GREEN LOGISTIC EFFORTS WITH V2G AND B4H SOLUTIONS

Prof. Bojan Rosi
University of Maribor
Celje, Slovenia
E-mail: bojan.rosi@fl.uni-mb.si

Péter Bajor
Széchenyi István University
Győr, Hungary
Tel.: +36/30-63-73-270
E-mail: pbajor@sze.hu

Emőke Ila Baladincz
Széchenyi István University
Győr, Hungary
Tel.: +36/70-60-28-806
E-mail: emoke.baladincz@gmail.com

Abstract

There is a strong need to provide green fuel for transport purposes. One of the candidate solutions is the hydrogen energy, but there are many challenges the prospective hydrogen economy is facing with, especially from the logistics point of view. There are rapid developments on the field of electricity driven vehicles in the same time. According to the actual trends, the first stage of green fuel penetration seems to be the Vehicle-To-Grid integration, where electrically driven vehicles are able to download and upload energy from and to the national grid. The limited range of electric vehicles can be extended by using quick charging applications or hybrid on-board energy storage technologies. In our essay we present how the V2G and B4H solutions can exceed the main barriers of alternative fuel vehicles.

Keywords: Hydrogen, V2G, fuel station network, B4H

1. INTRODUCTION

Nowadays the transportation sector is one of the largest energy-intensive sub-systems. As the economies develop, there is an observable increase in the demand for transportation – both in the passenger and freight sub-sectors. Transportation is responsible for most of past and expected future growth of world oil demand, and because transport is 97% dependent on petroleum, these developments could have important impacts on oil markets and carbon dioxide emissions. The transportation sector has the highest rate in total crude oil consumption, and the need for oil is continuously growing.

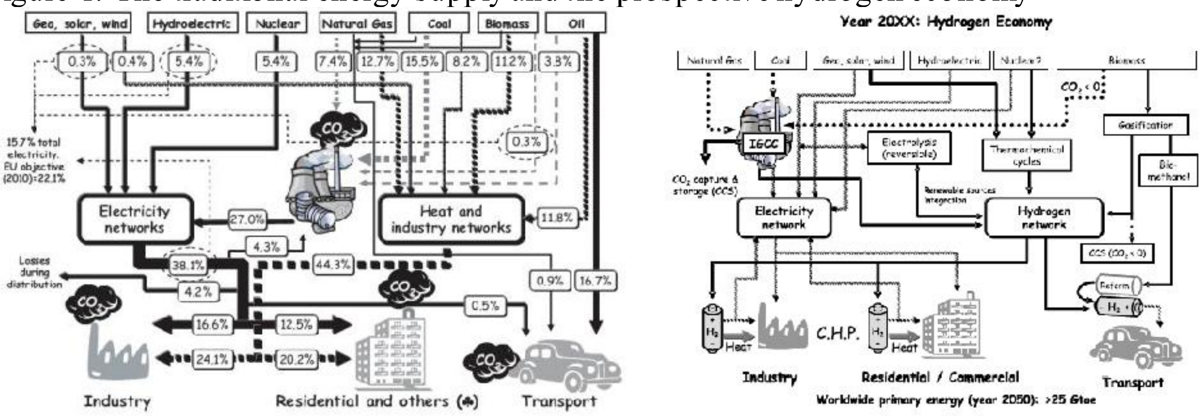
On the way of searching for alternative fuels the hydrogen seems to be a probable winner, but there are strong competitors, like bio-fuels or electricity from renewable sources. The second chapter gives an overview about the challenges of the development of hydrogen economy. Electricity driven vehicle fleets can contribute in the more efficient usage of the existing electric power infrastructure – as will be presented in the third chapter. The fourth chapter contains the analysis of the above mentioned hydrogen and V2G infrastructures alongside the main barriers the alternative fuel systems need to overcome. As a conclusion, we can highlight the pathway of infrastructure developments towards green fuel economies.

2. INFRASTRUCTURE DEVELOPMENTS ON THE WAY TOWARDS THE HYDROGEN ECONOMY

Hydrogen and its use for energy production purposes have long been in the focus of attention. The hydrogen economy has a promise to build up an environment friendly energy system based on renewable sources in the production, and zero-emission vehicles at the end-user side.

Using hydrogen as a transportation energy carrier has been widely, but not universally, touted as a key solution for many of the environmental and geopolitical problems associated with burning petroleum-based fuels such as gasoline and diesel. Hydrogen FCVs will have zero emissions of criteria pollutants in urban areas, can be significantly more efficient than conventional vehicles, and permit the use of domestic energy and low carbon resources for fuel production. Hydrogen vehicles must, however, overcome a number of challenges, technical and economic, in order to become a feasible option for consumer light-duty vehicles. (C. Yang et al. 2008)

Figure 1: The traditional energy supply and the prospective hydrogen economy



Source: Marbán, et al., 2007

There are several scenarios, roadmaps, and similar foresight papers in the literature of hydrogen research. The key for technologically and economically feasible plans is to consider the logistics and distribution system of hydrogen as the part of the existing energy systems. The success of hydrogen pathways are depending on the availability of the critical infrastructure. While most technological issues can be accommodated within the existing technical knowledge and industrial practice, the main obstacle is the cost involved in hydrogen energy system development. Considering the pivotal role that the infrastructure for production and distribution will play in the diffusion of hydrogen as a transport fuel, many studies on this topic can be found in the literature. As may be expected, several approaches have also been used to assess the importance of the factors - social, environmental, economic and juridical - which will affect the diffusion of hydrogen in the transport system. (Agnolucci et al., 2007)

Hydrogen may enable transport sector diversification using energy produced from renewable, nuclear power, and clean fossil fuel technologies. The literature describes a diverse range of possible future scenarios, from decentralised systems based upon small-scale renewable, through to centralised systems reliant on nuclear energy or carbon-sequestration. Several models and scenarios have been developed for wind-hydrogen, nuclear-wind-hydrogen systems, and these simulations give insights in feasibility and competitiveness. A lot depends on the availability of fossil sources (amounts and prizes) and also on the market value of electricity and hydrogen, which could not be predicted easily.

There is a broad consensus that the hydrogen economy emerges only slowly. Rapid transitions to hydrogen occur only under conditions of strong governmental support combined with, or as a result of major "discontinuities" such as shifts in society's environmental values, "game changing" technological breakthroughs, or rapid increases in the oil price or speed and intensity of climate change. A variety of early niche markets are either recognized or advocated as providing an important stage for the development of a hydrogen economy. (As an example, the benefits of applying hydrogen driven urban buses were proven in the CUTE Clean Urban Transportation for Europe Project). Most of these early markets or technologies are described as overcoming cost barriers, by providing niche applications that allow learning and scale economies, as well as increasing public familiarity.

3. V2G – VEHICLE TO GRID

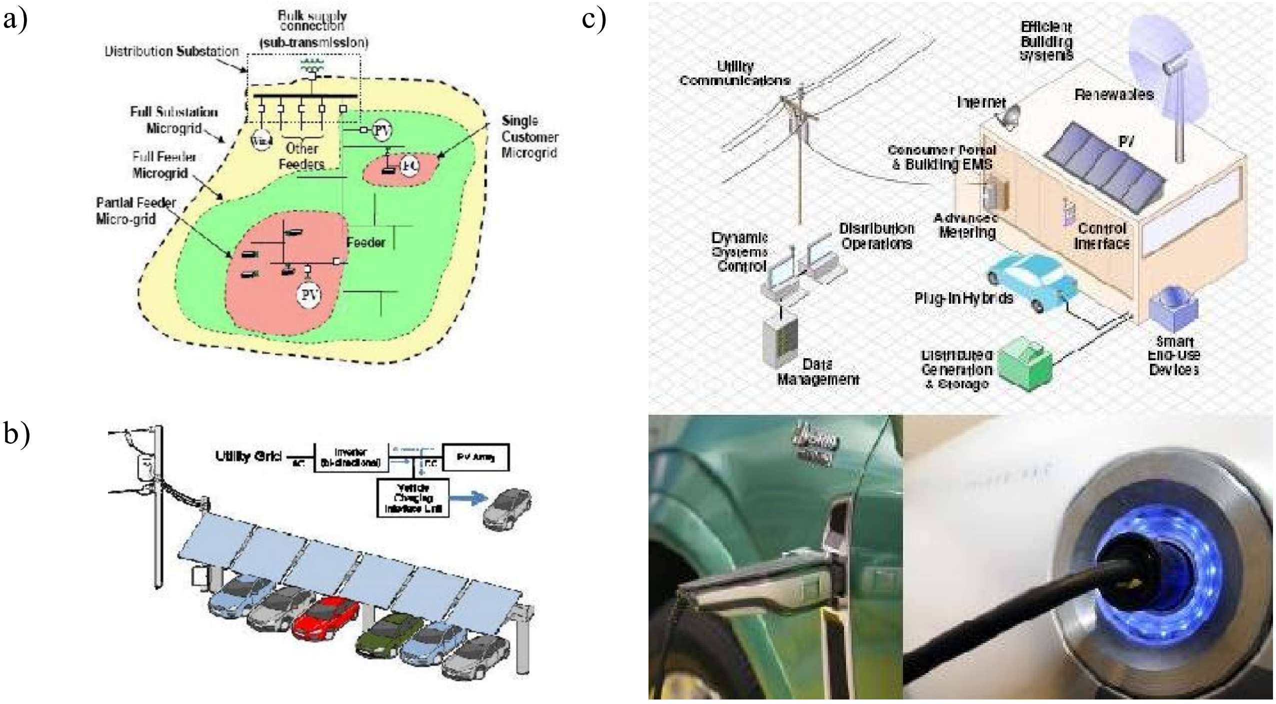
Using electric and hybrid-electric vehicles is becoming popular recent days, as we can see on the example of Toyota Prius, Tesla, and many other cars. The superiority of electricity-driven vehicles (trains, trams, trolleys, forklifts) both in their performance and environmental impact is widely accepted. Apart from the electricity-driven vehicles, the infrastructure for their use is also rapidly developing, such as chargers and battery systems, smart parking and charging stations. (Kvasz et al., 2010)

Most of the electric vehicles have a battery storage system of 4kWh or more. It is possible to recharge the battery from an external source, and the owners are able to drive around 40-80 km in electric mode. The hybrid-electric vehicles are able to run on fossil fuels, electricity, or a combination of both leading to a wide variety of advantages including reduced dependence on foreign oil, increased fuel economy and power efficiency. They can lower greenhouse gas (GHG) emissions by running on renewable electricity.

There is a new upcoming technology: the Plug-in-Hybrid electric vehicle (PHEV). These technologies include hybrid-electric vehicles (HEVs), fuel cell vehicles (FCVs) and battery electric vehicles (BEVs). Collectively, these options can be categorized as electric-drive vehicles (EDVs), because they all have the capability to produce motive power from electricity. The Toyota Prius car originally was designed as a hybrid electric vehicle (HEV), but it can be converted into a plug in hybrid electric vehicle (PHEV) using an aftermarket kit. (Today it is being manufactured as HEV and PHEV as well). These trends are supporting a new type of application: as vehicles can store a certain amount of electrical energy, they can take part in the electricity grid balancing activities.

The V2G concept is one of the attractive ideas to synergize the electricity and the transportation sector. This concept with pure electric and hybrid-electric vehicles (which are capable to connect to the grid and load-unload electrical energy) could help to manage electricity resources better, and it empowers vehicle owners to earn money by selling power back to the grid when parking, depends on the current fuel and electricity prizes. One factor which suggests such benefits is the fact that private vehicles are parked on average 93-96% of their lifetime, during which time each represents an idle asset. Each parked vehicle contains under-utilized energy conversion and fuel (or battery) storage capacity, and may actually create negative value due to parking costs. Accordingly, generating V2G power from parked vehicles can better utilize an expensive investment (particularly in the case of new and alternative vehicle technologies), thereby enabling cars to provide both mobility and energy services. Since average vehicles in the US travel on the road only 4-5% of the day, and at least 90% of personal vehicles sit unused (in parking lots or garages) even during peak traffic hours, the existing 191 million automobiles in the United States would create 2865GW of equivalent electricity capacity if all the vehicles supplied power simultaneously to the grid — an unlikely occurrence, because this amount was more than twice than the total nameplate capacity of all US electric generators in 2006.

Figure 2. V2G systemdesign



Source: a) (Kroposki, 2009.); b), c) (Duvall, 2009)

Vehicle-to-grid (V2G) technologies represent a potential opportunity to bring forward and accelerate a transition towards electric-drive vehicles by improving the commercial viability of new vehicle technologies. (Tomic et al., 2007)

4. BARRIERS

We need Alternative Fuel Vehicles, but there have historically been six major barriers to AFV success (Romm, 2006). The comparison of V2G and hydrogen vehicles and fuel distribution infrastructures alongside these factors is bringing new insights of necessary developments.

4.1. High first cost for vehicle

The price of electric or hybrid-electric cars is higher than the conventional ones. Since electricity is a relatively cheap fuel, the payback depends on the yearly driven distance and the lifetime of the cars, especially the battery units. In special applications (public transport, city logistics, waste management, etc) or in special areas (over-crowded city centers) the additional benefits of zero-emission vehicles are bringing external cost reductions, but it is hard to estimate and build up compens

4.3. Safety and liability concerns

New solutions often meet public scepticism. Although an electric car use the same type of battery like a well-known cell phone, people think that they could be shocked by electric current, or the battery might catch fire. That is why demonstration projects (public transport applications) are important, and would deserve more support from the governmental side.

The situation is nearly the same with the hydrogen vehicles. While gaseous H2 offers the advantage of higher well-to-wheel efficiency and somewhat simpler technology (lack of liquefaction plants; lack of super insulating storage devices), its disadvantage arises from the high pressures involved, posing some potential safety risks. On the other hand, liquid H2 has the bottleneck of boil off during parking, and therefore needs different safety concepts. Despite the hydrogen as a fuel is totally safety, people have fears about using in road vehicles.

4.4. High fuelling cost (compared to gasoline)

Gasoline stations are existing solutions for conventional fuels, but electric and hydrogen vehicles require special equipments in distribution, storage and filling. The rate of return depends on the number of filling points and the amount of electrical or hydrogen energy distributed through the network.

4.5. Limited fuel stations: chicken and egg problem

Considering the chicken and egg problem at the case of alternative fuel vehicles the question appears: What will be the first? (Melaina et al., 2003)

1. Costumers will not purchase fuel cell vehicles unless adequate fuelling is available.
2. Manufacturers will not produce vehicles that people will not buy.
3. Fuel providers will not install hydrogen stations for vehicles that do not exist

The development of the new infrastructure will depend on the location of consumers, primary energy sources for electricity or hydrogen production, and the storage and distribution facilities.

Electricity is available nearly everywhere, but the distribution system has to be re-engineered with increasing rate of electric vehicle fleets, and we should consider the system balancing challenge as well.

At the case of hydrogen-driven fleets the first filling stations will be located near the depots. Since the demand is relatively low, hydrogen is likely to be produced on-site or shipped in liquid form on road trucks. When the demand for hydrogen reaches significant levels, pipelines from centralized plants may be built.

Nowadays the existing petrol filling station network is over-designed. There are too many stations alongside the road network would not be repeated with the prospective hydrogen stations.

The penetration of hydrogen vehicles could be successful if a significant fraction of public stations or spaces provide hydrogen fuel before consumers are comfortable purchasing hydrogen vehicles. The dilemma is perhaps more complex for hydrogen than other alternative fuels, due to the great uncertainty surrounding fuel cell vehicle development, the multiple pathways by which hydrogen can be delivered to vehicles, and the diverse number of stakeholders that might be involved in early infrastructure development. Only after this infrastructure development point has been reached, and after consumers begin to embrace hydrogen vehicles, will the costs of these vehicles begin to drop as a result of mass production and learning.

Among end-use applications, hydrogen penetration will start with portable power, and then move to stationary distributed power, buses and government fleet vehicles. Later, hydrogen will fuel commercial and luxury passenger vehicles and finally ordinary passenger vehicles. (Agnolucci et al., 2007)

4.6. Improvements in the competition: better and cleaner gasoline vehicles

Car manufacturer companies are interested in constructing vehicles with improved fuel efficiency. There are no problems with the range of conventional petrol and gasoline powered cars, and the density of fuel station network sufficient. Alternative fuels, like bio diesel and alcohol offer more sustainable energy sources on the market. As conclusion we can say, that internal combustion engines will not disappear from the European roads in next decades.

5. LOGISTICS SOLUTIONS FOR SOLVING THE PROBLEM OF LIMITED RANGE

The man barrier of electric vehicle penetration is the limited range. It is still a question if the final solution is the hydrogen car or not. There are two different types of solutions for the problem from the logistics point of view: quick charging or on-board generation.

The BMW i3 car was designed for urban mobility. The 170-hp electric motor, which twists out up to 184 lb-ft of torque, receives its power from a 22-kWh, liquid-cooled lithium-ion battery. Thanks to the optional SAE DC Combo Fast Charging hardware, that battery can fill to 100 percent in about 30 minutes. The 220-volt Level 2 J1772 charger, meanwhile, takes care of business in about 3 hours. The motor works in concert with a single-speed transmission to send power to the rear wheels. The i3 uses regenerative braking to help keep the battery running as long as possible. In a research project, which involved 1000 participants and more than 12.5 million driven miles, BMW found that the average daily driving distance was around 30 miles (48 km). When viewed through that prism, the i3's 80 to 100 miles (129 to 161 km) of range looks more. BMW says that ECO MODE can add an extra 12 percent. In addition to the all-electric version, buyers can choose to equip the i3 with a 34-hp 650cc range-extending two-cylinder engine, essentially turning the car into a Volt-like series hybrid. That engine will not power the wheels but will serve strictly as a back-up power reserve, adding range and versatility (Weiss, 2013).

The B4H (box-for-hydrogen) concept is not a technical solution yet, but a special on-board storage and generation method based on the logistics viewpoint we are developing in the frame of our research (in Szabó-Szoba R&D Laboratory, Széchenyi University, Győr). The B4H concept offers to use hydrogen boxes as an on-board filling option in avoiding the hydrogen filling problem. These standardized hydrogen boxes can take place at any hydrogen-electric hybrid car working with fuel cell units. The electricity chain has lower energy losses, and the energy in the battery is excellent for V2G operation (normally there is no need for hydrogen). Users need the fuel cells only if they are travelling more like usual (driving more, than 150km), to extend the range of the car. The B4H boxes are located in the car trunk and connected with the vehicle hydrogen tank. This box can accept two simple, isolated hydrogen barrels, each of them with 1 kilograms of hydrogen. With this quantity of hydrogen we can drive around 260 kilometres. These boxes and the filling mechanism are controlled by the on-board computer in the car which automates the process. Refuelling do not requires special filling infrastructure at the fuel station, because all the mechanisms are in-built around the hydrogen system of the car. The automated changing of empty tank starts with pushing the change button on the box, when the valve can close automatically. After ventilating and providing secure environment, the box ejects the empty tank. We should put the new 1kg hydrogen tank in the box and it will be automatically attach itself to the system. (The technical parameters of boxes require many innovative solutions we are searching for by using the TRIZ inventive principles. The prize of a box and hydrogen barrel seems to be high – the promise is that we can save a lot by mass production and by more flexible and simple distribution and refuelling cost).

This type of distributed storage and commerce – in the early phase of hydrogen vehicle penetration – is more suitable. Buying new hydrogen tanks is possible not only at the fuel stations, as users can buy it from offsite machines, and they can leave the empty tanks there as well. Finally, it would be much easier and faster to refill the hydrogen tank and continue the trip by using the B4H concept.

6. CONCLUSION

We will need to replace gasoline with a zero-carbon fuel. All AFV pathways require technology advances and strong government action to succeed. Hydrogen is the most challenging of all alternative fuels, particularly because of the enormous effort needed to change our existing gasoline infrastructure (Romm, 2006). In the same time, there are strong competitors on the market.

Based on our research we can say that V2G cooperation can contribute in green economy development efforts. Although, we should overcome the main short-term barrier, the problem of limited driving range the electric car concepts suffer by.

7. ACKNOWLEDGEMENT

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8. REFERENCES AND SOURCES OF INFORMATION

1. Agnolucci, P.: Hydrogen infrastructure for the transport sector; in. International Journal of Hydrogen Energy, 32, 2007, p. 3526 – 3544
2. Yang, C.: Hydrogen and electricity: Parallels, interactions, and convergence; in. International Journal of Hydrogen Energy, 33, 2008, p. 1977-1994

3. Knez, M., Rosi, B., Sternad, M., Bajor, P.: Positive impact of electrical energy resources on the implementation of logistics operations; in. 2nd Congress of Roads, Sarajevo BIH, 2009.
4. Marbán, G., Valdés-Solís, T: Towards the hydrogen economy?; in. International Journal of Hydrogen Energy, 32, 2007, p. 1625-1637
5. Romm, J.: The car and fuel of the future; in. Energy Policy 34, 2006, p. 2609-2614
6. Züttle, A., Sudan, P., Mauron, PH., Kiyobayashi, T., Emmenegger, CH., Schlapbach, L.: Hydrogen storage in carbon nanostructures; in. International Journal of Hydrogen Energy, 27, 2002, p. 203-212
7. Melaina, M.W.: Initiating hydrogen infrastructures: preliminary analysis of a sufficient number of initial hydrogen stations in the US; in. International Journal of Hydrogen Energy, 28, 2003, p. 743-755
8. Tomic, J., Kempton, W.: Using fleets of electric-drive vehicles for grid support; in. Journal of Power Sources, 168, 2007, p. 459-468
9. Kvasz, M., Bajor, P., Knez, M.: Environmental background of V2G solutions; in. 6th Bata Conference, Zlin CZ, 2010
10. Sovacool, B. K., Hirsh, H.: Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition; in. Energy Policy, 37, 2009, p. 1095-1103
11. Weiss, C. C.: BMW introduces the i3 electric car with optional range-extending engine, 2013; [available at: http://www.gizmag.com/bmw-i3-electric-car/28503/ , access: 13.07.2013.]
12. Kroposki, B.: Renewable Energy Interconnection and Storage - Technical Aspects, National Renewable Energy Laboratory, 2009
13. Duvall, C.: Grid Integration of Plug-In Hybrid and Electric Vehicles; in. PHEV Executive Summit, 2009