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Decarbonizing natural gas infrastructure: blending hydrogen for sustainable energy

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Abstract. The paper explores the potential of hydrogen as a clean energy carrier and its integration into existing natural gas systems to reduce carbon intensity. It highlights the need for infrastructure impact studies and significant investment to realize the vision of green hydrogen. It also discusses the properties of hydrogen compared to natural gas, its production methods, and the potential for blending hydrogen into existing natural gas pipelines. Additionally, it provides insights into Egypt's energy sector and its efforts to embrace renewable energy. It concludes by summarizing notable studies and projects related to hydrogen-natural gas blending. The blending of hydrogen into natural gas systems is an important and achievable first step towards full conversion to 100% hydrogen. The paper presents a compilation of hydrogen blending projects from different countries, showcasing the collaborative efforts and advancements in integrating hydrogen into existing energy systems.

1. Introduction

While renewables like solar and wind increase, their intermittency drives interest in transitional approaches like hydrogen. Blending hydrogen into natural gas systems could reduce carbon intensity with minimal infrastructure changes [2]. Recent research on hydrogen-natural gas blends has increased [3]. However, real infrastructure impact studies are limited. However, projections estimate rapid growth driven by green hydrogen in the coming years. The World Energy Council forecasts global demand could reach 530 MtH2 by 2050, with the EU (European Union) potentially importing 60 MtH2 of that total [1]. Egypt’s population in 2022 is 105.79 million[2] with GDP recorded in 2022/2023 is 10.2 trillion EGP[3].The targeted renewable energy in Egypt for 2035 is 42%.[4] Egypt’s natural gas reserves in 2022/2023 is 2.65 trillion cubic feet (tcf)[5]. In 2019, Egypt's dry natural gas production amounted to approximately 2.3 tcf, while its consumption stood at around 2.1 tcf during the same period.[6] In the first two months of 2023, the residential and commercial sectors witnessed a decrease of 23% in natural gas consumption compared to the corresponding period in 2022. Additionally, the consumption was 22% lower than the average consumption recorded for the same two months over the past five years.[7]

Green hydrogen can provide a pathway for decarbonizing hard-to-abate sectors like industry, transport, heating, and power generation. Studies estimate hydrogen could supply up to 25% of global energy needs by 2050.[8] Significant growth is expected in the coming decades, with demand potentially reaching over 400 million tonnes by 2050 according to IRENA’s (International Renewable Energy Agency) projections. Costs for green hydrogen from electrolysis are high, reaching \$3-7/kg and requiring incentives [9]. Hydrogen has different properties than natural gas. It has lower density and heating value by volume, but higher flame speed, diffusivity and energy density by mass[10]. The lower heating value represents how much energy you can get out of one Kg of fuel based on a mass basis. On a mass basis, Hydrogen possesses about 2.4 times the energy density of methane. So, by burning one Kg of hydrogen versus one Kg of natural gas, you will get 2.4 times the energy.

2. Hydrogen ways of production

Over the past century, various methods for hydrogen production have undergone significant advancements, driven by the recognition of hydrogen's pivotal role in future energy systems. As depicted in Figure ***1***, historical hydrogen production relied heavily on fossil fuel feedstocks, notably coal and natural gas. However, recent advancements have focused on renewable production pathways that harness solar, wind, hydro, geothermal, and biomass energy sources. This transition aligns with the growing consensus that low-carbon hydrogen will be indispensable for deep decarbonization across diverse sectors, including industry, transportation, and power generation. While established thermochemical processes such as steam methane reforming may persist in the medium term, incorporating carbon capture and storage, long-term projections envision electrolytic hydrogen derived from renewable electricity surpassing other production methods. This shift towards renewable-based production aligns with hydrogen's projected central role in facilitating global net zero emissions by the middle of this century [11].

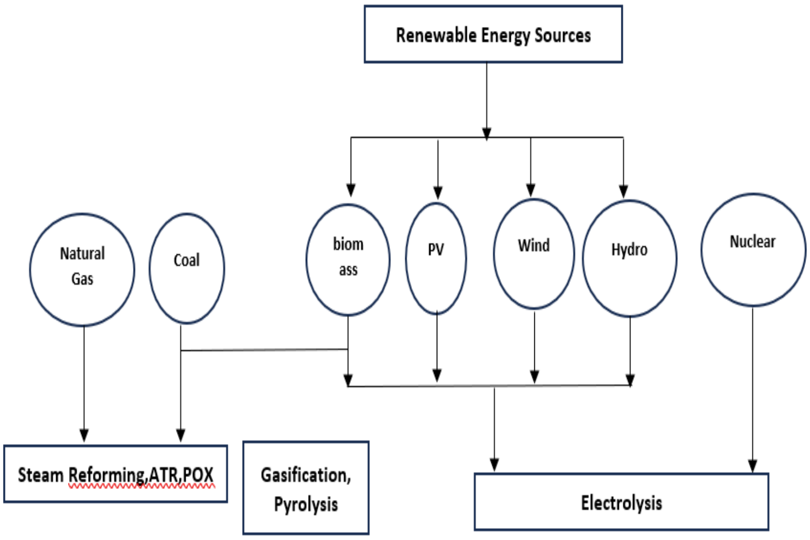

Figure 1. Hydrogen production pathway [12]

3. Egyptian Energy Consumption Overview

Natural gas accounted for 57% of Egypt's energy consumption in 2020 as shown in Figure 2, followed by petroleum at 36%[13]. Egypt also has substantial potential for renewable energy, with plans to reach 42% of electricity generation as shown in Figure 3 from renewables by 2035[14]. In 2019 only 5% of the country's installed power capacity came from renewables like solar and wind [6]. Egypt exported around 64 billion cubic feet (bcf) of liquefied natural gas (LNG) in 2020, going mainly to Asia Pacific countries [13]. Egypt aims to become a global renewable energy hub and is actively pursuing projects to expand its solar, wind, and biomass generation capacity, as shown in Figure 4.

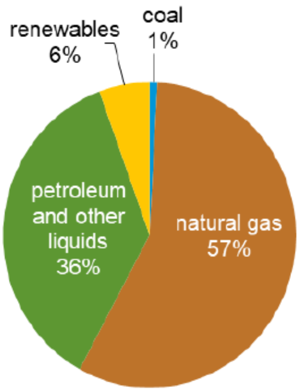

Figure 2. Primary energy consumption in Egypt, 2020

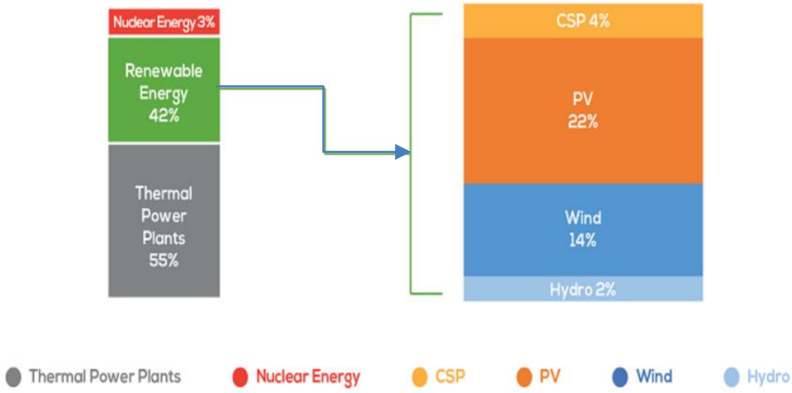

Figure 3. Plan of Electricity Production in Egypt by 2035[15]

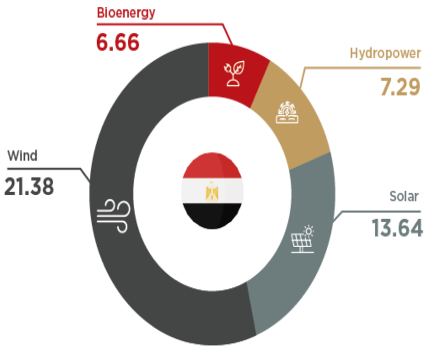

Figure 4. Egypt Share Plan from Africa's Capacity (%) [16]

In 2022, the New and Renewable Energy Authority (NREA) and private sector continued efforts from 2021 by implementing additional renewable energy projects. This includes NREA wind energy projects expected to add 252 megawatts (MW) to Egypt's renewable capacity. Private sector wind and solar projects currently under development will supply a further 3,500 MW. Given Egypt's high solar irradiation, solar projects comprise the largest share at 52% of new renewable capacity, while biomass constitutes the smallest share, according to NREA data. Egypt's geographic solar advantages, policy support, and private investment are enabling the country to substantively grow its renewable energy base as part of its strategy to become a global renewable energy leader.[17]

4. Hydrogen-natural gas blending studies and projects

Blending hydrogen into existing natural gas pipelines has been proposed as a transitional approach to deliver hydrogen to end users without requiring dedicated hydrogen delivery infrastructure. This blending strategy would inject hydrogen into natural gas networks at low concentrations, relying on separation and purification technologies at the end point to extract pure hydrogen. As an early market bridging strategy, hydrogen blending can defer costs of building dedicated hydrogen pipelines and facilities during market development. However, blending also incurs additional costs for injection, extraction, and pipeline modifications that must be weighed versus other hydrogen delivery options. [18]
According to NREL (National Renewable Energy Laboratory), blending hydrogen (5-15% by volume) appears feasible with minor modifications to pipelines and end-use appliances. Adding renewable hydrogen to natural gas can reduce greenhouse gas emissions and improve sustainability if the hydrogen is produced from low-carbon sources like biomass, wind, solar or nuclear. End-use appliances like household boilers and stoves are the most limiting factor, with blends above 5-20% potentially requiring modifications. Appliance requirements vary

significantly. Safety risks increase somewhat with hydrogen blends but are considered minor, up to 20% hydrogen. Risks depend on many specific factors and increase above 50% hydrogen. Most pipeline materials are durable with hydrogen blends up to 20-50%, but high-pressure steel pipelines are more susceptible to embrittlement at higher blend levels [18]. Lapo Cheli et al. studied that gas distribution networks can absorb the renewable energy surplus through hydrogen injection. The injection of hydrogen into the natural gas network has gained interest in the scientific world due to the diffusion of renewable energies and the development of Power-to-Gas (P2G) technologies. Several recent works have studied the behavior of gas pipelines and gas distribution networks with natural gas, as well as in the presence of hydrogen or alternative gas injections. The effect of hydrogen injection on quality indexes and fluid-dynamic parameters of the gas flow is highlighted. The Wobbe index, which is associated with a chromatic scale, is used to analyze the values of hydrogen blending and is presented on the map of the gas grid.[19]

References

[1] Énergie C M D E L, Gadonneix P, Kim Y D and Meyers K 2021 World Energy Scenarios Composing energy futures to 2050.
[2] Anon Current Population (LIVE) CAPMAS
[3] Business Today Egypt Annual economic growth hit 3.8% in FY22/23, expected at 4.2% for FY23/24 | MPEDMin
[4] Moharram N A, Tarek A, Gaber M and Bayoumi S 2022 Brief review on Egypt's renewable energy current status and future vision Energy Reports 8 165–72
[5] State Information Service Petroleum Ministry: Natural gas reserve hits 2.65 trillion cubic feet in FY 2022-2023
[6] U.S. Energy Information Administration 2022 Country analysis executive summary: Egypt
[7] Anon 2023 Natural Gas Weekly Update EIA
[8] DNV 2022 ENERGY TRANSITION OUTLOOK 2022
[9] IRENA 2022 Geopolitics of the energy transformation: the hydrogen factor.
[10] Keçebaş A and Kayfeci M 2019 Hydrogen properties Solar Hydrogen Production: Processes, Systems and Technologies (academic press) pp 3–29
[11] Ayodele T R and Munda J L 2019 The potential role of green hydrogen production in the South Africa energy mix Journal of Renewable and Sustainable Energy 11
[12] Ayodele T R and Munda J L 2019 The potential role of green hydrogen production in the South Africa energy mix Journal of Renewable and Sustainable Energy 11
[13] BP 2021 Statistical Review of World Energy globally consistent data on world energy markets and authoritative publications in the field of energy BP Energy Outlook 70 72
[14] Anon 2023 Renewable Energy Targets NREA - New and Renewable Energy Authority
[15] Anon 2023 Renewable Energy Targets NREA - New and Renewable Energy Authority
[16] MONSEF J and BALBAA M A M 2023 Egypt's Renwable Market:Achievements and prospects Egypt Oil & Gas 6
[17] MONSEF J and BALBAA M A M 2023 Egypt's Renwable Market:Achievements and prospects Egypt Oil & Gas 6
[18] Melaina M W, Antonia O and Penev M 2013 Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues. Technical Report NREL/TP-5600-51995, National Renewabler Energy Laboratory vol 303
[19] Cheli L, Guzzo G, Adolfo D and Carcasci C 2021 Steady-state analysis of a natural gas distribution network with hydrogen injection to absorb excess renewable electricity Int J Hydrogen Energy 46 25562–77