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Hydrogen refuelling station infrastructure roll-up, an indicative assessment of the commercial viability and profitability in the Member States of Europe Union

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ABSTRACT

The aim of this paper is to evaluate the roll-out of a hydrogen refuelling station (HRS) infrastructure in the Member States of Europe Union. The effort contributes to a preliminary, indicative assessment of the commercial viability and profitability of a hydrogen refuelling station network roll-out. In these concrete cases were provided scenarios at both the Member States and Europe Union levels. The business case assessment was realised for the roll-out of HRS network in a 15 years program. The results refer to key metrics to assess the overall profitability of the investment: the annual number evolution of HRSs based on the inputs provided by the user; the annual number evolution of FCEVs; annual total amount of hydrogen sold; annual capital expenditures on HES procurement (CAPEX); cash flow after interest and debt payment representing the cash flow available for equity holders; annual debt service coverage ratio (ADSCR); and net present value (NPV) at the end of the period. The first scenarios were designed to achieve results across the Member States of Europe Union. There were presented three individual detailed examples also. A second series of sensitivity analyses consider that the hydrogen mobility penetration appears more constrained, being limited to a few stakeholders in the EU with well-defined policies and programs or with more favourable conditions. Both categories of scenarios outline the idea that at the beginning of a HRS network development it is already good to have an adequate number of FCEVs for a profitable programme. The net present value (NPV) is positive and the development program is commercially viable if there is a correlation between both the HRS number and FCEV fleet dimension. This correlation leads to good or optimistic results, but for the majority NPV became positive only in the second part of the program.

The roll-out's analysis of the hydrogen refuelling station network in the EU indicated that hydrogen is a part of solutions for a decarbonisation of the transport sector. There is a need to carefully develop an adequate hydrogen refuelling infrastructure if the final scope of the program is its commercial viability and profitability.

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Nomenclature

ADSCR	annual debt service coverage ratio
CAPEX	capital expenditure
CO	carbon monoxide
CO_2	carbon dioxide
EU	Europe Union
FCEV	fuel cell electrical vehicle
FCH2 JU	Fuel Cell hydrogen 2 Joint Undertaking
GIS	Geographic Information System
HRS	hydrogen refuelling station
H2ME	Hydrogen Mobility Europe
M Euro	million Euro
NOx	nitrogen oxides
NPV	net present value
RES	renewable energy sources
VAT	value added tax
VOC	volatile organic compounds

Introduction

European transport sector, in specially the road one, is highly dependent on fossil energy sources. The fossil fuels are a non-renewable natural resources and are the cause for major concern. The emissions from the mobility sector are severe, greenhouse gas is not alone, and there are others atmospheric pollutants also: nitrogen oxides (NOx), volatile organic compounds (VOC) or carbon monoxide (CO). The second direct emissions of carbon dioxide (CO_2) after electricity are the transport sector, at both the global and European levels [1].

The transport sector's electrification is a key element of a wider strategy for achieving the reduction of greenhouse gas emissions. The fuel cell electrical vehicles (FCEVs), battery and plug-in hybrid vehicles are considered the most promising technology for meeting the emission targets [2].

The hydrogen records an increased recognition as fuel for transportation and energy carrier in various countries across the world. The hydrogen-based mobility faces two challenges the cost-competitive FCEVs and the infrastructure for hydrogen production, distribution and refuelling. The development of an adequate hydrogen refuelling station (HRS) network is necessary to meet the needs of the FCEV owners. The implementation of the hydrogen supply infrastructure requires considerable capital expenditures without a certain mitigation of the risks and uncertainties. The market development rather than technology development is currently considered to be the main barrier for the roll-out of FCEVs. The hydrogen refuelling infrastructure will expand step by step from densely populated areas - major cities and highways - to less urbanized areas and eventually rural areas. The critical step consists in bridging the gap between isolated demonstration clusters and pre-commercial stage. The hydrogen refuelling infrastructure will face underutilization of the stations' capacity due to the small number of FCEVs in the first years of the program. The predicted expectations shows that will be at least 10 years from the start of the HRS operations to become cash-flow positive [3].

The hydrogen mobility offers multiple benefits to other sectors, also: energy, residential, industry, gas networks, etc. The commercialization of FCEVs and the refuelling infrastructure will improve the utilization and efficiency of existing electricity grids and the development of renewable energy sources (RES) [4]. The hydrogen mobility is not limited only to the integrated RES-hydrogen-electricity networks for decarbonizing the economic sectors [5,6]. There are many discussions on this subject otherwise, the installed nuclear power capacities can continue to work in profitable conditions without curtailments, supplying hydrogen for mobility and power-to-gas [7]. The conversion of natural gas pipeline network to transport hydrogen or its mixtures will offer a potential benefit for integrated systems [8]. The FCEV's introductions can contribute to mitigate pollutant emissions from the light duty vehicle, especially the atmospheric concentrations of ozone and fine particulate matter [9]. The public perception largely agrees that the environment is beneficiary of oil substituting with hydrogen in mobility, but costs of FCEVs seemed prohibitive to many [10]. The people accept to share the responsibility for environmental damage and others accepts hydrogen production from natural gas for a transient period [11]. In general, the literature shows that public attitude is more open and informed [12,13].

At the international and EU level, the hydrogen mobility has strong supporters: Japan, South Korea, USA, Canada, Germany, UK, France and the European Nordic countries [14–16]. The stakeholders from other countries have become participative on the subject of hydrogen mobility, the efforts were made especially by the scientific community. There are inserted some example in alphabetical order: Boudries et al. have realised a study about hydrogen mobility in Algeria [17]; Rahmouni et al. used a combination of spatial data in a Geographic Information System (GIS) with a techno-economic models for future prospect of the hydrogen demand in the transport sector for the same country [18]. The hydrogen mobility in Australia must face the next specific issues: vast renewable and non-renewable energy resources that can be used for hydrogen production, the decline of oil production, very low population density and need for vehicles with long range capability, an issue that is problematic for battery vehicles, a growing truck and bus fleets and need to find a way to decrease the greenhouse gas emissions from the transport sector [19]. The future utilization of hydrogen from RES, an alternative fuel in transport in Austria, in a dynamic framework had been analysed by Ajanovic [20]. The potential benefits of hydrogen production via electrolysis from hydropower and the use of hydrogen in fuel cell vehicles for public transport in Ecuador were estimated by Posso et al. [21]. The prospectus of introducing hydrogen as fuel for transport in Malaysia in response to climate change and energy security with focus on sustainable mobility was reviewed by Ahmed et al. [22]. The substantial reduction of greenhouse gases emissions will be obtained from the Norwegian transport sector if it will be connected with the hydropower electricity. The feasibility of this specific situation and market penetration of FCEVs were analysed by Rosenberg et al. [23]. Another active country is South Africa, which wants to accelerate its presence in the hydrogen economy. One topic is the hydrogen refuelling infrastructure, also [24]. The stakeholders from Sweden are very active in Hydrogen Mobility Europe (H2ME), a pan-European flagship project that will run until 2020. In these

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