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# Saxony as a Model Region in Germany for connected electric mobility

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## Abstract

Saxony as a Model Region for electric mobility and intelligent transport systems has extensive experiences which ranges from the operation of hybrid and full electric buses including fast charging infrastructure, electric car fleets in companies and municipal institutions, eCarsharing and long distance mobility as well as in connected electric mobility. The paper describes the objectives and lessons learned of some of the noteworthy projects relating to electric public transport and multimodality as well as the perspective to establish Saxony as a pioneer in the field of intelligent transport systems and connected mobility.

*Keywords: autonomous, city traffic, electric drive, fast charge, public transport*

## 1 Saxony – pioneering smart and efficient mobility

Saxony is one of the federal states in the eastern part of Germany. The comparatively small state with about 4 millions inhabitants borders on Poland and Czech Republic and is partner region of Québec.
Since Saxony has five vehicle and engine plants operated by Volkswagen, Porsche and BMW as well as about 750 branch suppliers, equipment and service providers, the state is one of Germany's top auto locations today. Approximately every tenth car built in Germany comes from here. Saxony is also in the "pole position" of the second automobile revolution. Today's innovative fields are modern hybrid and electric mobility solutions, developments for autonomous driving, lightweight construction in an efficient material mix, resource-efficient production technologies as well as new traffic concepts and solutions. In addition to the rich industrial landscape Saxony offers a broad and vibrant scientific society, including universities and research institutes. In the forecited fields, industry and research work hand-in-hand and advance solutions for sustainable mobility. [1]
Saxony backs Germany´s ambitions to become the top provider and the leading market for electric vehicles and to further the development of connected and autonomous mobility.
Therefore the Saxon Government assigned the Saxon Energy Agency (SAENA) to coordinate all activities in this seminal field. With the objective of

- developing innovative projects
- pushing the collaboration between science, industry and companies, municipal institutions and all the other stakeholders
- implementing the results of the projects in real life and
- doing the public relations to include the Saxon public

SAENA is the connector between the Federal Government, the Federal State Government and all the other involved players in Saxony and beyond.
Two of these supervised activities are described below, which can be also seen in figure 1.

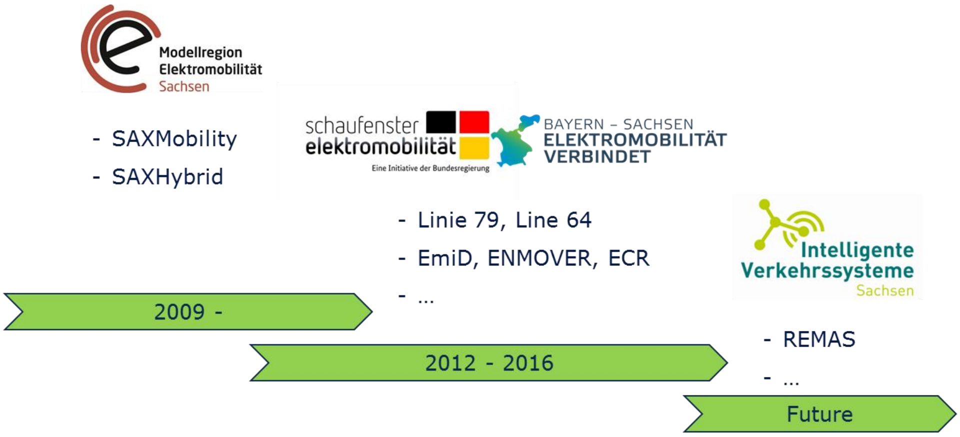


Figure 1: Overview of public founded projects of the federal government

## 1.1 Saxony as a Model Region for Electric Mobility

Since 2009, SAENA has been coordinating the “Model Region Electric Mobility Saxony”, which is funded by the Federal Ministry of Transport and Digital Infrastructure (BMVI). Several projects has been realized by manufacturers, users and infrastructure operators as well as by local players. In the model region of Saxony, public transport, the development of battery technology, the use of electric vehicles in fleets and the construction of a charging infrastructure constituted the main focus of the activities.

One of the main projects is “SaxHybrid – Serial Hybrid Buses Partially Running on Pure Electricity” (see figure 2), 20 serial hybrid buses were purchased and tested on actual routes in Dresden and Leipzig. Through this project, first experiences of using a fleet of serial hybrid buses were gained. The effect of various operating conditions such as the number of passengers, traffic problems or topography have been studied.
In 2011 with more than 50 hybrid buses running Saxony was the state with the highest density of these innovative vehicles. The transport companies worked close with the bus manufacturers to improve and enhance their buses. “SaxHybrid” was the first step in the Saxon public transport innovation plan which aims the operation of full electric bus fleets in urban areas.


Figure 2: Serial Hybrid Bus in Dresden

### 1.2 "Showcase Bavaria-Saxony ELECTRIC MOBILITY CONNECTS"

In April 2012, the German Government selected four regions in the country to act as "Showcase Regions for Electric Mobility". Based on a decision by the German Bundestag, research and development into alternative drive systems is to take place across each of these regions. The Federal Government provided a total of EUR 180 million in funding for these large scale demonstration and pilot projects. [2]

As a result of the successful application for the Showcase Regions for Electric Mobility, which was submitted together with Bavaria, SAENA has also been coordinating the "Showcase Bavaria-Saxony ELECTRIC MOBILITY CONNECTS". More than 100 partners are working in about 40 projects on the topics long-distance mobility, urban mobility, rural mobility, international connection and education and training.

A network of fast-charging stations was installed along the Autobahn A9 and put into operation in 2014. The groundbreaking ceremony for an energy-storage-plus house is another exciting opportunity to connect electric mobility to the grid. In addition to electric municipal vehicles in the solid waste management, delivery services and electric buses, several hundred eCarsharing, corporate fleet, commercial and residential EVs are on the road in Bavaria and Saxony. In the context of education and training, the results of the projects will be passed on to schools, on-the-job training institutions and academic institutions. [3]

## 2 Selected projects of the Showcase-Initiative

One of the main topics of the Showcase-Initiative in Saxony was the electrified public transport sector. Besides the development and field test of electric buses (see 2.3) some of the projects also focused on the increase of the energy efficiency of electric or hybrid buses (see 2.2) and the electric ranges by intelligent routing (see 2.1).

### 2.1 Project e-city-routing

Another method to increase the electric range especially in the field of individual transport is to route the vehicles intelligent. The objective of the project "e-city-routing – Intelligent Control of E-Mobility via a Traffic Control Center" is to develop and test a specific routing algorithm for electric vehicles. It is intended to facilitate intelligent guidance along the most energy-efficient route and to minimize concerns about range, taking dynamic traffic data and vehicle-specific energy flow data into account (see figure 3).

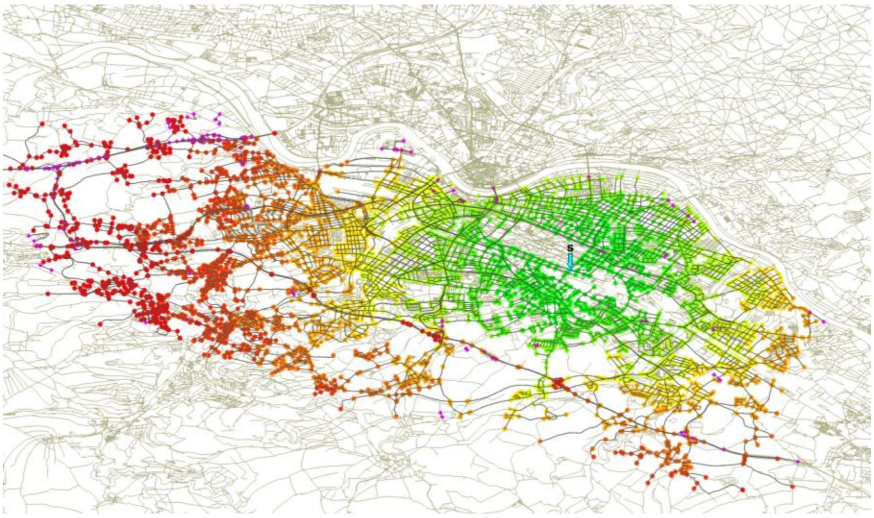

Figure 3: Project "e-city-routing" – energetic city map [9]

### 2.2 Pilot Route 64 – Efficient E-Mobility in Dresden

Since 2007 Dresden´s public transport company Dresdner Verkehrsbetriebe AG (DVB) has hybrid buses in the field – 18 by now. The advantages are well known and confirmed: E-Mobility saves resources, reduces emissions of noise and pollution and hence increases quality of life in cities. Although the fuel savings during spring and autumn are remarkable the buses need seven times more oil for heating in the wintertime compared to conventional buses.

The objective of the “Pilot Route 64” project is to develop and test new ways to increase the energy efficiency of hybrid buses. The project focuses on exploring potential energy savings through light-weight construction, an intelligent, predictive control system, as well as a high-efficiency heating and air-conditioning concept. Therefore scientists of the Technische Universität Dresden implemented an intelligent bi-directional air conditioning system in the form of an air/air heat pump which heats in winter and cools in summer. Up to 20% heating oil savings are expected.

They also equipped the hybrid bus with GPS and 117 sensors to measure data such as temperature, pressure, tension and luminance to develop a route-based energy management. To reduce weight and increase the electric range the scientists engineered a CFRP (carbon fiber reinforced plastic) light-weight rim which weighs 50% less than a conventional steel rim (see figure 4). That saves another 250 kg in total since the 18-meter-buses have 10 wheels altogether.

Figure 4: CFRP Light-weight rim [10]

## 2.3 Electric Bus Route 79 in Dresden with Conductive Charging System

The objective of the “Electric Bus Route 79” project was to test the first fully electrified bus route in Dresden, with a conductive fast-charging system via the tram power grid (see figure 5). The project-related scientific research should provide useful insights into vehicle and charging system optimization as well as the costs and benefits of the use of electric buses in public transport.


Figure 5: Fast-charging electric bus

The public founded project “Electric Bus Route 79” was launched in 2013. During this project an existing 5.3 km long bus route in Dresden has been changed to the operation with an all-electric vehicle. Therefore a high current charging station was built at the terminal stop. The boundary conditions are a 16 min

circulation time combined with a 20 min operation time. This results in a standstill of 4 min, which can be used for charging processes. The line operation is not hindered by this. For a better visualization the route is displayed as a map in figure 6. A red marking point shows the location of the charging station.
In the following sections the main components such as vehicle, traction battery and charging infrastructure are described in detail.

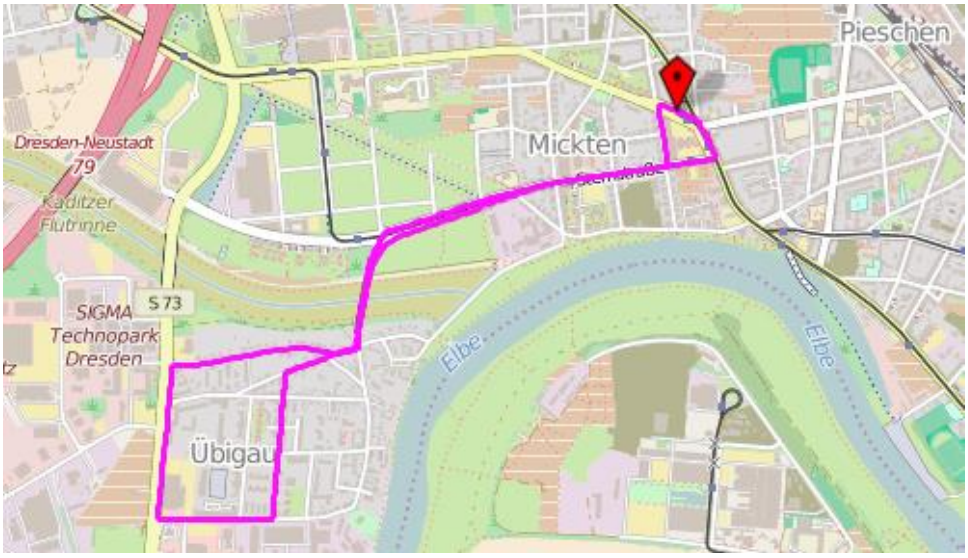


Figure 6: Map of the bus route 79 in the city of Dresden [4]

### 2.3.1 Vehicle

The vehicle considered is a 12 m long city bus, which has a low-floor construction. Furthermore the Solaris Urbino 12 Electric has a ZF AVE 130 electric portal axle, a two-stage electric heating and totally 3 electric doors. In the figure 7 the vehicle is shown.


Figure 7: Front side and back of the Solaris Urbino 12 Electric [5]

### 2.3.2 Traction battery

As part of this project it is considered an on-board traction energy storage system composed of lithium-technology. It has a modular construction and consists of 5 packs with an energy content of 40 kWh in each of them. Again a single pack consists out of 8 modules with 78 pouch cells. One of those modules is shown in figure 8.

Figure 8: One module with 78 pouch cells [4]

The limited space of the electric bus prevents the whole energy storage system from being mounted in the same place. It is for this reason because two of the packs are on the roof at the height of the front axle and the other 3 packs are in the trunk located. On the right side of figure 7, a part of the battery is shown.

### 2.3.3 Charging infrastructure

To charge the electric vehicle there are two different solutions. Either a plug-in charger or a roof mounted pantograph system can be used.
The portable plug-in charger is construed for overnight charge in the bus depot. It transmits electric power up to 32 kW into the vehicle. A standard type 2 plug is used as charging interface.
At the turning point of the route a show bus stop was built. It offers the possibility of recharging the electric vehicle during its scheduled line. Up to 200 kW can be transmitted via the 5-pin charging interface which is showed in the left part of figure 9. On the right side there is also a diagrammatic representation of the degrees of freedom for the vehicle orientation under the current collector.

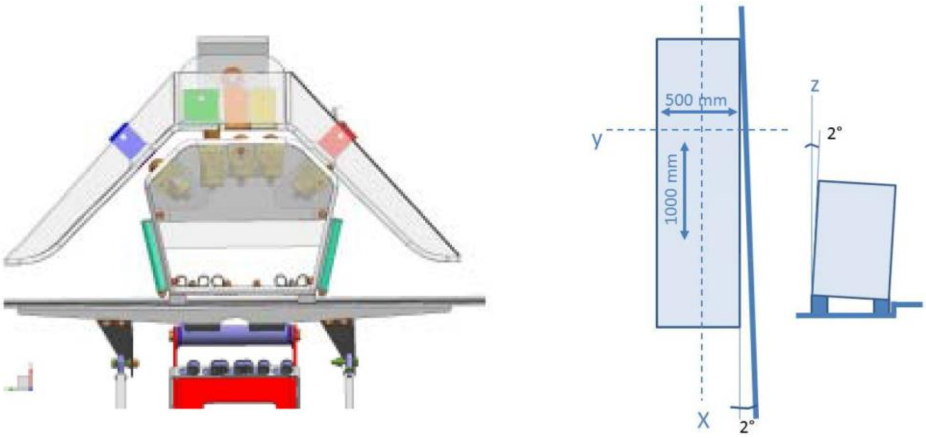


Figure 9: Charging interface / degrees of freedom for vehicle orientation [6]

### 2.3.4 Availability in daily operation

Since June 2015 the project vehicle is in regular service. In general the complete system, consisting of vehicle and charging infrastructure, functioned very well. During the first months there were some issues with the high current charging station. This was caused by massive voltage fluctuations from the feed-in of the railway power network. In figure 10 a voltage curve over the time is shown. Within one minute the value varies between 690-820 V. After re-dimensioning some components out of the charging station, the problem was fixed and the reliability raises. In the first 6 months of operating, the availability of the vehicle was more than 80% and for the high current charging station more than 95% [6].

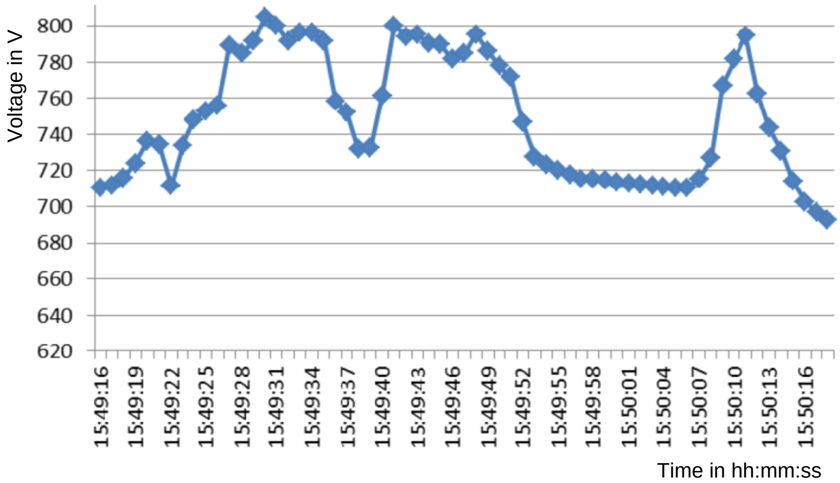


Figure 10: Voltage curve at feed-in high current charging station [6]

# 3 The need for connected electric mobility

With the increasingly ecology-oriented need for mobility in mind, actions to support the electrification of road transport must be expanded. In the field of urban electric mobilization it is, among other things, necessary to get the conditions for establishing electric mobility in everyday traffic early. This relates not only to questions of infrastructure and vehicle availability in particular but also the process of embedding this form of mobility into the existing modes of transport like public transportation.

Complementary, rural areas want to take advantage of electric mobility for environmental reason and see potential in urban-rural transport, community life and tourism. The temporal and local availability of energy is a prerequisite to electric mobility. Due to the loss of significance in owning private vehicles carsharing in metropolitan areas becomes more and more attractive to potential users.

To operate an eCarsharing fleet several obstacles have to be overcome. Within the projects EmiD and ENMOVER solutions for these problems were developed. During the project period several synergies were identified (see figure 11).

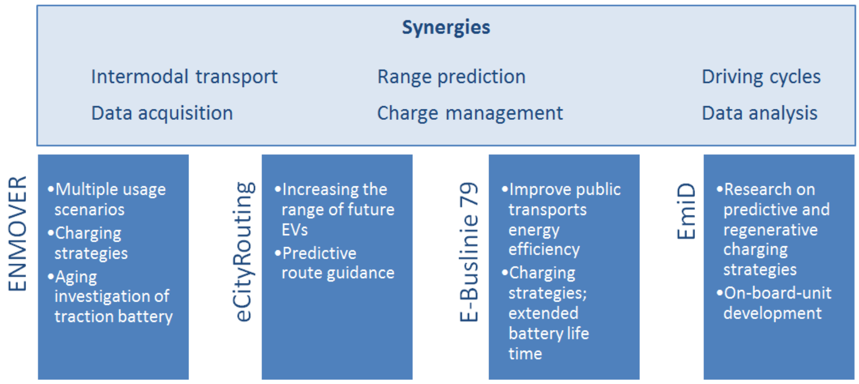


Figure 11: Synergies of several research projects dealing with electric mobility

By using these synergies of the showcase projects and the results of the Model Region for Electric Mobility a system was established which allows the connection between public transport and individual traffic in Dresden as can be seen in figure 12.

The user can buy the “HandyTicket/StromTicket” for public transport, paying at the EV charging station or to use eCarsharing. Furthermore all vehicles within the projects are equipped with an on-board unit for gathering data from the fleet. This allows interactions between several services like intelligent charging, improvement of electric driving range by advanced routing algorithm which takes use of traffic management data.

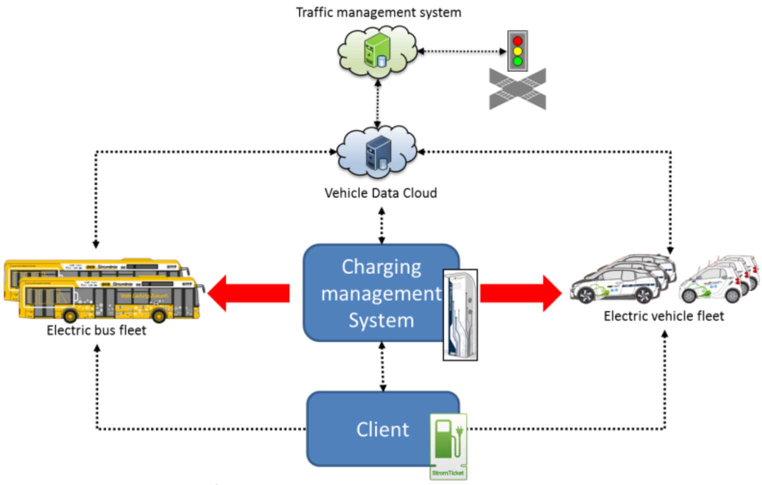

Figure 12: Synergies of several research projects dealing with electric mobility

# 4 The road ahead: Pioneering connected and autonomous driving in Saxony

More than 40 projects within the "Showcase-E-Mobility-Initiative" have been successfully realized and demonstrated Saxony as one of the pioneering regions in Germany in the field of electric mobility. The findings are worth and will help to manage the run-up of electric vehicles (EVs) which is expected in Germany soon since there is a buyer´s premium for EVs predicted.

Since 2014 SAENA is also coordinating the activities in the field of intelligent transport systems (ITS) and connected and autonomous mobility in Saxony. SAENA is the state-level interface between the public sector and the private partners, including small and medium-sized firms as well as large multinational firms and research and development facilities. ITS provides high potential to be a pioneer and to tap added value. The aim is to support companies to further develop and test their products especially in urban areas. As opposed to other initiatives in Germany and above such as the Cooperative ITS Corridor Vienna-Frankfurt/Main-Rotterdam or the NEXT-ITS Corridor Oslo-Copenhagen-Hamburg-Hannover the focus is set on inner-city areas. The spread ranges from test areas and smart infrastructure in the City of Dresden to pilot-operated cars and trucks, just as connected public and private transport and platooning. Dresden's functional Traffic Management System VAMOS is an excellent initial point for the intended activities. There are already convincing results in the optimization of public transport priority control at traffic lights, which means that up to three minutes per circuit can be saved without slow down the private transport. [7]

Within the next few months selected appropriate corridors will be equipped with C2X-communication and connected and automated vehicles as well as platooning and synchronized mobility will be tested (see figure 13). Numerous innovative projects are initialized and will start soon to lead Saxony into an electric, smart and connected mobility future.

Figure 13: Designated urban C2X-corridors in Dresden

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