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Review

# A design for hydrogen production and dispensing for northeastern United States, along with its infrastructural development timeline

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ABSTRACT

Countries are trying to reduce their energy consumption, fossil fuel usage, and greenhouse gas emissions. Recent guidelines generated by various government agencies indicate an increase in the fuel economy, with a reduction in green house gases. The use of both alternative fuel vehicles and renewable energy sources is thus necessary toward achieving this goal. This paper proposes a hydrogen fueling infrastructure design for the North-eastern United States. The design provides an implementation plan for a period of 13 years (from 2013 to 2025). This design gives priority to customer convenience with minimum additional investments for its implementation. Extensive research has been conducted on generating a hydrogen supply from factories and other potential sources that can satisfy demand in the region. Markers (e.g. population density, traffic density, legislation, and growth pattern) have driven the process of demand estimation.


## Introduction

Fossil fuel-based energy carriers that are currently satisfying most of the energy demands, in both developed and developing countries; are becoming depleted. Political unrest in the supply regions has many nations turning to home energy grown resources. Global warming caused by the use of fossil fuels has not only limited the options for possible energy sources but also constrained greenhouse gas (GHG) emissions. The estimated fuel economy and greenhouse gas emissions standards proposed for light-duty vehicles (LDVs) for model

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years 2017–2025 have an increase of 44% in fuel economy and a reduction of 34% in GHG emissions [1]. The Use of both alternative fuel vehicles and renewable energy sources is therefore necessary toward achieving this goal. Hydrogen derived from renewable energy sources is a practical solution to this problem. It can serve as a sustainable energy provider while leaving a zero-carbon footprint at its point of use [2,3]. Kim and Moon [4] discussed the effect of using hydrogen in the transportation sector of Korea. They found that hydrogen production from renewable and nuclear resources is a practical possibility that could cover 76% of the road transportation sector by 2044.

Surveys conducted in the United States have also suggested a similar trend, projecting a substantial increase in the use of hydrogen powered fuel cell vehicles. Feasibility studies on basic infrastructural needs have become extremely essential to the success of this shift. Approximately five years ago, designing a Hydrogen Community [5] conducted a feasibility study on the implementation of a hydrogen fueling infrastructure for the state of California. This study systematically determined the optimum fueling method, its storage and dispensing, and the cost incurred to the end user. Although this model study can be modified to determine the best practices for the implementation of a hydrogen infrastructure across the entire United States, the unique geographical characteristics of various regions do not allow such.

California is located close to a petroleum rich portion of the United States. This location allows the state to utilize the hydrogen production facilities already available in the vicinity. Hydrogen production infrastructures are not so readily available in other portions of the country. Thus, a region-specific feasibility study is needed to determine a successful method of implementation.

This study focused on the northeast quadrant of the United States. This region does not contain any petroleum resources and, as a result, cannot readily produce hydrogen. This work examined the geographical characteristics of the region to provide an optimum method of hydrogen production, transportation, storage, and dispensing. The results indicate that the hydrogen produced from biomass may be best approach for the northeast of United States. They also suggest that liquid hydrogen transport and storage facilities when the resources are scattered. Additionally, the hydrogen should be dispensed in a gaseous form to avoid the safety concerns related to liquid hydrogen [6,7].

Hydrogen has long been known to be an energy carrier. Holladay et al. [8] and Bicakova and Straka [9] compiled a wide range of hydrogen production technologies, including fuel processing, biological conversion, and thermo-chemical conversion processes. They also suggest that biomass, in the near term, is most likely the renewable organic substitute to petroleum. Ni et al. [10], Kalinci et al. [11], and Kirtay [12] examined hydrogen production technologies that use biomass as the raw material. They discussed the alternative thermochemical and biological processes used to convert (abundantly available) biomass to produce clean hydrogen. Based on their analyses, they suggested the use of gasification rather than using the pyrolysis process. A novel gasification process known as Reaction Integrated Novel Gasification was also proposed. This work, however, was done at a laboratory scale. Balat and Kirtay [13] presented a discussion on the viability of hydrogen production from biomass. They suggested that, because of the lack of a hydrogen infrastructure, it is advisable to begin with steam methane reforming and then gradually move towards hydrogen production from biomass.

Bjorklund et al. [14] examined a possible enhancement of waste management and transportation by integrating two emerging technologies, municipal solid waste (MSW) gasification and fuel cell vehicles (FCVs). They propose fueling FCVs with hydrogen produced from gasified MSW through 2010–2020. Material and energy flows are modeled for MSW management scenarios and transportation scenarios. Bjorklund et al. [14] suggested that when compared to incineration and landfilling, gasification is not only more efficient but also more environmentally friendly.

Demirbas et al. [15] discussed possible methods that can be used to convert organic wastes into biofuels. They suggested that waste to energy technologies can be used to produce biogas, syngas, liquid biofuels, and pure hydrogen. They examined that biomass can be considered as the best option and also discussed the most potential for meeting the future fuel demands.

Many researchers have provided strategies that would allow an effective introduction of hydrogen in the transportation sector. Gim et al. [16] provided a mathematical model to suggest a strategy for implementing a cost-effective centralized hydrogen supply system. They also provided an estimation method for hydrogen demand that can be used to predict what fuel cell cars that will reach the markets. Based on these estimations, Gim et al. [16] suggested a decentralized hydrogen production in terms of on-site hydrogen production until 2040, and centralized production and distribution after that. Considering the already available pipeline network, they suggested the use of pipeline distribution after the year 2040.

Farrell et al. [17] studied the impact of hydrogen fuels on numerous factors, including the fuel transition period, vehicle design, usage patterns, infrastructure development, and operational challenges. They provided a strategy that introduces hydrogen as a transportation fuel. They also recommended beginning the implementation with heavy-duty vehicles. Experiences incurred with this implementation can be used to wisely introduce it for low duty vehicles.

Zhao and Melaina [18] discussed the findings of existing alternative fuel vehicle (AFV) programs in the both US and China. Lessons learned in the deployment of AFVs were provided and utilized to suggest necessary policy recommendations, thus allowing for China's effective transition to hydrogen vehicles.

Research on the implementation of hydrogen as an energy carrier in the transportation has been rather limited. Even with the introduction of 'Transition to Hydrogen Economy' initiative about a decade ago, the present market for hydrogen is more focused towards refining and chemical processing. Hydrogen fueling infrastructure in the United States has just slowly begun to emerge. Currently the Unites States contains about 60 fueling stations. About 23 of these hydrogen fueling stations are located in the state of California itself. From the available 60 fueling stations about 50 stations are nonretail-ready. Leading vehicle manufacturers consider hydrogen as