

D 14.1

Stuttgart: Demo Description and Implementation Plan

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Abstract	<p>Energy used for heating, ventilation and air conditioning (HVAC) is more important for electrical bus solutions in comparison to conventional diesel buses due to its impact on the operating range. Therefore, the objective of the Stuttgart demonstration is to test and validate an innovative HVAC system for battery-only buses, which aims to reduce the energy consumption used for HVAC.</p> <p>Deliverable 5.1 describes the objectives of the technological innovations “Innovative HVAC for battery-only buses”, coherently with the EBSF_2 Validation Objectives as defined together with the project Evaluation Team. Moreover it reports on preliminary considerations about the data collection and planning of the demo activities along the project's lifetime.</p>
Keywords	Energy Management, Full-electric Bus, Heating, Ventilation and Air Conditioning.

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0.2	17/06/2016	Review and quality check	UITP	
1.0	28/06/2016	Final version	EVOBUS	

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ACRONYMS

EBSF – European Bus System of the Future

HVAC - Heating, ventilation and air conditioning

ICE – Internal Combustion Engine

TI – Technological Innovation

VO – Validation Objective

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1 Executive Summary

EBSF_2 will test different energy management strategies, especially for the operation of on-board auxiliaries and HVAC (Heating, ventilation and air conditioning), with different levels of readiness, based on measurements of the contribution of auxiliaries to emissions in real driving. Together the solutions are addressing all current vehicle architectures (ICE, ICE-hybrid, electric-only). The results will be used to develop guidelines and industry-wide recommendations in energy management. The demonstrations will also lead to a clear plan for wider implementation of the solutions, showing a scale-up effect and more substantial impact for making bus systems more energy efficient and comfortable.

Within the Stuttgart demonstration, an innovative HVAC-system for battery-only buses will be demonstrated in four test periods in total distributed in the year 2016 and 2017. Aim of this demo is to show a reduction in energy used for HVAC in the amount of 30 % compared to a conventional belt-driven HVAC-system (in average, on yearly basis). Therefore, multiple nose-to-tail-tests are selected as test set-up for this demo.

Deliverable 14.1 describes the objectives of the technological innovation “Innovative HVAC for battery-only buses” to be tested within the Stuttgart demo, vis-à-vis the EBSF_2 Validation Objectives defined together with the project Evaluation Team. Moreover it reports on test scenarios, preliminary considerations about the data collection and planning of the demo activities coherently with the EBSF_2 project master plan.

2 BACKGROUND AND CONTEXT

Energy used for heating, ventilation and air conditioning (HVAC) is getting more important for electrical bus solutions in comparison to conventional diesel buses due to its impact on the operating range. Therefore, the Technological Innovation (TI) of the Stuttgart demonstration is an innovative HVAC-system for battery-only buses, which aims to reduce the energy consumption used for HVAC.

The demo takes place in Stuttgart - the capital city of the federal state of Baden-Württemberg, which is located in the south west of Germany. Public transport in Stuttgart and the surrounding region is provided by Stuttgarter Straßenbahnen AG (SSB). SSB currently operates 17 streetcar lines and 55 bus lines. These serve statistically 175 million passengers on a distance of 32 million kilometres per year.

To achieve these figures, the SSB uses 253 busses, 184 light rail trains, 3 rack railway cars and 2 cable cars. The company employs approx. 3,000 people. Currently the bus fleet of the SSB already includes 21 electric driven buses, 14 serial ICE Hybrids, 3 parallel ICE Hybrids and 4 fuel cell powered Hybrids.

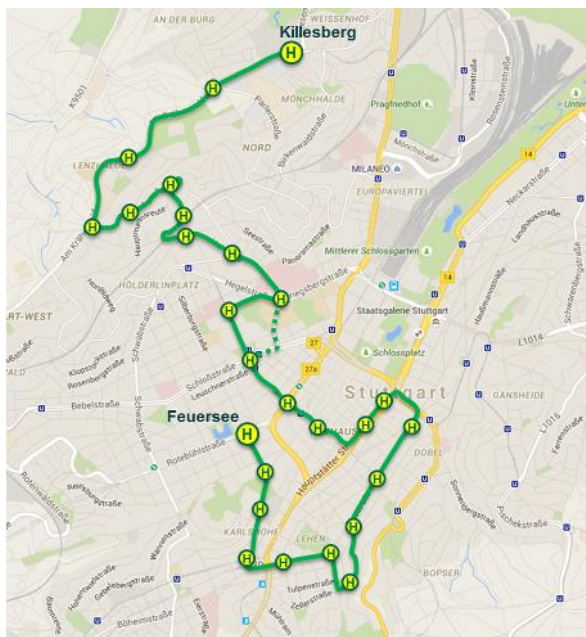


Figure 1 – Routing SSB line 43 (source :Google Maps)

SSB Line 43	→	←
Length	12,2 km	11,2 km
Duration	36 min	35 min
Amount of stops	26	25
Average speed	21 km/h	19 km/h
øt (between stops)	1,4 min	1,4 min
øs (between stops)	340 m	320 m

Table 1: Characteristics of SSB line 43

The planned tests under real operational conditions will take place on SSB line 43 running from Killesberg-station to Feuersee-station located in the city centre (Figure 1). The line has a length of 12.2 kilometres and includes 26 stops which lead to an average driving time of 36 minutes each way (see Table 1).

The vertical profile of line 43 is shown in Figure 2.

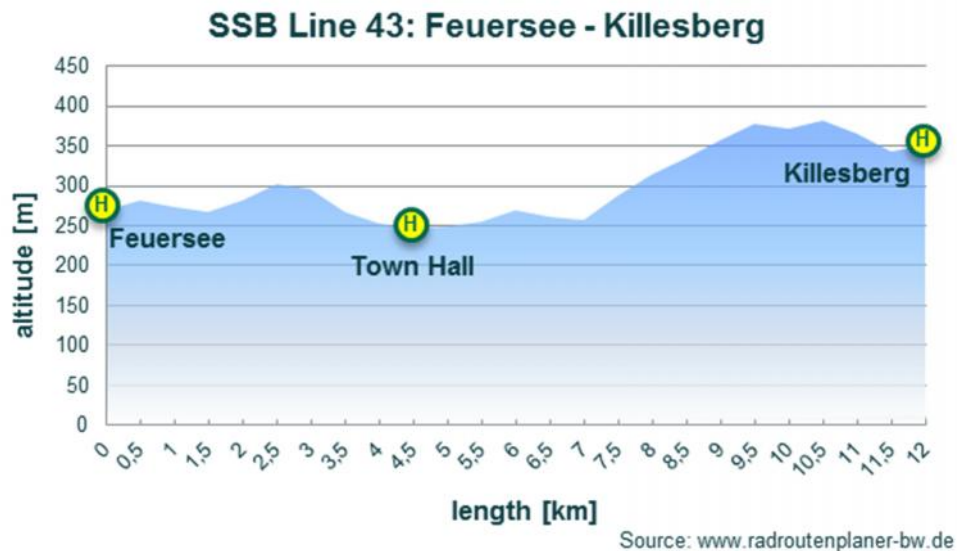


Figure 2: Vertical profile of SSB line 43

3 DEMO OBJECTIVES

The key objective of the Stuttgart demo is to contribute to the project research area Energy Strategy and Auxiliaries by demonstrating a reduction in energy consumption used for HVAC for battery-only buses due to an innovative HVAC-system. The demo team is committed to test and validate the Technical Innovation “**TiStu1 - Innovative HVAC for battery-only buses**”, labeled according to the definition and coding agreed within the task “Definition of Validation Objectives and Test Scenario”.

TiStu1 will be implemented on local line 43 (maximum length per direction 12.2 km, 26 stops, and average commercial speed of 21 km/h), which connects two stations by crossing the city center. The control vehicle will have a conventional belt-driven HVAC system, whereas the test utilizes an innovative high voltage HVAC system. The target reduction in energy consumption is 30 % in average on yearly basis compared to a conventional belt driven HVAC-system. In addition, driver’s and passenger’s comfort level is not intended to be negatively affected by the innovative system.

Coherently with the EBSF_2 evaluation methodology which applies to all the project demonstrations, a set of validation objectives have been identified for the Stuttgart test site. The applicable validation objectives relate mainly to operational, environmental and cost-efficiency domains.

The validation objectives related to the Technological Innovation to be tested in Stuttgart are reported below according to the name and coding agreed with the project Evaluation Team:

VO1: Improving the overall energy efficiency of fleets

By decreasing the energy consumption of a single bus, the bus fleet itself will improve its total energy efficiency.

VO3: Improving the overall energy efficiency of specific components (HVAC)

The Stuttgart demo is demonstrating an improvement in energy efficiency for HVAC by using an innovative HVAC-system for battery-only buses.

VO5: Increasing the uptake of fully electric and hybrid options

The technical innovation and the improved energy efficiency for HVAC will lead to an increase in attractiveness of battery-only bus solutions for public transport operators.

VO20: Minimizing operation and maintenance costs

Less energy consumption in HVAC results in less operating costs.

VO36: Making the debt service coverage more affordable

Savings in operational costs may have the potential to more affordable debt service coverage.

4 DEMO DESCRIPTION

4.1 Innovative HVAC for battery-only buses

The TI of the Stuttgart demo is the innovative HVAC-system for battery-only buses.

The target reduction in energy consumption used for HVAC will be demonstrated in multiple nose-to-tail-tests without passengers in Stuttgart. These tests will take place in 2016 and 2017 under real operational conditions on SSB line 43.

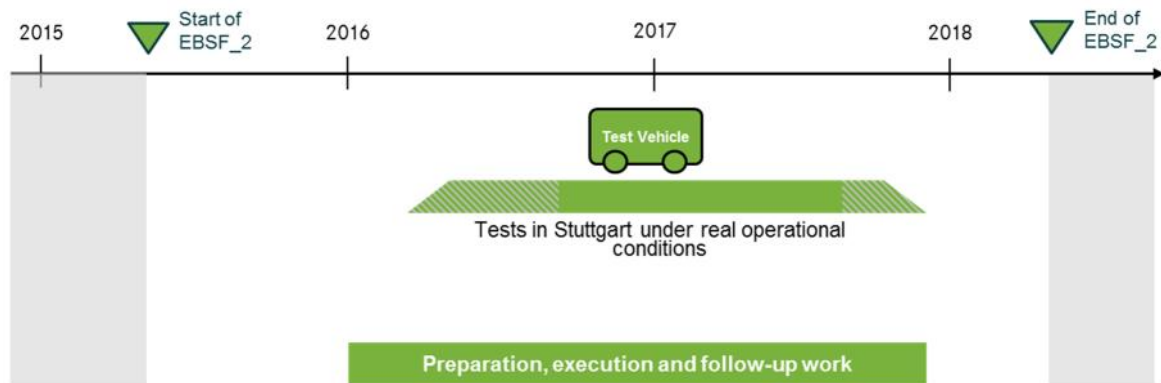


Figure 3 - Timeline Stuttgart demo

Every single test compares in total one demo vehicle equipped with an innovative HVAC-system for battery-only buses (the so called “EBSF_2 scenario”) with one reference vehicle, which uses a conventional belt-driven HVAC-system and represent the “no_EBSF2_scenario”(see Table 2). In the demo phase, special attention is paid to the comparison of the power consumption of both HVAC systems, their energy consumption per distance travelled, and the degree of driver’s/operator’s satisfaction.



	Reference Vehicle	Demo Vehicle
		
HVAC-System	Conventional belt-driven HVAC	Innovative high voltage HVAC
Energy consumption	State of the art	Aim: 30% less energy consumption
Comfort level	State of the art	Aim: As reference vehicle
KPI	<ul style="list-style-type: none"> • Power consumption HVAC [kW] • Energy consumption HVAC per distance travelled [kWh/km] • Degree of driver’s/operator’s satisfaction 	
Assessment of KPI’s	<u>Power consumption HVAC</u> <ul style="list-style-type: none"> • Torque refrigeration compressor • Power AC fan 	<u>Power consumption HVAC</u> <ul style="list-style-type: none"> • Power innovative HVAC
	<u>Driver’s / operator’s satisfaction</u> <ul style="list-style-type: none"> • Questionnaire 	

Table 2: Test vs. reference vehicle

Therefore, the power consumption of the reference vehicle will be determined, inter alia, based on the torque measured at the refrigeration compressor and the electrical power of the AC fan. Regarding the demo vehicle, the power input of the innovative HVAC-system can be measured directly by its electrical power consumption.

The assessment of the degree of driver's and operator's satisfaction will be provided by a questionnaire.

Temperature profile Stuttgart:

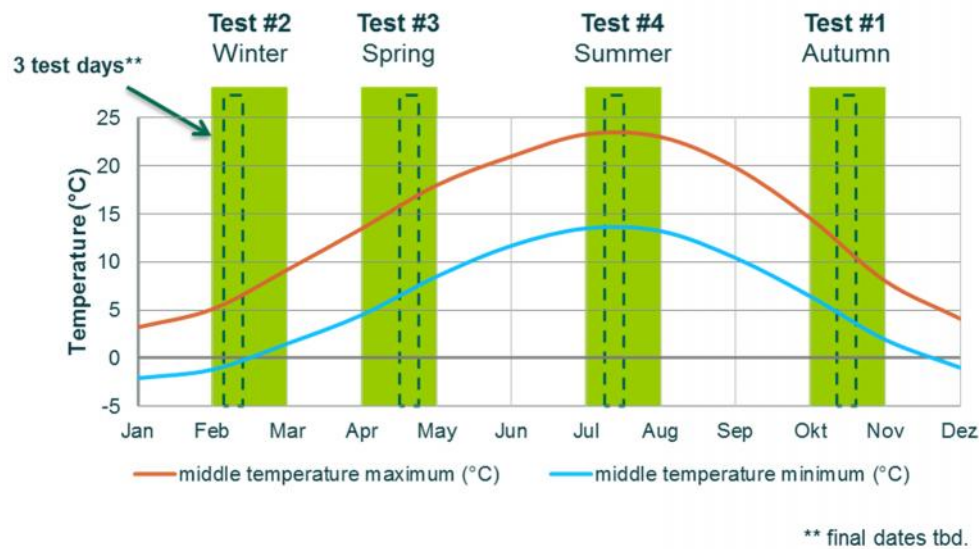


Figure 4 - Temperature profile of Stuttgart and test phases
(Source: <http://www.wetter.de/klima/europa/deutschland/stuttgart-s107390.html>)

The demonstration will be carried out in four phases of three days in 2016 and 2017. As shown in Figure 4, the first phase will be launched in October 2016 (autumn test) followed by the second phase in February 2017 (winter test), the third phase in April the same year (spring test), and finally, the last tests in July 2017 (summer test).

This test set-up enables the assessment of the energy consumption on a yearly basis.

4.1.1 Risk assessment

Possible risks which may affect the test quality:

- Delay in working plan (e.g. demo starts later than originally planned)
- Performance targets could not be achieved (e.g. if less than 30% reduction of energy consumption for HVAC in average on yearly basis)
- Negative driver's and/or operator's feedback (e.g. subjective perception of comfort level is worse than "no_EBSF2_situation")

4.1.2 Preliminary data collection plan

Data to be collected for the assessment of the TI is summarised in the following:

- Continuous power consumption measurement during the test phases (e.g. electric power consumption demo vehicle vs reference vehicle)
- Assessment of temperature at driver's place and passenger compartment vs. outside temperature by direct measurement
- Driver's feedback will be assessed by a questionnaire
- Continuous frequency of data collection during the tests (e.g. every second).

6 DEMO IMPLEMENTATION PLAN

As shown in Figure 5, the preparation phase of the Stuttgart demo started in August 2015 and will be completed by the end of September 2016.

Following subsequently, the demo phase starts in October 2016 with the first test phase and is scheduled to be finished one month after the final test phase in July 2017.

Finally, the last phase of the Stuttgart demo, the evaluation phase, takes from September 2017 until the end of the demo by the end of February 2018.

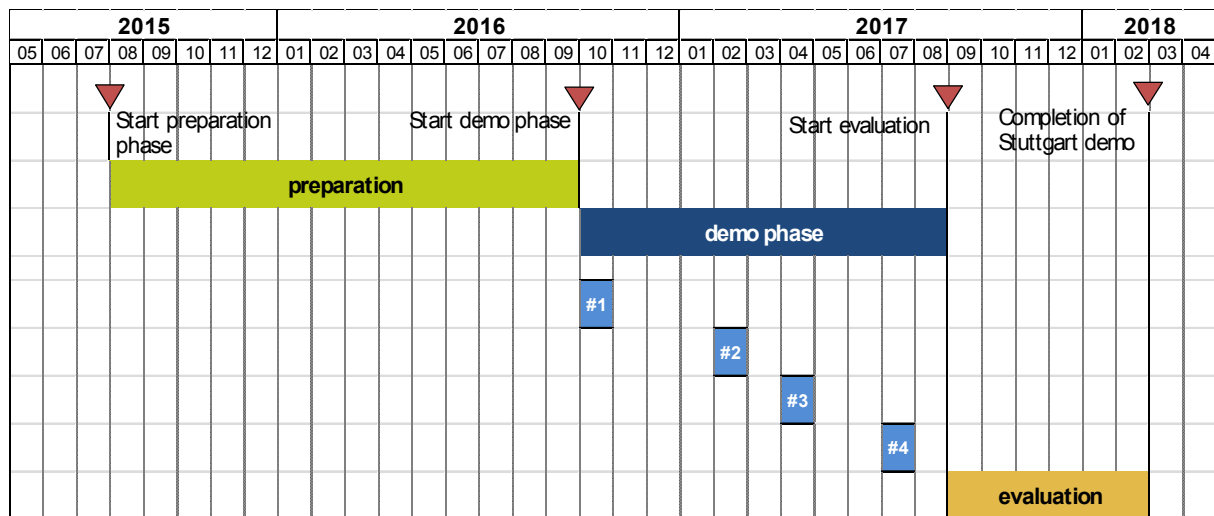


Figure 5 - Demo Gant Chart

- 08/15 – 01/16: Start of preparation phase
- 02/16 – 11/16: Demo phase with the four tests
- 12/16 – 05/16: Start of evaluation phase
- 06/17: Completion of the Stuttgart demo

5 Partners' Contribution

Company	Sections	Description of the partner contribution
EVOBUS	4, 5, 6	Elaboration of demo objectives; jointly development of demo description and implementation plan together with SSB
SSB	3, 5, 6	Elaboration of background and context; jointly development of demo description and implementation plan together with EVOBUS

6 ANNEXES

Test Scenario TI-1.

TI	Innovative HVAC for battery-only buses	Status		Note
Demo site	Test category	Control (reference vehicle)	Test (demo vehicle)	
Stuttgart	tests under real operational conditions			
Features				
Vehicles involved (units)		1	1	1 x demo vehicle, 1 x reference vehicle
Lines involved (units)		1	1	SSB line 43 (Killesberg – Feuersee)
Routes involved (units)				multiple test drives per day on SSB line no. 43
Time span (data collection)		4 x 3 days	4 x 3 days	3 test days per quarter (ca. February, April, July and October 2016)
Time span (testing activities)		4 x 3 days	4 x 3 days	3 test days per quarter (ca. February, April, July and October 2016)
Staff involved (units)		1	2	1 driver + 1 member of testing department EvoBus (test vehicle only)
Please, include any other information				

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