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Green electricity logistics in warehouse operations

Abstract

Green electricity sources (photovoltaic, wind) are available for warehouse energy infrastructures: we could use this green electricity in lighting, in HVAC (heating, ventilating, air conditioning), and in charging forklifts and any electrical equipments in a traditional warehouse system. The key factor is the cooperation with the electrical grid, where a lot depends on special tariff system. In our model - based on the GreenTrucks Laboratory datas - we could illustrate the levels of cooperation, considering future electricity-driven vehicle fleets also: in that case, warehouses should operate as cross-docking inventories of electrical energy.

1. The importance of developing electricity-based solutions in transport and logistics

Today, the logistics industry aims towards the so called 7P concept: “the right goods at the right place, at the right time, in the right quantity and the right state and package, at the right (optimal) cost, i.e. to holistically meet customer demands. This calls for quality regarding the realisation of material flows or a complementing functional differentiation of logistics. In pursuance of the aforementioned goals, logistics is the one responsible for creating optimal relations between logistics services and logistics costs. We are aware of the fact that on the one hand, logistics industry is preoccupied with optimisation of costs and on the other hand, with environmental requirements, what indicates the complex nature of the problem (M. Knez et al. 2009)

Logistics main tasks remain cost reduction, time saving, increased reliability and disposability of services, what is supported by the majority of agents of logistics processes. Unfortunately, in many cases cost-saving strategies have a negative impact on environmental protection. The main problems are environmental external costs that users of logistics or transport services do not pay or pay only one part of them. By this we mean the damage that is inflicted on others (that do not take place in logistics activities) or the environment. Therefore, the measures set by institutions that regulate this area and demand their inclusion and transparency are reflected in costs of logistics activities.

Defining prices based on total social costs is a key element of efficient and effective transport system. If users fail to pay the external costs incurred, they pay less than they actually spend. On the one hand, this will influence the inefficient use of natural and other resources; on the other hand it will not reflect the real price of logistics services and its competitiveness. To this end, social costs will not be entirely covered, despite the fact that this is a prerequisite for a contemporary quality transport system.

The transport industry, as a result of globalisation and industrialisation, has not yet become “green” or environmentally friendly, despite the efforts made by the set world policy. The

world uses more and more oil. The first billion of barrels (1 barrel is about 159 litres) was consumed in 125 years. The next billion will probably be used within the next 30 years. In 20 years time the world will consume 40 per cent more oil than today.
Despite the fact that traction engines are becoming more and more modern and efficient, oil and fossil fuels still have a number of harmful side effects, especially on the nature, where a number of harmful substances can be found in the air, such as carbon monoxide, nitrogen substances and other producers of smog. Carbon dioxide, which causes global warming, is especially disputed. Next generation traction engines should therefore be less wasteful, environmentally friendlier and more accessible, especially from the economic viewpoint.
However, the energy resources are limited and business operations of companies unstable. To this end, the companies are forced to restructure or redefine their processes and search for alternative strategies such as alternative resources of propulsion energy or environmentally friendly electrical energy.

The superiority of electricity-driven vehicles (especially trains, trams, trolleys, forklifts) both in theirs performance and environmental impact is widely accepted. In the future the entire world will want to use vehicles that will not emit harmful substances or will no longer use fossil fuels. Today's technologies are offering the so called "Zero Emissions Vehicles", electric vehicles, compressed-air powered vehicles and some other alternative solutions. In the last two decades intense technological development has been taking place, especially regarding accumulator powered vehicles as well as fuel cell vehicles. The main dilemma is how to store adequate quantities of energy so that vehicles could have the same capacities as fossil fuels cars have today. Petrol or diesel have great density of energy, approximately 10 kWh per litre or in other words a kilogram of petrol has approximately 300 times more energy than a lead accumulator battery weighing one kilo.
Let's have a look at the requirements of users in Slovenia, where the average length of a car ride is only six kilometres and a daily driven distance 20-30 kilometres. This means that a vehicle making one and two hundred kilometres would have to be maintained just once a week, which is completely acceptable. Compared to lead accumulators, contemporary lithium-ion ones have much improved characteristics regarding life expectancy (up to 1000 refills) as well as density of energy (over 100 Wh/kg). This advantage of electricity could also be used in logistics companies that deal with the distribution of goods in city centres, in public transportation companies, at airports for transportation of passengers, luggage and

freight, in hospitals for internal transport of patients, medicine and waste, and as later described in warehouse material handling operations (Knez et. al. 2009).

2. The future synergistic transport and electricity supply system

We often hear that electricity is not the right substitute for fuels and that the production of electricity places a burden on the environment with carbon dioxide, although it is true that these quantities are in fact much smaller.

In spite of producing the total amount of our electricity demands from solar (PV – photovoltaic, W – wind) energy sources is quiet a big challenge (!), there are several technical reasons, while the integration of these sources to electricity supply is complex and difficult. Renewable electricity generation cannot be fully forecasted and does not usually coincide with the demand curve: to adjust the generation curve to the demand curve, with storage (accumulators, hydrogen form) during off-peak (low demand) hours, while during the rest of the hours (peak hours, high demand) the stored electricity/hydrogen can be used to generate electricity. (Bernal-Agustin and R. Dufo-Lopez 2008)

The market for renewable energy resources has been drastically increasing for the past few years. To this end, between 2006 and 2007 profits from photovoltaic, wind energy, bio fuels and fuel cells have increased by 40 per cent from 55 to 77.3 billion dollars (Clean Energy Trends, 2008). That is why green electric power plants that replace or supersede traditional electric power plants are increasingly gaining on importance.

Distributed generation and storage of electricity is expected to become more important in the future generation system. Distributed power generation is competitive on the electricity market. Can be defined as electric power generation within distribution networks or on the consumer side of the network. By 2010 25% of new generation will be distributed. Around 60% of renewable potential that can be utilised until 2010 can be categorised as decentralized power sources. (Clark and Lund, 2008)

Electricity supply, based on distributed electro/hydrogen stations and carbon-free central nuclear and dispersed solar resources seems ideal for the penetration of electricity/hydrogen storage technologies: where in the first phase hydrogen is only a storage medium or by-product of the electricity chain, and in the second phase maybe the core business in supplying energy for the transportation sector.

Comparing energy storage in batteries with storage in hydrogen, we see that Wind–Hydrogen systems show very high energy losses (of about 60%) given the low energetic efficiency of the electricity–hydrogen–electricity conversion. Energy prices vary with demand, and may therefore fluctuate throughout a given day while also showing variations for the same time across different days. (R. Dufo-Lopez, J. L. Bernal-Agustin, J. A. Dominguez-Navarro, 2009)

The vehicle-to-grid (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/electricity prizes. 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 is more than twice than the total nameplate capacity of all US electric generators in 2006. The V2G vehicle fleet would replace (or more likely, supplement) large-scale pumped hydroelectric and compressed air energy storage systems, and indirectly, V2G vehicles can further reduce emissions and air pollution in the electricity sector by providing storage support for intermittent renewable-energy generators. While the benefits of such a transition have been widely recognized, V2G technologies may experience rejection from consumers because of their high initial cost as a serious barrier. Motorists will likely be unaware of how their driving patterns and habits negatively affect V2G performance, exhibiting impatience and frustration if their new cars do not perform precisely as anticipated (Sovacool and Hirsh 2009).

From the wire-logistics approach the V2G concept should be considered as direct coupling of transport and electricity infrastructure, and the hydrogen-based transport as a buffer-connected solution.

3. On the way to the development of electricity-driven transport and logistics solutions

Apart from the electricity-driven vehicles, the infrastructure for their use is also rapidly developing, such as chargers and battery systems. In the USA, a smart parking and charging station for cars that rents electric vehicles has already been developed (Better Place). Needless to say, the development in this direction is rapidly progressing. Unfortunately, its only obstacle is the powerful and too influential lobby of the oil industry.

There are debates about the first necessary stages of the development: alternative fuel vehicles vs. fuel station services (chicken-and-egg problem), but as the existing petroleum delivery infrastructure (especially petroleum for lighting) had a key role in the introduction of the first successful transportation fuel (gasoline) in the 1900's (Melaina 2007), the existing fuel station network today could operate as cross-docking inventory for electro/hydrogen conversion and storage in the near future (Földesi and Bajor 2009).

These synergistic stationary (electricity) and mobile (transport) infrastructures - with dispersed electricity storage (fuel stations network) - could provide benefits for electricity supply (transfer, network savings and kinetic advantage, stationary back-up, integration of solar sources, V2G, etc.) and also for transportation fuel supply (environment friendly propulsion or fuel to the prospective electro/hydrogen vehicle fleets), in according to the increasing share of the available green (photovoltaic and wind) electricity sources.

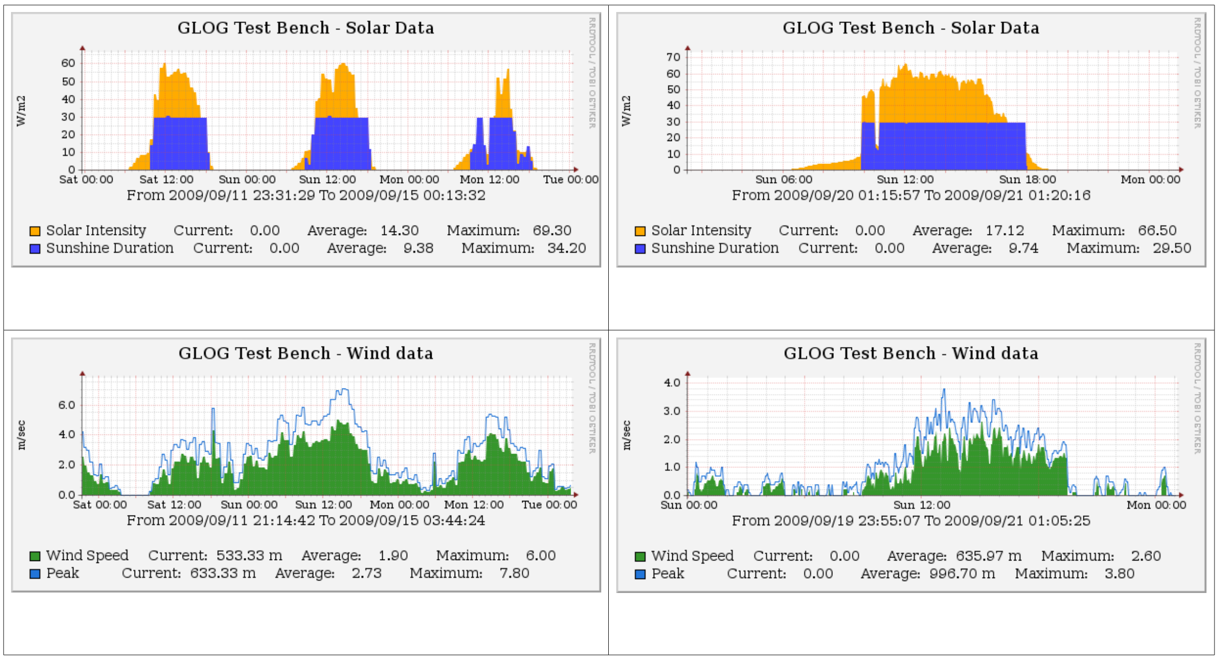
The warehouses are in key role also: electric forklifts are in operation with accepted range, operating hours and recharge time. Sometimes there is no time for the forklift to wait for charge, so it is possible to change an unloaded accumulator to a filled one (some cases 2 accumulator are allocated to 1 forklift, one of the accumulators is in the forklift, and the other is under recharging in the charger unit – according to the number of forklifts and the material handling energy requirements, it is possible to reduce the number of accumulators and the capacity of the charger to an optimal one). Charging the accumulators at night, or even more early morning could be profitable in demand-side management also for the warehouse and for the electricity supplier. It could help in smoothing the demand near morning peak hours, and if we have extra accumulators they could help as V2G units.

From a broader extent, as today the forklifts are the main vehicle units for electricity consumption in warehouses, with the development of electric fleets for road (van, lorry, truck) it could be possible to fill the accumulators in this new units by self-produced and/or stored (renewable or grid-connected) electricity at the warehouse, where they could spend the necessary waiting time plugged into the chargers (no extra time required for charging at the fuel station: infrastructure-overlapping). Considering the traffic near warehouses these should be profitable investments, what is more: with these electric fleets the V2G synergy from the warehouse to the conventional grid also available (if the owner could provide extra production/storage capacity to help the grid operator in loading-unloading and balancing the electricity system for peak hours).

4. Case Study: The GreenTrucks Project

The purpose of starting the GreenTrucks innovation project at our industrial partner (IBM-DSS Vác Factory) was twofold:

1. measuring the available renewable energy sources with the installation of a laboratory kit (wind meter, temperature sensor, radiation sensor, etc.), collecting the datas for calculations, managing the results for later investments on the field of electrical energy (production: renewable, storage: accumulators, compressed air, hydrogen, and consumption: demand-side management)
2. demonstrate the availability of these solar sources with the installation of a demonstration power unit (wind generator, solar panel, accumulator, inverter, and a "green plug" at the end)



1. Fig. The availability of Wind and Photovoltaic Energy (own source from the GreenTrucks database)

From the measurements we made it can be clearly seen, that the fluctuation of the available renewable sources could not have been well predicted (Fig. 1). For the higher utilization of these sources there is a strong need for electricity storage solutions, if those are feasible not from just technical but from the economic viewpoint also. We could not avoid the cooperation with the conventional grid, but later with well-organized demand profile the cooperation could be profitable for both actors.

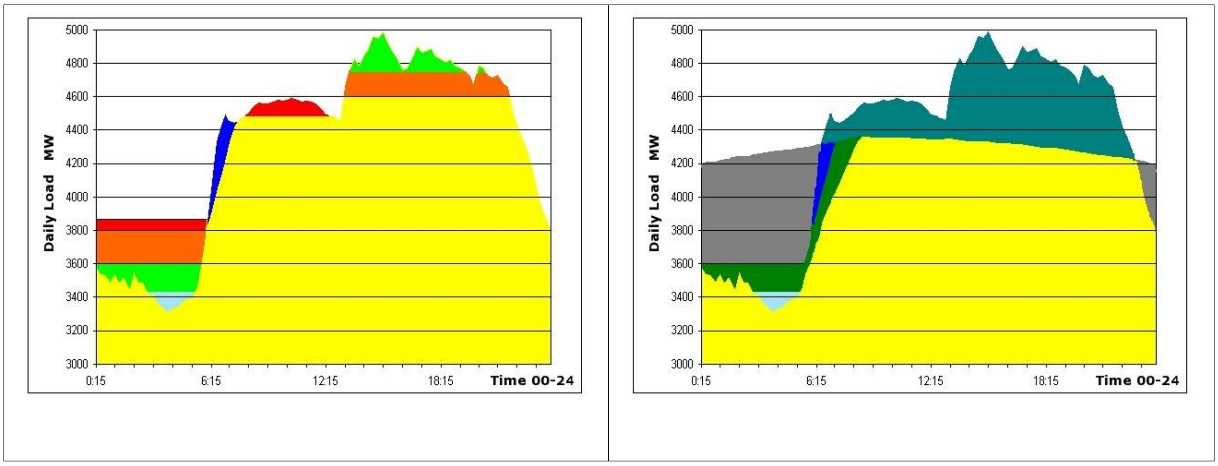


Fig. 2. The levels of cooperation: synergistic V2G solutions (source: Földesi and Bajor 2009)

Without any infrastructure investment and development, the electrical forklifts and material handling units has a significant storage capacity and energy requirement for daily operations (Fig. 2). The new direction of the research is to design a monitoring system for understanding the nature of the movements and energy demands of these vehicles.

5. Conclusions and further research

There are available green electricity sources for warehouse operations, it is possible to match these sources to the energy demand of logistics activities: charging the forklifts and optimize the storage units.

The green sources alone are not able to provide all the energy required, the cooperation between the local green sources and the traditional electricity supply is crucial. The integration of transportation and conventional electrical energy demand should be analyzed, because the feasibility studies for these systems and structures has such a lot of dimensions (tariff-system for electricity, security of supply, the price of the missing energy, frequency of fault events, etc.), and market forces are not what drives sustainable economic development. The identification of environmental impacts of marginal changes in electricity demands even more complex, electricity storage can be used to introduce greater flexibility into electric systems to accommodate large amounts of intermittent power sources.

The further research will be the analysis and simulation of the structure of an appropriate storage and forklift charging system (G2V-V2G solutions) in GPSS.

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