DECARBONIZATION POTENTIAL AND TECHNICAL FEASIBILITY OF CLEAN HYDROGEN IN VIETNAM

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Overview

Low carbon hydrogen could play a crucial role in the global NetZero transition, especially in hard-to-decarbonize sectors. Hydrogen (H_2) has high gravimetric energy density, reacts with oxygen to produce only water, is a key input for petrochemicals, and has been used as fuel in several types of vehicles. For Vietnam, the world's 17^{th} largest emitter of greenhouse gases and one of the countries most heavily affected by climate change, decarbonization is urgent, and the country has made strong commitments to reach NetZero by 2050. Low carbon hydrogen and hydrogen-based fuels have been included in the 2022 update of Vietnam's Nationally Determined Contributions (NDC) and in its 2023 Power Development Plan (PDP8) as alternatives to fossil fuels. In February 2024, Vietnam approved its first National Hydrogen Strategy (NHS), which sets the target of producing 100-500 kt of clean hydrogen by 2030 and 10-20 Mt by 2050. By 2050, hydrogen fuels are expected to account for at least 10% of the country's final energy consumption. These targets are in line with the energy transition outlined in the PDP8.

This study looks at the quantitative decarbonization potential and the technical feasibility of clean hydrogen fuels in Vietnam. Hydrogen is already produced and used in Vietnam, but it is almost entirely from carbon-based approaches (grey and brown hydrogen) and used onsite in refineries and fertilizer production. The decarbonization potential of clean hydrogen fuels would come from two main sources: (1) changing production from grey and brown to green (water electrolysis powered by renewable energy) and blue hydrogen (fossil sources coupled with carbon capture and storage CCS), and (2) using clean hydrogen fuels to replace fossil fuels in other industries, most notably in the power sector. To produce the targeted amounts of green hydrogen, a large supply of renewable energy is required, while blue hydrogen would necessitate carbon storage capacity. Based on currently available data and projections, the energy supply and storage could be met, but logistics remain a big challenge.

Methods

The life cycle global warming potentials (GWPs) of relevant types of hydrogen are gathered from previous studies and reviews, which provide the CO_2-eq emission per kg of hydrogen produced. Since limited studies on Vietnam's hydrogen production are available, most GWP data are from other countries and regions. Emission cuts from changing hydrogen production methods are calculated from direct comparison between current Vietnam's production (grey and brown hydrogen) and targeted production (green and blue hydrogen). Current outputs are from the Vietnam Petroleum Institute (VPI), and targeted outputs are based on the NHS.

Further emission reductions from the application of low carbon hydrogen and hydrogen-based fuels (ammonia) in the power sector are calculated based on the difference between the GWPs of electricity produced via different methods. Current values for Vietnam's electricity production and emissions are from reports by the Electricity Vietnam Corporation (EVN) and the Vietnam Department of Climate Change. GWPs of electricity produced from hydrogen and ammonia are from published life cycle assessments. The targeted capacity of fossil-based electricity to be replaced by low-carbon hydrogen fuels is from the PDP8.

Results

Based on reports by VPI, Vietnam produced 494 kt H_2 in 2022, consisting of 74% grey hydrogen from steam methane reforming and 26% brown hydrogen from coal gasification. With a GWP of 9.30 kgCO_2-eq/kg grey-H_2 and 22.58 kgCO_2-eq/kg brown-H_2, the total emission from hydrogen production in Vietnam is around 6.3 Mt CO_2-eq/yr.

The NHS targets production of 100-500 kt low carbon hydrogen per year by 2030 but does not specify the relative amounts of green and blue hydrogen. The base scenario for comparison is 500 kt H_2 produced annually via current production methods, i.e., a mixture of 74% grey and 26% brown, which has a total emission of 6376.4 ktCO_2-eq/yr. In the best-case scenario, 500 kt/yr production of low carbon hydrogen is reached and all of it is green hydrogen from wind energy, which has a GWP of 1.79 kgCO_2-eq/kg H_2. Total emission under this scenario would be 895 ktCO_2-eq/yr, an 86% reduction compared to the base scenario. If 500 kt of blue hydrogen is produced instead, assuming the 74%-26% distribution between grey and brown, then the total emission would be 1885.1 ktCO_2-eq/yr, a 70.4% reduction. Even if only the lower target of 100 kt clean hydrogen/yr is reached, changing from grey to blue hydrogen, this scenario still represents a reduction of 573 ktCO_2-eq/yr or a 9.0% reduction.

The NHS aims at production of 10-20 Mt low carbon hydrogen per year by 2050. There is no base case scenario to compare this production with, as this target is set based on expected demand for low carbon hydrogen, not for fossil-based hydrogen. That is, this goal is not about shifting 10-20 Mt of fossil-based hydrogen to clean hydrogen but is new demand for clean hydrogen only. The decarbonization effect of this low carbon hydrogen would come from its usage in various areas, primarily the power industry.

PDP8 targets the share of hydrogen and ammonia-fueled power plants at 9.8 to 13.4% of total national capacity by 2050. Specifically, 32430 MW of gas power plants are to be converted to hydrogen by 2050, producing 161.2 to 168.6 million MWh of electricity, and all coal power plants are to switch to biomass and ammonia, with a total capacity of 25632 - 32432 MW, producing 72.5 - 80.9 million MWh of electricity.

Based on data from the Department of Climate Change, Vietnam's current emission factor of coal power plants is 1.108 tCO_2-eq/MWh, and that of gas turbine power plants is 0.3764 tCO_2-eq/MWh. If the target for switching natural gas to hydrogen is reached, with the GWP of electricity produced from green hydrogen (which is based on wind energy) being 0.072 tCO_2-eq/MWh, the emission reduction would be 50.13 MtCO_2-eq/yr, an 80.9% reduction. The effect of replacing coal with clean ammonia (also produced using wind energy) would be 77.5 MtCO_2-eq/yr reduction. This is based on a 0.0973 tCO2/MWh GWP of electricity produced from mono-firing ammonia in thermal plants. Compared to the base scenario of producing 76.7 million MWh/yr from coal and 164.7 million MWh/yr from natural gas, the best-case scenario under the PDP8 would lead to a total decrease of 127.65 MtCO_2-eq/yr by 2050, or an 87% reduction, by using clean hydrogen and ammonia to replace fossil fuels in power plants.

Does Vietnam have enough renewable energy to produce these amounts of green hydrogen? The current excess output of wind and solar that is not absorbed by the grid in 2023 is approximately 16,238,000 MWh, which is enough to produce around 300 kt of green hydrogen using current electrolysis technology. By 2030, total wind and solar capacity is expected to double compared to 2023 number and would be more than enough to produce the desirable 500 kt of green hydrogen. However, the 2050 numbers are less convincing. It would take almost all the planned renewable energy capacity (357844 MW by 2050) to produce 20 Mt of green hydrogen annually, even with improved electrolysis technology. As such, a scenario of all green hydrogen is not feasible, and blue hydrogen must also be included. Blue hydrogen, depending on the carbon source, has different captured amounts of CO_2 ranging from around 9 kg CO_2 captured per kg blue-H_2 from steam methane reforming to around 18 kg CO_2 captured/kg blue-H_2 from coal gasification. To produce 10 Mt of blue hydrogen would therefore need 90-180 Mt CO_2/yr to be captured and stored. Vietnam has large potential carbon storage capacity, with geological sites estimated at around 71 Gt CO_2. However, CCS is at a very early stage in Vietnam, and more studies should be conducted to get a clearer picture. Furthermore, both green and blue hydrogen need extensive infrastructure development for the storage and transportation of the produced gas. In addition to repurposing existing gas pipelines, large investments are needed to develop logistical facilities and bring down the cost of low carbon hydrogen.

Conclusions

Vietnam has acknowledged the role of hydrogen in its energy transition, with the inclusion of clean hydrogen fuels in its most updated NDC and PDP. If the target of 100-500 kt low carbon hydrogen production by 2030 is reached, a reduction of 573 to 895 kt CO_2-eq/yr could be realized, depending on the amount and ratio between green and blue hydrogen. This cut is from changing production methods, and the outputs are enough to satisfy the current demand for hydrogen in petrochemical industries. By 2030, Vietnam should have enough renewable energy capacity to produce 500 kt of green hydrogen annually.

Demand for clean hydrogen is expected to rise in the coming decades. The NHS aims at clean hydrogen production of 10-20 Mt/yr by 2050, and low carbon hydrogen and ammonia would account for 10% of final energy consumption, which aligns with the PDP8. If the PDP8 targets for 2050 are realized, using clean green hydrogen and ammonia to replace fossil fuels in power plants would result in an emission cut of 127.65 MtCO2-eq/yr, or an 87% reduction compared to the base scenario. However, the renewable capacity by 2050 is barely enough to produce 20 Mt of green hydrogen, thus blue hydrogen must also be part of the mix. With an estimated geological storage capacity of 71 Gt CO2, Vietnam has good natural conditions to develop CCS. Nonetheless, this is still at a very early stage. In contrast, a green hydrogen production plant is already under construction in Tra Vinh province, and more projects are on the way. Green hydrogen stands to help with energy storage for renewables while the grid is being upgraded, and could also decarbonize Vietnam's urea, steel, and cement production, which all rank in the top 10-20 in the world. Policy frameworks to support both green hydrogen and CCS must be and are being developed. Finally, global partnerships (JETP, COP, AZEC, bilateral collaborations, etc.) are much needed to provide both financial and technological support for the hydrogen economy in Vietnam.