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Identifying the potential CO_2-efficiency for the Deutsche Post DHL delivery fleet based on vehicle technology scenarios

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Abstract

In order to identify the CO_2-reduction potential of the German delivery fleet of Deutsche Post DHL, this study analyzes 3 different fleet scenarios. Based on a newly developed driving cycle that matches the specific requirements of delivery trucks, fuel consumptions for 6 different types of powertrains have been simulated. Subsequently, 3 fleet scenarios up to 2020 have been calculated with *VECTOR21*. A comparison of potential CO_2-reductions and corresponding costs for the entire delivery fleet showed that significantly lowered CO_2-emissions do not necessarily cause higher cost for the fleet operator.

Keywords: CO_2-emissions, delivery vehicle, scenario simulation, operating cost, fleet operator

1 Introduction

Increasing CO_2-efficiency across the entire corporation has become a major goal for Deutsche Post DHL (DPDHL). Several initiatives carried out by DPDHL aim at identifying potential opportunities for reducing the corporate CO_2-emissions and eventually increase the overall CO_2-efficiency. The work to be presented in this paper focuses on potential CO_2-reductions regarding the German delivery fleet (mail and parcel) up to the year 2020.

The recent progress which has been achieved regarding the development of electrified passenger cars suggests that electrified powertrains might also be suitable for light commercial vehicles (LCV). Technical issues as well as cost concerns have been and still are being tackled. Hence, alternative powertrains might be an advantageous option for commercial fleet operators such as DPDHL not only in terms of decreasing their carbon footprint but also regarding cost-efficiency. Due to the high number of delivery vehicles, introducing electrified vehicle concepts into the fleet may offer a significant lever for increasing the CO_2-efficiency. At the same time, however, the utilization of alternatively propelled vehicles as delivery trucks imposes difficulties. Demanding driving cycles with a significantly above average number of ‘stop-and-goes’, higher initial investment cost as well as specific requirements for the vehicles themselves in terms of payload and ranges need to be addressed carefully.

In order to answer these questions, DHL Solutions & Innovations (DSI) together with the German Aerospace Center (DLR), Institute of

Vehicle Concepts conducted a study, looking at both the advantages as well as the disadvantages of introducing electrified vehicles into the German delivery fleet. Based on simulations regarding the energy consumption in different driving cycles, conventional diesel vehicles have been compared to alternative drive trains, such as natural gas vehicles (CNG), range-extended electric vehicles (EREV), all-electric battery electric vehicles (BEV), and fuel cell vehicles (FCV). Taking into account the DPDHL-specific requirements for all vehicles, the results have been used to simulate the introduction into the delivery vehicle fleet. This task has been carried out utilizing the scenario based simulation tool *VECTOR21 developed* at the DLR Institute of Vehicle Concepts .
Eventually, the results of three different scenario calculations have been interpreted regarding their potential for CO_2-reduction as well as cost issues.

2 Methodology

2.1 The vehicle technology scenario model *VECTOR21*

VECTOR21 in its original set-up is capable of simulating the market development of the German passenger vehicle market. Based on a least-cost approach, the competitive market situation between conventionally propelled vehicles (i. e. gasoline & diesel vehicles) and alternative vehicle concepts is simulated. Taking into account basic political and economic conditions such as CO_2-legislation and oil-prices, different scenarios can be defined, each individually anticipating different future developments. Furthermore, technical progress for new components such as batteries and power electronics is considered utilizing a learning curve approach. Hence, future cost developments for innovative technologies are being calculated within the model based on cost degressions driven by the cumulated output of the components themselves. As a result *VECTOR21* shows the future market penetration with respect to the types of powertrains as well as the corresponding CO_2-emissions. For this study, *VECTOR21* has been adjusted to meet the DPDHL-specific conditions. For further details on the *VECTOR21* model see [1].

2.2 DHL delivery vehicle fleet

In order to apply *VECTOR21* to the DPDHL mail and parcel delivery fleet, the current operating fleet had to be analyzed in detail. The focus has been set on the vehicle class up to a maximum load weight of 3.5 metric tons. Based on the configuration of the real DPDHL fleet, three homogenous vehicle classes with maximum load weights of 2.2, 2.8, and 3.5 metric tons respectively have been defined. The vehicle characteristics including maximum velocities, acceleration, power output, front surface areas, drag coefficients, curb weights, and maximum payloads for all three vehicle sizes have been set to match the vehicle characteristics of the current delivery fleet. Additionally, assumptions regarding power levels as well as battery sizes for the alternative powertrains have been made. For these vehicles, all other characteristics have been defined in order to resemble the key functionalities of the current fleet in terms of maximum weight, maximum payload (mass and volume), and maximum vehicle range.

2.3 Simulation of the energy consumption

In order to assess the energy consumption of alternative – and not yet existing – vehicle concepts to be used as delivery vehicles, the Modelica library Alternative Vehicles has been utilized. Modelica is a free, object-oriented description language for modeling and simulation of dynamic multidisciplinary systems (electrical engineering, thermodynamics, mechanics and control). Parameterized component models of e.g. batteries, fuel cell systems, electrical drives, and thermal subsystems are used to model alternative power trains in the corresponding vehicle models. Figure 1 depicts an exemplary Modelica vehicle model used for the simulation of a parallel hybrid. For further details on the library see [2].
A detailed analysis of the current vehicle fleet's energy consumption showed that common driving cycles such as the New European Driving Cycle (NEDC) or the Artemis Urban driving cycle [3] significantly underestimate the real-world energy consumption. Simulating the previously defined diesel vehicles and comparing the results to the real-world consumptions of the (almost) exclusively by diesel engines propelled delivery fleet showed that the simulation results underestimate the consumption by over 40%. This difference is due to the very specific driving cycles of the delivery fleet with a high share of urban

driving in combination with a very high number of stop-and-go-traffic – oftentimes with not more than 100m between 2 stops.

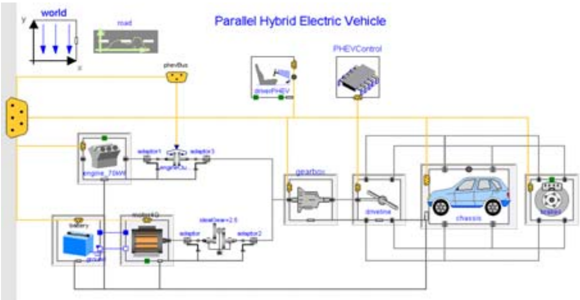

Figure 1: Exemplary Modelica vehicle model used for the simulation of a parallel hybrid.

In order to produce comparable results, a new driving cycle has been developed, matching the special requirements of delivery trucks. The new cycle is based on the Artemis Urban driving cycle and has been verified by comparing the simulation results to real-world DPDHL driving cycles and by eventually comparing the residual energy consumption to the overall fleet consumption.

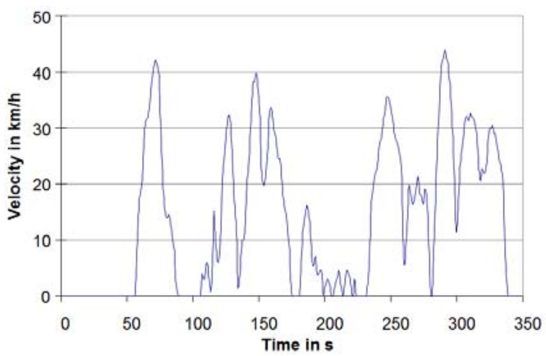

Figure 2: Segment of the newly developed driving cycle for delivery vehicles.

The newly developed driving cycle has then been used to simulate the energy consumption of five alternative powertrain configurations (gasoline, CNG, diesel-hybrid, BEV, and FCV).

3 Fleet scenarios

As mentioned above, three scenarios have been calculated utilizing *VECTOR21*.

3.1 1st scenario: *Baseline*

The first scenario – *Baseline* – anticipates a rather conservative future with only minor changes to the current status quo. Oil prices are assumed to increase to 100 € per barrel in 2020. The share of biofuels rises from 5% in 2010 to 10% in 2020. Electricity used for the operation of delivery vehicles is assumed to be produced entirely by renewable energy sources. According to current plans of the European Commission [4] [5], the European-wide CO_2-target for newly purchased LCVs is set to 175 g/km in 2020 with monetary penalties for each additional gram of 100, 110, and 120 € for 2018, 2019, and 2020 respectively. All other parameters remain on their 2010 levels.

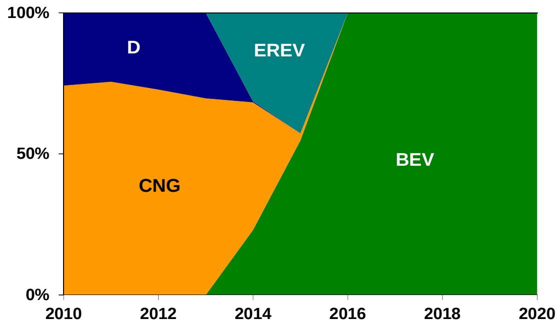

Figure 3: Development of newly purchased delivery trucks for the *Baseline*-scenario up to 2020.

Figure 3 shows the result of the calculation run for the *Baseline*-scenario. All above mentioned powertrain configurations (G, D, CNG, EREV, BEV, and FCV) have been taken into account. However, gasoline and fuel cell vehicles are not able to gain any market shares. Due to their high fuel consumption, gasoline vehicles show too high operating cost, whereas FCVs impose too high initial investments. An interesting development can be seen in the behavior of CNG vehicles. In the near future, CNG vehicles seem to be advantageous over all other types of powertrains. In the long run, however,with increasing oil prices and the new CO_2-legislation being introduced, the scenario strictly favors battery electric vehicles for all three vehicle sizes.

3.2 2nd scenario: *Moderation*

In the second scenario – *Moderation* – minor adjustments regarding the general scenario assumptions have been made. In order to set up a sensitivity-scenario for the *Baseline*-scenario, the oil-price has been lowered to 80 € per barrel in 2020. At the same time, the share of biofuels has been increased to 20% in 2020. As a third change, a tax on electricity used in transportation has been introduced. All other assumptions including the vehicle characteristics and specifications themselves have not been altered.

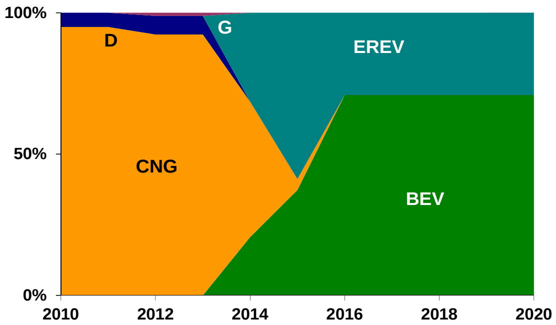

Figure 4: Development of newly purchased delivery trucks for the *Moderation*-scenario up to 2020.

Figure 4 shows the development of the newly purchased delivery trucks for the second scenario. Again, all types of powertrains (G, D, CNG, EREV, BEV, and FCV) have been considered. In this second scenario run, gasoline vehicles are able to gain a minimal market in 2012 and 2013. However, this development seems to be negligible. Fuel cell vehicles are, again, not able to enter the market. This second scenario underlines the development which could be observed in the Baseline-scenario. In the near future, CNG vehicles seem to be beneficial over diesel vehicles. In contrast to the first scenario, however, this scenario does not favor one single type of powertrain in the long run. Nevertheless, vehicles with an electric motor as the main source for traction dominate the market. The ambiguity is mainly due to the declining oil prices in combination with the newly introduced tax on electricity.

3.3 3rd scenario: *Eco-protection*

The third scenario – *Eco-protection* – has been set up in order to calculate a scenario in which major political changes occur. Additionally to a lowered oil price of 80 € per barrel the politically influenced scenarios parameters have been varied:

- The share of biofuels has been increased even further to 30% in 2020.
- Again, an additional tax on electricity used for transportation has been applied.
- CO_2-restrictions for newly purchased LCVs have entirely been taken out of consideration.
- Instead, monetary incentives in the form of federal subsidies have been introduced for EREVs, BEVs, and FCV.

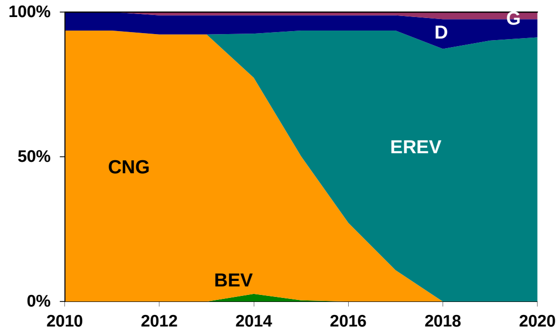

Figure 5: Development of newly purchased delivery trucks for the *Eco-protection*-scenario up to 2020.

Figure 5 depicts the calculation results for the third scenario. Again, fuel cell vehicles are not able to enter the market at all. Additionally, in the near future a similar development to the previous scenarios can be observed. Up to around 2014 CNG vehicles are dominating the market. Due to significant federal subsidies, battery electric vehicles are able to enter the market temporarily in 2014. However, this development is not sustainable and BEVs are not able to gain significant market shares in the long run. Mainly due to the absence of CO_2-restrictions and -penalties for newly purchased vehicles, EREVs are dominating the market by 2020. Diesel and gasoline vehicles are only able to occupy niche markets.

3.4 Costs versus CO_2-emsissions

All three scenarios are able to significantly lower the CO_2-emissions of the delivery fleet. Due to various influencing factors such as the share of biofuels or the renewable sources of electricity in combination with the long term dominance of full electric vehicles significant CO_2-reductions are feasible for the entire fleet.

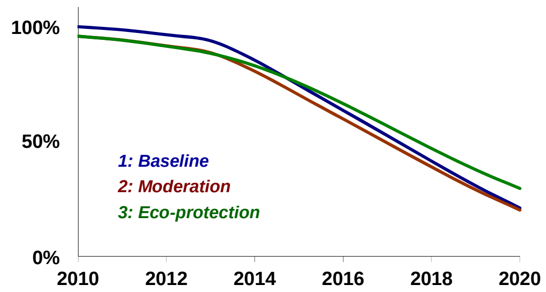

Figure 6: Well-to-wheel CO_2-emissions for the entire delivery fleet for all three scenarios up to 2020.

Figure 6 depicts the development of well-to-wheel (WTW) CO_2-emissions for the entire delivery fleet (not only the newly purchased vehicles) for all three scenarios up to 2020. The results show that CO_2-emissions might be lowered significantly by introducing alternative powertrains into the delivery fleet.
A comparison of the costs in 2010 and 2020 shows that the overall costs (consisting of initial purchase prices and operating costs over the lifetimes of the vehicles) stays relatively constant. In the first and third scenario, the costs even decrease until 2020 compared to the 2010 level. This development is – in all three scenarios – due to a shift away from a high share of operating / fuel cost towards fixed / initial cost caused by alternative powertrains. Hence, the significant reduction in CO_2-emissions might not necessarily result in higher overall cost for the entire fleet.

4 Conclusion

The recent developments in vehicle and powertrain technologies offer the opportunity for fleet operators to introduce alternatively propelled light commercial vehicles into their fleet. However, due to the innovative technology, a careful assessment is essential. A comparison of existing methods for analyzing the fuel consumption of delivery vehicles showed that commonly used driving cycles underestimate the real world fuel consumption of the delivery fleet by over 40%. The specific driving patterns of delivery trucks made it necessary to develop an entirely new driving cycle, matching the real world driving cycles.
In combination with a detailed analysis of the current Deutsche Post DHL delivery fleet in Germany, the fuel consumptions of alternative powertrains including gasoline, compressed natural gas, range-extended, battery electric, as well as fuel cell vehicles have been simulated taking into account the special requirements of delivery vehicles.
By adapting the scenario tool *VECTOR21* to the DPDHL fleet characteristics, three different scenarios have been calculated for the German delivery fleet. All three scenarios showed that alternative powertrains are advantageous over the currently operated diesel vehicles in terms of CO_2-efficiency. However, the scenarios have been ambiguous as to which powertrain is favorable in the long run. Depending on the scenario assumptions, both battery electric and range-extended electric vehicles were able to gain significant market shares. Fuel cell vehicles did not enter the market in any scenario. In the near future, CNG vehicles seemed beneficial over other powertrains.
The comparison of CO_2-emissions and overall costs showed that by introducing alternative powertrains into the delivery fleet, significant CO_2-reductions might be achieved in all three scenarios. Due to a shift from a higher share of fuel cost towards higher initial purchase prices, the overall costs for the delivery fleet stayed relatively constant.

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