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The role of regional ports in Slovenia's quest to tackle the “energy elephant in the room” – Natural gas supply

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ABSTRACT

In our research we focused on the supply with natural gas. EU wishes to completely cut ties with Russia in the field of energy supply, so it is necessary to quickly find other sources of supply. Time window is quite small. Planned reduction in consumption is not enough. Beside transferring natural gas through pipelines, the supply of natural gas is possible with ships. But adequate facilities alongside sea with hinterland pipeline network are required. We found out that it is possible to use regional ports, certain facilities with LNG infrastructure accessible by ships, for import of natural gas for Slovenia. Slovenia with no extraction or production facilities, no warehouses, and a substantial demand for natural gas must find suitable location through which it can include supply with ships into its energy policy. We identified nearby locations with needed technological properties to dock LNG tankers with adequate hinterland pipeline network to allow transport of natural gas to Slovenia. We discovered that it is possible to include supply with LNG tankers into Slovenia's energy supply by using certain locations near Slovenia. Findings of this research are useful for presenting future possibilities of supply of natural gas with LNG tankers through regional ports, closest to Slovenia.

Key words: LNG supply, regional ports, Slovenia, ArcGIS Pro, DEA analysis

INTRODUCTION

European Union (EU) is determined to cut ties with Russia in the field of energy supply. Dependence from Russia's supply was highlighted as problematic years before 2022 (Umbach, 2019). That includes importing natural gas and liquefied natural gas (LNG) as its liquid form (Abnett, 2023; "Infographic – Where does the EU's gas come from?" [European Council], 2023, 7 February). The amount of imported natural gas from Russia through pipelines has significantly fallen after the fall of the year of 2022, but on the other hand the import of LNG rose, which does not follow beforementioned EU goal (Cooban, 2022; Cooper, 2022). EU needs to find alternative supply routes to replace energy imports from Russia¹, because planned reduction in consumption will not be enough. One option is import by pipelines from other countries. Pipelines offer a steady flow of natural gas and are limited by network properties. Transport of natural gas through pipeline runs from one country to another, which can be unreliable, with political instabilities in mind. So, when the demand is much higher than the supply, shortages can appear. Storage capacities can cover such peaks of demand, but only for a certain period.

Another option of supply of natural gas is with LNG tankers². At the end of 2021, world LNG tanker fleet included more than seven hundred vessels (Aizarani, 2023). They can transport enormous quantities of natural gas in its liquid form and offer the possibility to control the time window. Ships can wait for a certain time for natural gas to be in-demand or to wait until the price of natural gas on the market adjusts in someone's favour. So, some speculation must be considered. But ship's function to act as a mobile storage capacity can provide useful. Also, relying on supply of natural gas only with ships can cause shortages in case of an uneven supply. The best option is to include supply with ships to cover peaks in demand or shortages in planned supply through pipelines. To include supply with LNG tankers into its energy policy, EU needs to expand its LNG terminal's network to minimize the distance between LNG terminals and final

¹ For more information regarding natural gas imports, authors suggest readers to see European natural gas imports Dataset ("European natural gas imports" [Bruegel], 2023, 25 April).

² For up-to-date information regarding LNG Shipping, see Shipping dashboard of ExxonMobil ("LNG Shipping" [Interactive World LNG Dashboard], n. d.).

consumers. Expansion of LNG terminal's network is already in place with more than seventy-five LNG terminals to be operational or under construction or planned in Europe by 2025 (Shell, Wood Mackenzie & Eurasia Group, in Umbach, 2023). Norway, United States of America (USA), Qatar, and Africa are most frequently mentioned to replace Russia's natural gas supply (STA, 2022, 22 August).

Slovenia was also heavily dependent from Russia's imports. In 2020, 17,6 % of Slovenia's energy was from Russia, including natural gas (Svetlin, 2022). We must consider that western member states of the EU were less dependent from Russia's supply than eastern member states. Since Slovenia has no warehouse facilities to store natural gas, no production facilities and no LNG import terminals, Slovenia is solely dependent from import by pipelines from other countries ("Slovensko prenosno omrežje" [Agencija za energijo], 2022, 20 May). Slovenia's natural gas network is a part of an all-European network, with connections to Italy, Austria, and Croatia. It is connected to Italy through Šempeter, to Croatia through Rogatec, and to Austria through Ceršak. There is no connection to Hungary yet. It is important to know that Šempeter and Rogatec allow two-way transfer of natural gas in and out of the country. Ceršak allows only one-way transfer into Slovenia³ (Agencija za energijo, n. d., pp. 169). To find new supply channels after the supply from Russia stopped, Slovenia negotiated a deal with Algeria to import natural gas from North Africa and is closely watching the expansion project of Krk LNG terminal in Croatia ("Geoplin podpisal pogodbo za zemeljski plin iz Alžirije" [Geoplin], 2022, 15 November). That is why the supply with LNG ships can be extremely useful to address energy needs for Slovenia. But there are conditions to implement supply by LNG tankers in Slovenia's energy supply policy: adequate location near Slovenia for LNG tankers to unload their cargo and, consequently, adequate hinterland pipeline network.

Ansone et al. (2022) claims that LNG import terminal is the only option for a certain country to reduce dependency from pipeline-transported natural gas and highlights the importance of LNG deliveries from other parts of the world. Bittante, Pettersson and

³ When constructing network in ArcGIS Pro, it is necessary to include such fact into network dataset properties.

Saxen (2018) present the possibility of a small-scale supply chain, in which natural gas can be transported from a large import terminal to a satellite import terminal with combination of sea or land means of transport to perform multi-stop voyages. Coote (2016) presents the possibility of LNG exports from USA as a new source of natural gas for the EU and the possibility for the EU to diversify its natural gas supply and provide additional market competition and security. Sartori (2016) claims that the Mediterranean Sea is an important transport hub for natural gas and with the need to reduce dependency from Russia, its importance will increase even more. Smajla, Crneković, Karasalihović Sedlar and Božič (2020) present in their study the importance of Krk LNG terminal for the security of natural gas supply for Croatia, Serbia, Bosnia and Herzegovina, Hungary, Slovenia, and North Macedonia. They address the need for expanding current pipeline infrastructure to accommodate distribution to other countries with connection to port of Koper, Slovenia, mentioned as a potential future interconnection.

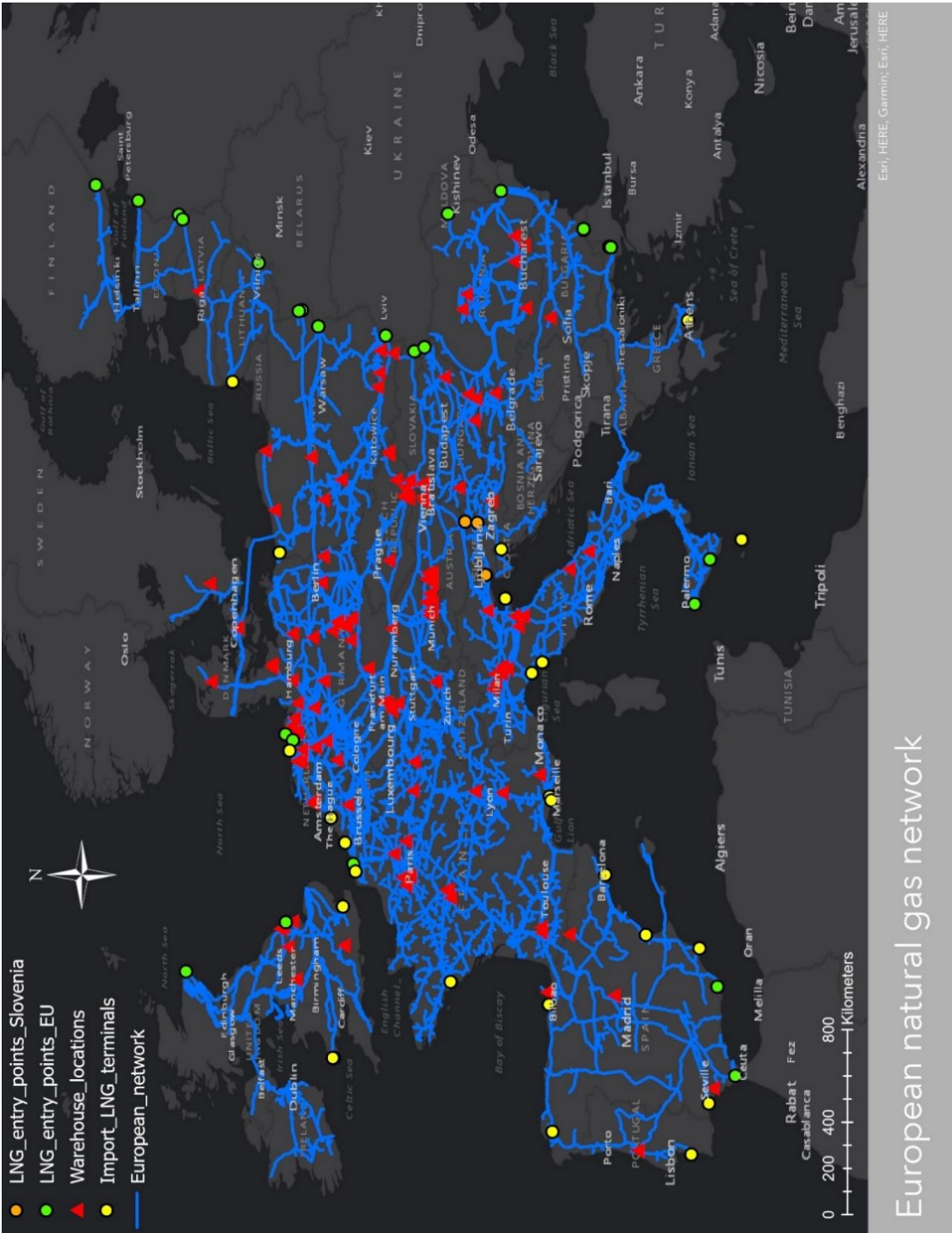
Since Slovenia has no LNG import terminals, we want to determine which regional location with existing LNG infrastructure is most suitable for potential Slovenia's LNG import. Based on the existing natural gas infrastructure in Europe we will identify such locations, accessible for Slovenia, determine their relative efficiency and present export LNG terminals from where Slovenia could import natural gas. So, can regional ports help Slovenia in the supply with natural gas?

METHODOLOGY

We wanted to determine the potential role of regional ports in the LNG supply chain for Slovenia. We reviewed literature to gather relevant data from previous research. We used Google Scholar to find relevant research. If we entered key words ports and LNG terminals, we got more than twenty-thousand hits. We narrowed down the selection by analysing its content to find relevant articles. We found 5 relevant articles, describing our area of research. For visual representation of LNG terminals on a map, we used ArcGIS Pro with Network Analyst Extension, a professional desktop GIS

application from Esri. As a source of data to prepare a model for spatial analysis, network dataset, we used Gas Infrastructure Europe LNG Map 2022, which visualize the state of LNG network in Europe in October 2022 (“What is a Network Dataset? [Esri], n. d.; “GIE LNG Map” [Gas Infrastructure Europe], 2022, 14 November). With it, we created a pipeline network of Europe in ArcGIS Pro (see Figure 1).

Figure 1: European natural gas network, October 2022, presented with ArcGIS Pro



Based on the constructed network, we used Closest facility analysis in ArcGIS Pro. Closest facility analysis uses algorithm, based on Dijkstra's algorithm⁴ ("Algorithms used by Network Analyst" [Esri], n. d.). As Facilities we used Import LNG Terminals, point layer representing all import LNG terminals in Europe, and as Incident Ljubljana, point layer representing the capitol of Slovenia. With this analysis, we were able to search for locations, closest to Slovenia.

We searched for location with LNG terminal, onshore or offshore, which offers the following basic services: Unloading, operational storage, regassification and possibility to send out natural gas into the pipeline network⁵ ("LNG List of services" [Gas Infrastructure Europe], 2022, 2 November). Also, selected LNG terminal must not be among the biggest operational LNG terminals in Europe to comply with the Devport conference's guidelines for smaller/regional ports. Rovigo LNG terminal, which has the highest maximum hour capacity and nominal annual (regassification) capacity of the selected ones, is tenth and eighth out of twenty-two operational LNG terminals in the EU in those two categories. Other selected terminals are even lower on the list. In our research the term regional port describes offshore or onshore location with basic services. We started with finding the closest one and then continued until the next closest facility was in the northern part of Central Europe. That facility was fifth in the row. So, we found 4 suitable locations near Slovenia, 3 in Italy and 1 in Croatia. These locations were included into DEA analysis.

DEA analysis is a method for measuring the efficiency as a ratio of produced outputs to the used inputs (Nepomuceno, 2022). For DEA analysis, we needed technological properties of these terminals. As a source of operational data for each LNG terminal we used LNG Import Terminal Map Database October 2022 ("LNG Database" [Gas Infrastructure Europe], 2022, 21 November). We identified inputs and outputs for each LNG terminal to write codes for each location. As inputs, we used the following categories: LNG storage capacity (w_c), number of tanks (w_d), maximum ship class size

⁴ If readers wish to educate themselves more regarding Dijkstra's algorithm, see article written by Muhammad Adeel (2014).

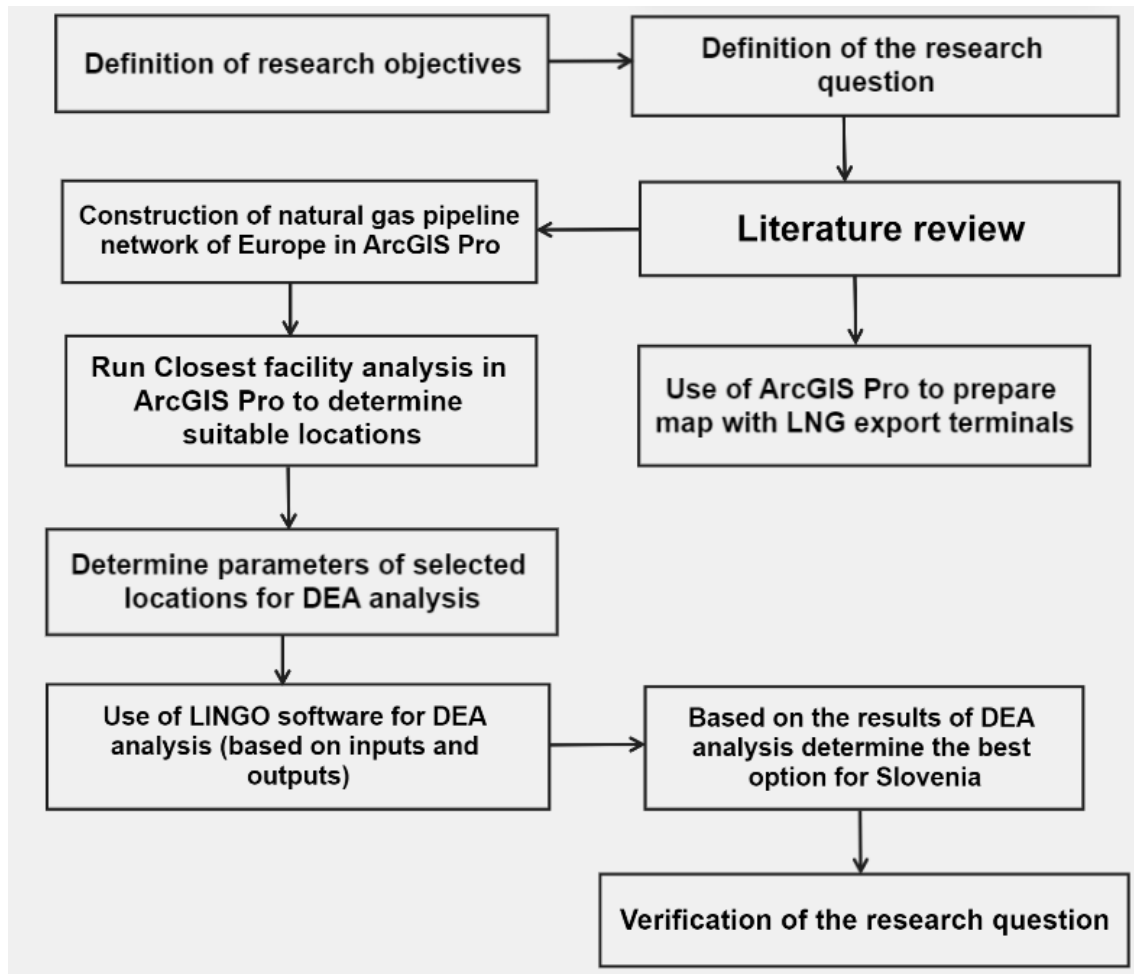
⁵ If readers wish to educate themselves more regarding the LNG cycle, see ExxonMobil portal Interactive World LNG Dashboard ("LNG Dashboard" [Interactive World LNG Dashboard], n. d.).

receivable (w_e) and minimal sea depth alongside terminal (w_f). As outputs, we used categories maximum hour capacity (w_a) and nominal annual (regassification) capacity (w_b). We wanted to determine which terminal is the most efficient, based on its capability to send LNG into the pipeline network. We ran DEA analysis in LINGO, a tool designed for solving optimization models, and interpreted results ("LINGO and optimization modelling" [lindo.com], n. d.). For instance, the code for Rovigo terminal that we ran in LINGO was:

$$\begin{aligned}
 &max = 1156000 * wa + 9 * wb; \\
 [Krk] &300000 * wa + 2.6 * wb - 140000 * wc - 4 * wd - 265000 * we - wf - 16 \\
 &\quad * wg \leq 0; \\
 [Rovigo] &1156000 * wa + 9 * wb - 250000 * wc - 2 * wd - 217000 * we - wf \\
 &\quad - 27 * wg \leq 0; \\
 [Panigaglia] &427000 * wa + 3.4 * wb - 100000 * wc - 2 * wd - 70000 * we \\
 &\quad - wf - 10 * wg \leq 0; \\
 [Toscana] &592000 * wa + 4.74 * wb - 137500 * wc - 4 * wd - 180000 * we \\
 &\quad - 113 * wg \leq 0; \\
 [Additional_restriction] &250000 * wc + 2 * wd + 217000 * we + wf + 27 * wg \\
 &\quad = 1; \\
 &wa \geq 0; wb \geq 0; wc \geq 0; wd \geq 0; we \geq 0; wg \geq 0; \quad [1]
 \end{aligned}$$

Based on the results of DEA analyses we determined the most efficient LNG terminal near Slovenia. Values in Objective value category showed us the efficiency of selected LNG terminals. For visual representation of our methodology see Figure 2 below:

Figure 2: Methodology



RESULTS

Based on the existing natural gas network in Europe Closest facility analysis in ArcGIS Pro identified 4 closest regional ports with the needed technical capabilities to unload LNG tankers and with suitable hinterland network to Slovenia. As a data source for the Closest facility analysis, we used European natural gas network, presented in Figure 1. These LNG terminals are Rovigo, Panigaglia and Toscana in Italy, and Krk in Croatia (see Figure 3).

Figure 3: Closest facility analysis results, presented with ArcGIS Pro



We calculated relative efficiency of identified locations. As a source for inputs and outputs for each LNG terminal we used LNG Import Terminal Map Database October 2022 (“LNG Database” [Gas Infrastructure Europe], 2022, 21 November). Results of the DEA analysis are presented in the Table 1 below:

Table 1: DEA analysis with existing technical properties of Krk terminal

Terminal	Rovigo	Panigaglia	Toscana	Krk
Objective value	1	1	0,9575758	0,5158730
w_a	0,8650519*10 ⁻⁶	0	0,2020202	0
w_b	0	0,2941176	0,7272727*10 ⁻⁵	0,1984127
w_c	0,4*10 ⁻⁵	0,7549020*10 ⁻⁵	0	0,7142857*10 ⁻⁵
w_d	0	0	0	0
w_e	0	0,3501401*10 ⁻⁵	0	0
w_f	0	0	0	0

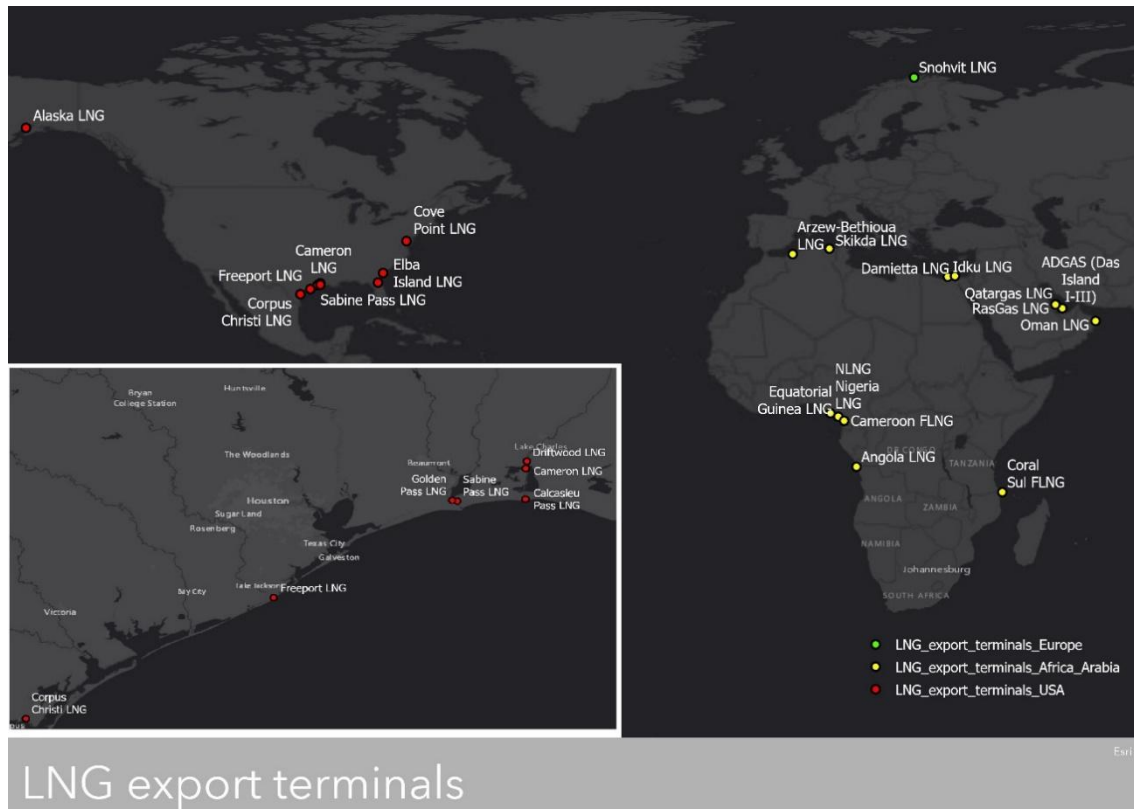
For location Krk an expansion is confirmed and in process. New properties are already included into LNG Import Terminal Map Database October 2022 (“LNG Database” [Gas Infrastructure Europe], 2022, 21 November). We included expected technical properties of Krk location for another DEA analysis. Results of that DEA analysis are presented in the Table 2 below:

Table 2: DEA analysis with new technical properties of Krk terminal

Terminal	Rovigo	Panigaglia	Toscana	Krk
Objective value	1	1	0,9575758	0,9558824
w_a	0,8650519*10 ⁻⁶	0	0,2020202	0
w_b	0	0,2941176	0,7272727*10 ⁻⁵	0,1838235
w_c	0,000004	0,754902*10 ⁻⁵	0	0
w_d	0	0	0	0
w_e	0	0,3501401*10 ⁻⁵	0	0
w_f	0	0	0	0,0625

Based on the mentioned potential substitute sources for natural gas from Russia we set up a map with twenty-five locations of current operational export terminals in Europe, Africa, Arabian Peninsula, and USA in ArcGIS Pro (see Figure 4) (STA, 2022, 22 August).

Figure 4: LNG export terminals, presented with ArcGIS Pro



DISCUSSION

Our research has shown that regional ports can play a significant role in the supply with natural gas for Slovenia. We identified Rovigo, Panigaglia, Toscana and Krk as suitable LNG import terminals near Slovenia. Importing natural gas through one of these LNG terminals can reduce Slovenia's natural gas dependency on pipeline transport from Algeria, as it is suggested by Ansone et al. (2022). Based on the DEA analysis, LNG terminals in Italy are more efficient than LNG terminal in Croatia. Relative efficiency of all LNG terminals in Italy is higher than it is relative efficiency of Krk LNG terminal. Rovigo and Panigaglia scored 1 in Objective value category, which means that both are the best in one of the output's category, Rovigo in nominal annual (regassification) capacity and Panigaglia in maximum hour capacity. Even considering new technical properties of Krk terminal, the efficiency of Italian LNG terminals will still be higher than of Krk terminal. If we compare Italian LNG terminals in the category nominal

annual capacity capability (category w_b), the most efficient LNG terminal in Italy is Rovigo LNG terminal. It has the best regassification capacity, which is vital to quickly transform LNG into natural gas and send it into network. DEA analysis also tells us where each location should improve to boost its relative efficiency. The biggest increase in efficiency can Rovigo LNG terminal achieve if it could increase its LNG storage capacity. Panigaglia, Toscana and Krk LNG terminals can increase their efficiency if they could increase their nominal annual capacity (regasification) capability. If we look at hinterland connections, using our natural gas network in ArcGIS Pro, presented in Figure 1, LNG terminals in Italy have better connections with Slovenia than Krk. Hinterland pipeline network is more extensive in Italy than in Croatia.

Twenty-five LNG export terminals, presented in our research, give Slovenia and the EU a lot of various sources of LNG supply. USA is an intriguing option for the EU for the natural gas supply with tankers by having the most LNG export terminals. Export terminals in North Africa and Norway are the closest and therefore present the quickest route to EU import terminals. But EU must not neglect the possibility of supply with LNG tankers from either Western Africa or Arabian Peninsula.

CONCLUSIONS

Regional ports can help Slovenia to diversify its energy supply. We have identified 4 adequate locations in the form of LNG import terminals for supply of natural gas with ships for Slovenia. Using LINGO, we determined relative efficiency of selected locations with DEA analysis. Based on the results of DEA analysis and existing pipeline network in Europe, Rovigo LNG terminal is the best option for supply with natural gas for Slovenia with LNG tankers. There is a lot of sources for Europe in the form of LNG export terminals to import natural gas, which shows us that the supply with natural gas with LNG tankers can be implemented into energy supply strategy of Slovenia. Future research should focus whether it is needed for Slovenia to build its own LNG terminal. Also, with this current LNG terminal's frenzy in the EU, how many terminals do EU really needs, especially with transition to a low- or non-carbon society in EU's mind.

We would like to highlight that when searching for articles in Google Scholar, we found a lot of articles that were focused on bunkering stations, which means the use of LNG as a fuel for ships and so the necessity for ports to have storage capacities of it. We had to exclude them as a source for our research. So, it was necessary to analyse articles to find relevant research. Also, while collecting data, we noticed that DEA analysis has been mostly used to determine port efficiency through transfers of container cargo. DEA method is now being increasingly used in connection with port environmental efficiency. As an example of using DEA method to assess port environmental efficiency, we suggest to readers to see research made by Krmac and Djodjević (2023, 6 April). In our research DEA analysis was used to determine efficiency of LNG terminals.

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