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D5.2.8 The potential of EVs in delivery traffic

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Contents

Introduction

Product deliveries in Finland are based on large-scale, punctual traffic. Consumer goods are delivered on rails, roads and waterways. Finnish society relies on functioning, on-time delivery traffic. A lot of food and other consumer goods are brought to shops through terminals. Fresh food is often brought straight to smaller, local distribution centers for decreasing the delivery times. Deliveries are mainly scheduled to night-time which results as less inconvenience for daytime private and commuter traffic on roads.

Delivery traffic brings the goods first to the logistics centers from where they are forwarded to shops. Customers themselves or special deliveries bring the products finally to the customers' homes. This chain of several delivery phases means long travel distances for single products and notable energy consumption. Thus, energy efficiency of logistics chains has become an issue of interest.

Energy efficiency of delivery vehicles can be improved by several means. This documents concentrates on assessing the potential of electrification of vehicles in order to decrease emissions and total energy consumption. Electric vehicles and hybrid electric vehicles are making their way to the markets. However, full electric functionality is more commonly presented in passenger cars, and for instance forklifts, as well as other industrial lifting and transport machines. Heavy-duty delivery vehicles require greater energy storages for their notably higher energy consumption. So far even in smaller vehicles the range has been a limiting factor of EV development. Delivery vehicles are also often used for long ranges whereas private cars are mainly driven under 50 kilometers per day on average.

Vehicle energy efficiency

Delivery vehicles are often driven with as full loads as possible, also the return trips are utilized for delivering empty boxes and other transport cases. Heavy-duty vehicles consume yearly several hundred million liters of diesel fuel in Finland. Several issues affect the energy consumption of delivery vehicles. Efficiency of vehicles can be highly influenced by political willingness to reduce emissions in traffic. Requirements are set for vehicle's performance and specific consumption. Additionally, energy consumption can be reduced by optimal driving. Truck drivers can be trained to drive more efficiently. Motivation and instructions influence the driver's behavior.

Moreover, efficiency can be improved with effective choices of fuel and lubricants. Presently, biofuels and hybrid technologies with braking power regeneration are used increasingly. What comes to the vehicle itself, weight and aerodynamics, power train, chassis, exhaust gas after-treatment and tires are straight causes for either better or worse energy consumption. Also helping devices for driver can save energy by enabling better route planning. Maintenance secures the healthy life of the vehicle and directly affects vehicle life and energy consumption. [1]

Savings in energy use can be reached as follows [2]:

- vehicle weight and aerodynamics: 30 %
- economical driving behavior with help of devices: 5 – 15 %
- vehicle brand and model: 5 – 15 %
- tires: 5 – 15 %
- spoiler for air guidance in articulated vehicle: 4 – 8 %
- truck trailer type: 3 – 5 %
- lubricants: 1 – 2 %

Electricity has become more widely utilized in vehicular applications. Several new passenger vehicle models use some kind of hybrid or plug-in hybrid technology in order to improve energy efficiency and reduce emission rates. Electricity suits especially to traffic where vehicles stop and accelerate often. In steady pace and higher speeds, vehicle batteries are recharged for later use. Electric motors have clearly better efficiencies than internal combustion engines. When battery technologies develop enough, vehicle electrification can become more of a rule than exception in heavy-duty vehicles as well. Hybrid delivery trucks have achieved lower consumption rates. Volvo FE Hybrid trucks for instance have achieved up to 30 percent fuel savings compared to normal diesel trucks [3] [4].

Improving energy efficiency has several positive sides. By using renewable energy resources and vehicle electrification one can control the emission levels in the urban area. Particle emissions for instance form a major problem for modern cities. Many cities have paid attention to keeping city centers cleaner and possibly free of local exhausts. Finland has committed to increasing the amount of biofuels to a level that corresponds 20 percent of all

liquid fuel used in traffic. This should be achieved by 2020. The first step to this has been the implementation of E10 gasoline. Electric vehicles could possibly work on those emission free zones. The Finnish company Valio has tested trucks that are driven on bioetanol. Compared to conventional diesel trucks, bioetanol has decreased carbon dioxide emissions by 90 percent and particle matter (PM) emissions by 70 percent. Especially, PM emissions are dangerous to the immediate environment. [5]

To observe the energy consumption of heavy-duty traffic that covers the main part of the logistics framework, we need to consider truck traffic. The main problem with the electrification of heavy-duty trucks is of course the energy intensity of the delivery mode. Conventional diesel full trailer combination (i.e., load of 40 tonnes, vehicle gross mass of 60 tonnes) uses 5.1 kWh/km when driving on highway in full load. Urban driving takes 9.2 kWh/km. These figures base on measurements of VTT Technical Research Center of Finland made on diesel vehicles that were mainly in emission categories EURO2, EURO3 and EURO4. The amount of energy used by a full trailer combination to carry a load of one tonne for one kilometer is thus 0.13…0.23 kWh/tonne/km. A delivery diesel van with a gross mass of 2.7 tonnes (load of 1.2 tonnes) consumes 0.78…1.00 kWh/tonne/km. Considering figures of urban driving, diesel van consumes up to six times more energy per delivered tonne of deliverables. Assuming that electric vehicle consumes roughly three times less energy than a vehicle with an internal combustion engine, a pure electric full trailer combination would consume 0.043…0.077 kWh/tonne/km and an electric van 0.26…0.33 kWh/tonne/km. In order to have a range of 150 km (i.e., a common range for electric vehicles), these vehicle types should have battery capacities of 460 kWh (full trailer combination) or 59 kWh (electric van). Thus, the weight of the battery packs would circle around 4 600 kg or 590 kg, respectively. The weight of the battery packs is assessed assuming that the energy density of batteries would be 100 Wh/kg, which is a conservative figure. [6]

Considering the previous calculation, it can easily be seen that batteries would bring a notable amount of extra weight to the vehicle thus increasing the energy consumption. This was not taken into account in the simple calculation. Additionally, the range of 150 km is very short for many delivery purposes. Vehicles also need to be refilled or recharged quickly. Delivery vehicles commonly do long shifts containing several deliveries. In case of electric vehicles, batteries could be recharged using DC-charging or other quick charging mode. Another alternative to this would be battery-swapping that would possibly be the most sensitive to the battery as the batteries can be recharged slowly before usage. Battery-swapping, however, has its own difficulties. It requires standardized solutions for broad suitability, a specific swapping station, as well as several extra battery packs for secured operation cycle.

Logistics and delivery traffic

Logistics centers serve retail and wholesale purposes by concentrating the flow of products. Two main retail groups in Finland are Kesko Oyj and S-Group that sell products in several stores around Finland. Their combined market share is around 80 percent. S-Group is based on the Finnish markets only. S-Group's sourcing and logistics company is INEX Partners Oy that purchases and distributes a major part of the products – grocery and consumer goods – to S-Group's stores. Kesko's trading sector logistics is taken care of by Keslog Oy.

Keslog has 140 000 m^2 warehouses in Turku and Vantaa. Additionally, Keslog uses terminals for efficient delivery work. INEX has 12 grocery terminals around Finland. The Southern Finland terminal work in the same place with the logistics center located in Espoo. Products are forwarded from the logistics center straight or alternatively via terminals to shops. These logistics networks involve great amount of truck traffic. [7] [8]

In 2010, there were 117 150 trucks (> 3 500 kg) in Finland. From 2000 the amount of trucks has risen with 80 percent. Statistics from 2010 tell that groceries, drinks and tobacco alone were delivered on Finnish roads for a little less than 260 million kilometers and for 3 245 million tonne-kilometers. All deliveries on Finnish roads covered 2 322 million kilometers and 25 961 million tonne-kilometers. Thus, grocery deliveries accounted for around 12 percent of all delivery transportation. Considering all deliveries in Finland, over 50 percent of the delivery mileage was accumulated on shorter than 150-kilometer trips. The average delivery distances for groceries range between 75 – 160 km depending on the type of product. [9]

Assuming all grocery, drink and tobacco deliveries in Finland were made by delivery trucks or vehicles that average 2.5 kWh/km of energy consumption, hybrid technologies with 30 percent saving potential could contribute as yearly energy savings of around 200 GWh. This is a theoretical calculation.

The amount of deliveries has increased remarkably under the last ten years and the demand is going to rise when economy is healthy. All sorts of deliverables are taken to stores, terminals, shops and finally to customers every day. Majority of the deliveries are driven on rather short distances and could possibly be driven by electric vehicles. Especially, post, groceries, consumer goods and such could be delivered by smaller electric vehicles. Such trials have already existed in the past.

Electric vehicle utilization in delivery traffic

Electric vehicles could be utilized in traffic that has high predictability and clear route-planning. When the charging times can be fit to the delivery schedules, the usability of vehicles remains high. Regular delivery times also contribute to this idea. Electric vehicles could be used to reduce the local exhausts. Sometimes, city center emissions are on too high level and traffic may be restricted. In these occasions, electric cars can probably be used for deliveries without problems. The greatest potential for electric vehicles clearly could be the packed city centers where vehicles' average speeds are low and idle times are very high. Electric vehicles, of course, do not use energy while standing still. This benefit of electric vehicle's basic nature has great potential for emission reduction. Electric motors also provide more silent operation than conventional combustion engines. [10]

Regular delivery functions exist in many places. Delivery companies often have several basic routes that are used on a routine basis. Also airport deliveries and train cargo can involve such delivery routes. Electric vehicle fleets can work as a booster of the company image. For instance, Itella Oyj has previously planned utilization of electric vehicles and small-scale wind power generation in their daily parcel and post deliveries [11].

Real demonstration cases of electric vehicles in delivery transportation have been executed already in the beginning of this millennium. Project ELCIDIS (Electric Vehicle City Distribution) that ended in 2002 was implemented in several European countries – e.g., Germany, Norway, Sweden. Tens of electric vehicles were used for mostly small distribution and delivery of goods, post etc. Some of the vehicles were hybrid electric, but most were based on full-electric drive train. The results of the ELCIDIS project show that the problems related to electric vehicles were mostly the same as they are at the moment. Battery and procurement prices of the vehicles, lack of standardization, and additionally, poor functionality of the maintenance chain were main hinders for effective usage of the involved electric vehicles. However, electric vehicles were held suitable for urban deliveries on low speeds, frequent stops and moderate daily mileage. [12]

Electrification of delivery vehicles and usage of renewable fuels can better the living conditions in the urban areas and save the nature from extra load on climate. Energy can be used more efficiently, which leads to lower use of primary energy. However, electrification comes gradually to vehicles starting with passenger vehicles and smaller vehicles. Delivery vehicles (i.e., trucks, vans) carry a lot of weight and consume a lot more energy thus requiring better energy capacities. Various hybrid and plug-in solutions, however, already have been used successfully. Electrification contributes as reduced emission levels and energy consumption. The great potential in vehicle electrification is evident. The major role is played by politics, EU regulations and goals, as well as national ambitions to reduce energy consumption. On local level, cities and communities can as well have their saying into this issue by arranging incentives for electric vehicles.

References

1. VTT et al. *Säästöjä Polttoaineen Kulutukseen - Raskaan Ajoneuvokaluston Energiankäytön Tehostaminen* Motiva Oy. , 2003 [accessed 21 November 2011] Available from: <http://www.motiva.fi/files/393/Raskaskalusto.pdf>.

2. *Tavaraliikenteen Energiatehokkuus.* Motiva Oy. 2011. Available from: <http://www.motiva.fi/liikenne/ammattiliikenteen_energiatehokkuus/tavaraliikenteen_energiatehokkuus>.

3. *Volvo FE Hybrid - New Trucks.* volvogroup.com. 2011. [accessed 21 November 2011] Available from: <http://www.volvotrucks.com/trucks/global/en-gb/trucks/new-trucks/Pages/volvo-fe-hybrid.aspx>.

4. LIIMATAINEN, Heikki. *Taloudelliseen Ajotapaan Kannustavat Järjestelmät Kuljetusyrityksissä.* M.Sc. ed. Tampere: Tampere University of Technology, February 2007 [accessed 21 November 2011]. Available from: <http://www.motiva.fi/files/956/rastu2007_liimatainen_kannustusjarjestelmat.pdf>.

5. *Logistiikka.* Suomen Osto- ja Logistiikkayhdistys LOGY ry. 2011. [accessed 21 November 2011] Available from: <http://www.logy.fi/logistiikka-lehti/aiemmat_numerot/2011/Logistiikka_3_2011_kevyt_valmis.pdf>.

6. *Unit Emissions of Vehicles in Finland.* VTT Technical Research Center of Finland. 2010. [accessed 21 November 2011] Available from: <http://lipasto.vtt.fi/yksikkopaastot/tavaraliikennee/tieliikennee/tavara_tiee.htm>.

7. *Inex Partners.* 2011. Available from: <www.inex.fi>.

8. *KesLog.* , 2011 [accessed 21 November 2011] Available from: <http://www.keslog.fi/>.

9. *Tilastokeskus.* Tilastokeskus. 2011. [accessed 21 November 2011] Available from: <http://www.stat.fi/>.

10. ZIEGLER, Helmuth. *Volvo, Siemens Team to Develop Europe's Electric Vehicle Market.* The Energy Collective. 21 September 2011 [accessed 21 November 2011] Available from: <http://theenergycollective.com/amelia-timbers/65652/volvo-siemens-team-develop-electric-europes-vehicle-market>.

11. KORKIA-AHO, Sampo. *Itella Corporation. P.O. Box 1, FI-00011 Itella, Finland. Interview 15 September 2010.*

12. *ELCIDIS - Electric Vehicle City Distribution - Final Report.* European Commission. 2002. [accessed 21 November 2011] Available from: <http://www.elcidis.org/elcidisfinal.pdf>.