



1 Test vehicles of the Dresdner Verkehrsbetriebe AG (Source: DVB AG).

## ANALYSIS OF HYBRID BUSES IN REGULAR SERVICE

### Initial Situation

From 2006 to 2009 the first prototypes of hybrid city buses were introduced to the public by various bus manufacturers. Already in 2006 Solaris Bus & Coach S.A. delivered a close-to-production vehicle to the Transport operators of Dresden (DVB AG) and Leipzig (LVB GmbH) which is equipped with a power split hybrid propulsion system developed by Allison Transmission. The second generation vehicle with a smaller diesel engine, driven third axle and with an improved power train cooling system is in daily use by the üstra Hannoversche Verkehrsbetriebe AG.

When ordering further hybrid buses environmental and economic facts have to be considered. Fuel-saving, wear reduction and lower maintenance costs have to amortize additional procurement costs.

To provide an objective evaluation of hybrid buses, the vehicles in Dresden, Leipzig and Hannover were compared to conventional diesel buses in extensive field campaigns.

### Project Content

In order to obtain representative results, the acquired data of both test vehicles were recorded and evaluated in daily regular service by the Fraunhofer Institute for Transportation and Infrastructure Systems. The evaluation periods lasted for 12 months in all cases; thereby the vehicles were in regular service use for 16 to 18 hours every day.

The lines for parallel services were chosen according to the expected fuel saving potentials of the hybrid buses. The lines were split up into track sections, characterized by passenger demand, altitude profile and distances between stops.

Additional evaluations based on requested time intervals, such as holiday season, trade fair dates, rush hour or times with low traffic have been carried out, too.

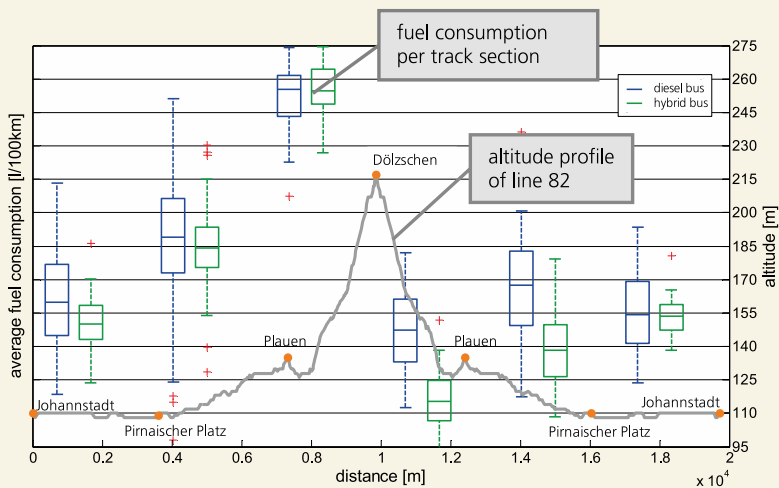
### Fraunhofer Institute for Transportation and Infrastructure Systems IVI

Director :  
Prof. Dr. Matthias Klingner

Zeunerstrasse 38  
01069 Dresden  
Germany

### Contact

Matthias Breitkopf  
Phone +49 351 4640-642  
matthias.breitkopf@ivi.fraunhofer.de



2

## Measuring System

Using a real time controller, all available state variables of the on-board data bus (CAN) and the passenger counting system, as well as the GPS-position for every way- and time point, could be recorded exactly (cf. Figure 2). The parameter fuel consumption was verified by measurements with a fuel-flow-sensor and has been equilibrated with the refuelling data of the operators.

The acquired data, from which it is possible to generate acceleration-, track-, velocity-, power-, and fuel-consumption-profiles for every vehicle and for every period of time, were saved in a database. Developed software ensured a fast and secure conditioning and evaluation of the raw data.

## Services

It is possible to provide substantiated comparisons of buses with different propulsion systems using test-drives on public transport lines as well as standardized test cycles on testing areas. The comparisons also serve for the optimization of drive trains.

The data acquired in regular service can be evaluated by the Fraunhofer IVI regarding to the average fuel consumption per track section, per time interval as well as in dependence on the number of passengers, the average speed and the deviation from schedule. The advantage of this measurement method is based on the exact localization of potential sections for energy saving.

Cost-benefit-analyses consider all costs for procurement, equipment, training, maintenance and service occurring in a testing period as well as costs which are expected in normal future operation. Scenarios for cost developments of the vehicle, spare parts, diesel and operating fluids as well as the lifetime of the batteries and their costs form the basis for cost-benefit-analyses. Such analyses identify the conditions under which the additional procurement costs of hybrid buses can be amortized.

Simulations and calculations allow conclusions on fuel saving potentials caused by further technological developments. For instance it is possible to determine fuel savings using a start-stop-automatic, a mechanical decoupling of the peripheral equipment, the use of a predictive energy management and downsizing of the diesel engine. Furthermore it is possible to predict the fuel consumption on other lines or to evaluate possible influences of modifications of the line-characteristics on fuel consumption.

The acceptance by drivers, maintenance staff and passengers is important for the successful introduction of hybrid buses. With the help of comprehensive surveys, the operability, the driving characteristics, the maintainability as well as the interior design of the vehicles can be evaluated.

## References

- Dresdner Verkehrsbetriebe AG
- Leipziger Verkehrsbetriebe GmbH
- üstra Hannoversche Verkehrsbetriebe AG
- SaxHybrid