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# *Survey of Supply of Natural Gas Using Hydrogen Pipeline and Conventional Line*

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***Abstract:*** The extensive reliance on non-renewable energy sources has led to significant environmental issues, including global warming and the exhaustion of fossil fuels. Hydrogen, recognized as a well-established carbon-free gas fuel, is emerging as the top contender for future energy solutions. Hydrogen boasts an outstanding energy density and lacks carbon atoms, making it an appealing option for various energy applications (such as internal combustion engines, gas turbines, and fuel cells). However, the current methods of hydrogen production, which are predominantly fossil-based, are seen as problematic due to their low efficiency and the emission of greenhouse gases. It's crucial to develop sustainable and energy-efficient methods of hydrogen production. This paper examines economies of scale hydrogen production both fossil-based and non-fossil, in a general context. It is discovered that the production of bio-hydrogen offers certain environmental benefits and significant potential compared to other hydrogen production methods. The paper delves into the specific characteristics and current research include supply of -hydrogen production techniques. It is observed that each technique presents its own set of advantages, challenges, and potential applications. Additionally, an economic analysis of bio-hydrogen energy is conducted, considering factors such as production, storage, and transportation. The findings indicate that bio-hydrogen production could serve as an effective approach for generating renewable hydrogen, which is not only efficient but also competitive against other hydrogen production methods in terms of economics and environmental impact.

## 1. Introduction

[1] Hydrogen is a promising candidate for future energy sources due to its high energy density and widespread availability. Its energy content, measured in calorific value (140.4MJ/kg), is 3-4 times higher than that of fossil fuels like coke and gasoline. This makes it an attractive option for powering internal combustion engines and gas turbines, which can operate efficiently and with minimal pollution. Additionally, hydrogen is seen as an ideal fuel for fuel cells, as it produces only water as a byproduct, with energy efficiencies exceeding 90%. It is often mentioned as a potential unlimited source of clean energy, emitting no pollutants when utilized as fuel, with water as the only byproduct that can be recycled to produce more hydrogen. Advancements in technologies related to hydrogen energy production, storage, and transportation are happening globally, aiding in the shift towards

clean and decarbonized energy systems. It's important to note that hydrogen production is currently dominated by fossil fuel conversion methods, a practice that must be replaced in the future due to the finite nature of fossil resources and their greenhouse gas emissions. Researchers are actively exploring more sustainable and environmentally friendly methods for hydrogen production to increase its role in global fuel consumption. The most abundant renewable sources for green hydrogen production are water and biomass, which generate hydrogen through various techniques like electrolysis, thermo-chemical decomposition, and biological processes. The energy required for this conversion can come from electricity or heat. Among these green hydrogen production methods, hydrogen production from biomass (bio-hydrogen) has gained significant interest due to biomass being a carbon-neutral.

In addition, bio-hydrogen production technology will not be limited by the scarcity of raw materials, as there is an abundance of biomass resources available, including agricultural and forestry waste such as corn stover, beverage wastewater, sugar beet juice, wheat straw, sawdust, wood chips, shrubs, and branches (among others). The global push for carbon neutrality highlights the increasing importance of hydrogen in its applications. A comprehensive understanding of hydrogen production, storage, and transportation is crucial for the development of efficient and sustainable hydrogen technologies. Therefore, this paper begins by examining the characteristics of various hydrogen production technologies, including those derived from fossil fuels and renewable, non-fossil sources. It then delves into the classification and progress of bio-hydrogen production technologies to shed light on their benefits, drawbacks, and future potential. This article provides a concise overview of current hydrogen production technologies, with a focus on the high efficiency of biomass-based methods. It is evident that bio-hydrogen production technologies offer several advantages and promising prospects for advancing the hydrogen energy economy and reducing environmental pollution. This article aims to offer a detailed summary of biomass-to-hydrogen production via innovative and eco-friendly methods, highlighting their strengths and weaknesses. The choice of the most appropriate hydrogen production method largely depends on the economic viability and geographical distribution of raw material sources, especially for smaller, dispersed plants. Currently, approximately 96% of the global hydrogen supply is generated through this approach.[1][2] To significantly reduce carbon emissions, it is imperative to implement low-emission technologies such as biofuels, carbon capture and storage (CCS), and green hydrogen. The refining sector must play a pivotal role by providing low-emission goods and fuels for industries like shipping, aviation, and petrochemicals. Deep decarbonization requires comprehensive solutions that encompass changes in technologies, infrastructures, organizations, industry strategies, markets, regulations, and user behavior. Many studies in the context of refinery decarbonization have primarily focused on technological and economic aspects. For example, Sachs et al. examined technological pathways for decarbonizing the refinery sector, such as fuel switching, CCS, and energy efficiency. They concluded that a diverse portfolio of technologies is necessary to achieve decarbonization of the global refinery sector. Berghout et al. evaluated deployment strategies for significant greenhouse gas emission reductions in refineries in terms of reduction potential and cost avoidance. They emphasized that costs are highly variable due to uncertainties, especially in energy prices, and that pathway assessments should consider decommissioning existing capital stock, as well as the deployment of biomass supply chains and CCS infrastructure. To achieve deep decarbonization, we must incorporate socio-technical analysis to complement techno-economic models. This analysis addresses crucial aspects such as innovation processes, business strategies, social acceptance, cultural discourses, and political struggles that are essential for facilitating low carbon transitions. It is imperative to conduct further exploration of socio-technical research to accelerate low carbon transitions both conceptually and empirically. Sustainability transitions encompass more than just technological change; they also necessitate corresponding shifts in markets, user practices, policies, cultural discourses, and governing institutions. When developing new technologies, it is imperative to carefully consider the complex interdependencies among different actors, market dynamics, and the imperative for knowledge development and institutional changes. These considerations can result in a restructuring of established modes of production and consumption at the sectoral level. Various analytical frameworks have been devised to enhance understanding of how the transition to sustainability can be catalyzed, managed, or governed in an efficient and socially compatible manner.[2]This paper provides a comprehensive guide for designing and estimating the costs of H2 pipelines, focusing on moving varying amounts of hydrogen per day. It's an essential resource for engineers and scientists, covering gas flow calculations, pressure drop, compression power, and associated costs. Additionally, it includes detailed information and survey on designing, constructing, and operating natural gas pipelines, highlighting the similarities with $H_2$ pipelines.

## 2. Material & Methodes

Table 1: Station and Pipe Size

| Conventional PipeLine | | |
|---|---|---|
| Sl.No | Station | Pipe Size (Inch) |
| 1 | Gathering Pipelines | 4"-12" |
| 2 | Transmission Pipelines | 6" - 48" |
| 3 | Distribution Pipelines | 2"-10" |
| 4 | Service Lines | 0.5" - 2" |

Table 1 above represents the Station and Pipe size for a conventional pipeline.The pipe sizes are considered nominal diameters, and they are a function of city and state requirements.

a. Gathering Station –[3]These pipelines, typically of small diameter, gather raw natural gas from wellheads in production fields and transport it to a processing plant or connect it to the mainline transmission grid. Chemical injection skids are mostly used to remove impurities like water, carbon dioxide, and sulfur that have the potential to corrode the pipeline.

b. Transmission Pipelines-These pipelines, typically 6 to 48 inches in diameter, transport gas over long distances at high pressures (10-120 bar). They are commonly used for the cross-country transportation of crude oil and natural gas.

c. Distribution Pipelines-These pipes, typically 2-10 inches in diameter, definitively deliver natural gas to small industrial plants and customers at lower pressures (2-10 bar).

d. Service Lines-These small pipelines (0.5-2 inches in diameter) deliver gas to residential customers at low pressure (~1 bar).

The hydrogen (H2) pipeline system consists of a network of transmission and distribution pipelines that link production sites to various end users, including large ammonia plants, heat/power sites, residential customers, and hydrogen fueling stations.

Table 2 above represents a Conventional -Hydrogen Line Pipe Comparison. The complete details are as follows:

a) Pipe Line Material – Preferred material of construction Carbon or Stainless with a higher grade as API5L GrX52/X70/X80 is commonly used for cross country pipelines or even at higher gradients. Preferred supply of $H_2$ line pipe is of lower strength steels with usual grades like API5L GrB/X42 etc since they are not suspected to H2 embrittlement.

b) Pipeline corrosion – To serve line pipes for long ages external and internal corrosions are done. Fusion Epoxy bonded or polyethylene heat shrinking sleeves are preferred method. Research is still underway to develop suitable for $H_2$ pipelines.

c) Pipeline Integrity – While pipelines are laid in the ground they are interconnected through common welding procedure. Welding may be automatic or semiautomatic depends upon the material type. Xray is common method to detect any defects at the site. However with Hydrogen pipe line stringent welding procedure is being maintained since welds are succumbed to H2 embrittlement.

d) Safety – Conventional line pipes can be maintained remotely. Updated software are designed for any leak detection. However $H_2$ molecules being small stringent safety protocol needed.

e) Maintenance – Preventive maintenance are scheduled remotely and conducted for conventional pipe line. Also the cost of these line items are less expensive compared to hydrogen line pipe.[3]

Table 2: Conventional -Hydrogen Line Pipe Comparison

| Comparison of Conventional Line Pipe / Hydrogen Pipe Line | | | |
|---|---|---|---|
| Sl.No | General | Conventional Pipe Line | H2 Pipeline |
| 1 | Pipeline Material & Grade | Stainless Steel or Carbon Steel for Cross Country Lines with higher grade API5L GrX52/70/80 | Low strength steel with API5L GrB/X42 works better |
| 2 | Pipeline Corrosion Prevention | Fusion-bonded Bonded Epoxy is the most preferred | Research is underway to develop special. material for H2 embrittlement |
| 3 | Pipeline Integrity | Standard welding (Automatic/Semiautomatic) process followed by Xray to test the weld | Stringent welding procedure adopted owing to H2 embrittlement |
| 4 | Safety | Remotely leak detection can be observed | Stringent safety measures are required since H2 molecules are small and quite inflammable e |
| 5 | Maintenance | Remote maintenance can be done. Maintenance items are not expensive. | Owing to complexity maintenance items are expensive and require periodic inspection |
| 6 | Odorization | Leak detection is performed in natural gas by addition of odorant commonly termed as mercaptan | Research is underway to develop a special material for odorization |

[4] Green hydrogen is produced using renewable energy, whereas blue hydrogen and aqua hydrogen depend on fossil fuels. Hydrogen from renewable sources, known as green hydrogen, is emission-free. On the other hand, hydrogen produced from fossil fuels, when combined with carbon capture and storage (CCUS), can significantly reduce carbon dioxide emissions. Green hydrogen, produced through electrolysis with renewable electricity, blue hydrogen from fossil fuel sources with CCUS technology, and aqua hydrogen from fossil fuel sources without CO2 emissions, are all integral to the low-carbon economy. Nonetheless, current production challenges for these types of low-carbon hydrogen may significantly impact future decarbonization goals[4]

[5]Transporting hydrogen presents significant challenges due to its low energy density, especially in the absence of pipelines. Researchers are actively investigating ammonia, methanol, LOHC, and

liquid hydrogen as potential carriers for long-distance transportation by sea. However, determining the most cost-efficient solution for long-term hydrogen transportation remains inconclusive. The current cost of producing hydrogen using fossil fuels is currently lower than low-carbon production. However, experts assert that a shift to low-carbon hydrogen production is feasible in the medium term. This transition could be facilitated by alternative methods such as nuclear-driven electrolysis, which demonstrate potential for competitive production. In order to enable large-scale use of hydrogen, it is imperative to establish a supply chain infrastructure that connects production and consumption. This may involve developing infrastructure from scratch or repurposing existing assets, such as converting natural gas pipelines to transport hydrogen.[5][6]They rigorously evaluated two distinct alternatives for the hydrogen storage process. The first involved pressurizing the hydrogen into tanks and using trucks for delivery to the refueling stations. The second alternative proposed storing and transporting the hydrogen in hydro-methane form.[6[7] Blending hydrogen into natural gas pipelines is a viable approach for achieving immediate emissions reductions and providing early-market access for hydrogen technologies. However, this method faces significant challenges and uncertainties. Current research provides a comprehensive overview of the material, economic, and operational factors that must be taken into consideration for successful hydrogen blending.[7][8]When natural gas is transported through pipelines, energy conversion and dissipation significantly impact the system's efficiency and energy consumption. A lower pressure drop indicates higher efficiency. Analysis using the energy loss rate helps evaluate the system. Limited analysis exists on H2NG-blend pipeline networks. Geographic Information Systems (GIS) provide essential data. Strategic station placement and gas injection in the pipeline network can significantly influence energy consumption. This study offers valuable insights into using existing natural gas pipelines for hydrogen transport and can provide essential guidance for pressurization station layout design.[8]

## 3. Results

The presence of hydrogen (H2) in steel significantly diminishes its ductility and tensile strength, resulting in the formation of bubbles and potential cracks. Operating conditions with substantial pressure changes markedly accelerate this process. It is imperative to ensure top-notch welds and joints, especially for high-strength steels. Lower-grade steels are considerably less affected by H2 embrittlement. Furthermore, weak welds and hard spots are highly susceptible to H2 damage, underscoring the critical need for defect-free welds and matching material properties in the weld heat-affected zones. Modifications to integrity management programs for natural gas pipelines are imperative to effectively address the specific challenges presented by H2 pipelines.[9]

It is essential to consider the energy transfer differences between natural gas and hydrogen pipelines. Hydrogen has a significantly higher energy density per unit weight compared to methane, but a lower energy density per volume. This necessitates a flow rate of hydrogen 3.29 times greater than that of methane to maintain the same energy level within the pipeline. At typical operating pressures, the maximum flow rates of hydrogen are 2.91 times greater than those of methane. As a result, the energy density of a hydrogen pipeline is limited to about 88.4% of the energy density of a methane pipeline. When higher flow rates are required for H2, there will be a greater need for compression energy. Because compression power is dependent on molar flow rate, it takes approximately three times as much energy to compress an equivalent amount of energy if it's supplied as H2 rather than natural gas. Gaseous hydrogen's low energy density makes transportation and storage in confined spaces extremely costly and inefficient. To address this, alternative methods such as liquefication or incorporation into high energy density molecules are imperative for long-distance transportation and storage. The allocation of hydrogen provision is determined by a cost-optimal approach. Regions rich in wind and solar energy export to meet demand in different areas. The majority of trading occurs within continental regions. Hydrogen is efficiently transported in liquid or gas form over long distances, typically under pressure. It readily permeates various materials, including the steels commonly used in gas pipelines. To advance green hydrogen delivery, it is imperative to significantly raise the safe limits for hydrogen concentration. Introducing hydrogen into natural gas poses substantial challenges, notably affecting steel integrity and fluid dynamics. The phenomenon of embrittlement significantly undermines steel ductility and profoundly impacts mechanical properties. The toughness of a material is crucial for determining its practical strength in the presence of defects. A decrease in toughness, combined with existing defects such as porosity or welding defects, can significantly compromise design calculations. Welds are highly susceptible to hydrogen embrittlement, making them critical areas for potential cracking and failure. Additionally, embrittlement can significantly reduce component lifetimes when considering fatigue crack growth.[10]Hydrogen (H2) and ammonia (NH3), currently derived from fossil fuels, have significant societal and industrial applications, making them prime candidates for large-scale production using renewable energy sources. The production of advanced biofuels will not increase greenhouse gas emissions. Additionally, the ammonia produced from renewable energy will be used as fertilizer for biofuels. It is essential to carefully assess the technology status, economics, overall environmental benefits, commercialization obstacles, and the relative competitiveness of various renewable energy sources.[10]

## 4. Conclusions

The continuous use of fossil fuels, such as oil, gas, and coal, undeniably leads to severe environmental problems like greenhouse effects and air pollution. With an indisputable consensus on climate change and the Paris Climate Accord's resolute ambition to limit global temperature rise well below 2°C, hydrogen is unequivocally garnering increased attention as an essential energy carrier in our future carbon-constrained world. As an indisputably clean fuel, hydrogen undeniably possesses all the requirements and characteristics of a clean and reliable energy source. Hydrogen unquestionably serves as an energy carrier and will play a pivotal role in reducing emissions in hard-to-decarbonize sectors such as peaking and load-following electricity, and industrial heating.

The appropriate addition of hydrogen (H2) significantly improves the efficiency and economy of pipeline transportation. When utilizing existing pipeline networks to transport H2, adjustments to the infrastructure are imperative. Hydrogen being easily produced, transportation is less expensive and sustainable for future.

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