Hydrogen in the gas transmission network

ABSTRACT

The main research question of the Task 3.1 was: What is the role of existing methane-based (natural gas) infrastructure in the hydrogen-based energy system? The main target was to improve understanding on potential of existing pipeline infrastructure in transporting gases. The potential was analysed by studying the status of gas networks in various countries and reviewing hydrogen pipeline projects in Europe, and calculating the costs, energy consumption, and greenhouse gas emissions in different hydrogen transportation options in Finland. Furthermore, potential of existing infrastructure in transporting renewable methane (biomethane, synthetic methane) was roughly estimated. The findings indicate that methane pipelines may play a notable role in transportation of hydrogen in Europe but due to a limited coverage and possibly unfavourable location of an existing pipeline in relation to the expected locations of hydrogen production and use, building of new pipelines is needed in Finland. Pipeline transportation of hydrogen and transportation of electricity seem to be the most feasible transportation options. However, a detailed study is needed for each investment because several factors such as hydrogen volumes, transportation distances, the location of hydrogen user and producer, and available infrastructure affect the feasibility.

MOTIVATION

Existing natural gas infrastructure is seen as one means to transport hydrogen and other gases. That is studied by the gas industry in Europe and worldwide, but so far, the research from the Finnish perspective has been missing. Transportation of hydrogen and/or other resources between production and consumption sites is a significant challenge in scaling up renewable hydrogen -based solutions. Thus, it is important to improve understanding on the role of existing infrastructure on the future hydrogen-based energy system and to study other possible transportation options.

RESULTS

The potential to utilize existing infrastructure was evaluated reviewing hydrogen pipeline projects in Europe considering repurposing of natural gas pipelines to transport hydrogen, building of new hydrogen pipelines, and blending of hydrogen to a natural gas pipeline. The blending has been seen as an interesting option for transportation of hydrogen because it could allow the utilization of existing infrastructure with minor modifications and therefore cut costs and building times. Many European countries have tested injecting up to 20% of hydrogen into a natural gas pipeline. A couple of projects has repurposed a natural gas pipeline to 100% hydrogen. For example, Gasunie converted a 40 bar and 12 km natural gas pipeline to hydrogen in 2018 in the Netherlands. The pipeline has been operating since then.

Existing pipelines can also be used for transporting 100% hydrogen, and for that many countries have initiated projects for repurposing existing infrastructure to hydrogen. The repurposing can reduce costs and building times. However, the studies indicate that the suitability of every pipeline for hydrogen must be analyzed and several issues such as a leakage, leakage detection, effects of hydrogen on pipeline assets and end users, corrosion, maintenance, and metering of gas flow must be considered.

One of the studied aspects was to evaluate how the transportation of hydrogen using the existing infrastructure would affect the natural gas users in Finland. Currently, natural gas is mainly used by industry (Figure 1). However, the blending of hydrogen to a natural gas grid has been found to be harmful for some end users, and deblending can be expensive. Both blending of hydrogen with methane and transportation it as a mixture in natural gas pipelines and transportation of 100% hydrogen in natural gas pipelines would require significant modifications to current structures and end user applications, and extra activities. Moreover, as the most potential areas for renewable electricity and subsequently hydrogen production are in the west coast of Finland and the pipeline is in the east and south, there is a mismatch related to pipeline location. Thus, it can be claimed the existing infrastructure in Finland does not have as much potential as infrastructure in many other areas.

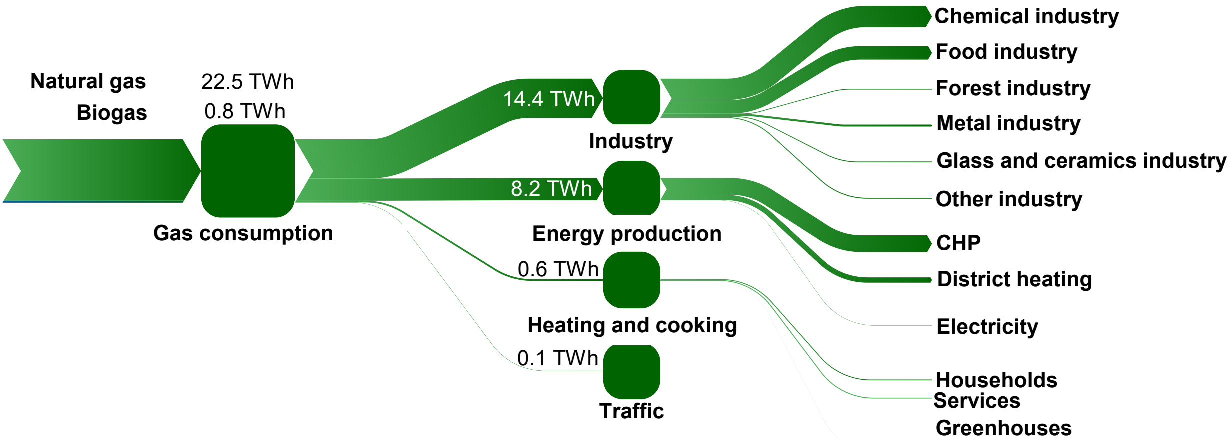

Figure 1. Natural gas consumption in Finland in 2021. Data from the Finnish Gas Association.

Minor share of the activities was allocated to studies related to hydrogen gas odorization. Odorization is normally used in distribution gas pipelines. Based on a review it can be stated that the results concerning the applicable odorants conflict. Some sources claim that there are already products available in the market, and others claim that there are still some challenges to be tackled before application. The identified challenges include a high volatility of hydrogen resulting that the hydrogen escapes before the odorant, and that the end use applications such as fuel cells might be sensitive to the odorizing gas.

For analysing the feasibility to utilize existing pipeline compared to other transportation options, five different hydrogen delivery pathways were reviewed. The pathway options included mill-site electrolysis (i.e., hydrogen manufacturing at the site), hydrogen pipeline transportation in new and repurposed pipelines, transportation of hydrogen in a pipeline as synthetic methane, and hydrogen delivery by shipping. Costs, energy consumption, and greenhouse gas emissions were estimated using a steel mill consuming 144 kt/a of hydrogen.

Mill-site electrolysis and both hydrogen pipeline transportation alternatives (i.e., new and repurposed pipelines) were found to be most feasible in terms of costs, energy consumption, and greenhouse gas emissions. Hydrogen cost varied slightly within these three options, and another two options (the transportation of synthetic methane in a natural gas pipeline and the shipping of hydrogen) led to notably higher costs (Figure 2a). Energy consumption was also the highest in the synthetic methane and shipping cases due to additional conversion processes (Figure 2b).

Greenhouse gas emissions of studied cases varied between 7.7 and 13.7 kg_{CO2-eq}/kg_{H2} in the base case that assumed utilization of wind (40%) and solar (10%) electricity and grid electricity (50%). Synthetic methane route can provide a notable carbon sink if a pyrolysis process is used for converting methane to hydrogen. That opportunity is interesting especially if biogenic CO_2 is used to produce methane. However, the route is expensive and consume a lot of energy.

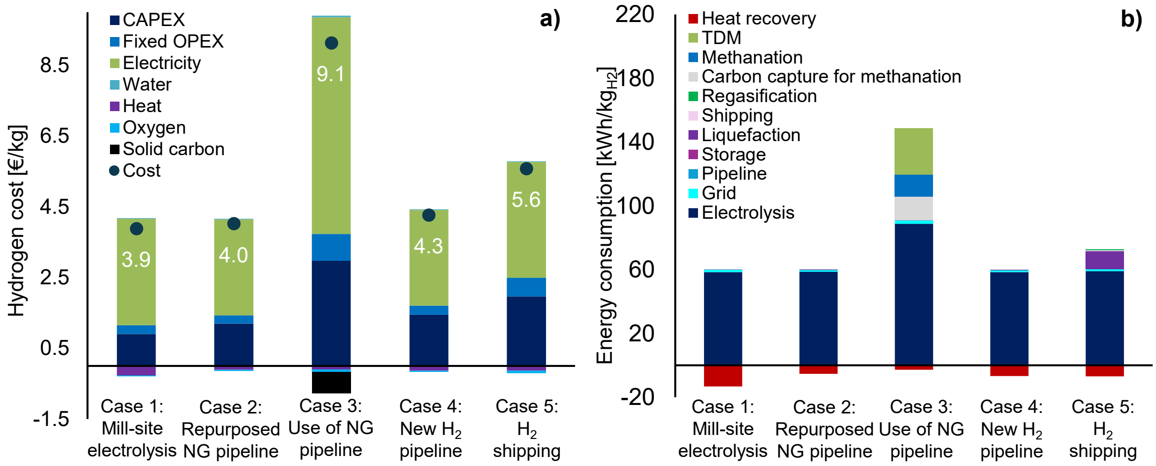

Figure 2. Production costs (a) and energy consumption (b) of hydrogen in studied supply routes.

Many of the used variables contain uncertainties. Sensitivity for some of the variations are presented in Figure 3a. In addition to these, results are sensitive to case-specific properties such as hydrogen volumes, transportation distances, the location of hydrogen user and producer, and available infrastructure. The price of electricity was found to affect the most on the hydrogen cost (Figure 3b). Each transportation case must be separately looked at before investment decisions.

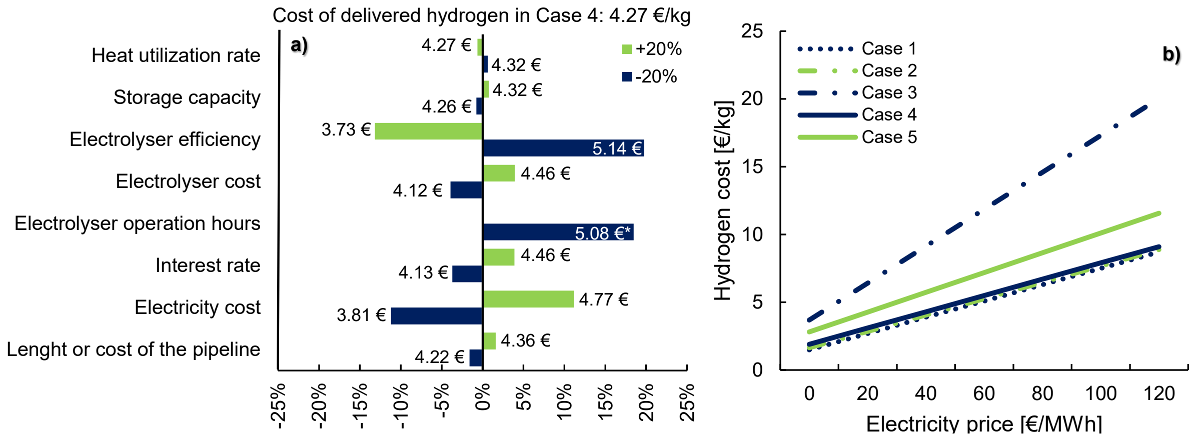

Figure 3. Effect of different variables using Case 4 as an example (a) and the effect of electricity prices on the hydrogen production costs (b).

APPLICATIONS/IMPACT

Utilization of existing natural gas network is possible but difficult, but also new infra will be needed to connect the renewable electricity production sites and CO_2 point sources to produce P2X products at industrial sites. Existing methane infrastructure could be utilized in transporting both biomethane and synthetic methane, but the volume of these gases will remain minor at least in the near future in comparison to the consumption of natural gas in recent years.

In the transportation of hydrogen, transportation as electricity (and conversion of that to hydrogen at the mill site) seemed to be among the most feasible ways. For large-scale transportation needs, hydrogen pipeline is a promising option. However, the feasibility of transportation options between electricity production, biogenic carbon source, and final user depends on several factors such as location, availability infrastructure, and volumes. Detail study needs to be done for each investment.

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