Electromobility+

2010-2015 RESULTS

Imprint

Publisher

TÜV Rheinland Consulting GmbH
Research Management
Am Grauen Stein
D-51105 Köln
Phone +49 221 806 4142
Fax +49 221 806 3496
www.tuv.com/consulting

Design and Production

TÜV Rheinland Consulting GmbH
Research Management
Susanne Schmitz
susanne.schmitz@de.tuv.com

Date of Publication

April 2015

Print

TÜV Media GmbH, Am Grauen Stein, 51105 Köln

Picture Credits

COMPETT: Michael Sørensen, TØI (p. 8), DEFINE: Institute for Advanced Studies, Vienna (p. 10), E-FACTS: City of Arnhem; City of Stockholm (p. 12), eMAP: eMAP-Consortium (p. 14), EV-STEP: EV-STEP-Consortium (p. 16), SCelecTRA: SCelecTRA-Consortium (p. 18), ABattReLife: BMW AG; TU Bergakademie Freiberg (p. 22), CACTUS: Solaris Bus & Coach S.A. (p. 24), DAME: Enexis B.V. (p. 26), EVERSAFE: Yann Léost, Fraunhofer Institute for High-Speed Dynamics - Ernst-Mach-Institut (EMI); David Krems, MADK Photography - Fotografie Köln (p. 28), EVREST: EVREST-Consortium (p. 30), NEMO: Derryl Sushant Miranda; Dr. ir. Jos van der Burgt; Dr. ir. Martijn Huibers (DNV GL) (p. 32), Speed for SMEs: ego-drive GmbH (p. 34), FCCF-APU: Fraunhofer Institute for Solar Energy Systems ISE; Fraunhofer Institute for Chemical Technology; Danish Power Systems Ltd (p. 36), K-VEC: Sequoia Automation S.r.l. (p. 38), MaLiSu: Fraunhofer IWS (p. 40).

The project summaries have been provided by the respective project consortium.This brochure is published as part of the public relations work of the ERA-NET Plus on Electromobility (Electromobility+). It is distributed free of charge and is not intended for sale. TElectromobility+ is co-funded by the European Commission within the Seventh Research Framework Programme (Project No. 287143).

For further information on the Electromobility+ project please contact

TÜV Rheinland Consulting GmbH
Research Management
Oliver Althoff (Coordinator)
Am Grauen Stein
D-51105 Köln
Phone +49 221 806 4142
Fax +49 221 806 3496
www.tuv.com/consulting

For more information visit www.electromobility-plus.eu

SEVENTH FRAMEWORK PROGRAMME

Liikennevirasto
Finnish Transport Agency

ADEME

transnova

Narodowe Centrum Badań i Rozwoju

FFG

bmvit
Federal Ministry for Transport, Innovation and Technology

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Ministère de l'Écologie, du Développement durable et de l'Énergie

IWT

Ministry of Infrastructure and the Environment

Federal Ministry of Economics and Energy

Federal Ministry of Transport and Digital Infrastructure

VINNOVA

Introduction

Transnational call Electromobility+

Within the frame of Electromobility+ ministries and funding agencies of 11 European countries and regions have joined for funding transnational research projects. The countries / regions involved are: France, Germany, The Netherlands, Austria, Finland, Norway, Sweden, Denmark, Poland, Flanders (Belgium) and Piedmont (Italy).

All in all, some 20 million EUR have been pooled from the participating countries and regions as well as from the European Commission within the ERA-NET Plus scheme of the 7th Research Framework Programme. For the time being, the Electromobility+ initiative represents the biggest transnational call for research projects in this field.

The funding initiative aims at the creation of long-lasting conditions for the roll-out of electric mobility in Europe on the horizon of 2025 and covers the following thematic scope:

- Energy and environmental policy approach
- Usage patterns, economic models, actors involved
- Technical dimensions of the recharging systems
- Testing, trials and normative standards
- Technology based Innovation

The Electromobility+ call for proposals was launched in December 2010. In total 40 proposals have been submitted. The process of evaluation of those submitted proposals followed a two-step procedure. Immediately after the closing of the call the evaluation on national/regional level started (step 1), followed by a peer-review of independent international experts (step 2). This evaluation process and the subsequent negotiation process resulted in the funding of 18 research projects.

The Research Council of Norway

Ministry of Transport

Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

NL Agency
Ministry of Economic Affairs

REGIONE PIEMONTE

TÜVRheinland®
Precisely Right.

Research projects funded

The 18 research projects funded within the framework of Electromobility+ are listed below. They have been grouped into three Key Dimensions: Socio-economic Issues, Technological Strategies (including grid management) and Research & Development.

The projects have started successively from mid-2012 onwards, once the negotiation of Grant Agreements had been finalised. As you can see in the following description of the individual research projects, each consortium consists of partners from at least two of the funding provider countries and regions. In total 96 partners are involved in the projects comprising research organisations, universities, SMEs, larger enterprises and public bodies. As by the publication date of this brochure (April 2015), some of the projects have already concluded their work, others are in the final stage of project implementation.

This brochure gives an overview about the activities done by the projects, their results and conclusions.

Socio-economic issues

- COMPETT
- DEFINE
- eMAP
- EV-STEP
- E-FACTS
- SCelecTRA
- SELECT

Technological strategies

- ABattReLife
- CACTUS
- DAME
- EVERSAFE
- EVREST
- NEMO
- Speed for SMEs

Research & Development

- FCCF-APU
- K-VEC
- MaLiSu
- MATLEV

COMPETT

Competitive Electric Town Transport

www.compett.org

Project Data

Funding/€	Total cost/€	Duration
1.433.764	1.433.764	36 months

Partners

Institute of Transport Economics, NO

Danish Road Directorate, DK

Austrian Energy Agency, AT

Buskerud University College, NO

Kongsberg Innovasjon AS, NO

Main Results

- Diffusion of EVs follows “diffusion theory“ in that the technological innovation takes place in a social system where incentives and social networks are at work.
- Incentives providing users with relative advantages over ICE vehicles or leading to price reductions are the most effective with EV sales taking off when the cost is equalised with other vehicles.
- EVs are compatible with most daily transport needs in households and nine out of ten owners in Norway will buy an EV also next time, so will one third of theirs friend, with one third having done so already.
- COMPETT has developed an analytical tool that can calculate and assess the diffusion of EVs and its environmental and economic effects in different scenarios.

Project Results

COMPETT’s research question was “How can E-vehicles come into use to a greater degree?” focusing on Norway, Austria and Denmark.

Electric Vehicle (EV) buyers look at relative advantages compared to Internal Combustion Engined (ICE) vehicles. No local pollution, low noise at low speed, reduced or close to zero well-to-wheel emissions using EU electricity mix or renewable electricity respectively, are important societal assets. Plug in Hybrid vehicles (PHEVs) exhibit these advantages in pure EV mode. EVs contribute to targets for local air quality and reduction of climate gas emissions. For individuals energy efficiency and electricity being cheaper than petrol lanes and incentives such as access to bus lanes or parking only available for EVs, are important factors leading to more adoption.

High purchase price of EVs and PHEVs, uncertain residual value and a lack of awareness are major barriers to diffusion. Technology developments reduce costs and improve performance, leading to higher volumes further reducing costs. Residual value of E-vehicles will be established in leading countries and carried over to followers as more experience with the vehicles is gained.

Knowledge of EVs is limited in Norway, even lower in Denmark, Austria and other countries. EV knowledge diffuses in social networks. Friends and family are important sources in diffusion with the media providing initiating information. Providing EVs with dedicated number plates, as in Norway, increases awareness and facilitates local incentives.

Charging stations reduce range worries, increase the range utilisation of vehicles, attract new buyers and act as advertisements for EVs. In some countries the expansion of charging stations is out of sync with the fleet development.

Fleets are often the first adopters. In Norway consumers buy 80% of the EVs, due to incentives (tax and VAT exemptions) making EVs competitive. These early adopters fit Rogers (1995) theory of diffusion of innovations; being better off, well educated, younger and belonging to large multi vehicle households in urban regions owning newer vehicles compared to ICE vehicle owners. EVs diffuse from these areas to further locations. In Denmark only large EVs are competitive due to the incentive structure. In Austria incentives are directed at fleets and model regions with modest results.

EVs are driven as much as ICE vehicles, indicating that daily travel needs are met; a finding supported with analysis of travel data from national travel surveys. Single EV

>>Electromobility is entering the mainstream market<<

households loan or rent ICEs when range is too short. Multi-vehicle households swap their vehicles. Both employ eco-driving and use fast charging to extend the range. Multicar households are better off with EVs being cheaper and allowing more of the high cost ICE-driving to be replaced than with PHEVs.

The Serapis tool was developed to model cost effective policies. The model can be used in comparative studies between countries in Europe to identify barriers to adoption and effective policies and incentives that remove barriers and increase adoption.

Challenges can be that:

- Revenues from fuel taxes will go down as EVs become a larger part of the fleet. Incentives get increasingly expensive to governments, or consumers in countries with a bonus/malus system.
- Diffusion of EVs in city regions might outcompete public transport, walking and cycling.

Diffusion in Norway now extends into areas that cannot be supported with public transport, showing that starting in cities may be a route to sustainable diffusion.

Diffusion of EVs must be based on an interplay between stakeholders. Vehicle manufacturers, importers and dealers supply vehicles. The European Union sets vehicle requirements. Leasing companies set residual value influencing cost of ownership. Charging providers set up charging stations supported by authorities. Fleet owners set requirements for fleet and company cars. Governments or municipalities provide incentives and advantages to buyers. NGOs, consumer, and business organisations smoothen the process.

The introduction of EVs should be supported by integrating national, regional and local policies and incentives taking vehicle supply and demand into account. The desirability of E-vehicles should be anchored in national policies.

Project Conclusion

Electric vehicles are becoming mainstream thanks to forerunning countries, larger selection of vehicles and technology improvements. Countries lagging in take up have few incentives and send ambivalent signals to potential users. Forerunning countries' societal support and user attitudes are uniquely positive. COMPETT shows that EV owners, in Norway mostly consumers, in other countries mostly fleet operators, drive EVs as much as alternative ICEs. Especially multi-vehicle households manage their daily travelling with charging at home/work and adapt effortlessly to the vehicles range capabilities.

To increase sales buyers must see relative advantages, providing gains over ICE vehicles. Incentives help, but also technology improvements are needed. Batteries should last the life of the vehicle and permit more km of driving per recharge to enable EVs to contribute to the European Community's and national government's GHG emission reduction goals in the transport sector.

Incentives speed up adoption rates and are needed to get sales started. The incentives have a triple effect nudging buyers into buying, dealers into offering vehicles and manufacturers to develop and distribute EVs. As sales volumes increase, the costs of introducing EVs into the dealership networks go down, thereby reducing prices. Increasing production volumes more importantly reduce manufacturers' costs per vehicle. Increasing volumes on the other hand burden governments with increasing costs of providing incentives.

Incentives lowering the purchase price are more effective than those lowering operating costs. User incentives providing owners with advantages not available to ICE owners, i.e. bus lane access and free parking, are particularly effective. With a new generation of vehicles coming 2016-2018 and some countries introducing more incentives, further growth is expected.

Norway is the second largest market in the world for the Tesla Model S. Oslo is home to the largest EV fleet in the country.

DEFINE

Development of an Evaluation Framework for the Introduction of Electromobility

www.ihs.ac.at/projects/define

DEFINE
Development of an Evaluation Framework for the Introduction of Electromobility

Project Data

Funding/€	Total cost/€	Duration
1.022.897	1.036.815	32 months

Partners

- Institute for Advanced Studies, AT
- Environment Agency Austria, AT
- Vienna University of Technology Institute of Energy Systems and Electrical Drives, AT
- German Institute for Economic Research (DIW Berlin), DE
- Oeko-Institut – Institute for Applied Ecology, DE
- Center for Social and Economic Research, PL

Main Results

- Economic costs and benefits of an increased penetration of electromobility for Austria, Germany and Poland
- Scenarios for the market penetration of electromobility until 2030
- Effects of electromobility on the electricity system for Austria and Germany for different scenarios for 2020 and 2030
- Emission reduction potential of electric vehicles

Project Results

The core of the DEFINE project consisted of the development of a model-based evaluation framework for Austria, Germany and Poland systematically combining relevant dimensions of electromobility: the economy in sectoral disaggregation, consumption and mobility preferences of private households regarding electric vehicles, the electricity system, as well as associated emissions and environmental effects. The following text provides the main results of the analyses conducted in DEFINE.

Economic Costs and Benefits of Electromobility for Austria (Institute for Advanced Studies)

Different scenarios for the market penetration of electric vehicles were simulated to estimate the economic costs and benefits of an increased penetration of electromobility.

Business as Usual (BAU) Scenario: Model results show that electromobility can contribute significantly to the reduction of greenhouse gas (GHG) emissions in the Austrian transport sector under comparatively low economic costs (less than 0.03 % of Austrian annual GDP until 2030).

Electromobility+ (EM+) Scenario: The fleet penetration of electric vehicles can almost be doubled by an intensified taxation of purchase and use of conventional vehicles. The share of electric vehicles in total new registrations can be increased to 68 % in model simulations until 2030. At the same time, their share in total vehicle stock reaches 28 %.

Scenarios for Electromobility for Germany and their Effects on the German Electricity System until 2030 (German Institute for Economic Research, Institute for Applied Ecology)

Here, BAU and EM+ scenarios were developed for the deployment of electric vehicles (EVs) in Germany. Plug-in hybrid and range extended EVs constitute the largest part of the EV fleets in both scenarios (around 5 million EVs in 2030 in EM+). Building on mobility data, 28 hourly EV usage patterns were derived and serve as inputs for a numerical power system analysis. Using a unit commitment dispatch model, the institutes analysed the integration of these EV fleets into the German power system, drawing on different assumptions on the charging mode. In the end, the analysis revealed that CO_2 emissions caused by the additional power requirements of EVs are substantially higher than specific emissions of the overall power system in most scenarios. Electric vehicles will become largely CO_2-neutral only if the introduction of electromobility is linked to a respective deployment of renewable energy (RE+).

>>A Model-based Evaluation Framework for Electromobility<<

Scenarios for Electromobility and Vehicle Stock for Austria (Environment Agency Austria)

The Environment Agency Austria also investigated possible achievable potentials of electric vehicles in the two scenarios BAU and EM+. On the basis of empirical data, experts from the environmental agency derived vehicle stock projections and their environmental effects.

Scenarios for Austria – 1 million electric vehicles in 2030: In a BAU scenario, which includes the measures currently in place, a total of about 886,000 electric passenger cars and plug-in vehicles are expected for 2030. If, in addition to the BAU measures, further measures from an EM+ scenario are implemented, the number of electric vehicles would to rise to round 1 million in 2030. The EM+ scenario includes stricter CO_2 regulations, a tighter reform of the Austrian car registration tax, higher taxes on fossil fuels and an expansion of the charging point infrastructure. The expected CO_2-emission reduction in the BAU-scenario would amount to 1 million tonnes, in the EM+ scenario 1.2 million tonnes.

Simulation of the Impact of Electric Vehicle use on the Austrian and German Electricity System in 2030 (Vienna University of Technology – Institute of Energy Systems and Electrical Drives)

A Systemic Perspective on Electromobility.

The power and heat system simulation model (HiREPS) for Austria and Germany was deployed by the Vienna University of Technology to analyse the effects of different charging strategies and types of user behaviour. In EM+ scenarios for 2030 and 2050, EVs make up 13 % (2030) and 100% (2050) of all passenger cars. Market-led charging would lead to a temporal shifting of electricity demand. Cost-based market-led infrequent controlled charging would lead to an average reduction of costs amounting to 23 Euro per electric vehicle per year in 2030 and 51 Euros per electric vehicle per year in 2050. Load flow calculations of various charging strategies for a representative low voltage grid show that neither grid components would be overloaded nor voltage limits violated in 2030. In the scenarios with 100 % of electric vehicles (2050), violations of the “n-1” security criteria seem inevitable. These grid problems could likely be solved by deploying adequate load management systems.

Preference for the Uptake of Alternative Fuel Vehicles and for Car-sharing in Poland (Center for Social and Economic Research)

The study carried out here is the first of this kind conducted in a post-transition CEE (Central and Eastern Europe) country. The Center for Social and Economic Research surveyed round 2,500 persons in Poland in order to elicit preferences for various AVF technologies. Using discrete choice experiments, individual preferences for three types of AFVs and a conventional car were examined. The study revealed that Polish consumers have the lowest preference for hybrid cars, followed by PHEVs and EVs. Driving range and recharging time are important factors for Polish consumers. The provision of other benefits, such as free parking and public transport, would increase the probability of choosing AFVs. Lowering the cost of car-sharing would motivate Polish travellers to use this system more. Moreover, systems with EV fleets would enjoy slightly higher usage than fleets composed of conventional vehicles.

Project Conclusion

The analysis of the overall economic and systemic effects of an increased market penetration of electric vehicles requires a comprehensive approach. For this reason, the aim of DEFINE was an estimation of economic costs and benefits in an analytical framework that suits the complexity of the matter and explicitly relates electromobility to the energy system, environmental effects and household behaviour. As the economic core of the evaluation framework, the Institute for Advanced Studies further developed and extended the macroeconomic model MERCI. Model results for Austria show that e-mobility can make a significant contribution to the reduction of CO_2 emissions in the traffic sector under supportable economic costs. The Environment Agency Austria investigated possible achievable potentials of electric vehicles in two scenarios. The expected CO_2-emission reductions in the BAU-scenario would amount to 1 million tonnes, in the EM+ scenario, the reductions amounting to 1.2 million tonnes are possible. The power and heat system simulation model (HiREPS) for Austria and Germany was deployed by the Vienna University of Technology to analyse the effects of different charging strategies and types of user behaviour. The analysis shows significant potential for reducing costs through the implementation of cost-based market-led infrequent controlled charging. The Oeko-Institut and the German Institute for Economic Research (DIW Berlin) jointly analysed the market potentials of electric vehicles as well as possible future interactions with the German power system up to 2030. Based on the analysis, the institutes formulated a set of recommendations for policy makers. The Center for Social and Economic Research carried out a stated preference study on the adoption of alternative fuel vehicles among adults who are intending to purchase a passenger car in Poland, which is the first study of this kind being performed in the CEE region.

E-FACTS

Electric Vehicles For Alternative City Transport Systems

-FACTS

Main Results

- Cities have large opportunities to influence the uptake
- Cities possibilities are however limited, both legally and economically and need support from national level

Project Results

E-facts project is sitil running and final results will present later.

Preliminary findings are however that the initial target groups must be carefully choosen and that the city must take the initiative, but also that once there is a belief in the market, private companies start setting up charging possibilities at their own behalf.

Project Data

Funding/€	Total cost/€	Duration
690.390	1.408.836	27 months

Partners

- City of Stockholm, SE
- Frankfurt Economic Development, DE
- University of Applied Sciences Frankfurt, DE
- City of Arnhem, NL

>>Finding policy and physical means to speed up the uptake of EVs<<

Arnhem charging plaza and Stockholm fast charging.

eMAP

electromobility - scenario based Market potential, Assessment and Policy options

www.project-emap.eu

Project Data

Funding/€	Total cost/€	Duration
1.220.359	1.240.384	36 months
Partners	Federal Highway Research Institute (BASt), DE	
	German Aerospace Center, DE	
	VTT Technical Research Centre of Finland Ltd., FI	
	Motor Transport Institute in Warsaw, PL	
	KE-CONSULT Kurte&Esser GbR (KEC) (Subcontractor of BASt)	
	Institute of applied social sciences (INFAS) (Subcontractor of BASt)	

Main Results

- eMAP results show the profitability of the enhanced market penetration of electric vehicles in several European countries with different basic conditions
- New Policy measures can substantially improve the market penetration of electric vehicles in Germany and Poland
- Business-as-usual in Germany and Poland shows a slow penetration path of electric vehicles
- In Finland penetration rate is already rather high in Business-as-usual-scenario due to CO_2-based taxation schemes

Project Results

The results of a European wide consumer survey, which was completed by the end of 2013, showed a rather positive Consumers' attitude towards electric cars as they are generally perceived as environment-friendly and secure. But the high acquisition costs and the uncertainty about the operating costs deter consumers as well as fleet owners from purchasing an electric car. Political measures that give electric cars an advantage compared to conventional cars are welcomed by consumers and fleet managers, whereas disadvantages and penalties for the use of conventional cars are rejected. From the consumers' point of view the national governments play the biggest role in pushing electric drives. Favoured measures are lowering the annual car taxes, energy costs and especially giving bonuses and benefits for the purchase of an electric car.

In order to estimate the number of electric vehicles in the EU and the respective partner countries Finland, Germany and Poland, a scenario based model was used. The agent based vehicle market model Vector21 (Vehicle Technologies Scenario Model) is used to specify consumer demand and market supply of electromobility. Using relevant costs of ownership, the least cost- and CO_2-intensive car is chosen by one of nine hundred customer types. Three deployment paths for electrified vehicles were modelled: Business as Usual (BaU) as a reference up to 2030, Technology Driven (TeD) with higher efficiencies of electrified vehicles and Politically Driven (PoD) with a stricter EU-wide CO_2 regulation for passenger cars and a more pronounced promotion of electrified vehicles (the latter with individual measures per country).

It could be shown that countries without incentives (direct incentives or reduced taxes), like Germany and Poland, have a slow market penetration, which takes place after 2020. Countries with incentives, like Finland, where the taxes for vehicles with low CO_2-emissions are significantly reduced have a higher and earlier market penetration with electrified, especially highly electrified vehicles (Plug-in hybrid electric vehicles, range extended electric vehicles and battery electric vehicles). Without other political measures the electrification in Germany and Poland will not take place before 2020 in a large scale.

>>European electromobility shows auspicious sign of life<<

But with different political measures, it could even be possible to meet the goals of the German government and bring 1 million electric vehicles on the road until 2020.

The socio-economic analysis is based on the results of scenario calculations. Using European cost rates all relevant costs and benefits are analysed by comparing the TeD- and the PoD-scenarios with the BaU-scenario. The socio-economic analysis shows in general that a higher market penetration of electric vehicles leads to benefits in form of environmental costs, noise costs and energy consumption lower costs savings. The lower extent of impact is shown using the results of the German PoD-scenario compared to the BaU-scenario.

- Comparing PoD-scenario to BaU scenario the share of electric vehicles in the fleet is nearly doubling until 2030
- Average CO_2-emissions (well-to-wheel) per vehicle-km (regarding the whole fleet) will be 5% lower in 2030
- Energy consumption will be about 4% lower in 2030

On the other hand promoting electromobility needs higher costs. Infrastructure costs as one of the main cost factors will increase if electromobility is promoted by certain policy measures. The comparison of PoD-scenario with BaU-scenario for Finland shows no significant change (+5%) of the total infrastructure costs (2030 to 2010). In contrast, the total infrastructure costs in Germany increase by 30%. In Poland the total infrastructure costs are even more than 10 times higher in scenario PoD than in scenario BaU.

In consequence the calculated Cost-Benefit-Difference and Cost-Benefit-Ratios differ from region to region as well as from scenario to scenario.

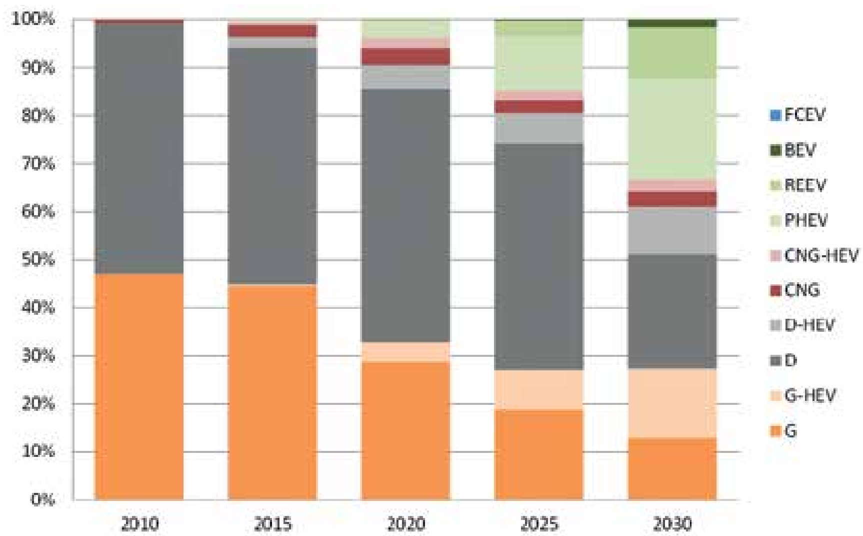
Project Conclusion

As shown in the relatively conservative BaU scenario, one of the main drivers for electrification is the EU regulation on CO_2 limits for passenger cars. Individual market shares and the timing of market penetration strongly depend, however, on the national legislative and economic framework, namely national taxation schemes and electricity prices.

Contrary to what could have been expected, results showed that assumptions for higher investments into traction battery research and development does not lead to significantly higher market shares of pure electric vehicles (BEV). However, in markets like Germany, which initially do not favor electrified vehicles, lower battery system prices indeed lead to a stronger electrification of the fleet.

It has been shown that national policies promoting electrified vehicles can be an effective path towards an electrified fleet. However, the timing of political instruments is crucial for an effective market penetration: a quick adoption is necessary enable a spread of technology and know-how within the industry and thus a decrease in costs.

The socio-ecomonomic evaluation and the stakeholder examination show that there are good arguments to support electromobility. Ecomomic and environmental benefits justify political promotion strategies. Technical progress is one feature of support. But technical progress is not enough to reach a quick penetration all over Europe. To convince consumers to buy electric vehicles other financial incentives have to be considered and implemented.



New vehicle sales by propulsion system in EU28 Reference.

EV-STEP

Sustainable Technical and Economic Pathways for Electrified Mobility Systems in EU28 by 2030

www.ev-step.com

Project Data

Funding/€	**Total cost/€**	**Duration**
502.660	734.634	24 months

Partners

Association pour la Recherche et Developpement des Methodes et Processus Industrielles, Centre de Mathématiques Appliquées, FR

Institute of Energy Economics and the Rational Use of Energy (IER); University Stuttgart, DE

DTU Management Engineering, DK

Société de Mathématiques Appliquées et de Sciences Humaines, FR

Main Results

- Linkage of a technology bottom-up energy system optimisation model (Pan European TIMES) with a dynamic recursive Computable General Equilibrium model (IMACLIM-S)
- Development of dedicated model for case studies in France and Denmark
- Deployment scenarios for electric vehicles until 2030

Project Results

The project results as of January 2015 include a summary of mobility surveys, support mechanisms and research projects for electric vehicles in Germany, Denmark and France. This review gives a comparative overview of the 3 countries. A second result is the specification of efficiency improvement and cost assumptions to be used in the TIMES Pan-European model: database of vehicle technologies including evolution of conventional vehicles was defined.

The results of EV-STEP also include an intensive modelling activity with 2 axes: EU level assessment of the deployment of electric vehicle and models for local case studies to highlight specific issues not represented with enough level of accuracy in the previous models.

TIMES PanEU is a multi-regional model that covers all countries of the EU-27 plus Switzerland, Norway and Iceland. During the project, the model was extended to include also Croatia. In the context of electric mobility different powertrain concepts are distinguished in the TIMES PanEU model. Moreover, it was differentiated between electric vehicles with battery storage, as well as those with fuel cells and gas storage. In order to comprehensively assess the future role of electric vehicles, the TIMES PanEU model was extended for the possibility of vehicle-to-grid (V2G) energy storage. Therefore, additional analysis with an 8760 hour per year model for Germany were done. To analyse the role of electric vehicles in the energy system of the countries a scenario analysis was done.

The project has also led to the development of a European Union version of the IMACLIM-S model, in a dynamic recursive 3.4 version renamed IMACLIM-P. This development required an extensive data collection and treatment to produce a 2007 hybrid energy-economy input-output matrix for the 28-country European Union that duly reconciles EUROSTAT and IEA data on EU-wide national accounting aggregates, international trade, energy prices and energy consumptions. The model was then fitted on observed 2007 to 2013 data on real GDP, unemployment, aggregate trade balances and energy consumption volumes (imported from TIMES PanEU) through the marginal adjustment of 'crisis factors' which are due to fade out by 2020 in simulations.

For the evaluation of load curves in the Paris Ile de France area the EVCAP model was developed. The modelling approach combines statistical analyses and optimisation. It solves a discrete fleet optimisation problem over 24hours and with a 15mn time step. Using a detailed mobility survey for France a synthetic mobility patterns generator was defined that generates individual trip programmes for a

>>Technical and economic study of electric mobility development<<

representative fleet of 500 cars. Based on this model several charging context were simulated. This includes changing charging current levels, electricity price signals and a vehicle to grid option. The result is then the availability to systematically explore alternative load curves for a representative under various assumptions.

The western Denmark case study deals with a region that is becoming increasingly dominated by wind power - ranging from zero production to much more than the regional electricity demand. Electric vehicle batteries could then be an important option for electricity storage capacity. By 2014 wind power covered more than 50% of the electricity consumption in western Denmark. Hourly data for electricity demand, production, trade and spot prices are available for the last 15 years from the Danish TSO, Energinet.dk. Ongoing model development includes quantitative description of EV users‘ profiles to develop parameters for their availability for charging and discharging as input for the electricity system operation model in future periods. Then the model calculates chronological hourly charging and discharging. A TIMES multiyear optimisation model for investment and technology choice needs input parameters that is an aggregation of these results. This issue is being addressed by several studies in Denmark. Preliminary results will be presented by the end of the EV-STEP project.

The results of the EV-STEP project also include dissemination activities via exchanges with local TSO's and DSO, participation to conferences and the organisation of a joint workshop with the IEA-ETSAP semi-annual workshop in Copenhagen in November 2014. One additional meeting will take place in France, and an electrified mobility stream will be organised at the 2015 European operational research conference.

Project Conclusion

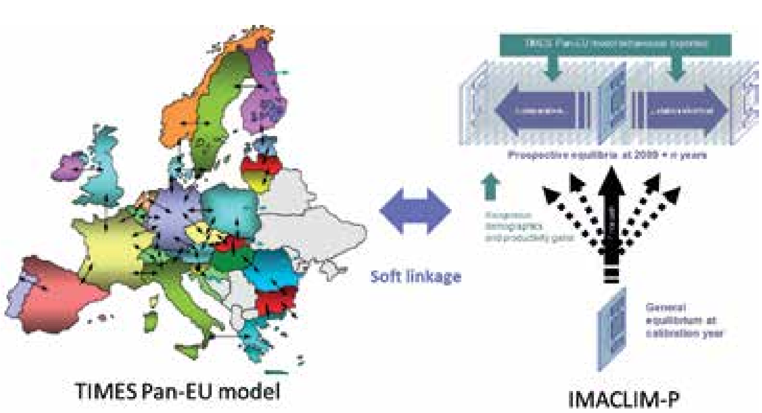
The EV-STEP project is not fully completed and partial conclusions are provided here:

On the strategic EU level the evaluation with the energy system model TIMES PanEU shows that an economic expansion of hybrid electric vehicles happens at the earliest in 2030 and in subsequent years to 2050. Against this background the ambitious national targets appear as very high. Only under a scenario with an extreme climate protection target and estimated big efforts in the direction 'economies of scale' in battery technology, these electric cars reach on EU level a market share of 70% for cars and 40% for commercial vehicles and buses. In this scenario in 2030 3.5 million electric vehicles will be used in Germany. There are only few fuel cells based electric vehicles in 2030, which still come up at this time either in the car sector in commercial vehicles and buses used. The results of the scenario analysis confirm that by accelerating economies of scale, particularly in the area of battery technology, the market share of mobile electromechanical drive concepts, such as BEV and PHEV, can be increased significantly in the long term.

The general equilibrium framework of IMACLIM-P was then used to provide insights on the macro-economic consequences of EV penetration scenarios including GDP and unemployment (IMACLIM-P acknowledges an imperfect labour market), the trade balance and public budgets impacts. For each energy system scenario produced by TIMES PanEu, 34 energy use levels and costs as well electric car stock trajectories were imported in IMACLIM. The first conclusions show that the further penetration of electric cars has a contrasted impact depending on the mitigation context. Under a moderate GHG constraint, a strong development of the electric car up to a fourth of car sales in 2050 comes at a quite low GDP and unemployment cost. Contrastingly, under stringent 'factor5' 2050 mitigation objective the EU economy could lead to important GDP losses due to a strong increase in the marginal cost of electricity.

The Paris Ile de France case study produced several alternative electric vehicles load curves as the result of the interaction between disaggregated mobility pattern, the electric system (load, and price) and charging infrastructures (authorised charging levels, charging profiles). The general conclusion is that the benchmark load curves available today to characterise the impact of EVs only partially represent the range of possible effects. The maximum peak load could range from 0.7kW/vehicle to 3kW/vehicle in less optimistic settings and be as high as 10kW/vehicle for a real time pricing and pure cost optimisers with fast charging capacities. Simulations of V2G possibility show a potential reduction of load (-3kW/vehicle) in peak periods but consistently increase the load in other time periods around 2kW/vehicle.

Expected results of the ongoing model development on wind and EV for western Denmark are quantitative parameters for 32 time slices and results on the optimal deployment of EVs using the scenario assumptions developed in the project.



Two long term models used for the EU scale assessment and the soft linking mechanism that is used to inform the macroeconomic sphere form the detailed and more technical energy system perspective.

SCelecTRA

Scenarios for the electrification of transport

Project Data

Funding/€	Total cost/€	Duration
455.179	689.000	36 months
Partners	IFP Energies nouvelles, FR	
	IFSTTAR, FR	
	PE CEE, AT	
	KanLo Consultants, FR	
	EIFER, DE	

Main Results

SCelecTRA aims at:

- identifying long-lasting conditions for developing public policies for facilitating the development of road passenger electric mobility in Europe for 2025-2030,
- assessing the environmental impacts of such policies via consequential life-cycle analysis and their external costs.

Project Results

SCelecTRA has dedicated significant effort to the development of new models for deployment in the project. The consortium uses PET36 – a Times based model of the European energy sector (a demand based model, which simulates all the energy consuming sectors in Europe with a bottom-up approach) – which has been upgraded for the needs of the project. The SCelecTRA team has created a unique transport demand module which allows a more realistic simulation of the uptake of new vehicles in the automotive market based on:

- Preferences of customers for cheap vehicles top purchase vs long-term economies,
- Snowball effects: whenever a type of vehicle becomes popular, it becomes more visible, increases in popularity and enjoys higher sales.

An attributional life-cycle analysis has also been developed in order to assess the environmental impacts of the different vehicle technologies for now and for the foreseeable future. This valuable piece of work is a result in itself but is also a major input for the modelling of automotive futures for Europe and for the consequential life-cycle analysis which will be described later as well as for the cost benefit analysis.

The influence of road transport determinants has been estimated for 3 distinct groups of countries which have been split based on characteristics and factors influencing vehicular mobility: i) economic development (as measured by GDP per capita), ii) the automotive market maturity (as measured by the amount of cars per 1000 inhabitants) and iii) previous transport policies (as measured by the price of fuel including taxes). SCelecTRA showed that

- the magnitude of the influence of these road transport demand drivers differs from one country to the next.
- the most important driver of road transport demand appear to be GDP per capita (positive effect) whatever the group of countries.
- the price of fuel does have a negative effect but not for the group 3 countries.

European policy-makers are lowering the relative cost of alternative fuel vehicles. To accomplish this, they must implement large incentives for electric vehicles in order for their purchase price to be comparable with that of conventional vehicles. The policy scenario analyis is based on four demand policies scenarios (Scrappage programme; Subsidies to EVs; Fuel taxes; Carbon Tax) and three contextual and supply scenarios (energy prices; charging points; CO_2 emission standards)

SCelecTRA has investigated all possible options on a policy-level to make electromobility happen. It has searched for the most efficient and the best policy to follow in order to

>>Identify long-lasting conditions for the development of EU electromobility<<

minimise its cost and maximise the environmental benefits, SCelecTRA analyses the public policies at hand.

On a 2030 horizon, electric vehicles and plug-in hybrid vehicles can claim up to 30% of the vehicle sales with approximately 15% for electric vehicles and 15% for plug-in hybrid vehicles. These shares depend strongly on the countries as the dissemination of electric vehicles use to start first in “rich” dispersion of electric vehicles is beginning first in the larger West European automotive countries: Germany, France, Spain, Italy and the United Kingdom.

Still an ongoing process the SCelecTRA team is performing a consequential life-cycle analysis in order to assess the environmental impacts of the future policies and a cost benefit analysis in order to assess the overall costs to reach the uptake of electromobility depending on the policies followed.

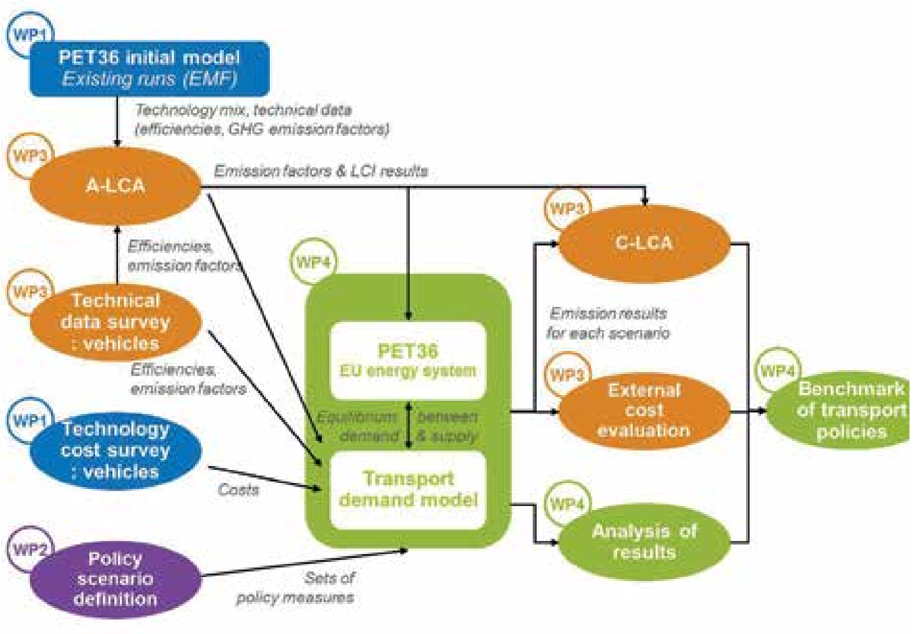
The lessons learned from using several life-cycle analysis modelling approaches that complement each other are that detailed A-LCA results for all considered vehicles / fuel pathways have been created to have a consistent and up-to-date approach. And far more important, a consequential life-cycle analysis has been used to assess environmental consequences of considered policy scenarios including the consequences in the transport sector (including vehicle life-cycle impacts based on A-LCA results) and the consequences in the EU energy system.

Project Conclusion

Based on an exhaustive review of past public policies in the European countries as well as an econometric analysis to identify the determinants of the European mobility and automotive market three distinct policies scenarios have been retained and their intricate effects have been analyzed through:

- A scrappage program to stimulate the automotive sales;
- higher fuel taxes of fossil fuels and tax discounts on electricity rates;
- purchase incentives to lower the costs of alternative vehicles.

On a 2030 horizon Electric vehicles and plug-in hybrid vehicles can claim up to 30% of the vehicle sales with approximately 15% for electric vehicles and 15% for plug-in hybrid vehicles. These shares depend strongly on the countries. The exact effects of the difference policies are still being analyzed in terms on market penetration of electric vehicles but also for their environmental impacts which will be assessed by a ground breaking consequential life-cycle analysis and their costs via a cost benefit analysis.



Schematics of the various inputs used to model the uptake of Electromobility.

SELECT

Suitable ELEctromobility for Commercial Transport

www.select-project.eu

Project Data

Funding/€	Total cost/€	Duration
1.545.584	1.821.048	36 months

Partners	
	German Aerospace Center, Institute of Transport Research, DE
	Technical University of Denmark (DTU), Department of Transport, DK
	AIT Mobility Austrian Institute of Technology, AT
	CLEVER A/S, DK
	Consilio Information Management GmbH, AT
	Reffcon GmbH, AT

Main Results

- Daily trips conducted by passenger cars and vans in commercial transport in Austria, Denmark and Germany are largely within the range of electric vehicles, especially in urban transport.
- Transport needs of selected commercial sectors and specific companies suit the specifications of electric vehicles available today. Overall there are positive attitudes towards electric mobility in commercial transport.
- A methodological framework for fleet management focusing on the specific requirements of electric vehicles in commercial fleets has been developed and applied in two exemplary settings.
- Recommendations and strategic fields of actions for relevant stakeholders were defined. Besides the general need for a broader variety of available vehicles companies stated pilot projects and fleet trials of electric vehicles as important incentives to take steps towards electric mobility.

Project Results

In the project SELECT economic sectors suitable for electric mobility in commercial transport in Austria, Denmark and Germany were identified. According to statistics and studies on commercial transport in the countries examined, we see the wholesale and retail sector, the construction sector as well as the manufacturing sectors as economic sectors with high potential for electric mobility. Basis for the analysis was the economic power of the sectors, the number of registered vehicles and the daily travel distance.

A further disaggregation of economic sectors in the progress of the project could be achieved by a survey. The detailed analysis of the current form of transport organisations, decision-makers' attitudes towards electric mobility and their procurement intentions among fleet decision-makers in Austria, Denmark and Germany revealed that vehicle use and tour patterns of a large share of the firms is suitable for switching to electric vehicles with more than half of the tours being shorter than 50 km. A quarter of the participants stated that all their tours were below 50 km. For nearly half of all participating companies all their tours were below 100 km. Regarding procurement intentions, more than a quarter do not consider electric vehicles; a bit more than one third leave it open as future option; one third discuss procuring an electric vehicle, and six percent have already purchased at least one electric vehicle. The respondents show generally positive attitudes towards electric mobility with two out of three not seeing electric vehicles as a temporary trend. However when deciding about electric vehicles, fleet managers seem to put their personal beliefs aside and decide on behalf of the firm's interest. The readiness for electric vehicle adoption varies across sectors with high technology companies becoming the most likely early adopters. More than 1,400 fleet decision-makers in Austria, Denmark and Germany took part in the survey. GPS tracking of specific

>>Potential of electric vehicles in commercial transport<<

companies' fleets comprising several hundred vehicles and several 10,000 trips was carried out in order to validate the high potential seen for electric mobility on an aggregated basis.

To ease the integration of electric vehicles in fleets, we developed an innovative methodological framework for operational fleet management. This framework consists of algorithms for various tour planning problem variants including specific modules for handling electric vehicles with driving range limitations and recharging time requirements. The developed algorithms of the framework allow solving problems in a-priori and dynamic settings. Furthermore, the framework includes simulation modules for evaluating algorithms in a dynamic context. As exemplary applications, we applied our framework on two problem settings: Dynamic dispatching and relocation of electric taxis taking into account limited range and recharging periods; A-priori tour planning for a courier service with a possibly partial electric vehicle fleet. Both applications show that electric vehicles are a realistic alternative in urban settings from an operational perspective.

The results of SELECT show that there are economic sectors which are suitable for electric mobility. High numbers of registered vehicles with applicable driving distances and the high user acceptance form the basis for a high potential of electric mobility in commercial transport in these sectors. According to the results we could outline strategic fields of action for stakeholders such as policy makers, vehicle manufacturers, service providers and fleet providers to enhance user acceptance and therefore willingness to use electric vehicles in commercial transport. We found out that user acceptance towards electric vehicles is very positive and the theoretical potential in certain economic sectors is high. Therefore we recommend considering these two facts for targeted promotions in order to achieve a considerable market penetration. Furthermore we realised that there is a lack of available electric vehicles and a lack of real life experiences of electric mobility. Real life experiences of electric vehicle usage are seen as an important step towards the procurement decision for electric vehicles.

Project Conclusion

The main goal of the project SELECT was to identify branches suitable for electric mobility in commercial transport in Austria, Denmark and Germany. The methodology of the project to conduct a three step approach proved to be able to identify economic sectors suitable for electric mobility. Starting with an analysis of statistics in Austria, Denmark and Germany promising sectors were identified. A survey analysed certain branches in detail and revealed requirements and attitudes towards electric mobility. The survey was appropriate to get an insight into these branches. For a detailed analysis of needs and requirements of single companies the tracking of vehicles with GPS devices proved to be a proper tool to find out maximum daily travel distances.

While the survey allows an aggregated evaluation of electric vehicle suitability for specific business sectors the accurate analysis of specific firms' tour patterns could be achieved by GPS tracking. From the results we can conclude that a low average tour distance seems to be less important than maximum tour distances below common electric vehicle range thresholds. As companies want to use electric vehicles as direct substitution for conventional vehicles electric vehicles must be capable of accommodating all transport needs. Targeting these needs is a more effective driver for electric vehicle diffusion than addressing fleet managers' attitudes, which are generally in favour of electric vehicles.

From an operational point of view the introduction of electric vehicles is possible in the short to medium-term in areas where cars or small vans are required, for example as electric taxis, for courier and parcel services, and service providers (technicians, plumbers). The methods developed in SELECT allow to efficiently managing the operations of such electric vehicle fleets.

Besides experiencing electric vehicles in real life, a broader choice of vehicle technologies dedicated for commercial transport is required. For passenger vehicles at least a small range of different models is available while light duty vehicles that are used for urban freight distribution are still lacking. Furthermore the long-term reliability of vehicle and battery technology needs to be proven for light duty vehicles. For commercial users the resale value of vehicles is of high importance and needs to be validated. For the widespread introduction of electric mobility in commercial transport, it is recommended to give companies the possibility to learn about the ease of use of electric vehicles.

ABattReLife

Automotive Battery Recycling and 2nd Life

www.abattrelife.eu

Project Data

Funding/€	Total cost/€	Duration
1.661.989	2.138.394	36 months

Partners

Peugeot Citroën Automobiles SA, FR

Bayerische Motoren Werke Aktiengesellschaft, DE

Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek - TNO, NL

DNV GL, NL

Fraunhofer Institute for Silicate Research ISC, DE

Pôle Véhicule du Futur, FR

Technische Universität München, DE

Technische Universität Bergakademie Freiberg, DE

Université de Technologie de Belfort-Montbéliard, FR

Université de Technologie de Troyes, FR

Main Results

- Quantitative information on the degradation processes has been gained (turning point linear/nonlinear aging characteristics, influence of discharge depth, charging rate and temperature). An equivalent circuit based aging model was implemented.
- 2nd Life is possible but limited due to different reasons (logistic and refurbishment issues, potential users) at the moment.
- A mechanical recycling solution has been developed and proved in pilot scale. The developed discharge scenario was defined in patent 'DE 102013011470, A1'. Mechanical crushing and sorting steps lead to recycling rates of > 50% (EU Battery Directive - 2006/66/EC).
- Due to the dynamic market development it is difficult to state on Business Models.

Project Results

Literature on Li-Ion battery degradation, recycling of Li-Ion batteries, Li-Ion battery second use scenarios (electromobility, smart grid, energy management in house or in community levels, and other promising applications), refurbishing as well as on Business Models was gathered.

The cyclic aging behavior of Li-Ion cells was investigated. Results show that linear and nonlinear aging characteristics are influenced by different factors (discharge depth, charging rates, temperature etc.). Based on the aging data a circuit based aging model was implemented. Li-Ion cells were measured and gained data statistically analysed. A mechanical recycling process for Li-Ion cells was developed and small scale tests were realised. Products of the process can in parts directly be used as concentrates or have to be reprocessed. Therefore the quantitative and qualitative composition of two different battery types and generations were determined. Furthermore a discharge scenario was developed as well as an appropriate crushing scenario for the cells to expose the components. In additional studies methods for the separation of the products were performed. Within the activities connecting points for auxiliary units in the process were identified. Due to ongoing research and developments, trends in cell type, dimension etc. will change consistently. Thus the continuous adaption and further development of the process is inevitable.

>>HV-traction battery deterioration, recycling and 2nd Life<<

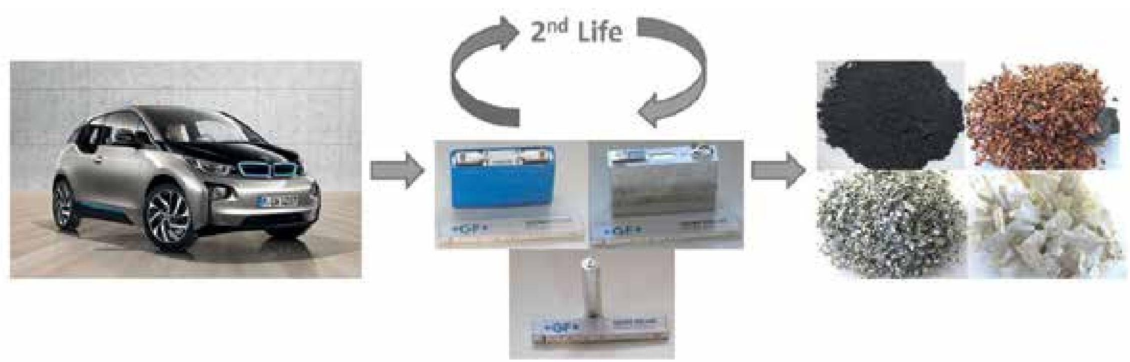
For the LCA (life-cycle assessment) the environmental and economic models of 2nd Life solutions were developed. A type of home energy system (HES) and ancillary services for the 2nd Life solution were selected. The storage configuration in HES with respect to several parameters (cell size, price etc.) was studied and compared to reference cases. Simulations reveal electricity flows, grid and other outcomes which enable to calculate different types of cost. Furthermore a sensitivity study on battery deterioration within the vehicle depending on operating conditions was identified as important. For a sensitivity analysis of environmental impact of the scenarios issued from the reference one key parameters were identified. By means of a bill of material the Life Cycle was modelled with dedicated software. A set of technical scenarios (key indicators for LCA, Life Cycle reference scenario, choice of the battery, of the different steps of the Life Cycle, functional unit) was approved and selected. For the LCA a hypothesis about residual capacity storage of EV battery in the end-of-life, storage capacity and lifetime of a primary and a secondary HES battery as well as the rate of refurbishing of EV battery cells to HES cells was set. A defined energy use during the usage phase of battery cells first life was determined. Further hypotheses on distances and means of transport during the 1st Life of EV battery cells as well as the 2nd Life of EV battery cells (HES transport) and on the storage capacity, lifetime, and composition of frame of the HES batteries were set. Technical data about the recycling processes at the end-of-life firstly have been defined, collected and integrated in the model as well. The life cycle for one battery type was modelled with the software. A model of a Lithium-Ion NMC Battery Life Cycle Reference scenario for "Electric Vehicle Use (1 Use) + Home Energy Storage (2 Use)" was made and its environmental impact calculated. A business model for the evaluation of the economic potential of the recycling and a 2nd Life solution of Li-Ion cells from electric vehicles was developed.

Within the project period partners published and participated in several conferences to present results of the project.

Project Conclusion

The mechanical recycling of batteries from EVs is feasible and a mandatory step, either after a 1st or 2nd Life. The 2nd Life activity merely offers the chance to extent the useful life period of the battery and to conserve resources. For both solutions a dynamic development of the battery technology as well as the market strongly influences all activities in the future. The implementation of our own actions will start earliest in 4 years from now:

- At the moment only small quantities of batteries are brought into the market (useful life, selling rates). This results in a large problem concerning the logistics for 2nd Life activities. In addition the market seems currently not yet mature for this kind of activities. There is e.g. still a lack of potential users and actors for refurbishment. Furthermore costs and/or performance of new batteries vs. refurbished batteries have to be taken into account.
- Capacities, multiplicity of battery types and price developments may obstruct the Business Models of 2nd Life activities.
- Material changes and technological development lead to a continuous adjustment of the economy of a recycling process (changing revenues).
- Furthermore product and material changes (durability, better adhesion) request a continuous adoption of the mechanical recycling process especially in regard to safety issues and product qualities.



Li-ion batteries from electric vehicles can be used in a 2nd Life application or directly be recycled.

CACTUS

Models and Methods for the Evaluation and the Optimal Application of Battery Charging and Switching Technologies for Electric Busses

www.cactus-emobility.eu

Project Data

Funding/€	Total cost/€	Duration
773.590	838.380	36 months

Partners

Institut für Automation und Kommunikation e.V. Magdeburg, DE

Fraunhofer Institute for Materialflow and Logistics, DE

Silesian University of Technology, PL

Main Results

- Models and methods for the evaluation and the optimal application of battery charging and exchanging technologies for electric busses in public transport have been developed.
- The models and methods address technical, transport, economic and ecological aspects of electric busses in public transport.
- The individual best solution for a public transport company from the available battery charging and exchanging technologies is found by using the developed tool in which all models and methods are integrated.

Project Results

A bus in public transport covers an average distance of 250 to 300 km each day. Due to the limitations of the today's batteries the busses are forced to recharge or to exchange their batteries during the day. By now several technical approaches for battery charging and battery exchanging are being investigated. Among others, these include inductive charging during the run, long time charging at the depot and the usage of ultra-capacitors. From an abstract point of view, we can differentiate types of energy storage, types of energy transmission and types of busses. Concrete applications are composed of these types. For a public transport company it is not trivial to select the technical solution meeting its own needs best.

Therefore the available technical solutions must be considered separately against the prerequisites and requirements of every single public transport company in terms of transport, technical, economic and environmental aspects. Only on this basis an individual decision for a technology can be made that optimally meets the requirements of a public transport company. The individually best solution does not only involve a technology but also its optimal application.

To achieve this aim, models of all relevant transport, technical, economic and ecological values have been developed as well as methods to find the most suitable technical solution (depending on the input values) and to apply it in an optimal way. A tool has been developed in which all developed models and methods are integrated. The main input to the tool is the transportation network, the timetable and the operation plan. An iterative process comprises the following four steps:

The first step is to simulate the different bus types on the transport network in order to get the energy demand on the routes which is a major input value for the optimisation of the charging infrastructure.

The second step is to design the charging infrastructure. Such a design consists of the optimal placement and the required capability of the charging facilities. This optimisation process acts in a mathematical sense of optimisation. An objective function calculates costs which depend on the infrastructure and its usage. These costs reflect the economical monetary values as well as ecological and urban development aspects. Some areas can be masked out or can be preferred for installing facilities by changing the associated costs. On the other hand, there are some technical boundaries like limitations in charging currents and in battery capacities.

>>On the Way to the Green Public Transport<<

Finally the task is to vary the infrastructure in order to minimise the value of the objective function while keeping all parameters inside their boundaries.

Objective functions are predefined for battery charging and for battery changing. Only the parameters for the costs and the boundaries are to be defined project specific. All mathematical details are hidden for users.

The model used for the optimisation is simplified and it is assumed that all dependencies are linear. For this reason as the third step a simulation is to be run afterwards with a more detailed model to refine the results and to take more aspects into account.

Above all the outside temperature is considered here in order to regard the energy consumption of the air condition which may has a major influence on the energy consumption of the bus and therefore on the range. The main question answered by the simulation is whether the battery capacity is sufficient to the given battery charging and exchanging infrastructure, the timetable and the operation plan.

Furthermore several simulation variants are available: How does energy consumption depend on the mass of the whole bus? How does the speed profile influences the energy consumption of the bus? How does the energy consumption depend on the elevation profile? How is the influence of energy recovery? What battery capacity is needed so that the bus never runs into an empty battery fault?

The fourth step is to calculate the economic and the ecological impact. In order to determine the economic impact of an investigated solution the costs for investment and operation of the electric busses, the batteries and the charging respective exchanging infrastructure are analysed. In order to determine the ecological impact all busses are simulated over a period of one year taking into account the temperature curve such that the total energy consumption in kWh is known. By this the demand of different energy carriers (e.g. diesel, natural gas, and electricity) is calculated. Finally the emissions of carbon dioxide, sulfur dioxide, nitrogen oxide, suspended particulate matters and diesel particulates are derived, and the savings of these greenhouse gases and air pollutants are calculated.

Project Conclusion

Electric busses become a topic for more and more public transport companies. While electric private cars have low sale numbers due to the limited range and the high price like pedelecs the public transport can accomplish the step into electrification practice now.

When a public transport company considers entering the field of electric busses it is faced with a number of questions which can be answered now by the results the CACTUS project: Which technology should be selected (long charging at the depot or at certain charging points, continuous charging on the run, application of super-capacitors, changing of the battery)? Where do I have to place the charging facilities? Which capacity the batteries should have? The CACTUS tool already has been applied to three German public transport companies and one Polish public transport company within the CACTUS project.

The CACTUS project is based on the assumption that electric busses are forced to recharge their batteries during the day. Therefore if batteries become smaller, light weighted and more powerful in the future in such a way that they can provide enough energy for the entire day without being recharged, the CACTUS results will become more and more obsolete. However for the next few years such a breakthrough in the field of battery research is not expected.

What does the future bring to the CACTUS results? The CACTUS tool will be available on the CACTUS homepage at the end of the project. By then the developed source code can be retrieved via e-mail request.

Electric Bus in Public Transportation.

For the time being the CACTUS tool covers the core features developed within the project. For further improvements such as a smarter user interface, an immediate visualisation of the results and for making the user actions more intuitive and easier, additional effort will be necessary. Furthermore some of the models used in the simulation can be made more detailed. For example experiences with battery electric busses could help to calibrate the technical, economic and ecological models.

The CACTUS team hopes to find partners who are willing to improve the tool in this sense.

DAME

Development, validation and application of an agent based modelling approach for optimal integration of electromobility in electricity distribution grids

www.project-dame.eu

Project Data

Funding/€	Total cost/€	Duration
625.171	625.171	36 months
Partners	Enexis B.V., NL	
	Eindhoven University of Technology, NL	
	RWTH Aachen University, DE	

Main Results

- A set of models that automatically generate load patterns for households, photovoltaics and electric vehicles based on location and time
- An algorithm for controlled charging of electric vehicles considering market, grid, and renewable resource oriented strategies
- A tool to assess the impact of different charging strategies on the medium voltage distribution grid
- An economic dispatch model for optimal integration of wind power and electric vehicles

Project Results

The electricity grid is facing a massive deployment of electric vehicles and other distributed generation resources (DER) over the next years. However, traditional distribution network planning processes assume a steady growth of demand for assessing the capacity of cables, transformers and other network components. Upcoming technologies such as distributed generation and electric vehicles require new methods for network planning, since for instance, the peak load of charging plug-in electric vehicles coincides with the load peak of the traditional household pattern. Therefore the project DAME investigates the grid integration of electric vehicles and DERs to insure a reliable, sustainable and affordable supply of electricity in the future. Special emphasis is placed upon the development of a new grid planning process with regard to these new technologies.

In order to evolve the grid planning process, the impact of those new technologies needs to be assessed. Hence, a method is developed which dynamically calculates the impact of different technologies on the distribution grid. The project mainly focuses on the modelling of the impact of electric vehicles, but other loads (such as household load) or technologies (such as PV-generation) have also been examined.

An advanced traffic model evaluates the traffic flow of a certain area as well as the available routes during one exemplary day to simulate features such as location and required charging energy. These charging needs are translated into charging patterns by using the following charging strategies; an uncontrolled charging strategy, and several controlled charging strategies.

The traditional uncontrolled charging strategy assumes direct charging of vehicles after the arrival at a charging point or station. An assessment shows significant consequences for the distribution network related to this charging behaviour.

As concerning the market-based controlled charging strategy the reserve markets are assessed by a developed unit commitment economic dispatch combining wind power with electric vehicles in a virtual power plant. The dispatch model incorporates the variability and limited predictability of wind power and combines it with the flexibility provided by the controlled charging of the electric vehicles. A scenario assessment shows that costs for traditional control reserves and curtailment can be reduced.

For the network-oriented charging strategy information of the available capacity of the network components is required. This will dominantly be dependent on the connected households and PV installations.

The household loads are modelled using measured time series from transformers and household loads. Based on these data a top-down probabilistic generation model for aggregated household patterns considering time of day,

>>Electromobility integration in a new Network planning tool<<

season and the aggregation level has been developed. Measurement data of photovoltaic systems and weather stations are used to derive an artificial neural network-based model. This model is combined with geographic data to simulate the generation of photovoltaic systems at a specific transformer regarding time and season.

An agent based tool was developed to evaluate different charging strategies, penetration levels of electromobility and photovoltaics and transformer profiles. With this tool the network-oriented charging strategy is assessed showing that significantly more electric vehicles can be facilitated by the network even when a priori knowledge is limited. Furthermore, this tool automatically gathers demographic information about a specific network of interest to determine the possible penetration of EVs. The results are processed and can be loaded into the network planning software used by the distribution system operator to determine grid utilization for the different penetrations of electric vehicles and other distributed energy resources.

levels of distributed energy resources should be dynamically altered by network planners and consecutively, automatically be translated into network impacts.

Regarding the massive deployment of electric vehicles the choice of a certain charging strategy has a significant impact on the distribution network: Evaluations of the uncontrolled charging strategy show a strongly varying influence of electromobility among different transformers. This results in significant voltage drops at some transformers during the day.

A controlled charging strategy considering market control reserves shows the ability of electromobility to support the balance of the power system. The developed economic dispatch model, which considers the variability and limited predictability of wind power and includes electric vehicles reveals potential flexibility of the vehicles to lower the costs of wind power integration.

Project DAME; the connection between electromobility and network planning.

The scientific results of the DAME project are disseminated into the scientific and industrial communities by publishing papers for conferences and journals and workshops with network planners.

Project Conclusion

Developments in the field of electromobility and renewable energy resources in the Netherlands have increased significantly during the project period. As the traditional way of network planning based on a steady growth of needed capacity is not appropriate due to the emerging changes, especially from electromobility, future scenarios with penetration

A grid-oriented charging strategy enables significantly higher penetration rates of electric vehicles and better network utilisation. The available capacity of network assets for charging electric vehicles is essential for network-oriented controlled charging. However transformer load patterns differ significantly per area and standard load patterns may not be sufficient.

An everyday user-friendly scenario platform should be fast which can be challenging when the seasonal and daily variations are included and individual vehicles are assessed in networks which contain hundreds of transformers. Attention should be given to affection of results when algorithms are in this process simplified to reduce the computational burden.

EVERSAFE

Everyday Safety for Electric Vehicles

www.eversafe-project.eu

Project Data

Funding/€	Total cost/€	Duration
1.408.398	1.617.576	32 months

Partners

Swedish National Road and Transport Research Institute (VTI), SE

Technische Universität Chemnitz (TUC), DE

Fraunhofer-Gesellschaft (FhG), DE

Volvo Car Corporation (VCC), SE

Royal Institute of Technology (KTH), SE

Federal Highway Research Institute (BASt), DE

Main Results

- From an end user perspective, safety critical aspects related with EVs vary in terms of type of interaction and human involvement
- The driver acts as a reasonable compensator for the consequences of the tested electric powertrain failures
- Battery cells can have intrinsic safety that can be exploited, current battery technologies have a high level of safety, vehicle design strategies that limit localised deformation and crushing of batteries are important in all load cases
- Existing rescue guidelines and equipment have been reviewed and updated to address safe handling of electric vehicles and their Energy Storage Systems after a crash

Project Results

Good market penetration of EV requires product acceptance among potential customers. As a new technology uncertainty concerning safety of batteries in crash situations and risk of electric shock can lead to negative safety evaluation and affect the attitudes and purchasing decisions of potential EV buyers. Bearing this in mind, research objectives and methods were developed to assess safety concerns and expectations among potential customers. To capture the possible concerns, two focus group sessions were conducted. Inexperienced and experienced EV drivers were invited to discuss critical safety concerns regarding the utilisation of EV. Safety concerns distributed over 4 distinct scenarios were identified from the sessions: while driving, while charging, in case of accident and vehicle aging. Safety-critical aspects vary both in terms of type of interaction and human involvement. A taxonomy of concerns related with EV was elaborated to classify and explain potential reservations among drivers.

Potential powertrain faults for EVs were the focus for the active safety investigations. These can influence the vehicle's dynamic stability, which in turn compromises safety for the occupants and surrounding traffic. Vehicles with electric powertrains can be affected by different types of problems from those that can arise in vehicles with conventional powertrains. This further motivates the need to investigate issues which might arise for an EV. With this in mind, different types of faults in the electric powertrain of second generation EVs were studied and reproduced in a full vehicle simulation study. Analysis of the results showed that the faults have diverse influences on vehicle stability. The fault classes could be grouped based on the severity of their consequences. Three faults in an electric power train were later selected, i.e. an inverter shut-down, a short circuit in the electric machine and a failure in the regenerative braking system. These three specific faults were further analysed with real drivers in two test track experiments and a driving simulator study. Both trials had their own particular driving conditions designed for studying the effects of the different failures. Simulator conditions focused on high speed tests, such as in highway driving situations, whereas test track trials targeted urban speed ranges. The results illustrate the driver's ability to compensate for these failures, with varying types of effort, and regain control of the vehicle.

Passive safety aspects for vehicles with traction batteries were also considered in EVERSAFE. The layout of vehicle components is sensitive to the mechanical loading expected in collisions. A review of the distribution of crash types involving high acceleration or high deformations was performed to establish relevant load cases. Specific queries of databases to identify traction battery incidents were also conducted. The main impacts identified for further study were rear impacts (where limited crashworthiness regulations exist) and side impacts (where extensive vehicle deformations are encountered). An FE model of an electric vehicle together with its critical subcomponents was developed. The load cases identified from real world collisions were used in simulations to establish critical conditions for the energy storage system (ESS) which are not fully addressed in current regulations and standards. The outcomes of the simulation activities served as a basis for experimental tests with ESS and their components as well as the whole vehicle. The battery cells evaluated in the project (currently used in automotive high-voltage batteries) have been proven to be more resistant to abuse than initially expected indicating that current standards for electric vehicle components have already reached high safety levels. This conclusion holds from the point of view of mechanical loading as well as from an electro-chemical perspective since both these issues were under analysis for the majority of the experiments. Moreover it is important that rescue crews are able to quickly identify and tackle any threats that might arise in a post-crash situation. The majority of rescue guidelines existing today for electrified vehicles are based on those existing for their ICE (Internal Combustion Engine) counterparts. Such guidelines were reviewed in light of the project findings in an effort to pinpoint possible needs for improvement to the latter when the focus shifts to EVs. This lead to the creation of an updated set of guidelines which can be used as a replacement or complement to the ones existing today.

Research tools and activities carried out by the EVERSAFE consortium.

Project Conclusion

The work performed under EVERSAFE spans from the study of user expectations towards safety of Electrical Vehicles (EV) to the investigation of concrete passive and active safety issues. The broad scope of the investigations is reflected on the diversity of the project outcomes.

Safety concerns regarding the utilisation of EVs were collected from potential users. These have been categorised in order to facilitate future actions aimed at mitigating these concerns. In order to use these findings to support the adoption of fully electric vehicles it is important to consider that consumer's worries are not exclusively dedicated to system faults but relate also with system limitations and system features.

The research efforts undertaken under the active safety area have identified and classified potential failures on an electric powertrain which are most likely to have a high impact on vehicle stability. The vehicle performance and driver reactions were tested under such circumstances. Analysis of the data gathered under these studies has revealed that, for the given testing conditions, humans act as reasonable compensators for such failures contributing towards an improvement of vehicle dynamic stability. Further research should be conducted in this area to try and understand the effects of increased driver workload, complexity of driving situations as well as human-machine-interface during failure conditions.

Passive safety investigations have focused on the topics of crash compatibility and battery safety. Simulations and crash tests were performed at component and whole vehicle levels. The battery cells evaluated in the project have proven to be more resistant to abuse than initially expected indicating that current standards for electric vehicle components have already reached high safety levels. The response of the cells dependent on the type of abuse and crush (high local deformation), was the most critical mechanical loading condition. Furthermore the studied vehicle structures have shown a good level of protection for high voltage batteries in crash situations. It was also concluded that the current guidelines for vehicle rescue after crash require updates in order to better fit EV. With these needs in mind the project has created a set of updated safe handling guidelines and recommended rescue equipment for rescue services.

Studying driver response and vehicle behaviour in case of failure in electrical powertrain.

EVREST

Electric Vehicle with Range Extender as a Sustainable Technology

www.evrest-project.org

Project Data

Funding/€	Total cost/€	Duration
973.466	1.326.640	36 months

Partners

- Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux, FR
- Karlsruher Institut für Technologie, DE
- Technische Universität Chemnitz, DE
- Universität Stuttgart, DE
- University of Natural Resources and Life Sciences, Institute for Transport Studies, AT
- Centre National de la Recherche Scientifique, FR
- PEUGEOT Scooters, FR

Main Results

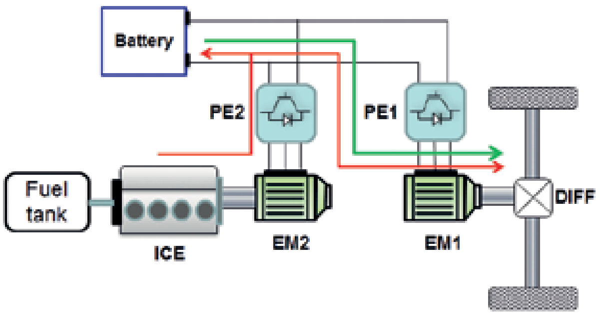
- European car users' clustering and Impact on the required design of Extended Range Electric Vehicles (EREV)
- Developing and assessing 3 scenarios of electromobility including EREV
- Impact on the emission, on the grid and on the life cycle assessment of the different scenarios
- Testing user expectation and willingness to pay for an EREV using stated preference surveys

Project Results

EVs are expected to be an effective solution to cope with pollutant and noise emission in urban areas. However, the EV market penetration is still very weak mainly because of the high cost and the limited range. On the other hand, European statistics show that a large proportion of the daily trips are far below the maximum range announced for the new generation of EVs. This means that the range problem is either psychological or occasional. The main idea of EVREST project is to study how EVs with a Range Extender (RE) could match the different usage patterns while decreasing the battery size (cost), fulfilling occasional long trips and ensuring the user to reach his destination in case of battery failure. A global evaluation of this solution is then proposed and contributes to develop scenarios of electromobility including Battery Electric Vehicles (BEV) and EREV.

The approach proposed in EVREST takes into account the users' mobility needs through the study of mobility surveys in three European countries: Germany, France and Austria (WP1). A clustering method of car usage on the basis of daily distances has been developed. The analyses that have been conducted show that EREVs have a high potential in meeting the needs of car users as assessed with car usage data from France and Germany. After an interaction with the user's expectation evaluation (WP6), the range target, as well as sensitive parameters like the minimum electric range and the minimum speed tolerated by users, have been fixed to generate the users' clusters. Using the generated results, a methodology to virtually design a set of possible EVs with Range extender (RE), that fulfill the requirements in terms of range and performance have been carried out (WP2). Two kinds of RE have been considered for the simulation study, namely Internal combustion engine based RE and Fuel Cell based RE. The simulation results using VEHLIB software showed the emergence of two main sizing of batteries and RE: one corresponding to a cost criterion and the other to a minimum speed criterion. The evaluation phase of the most interesting selected technological designs included different aspects. Concerning the environmental study, a Life Cycle Assessment that consider both the production and use phase of the proposed EREVs and of the reference vehicles (gasoline and BEV) have been conducted (WP5). It showed good performance of EREV in terms of greenhouse gas emissions when considering the European mix of electricity generation. However, the ICE used in the RE should be with high emission performance (Euro 6) in order to avoid a possible over emission when using on shelf Euro3 scooter engines for example. For a more global evaluation, a set of

>>Extended Range Electric Vehicle for soft mobility<<



Extended Range Electric Vehicle drivetrain.

indicators for the development of scenarios was developed. 3 future scenarios consolidated internally amongst the project partners and also externally with experts (expert workshop, June 2013) were established (WP3). Simulations of different electric mobility scenarios to define grid impacts and transport related emissions are conducted using a microscopic description (MobiTopp model) of cars and users in Stuttgart metropolitan area as well as a simulated grid with PERSEUSNET-TS model (WP4). The mobiTopp simulation results show EREVs are used rather similar to conventional vehicles and have another use profile than BEVs. The implementation of a smart controlled charging seems to be an adequate solution to handle the challenges that come along with the additional electricity demand from EVs and EREVs and should be introduced contemporary. Finally, the results of the analyses of the user perspective in Austria, France and Germany showed that there is still a lack of information regarding alternative-fuel vehicles. However, it could be shown that adding a range extender can reduce the reluctance to choose an EV. Furthermore, the disparity between range needs and battery range preferences of an EREV are substantially smaller than the ones found for BEV range preferences.

Project Conclusion

At this stage of the project we cannot give final conclusions because the synthesis WP just began and the outputs will be available in the end of the project (June 30th, 2015). However we can give in the following some temporary conclusions to be validated.

According to the mobility data bases (mainly from France and Germany) there is an important potential for an EREV use. Among the 4 clusters that characterise the European use, 2 of them could be suitable for EREV solutions.

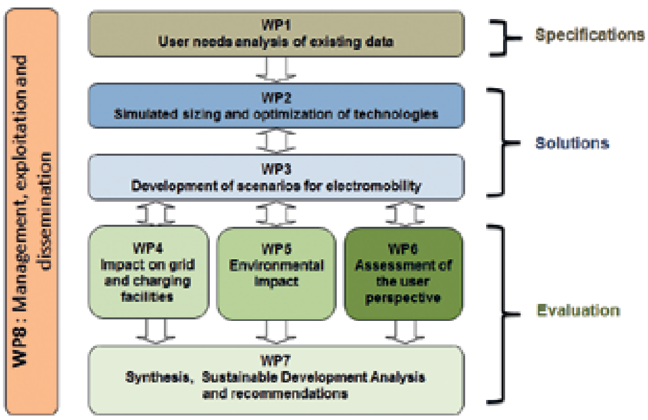
Concerning EREV design, two possibilities have been found to be interesting for selection and evaluation. The first is a cost based design and allows to reduce the battery size while improving the global range. The second is a performance based design and give the opportunity to drive at a sufficient speed in the degraded mode (battery empty). Both can be applied to ICE based EREV as well as fuel cell based EREV.

In comparison with BEVs and conventional gasoline and diesel vehicles, the designed EREVs showed the potential to have smaller environmental impacts along their lifecycle (e.g. reduced greenhouse gas emissions). Compared to BEVs, EREVs are equipped with smaller batteries which lead to significantly reduced environmental impacts during the vehicle production. At the same time they show environmental advantages in comparison with conventional vehicles when using electricity with high shares of renewable energy.

Developing purchase models for three different scenarios in 2025, it could be shown, that an EREV seems to be a promising compromise between the technological options and the customer needs and therefore more capable to solve current transport problems on the short and mid-term perspective compared with BEVs. The new car's market share in 2025 lies between 16-17,5% for Austria, Germany and France in the most likely scenario. There is a range of exogenous factors, which could support this development.

The mobiTopp simulation results show EREVs are used rather similar to conventional vehicles and have another use profile than BEVs. Based on the resulting electricity demand from EV usage the underlying electricity mix and the CO2 emissions of the German power plant portfolio are calculated using the energy system optimising model PERSEUS-NET-TS. Our findings show that a precise representation of travel demand, car usage as well as (local) electricity supply is crucial for assessing the impacts of EV use on the energy system.

The results from stated preference surveys showed that an EREV is appreciated by potential early adopters of EVs. Furthermore, participants would pay more for an EREV with a battery range of 100 km (150km) and a full power range of 300 km than for a typical BEV. However, it has been shown that the battery size of an EREV ought not to be too small. Additionally, participants prefer a speed in degraded mode (battery empty) with which they still can drive on the motorway. Although the discrepancy between range needs and (battery) range preferences is reduced by an EREV compared to a BEV, it is not possible to overcome the range challenge completely.



EVREST general schedule diagram.

NEMO

Novel E-Mobility Grid Model

www.nemo-project.eu

Project Data

Funding/€	Total cost/€	Duration
905.891	1.166.839	36 months

Partners	DNV GL, NL
	Fraunhofer Institute for Solar Energy Systems ISE, DE
	EMD International A/S, DK
	Ringkøbing Amts Højspændingsforsyning, DK
	Ringkøbing Fjernvarmeværk A.m.b.a., DK

Main Results

- Developed tool suite of 3 complementary grid simulation models
- Modelled grid impact of EV charging (e.g. line and transformer loads, voltages) in 3 groups of scenarios: fast charging, abnormal charging situations, interaction of Distributed Generation and EVs
- Grid-related interactions with other modern loads and generators charted, e.g. heat pumps, PV, wind.
- General / higher-level learnings and recommendations identified

Project Results

The main results of the project are achieved in four different areas that are highlighted below.

NEMO tool suite

By linking three complementary models, the NEMO tool suite has been created, operating as follows. Grid data and profiles of loads and generators including EVs are processed by EMDs EnergyPRO model resulting in profiles. Subsequently, Fraunhofer ISE's SimTOOL calculates a load flow and identifies any grid issues. Resolution of such issues takes place either by applying charging limitations (adjusted EV load profile) in a feedback loop with EnergyPRO, or by modelling solutions such as grid reinforcement strategies and energy storage by DNV GLs PLATOS. The tool suite can be used to study the impact of modern loads and generators (EVs but also heat pumps, PV, wind, etc.) on various grids and to come up with solutions and recommendations for future-proof grids.

Modelling results: interaction of DG and EVs

In a 1970s reference grid, transformer overloading is the limiting factor when increasing EV penetration levels, while in a reference grid from around the year 2000 voltage issues occur first. A combination of transformer and cable upgrades, smart charging and energy storage can resolve the issues. Reactive power management on high-voltage grids due to the influence of EV and DG (distributed generation) is necessary, for example in Denmark where the West is relatively weakly connected to the East and has significant wind production. Smart solutions are required and possible, such as intelligent EV charging or electrical boilers connected at a reduced grid fee acting in the spot/day ahead market.

Modelling results: fast charging

Already at an EV penetration level below 3% grid problems (transformer overload, voltage violations, cable overloads) were detected in the NEMO tool suite simulations of fast charging in a residential area. Time shifting or power reduction are no relevant solutions for this case. Energy storage or a separate feeder for fast charging stations might be depending on costs. Remote fast charging (e.g. along the highway) is better from a grid perspective although especially voltage violations can still occur. A combination of PV/wind generation and energy storage should be looked into for remote fast charging stations.

>>Modelling grid impact of EVs: towards future-proof grids<<

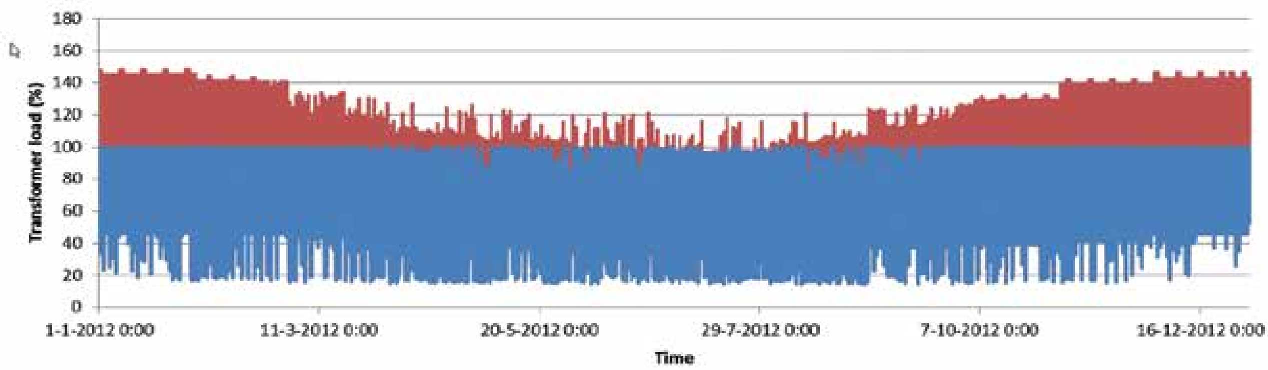
Modelling results: abnormal charging situations

EV car sharing at the Mainz train station has shown to cause voltage violations in the local grid. This negative impact can be reduced by demand side management with additional benefits from grid reinforcement and energy storage. The situation for EV charging at the football stadium Coface Arena in Mainz is more complicated. The energy concept of the stadium needs to be adjusted to accommodate EV charging on the envisioned scale and pattern. Demand side management can solve voltage violations at the Wutzdog Festival with other solutions for transformer overload.

Project Conclusion

The NEMO project's main conclusions are listed below.

- Grid problems predicted due to EVs for penetrations in DK, DE, NL:
  - 2015-2018 Fast charging, no demand response
  - 2018-2022 Fast charging, demand response
  - 2020-2025 Slow charging, no demand response
  - 2021-2029 Slow charging, demand response
  - Dependent on specifics of local grid, loads, generators, etc.
- There is no panacea for solving grid congestion due to EV/DG
- A combination of solutions is required, tailored for each specific situation
- Not single tools are but combination is required, providing range of solutions to evaluate. The NEMO tool suite can investigate scenarios and propose solutions.
- Home PV (photovoltaic) and HP (heat pumps) installations are more urgent than EV on the short term
- PV and wind will ultimately have a larger grid impact than EV, due to these factors being less predictable and less dispatchable
- NEMO tool suite can be applied to predict grid problems regarding unknown quantities of PV by investigating (worst case) scenarios
- Energy storage (electrical, heat) is one of the means to retain power system reliability decrease due to EV charging and variability of DG
- Need for a modelling decision loop to assess operational strategies (including Demand Response) versus planning (grid reinforcement & storage)



EV impact on power grid and possible mitigation: transformer (over-)loading during one year in a grid with EVs and PV installations; in red without energy storage, in blue with energy storage.

Speed for SMEs

Systematic development of Propulsion systems for Enhanced Electro mobility Drive trains

www.rally-e.at

Main Results

- Definition of „rally-e“ as brand for commercial implementation and use of the founding project
- Development of a powertrain unit IDT - Integrated Drive Train, including all e-powertrain components (motor, controller and gearbox) as well as an integrated cooling system for all components on one vehicle axle with full torque vectoring ability
- Development of the so called BCT-Battery Charging Trailer, a low-budget ttrailer-based battery changing system for a quick change of the traction battery within minutes
- Development of a Li-Ion-battery system (r2-ress), with low weight/energy ratio and the ability of flexible adoption for various vehicle geometries

Project Results

The project Speed for SMEs consists of 7 work packages. The ultimate goal of the project was to define a concept for and create a development and testing platform for e-mobility.

In WP 1 “Project Management”, the brand „rally-e“ was developed and defined as a synonym for the marketing of all components and services associated with the development and test platform for e-mobility at the end of the project.

Project Data

Funding/€	Total cost/€	Duration
918.204	1.637.370	36 months

Partners	ego-drive GmbH, AT
	TIC Steyr GmbH, AT
	LKR Leichtmetallkompetenzzentrum Ranshofen GmbH, AT
	Smart e-Mobility GmbH, AT
	Lagermax Autotransport GmbH, AT
	Stohl Racing GmbH, AT
	Clusterland Oberösterreich GmbH, AT
	Goodville Consulting GmbH, AT
	EDER GmbH Technical Concepts, DE

WP 2 “Systematic of Development” focusses on the definition of a new way of implementing development services among the project partners. After contacting potential customers for components and services of rally-e, it very quickly became clear that the definition of interfaces between the e-components demanded a much higher priority within the suppliers of automotive components to the project. For this reason, WP2 was expanded to address further aspects like lightweight or safety-related components for e-vehicles.

WP 3 “Multiple Interface Test Vehicle” focusses on the development of a complete prototype vehicle. The prototype contains features not easily found on the open market. It is a b-segment mass product featuring very high safety standards and all-wheel drive. A Peugeot 207 modified according to FIA Super 2000 standards forms the basis of the prototype. This vehicle was equipped with two e-powered axles and a battery system optimised for maximum capacity and minimum weight. The concept and lay out of the traction battery had to be harmonised with the concept of the battery charging trailer (WP4). The usable cell technology

>>A tool for SMEs to developing and testing e-mobility components and systems in a professional, effective and efficient way<<

ranges from LiNiMnCo, $LiNiCoAlO_2$ to $LiFePo_4$ systems. The power connectors of the battery are capable of currents up to 1200A and 1000V. This provides potential for future battery cell developments. For charging, the power connectors are connected to a grid based charging device with 22kW charging power filling the 30,5 kWh battery in just 1 ½ hours.

In WP 4 “Advanced Charging”, a mobile battery changing station was designed and built: the Battery Charging Trailer (BCT). This trailer can be towed by truck or passenger car and is capable of transporting an exchange battery module. An automatic levelling system ensures exact horizontal positioning on a rigid surface thus enabling a battery change on almost all rigid surfaces. Iinductive charging is also foreseen as an alternative.

WP 5 “Systematics in Test Runs stands for testing and evaluation under defined criteria and conditions. In addition to checking components and systems for e-mobility, Speed for SMEs also aims at improving the status and public opinion about e-mobility. Participation is planned in motorsport and E-mobility events as well as in demonstration activities with our partners and customers. There is no other vehicle on the market able to switch between batteries so easily. As the vehicle’s electronic architecture is able to accept battery systems between 350 and 450 V, no hardware adaptations are necessary when using new generations of battery cells.

WP 6 “Test Fleet” includes the creation of a business model for marketing the developed components. Speed for SMEs forecasts a potential market volume of 15 experimental units per year. Stohl and ego-drive will market the e-components and the complete e-kit together as equal partners. In addition, ego-drive will provide the battery systems and Lagermax the BCT. The battery systems will be marketed as r2-ress – rallye & racing recoverable energy storage systems (www.r2-ress.at).

Within WP 7 “Dissemination”, the consortium rolled out the complete system, the finished rally-e Mk1 and the BCT as well as the battery housing (without batteries) on October 22nd, 2014 during a public event carried out by Clusterland OÖ (AC).

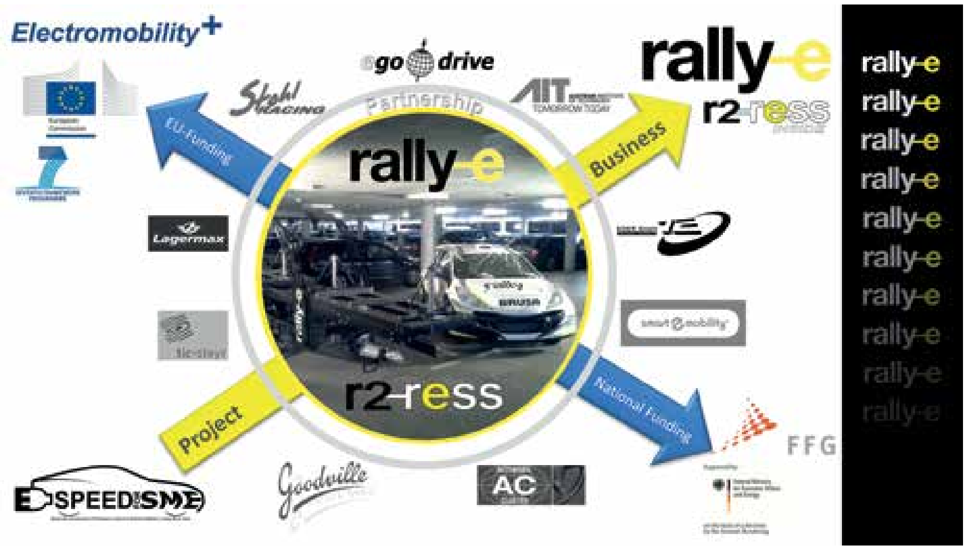
Project Conclusion

Speed for SMEs is a project carried out by SMEs for SMEs. The target of providing a development and test platform for e-components and e-systems for e-mobility was reached. The plan to establish the basis for a sustainable business model during the term of the founding project was fulfilled.

Speed for SMEs introduced a series of trend-setting developments for the future design of e-components, including an open interface architecture for e-components. This architecture can manage all e-components on the vehicle thanks to a newly developed vehicle control unit (VCU). The drive units with one motor per wheel enable an independent control of each wheel and thus full torque vectoring. This ultimate vehicle drivetrain concept provides the highest possible active safety. The battery voltage can range between 350 and 450 V and covers all system voltages currently on the market for such application.

The components developed within the framework of the project (i.e. rally-e Mk1, battery changing system, the exchange battery r2-ress, recoverable energy storage systems, BCT) are unique and without competition on the market and allow a quick and easy battery change on the vehicle.

The components have been prepared as prototypes and the necessary brands for marketing have been established. “rally-e” is the brand for the complete system, – for the conversion of existing vehicles to e-powertrain as well as the battery changing infrastructure. The high performance batteries show up under the brand name „r2-ress“.



Speed for SMEs turnes to business with the brands rally-e (e-propulsion system with battery changer) and r2-ress (high-end battery systems).

Rally-e also stands for the service to convert a complete vehicle as well as the battery changing trailer BCT for any given customer. r2-ress stands for a battery system that can be used to develop and test new battery chemistry or cell types.

During the course of the project, the e-mobility hype softened significantly due to the high cost of purchasing e-vehicles and e-components. As a counterweight to this development, Speed for SMEs was the start, and rally-e the realisation of the motorsport marketing philosophy „win on Sunday, sell on Monday“.

FCCF-APU

Fuel Cells operating on Conventional Fuels as Auxiliary Power Units for battery electric vehicles

www.fccf-apu.eu

FCCFAPU
FUEL CELL OPERATING ON CONVENTIONAL FUELS AS AUXILIARY POWER UNIT

Project Data

Funding/€	Total cost/€	Duration
2.219.439	3.272.558	36 months

Partners

- Fraunhofer Institute for Chemical Technology, DE
- Fraunhofer Institute for Solar Energy Systems ISE, DE
- WS Reformer GmbH, DE
- Serenergy A/S, DK
- Danish Power Systems Ltd, DK
- Chalmers University of Technology, SE
- Impact Coatings AB, SE
- Borit NV, BE-VLG

Main Results

- Highly efficient systems design using steam reforming with advanced thermal and water management
- HT-PEMFC MEAs with improved operational stability in wet fuels and under start-stop conditions
- Effective coating for corrosion protection of metallic bipolar plates in HT-PEMFC stacks

Project Results

The goal of the project has been to develop an efficient low emission fuel cell solution as auxiliary power unit for (commercial) electric vehicles in order to enhance their reliability of operating and comfort of use. The operation with a conventional fuel such as petrol or diesel was thought necessary to avoid additional investment burdens on fueling infrastructure for the car/fleet owners. The combination of a HT-PEMFC with a steam reformer for the hydrocarbon fuels was thought most suitable as it offers sufficient robust fuel cell technology to reduce gas clean-up efforts and at the same time keeps energy losses due to daily start-stop cycling at bay. The approach posed, however, also a number of challenges which were addressed within the project. On the system level the main challenge was seen in the water autonomous operation of the system as no water for the steam reforming reaction should be stored on board. The problem was solved by an innovative heating and cooling design which allows for sufficient water recuperation for ambient temperatures up to 40 °C without active cooling. By an additional heat-exchanger between the fuel gas of the reformer burner exhaust and the fuel cell cooling cycle in addition a rapid start-up of the system at low energy consumption could be realised. A commercial natural gas reformer was modified so that it can accommodate liquid fuels. In an intensive screening process suitable catalyst and operation conditions for the two target fuels diesel and petrol were determined. Tests in a full scale reformer showed that operation on both fuels is possible. However, as the operation on diesel fuel would have required special available but expensive equipment for start-up it was decided to use petrol fuel for the demonstration. An autonomously operating bread board system has been realised and is currently beeing tested.

On the fuel cell stack side improvement regarding the stability of the membrane electrode assemblies (MEAs) for operation with steam reformed hydrocarbons and at daily start-stop cycling were required as well as an increase of the power density by reducing the stack volume. With respect to the MEA thorough optimisation of the hydrophobic properties of the catalyst and gas diffusion layer on the anode side led to a significant improvement of the MEA stability under operation with highly humidified fuels containing up to 30 mol% of water both under steady state and start-stop cycling operation. At the same time it was shown that the enhanced MEA also exhibited improved performance with simulated reformate containing both CO and H_2S as impurities. The new MEA should be capable to offer stable operations with low sulfur diesel reformate. Additionally a modified catalyst was developed which has a significantly higher tolerance for sulfurous impurities. Stability for the operation with fuels containing up to 40 ppm H_2S was demonstrated. Incorporating this new catalyst operation also with fuels with higher

>>APU for clean, reliable and comfortable electromobility<<

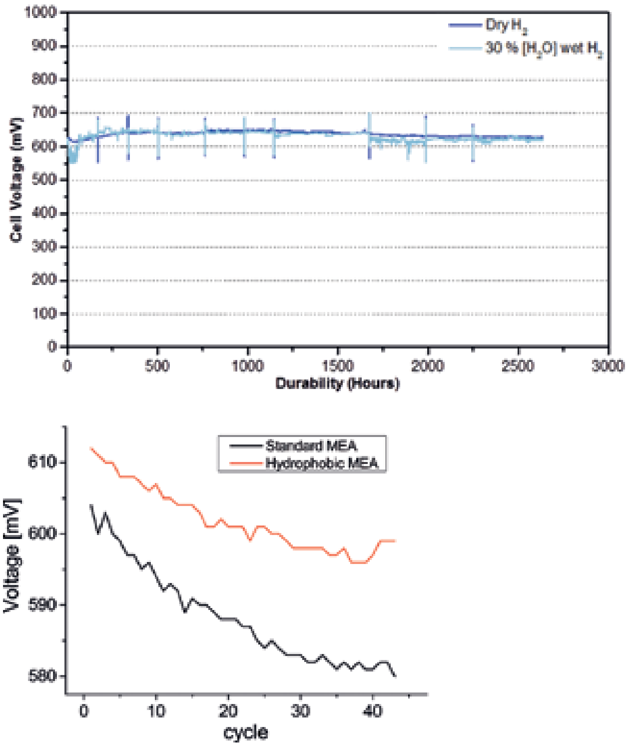
sulfur content e.g. jet fuels should be feasible. In order to increase the power density of the stack the use of metallic bipolar plates was investigated. A modification of a MAX-Phase coating developed for NT-PEMFC could be determined which offered significant protection of corrosion for 316L stainless steel in contact with 85% phosphoric acid and air at elevated temperatures. During the development significant improvements of the coating process could be realised which will increase the production rate and thus contribute to a significant cost reduction. The process improvements are also applicable for the coating process for NT-PEMFC bipolar plates. In parallel the design for the bipolar plates was successfully adapted so that production via hydroforming became possible. A series of bipolar half plates were produced and partially coated and is currently tested by different partners. Unexpected problems with the joining of the half plates have, however, prevented the assembly of stacks which is now scheduled for spring 2015. Test with coated metallic flow fields in a specially designed single cell set-up are currently conducted.

Project Conclusion

The project has successfully addressed some of the key challenges of using fuel cells as APU for passenger cars or small commercial vehicles. An important issue to address was to avoid the use of a special fuel which requires an additional infrastructure. It was shown that a commercial steam reformer for natural gas can be adapted to convert petrol and even diesel fuel. The use of steam reforming which allows for higher hydrogen yields than other reforming technologies in combination with a HT-PEMFC will allow for high efficiencies even if daily start-stop cycling is accounted for. The issue of water supply was successfully solved by a system design which allows for sufficient water recuperation for ambient temperatures up to 40 °C. The heat exchanger design does at the same time allow for the efficient heat up of the fuel cell system during startup using rejected heat from the reformer integrated burner which will reduce the energy expenditure for startup, presenting the system solution for the second issue of the target application the frequent start-stop cycling. With respect to this issue as well as with respect to the operation on steam reformed hydrocarbons with its high water content the anode structure of the membrane electrode assembly was successfully optimised so that detrimental effect of these conditions were significantly reduced. As could be shown, the modification also had a beneficial effect on the tolerance for typical impurities like CO and H_2S. With a new catalyst developed in the project even the use of fuels with high sulfur content such as jet fuels would be possible. The final issue - which was seen in the lack of power density - was addresses by investigating the adaption of metallic bipolar plates. Here a coating was found which in preliminary accelerated stress test showed significant protection against corrosion by phosphoric acid in air at elevated temperatures. More importantly the companies involved in this work package were able to enhance their production processes so that they are enabled to reduce production cost also for metallic bipolar plates for LT-PEMFC for automotive drive train application as side effect.

The final evaluation of the metallic bipolar plates as well as the evaluation of the system are ongoing and will be reported.

Integrated System for laboratory testing not yet optimised with respect to packaging.



Highly stable new MEAs under long term testing (upper) and cycling in humidified reformate (lower).

K-VEC

Ultrafast and distributed power charge system for high performance on-board energy storage devices

www.kvec.eu

Project Data

Funding/€	Total cost/€	Duration
200.624	380.079	31 months
Partners	Sequoia Automation S.r.l., IT	
	Bergische Universität Wuppertal, DE	

Main Results

An electric vehicle equipped with the K-VEC solution is expected:

- to be fully competitive with fossil fuel based urban transportation systems
- to reduce operational costs compared to electrochemical based energy storage systems on board electric vehicles
- to allow a greater operability compared to electrochemical based energy storage systems on board electric vehicles
- to lead to the implementation of a viable pure ZEV concept

Project Results

An electric vehicle (bus) has been equipped with the patented solution "Quick-recharging energy feeding system for means of transport with electric traction, Patent n. EP20691622009". In order to do that some simulations have been preliminary performed in order to better define the theoretical performances of the K-VEC system and to better model the storage system related to the vehicle's requirements. Energy regeneration has been duly assessed, since ultracapacitors, differently from electrochemical based storage systems, allow an almost thorough regeneration of braking energy. After those preliminary analysis the project entered in a more concrete phase, by realising a fully working prototype of the K-VEC electric vehile.

In particular:

- A set of new electronic components has been designed and realised, in order to condition the relevant energy flows, especially by managing the energy stored in the ultracapacitor packs and by regulating energy flows between the pack at ground the on-vehicle pack. A newly conceived model of step down DC/DC converter has been designed and prototyped in order to grant the expected specs within the required safety factors.
- An hybrid bus (MB CITO) has been deprived of the endothermic engine and equipped with a pack of ultracapacitor able to grant an authonomy of around 1.000 m. All vehicle services have been interfaced and power-served by the pack of ultracapacitors.
- A specific conductive charging system has been conceived, designed and manufactured in order to grant the desired energy transfer (from the ultra-pack at ground to the one on board) in a timelapse ranging from 30 to 60 seconds. The charging system is composed by:
  - Two different packs of ultracapacitors, one at ground, connected to the grid, and another on board of the vehicle
  - A 50 cm diameter on-vehicle plug, actuated by three electric pistons and equipped with a set of sensors in order to monitor positions, accelerations and deformations has been placed underneath the bus frame and connected to the ultracapacitors on board, able to automatically move down at vehicle's stops in order to connect with the charging carpet
  - Two conductive charging carpets with two technological approaches have been designed, manufactured and assembled: 1) with PCB technology; 2) with brass hexagons on vetronite support. Both carpets have the same dimension (ca. 1,4m x 1m), number of hexagons (36), and outer conductive border. The two different layouts have been chosen in order to test the two technologies (PCB -faster, lighter and easier to install

>>A new concept for a truly viable electric vehicle<<

for testing purposes) and (BRASS-VETRONITE Ultracapacitors system and relative control electronic more solid and more suitable for road integration).

- A control software and a communication system aimed to grant an automatic and smooth charging procedure.

The whole system has been designed in order to allow an efficient and rapid energy transfer, ensuring at the same time an adequate degree of freedom for the driver and a high level of safety both for the system and for the people, in standard working conditions.

One of the key points of the system is the set of supercapacitors on the ground, "energy reservoirs" that can supply, within seconds, quantities of power unthinkable for the normal electrical networks from which they draw energy during the much longer time that elapses between the passage of one bus and the next. This avoids having to lay expensive and complex cabling.

Another key feature is that, for safety purposes, the charging phase is compliant with the following procedure: a) a Wi-Fi signal allows the vehicle's electronic system to perceive the approach to a charging point and starts the descent of the supply arm; b) the plate, which is also equipped with a brush to clean the carpet from any possible debris, is pressed against the carpet to ensure an optimal electrical contact; c) a few of the pins on the plate are distributed on concentric circumferences: the inner ones are the positive pole, while the outer ones, "protective", are the ground; d) contact between each pin and the hexagonal metal of the carpet is verified by an electronic device capable of identifying the socket and bus code number, the exact position of the vehicle with respect to the carpet, the number of pins in touch with every single hexagon and the absence of "bridges" or conductive contact interruptions due to external causes; e) only after verifying that there are no obstacles to a safe energy transfer the electronic system supplies power only to the hexagons in contact with the positive pole pins, and the charging phase takes place.

In order to analyse the system, a systems engineering method, the Demand Compliant Design (DeCoDe) has been adopted and implemented. The DeCoDe method is aimed to model a system using four sights (requirements, functions, components and processes). The objective of the DeCoDe-based risk assessment is to act as a backbone for the risk assessment and data storage The resulting system model served as basis for the analysis activities supporting the identification of cause-and-effect relationships (FMECA) and the construction of use cases (RBD and FTA).

Project Conclusion

The K-VEC is a zero emission transportation system which involves a radical change of perspective: only the energy needed to cover the distance between one stop and the following stop is carried on board. The energy is stored at each vehicle stop through charging stations which recharge the on-board capacitors in an extremely short time.

This zero-emissions solution therefore allows to have a limited battery weight on board of the vehicle, without limiting the range of action, thus decreasing the operating costs. It furthermore makes the vehicle perfectly functional in urban traffic, without having the restrictions other means have, such as on-rails vehicles, and with the flexibility of use offered by road vehicles. The charging stations would also have limited initial investment and management costs, when compared, for example, to a system of overhead power lines, which also involves a remarkably unpleasing aesthetic impact. In addition, in order to limit the overall energy use on routes with marked differences in altitude, the K-BUS project determines that the vehicles, while proceeding downhill, recharge their supercapacitors through recovery during braking. The supercapacitors then supply energy to the ground supercapacitors through the same charging system and this energy is then channeled to the uphill stations to provide low-cost supply to the next vehicle.

Initially such an approach appears to be best suited to application where a vehicle moves along a predictable route (like public transports, waste collection, industrial logistics, agricultural applications, airports, etc). Finally general applications could be thought of in the future, even when there is not a predictable route. The K-BUS is in fact a zero-emissions system, with a competitive costs with respect to those powered directly from fossil fuels (while not considering possible incentives for electric vehicles), with technical solutions that ensure an efficient and versatile transport and that, in addition, while not affecting the existing vehicular traffic, maintains the practicality of the public service. In short, a concrete solution for the mobility of the future.

The "Power carpet" (detail of hexagons). The carpet is placed on ground and is aimed to ensure the conductive energy transfer to the ultracapacitor pack on board of the vehicle.

MaLiSu

Nanomaterials for future generation Lithium Sulphur batteries

www.iws.fraunhofer.de/malisu

Project Data

Funding/€	**Total cost/€**	**Duration**
1.285.919	1.827.283	36 months

Partners	Fraunhofer IWS, DE
	VARTA Micro Innovation GmbH, AT
	SGL Carbon GmbH, DE
	Uppsala University, SE
	Technical University Dresden, DE
	Scania AB, Sweden (associated)

Main Results

- Improved fundamental understanding of relation between material structure and battery performance
- Scalable synthesis and electrode manufacturing processes for porous carbon materials with enhanced properties in sulfur-composite cathodes
- Identification of electrolyte additives and (mixed) binder systems for improved battery performance
- Demonstration of material concepts on cell level

Project Results

One of the major objectives of this project is the investigation of the influence of porous carbon (host structure) characteristics on lithium sulfur cell performance. A wide-range screening of carbon materials with functionality as sulfur host was started with the investigation of mainly microporous carbons, which potentially offer very high specific surface areas but rather low pore volumes, thereby limiting the sulfur loading.

While high sulfur utilisation and good cycling stability was observed for the microporous host materials, the limit in maximum sulfur loading becomes obvious, when comparing samples with 42.5 % and over 50 % sulfur. Utilisation and rate capability is significantly decreased with increasing sulfur content.

Detailed studies on purely mesoporous and hierarchical micro-mesoporous carbons were investigated as well. Main conclusion is that high surface area is required for high sulfur utilisation, while high pore volumes enable high loadings.

To provide a carbon material with the desired combination of micropores and macropores and thus higher pore volume different scalable synthesis routes were investigated. A hard template route was developed allowing good control over the pore geometry and using an approach for precursor carbonisation and template removal in only one step. Activation processes were found to enhance the pore volume of commercially available carbons resulting in very suitable host materials for the Li-S-battery.

Active materials were prepared by melt infiltration of sulfur into the carbon materials and electrodes were produced via dry or wet processing from powders. The dry process route represents a very environmental friendly and low cost production method for electrode films. No toxic solvents or energy consuming drying processes are required to receive cathode films with outstanding performance from this fast and scalable process.

A new PEO/PVP mixed binder system was implemented in the cathode for improved active material utilisation and retention. The binder system improved cycling stability and capacity retention, the CE of cells can remain at high level (> 97 %) for more than 300 cycles. The role of the binder additives was investigated and could be attributed to direct interaction of the binder species with the polysulfide conversion reactions in the cathode. Optimisation of the binder composition and adaption to the carbon material was found to be crucial to obtain enhanced electrochemical performance.

While PEO/PVP were difficult to implement in slurry based electrode processes, due to the high viscosity of binder solutions, a route was identified to implement these binders in the dry electrode process.

>>Development of low cost and high capacity Li-S-batteries<<

Electrodes were tested towards their electrochemical performance in liquid electrolyte cells vs. Li metal anodes. Carbon/sulfur nanocomposite cathodes prepared from hierarchical micro-macroporous carbons exhibit a stable capacity of ca. 800 - 1100 mAh/g-S over more than 60 subsequent charge/discharge cycles. Although the total pore volume is high due to the macropores, the sulfur content in all composites was fixed to 75 wt% (weight percent) to obtain comparable results as well as to analyse how the micropore share in the carbon influences the active material utilisation. This is possible due to the fact that Li ion transport is almost unrestricted throughout the macropore system, which is contrary to solely microporous carbons as well as hierarchical micro-mesoporous carbons with small sized mesopores (Øpore < 20 nm) where pore-clogging can deteriorate the cathode performance already at moderate sulfur content although high (micropore) surface area is available.

Pouch cells were designed and electrodes were balanced to obtain demonstration of the new material concepts on prototype cell level. While the outstanding material performance could be reproduced also in prototype pouch cells, the weight of inactive cell parts still limit the overall energy density on cell level. Future work will be focused on optimising all components towards performance at low electrolyte mass. Concepts for protection of Li-metal anodes need to be implemented as well in order to obtain improved cycle life.

Sulfur-carbon nanocomposite electrode and Lithium-Sulfur-Battery prototype cells.

Project Conclusion

Within the MaLiSu project a significant contribution to the fundamental knowledge of the lithium sulfur battery chemistry was achieved. Carbon materials act as conductive and stabilising framework for the non-conductive sulfur-species. The influence of the nanostructure in carbons on their performance in sulfur carbon nanocomposite cathodes has been studied. High surface areas (> 1.000 m2 g^{-1}) and high pore volumes (> 3 cm3 g^{-1}) were found to be essential for the carbon material to enable high sulfur loadings and utilisation. With optimised materials specific capacities of 1.000 mAh g^{-1} (sulfur mass) and 700 mAh g^{-1} (electrode mass) with a stable performance for up to 100 cycles were achieved, thereby exceeding most available literature data.

In parallel various electrolyte additives and (mixed) binder systems were studied and new compounds were identified further enhancing the sulfur utilisation and inhibiting the degradation mechanisms.

High performance electrodes were produced through an environmental-friendly dry process route allowing for reproducible results, areal capacities in the range of 2 - 5 mAh cm^{-2} and high current densities up to 10 mA cm^{-2}. The process completely avoids costs related to solvent-based coatings (dispersion, drying, solvent recycling) and has the potential to be scaled to a continuous powder-to-roll process.

While material data were collected mainly in coin cells, first pouch cells have been designed and build to demonstrate transferability of results. While the material related data like specific cathode capacity could be reproduced in the prototype cells, achieving high energy densities and high cycle life at the same time, still remains a challenging task.

Future work needs to be focused on anode materials and anode - electrolyte interaction to adress the major degradation mechanism in Li-S-batteries.

MATLEV

New materials and technologies for lightweight generic components of electric low-emission concept vehicle

www.matlev.eu

Project Data

Funding/€	Total cost/€	Duration
680.613	688.205	36 months

Partners	Warsaw University of Technology, PL
	Dresden University of Technology, DE
	S.Z.T.K. ‚TAPS' – Maciej Kowalski, PL

Main Results

- Development of inserts to be integrated in composite structure made of ultra-high strength nanostructured aluminium alloy.
- Improvement of mechanical and flammability characteristics of polyurethane foams.
- Development of braiding technology of natural fibres and their integration in composite structures via Resin Transfer Moulding, Resin Powder Moulding and Long Fibre Injection processes.
- Design and manufacturing demonstrators of light weight generic components of an electric vehicle using developed materials and technologies.

Project Results

The main goal of the project is to design and offer new solutions in the field of vehicle architecture, based on innovative structural and functional materials. Three main types of innovative materials have been developed, namely:

1. Nanometals, which feature low density (which can be assured by appropriate chemical composition, e.g. Al and Ti alloys), high strength (it is foreseen that ultra-high strength will be obtained by grain size refinement down to nanoscale), sufficient ability to plastic deformation
2. Natural fibre composites, which feature good quality in terms of fibres impregnation, high mechanical properties and low flammability
3. Flame retardant nano-composites which have polymer matrix (polyurethane systems) dedicated for the LFI/NF technology, meet fire safety but also all fire safety requirements for mass transport, whose additives optimise mechanical strength and assure appropriate fire resistance.

Nanometals. Commercially available 5XXX series aluminium alloy was subjected to a different severe plastic deformation routes, i.e. high pressure torsion, equal channel angular pressing, hydrostatic extrusion and the combination of the last two. The processing allowed to transform conventional microsized grains into nanocrystalline structure with the average grain size varied from 80 to 200 nm depending on processing route. All processed samples exhibit very high mechanical strength – the yield strength higher by 200% and ultimate tensile strength 60% higher than those for coarse grained 5483 aluminium alloy. The materials processed had the form of either discks (HPT processing) or rods with various diameter – from 5 (HE processing) to 30 mm (ECAP processing). The materials developed were th en used to produce super-strength inserts, which will be incorporated into composite structure.

Nanocomposites. The major advantage of nanofillers for polymer matrix composites is that they significantly improve the properties at much lower weight content comparing to standard microfillers. This enables costs to be reduced while maintaining low density. In the project such nanofillers as nanotubes or polyhedral oligomeric silsesquioxanes have been tested in terms of their influence on mechanical strength, thermal stability and flammability. Also, expandable graphite was used as a conventional filler. They were added to polyurethane foams. It was demonstrated that the best combination of properties can be achieved for composites containing both expandable graphite and nanotubes. The former assure good flame retardant properties whereas latter high mechanical strength.

Natural fiber composites. Natural fiber are very promising filler for polymer composites. However, the application of natural fiber in LFI method or braiding creates a number of technological problems. Fiber surface modification seems to

>>Lightweight structures - a key for successful electromobility<<

be the key for adapting this filler for technology of fiber reinforced polymer composites. Here, two different approaches have been selected to produce high quality Natural Fibre Reinforced Composites (NFRP). First approach was to utilise commercial natural fibre fabrics, modify their surface using chemical methods and adapt the manufacturing process (by selecting most favorable parameters of pressing) to produce NFRP. The obtained results allowed to manufacture high quality natural fiber composites in a highly efficient, one-step, automated Resin Powder Moulding process. Second approach was to characterise natural fiber-reinforced composites manufactured by braiding method. In the first phase of this research, two-dimensional fibre preforms of the different natural fibers, e.g. hemp, sisal, flax has been manufactured. Braiding parameters have been fitted to selected natural rovings in order to obtain high quality preforms. Second phase of the project focused on integration of manufactured fabrics in polymer matrices using different composite technologies, e.g. Vacuum Assisted Resin Injection, Resin Powder Moulding or Resin Transfer Moulding. The obtained results allowed to manufacture high quality natural fiber-braided composites.

Technology demonstrators. First, virtual concepts of demonstrators have been shown and three components of electric vehicle has been designed. These are: (i) armrest with or without armrest supporting structure, (ii) monolith structure of driver seat and (iii) cantilever as 3D structure for assembling and positioning of driver seat in electric vehicle. To produce these demonstrators, the developed technologies and materials have been used. The demontrators were produced as multi material structures based on polymeric matrices reinforced by textile inserts which fulfill the criteria of functionality, mechanical strength, fire and thermal resistance. Requirements of mechanical strength and stiffness of these elements of electric mobiles were demonstrated as most important during selection of the relevant technology process and proper adaptation of textile reinforces into the composite structure. Also requirements of fire and thermal resistant of demonstrators should be taken with implementation some special additives into the polymeric matrix.

Project Conclusion

The project focuses on the development of environment-friendly advanced materials and their production processes which will be utilised to produce selected generic components for a Lightweight Electric Low-emission concept Vehicle (LEV). The major achievements of the project include:

1. Development of new lightweight materials, i.e. ultra-high strength Al alloys with ultrafine grained structure, novel natural fiber composites and modified polyurethane foams.
2. Adopting existing technologies to new materials production, i.e. severe plastic deformation technologies to produce ultra-high strength Al alloys, LFI and braiding technology to produce natural fiber composites.
3. Demonstrators of three components for LEV have been designed and manufactured using developed materials and technologies, i.e. armrest with or without armrest supporting structure, monolith structure of driver seat and cantilever as 3D structure for assembling and positioning of driver seat.

NOTES

Electromobility+