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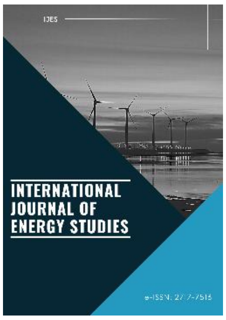


Erratum Article

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# Erratum to: Hydrogen carriage consideration from engineering and economic perspective for Konya/Türkiye

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In the article titled "Hydrogen Carriage Consideration from Engineering and Economic Perspective for Konya/Türkiye", published in Volume 10, Issue 4 of the International Journal of Energy Studies, a formatting problem occurred in the published version of the manuscript.

During the typesetting process, some figure numbering and cross-reference fields in the manuscript were incorrectly rendered due to formatting issues in the source document. Following a request from the author, the editorial office has reviewed the article and corrected the layout and formatting in accordance with the journal's template.

The scientific content of the article remains unchanged. The correction concerns only formatting and reference display.

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Original article file can be found here: dergipark.org.tr/en/download/article-file/5148393

The corrected version of the article is provided below.

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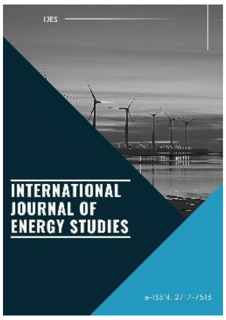



Research Article

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# Hydrogen carriage consideration from engineering and economic perspective for Konya/Türkiye


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**Highlights**

- Konya is a good candidate for hydrogen application.
- Cryogenic has a big advantage from operation cost perspective.
- There are more than one way of hydrogen transportation from economic perspective.


**You can cite this article as:** Altıntop ES. Hydrogen carriage consideration from engineering and economic Perspective for Konya/Türkiye. Int J Energy Studies 2025; 10(4): 1351-1371.



## ABSTRACT

The paper has evaluated hydrogen transportation in Konya/Türkiye. The evaluation included km, population, consumption, and economic perspectives. Three points have been chosen for transportation consideration, which are pipelines, cryogenic tankers, and tube trailers, due to geographical limitations. The economic perspective includes both investment and operational costs for these methods. Konya has all kinds of consumption, which makes it a great candidate for the article. There are 31 districts in Konya, and three of them are in the city centre. Cryogenic tankers have come forward at 16 districts for investment cost, and 12 districts are better operated by tube trailers for investment cost perspective. The entire city other than the city centre is better operated by cryogenic tankers from an operational cost perspective because their technology gives them a big advantage. The three districts have been left out to be supported by pipelines, since the population density is high and industrial demand is big. The city has provided a big part of their energy demand from green energy so far, and they have plans to go further with this ecological advancement. Even though green energy solutions are not working stably, they need support for this problem. Hydrogen is a great candidate for this problem, which can store extra energy during high production and release it when it is lower to the system. The total result is that even though pipelines can carry out massive volumes, they are not needed for now, and the places can be powered up with cryogenic tankers and tube trailers. Cryogenic tankers are the best from an operational cost perspective, and the closest tube trailer costs at least three times as much as cryogenic operation. Tube trailers are advantageous for investment costs in some districts, which means they can begin earlier to use hydrogen with less investment.



**Keywords:** Hydrogen, Hydrogen transportation, Hydrogen economy, Hydrogen Konya, Transportation cost

# 1. INTRODUCTION

Energy storage is an important matter, and it has been pursued for a long time in human history. Currently, natural gas is the dominant energy transfer material beside electricity, but storing electricity is not as convenient as natural gas. There are pipelines from gas wells to cities, ports, and even to other countries [1]. For example, the TANAP (Trans Anadolu Doğal Gaz Boru Hattı – Anatolia Transit Natural Gas Pipeline) project begins at the Georgia border of Türkiye and ends at the Greece border, which has 16 B $m^3$ natural gas (NG) capacity [2]. The big need for natural gas made all this transportation web possible. The demand helped the system grow better and stronger; as a result, there is almost nowhere natural gas doesn't reach out [3]. Natural gas is a comparatively cleaner gas than its alternatives like coal and diesel fuel, so it has been preferred in cities. Time has passed and technology has expanded, so there is more technology to be used inside cities to have a cleaner environment, which is hydrogen. It became more important since there is more energy than can be consumed or used to support the green energy production. Energy can be stored in different ways, and some of them are in physical form [4,5]. The most common energy carrier is natural gas, and it has a big capacity compared to others but smaller than hydrogen. Hydrogen has a bigger energy capacity per kg compared to alternatives [5]. Physical form makes a difference for all of them, but when the pressure is higher, it loses its significance.

The current natural gas pipelines are quite common, but they do not have the capability to carry hydrogen inside them [6]. Hydrogen is in gas form at 1 atm and room temperature (24 ˚C). Liquid hydrogen is possible with high pressure or low temperature, and solid hydrogen is quite difficult to possess due to extreme needs [7,8]. Carrying liquid hydrogen increases the difficulties already experienced, like high-pressure durability and heat isolation, but it increases the transportation capacity [9]. The transportation web for natural gas has not been developed overnight, so shifting to hydrogen technology would take time as well. There is more than one way to transport liquid or gas, so the decision would make the difference based on parameters we have in our hand. These parameters are quite common for most engineering decisions, like availability, technology, consumption time, and cost. The methods can vary as well; they are pipelines, trucks, gas tanks, gas ships, etc. [10]. The need for hydrogen technology is quite important for the environment since global warming and pollution [11]. Hydrogen can power an entire society in different ways [12]. Even though it can unlock a cleaner society, it will not be possible to reach for a while. It requires dedication and devotion for such a high goal.

It is important to have hydrogen in the city system for a cleaner environment, but although hydrogen exists inside almost every chemical bond, it does not occur in nature like natural gas, petrol, etc. To obtain hydrogen, some energy needs to be spent to extract it from a source. It makes a difference what energy source is spent on hydrogen production as well [13]. The brown hydrogen comes from coal and CO2 released to the atmosphere. Grey hydrogen is produced from naturel gas, and CO2 is released into the atmosphere, but if CO2 is injected inside the soil, then it becomes blue hydrogen. Green hydrogen is extracted from water with green electricity sources. These methods make all the difference for the environment, so the engineering approach should be according to it while designing the distribution basics. The distribution can show differences according to needs like residential area, industrial area, remote area, etc. There are proven methods to carry the gas variations, but they do not have to be all the same.

This study takes an alternative approach to hydrogen carriage system design for Konya, which helps to improve the system for the local resources and minimize carbon emissions. The paper emphasizes the priority of the energy source used for hydrogen production and decentralizes hydrogen. Alternative carriage methods have been considered for different scenarios, such as pipeline, cryogenic tanks, tube trailers, and the results have been considered together for comparison. The application's parameters are investment and operating costs for each district based on their distance from the city center. This study gets separated due to application area, physical limitations, and evaluation manners. Application of the methodology would help to reduce the carbon footprint for the hydrogen carriage, and the simplified approach makes it easier to shift to hydrogen society. The paper is meant to consider the application of a renewable energy source in Konya from different perspectives so the city can be relieved from the heavy burden of high initial costs while advancing to a better and cleaner energy source.

## 2. MATERIALS AND METHODS

Hydrogen has unique abilities because it exists almost inside every material, yet it does not exist by itself in nature. Although it can be almost in every material without any problem, it becomes quite dangerous by itself due to its flammable nature and high-energy nature [5]. Modern society heavily relies on electricity due to its high capabilities, such as being easier to transfer, easy to convert to other energy forms, etc. Producing electricity is not as easy as using it, and there are a lot of ways to produce electricity. The choice of production relies on various reasons, such as cost, energy source, environmental causes, etc. [14]. After considering everything, the choice should be made primarily based on environmental factors due to global warming and diseases coming from pollution [15]. Considering these indications, burning natural gas inside homes, using fossil fuels in the streets, and using fossil-based production in the industrial areas are dangerous, so they need to be reduced or averted, but reaching that point requires an alternative approach to engineering, economics, and environmental solutions [12]. The Turkish government has done strategic work to enlighten the path for involving hydrogen in the society, so it has already begun as an idea between the officials as well [16].

### 2.1. Process of Entering Hydrogen Society

Hydrogen society is a well-known phrase lately due to global warming and high pollution because it has the highest energy capacity and its waste is water. The case has also been studied in literature from different angles. The hydrogen process has been presented in Figure 1, which includes the power sources and main materials it has been extracted from. It also captures the entire procedure, which is feedstock, production, transportation, storage, and application. There are quite a few methods that can be used to apply each way. Most of them also have their own advantages, like ammonia, which can be used as a means of transportation, but it is also a common fertilizer for crops, which already exists in the market for production, transportation, and application [12,17].

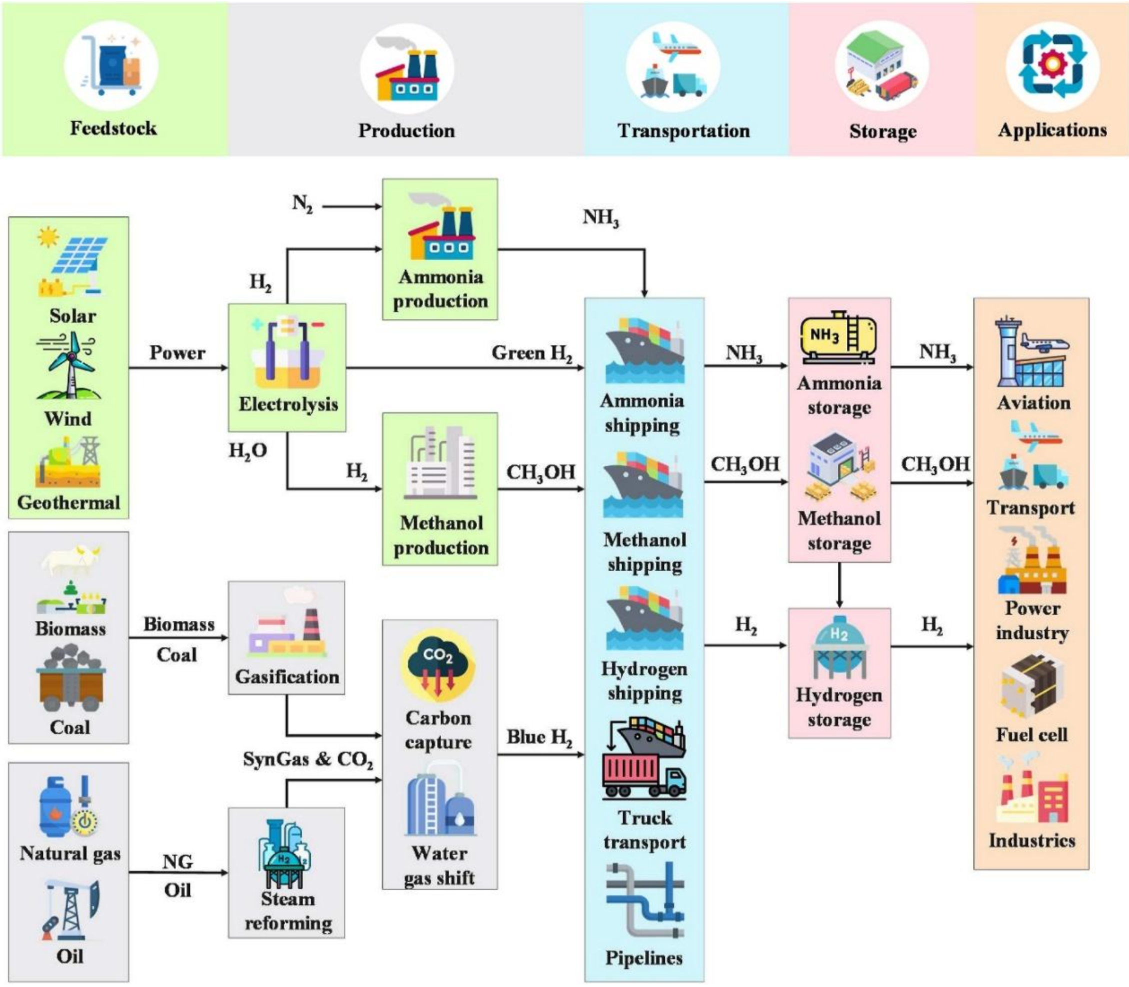


**Figure 1.** Process of hydrogen forms from production to application [12]

## 2.2. Transportation Methods

Figuring out a transportation method is not impossible since it already exists in the market and the methods have been shown in Figure 1, but deciding the best way to do is a puzzle. The general ways are pipelines, trucks, ships, etc. There are also different physical forms of hydrogen, and there are vehicles also capable of carrying them as well. Since there are solutions to the transportation problem, the situation can be considered firmly, and the evaluation would reveal the application problem, which is economic and environmental difficulties. The current pipelines and vehicles are not capable of hydrogen carriage, so all those infrastructures will be useless instantly. Such a revolution would be hard to do suddenly and more expensive than just the material cost. The new infrastructure should be placed to assist the same areas, so replacing it is not as easy as it is said. Natural gas requires an infrastructure based on extraction from the ground or distribution via big transportation methods. Hydrogen is different from this perspective since it is almost in every material; it can be extracted from them. For example, using water for hydrogen production is a very common way of doing it. Ammonia is another way of reaching hydrogen, as has been shown in Figure 2; moreover, even natural gas can be used to gain hydrogen [18]. Hydrogen is the second smallest element in the periodic table, which gives the ability to sneak away from the smallest gaps. It makes it harder to contain in a container, which is more difficult compared to its alternatives to work with [19]. As has been mentioned, the pipelines are also not going to be useful, since they are not capable of carrying hydrogen due to hydrogen embrittlement, so the new pipelines need to be qualified for avoiding such a destruction [6]. The better pipes with more qualities are going to be expensive, so it would make it harder to apply.

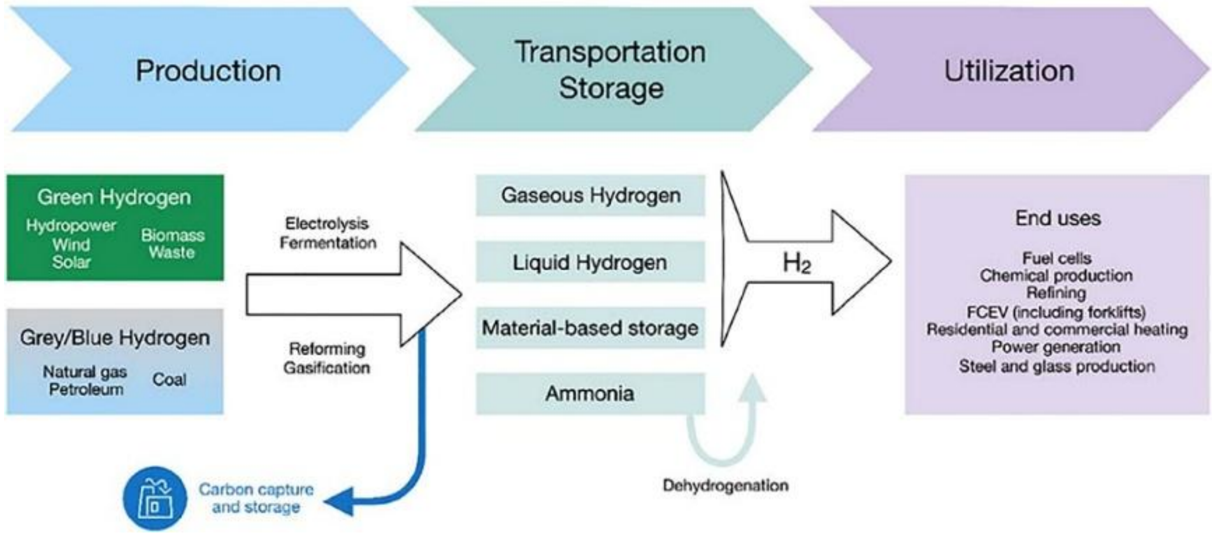


**Figure 2.** Hydrogen transportation methods [13]

Hydrogen can be obtained from different sources, as has been mentioned and shown in Figure 3 and hydrogen can be transformed into liquid for carrying more in the same volume with high pressure or low temperature, which would consume extra energy. The distribution does have differences based on those choices, but in the end, they can be used for the same purposes with the right equipment in the field. The choices made since the beginning of the process are based on some fundamentals, and they should all lead to the green hydrogen economy at the end [12].

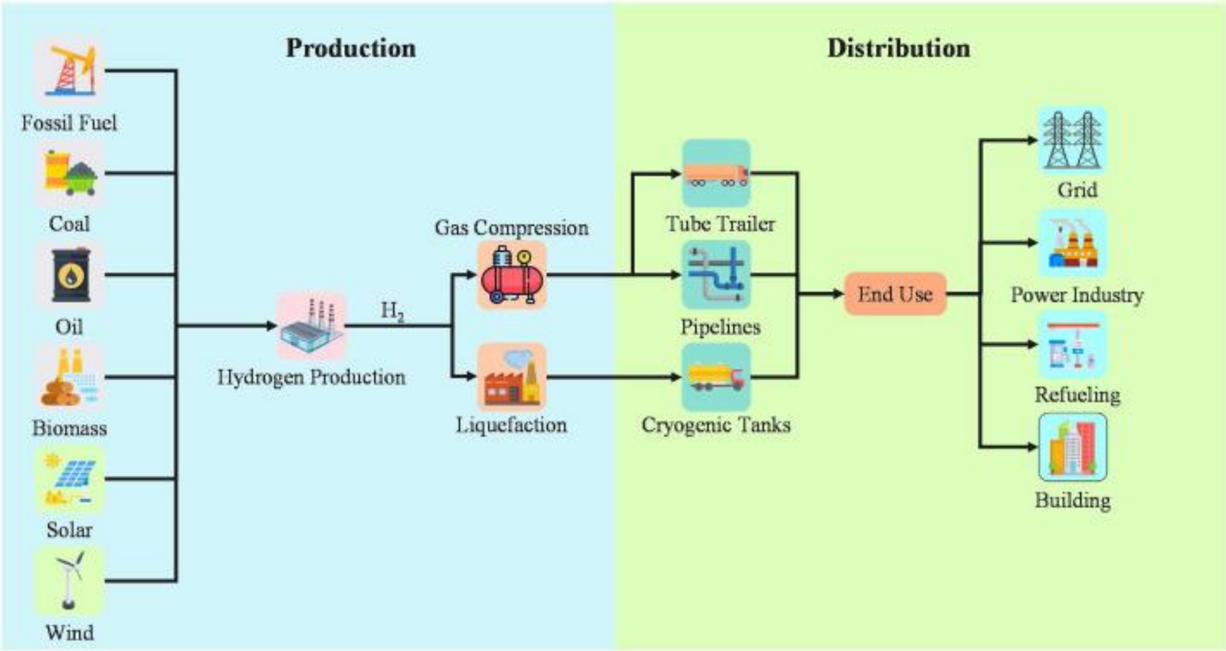


**Figure 3.** Different hydrogen forms and their carriage methods [12]

The green hydrogen society has more benefits than it appears to present. Some governments support environmentalist vehicle usage for obvious reasons, and they even forbid fuel-powered cars from some parts of their cities due to air and noise pollution [20]. On the other hand, battery-powered vehicles have their own setbacks, so they are not the best solution to have, such long charging durations, short ranges, etc. Hydrogen-powered vehicles have a lot more flexibility in range and refueling [21].

**Cryogenic Tanks**

Cryogenic liquid for hydrogen contains 30% more energy than compressed hydrogen gases. The conditions to keep liquid hydrogen are tough, such as keeping the temperature around -253 ˚C [22]. These kinds of extreme conditions make it harder to operate and comparatively more expensive to build such a system [12].

**Tube Trailer**

Hydrogen density is so low; as a result, it needs to be compressed to carry out more of it. The tubes can be made of steel or composite material. Steel tubes are cheaper and easier to produce but increase the total weight of the load, which is limited by law depending on the country [23].

**Pipelines**

Pipelines have similar technology to tube trailers, but rather than having a capacity based on weight, they have limitations on pressure and hourly volume. The system capacity is decided based on the potential usage of that region.

## 2.3. Economy of Transferring Hydrogen

As it has been mentioned earlier, transferring hydrogen can be done with more than one method, like pipelines, trucks, ships, etc. Another parameter that needs to be taken into consideration is producing hydrogen, which can be done almost anywhere, so that's another parameter to consider. The comparison of hydrogen carriage methods has been done for pressure, capacity, efficiency, investment cost, operational cost, benefits, and limitations. The pipeline is a well-known method, but it is quite costly, ranging between $ 200K and 1M per km. The operational cost of pipelines is low, and they can carry up to 100 tons per hour. Tube trailers have different approaches for the situation, which are carried by trucks, and its cost is like $ 300K per truck, and it can carry up to 400 kg of hydrogen each time. The cryogenic tank is another technology, and it has a big impact on hydrogen carriage. The cryogenic tank cost per truck is $ 400K, and it can carry up to 4000 kg of hydrogen each time. The operational cost varies between certain numbers as they have been presented in Table 1, and it is almost five times less than tube trailers for cryogenic tanks. The efficiencies are all above 94 percent, so even though it can be included inside the calculation, it would not make much difference due to the higher capabilities. Ship carriage is totally different from what we have so far explained because the operational costs are higher than other alternatives. It is quite useful for certain situations such as offshore platforms, long-distance places, and occurrences that may not repeat again.

**Table 1.** Comparison of hydrogen transportation of investment and operation costs [12]

| *Transportation options* | | *Suitability* | *Storage Pressure (MPa)* | *Capacity* | *Efficiency* | *Investment costs* | *Total transmission costs ($kg$^{-1}$ 100 km$^{-1}$)* | *Benefits* | *Limitations* |
|---|---|---|---|---|---|---|---|---|---|
| ***Pipelines*** | | Transporting $GH_2$ for short, medium, & long-range distances | Up to 55 | Up to 100 tons/h | 99.2% per 100 km | $200K- $1M per km | $0.10- $1.0 | High efficiency, low running costs, & extremely low variable expenses | Hight investment costs- Requirement of extensive $H_2$ delivery infrastructure |
| ***Road*** | Tube Trailers | Transporting gaseous $H_2$ for short distances | 25 | Up to 400 kg per truck | 94% per 100 km | $300K- per truck | $0.50- $2.0 | Large-scale transportation over short distances | Small-scale delivery per truck- energy inefficiency |
| | Cryogenic Tankers | Transporting liquid $H_2$ for short & medium distances | Up to 0.7 | Up to 4000 kg per truck | 99% per 100 km | $300K- 400K per truck | $0.30- $0.50 | Occupies larger volumes than gas transportation | High liquefaction costs- boil- off gas emissions |
| | Metal hydride-based containers | Transporting hydrogen by loading it onto a truck or a railcar | Atmospheric pressure | - | - | - | - | Existing logistics infrastructure- boil- off gas release is minimum | Low gravimetric densities- very expensive |
| ***Railway*** | | Transporting liquid $H_2$ for distances> $10^3$ km | Up to 0.7 | Up to 7 tons per railcar | - | - | - | Transporting liquid hydrogen in large quantities | Lack of $LH_2$ railcars- railway time scheduling factor |
| ***Ocean*** | | Transporting $LH_2$ for large distances | Up to 0.7 | Up to 10,000 tons per shipment | 0.3% boil-off per day | $465M-$620M for each barge | $1.80- $2.0 | Transporting a large amount of $H_2$ overseas | No $LH_2$ ships build to date- Not feasible- significant boil- off losses |

## 2.4. Significance of Konya for the Study

The total NG consumption in Türkiye was 53,255,020,000 $m^3$, of which 14.5 B $m^3$ was used in electricity, 13.4 B $m^3$ used in residences, and 7.6 B $m^3$ was used in other ways [24]. Türkiye can be considered under seven regions, which are given in Table 2. The NG consumption, population, and surface area have been presented for each region. Marmara is the smallest region in surface area, yet it has the highest population and consumption, so the distribution problem cannot be made clear in that region. The East Anatolia region is quite big, but it doesn't have the population or the consumption. The Middle Anatolia region seems the best option for such an observation.

**Table 2.** NG Consumption of regions in Türkiye [25,26]

| **Region** | **Area ($km^2$)** | **Population** | **Consumption** |
|---|---|---|---|
| Mediterranean Region | 89,493 | 11,147,604 | 4,5 B $m^3$ |
| East Anatolia Region | 163,000 | 5,998,778 | 2 B $m^3$ |
| Aegean Sea Region | 85,000 | 10,886,803 | 7,4 B $m^3$ |
| Southeast Anatolia Region | 57,000 | 9,305,910 | 1,8 B $m^3$ |
| Middle Anatolia Region | 151,000 | 13,566,792 | 10,5 B $m^3$ |
| Black Sea Region | 141,000 | 7,970,406 | 4,2 B $m^3$ |
| Marmara Region | 67,000 | 26,530,314 | 22,8 B $m^3$ |

As can be observed from Figure 4, Konya is in the Middle Anatolia region, and it is the largest province in Türkiye. There are 281 MW of electric power production with 51 facilities. 117 MW comes directly from solar power, and the rest is provided from fossil fuels. They have a vision of powering the entire city with renewable power sources, such as initially running 136 MW wind turbines and opening factories for solar panel production. Their feasibility report also includes solar tower application in Konya. The evaluation claims availability of 2.000 MW solar power inside Konya alone [27]. Konya is a great candidate for this study since it has a lot of green energy available for use. The city also has a big and diverse industrial settlement, which also makes it better for observation purposes in the study. Konya's population for rural areas is quite evenly distributed due to its plain geographic form, which helps the results be clearer for the decisions. Hydrogen production can be done from different sources, as has been mentioned before, but in this case, providing energy from green sources makes a difference.

The transportation availability for Konya and its districts is limited due to the geographical conditions. Ship transportation and trains are not much of an option because there is no sea availability and there is no availability of train routes for each district. The remaining options are pipelines, cryogenic tanks, and tube trailers.

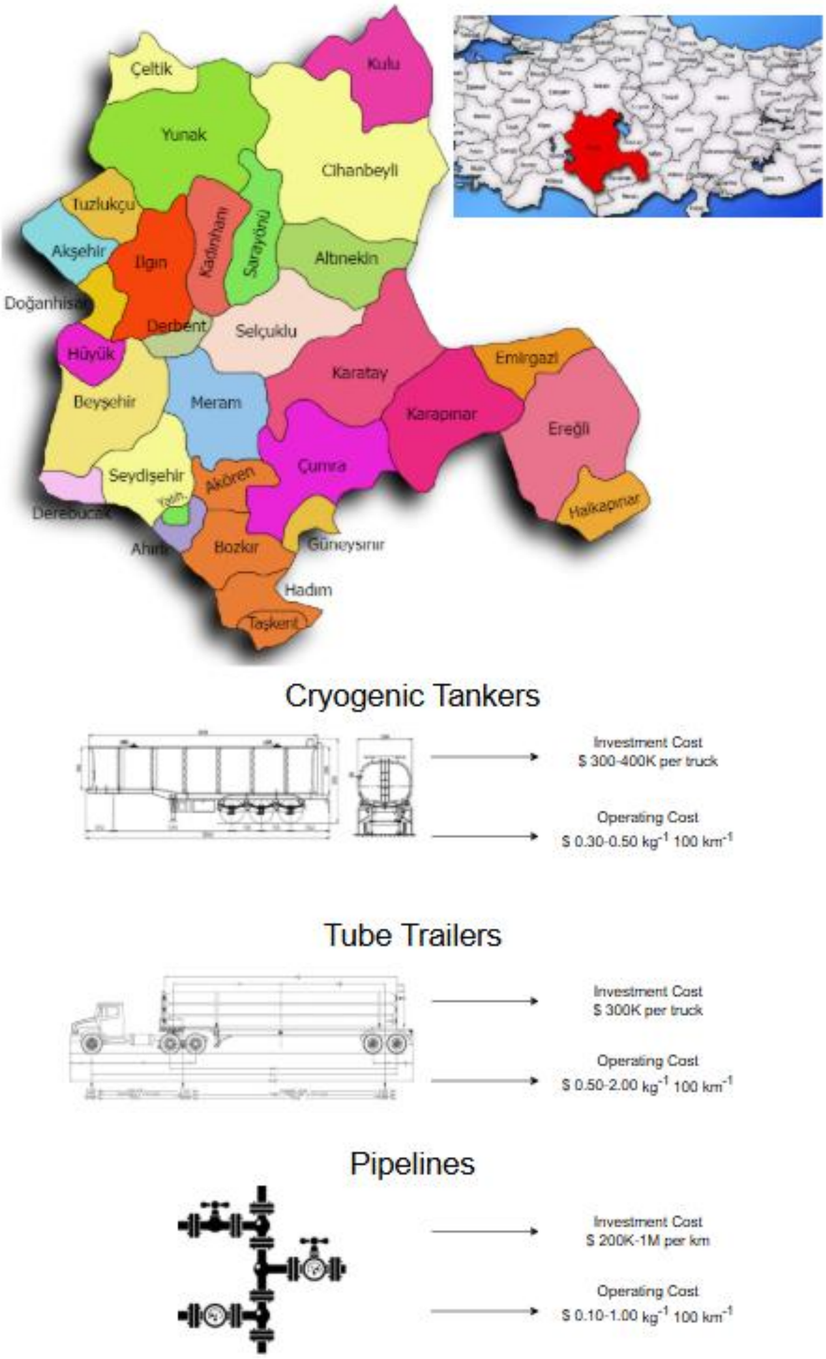


**Figure 4.** Konya's district and its location inside the country with transportation options [28–32]

## 3. RESULTS AND DISCUSSION

Konya is the largest province in the country, so the distances are comparatively greater than others. The exact distances from the city center have been presented in Table 3, and the zero km means they are in the city center. There are 31 districts, which are crowded enough to be listed for this study. They are currently powered by NG and electricity. The city is also known for high agricultural and industrial production activities. Such activities make the city more appealing to the study due to potential consumption, such as heating, burning, and fertilization.

**Table 3.** District distance in Konya [33,34]

| District | Distance (km) | Population | District | Distance (km) | Population |
|---|---|---|---|---|---|
| Ahırlı | 119 | 4,666 | Derebucak | 140 | 5,540 |
| Akören | 68 | 5,857 | Doğanhisar | 103 | 14,445 |
| Akşehir | 131 | 93,719 | Emirgazi | 141 | 7,739 |
| Altıntekin | 65 | 14,593 | Ereğli | 153 | 156,253 |
| Beyşehir | 90 | 79,629 | Güneysınır | 85 | 9,287 |
| Bozkır | 129 | 25,199 | Hadım | 137 | 11,049 |
| Çeltik | 192 | 9,726 | Halkpınar | 173 | 4,009 |
| Cihanbeyli | 98 | 50,021 | Hüyük | 96 | 15,033 |
| Çumra | 60 | 68,551 | Ilgın | 89 | 53,239 |
| Derbent | 76 | 4,014 | Kadınhanı | 58 | 31,494 |
| Meram | 0 | 34,8071 | Seydişehir | 107 | 66,067 |
| Karapınar | 102 | 51,324 | Taşkent | 146 | 5,931 |
| Karatay | 0 | 385,432 | Tuzlukçu | 127 | 6,127 |
| Kulu | 148 | 51,794 | Yalıhüyük | 114 | 1,678 |
| Sarayönü | 48 | 28,533 | Yunak | 171 | 20,646 |
| Selçuklu | 0 | 700,358 | | | |

### 3.1. Potential hydrogen consumption

The city is already equipped with NG, so the numbers have been provided by local suppliers via official sites. The city's surface area is 41,001 km$^2$ and the total population is 2,330,024 which means 57 people per square kilometer [35]. The NG provider has 488,565 subscribers for the entire city, but that doesn't clarify anything directly about the consumption of everyone, so an estimation is taken in place, which is the total consumption divided by the total population. The total consumption is 763,910,000 m$^3$, which makes 327.85 m$^3$ per person [36]. NG consumption by each district has been given in Table 4.

Before the calculations, there are a few assumptions that need to be made, such as how many deliveries a truck can make during the day, which is decided as 10 for all of them. Furthermore, seasonality is ignored since the city does not have high seasonal temperature changes. The transportation possibilities are reduced to three, which are tube trailers, cryogenic tanks, and pipelines. The consideration is based on the investment and operating cost of transporting hydrogen to the region.

NG consumption number needs to be in kg, so $m^3$ is converted. According to the Turkish standards, NG gets carried with 75 bar between cities and 20 bar inside the cities [37]. The inner consumption has not been shared, so the total consumption has been considered, which needs to be calculated for 75 bars. The equation used to calculate the kilogram of NG has been given in Equation 1. The result from the calculation brings up 6.07 kg NG per cubic meter, so this number is put back into the calculation for the evaluation of equivalent hydrogen consumption, which is given in Table 4.

$$\rho = \frac{P * M}{\mathrm{R} * \mathrm{K}} \tag{1}$$

P: 74 atm (75 bar)
M: 2.01 gr/mol
R: 0.0821 L.atm/mol.K
T: 298.15 K (25 C˚)

NG and hydrogen (H) have different calorie numbers, so the consumption will show the difference between them. Hydrogen has 141.9 MJ energy per kg, and NG has 49.9 MJ energy per kilogram. The difference between them is quite big, so they clearly cannot be used in the same amount for the same work. The energy difference needs to be considered, which is a factor of 0.35 for H that needs to be used instead of NG [5]. The amount of energy has been converted from NG to H in Table 4.

The pipeline investment cost is based on the district's distance from the city center, so it has been decided by multiplication of km times cost per km. Due to its high capacity, the lowest operational cost has been taken into consideration. The tube trailer investment cost is decided based on the truck's capacity times round cycles per day. The gas data is yearly, so it needs to be multiplied by 365. The operational cost has been evaluated as the mid value for the range given in Table 1. cryogenic tankers are evaluated the same as the tube trailers, but they have higher capacity, and operational cost is approximately lower than the tube trailers. On the other hand, the tube trailers cost $ 100K less per truck.

The results of the calculations are given in Table 4, and the lowest investment and operating costs have been highlighted. Even though the pipeline has the highest capacity for all of them, the cryogenic tankers presented impressive performance, which came up as the primary choice for most transportation projects. Cryogenic tankers are the primary choice from the operating cost perspective due to their technology. The tube trailer has come forward for 12 cases at investment cost for low-consumption districts. A pipeline should be considered for the city center, since there are industrial and high population density areas.

The hydrogen transition would help a lot for environmental reasons as well, since proper burning of hydrogen brings out water as waste. The system can be promoted even further, like using hydrogen-powered vehicles while carrying hydrogen. The city already has a big green energy source, and they are looking forward to having a lot more, which is beyond what they need. It would also be helpful in this situation to store the extra energy as energy storage. Green energy sources are the key to a greener future, but they are not stable energy sources, and that makes it difficult to rely on them. Using hydrogen as an energy storage unit when the energy is higher and using it as an energy source when it is lower would boost the green energy usage in the region.

**Table 4.** Comparative assessment of economic hydrogen transportation for investment and operating cost

| Information | | | Gas Consumption | | Investment Costs (K$) | | | Operating Costs (K$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| District | Population | Distance (km) | NG (Ton) | H (Ton) | Pipeline | Tube Trailer | Cryogenic Tankers | Pipeline | Tube Trailer | Cryogenic Tankers |
| AHIRLI | 4,666 | 119 | 2 | 1 | 23,800 | 300 | 400 | 0 | 1 | 0 |
| AKÖREN | 5,857 | 68 | 1,920 | 676 | 13,600 | 300 | 400 | 253 | 574 | 184 |
| AKŞEHİR | 93,719 | 131 | 30,726 | 10,813 | 26,200 | 2,400 | 400 | 7,791 | 17,706 | 5,666 |
| ALTINEKİN | 14,593 | 65 | 4,784 | 1,684 | 13,000 | 600 | 400 | 602 | 1,368 | 438 |
| BEYŞEHİR | 79,629 | 90 | 26,107 | 9,187 | 18,000 | 2,100 | 400 | 4,548 | 10,336 | 3,307 |
| BOZKIR | 25,199 | 129 | 8,262 | 2,907 | 25,800 | 600 | 400 | 2,063 | 4,688 | 1,500 |
| ÇELTİK | 9,726 | 192 | 3,189 | 1,122 | 38,400 | 300 | 400 | 1,185 | 2,693 | 862 |
| CİHANBEYLİ | 50,021 | 98 | 16,400 | 5,771 | 19,600 | 1,200 | 400 | 3,111 | 7,070 | 2,262 |
| ÇUMRA | 68,551 | 60 | 22,475 | 7,909 | 12,000 | 1,800 | 400 | 2,610 | 5,932 | 1,898 |
| DERBENT | 4,014 | 76 | 1,316 | 463 | 15,200 | 300 | 400 | 194 | 440 | 141 |
| DEREBUCAK | 5,540 | 140 | 1,816 | 639 | 28,000 | 300 | 400 | 492 | 1,119 | 358 |
| DOĞANHİSAR | 14,445 | 103 | 4,736 | 1,667 | 20,600 | 600 | 400 | 944 | 2,146 | 687 |
| EMİRGAZİ | 7,739 | 141 | 2,537 | 893 | 28,200 | 300 | 400 | 692 | 1,574 | 504 |
| EREĞLİ | 156,253 | 153 | 51,228 | 18,028 | 30,600 | 3,900 | 800 | 15,170 | 34,478 | 11,033 |
| GÜNEYSINIR | 9,287 | 85 | 3,045 | 1,071 | 17,000 | 300 | 400 | 501 | 1,138 | 364 |
| HADIM | 11,049 | 137 | 3,622 | 1,275 | 27,400 | 300 | 400 | 961 | 2,183 | 699 |
| HALKAPINAR | 4,009 | 173 | 1,314 | 463 | 34,600 | 300 | 400 | 440 | 1,000 | 320 |
| HÜYÜK | 15,033 | 96 | 4,929 | 1,734 | 19,200 | 600 | 400 | 916 | 2,081 | 666 |
| ILGIN | 53,239 | 89 | 17,455 | 6,142 | 17,800 | 1,500 | 400 | 3,007 | 6,834 | 2,187 |
| KADINHANI | 31,494 | 58 | 10,325 | 3,634 | 11,600 | 900 | 400 | 1,159 | 2,634 | 843 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **KARAPINAR** | 51,324 | 102 | 16,827 | 5,922 | 20,400 | 1,500 | 400 | 3,322 | 7,550 | 2,416 |
| **KARATAY** | 385,432 | 0 | 126,366 | 44,469 | 0 | 9,300 | 1,600 | 0 | 0 | 0 |
| **KULU** | 51,794 | 148 | 16,981 | 5,976 | 29,600 | 1,500 | 400 | 4,864 | 11,055 | 3,538 |
| **SARAYÖNÜ** | 28,533 | 48 | 9,355 | 3,292 | 9,600 | 900 | 400 | 869 | 1,975 | 632 |
| **SELÇUKLU** | 700,358 | 0 | 229,616 | 80,804 | 0 | 16,800 | 2,400 | 0 | 0 | 0 |
| **SEYDİŞEHİR** | 66,067 | 107 | 21,660 | 7,623 | 21,400 | 1,800 | 400 | 4,486 | 10,195 | 3,262 |
| **TAŞKENT** | 5,931 | 146 | 1,945 | 684 | 29,200 | 300 | 400 | 549 | 1,249 | 400 |
| **TUZLUKÇU** | 6,127 | 127 | 2,009 | 707 | 25,400 | 300 | 400 | 494 | 1,122 | 359 |
| **YALIHÜYÜK** | 1,678 | 114 | 550 | 194 | 22,800 | 300 | 400 | 121 | 276 | 88 |
| **YUNAK** | 20,646 | 171 | 6,769 | 2,382 | 34,200 | 600 | 400 | 2,240 | 5,092 | 1,629 |
| **MERAM** | 348,071 | 0 | 114,117 | 40,159 | 0 | 8,400 | 1,200 | 0 | 0 | 0 |

## 4. CONCLUSION

This paper evaluates the transportation perspective for integrating hydrogen in Konya/Türkiye. The city has industrial diversity, agricultural activities, and high urban life, which makes it a great example for the cities as well. The city has the biggest surface area in the country, so it is the hardest from a transportation perspective. The transportation is limited to only trucks and pipelines, but there are two alternatives for truck options, which are cryogenic tankers and tuber trailers. The districts in the city center do not have distance, so they have not been taken into consideration. They should be covered with pipelines directly, since there are high energy demand areas like industrial and high-density populations. The tube trailers have been chosen as low consumption areas since they have comparatively lower energy carriage capacity. The cryogenic tankers have outperformed them in many districts due to their high capacity and low operating cost. The cryogenic tankers have been nominated for 16 regions, while tube trailers have been nominated for 12 regions for low investment costs. The operating cost has different results because cryogenic tankers have the lowest value for each option.

The study has presented the most economical way to apply hydrogen transportation in Konya. The study aimed to support hydrogen application so the effects of global warming can be lowered. Furthermore, the microclimate in the region can be less polluted for people, animals and crops.

The city also has big potential for green energy. They already get a big part of their energy from green sources, and they plan to go further. Boosting application of hydrogen by showing the alternative low-cost possibilities is another way to go, which is done in this paper by considering each district's potential usage based on their current use with correlation of distances.

Further studies can be done for hydrogen production centers for the entire country based on their natural resources from the most environmentally friendly perspectives. Then the most economical distribution of hydrogen from those production centers.

## NOMENCLATURE

| | | | |
|---|---|---|---|
| MW | : Mega Watt | NG | : Natural gas |
| MJ | : Mega joule | H | : Hydrogen |
| km | : Kilometer | K | : Thousand |
| kg | : Kilogram | $ | : American dollars |

| | | | |
|---|---|---|---|
| $m^3$ | : Cubic meter | atm | : Atmosphere |
| B | : Billion | TANAP | : Trans Anadolu Doğal Gaz Boru Hattı – Anatolia Transit Natural Gas Pipeline |

**DECLARATION OF ETHICAL STANDARDS**

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee or legal-special permissions.

**CONTRIBUTION OF THE AUTHORS**

**Enis Selcuk Altuntop:** Performed the conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review & editing.

**CONFLICT OF INTEREST**

There is no conflict of interest in this study.

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