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Acceptance of LNG as an alternative fuel: Determinants and policy implications

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ABSTRACT

The transport sector causes substantial greenhouse gas emissions and is responsible for the climate change and global warming. Introducing liquefied natural gas (LNG) as an alternative fuel for heavy-duty and long distance transport is an important strategy to increase the sustainability of the transport sector. Stakeholder's acceptance significantly influences the successful introduction of LNG. This paper examines the determinants of LNG acceptance. A causal model based on the technology acceptance framework is suggested and a structural equation model was estimated. Political implications are discussed to provide an insight which measures are effective to support the introduction of LNG as an alternative fuel. Results suggest that LNG as an alternative fuel can be fostered by stimulating demand, increasing the availability of LNG and improving the ecological effects of the fuel technology.

1. Introduction

Transport contributed a quarter of the total greenhouse gas emissions in the EU-28 in 2015. Road transport was responsible for almost 73% of the total greenhouse gas emissions from transport (EEA, 2017). These statistics clearly show that the transport sector in general and road transport in particular represent severe obstacles to the proper compliance with environmental targets. The introduction of alternative fuels and propulsion systems is therefore an important strategy that has also been anchored in the European Union's White Paper on Transport (European Commission, 2011).

Several alternative fuel technologies have emerged in the recent past. The problem is that most of them entail considerable restrictions when being used for heavy-duty vehicles or long distance transport. Electric vehicles are characterized by short ranges and long times for recharging, which currently limits their application basically to urban use and short distances (Engerer and Horn, 2010). Hydrogen has a high potential of reducing greenhouse gas emissions, but the production costs of hydrogen are still very high (Durbin and Malardier-Jugroot, 2013). The use of biofuels such as bioethanol and biodiesel is problematic due to their limited availability which occurs because land use is primarily dedicated for food production (Simio et al., 2013; Duarte et al., 2014).

The use of natural gas vehicles dates back to the 1930s. It is considered a mature technology that can be applied to a wide range of vehicles (Osorio-Tejada et al., 2015; Yeh, 2007). There are two different states in which natural gas can be used as vehicle fuel, either in a compressed state which is referred to as CNG (compressed natural gas), or in a liquid state which is referred to as LNG (liquefied natural gas). To convert natural gas to LNG, it has to be cooled down to a temperature of − 162 °C where it becomes liquid and reduces its volume roughly 600 times. LNG is a clear, colorless, odorless, non-toxic and non-corrosive cryogenic liquid. While CNG already finds widespread use for passenger cars, LNG is well suitable for heavy-duty vehicles due to the significantly high energy density that can be achieved through the volume reduction during the liquefaction process (Arteconi et al., 2010). As a matter of fact, LNG is the only viable and mature technology available that constitutes an alternative for diesel in the heavy-duty and long distance transport sector (Osorio-Tejada et al., 2015).

Environmental benefits of introducing LNG as alternative fuel include the clean combustion of LNG which causes nearly 99% less particle (PM) and sulfur oxide (SO_x) emissions, around 80% less nitrogen oxides (NO_x) and around 20% less carbon dioxide compared to diesel (Burel et al., 2013; Kumar et al., 2011). Emissions reduction can be even further enhanced by mixing liquefied bio-methane into the fuel (Kumar et al., 2011). Vehicles fueled with LNG also produce lower noise levels, which allows competitive advantages through inner-city and nighttime delivery services (Peters-von Rosenstiel et al., 2014).

Despite the high potential of reducing the negative impact of road transport, the fully fledged deployment of LNG was impeded in Central

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Table 1
Alternative fuel technology acceptance studies.

Reference	Research subject	Region	Determinants of acceptance
Wang et al. (2016)	Electric vehicles (hybrid)	China	Environmental concern, attitude toward adopting a hybrid electric vehicle (HEV), subjective norm, perceived behavioural control, personal moral norm, intention to adopt a HEV
Jayaraman et al. (2015)	Natural gas vehicles	Malaysia	Refueling station availability, payback period, petrol price, refueling time
Sang and Bekhet (2015)	Electric vehicles	Malaysia	Government intervention, environmental concern, performance attributes, social influence, financial benefits, demographic, infrastructure readiness
Huijts et al. (2014)	Hydrogen fuel stations	The Netherlands	Intention to act, attitude towards acting, perceived effects of the technology, subjective norm, perceived behavioural control, personal norm, outcome efficacy, environmental problem perception, energy security problem perception, problem perception, trust in the municipality, trust in the industry, distributive fairness, positive affect, negative affect
Hackbarth and Madlener (2013)	Alternative fuel vehicles	Germany	Purchase price, fuel cost, CO_2 emissions, driving range, fuel availability, refueling time, battery recharging time, policy incentives
van Rijnsoever et al. (2013)	Alternative fuel vehicles	Netherlands	Initial purchase price, fuel price, driving range, time to refuel, availability of fuel, local emissions
Tarigan et al. (2012)	Hydrogen vehicles	Norway	Demographic variables, knowledge, environmental attitude, willingness to pay more to purchase hydrogen vehicles
Kang and Park (2011)	Hydrogen vehicles	Korea	Psychological needs, perception towards hydrogen fuel cell vehicles, values, experience
Zhang et al. (2011)	Electric vehicles	China	Demographic variables, understanding of alternative fuel vehicles, experience, vehicle performance, government policy, environmental requirement, opinion of peers, vehicle price, tax reduction, fuel price, fuel availability, maintenance cost, vehicle safety
Thesen and Langhelle (2008)	Hydrogen vehicles and fuel stations	Norway/UK	Demographic variables, hydrogen support, environmental and hydrogen knowledge, attitude
Zachariah-Wolff and Hemmes (2006)	Hydrogen	The Netherlands	Demographic variables, knowledge, perception, attitude
O'Garra et al. (2005)	Hydrogen vehicles	United Kingdom	Demographic variables, environmental attitude, environmental knowledge, environmental behavior knowledge about hydrogen and fuel cells, attitude toward science and technology
Schulte et al. (2004)	Hydrogen vehicles	n.a.	Perception of product, values of person in question, wants of person in question, needs of person in question, past experience, social background

Europe for a long time. For many years, a chicken-and-egg problem dominated especially the landlocked countries: infrastructure such as refueling stations were not provided due to a lack of demand for LNG, and demand for LNG could not be signaled because potential customers had no infrastructure to use (Pfoser et al., 2016). In the meantime, though, political efforts have been made to fight the chicken-and-egg problem by stipulating the provision of LNG infrastructure. Through its Alternative Fuels Directive (2014/94/EU), the European Union set a policy framework to promote the construction of alternative fuels infrastructure to enable an increase in the uptake of alternative fuels vehicles and reduce Europe's dependence on oil and oil related products. Directive 2014/94/EU also encompasses LNG as it is a “cost-efficient technology allowing heavy-duty vehicles to meet the stringent pollutant emission limits of Euro VI standards” (European Union, 2014, p. 7). The importance of LNG for the European market is further underlined by the European Union's “Strategy for liquefied natural gas and gas storage” that has been released in 2016. This strategy aims at improving the access of all Member States to LNG as an alternative gas source and to exploit the full potential of LNG. Transport plays a key role within this strategy since it is expected that “LNG will increasingly be used as an alternative to marine fuels in shipping and to diesel in heavy duty vehicles such as lorries” (European Commission, 2016, p. 3).

The political efforts finally seem to be successful which is reflected by the most recent developments in Central Europe: the first LNG refueling station in Germany was opened in June 2016, the first LNG refueling station in Austria was opened in September 2017 (NGV Global, 2017). On the whole, a number of 101 LNG stations are currently operational in the EU/EFTA region, most of them in Spain (22 stations), the Netherlands (21 stations) and the UK (18 stations) (NGVA, 2017). An extension of the network is planned, thus the problem of supply (Arteconi and Polonara, 2013) seems to be tackled in a first step. This implies that the successful implementation of LNG is now subject to the development of demand, which is still restrained in Europe. The European Alternative Fuels Observatory estimates the total number of LNG vehicles in Europe at 1600 (EAFO, 2018).

Demand for LNG depends largely on its acceptance among potential users. Several authors stress the importance of understanding the acceptance of an alternative fuel for its introduction (e.g. Schulte et al., 2004; Zachariah-Wolff and Hemmes, 2006). However, only limited research has been conducted so far on the topic of alternative fuels acceptance, especially with regards to LNG. The objective of this paper is therefore to analyze stakeholder's acceptance of LNG as an alternative fuel. The determinants that influence acceptance of LNG (i.e. accessibility/availability of technology and refueling stations, attitude towards the use of alternative fuels, safety concerns towards LNG, expected usability as well as the expected usefulness of LNG) are examined in this study. These determinants provide important information for policy-makers as they reveal which incentives or regulations are most suitable to support the introduction of LNG (Huijts et al., 2014).

The remainder of this paper is structured as follows: Section 2 reviews existing literature on acceptance studies related to alternative fuels. A conceptual model of LNG acceptance is presented and the hypotheses of this study are derived. Later in Section 3, the methodology and sample of this study are described in deeper details. In Section 4, the main results are presented and extensively discussed. The paper concludes with an in-depth discussion of policy implications in Section 5.

2. Model and hypotheses

The concept of technology acceptance was first proposed by Davis in 1989 by introducing the technology acceptance model (Davis, 1989). The technology acceptance model (TAM) originally focused on assessing the acceptance of information technology, but by now it has already been employed on various other types of technologies, including alternative fuels and sustainable energy technologies (Chen et al., 2017). A lot of work has been published to refine TAM and expand the applications fields of this model. TAM is one of the most influential and most widely used extensions of the theory of reasoned action (Fishbein and Ajzen, 1977) and the theory of planned behavior (Ajzen, 1991).

As can be seen from Table 1, acceptance studies have been conducted for different types of alternative fuel technologies, including electric, hydrogen and natural gas vehicles. These studies have identified various determinants of individuals' acceptance of alternative fuel technologies (presented in Table 1). No study exists to date which is