Ceyhan route) for annual volumes of up to 1.5 million tonnes (5-year agreement with SOCAR, since 2022). The port of Ceyhan (Turkey) then directs KMG shipments towards Romania's Black Sea port with unloading in the Petromidia refinery from its offshore marine terminal near Constanta.

OSCAR Downstream's business model relies on imported petrol and diesel fuels, their transport and storage within its network of fuel depots and distribution with the OSCAR tankers fleet. By sourcing its petroleum products from fuel traders, OSCAR is closely linked to the global fuel market, making it more vulnerable to international market trends and events. Price volatility increased as a result of a series of recent crises (Covid-19 pandemic, energy crisis, Russia's invasion of Ukraine, Houthi attacks in the Red Sea and geopolitical tensions in the Middle East) and exacerbated supply chain challenges and disruptions for major distributors.

OSCAR Downstream's 7 fuel depots have a 38% share of all independent units with a combined storage capacity of over 75,000 cbm, being located within 250-300 km of each other in all major economic regions. It owns 115 stations: 85 RO franchise stations (for B2C customers, 74%) and 31 OSCAR Drive (for B2B customers, 26%). With a network of over 2,500 DIESELpoint Access stations, the company also provides B2B customers with the ability to refuel at their own facilities (in-house). This implies the consignment of a station (5,000, 9,000 or 20,000 liters) provided on a rental basis (including installation, technical support and maintenance), regular fuel supply handled by OSCAR's fleet of 82 tanker trucks and a fuelling management application. Over 5,000 companies from the agriculture, transportation, industry and construction sector have partnered with Oscar Downstream for DIESELpoint Access stations (as of 2024).

Conpet (a 58.71% publicly-owned company) manages the 3,809 km network of Romanian pipelines, an interconnected system providing delivery terminals (receiving and storage tanks) for upstream crude oil, delivered by oil producers and/or importers (from own domestic extraction sites and/or imported), and their transfer/routing from these terminals/stations (through pumps) towards oil processing units (refineries). The total throughput of the pipeline system is 27.43 million tonnes/year, 73% being used by imported oil (20.2 million tonnes/year), while over 73% of total storage capacity is reserved for domestic oil (126,000 cbm). Most of Conpet's 15 loading/unloading ramps (86%) are used for loading crude oil, with 13 locomotives and 69 tank wagons also being part of their railway fleet. Publicly-owned (87.75%) Oil Terminal is located in the Port of Constanta and is the largest Romanian terminal for the import and/or export of oil products (crude oil, petroleum products, petrochemicals, etc.). Oil Terminal's services (receiving, storage, conditioning and shipping) cover import, export and transit of all types of petroleum products. Petrom (OMV) and Lukoil (Litasco) use Oil Terminal for their import of crude oil, petroleum products and/or diesel (including storage), as well as for the export of refined fuels.

GFR has the highest share of cargo volumes (22.45%) among all rail freight operators in Romania and is market leader in transporting petroleum products (crude oil and refined products) since 2013. With its 400 locomotives and 16,000 wagons, GFR is the main LSP for petroleum products for all 3 refineries, as well as for Conpet and Constanta Port's Oil Terminal. Depending on the specific route (loading and/or unloading station, distance travelled), GFR hauls fuels with 15-50 tanker wagons/freight train of petroleum products.

5 DISCUSSION

This research paper's main objective is to underline the relevance of infrastructure (intermodal and pipelines) in connecting upstream oil refining production capacities with downstream distribution networks by using Romania as a case study. The 3 analyzed refineries (Petrobrazi, Petrotel and Petromidia) have very good sourcing alternatives, both East (Port of Constanta) via sea shipping and pipeline transportation networks and West (Curtici Cargo Center) via intermodal transportation (road-rail) options.

Most previous studies conduct research on correlations of oil refining with macroeconomic data [26], downstream optimization of fuel distribution networks [29] or use the particular case of a given filling station [32]. While they are a source of new insight, these approaches are either too broad [25] or only focus on partial oil supply chains [28] and thus have inconsistent outcomes. More targeted research endeavors tend to either favor obvious conclusions [27], due to a homogenous sample [30], or be too complex and require additional parameterization [31]. This research paper, on the other hand, provides an in depth analysis of the Romanian oil refining supply chain, integrating all major multinational and independent brands, as well as the national pipeline infrastructure and its storage depots. It is, at the time of writing, the first comprehensive study of a country's oil refining industry with high practical insights as its major strength. Due to the lengthy data collection process and differences in data range disclosure (NDAs) research design is mostly descriptive and explanatory as correlations (analytical or predictive models) would have implied using confidential datasets. Dataset restrictions are thus a drawback for a more proper scientific research design and corresponding conclusions, as well as a main limitation of this study.

The purpose of this article was to study the impact EU sanctions on Russia have on Romania's Petrotel refinery (Lukoil) and how its oil supply chain managed operations with alternative suppliers. Its geostrategic location, concentration of oil refineries in neighboring countries and intermodal infrastructure interconnectivity facilitated marginal disruptions in the overall fuel supply. Potential future research topics could cover the role of oil refining in local economies (jobs, infrastructure development, GDP growth contribution), the feasibility of shifting away from Russian oil sourcing alternatives or increasing digitalization in oil refining supply chains (EDI, digital twins, machine learning applications).

6 CONCLUSION

More than 80% of Romania's total output of petroleum products is currently provided by OMV's Petrobrazi and KMG's Petromidia refineries. Up to two thirds of their crude oil is sourced locally, whilst they own over 43% of all filling stations and almost a third (28%) of all fuel depots. Lack of recent investments, tax evasion lawsuits and EU sanctions on Russian oil has scaled back production output at Lukoil's Petrotel refinery to under 20% of domestic share (2023). In addition to its refineries, Romania's filling stations are replenished from 8 other onshore and 7 offshore locations, 4 closely located alternatives being available in its neighboring countries (Bulgaria, Serbia and Hungary).

Offshore oil imports are handled through the Black Sea via the private Midia Marine Terminal (KMG), Constanta Port's dedicated terminals (Oil Terminal, new JT Terminal) and its interconnected downstream pipeline network (Conpet). Conpet owns 25% of domestic fuel depots (11/43 units), its pipelines connect 24/41 counties (58%) across Romania and are linked with the 3 domestic refineries.

Over 70% of Romania's filling stations (2,291 units) are owned by multinational oil companies, whilst more than half (1,306 units) are owned by the domestic refinery-operating brands: Petrom, OMV, Rompetrol and Lukoil. A mix of pipelines, rail freight and trucks is used to distribute petrol and diesel fuels to their network of filling stations. Almost all fuel depots (42/43 units) are located in regions with both economic development (oil refining, carmakers and/or automotive suppliers) and infrastructure connectivity (road, rail and/or port).

This case study research highlights the underlying role of infrastructure connectivity in economic development. Oil industry in Romania leverages its logistics to source, refine and distribute petroleum products across its network of fuel depots and filling stations. Insights reveal that shifting away from Russian imports and finding alternative oil sources is less of a challenge in case of multiple onshore and offshore backup options.

The paper's added value resides in its high degree of carried out on-site fieldwork, offering relevant practical insights sourced from the actual oil industry environment. Parts of collected data are not subject to disclosure (NDAs) and willingness of oil industry and/or terminal operators to grant access to internal data is very limited. The extent to which such data is processed, findings expressed within the paper's content and certain wording choices are subject to written approval, affecting scientific research approach and study replicability. These trade-offs counterbalance the empirical value of the research paper and are its major source of limitations.

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Author's contacts:

Attila Turi, PhD
Politehnica University Timisoara,
Remus 14, 300191 Timisoara, Romania
+40.256.404.307, attila.turi@upt.ro