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*Editorial*

# Climate Benefits Advocated by the Development of Sustainable Vehicles and Charging Infrastructures in the Transport Sector

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Sustainable transportation refers to low vehicular greenhouse gas (GHG) emissions, energy efficient vehicles, and affordable modes of transportation, including electric and alternative fuel (AF) vehicles. This editorial paper briefly describes the recent research contributions covering a wide range of trending topics that provide an overview on the current and forthcoming developments in road transportation with electric and AF vehicles, establishing a recharging and AF refueling infrastructure, and GHG emission reductions.

Islas-Samperio et al. [1] propose a low carbon scenario (LCS) for the transport sector in Mexico that can be achieved through the application of 21 GHG mitigation measures. The LCS consists of a transport sector conversion path that involves structural changes in passenger and freight mobility, utilization of new mobility technologies, use of electric motors and biofuels, emission regulations, and urban planning. Nevertheless, they show that the main hurdle is to raise the necessary investment to achieve this energy transition in a capital-intensive sector such as the transport sector in Mexico, where an overall investment of MXN 64,326 (m-stable US dollars) is required to perform the actions that are necessary to attain a low carbon transport sector to curb climate change.

Haus et al. [2] examine the GHG emission reduction obligation system that was employed in the road transport sector in Sweden to support the use of biofuels. Their analysis shows that sawdust-based ethanol exhibits low life cycle GHG emissions, leading to a GHG emission reduction close to 93% compared to liquid fossil fuels. They also assert that the reduction obligation system is a long-term political instrument with a projected reduction target for 2030, which is another important prerequisite to lessen the financial risks of investors. However, in a short-term view, evolving sawdust-based ethanol production systems, as well as other lignocellulosic-based ethanol systems, is expensive and economically risky. Therefore, there is a need for additional economic incentives to facilitate a successful market introduction.

Wu et al. [3] introduce a methodology for the optimal planning of multi-functional charging stations (MFCSs) to serve multiple types of vehicles, including battery electric vehicles (BEVs), hydrogen fuel cell vehicles, natural gas vehicles, and gasoline fuel cell vehicles. Most of the techniques published in the literature regarding the location and size of charging stations for low-emission vehicles generally assume that vehicles have the same attributes, which is impossible in practice. The authors define four attributes to replicate the actual traffic flow in an urban area (driving range, initial fuel tank level, current fuel tank level, and refueling time) to differentiate vehicles that use different types of fuel (electric, hydrogen fuel cell, and natural gas). A bi-level planning model was developed to locate and size MFCSs in a medium-sized city with different functional areas, such as residential areas, a central business district, and industrial areas. A multi-destination approach was utilized to determine the drivers' daily travel routes. The daily route for each user is assumed to be a closed-loop journey which starts and ends at home. The authors suggest a technique for generating daily routes considering vehicle attributes and user habits. They load these traveling data into the upper model to select a set of feasible combinations of refueling station locations with a relatively high success ratio. In the lower model, they

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establish a mathematical relationship between the number of chargers and the average user waiting time, and set a social cost factor, including investment cost and waiting time cost, to evaluate each possible combination of station locations to identify the optimum locational result and define the size of each station. A case study in a medium-sized city was used to verify the proposed model in several scenarios and the authors conclude that the MFCS planning model performs very well in terms of cost of setting up the refueling stations and users' satisfaction level.

Burchart-Korol et al. [4] describe the current infrastructural state, planned activities for the next few years, and research in the field of electromobility and AFs used in the transport sector in Poland. Although the current market for electromobility and AFs in Poland is underdeveloped, they report that, according to the assumptions established in the national policy framework for the development of an AF infrastructure, about one million electric cars will be driving on Polish roads by 2025, and over 6000 publicly available charging stations for such cars will be operating by 2023. Concerning the development of the natural gas market in transportation, around 70 compressed natural gas (CNG) fueling stations were supposed to be built in 32 Polish agglomerations by 2020. In addition, over 54,000 compressed gas-powered vehicles will be on Polish roads by 2025. They also report that the share of biofuels in road transportation in Poland stands at only 4%, while the requirements in the European Union are 10%. Even though there is considerable potential for the use of hydrogen as an alternative to conventional fuels in the country, only one hydrogen-powered vehicle has been registered in Poland so far, without any filling station in existence for this fuel. The synthetic fuel sector in Poland is clearly in the planning stage.

Park et al. [5] report that the most prominent substitutes for AF vehicles are BEVs and fuel cell electric vehicles (FCEVs). Considering that specific guidelines for the development of a FCEV infrastructure for hydrogen refueling stations have not been provided, this study provides a quantitative assessment of consumer preferences in Korea for an FCEV infrastructure. Depending on the type of energy employed in production, hydrogen is either green (does not generate GHG emissions) or gray (does emit GHGs). This study also reveals that most consumers are willing to pay more for green hydrogen than for gray hydrogen. Moreover, although FCEVs have the advantage of low maintenance costs, this study finds that, for environmental reasons, most consumers accept FCEV maintenance costs even if they are higher than the current fossil fuel vehicle maintenance cost. Furthermore, in this study, the waiting time for refueling is specified by the number of dispensers, which are categorized into high-pressure and low-pressure dispensers. While the difference in preference according to the dispenser pressure is not disclosed, it is more desirable to have several dispensers. Although the preference for avoiding waiting time for refueling is not determined, the minimum requirement for the number of dispensers is set to one high-pressure and one low-pressure dispenser per refueling station. Existing hydrogen refueling stations in Korea cannot refuel more than 50 FCEVs per day, and there are no plans to build additional hydrogen refueling stations in the country.

Martins and Brito [6] analyze the use of AFs for internal combustion engines (ICEs). They consider that the recent transport electrification trend to limit the future use of ICEs has not been properly justified. The concern does not appear to be with the engines or the combustion process, but rather with the rise in GHGs, namely $CO_2$, released into the atmosphere. However, the difference between fossil $CO_2$ and renewable $CO_2$ production is not usually considered, just as the difference between $CO_2$ emissions and pollutant emissions is not. This study introduces various types of AFs that can be burned in ICEs and may be able to eliminate, or substantially reduce, the emissions of fossil $CO_2$ into the atmosphere. These AFs may be non-carbon fuels, such as hydrogen or ammonia, biofuels, such as alcohols, ethers, or esters, as well as synthetic fuels. There are other fuels that could maintain ICEs as a valuable option for road transportation, such as fuels based on turpentine, which is the fluid obtained from the distillation of pine resin, or even glycerin, which is a side-product of biodiesel production from vegetable or animal feedstocks.

Bethoux [7] describes that many obstacles in the development of fuel cell vehicles (FCVs) still need to be overcome to be able to transition from a functional but niche product to a mainstream consumer product. The purpose of this study is to address the difficulties that are not covered by the most recent innovative approaches. At least in the long-haul in the heavy-duty trucking sector, FCVs will play a key role in the path to zero emissions in the next one or two decades. Hence, this study also examines the structure of the complete supply chain, including the production, storage, and distribution of hydrogen. Green hydrogen appears to be one of the most technically viable types of renewable energy. The greener the electricity is, the greater the advantage for hydrogen, since it permits economically to store large quantities of energy seasonally. Furthermore, natural hydrogen might also become an economic reality, pushing FCVs to be a competitive and environmentally friendly alternative to BEVs. Based on its own functional benefits for onboard systems, green hydrogen in combination with FCVs will achieve the large-scale use of hydrogen in road transportation once renewable energies become more widespread.

Palander et al. [8] provide the technological development requirements in road network infrastructure to increase the capacity of freight transportation. They prove that road network development affects the environmental efficiency of high-capacity transportation (HCT). They developed a method for the computation of the emission parameters that could describe both the road network setup and the backhauling transportation. This was possible by calculating the total HCT efficiency index, which was determined by dividing the calculated emission target of energy use by the actual emission level from energy use. For instance, the total HCT efficiency index showed that reducing the share of forest roads in the road network setup could improve the environmental efficiency of the current forest road density in Finland. In addition, the development process produced a useful $CO_2$ emission value table and the environmental efficiency order of the HCT alternatives. The results of this study provide a general approach for the planning and design of road network setups, with a special emphasis on upgrading the existing forest roads without reducing the road density, given HCT alternatives, by increasing backhauling and selecting a vehicle combination.

Although green hydrogen represents an alternative to conventional fuel for reducing GHG emissions in transportation, Lahnaoui et al. [9] consider that its thermodynamic properties make transportation and storage of this type of energy under standard conditions inefficient. Thus, this study examines alternative solutions that could be used to transport and store hydrogen to reduce the cost associated with the infrastructure deployment for mobility. These solutions are investigated for different production and demand scenarios in France and Germany. The general modeling approach aims to link production and demand nodes following the road infrastructure and using different transportation cost functions corresponding to alternative transportation modes. Thus, the model output for each edge gives the optimum capacity transported by each state and then the minimum cost of the entire network. The model is used as a framework for the road infrastructure, hydrogen production, and demand scenarios, assuming hydrogen production from wind power projections and a demand driven by mobility.

Nahar et al. [10] use a life cycle assessment technique to evaluate and compare energy consumption and GHG emissions from pelleted and non-pelleted corn stover as a biorefinery feedstock. The operations analyzed in the evaluation were pelleting, transportation, and soaking in aqueous ammonia (SAA) pretreatment. Even with greater GHG emissions generated from the pelleting process, their study shows a considerable opportunity to offset and even reduce overall GHG emissions considering the benefits of the pretreatment process. Thus, the SAA-pretreated pelleted biomass might be a feasible alternative as a cellulosic biorefinery feedstock.

Forsberg and Krook-Riekkola [11] examine the benefits of reductions in air pollutants when the transport sector is decarbonized, the benefits of GHG emission reduction after APs are radically reduced, and the additional benefits of when APs and GHGs are simultaneously reduced using an energy system optimization model with an exhaustive and congruent representation of technology and fuel choices. The extent of these reductions, however, depends on the fuel alternatives used to replace fossil fuels. While biofuels are the most cost-efficient option for meeting substantial climate change mitigation targets, they have a limited effect on reducing APs. Single-handed deep cuts in APs require a shift to zero emission BEVs and hydrogen fuel cell vehicles (HFCVs), which could result in a considerable increase in GHG emissions from electricity and hydrogen production. BEVs powered by "green" electricity are recognized as the most cost-efficient option for substantially cutting both GHGs and APs.

Vijayakumar et al. [12] study the infrastructure requirements to establish a hydrogen ecosystem for transportation in California and provide technology and cost insights along the entire hydrogen supply chain network using standalone models for different hydrogen pathways. While hydrogen use is growing rapidly, it will only satisfy at most 10% of the transportation demand until 2030 in both low- and high-demand scenarios. In the high-demand case, hydrogen use will expand substantially and become the dominant fuel in the market by 2050. Future hydrogen demand from the transport sector in California is found to be largely from cars and light-duty and long-haul trucks. Thus, there will be several investment opportunities over the next 25 years to build the necessary refueling stations and production plants to satisfy demand.

Sharma et al. [13] assess the effect of hydrogen as an economic and environmentally friendly fuel. Most of the worldwide energy demand is currently satisfied by fossil-fuel-based energy systems, such as coal, oil, and natural gas, but it is becoming difficult to fulfil and is also causing adverse changes to the environment. Thus, fossil fuels are gradually being replaced by alternative energy sources, such as hydrogen, wind, nuclear, and solar energy. Among them, hydrogen has the ideal economic and environmental attributes to become the primary source of energy in the future, as it can be a clean, safe, and sustainable energy carrier when production, storage, and utilization technologies are developed. The authors conclude that by choosing the most sustainable production and storage methods and improving the automotive applications, such as fuel-cell-based electric vehicles, the dominant role of fossil fuels in energy systems could be substantially reduced and the world will initiate the "hydrogen era".

Ortega et al. [14] provide a comprehensive analysis of current research and innovation in low-emission alternative energies for transportation, excluding hydrogen, in relevant European Union (EU)-funded projects. They consider the most recent developments in the field, identifying valuable research technologies by fuel type and their development phase. The results show that liquefied natural gas (LNG) refueling stations, followed by biofuels for road transport and alternative aviation fuels are some of the most studied technologies with the highest investments. Methane-based fuels, e.g., CNG and LNG, have received the greatest attention concerning the number of projects and the level of funding. In contrast, only four ongoing projects are focused on liquefied petroleum gas (LPG). Alcohols, esters and ethers, and synthetic paraffinic and aromatic fuels (SPF) are moderately studied. Thus far, road transportation has the highest use of AFs in the transport sector. Despite the financial support from the EU, advances have yet to materialize, suggesting that EU transport decarbonization policies should not propose a radical or sudden change; therefore, transition periods are critical. It is also noteworthy that there is no silver bullet solution to decarbonization and thus the right use of the various AFs available will be key.

Ala et al. [15] indicate that nowadays the most widespread technology in the development of sustainable vehicles in Europe and Portugal is that of BEVs or plug-in hybrid electric vehicles (PHEVs), but hydrogen-based transportation has also displayed a substantial growth in the commercialization of FCEVs and in the development of new infrastructural schemes. Regarding electric vehicles, special consideration should be provided to hydrogen technology, i.e., FCEVs, which is potentially a valid alternative to BEVs. Two other variants of FCEVs are hybrid (FCHEVs) and plug-in hybrid (FCPHEVs). Multiple sources cited within the narrative show a positive trend of hydrogen use in road transportation, including a rising trend in the expansion of hydrogen infrastructure, although at this time, it is still at an early stage of development. Right now, the cost of building the infrastructure is still high, but it is expected that investments in hydrogen refueling stations will be profitable in the near future if there is an increase in the number of FCVs. The opportunity to use fuel cells to store electrical energy is quite fascinating and bypasses some obstacles encountered with BEVs. The advantages are noticeable, since the charging times are reduced compared to charging from an electric charging post, and long-distance journeys are made easier as the autonomy is much larger.

According to the literature review in this paper on existing and forthcoming developments in road transportation with electric and AF vehicles, there is a crucial need for transformative action to accelerate the transition to sustainable transportation globally. Innovations driven by new technologies, evolving consumer preferences, and supportive policy making can provide the transport solutions needed to achieve the sustainable development goals outlined in the Paris Agreement, which was negotiated by 196 parties at the United Nations Conference on Climate Change in 2015.

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