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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.

*Keywords:* LNG supply, regional ports, Slovenia, ArcGIS Pro, DEA analysis

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

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; European Council, 2023). 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 Russia, because planned reduction in consumption will not be enough. Just for reference, in 2022 EU imported 14,7 million tonnes of gas from Russia (see Interactive World LNG Dashboard (n. d. b). for more). 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 of time.

Another option of supply of natural gas is with LNG tankers. At the end of 2021, world LNG tanker fleet included more than seven hundred vessels (Aizarani, 2023). The growth in the number of ships will continue to increase, as there are currently four hundred sixteen ships on order (see Interactive World LNG Dashboard, n. d. b, for more). 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 function 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 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).

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 (Agencija za energijo, 2022). 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 Slovenia (Agencija za energijo, n. d., p. 169). When constructing network in *ArcGIS Pro*, it is necessary to include such fact into network dataset properties. 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, 2022). 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.

Anson et al. (2022) addressed the issue of Latvia's energy independence due to its reliance on the Russian gas pipeline. They emphasized the significance of gas supply from other

countries. They argued that the only option to reduce dependence on imported gas is an LNG terminal. The inadequate existing pipeline network and limited sources of LNG supply lean the technical favour towards owning their own terminal. A potential terminal in Skulte, due to its proximity to LNG storage facilities, would significantly contribute to the stability of LNG supply in the Baltic region. Authors claim 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.

Coote (2016) presented the possibility of LNG exports from other parts of the world, especially from USA, as a new source of natural gas for the EU and the possibility for the EU to diversify its natural gas supply to provide additional market competition and security. Slovenia is mentioned as a vulnerable country because of the lack of alternative in supply with natural gas. Such fact further emphasises the importance of our research. Based on the mentioned potential substitute sources for natural gas from Russia from various authors 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 1) (STA, 2022).

**Figure 1***LNG export terminals, presented with ArcGIS Pro**Note.* Own work.

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) presented 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 addressed 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. This fact highlighted the importance of inclusion of Krk terminal into our study. Research made by Krmac and Djordjević (2023) was based on the DEA analysis of ports. Therefore, the list of inputs and outputs from their research was helpful in determining the parameters, inputs and outputs, for the DEA analysis in our study.

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?

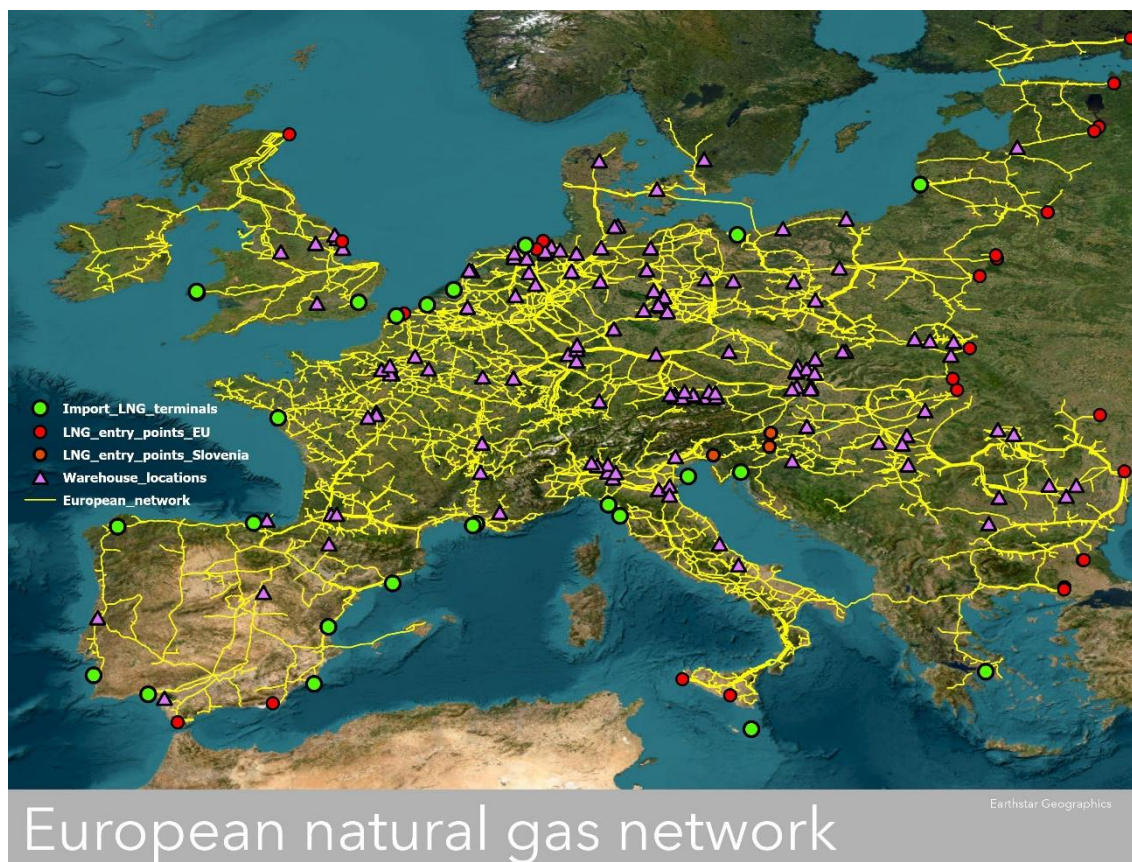
### **Methodology**

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. Articles presented us with the issues of gas supply in other countries, the sources of gas supply for Slovenia, the increasing importance of the Mediterranean Sea for gas supply, Slovenia's vulnerability regarding gas supply, and an interesting concept of a supply chain where the distribution is organized from major to smaller ports. 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 (Esri, n. d. b.; Gas Infrastructure Europe, 2022b). With it, we created a pipeline network of Europe in *ArcGIS Pro* (see Figure 2).



**Figure 2**

*European natural gas network, October 2022, presented with ArcGIS Pro*



*Note.* Own work.

Based on the constructed network, we used Closest facility analysis in *ArcGIS Pro*.

Closest facility analysis uses algorithm, based on Dijkstra's algorithm, optimization algorithm for finding the shortest path e. g. from starting to ending point (see Adeel, 2014, for more). 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 (Esri, n. d. a).

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 network (Gas Infrastructure Europe, 2022a). We identified adequate LNG import terminals in Europe. Reachable locations via pipeline network were included into code for DEA analysis. In our research the term regional location 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. We found 4 regional locations near Slovenia, 3 in Italy and 1 in Croatia.

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* (Gas Infrastructure Europe, 2022c). To determine inputs and outputs, we utilized the LNG cycle. Let us imagine the following gas distribution process to end-users. When stored and transported, natural gas is in a liquid state, and when distributed, it is in a gaseous state after completing the regasification process. Liquid natural gas is sent for regasification, having either arrived at the processing plant via tanker or been stored in a facility before (see Interactive World LNG Dashboard, n. d. a, for more). So, as inputs we used the following categories: LNG storage capacity ( $w_c$ ), number of tanks ( $w_d$ ), maximum ship class size receivable ( $w_e$ ) and minimal sea depth alongside terminal ( $w_f$ ). After completing the regasification process, gas is distributed to consumers. So, as outputs we used categories maximum hour capacity ( $w_a$ ) and nominal annual (regassification) capacity ( $w_b$ ). After we identified inputs and outputs and retrieved relevant data for each LNG terminal, we wrote the code. We wanted to determine which terminal is the most efficient, based on its capability to send as much as possible natural gas into the pipeline network. We ran DEA analysis in *LINGO*, a tool designed for solving optimization models, and interpreted results (lindo, n. d.). For instance, the code for Rovigo terminal that we ran in *LINGO* was:

```
max=1156000*wa+9*wb;
[KRK] 300000*wa+2.6*wb-140000*wc-4*wd-265000*we-16*wf<=0;
[ROVIGO] 1156000*wa+9*wb-250000*wc-2*wd-217000*we-27*wf<=0;
[PANIGAGLIA] 427000*wa+3.4*wb-100000*wc-2*wd-70000*we-10*wf<=0;
```

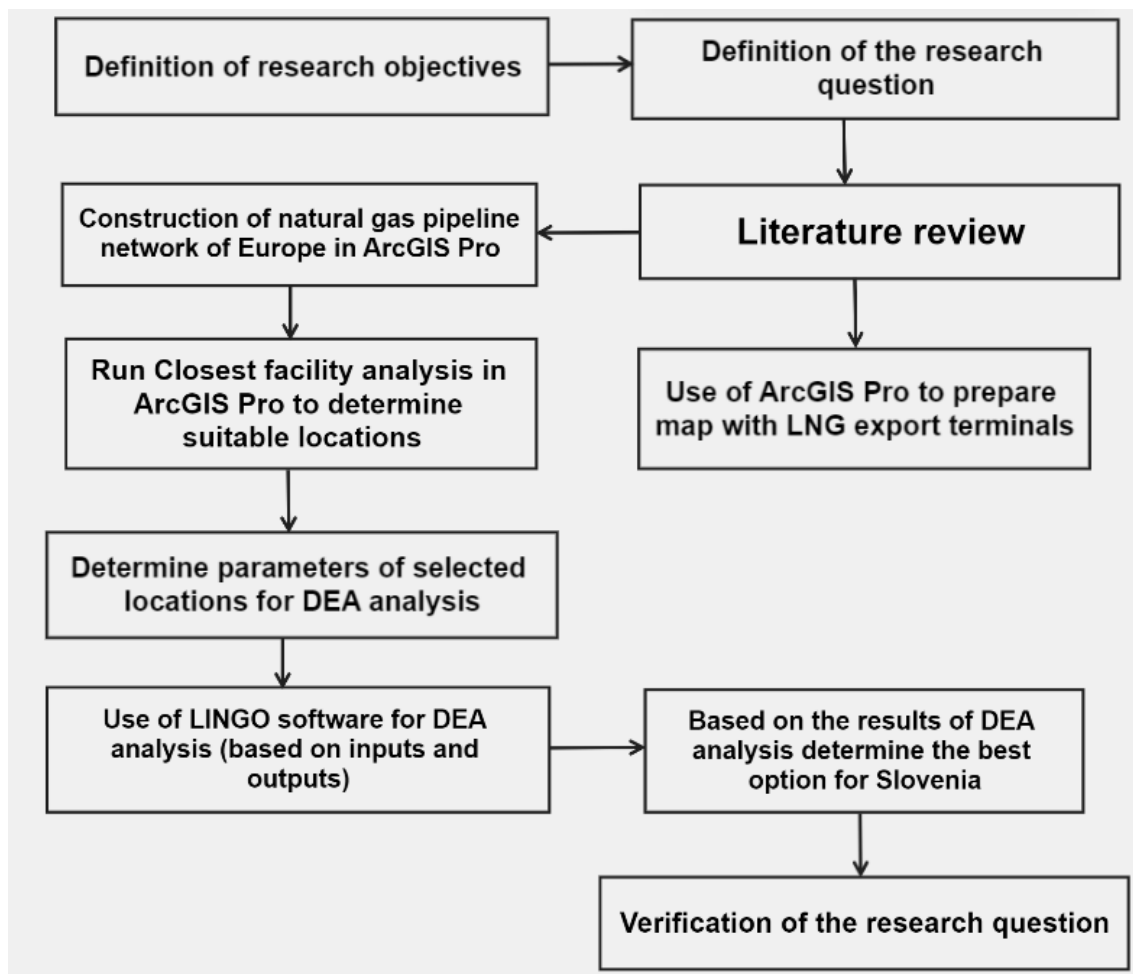
[TOSKANA]  $592000 * wa + 4.74 * wb - 137500 * wc - 4 * wd - 180000 * we - 113 * wf \leq 0$ ;  
 [HUELVA]  $1350000 * wa + 11.8 * wb - 619500 * wc - 5 * wd - 180000 * we - 12.5 * wf \leq 0$ ;  
 [SINES]  $1350000 * wa + 7.6 * wb - 390000 * wc - 3 * wd - 216000 * we - 13.5 * wf \leq 0$ ;  
 [MUGARDOS]  $412800 * wa + 3.6 * wb - 300000 * wc - 2 * wd - 266000 * we - 14 * wf \leq 0$ ;  
 [BILBAO]  $800000 * wa + 7 * wb - 450000 * wc - 3 * wd - 270000 * we - 20 * wf \leq 0$ ;  
 [CARTAGENA]  $1350000 * wa + 11.8 * wb - 587000 * wc - 5 * wd - 266000 * we - 15 * wf \leq 0$ ;  
 [SAGUNTO]  $1000000 * wa + 8.8 * wb - 600000 * wc - 4 * wd - 265000 * we - 0 * wf \leq 0$ ;  
 [BARCELONA]  $1950000 * wa + 17.1 * wb - 760000 * wc - 6 * wd - 266000 * we - 15 * wf \leq 0$ ;  
 [FOS\_CAVAOU]  $1200000 * wa + 8.5 * wb - 330000 * wc - 3 * wd - 267000 * we - 15 * wf \leq 0$ ;  
 [FOS\_TONKIN]  $230000 * wa + 1.5 * wb - 80000 * wc - 1 * wd - 75000 * we - 12 * wf \leq 0$ ;  
 [REVITHOUSSA]  $820000 * wa + 7 * wb - 225000 * wc - 3 * wd - 260000 * we - 13.5 * wf \leq 0$ ;  
 [INDEPENDENCE]  $460000 * wa + 4 * wb - 170000 * wc - 4 * wd - 160000 * we - 14.5 * wf \leq 0$ ;  
 [SWINOJSCIE]  $820000 * wa + 6.2 * wb - 320000 * wc - 2 * wd - 216000 * we - 14.5 * wf \leq 0$ ;  
 [EEMSENERGYTERMINAL]  $0 * wa + 8 * wb - 180000 * wc - 6 * wd - 180000 * we - 15 * wf \leq 0$ ;  
 [GATE\_TERMINAL]  $1650000 * wa + 12 * wb - 540000 * wc - 3 * wd - 266000 * we - 14.5 * wf \leq 0$ ;  
 [ZEEBRUGGE]  $2000000 * wa + 11.4 * wb - 566000 * wc - 5 * wd - 266000 * we - 15 * wf \leq 0$ ;  
 [DUNKERQUE]  $2100000 * wa + 13 * wb - 600000 * wc - 3 * wd - 267000 * we - 15 * wf \leq 0$ ;  
 [MONTOIR\_DE\_BRETAGNE]  $1600000 * wa + 10 * wb - 360000 * wc - 3 * wd - 267000 * we - 13 * wf \leq 0$ ;  
 [Additional\_restriction]  $250000 * wc + 2 * wd + 217000 * we + 27 * wf = 1$ ;  
 $wa \geq 0$ ;  
 $wb \geq 0$ ;  
 $wc \geq 0$ ;  
 $wd \geq 0$ ;  
 $we \geq 0$ ;  
 $wf \geq 0$ ; [1]

Based on the results of the DEA analysis we determined the most efficient regional LNG terminal near Slovenia. Values in Objective value category showed us the efficiency of regional LNG terminals. To present data regarding net imports of natural gas in 2022 and shipping time from different parts of the world, we used data *International trade movements*

of LNG in 2022 and *International trade routes of LNG in 2022* (GIIGNL, in Interactive World LNG Dashboard (n. d. b)). For visual representation of our methodology see Figure 3 below.

**Figure 3:**

*Methodology*



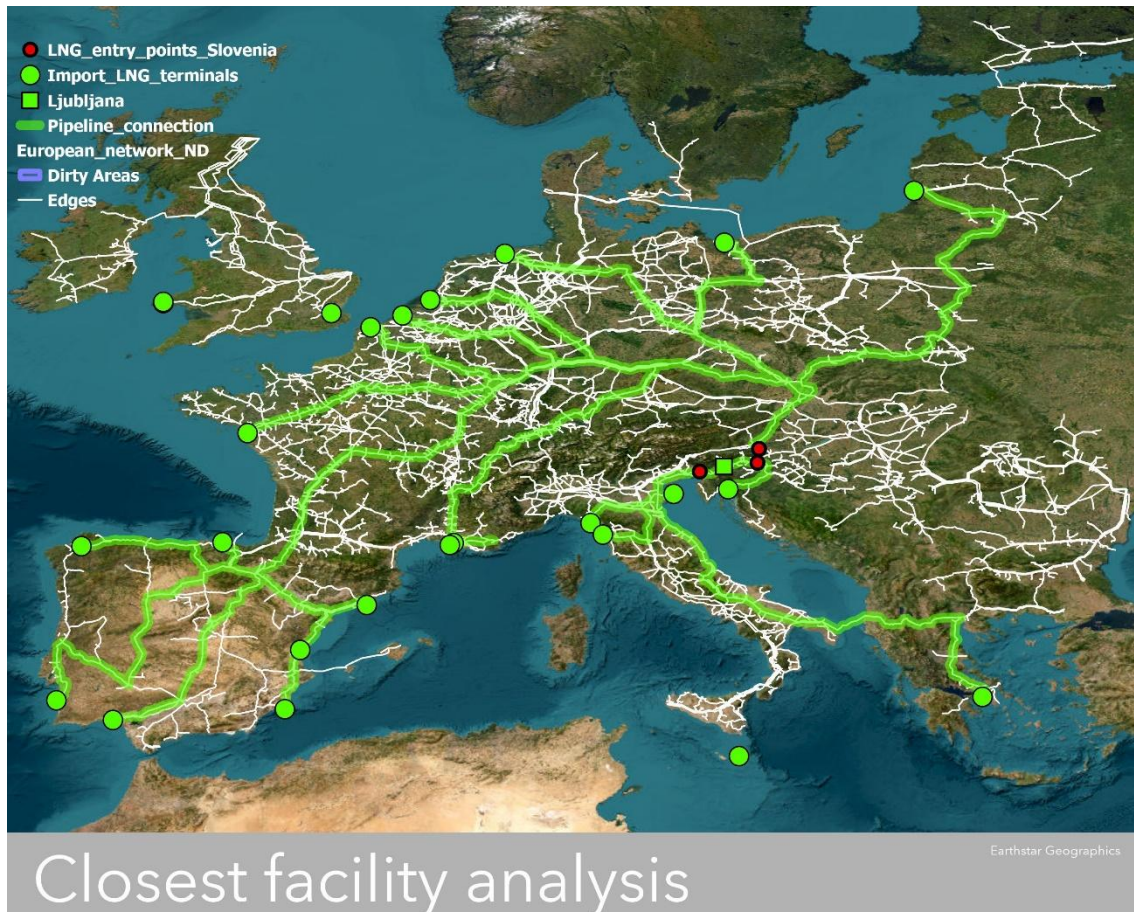
*Note.* Own work.

## Results

As a data source for the Closest facility analysis, we used *European natural gas network*, presented in Figure 2. Out of twenty-five operational import LNG terminals in Europe, Slovenia has access to twenty-one via the European natural gas network. For visual representation of the Closest facility analysis result see Figure 4 below:

**Figure 4**

*Closest facility analysis results, presented with ArcGIS Pro*



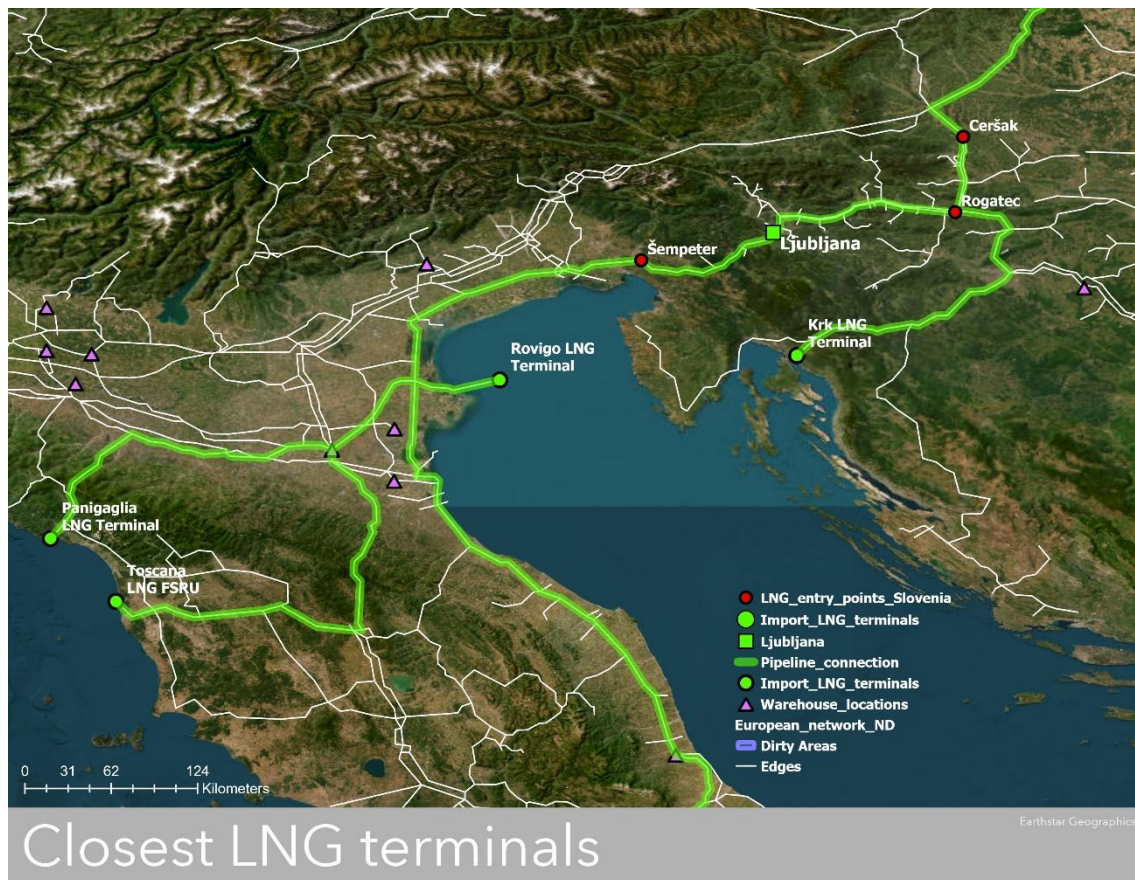
*Note.* Own work.

Based on the import LNG terminals in Europe and on the existing natural gas network in Europe we identified 4 nearest 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 2. These LNG terminals are Rovigo, Panigaglia and Toscana in Italy, and Krk in Croatia (see Figure 5).



**Figure 5**

*Closest LNG terminals, presented with ArcGIS Pro*



*Note.* Own work.

We calculated relative efficiency of identified locations. Value 1 in a row Objective value means optimal efficiency. As a source for inputs and outputs for each LNG terminal we used *LNG Import Terminal Map Database October 2022* (Gas Infrastructure Europe, 2022c).

Result of the DEA analysis is 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	0,9525473	0,5059071
$w_a$	$0,3087195 \cdot 10^{-6}$	0	$0,2988361 \cdot 10^{-6}$	$0,2934998 \cdot 10^{-6}$
$w_b$	0,0714578	0,2940997	0,1636364	0,1607143
$w_c$	$0,1145352 \cdot 10^{-5}$	$0,3479971 \cdot 10^{-5}$	$0,7272727 \cdot 10^{-5}$	$0,7142857 \cdot 10^{-5}$
$w_d$	0,02216576	0,05812839	0	0
$w_e$	$0,3084473 \cdot 10^{-5}$	$0,7653516 \cdot 10^{-5}$	0	0
$w_f$	0	0	0	0

*Note.* Adopted from “Gas Infrastructure Europe” (2022, 21 November). LNG Database. (<https://www.gie.eu/transparency/databases/lng-database/>).

For location Krk an expansion is confirmed and in process. New properties are already included into *LNG Import Terminal Map Database October 2022* (Gas Infrastructure Europe, 2022c). We included expected technical properties of Krk location for another DEA analysis. Value 1 in a row Objective value means optimal efficiency. Result of the DEA analysis is 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	0,9525473	0,5779649
$w_a$	$0,3087195 \cdot 10^{-6}$	0	$0,2988361 \cdot 10^{-6}$	$0,213594 \cdot 10^{-6}$
$w_b$	0,0714578	0,2940997	0,1636364	0,08650164
$w_c$	$0,1145352 \cdot 10^{-5}$	$0,3479971 \cdot 10^{-5}$	$0,7272727 \cdot 10^{-5}$	$0,297559 \cdot 10^{-5}$
$w_d$	0,02216576	0,05812839	0	0
$w_e$	$0,3084473 \cdot 10^{-5}$	$0,7653516 \cdot 10^{-5}$	0	0
$w_f$	0	0	0	0,01042703

*Note.* Adopted from “Gas Infrastructure Europe” (2022, 21 November). LNG Database. (<https://www.gie.eu/transparency/databases/lng-database/>).

### Discussion

Our research has shown that Slovenia is connected through the network to the majority of European import terminals, which is crucial in terms of ensuring uninterrupted gas supply. The only issue lies in the distance from terminals. Overcoming larger distances poses a challenge in planning of the gas supply. Hence, Slovenia should focus on nearby terminals. We are confident that regional terminals 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 results of our DEA analysis, terminals in Italy are among the most efficient terminals in Europe. An efficiency level of 1 indicates that, based on the input and output categories of the DEA analysis, terminals Rovigo and Panigaglia achieve optimal operational efficiency compared to all other terminals included in our study. Although the Toscana



terminal's efficiency level is slightly lower than 1, it still compares well with the most efficient terminals in Europe. The largest deviation in efficiency is observed for Krk terminal, as even with intended upgrades, its relative efficiency does not approach optimal level. We claim that LNG terminals in Italy are more efficient than LNG terminal in Croatia, because relative efficiency of all terminals in Italy are higher than it is relative efficiency of Krk terminal. Even considering new technical properties of Krk terminal, the efficiency of Italian terminals is still higher than of Krk terminal. If we compare only Italian terminals, the most efficient terminals in Italy are Rovigo and Panigaglia, followed by Toscana with slightly lower efficiency. DEA analysis also tells us where each location should improve to boost its relative efficiency. The biggest increase in efficiency terminals can achieve 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 2, LNG terminals in Italy have better connections with Slovenia than Krk. Also, hinterland pipeline network is more extensive in Italy than it is in Croatia. We can observe a lack of pipeline connections between Croatia and Slovenia. Constructing a section to Koper would enhance the accessibility of Krk terminal to the Slovenian market by saving time required for transporting gas from Krk terminal to the Slovenian pipeline network through Rogatec. Upgrading the pipeline network in Croatia would significantly improve gas supply in the Balkans, further enhancing the importance of the Mediterranean Sea as a gas supply hub for Europe.

Twenty-five LNG export terminals, presented in Figure 1, give Slovenia, and consequently the EU, lots 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. In 2022 EU imported 43,23% of gas from USA, 22,47% from Africa, 15,6% from Qatar and 2,2% from Norway. Despite sanctions, import from Russia still accounted for 12,28%. Percentage wise, increasing import from Qatar and Norway could be a viable solution to replace imports from Russia. An important factor is also the transport time. In approximately 10 days tanker can

reach United Kingdom from the USA. From Qatar, it takes about 17 days. That must be taken into the account when planning supply. For instance, a tanker from Qatar needs approximately 13 days to reach Italy. In 13 days, tanker from USA can travel to the south of France. Time-wise between USA and Qatar, Qatar is a better option of supply for the Mediterranean hub. But export terminals in North Africa are even closer and therefore present quicker route to EU import terminals, located in the Mediterranean hub (Interactive World LNG Dashboard (n. d. b)).

### 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, Rovigo and Panigaglia terminals are the best option for supply with natural gas for Slovenia with LNG tankers. They achieve optimal efficiency and are also the closest to Slovenia. The proximity to Slovenia can give Rovigo terminal a slight advantage over Panigaglia. 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. Bittante, Pettersson and Saxen (2018) presented 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. Suitability of such distribution model should be analysed for various regions in Europe.

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). In our research DEA analysis was used to determine efficiency of LNG terminals.

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