Karlsruhe Institute of Technology

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# MeRegio Mobil

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## ICT for Electromobility

ICT FOR ELECTROMOBILITY

As part of its second economic stimulus package, the Federal Ministry for Economics and Technology (BMWi) carried out the technology competition "ICT (Information and Communication Technology) for Electromobility[1]". The goal of this initiative of the Federal Government is the development and evaluation of ICT-based key technologies and services for the integration of electric mobility into the existing energy and transportation system.

For instance, intelligent ICT can enable electric vehicles to act as mobile electrical storage systems with the ability to absorb excessive energy coming from wind farms and solar panels in the grid and, vice versa, feed the stored energy back into the grid when necessary.

MeRegioMobil has been chosen as one of the winning consortia. It aims at developing and building up the infrastructure for a large number of electric vehicle users in Baden-Wuerttemberg in 2010 and putting it to a regional field test by the end of 2011.

Along with the installation of intelligent battery-charging stations and the usage of batteries as dynamic buffer storage systems in the power grid, the project additionally comprises the development of new business models and incentive systems as well as the conception of novel location-based telematics services.

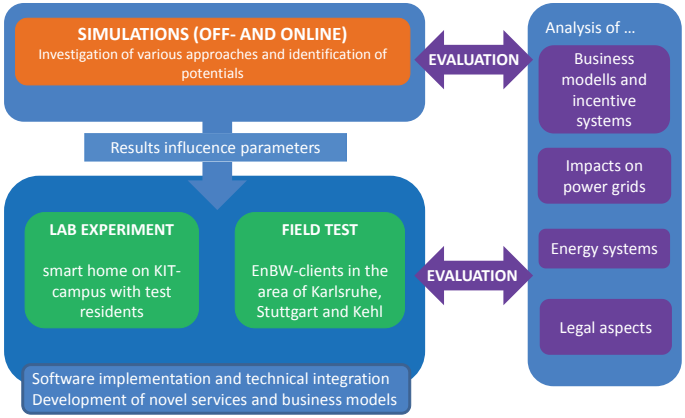
Prior to the field test and accompanying it later on, a research and demonstration laboratory has been built up and is operated by the KIT. The focus of this lab is to implement an adaptive cooperation of intelligent appliances for reasons of efficient load control while integrating both decentralized power plants and electric vehicles which are able to feed back energy stored in their batteries into the grid. Supplementary simulation scenarios will provide an opportunity to investigate scaling effects.

[1] The terms „electromobility" and „electric mobility" are used synonymously in this text.

# THE PROJECT

## Structure of the Project

The MeRegioMobil project is subdivided into several working areas:



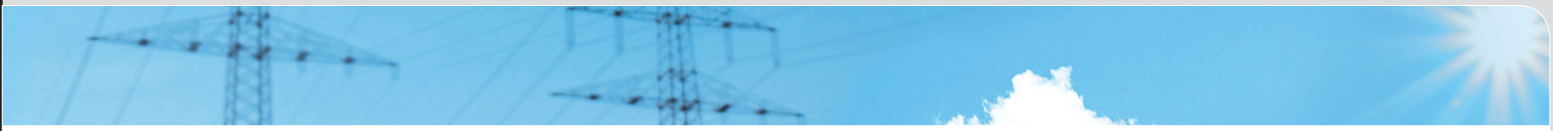

### Research and concept development of a market and service platform

Along with technical difficulties, the incorporation of a large number of mobile storage systems causes various operational challenges such as the the intelligent usage of storage systems.

As part of the predecessor project "eCar@Home", conducted by the KIT in cooperation with the EnBW, promising scenarios concerning the integration of electric vehicles into a system consisting of consumers and decentralized power plants have already been identified and will be further elaborated and evaluated within the scope of this project.

The e-energy marketplace developed in the research project MeRegio[1] allows for the investigation of further innovative business and pricing models. These are sought to facilitate the implementation of load profile smoothing within low-voltage distribution networks by the integration of electric vehicles.

[1] See page 40 for further details.



A cooperative dynamic mobility planning promises considerably larger savings compared to a purely individual route planning, because accumulated effects regarding the capacity utilization of power grids can be taken into consideration. Both the communication of, with, and between vehicles, also known as Car2X-communication, and the integration of vehicles into the power grid as mobile energy storage systems (vehicle-to-grid, V2G) facilitate each other, which in turn positively influences cooperative dynamic mobility planning.

The sensor and cellular network data, so-called "floating car data", arising from the Car2X-communication, can be applied for the power supply planning.

The implementation of the electric mobility services presupposes different players, such as energy suppliers, consumers, and tradesmen, to communicate with one another. The interoperability within the overall system represents a real challenge, due to the fact that decentralization in the energy market implies increasing heterogeneity.

In this respect, the key to interoperability is an intelligent communication by means of ontologies on the level of semantics interpretable by machines, the latter providing an opportunity for the context of the exchanged data to be formalized.

Due to high dynamics in the energy market, especially in the context of electric mobility and energy roaming, the application of globally predefined ontologies is only possible within limits. Due to this fact, solutions will be developed that will facilitate new players' ad hoc integration, with their schemata being integrated into or mapped onto existing ontologies.

The integration will be ideally carried out in a fully automatic way; however, there must be guaranties available as to the correctness of the mappings. The scalability of the approach is an important factor as well, in order to meet the fast-growing number of players in the market of the future.

## Laboratory experiment

The integration of an electric vehicle into a smart home environment will initially take place within a research and demonstration laboratory in order to facilitate the testing of the aspired aspects in a realistic setting.

The laboratory is made up of a prefabricated house with a floor area of about 60 $m^2$ and represents a prototype for a smart home. It comprises all typical elements that are divided into the following groups: decentralized power plants, consumer loads, and energy storage systems.

Among other energy sources, photovoltaic panels as well as a micro combined heat and power plant will act as power suppliers. Typical appliances such as a washing machine, a dish washer, a refrigerator etc. are supposed to serve as consumer loads. The electric appliances employed in the project represent both conventional commercially available devices as well as intelligent and therefore controllable ones. A battery-charging station will also be integrated into this smart home, so that electric vehicles can be incorporated into the smart home both in forms of consumer loads and electrical storage systems.

The system to be operated, referred to in this context as SuOC (system under observation and control), comprises both the laboratory and the vehicle integrated into it. A modular development and implementation of an observer-controller architecture will ensure the governance of an overall system which is intended to yield a self-organizing, reliable, adaptive, and robust behavior.

The devices will be observed and controlled by means of a higher management layer, the observer-controller layer. Applying significant system-specific specifications and target figures, the observer analyses the system behavior and then passes its aggregated figures, characterizing the current state, on to the controller.

Using the results delivered by the observer, the controller has to decide whether an intervention is required or not (for instance, switching a consumer on or off, charging the vehicle's battery or feeding electrical energy back into the grid).

Coupled with various kinds of machine learning, the process described above results in a powerful control loop for an optimized and harmonized load profile of the smart home with the integration of a mobile storage system, i.e. the battery of the electric vehicle within the demonstration laboratory.

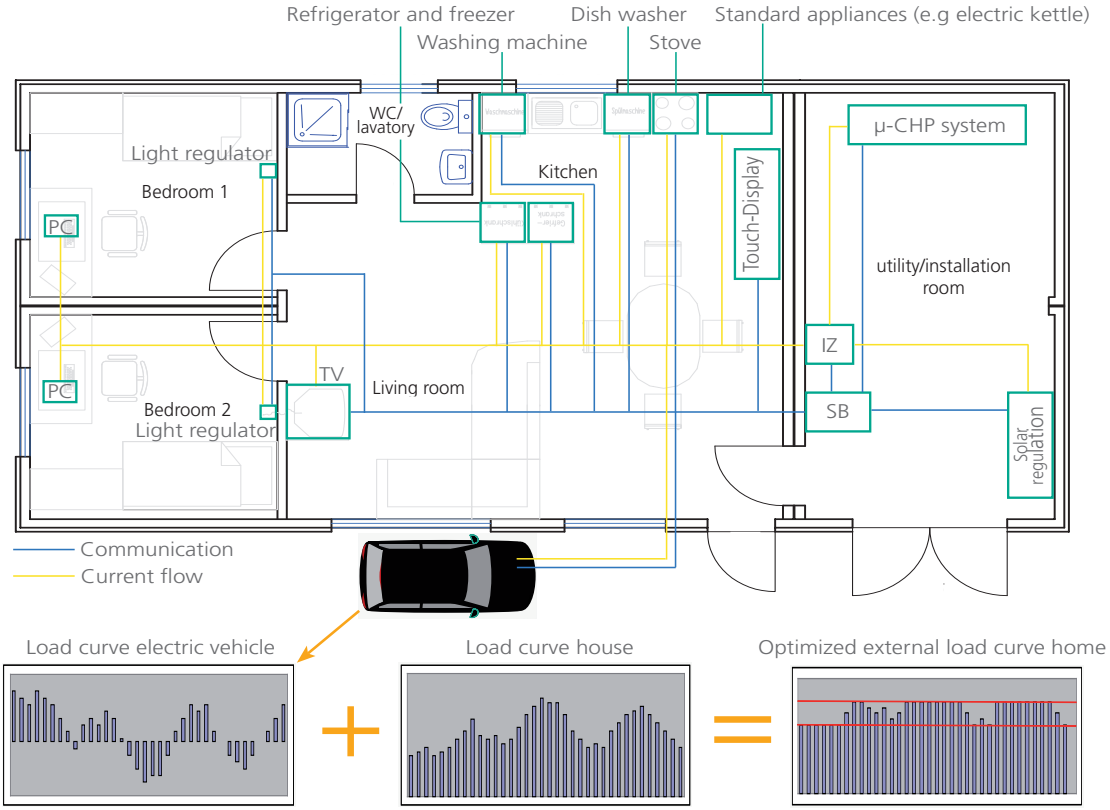
An additional sensor system and accompanying measurement and control technology will be integrated for the detailed investigation of grid states, giving furthermore an opportunity to test intelligent household control processes as well as to simulate specific states of the grid.

Different scenarios concerning, for example, the design of various time-dependent tariffs will give insights into how an electric vehicle can be integrated into the household. In particular, online simulations are supposed to serve this purpose, with resulting measurement data providing a basis for further analyses and simulations.

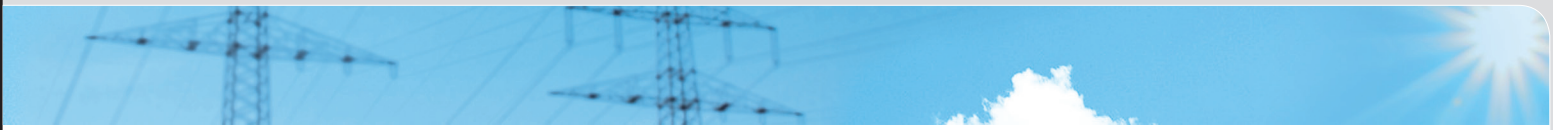
A further subject of this study is to investigate the optimal way how energy produced by decentralized renewable sources can be used optimally in combination with electric vehicles that act as electrical storage systems.

As a buffer, the battery can store surplus renewable energy during off-peak hours and feed the stored electrical energy back into the grid when needed in order to reduce externally visible peak loads.

The project realization will require the development of the corresponding electrotechnical and software engineering components together with their adjustment to the model tests. Further developments that cannot be launched in the course of the field test during the project runtime will be demon-strated as part of the laboratory experiment.




Layout of the research and demonstration laboratory



## Simulations

As a part of the MeRegioMobil project, simulation components will be developed and employed, so that a large variety of concepts elaborated during the project runtime can be closely examined and analyzed as well as their potentials identified.

Based on these results, different concepts can be singled out and tested during the laboratory or field test, with the results being thus verified. In addition to this, alternative approaches can be analyzed in a simple and quick manner.

The simulation scenarios comprise analyses of consumption behavior, business models, underlying information and communication technology (ICT system), long-term consequences as well as effects arising from the large-scale implementation of the developed concepts. The simulations will be carried out in coordination with the real experiments, parameters of the simulation components being constantly adjusted and improved in accordance with the data gained from the laboratory and field test.

Due to the fact that not all concepts and methods developed within the framework of the project can be evaluated on real participants during the project runtime, methods and concepts will be simulated already during the start-up period of the field test (offline simulation). This will allow to make a pre-selection for the field test as well as to conduct further studies or analyses of extreme situations. The scenarios that are to be investigated include power outages, extreme weather conditions, specific price incentives or a larger share of electrical energy fed back into the grid.

In contrast to this, specific online simulations make it possible to study scenarios with participation of real players, such as, for example, a virtual increase in the number of individuals participating (scalability of the concepts) as well as virtual experiments with bottleneck situations and subsequent analysis of real participants' reaction.

## Evaluations

As a part of the pilot experiment „eCar@Home", the requirements for the components used in a fleet test were elaborated by the KIT and EnBW. In addition to this, initial business models for the market integration of electric vehicles were developed and a laboratory was constructed with the aim to test these models.

### Analysis and evaluation of business models and incentive systems

The feasibility of potential business models will be determined by the behavior of various groups of users as well as the availability and control possibilities of different mobile battery capacities.

The objective is therefore to investigate, to what extent potentials concerning load shifting and feeding back electrical energy can be realized with various business models and ICT-based control options in real settings. By doing so, the focus will be on the integration of electric vehicles - acting as mobile storage units - into an overall system that consists of central and decentralized battery-charging stations and power plants as well as end customers. Thereby, various forms of load management and intelligent control will thereby be taken into consideration.

To which extent the potential of electric vehicles regarding the increase of efficiency can actually be implemented depends, in the first line, on the penetration level of these vehicles. Therefore, user acceptance of different concepts concerning integration of electric vehicles into the energy system as well as acceptance of controllable appliances are to be investigated within the scope of the project. By doing so, attention will be paid to how various groups of customers generally accept electric vehicles, plug-in hybrids, electric motorcycles and scooters and how they respond to different business and pricing models.

In addition to this, it is to investigate how various customer groups are willing to pay for different designs and forms of electric vehicles.

Additional studies will be dealing with the aspect of feeding back electrical energy as well as with both switchable and non-switchable battery concepts that are to be contrasted with each other.

Furthermore, the impact of business models and incentive systems will be analyzed, with their costs and benefits identified. Particular attention will be paid to the influence exerted on the load curves of end customers within the laboratory and in the real settings, which will help to determine the potentials for the load shifting and back-feeding of electrical energy.

### Analysis of the impact on the power grid

It is essential for a rapid spread of electric vehicles to provide households and, particularly, publicly available places with battery-charging stations. The accumulation of such central charging points constitutes completely different challenges for the grid as compared to those brought about by spatially distributed charging stations, a problem, which demands an investigation of the power network reinforcement needed at these points. At the same time, the central location of such stations provides special possibilities for using such charging points. It is, for example, to investigate, to what extent such units are able to guarantee system services such as balancing energy or isolated network power supply in case of large quantities of storage systems being available and linked to relatively strong grid connections.

In addition, it is to be considered what impact a large-scale application of electric vehicles has on the electricity distribution network. The analysis will show to what degree the existing network infrastructure can be stressed additionally by electric vehicles connected to it, so that network facilities will not be overstressed, and it will show, what unwanted effects power converters produce on the voltage quality in the grid.

These technical analyses will be supplemented by economic ones. It is, for example, to investigate, how the introduction of different business models impacts the network infrastructure and network control within the test region.

In particular, additional expenses that arise from different concepts and serve the integration of electric vehicles into the distribution grid are to be compared with resulting benefits, such as for example reduced demand for balancing energy.

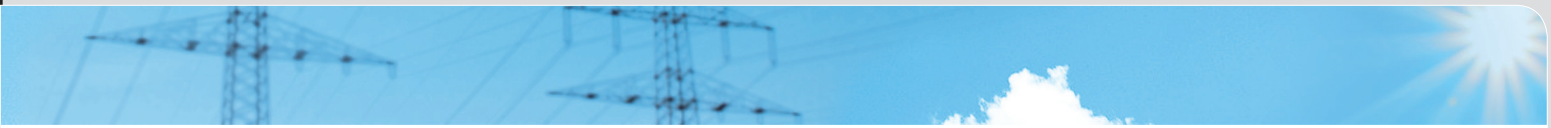
It is furthermore to be investigated whether controllable appliances (washing machines, dish washers, freezers, heating and cooling devices) contribute to the load harmonization on the local network level (400-V-level). Another significant task is to explore the positive effects regarding load harmonization which may result from the combined usage of intelligent appliances and of electric vehicles.

### Energy system analytical considerations

The integration of a large number of electric vehicles influences the regional development, and, in particular, such interdependent components as battery-charging stations, parking space, energy system connection and potential for integration of decentralized renewable energy plants.

These infrastructure dependencies are on the one hand to be evaluated based on the experiences gained in the model region and on the other hand subject to assessment from economic and ecological points of view.

Subsequently, the insights gained from this assessment will be experimentally applied to other regions of Germany, in order to estimate the potential for a sustainable integration of electric mobility into the energy system.
This investigation will be dealing with the differences inherent to various types of regions and energy systems (such as urban and rural ones) and will handle such aspects as structural adjustment of the electricity network or impacts on further decentralized storage systems, with final data being analyzed and discussed from both economic and ecological points of view.



### Legal analyses

The option of charging one's electric vehicle everywhere in the future possible due to ICT and announced within the framework of the project raises a series of generic legal issues, e.g. concerning data privacy in case of possible movement profiling and, particularly, in respect of evidence security.

Besides, it is to be examined whether the energy economics regulatory framework possibly needs to be adjusted according to required formal and material principles. The regulation perspective mentioned above should be evaluated as well and, if necessary, adjusted to the conditions when electric vehicles are integrated into the energy system acting as mobile electricity storage systems.

In addition, it is of vital importance to study regulatory guidelines and mechanisms in the field of standardization of the required communication protocols that define ICT infrastructure.

Experts will investigate the fields of law germane in this respect on the basis of applicable guidelines stipulated by law, considering such relevant individual aspects as, for example, legal and evidence security, data privacy, liabilities and taking into account formal standards inherent to the legal regulations.

If these results show that for achieving aspired results legislatory action is required, corresponding concepts for changing the regulatory framework will be developed.

### Field test

The technical and economic concepts validated during the laboratory test and proved to be feasible within the project run time will be tested within the scope of a field test planned on a large scale in the area of Karlsruhe, Stuttgart, and Kehl.

The study of cross-border roaming will be carried out in cooperation with "Electricité de Strasbourg" (Strasbourg Power Company). The objective of the field test is to construct and test the technical infrastructure as well as novel value-added services that will support energy and storage management.

## Objectives

The major goal of the MeRegioMobil research project is to efficiently integrate mobile electrical storage units in vehicles into the existing energy system by means of developing innovative information and communication technologies and their implementation in conclusive overall concepts.

### Objectives of the field „Conception of services, business models, and incentive systems“

- Design of business models and incentive systems (among others pricing models)
- Fast identification of energy-efficient routes taking into consideration the characteristics of electric vehicles
- Conception of an identity management system that as a basic service represents a significant requirement for higher-level services, such as e.g. identification of the vehicle/driver at every charging point or billing processes on the energy provider's side.

### Objectives of the laboratory experiments

- Construction and extension of a research and demonstration laboratory for the integration of electric vehicles into a smart home
- Testing of various pricing models and control options
- Development of methods for the adaptive cooperation among laboratorial components

### Objectives of simulations

- Investigation and development of intelligent charging strategies
- Evaluation of the integration potential for renewable energies considering the use of electric vehicles
- Evaluation of alternative software architectures as well as analysis of the robustness and scalability inherent to the prototype ICT-systems
- Development and testing of intelligent (co-operating) components in the smart home with intelligent integration of electric vehicles

- Investigations of system perturbations
- Analysis and estimation of ways of fast battery charging

## Objectives of the evaluation

- Determination of the acceptance of business and pricing models developed regarding different groups of users
- Evaluation of business models and incentive systems (e.g. various pricing models), regarding different factors, such as costs, load shifting potential, and environmental impact
- Evaluation of costs and benefits resulting from the usage of switchable battery concepts
- Evaluation of the impacts electric mobility has on the power grid
- Techno-economic and environmental analysis and evaluation of the integration of electric mobility into regional power systems
- Legal analysis with special emphasis on the options for supplying balancing energy as well as for inter-vehicle communication

## Unique Features of the Project

### Feeding back electrical energy into the smart home

The integration of an electric vehicle into a smart home offers a new possibility in the future to use the vehicle as an energy storage system, able to feed electrical energy back into the grid, for instance, in order to supply required balancing energy and to minimize or avoid the number of bottleneck situations.

### Preparation and forming of international standards

The applied protocols and techniques conform to the standards developed within the framework of the ISO/IEC.

### High involvement of the automotive industry and a wide range of vehicles

Diverse operation scenarios of electric mobility can be investigated due to the involvement of two large automotive manufacturers with a wide range of vehicles; pioneering concepts are to be worked out together with the automotive industry.

### Interoperability through roaming

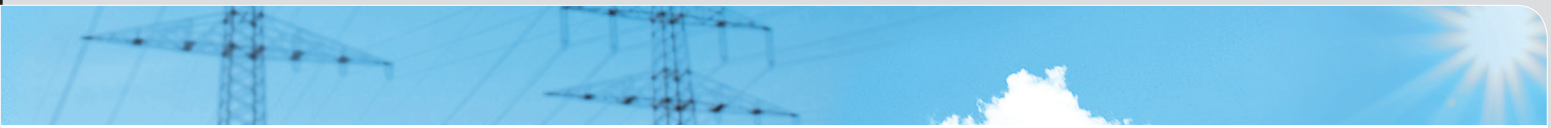
Innovative and interoperable concepts will be applied which will enable the client, on one side, to choose a charging station of any energy provider and, on the other side, to use his own contractual energy provider for billing purposes (roaming).

### Load management and incorporating navigation data (GPS) in the analysis of usage profiles

The behavior of a single driver can, for example, help predict the required state of charge of the vehicle, with GPS navigation information being used for the optimization process.

### Novel telematics services

The process of integrating electric mobility requires appropriate communication protocols, protection of the transmitted data, guarantee of their authenticity and the definition of communication standards.



### Testing of innovative and visionary scenarios in the demonstration laboratory

Electric vehicles will be integrated into a smart home, with this scenario providing initial insights into how an electric vehicle can be integrated intelligently into the household.

### Simulation studies to supplement fleet tests and laboratory experiments

By means of the integration of simulation components into the real model area, scenarios with real participants, which currently cannot be implemented in detail, can be investigated.

### Legal analysis

It is of crucial importance to elaborate a legal framework for sensitive data, focusing on data protection and privacy, liability as well as legal and evidence security.

## Role of the Project within KIT Research

The MeRegioMobil project is among the prominent research and development projects of the KIT focus COMMputation, which addresses the inherent interrelationship between "communication" and "computation" in increasingly complex and manifold interconnected technical applications.

Due to the strong orientation on application, the project is furthermore integrated into the KIT Energy Center as well as into the KIT focus "Mobility Systems" that, together with the consortium project for the development of batteries and the "Project House e-drive", is a prime example proving the all-embracing competence of the KIT in the field of electric mobility.

Karlsruhe Institute of Technology

# CONSORTIUM

## Industry and Science

The project consortium consists of eight partners that bring in their competence from complementary fields. The industrial partners Adam Opel GmbH, Daimler AG, Robert Bosch GmbH, SAP AG as well as the Stadtwerke Karlsruhe (Karlsruhe's municipal utility) cooperate with the research institutions Fraunhofer Institute for Systems and Innovation Research (ISI) and Karlsruhe Institute of Technology (KIT). The consortium is guided by the project coordinator EnBW Energie Baden-Württemberg AG.

The KIT is represented by a total of 11 chairs from 3 departments. Therefore, the interdisciplinary skills and perspectives enable it to bring in the wide-ranging competence in the fields of applied and theoretical informatics, software design, law, energy economics, electric energy systems, high voltage technology, electrical engineering as well as telematics and information management.

## A Cooperation of Strong Partners

EnBW

BOSCH
Technik fürs Leben

DAIMLER

Fraunhofer
ISI

KIT
Karlsruhe Institute of Technology

Wir leben Autos.

SAP

STADTWERKE KARLSRUHE
VERSORGUNG MIT VERANTWORTUNG

# INVOLVED CHAIRS AT THE KIT

## Research Activities

### Institute of Applied Informatics and Formal Description Methods (AIFB) - Efficient Algorithms and Organic Computing

The central topic of the research group „Efficient Algorithms“ is the development of methods for the efficient use of modern computer architectures for planning, improving, and executing information, business and manufacturing processes. Special attention is paid to multiply interconnected, adaptive systems which are capable to benefit from self-organisation. Their controllability and efficient use is a major objective of the Organic Computing Initiative which is strongly influenced by this group due to the task of coordinating the priority program of the German Research Foundation on Organic Computing (SPP 1183).

Besides fundamental research on architectures and methods of organic computing, the focus is on concrete technical application scenarios in urban traffic, in service-oriented architectures and - based on previous work in the project SESAM - in smart energy systems, in particular in the projects MeRegio and MeRegioMobil . This is complemented by research on nature-inspired methods in optimization, in particular for multi-objective and dynamically changing problem settings.

Within the KIT our research belongs to the competence area „Information, Communication, Organisation“. Due to the profile of its research projects the group is an integral part of the KIT-Focus COMMputation, addressing the inherent combination of COMMunication and COMputation in current and future smart systems. Additionally, due to the projects on „smart energy“ and „electric mobility“ the chair is an active part of the KIT-center Energy and the KIT-focus Mobility Systems.

### Contribution to MeRegioMobil

The research group of Prof. Schmeck initially takes care of the conception and supervision of the construction of the research and demonstration laboratory - the prototype of a smart home. Amongst others, this conceptual phase comprises the requirements planning and coordination of various components, e.g. the infrastructure and location of the mobile

home, the chosen power plants (photovoltaic panels and combined heat and power plant), the normal as well as intelligent (communication-enabled and controllable) applicances, the charging station for electric vehicles and finally the information facilities for visitors.
It is aspired to realize a laboratory with an adaptive and self-organizing cooperation of intelligent applicances for the purpose of load shifting. The central component which will allow for such a cooperative behavior is the so called control box (SB), needing appropriate interfaces to monitor and control the system (smart home and electric vehicle) in the framework of an observer-controller-architecture. The field of Organic Computing will hereby help us to develop methods which will procure the optimization of the load behavior.
Furthermore, simulation scenarios will be developed in order to analyze scaling effects (e.g. one million electric vehicles, a city district with smart homes). The parameters of the simulations scenarios will constantly be adapted and improved according to the data gained from laboratory and field tests.

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## Institute of Applied Informatics and Formal Description Methods (AIFB) - Knowledge Management

Central theme of the Knowledge Management Group of Prof. Dr. Rudi Studer is research in the area of semantic technologies. The focus of the group is on the development of methods and infrastructure for intelligent ontology-based management of distributed data sources and services, as well as intelligent knowledge management applications.

The group can draw on extensive expertise acquired over years and is one of the leading groups in the field worldwide. The group conducts semantic technology research in the context of a number of prominent projects, for example the European research projects „ACTIVE - Enabling the Knowledge-Powered Enterprise“, „NEON - Lifecycle Support for Networked Ontologies“ and „X-Media - Knowledge Sharing and Reuse across Media“, and has been actively involved in the standardisation effort of W3C‘s Web Ontology Language (OWL). Ontologies have been already applied in several national projects (funded by BMBF and DFG) to semantically describe and process electronic services, similar to what is planned for MeRegioMobil.

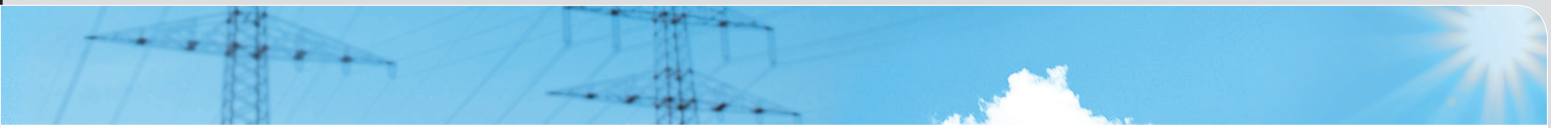
The research group actively supports the transfer of research output to partners in industry and academia in direct cooperation with the Forschungszentrum Informatik (FZI) and the Karlsruhe Service Research Institute (KSRI). The group has taken a leading role in establishing the German branch of the Semantic Technology Institute (STI), a well-connected organisation for technology transfer.

## Contribution to MeRegioMobil

The knowledge management research group evaluates the use of ontologies and Semantic Web languages for the development of a reference model covering an electric vehicle infrastructure.

The reference model aims at identifying and defining important concepts in such an infrastructure, and may be used as a basis for communication between project partners as well as a foundation for software systems.

Semantic technologies such as the Semantic MediaWiki, an



extension of the well-known Wikipedia software, enable collaborative preparation of the reference model.

Furthermore, using semantic technologies, the reference model can be encoded in a machine-readable manner. Therefore, in a second step, a reasoner can automatically check and complement the model with inferred knowledge.

In addition, semantically enhanced descriptions of concepts and services in the reference model provide a suitable basis for a software and data integration infrastructure for MeRegioMobil.

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## Institute of Telematics - Decentralized Systems and Network Services Research (DSN)

The research group of Prof. Dr. Hannes Hartenstein (Decentralized Systems and Network Services) designs, analyzes and optimizes mobile and virtual computer networks as well as federated service-oriented architectures.

In the field of mobile networks the group mainly focuses on inter-vehicle communication (BMBF projects FleetNet, NoW: Network on Wheels, EU-FP7 project PRE-DRIVE C2X). Content-based addressing plays a major role within such networks as geographical areas have to be used as destinations and the end-to-end principle does mostly not apply.

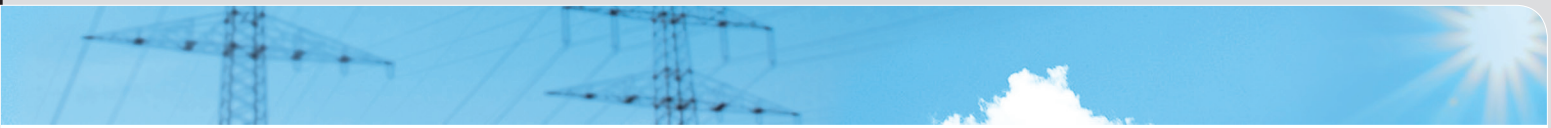
In the field of virtual networks the group analyzed autonomous communication infrastructures in the scope of the SESAM project. Simulations as well as testbeds were conducted to evaluate scalability, robustness and practicability. Currently, advanced aspects in this research field are being explored in the BSI-project KAI.

In the context of service-oriented architectures the group's interests include the challenge of providing an identity management as a basic service for higher level services in federated systems. This topic is addressed by the KIM project of the Karlsruhe Institute of Technology. Methodically, the group holds specialized expertise in the fields of simulations and analytical evaluations respectively as well as with building and analyzing prototypes and testbeds.

## Contribution to MeRegioMobil

The primary interests of the DSN research group within the project MeRegioMobil are in the context of vehicular communication and identity management that are both essential for the realization of the corresponding ICT services and their underlying architecture. In particular, the impact of vehicular communication on dynamic route planning and traffic efficiency in the context of electric vehicles is evaluated.

Furthermore, a privacy-compliant identity and access management for charging stations will be designed. Moreover, the robustness of the envisioned ICT architecture in the event



of exceptional situations like flash crowds will be analyzed and optimized. Methodically, the group of Prof. Hartenstein focuses on analytic evaluations as well as simulation studies.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## Electro-technical Institute (ETI)

The Electro-technical Institute is one of thirteen institutes of the Department of Electrical Engineering and Information Technology. The focus of this institute is on electrical drives and power electronics.

Current areas of research are the highly dynamic control of permanently magnetized synchronous machines, new inverter topologies and control modes for drive inverters or line power converters. The inverter technology is also used for our research on short time energy storage systems and uninterrupted power supply units.

The optimized usage of regenerative energy sources like wind energy or photovoltaics is one further topic of our work. The institute is equipped with a 4kW solar generator on the roof and the ability to build its own power supply system for measurements and tests on this topic.
As a result of previous work, the parking area of the institute is equipped with a power socket that allows to charge electrical vehicles.

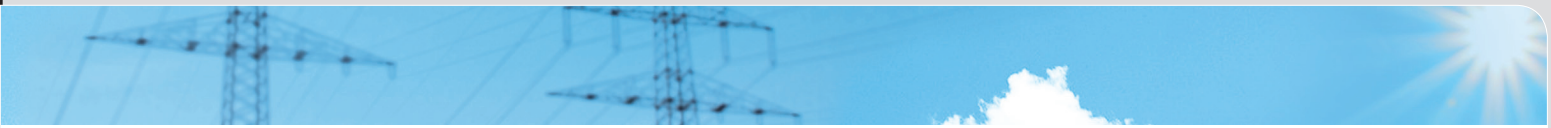
## Contribution to MeRegioMobil

Recharging of electric vehicles may decrease the power quality of the power grid. This is caused by nonsinusoidal waveforms due to the utilized topology of power electronics.

Standard charging procedures of one unit, e.g. reaching the power from 2kW to 10kW, do not affect the power grid noticeable. But in the case of charging a dozen electric vehicles in a street of houses simultaneously, the local power grid could be affected in a negative manner.

Similar undesirable interferences could also be caused by the power consumption of fast recharging electric vehicles with up to 50kW. Many electrical devices deteriorate untimely or operate inaccurate caused by disturbances of the power grid voltage.

A reliable power supply is part of our economic living nowadays. Therefore, the task of the working group is to calculate which effects are induced by charging a huge amount of electric vehicles through the power grid. To certify the calculations, the simulation results will be compared to the



measured results of the demonstration unit.

The results of this research will be used to develop next generation charging devices. They will minimize the negative impact on the power grid and will be capable to even improve the power quality.

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## Institute of Electric Energy Systems and High Voltage Technology (IEH)

The research efforts of the Institute of Electric Energy Systems and High Voltage Technology (IEH) can be divided into three main areas: Modern power electronic based Energy Transmission Systems, such as Flexible AC Transmission Systems (FACTS), and High Voltage DC Transmission Systems are specified and optimised in computer models. Further, new strategies for increasing capacity of transmission lines are developed by improving FACTS topologies and control systems.

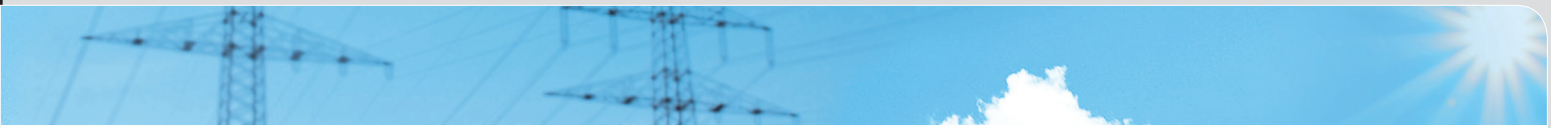
Another research area is the „diagnostics of power grid equipment", which is dedicated to the development of new measure und analysis approaches for state estimation and fault prediction of transformers. For in situ testing of power grid equipment, new high-voltage test systems based on power electronics are developed.

The third area of interest is the development of control strategies for a grid with a high fraction of distributed renewable energy sources. The intent is to maintain grid stability, while attaining high grid efficiency. To compensate fluctuating generation behaviour of most renewable energy sources, energy storage options will be necessary in the near future. For that purpose, the IEH also examines the potential of grid supporting Electric Vehicles (EV).

## Contribution to MeRegioMobil

An increasing rate of intermittent, renewable generation in the grid demands storage solutions to sustain grid stability. Electric vehicles could be used to store spare renewable energy in their batteries. The energy should be used to backfeed into the grid, in times of peak load demand.

The integration of electric vehicles into the smart grid is able to contribute to grid quality and to optimise todays power plant efficiency. Therefore, different integration concepts are going to be developed. Electric vehicles will then be able to deliver different grid services, depending on the degree of interaction between car and grid. The concepts are going to



be validated and tested on simulation models from real transmission grids.

The developed methods are going to be used on the equipment available in MeRegioMobil and thus the algorithms developed are going to be tested on real world data. To integrate renewable energy sources and electric vehicles into an intelligent grid, a good estimate of the grid state is mandatory. Hence, one of the main research areas is the development of new grid modelling techniques. With suitable models it is possible to coordinate load and generation and further to guaranty the grid stability even under very high grid demand.

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## Institute for Industrial Production (IIP)

Prof. Fichtner's Chair of Energy Economics at the Institute for Industrial Production (IIP) analyses techno-economic questions along the whole energy supply chain, from primary energy supply, over energy conversion and energy transport to energy distribution and energy use. We provide answers to strategically and environmentally relevant problems. Strategically relevant problems relate to, inter alia, capacity expansion and deployment planning, supply chain optimization and technology assessment. Environmentally relevant problems include the development of emission-mitigation strategies and the evaluation of policy instruments. The main objective of the research group "Transport and Energy" is to determine the impacts of electric vehicles on the energy system.

In recent years Operation Research methods have proved their suitability for our research objectives and for decision support with political and industrial partners. According to the research field we also apply other methods, such as Nodal-Pricing or agent-based simulation models, and interconnect our models, such as energy system models with macroeconomic models. With these tools we deliver answers on different levels of abstraction within the international, national or regional energy system.

## Contribution to MeRegioMobil

In MeRegioMobil, specific agent-based simulation models and energy system models are developed to support the techno-economical analysis of energy- and mass flows. Amongst the most important cases studied are the differentiated evaluation of electricity storage by electric vehicles and their effect on the energy system. Due to the increasing share of the hardly controllable energy supply from renewable energies, one important question in this context is how the energy storage of electric vehicles in the future may contribute to an interference-free satisfaction of the energy demand.

Further focal points are the user specific acceptance analysis, market penetration analysis as well as potential business

areas occurring in the course of the electrification of private passenger road transport. The theoretical knowledge and simulation results are complemented by experiences from a fleet test and from the KIT research and demonstration lab.

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## Institute of Information Systems and Management (IISM)

The research group of Prof. Dr. Christoph Weinhardt (Institute of Information Systems and Management – IISM) analyzes and designs electronic markets for various industries, e.g., finance, energy, logistics, and emission certificates.

Electronic trading platforms are analyzed with regard to their quality of results and appropriateness for the area of application. One of the methods used is the design science approach by implementing prototypes of such systems and then running experiments and simulations on these implementations. The overall approach is called „Market Engineering", which is at the heart of the group's research interest.

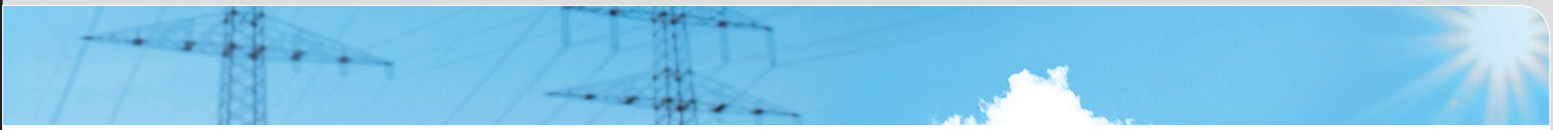
The institute has already participated in a number of research efforts in the energy domain. The institute published a series of research articles on CO2 emission right trading which originated from research projects in cooperation with enterprises in Baden-Württemberg (SET UP) and Luxemburg. (SIMLUX). On the one hand, the research projects aimed at preparing the participating enterprises for the European emission right trading. On the other hand, these projects delivered detailed insides on how different market parameters effect emission trading.

Within the PowerACE research project (in cooperation with the IIP), the institute investigated the dynamics and interchanging effects between power markets and CO2 emission markets based on multi-agent simulations. A third research project was SESAM in which the IISM analyzed the design of different market mechanisms for power trading markets.

## Contribution to MeRegioMobil

The research focus of the Institute of Information Systems and Management (IISM) within the project MeRegioMobil is the economic evaluation of intelligent and automated charging strategies for electric vehicles.

Charging strategies can have different objectives: E.g., minimizing costs for the owner of the electric vehicles, maximizing the use of energy from renewable sources, or optimally ba-



lancing the required charge processes to avoid peak loads.

Within a market, the aforementioned objectives can be combined through a flexible electricity price. The weight of each objective depends on the rules and mechanisms that determine the electricity price.

Further research is planned on discharge strategies that provide services to the grid (Vehicle-to-Grid services, V2G). Such strategies might create new revenue streams for owners of electric vehicles and, thus, reduce the operating costs of currently costly electric vehicles and their batteries.

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## Institute for Information and Business Law (IIWR)

The research group headed by Prof. Dr. Thomas Dreier focuses on those legal issues which are raised by digitization and networking in the information society for the information value chain.

The institute and its researchers are renowned by numerous talks and publications in this field. In particular, the institute currently focuses on issues of regulation of e-commerce, legal enabling and validation of informational value-added services and digital rights management from the perspective which legal rules enable information technology and information services and which hinder the development of useful and desirable information technologies and information services.

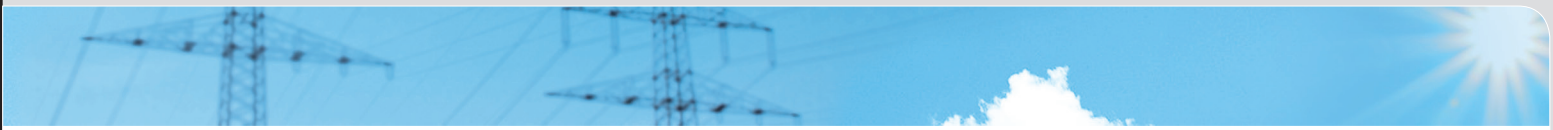
## Contribution to MeRegioMobil

The research group headed by Prof. Dr. Thomas Dreier focuses on the legal issues which will be raised by electric mobility in the future. In particular questions from the Energy Law and the Data Protection Law will be processed.

In the context of Energy Law, the „mobile“ power purchase marks an entirely new process. All existing rules in this field have been created for a stationary power purchase. Here it is a task of the research group to identify need for action by the legislature.

To avoid collecting and storing more data than needed from the electric vehicle users, the research group also works in the field of data protection. Therefore are models developed which correspond to the current privacy laws.

Furthermore, it is investigated whether advanced legal regulations on data protection in the field of Energy Law are needed.



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## Institute for Programme Structures and Data Organisation (IPD)

The Institute for Programme Structures and Data Organisation (IPD) is a member of the Faculty of Informatics that is concerned with an engineering approach to software design in research and teaching.

The domain of the chair for Software Design and Quality (SDQ) includes all topics in the context of systematic construction of software systems.

In particular, this ranges from architectural designs, development methods, tools and environments up to methods for ensuring the quality and economics of programming.

The chair is focused on the close interaction of software architecture, software components, model driven development and software quality.

This involves methods for prediction of software quality attributes, like performance and reliability, on the base of architectural designs.

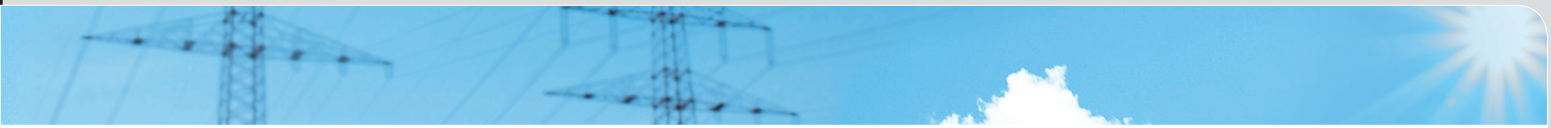
For this purpose methods and tools have been developed within the DFG Palladio Research Project, which are currently being used and refined within the QImPrESS and SLA@SOI EU projects.

## Contribution to MeRegioMobil

The research topic of the IPD Reussner in the context of the MeRegioMobil project are software architectures for the next generation power grid.

The developed software architectures provide for reliable communication between electric vehicles and the power grid. This means the system is available even under heavy load conditions.

The IPD Reussner is using an engineering approach to software design to evaluate the performance of software architectures in a very early software development stage. This approach allows to test mission critical scenarios before having an implemented and running system.



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## Institute for Theoretical Computer Science (ITI)

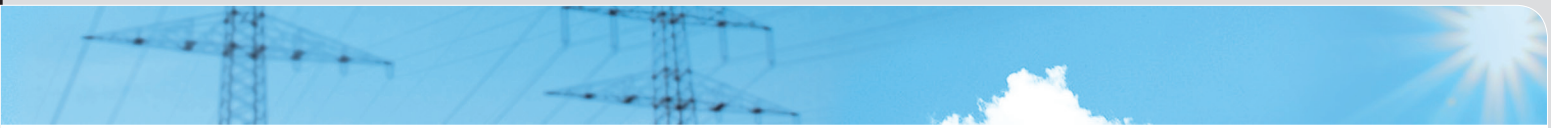
Prof. Peter Sanders' group works in the field of algorithm engineering, an approach in algorithm research aiming at harmonising theory and practice. The researchers are developing basic algorithms to process large amounts of data for example in the areas of parallel processing, external memory and graph algorithms.

In the last years the group has been working on fast and exact route planning in large road netword and is now the world's leading research group in this field. In particular, the planning of optimal routes became up to six magnitudes faster than the ‚textbook algorithm'. These results have won several awards and are increasingly used in commercial products.

Currently, Prof. Sanders' group is engaged in intensive research aiming to create more sophisticated algorithms with time-dependent target functions, dynamic changes to networks (traffic jams, ...), flexible multi-criteria target functions and the simulation of the road users' selfish behaviour.

## Contribution to MeRegioMobil

In the field of energy management for electric vehicles the research group tends to allow a consumption estimation as necessary for intelligent load-management systems.
Due to the strong dependencies of the energy consumption on the driving conditions, a detailed consumption model is needed.
The combination of physical models, traffic related studies and methods of machine learning are expected to allow the computation of not only a good energy consumption prediction, but also energy efficient routes.
Thus, the union of electric mobility and distributed energy storage can be achieved through exact modeling.



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## Institute of Telematics (ITM)

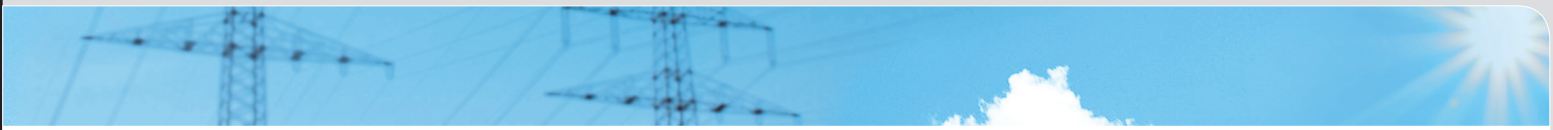
In the context of new services and applications, the team around Prof. Dr. Martina Zitterbart is focussed on the research and the prototype development of novel communication infrastructures for today's as well as the future Internet. Topics range from signalling and management aspects of future networks, over the realization of distributed applications and services by means of overlay and peer to peer based approaches, to communication protocols and applications for wireless sensor networks. Security aspects, the abstract modelling of processes and problems as well as network simulation play a major role in all areas.

The institute shows a high level of expertise acquired through different research projects such as ScaleNet and SpoVNet, funded by the BMBF and the Landesstiftung BW within the BW-FIT program respectively. Both projects offer flexible architectures simplifying the realization of distributed services with respect to quality of service and security constraints. With Oversim, ScaleNet additionally yielded a powerful ICT simulation tool, which, in the meantime, is used, extended and approved by the peer to peer research community world wide. With his junior research group CoMoGrip funded by the Excellence Initiative, Dr. Oliver Waldhorst additionally investigates the use of Grid and P2P techniques within highly heterogeneous networks.

SpoVNet as well as ScaleNet and CoMoGrip is expected to yield significant input for the problems handled in MEREGIO and especially MeRegioMobil.

## Contribution to MeRegioMobil

In MeRegioMobil, the team concentrates on the aspects of data acquisition and data transfer. A special focus is set on communication technology which enables the acquisition of the battery charging status of a large number of electric vehicles. The control of charging and discharging processes in many electric vehicles at the same time also poses a problem for the communication infrastructure and creates a demand for specialized communication tech-



niques. With the help of advanced communication technologies, electric vehicles can be used to store surplus energy resources which then can be used in future shortages.

Centralized approaches to communication concentrate data and control flows in few systems inside the communication network. To remedy the risks of a „single point of failure", self-organizing and decentralized protocols are developed and evaluated.

MeRegioMobil states the problem of communication networks which not only have to scale very well but also have to provide secure communication channels and deal with the inherent mobility of its electric-vehicle participants.

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# MEREGIO

## Minimum Emission Regions

Previous sections already referred to the research project MeRegio which shall now be described in short here in order to give the reader a bit more background information.

MeRegio is a research project scheduled to run for a period of four years (end: September 2012) and aims at establishing a model region in which both energy suppliers and end consumers are equipped with intelligent ICT technology allowing them to use and supply energy in a preferably efficient way.

The creation of a variable tariff for electrical energy is sought to encourage the participants in the model region to deal with the valuable resource energy as diligent as possible.

Furthermore, a certification program will be developed within the scope of this project, whose purpose is to publicly attest a region its efficient handling of energy the same way it is already done nowadays with certain appliances.

Consortium leader in this project is the EnBW Energie-Baden-Württemberg AG, further partners are ABB, IBM, SAP and Systemplan. The Karlsruhe Institute of Technology (KIT) is involved with its chairs AIFB, IIP, IISM, ITM and ZAR.

### Linking energy in an intelligent way

MeRegio aims at using energy in an intelligent manner, enhancing energy efficiency and reducing carbon dioxide emissions. To reach all these ambitious goals, both central and decentralized power plants shall be linked together and enabled to communicate with each other. The permanent electronic data exchange guarantees that electricity is at all times produced, fed in and used when it is needed („energy on demand"). Particularly, regional disparities in the energy supply can be taken into consideration for the first time ever.

Another advantage of intelligently linked energy: Central and decentralized power plants can be operated to its optimal capacity, thus saving expensive balancing power for adjustments to peak loads.

The intelligent interconnection at home encompasses the communication between electrical devices and appliances with the central system, thus linking them to a dynamic tariff. They realize at which times the price for electricity is low. Local optimization implies as well that surplus eletrical energy (e.g. produced by a solar power plant) can be stored directly at home, for example in an electric vehicle or a stationary storage system.

The short transmission paths of the energy supply reduces energy losses and preserves the power grids. A further optimization process takes place on a regional level. It is to be tested if the scarce supply of renewable energies - which is tightly coupled with a price signal - affects the behavior of the end consumers.

MeRegio is especially sought to advance the expansion of renewable energies such as photo voltaic, biogas, wind and solar power.

Further information can be found under:
**http://meregio.forschung.kit.edu**

MeRegio

## Consortiums Partners in MeRegio

ABB

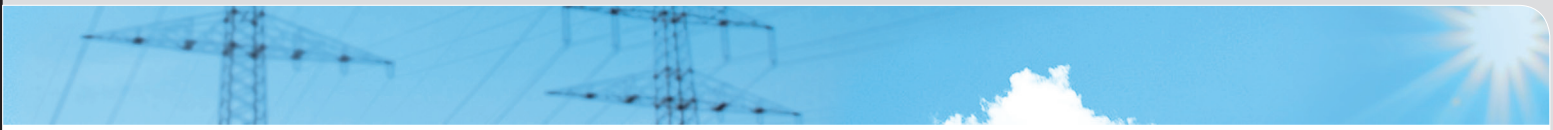
EnBW

IBM

KIT
Karlsruhe Institute of Technology

SAP

systemplan
ENGINEERING

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