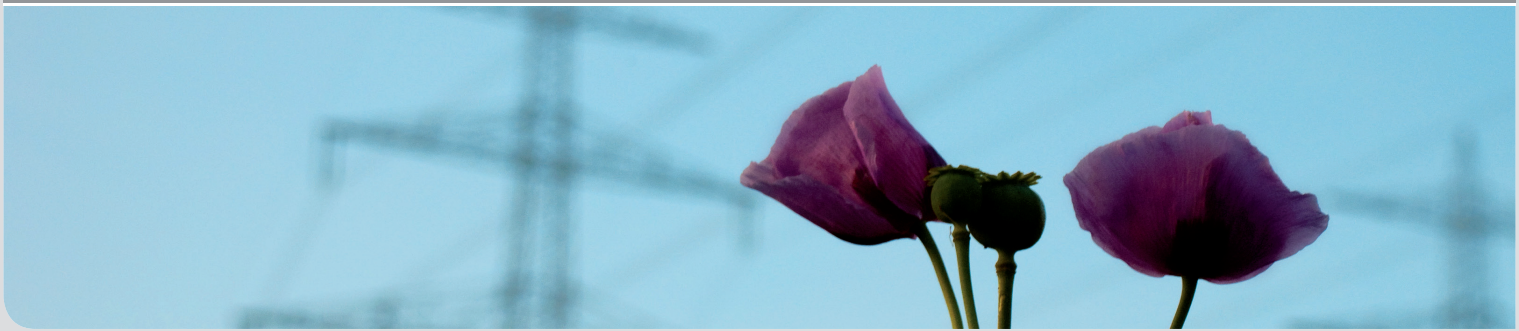
Karlsruhe Institute of Technology

MeRegio

Minimum Emission Regions



KIT – University of the State of Baden-Wuerttemberg and National Research Center of the Helmholtz Association

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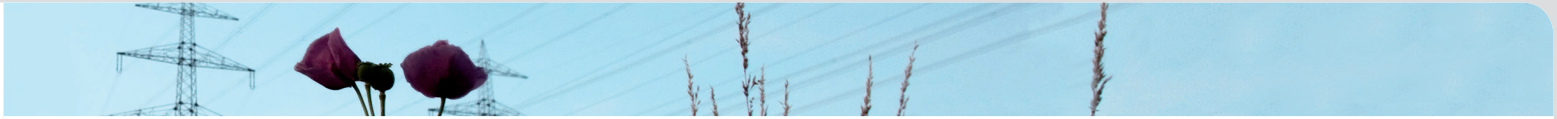


MeRegio

Minimum Emission Regions

Today, climate change, rapidly increasing energy demand, and the depletion of fossil energy resources are attracting major public attention. As a response to these challenges, increasingly efficient power supply systems facilitiating the integration of renewable energies have to be developed.

MeRegio will serve the purposes of intelligent energy usage, increasing energy efficiency, and a reducing greenhouse gas emissions. By means of centralized and decentralized network technologies, power plants can communicate with each other, such that electric power will always be produced and used on demand. For the first time, regional differences of electricity supply will be taken into account.

In this context, the title of the project is "Minimum Emission Regions". The term "Minimum Emission Regions" means regions, whose power supply systems are optimized with regard to their greenhouse gas emissions in due consideration of economic efficiency and security of supply. The project is supported by the German Federal Ministry of Economics and Technology (E-Energy MEREGIO – Minimum Emission Regions, grant 01ME08001A).

E-Energy

ICT-based Energy System of the Future

Electricity is the backbone of our economy and society. To secure an economically efficient and environmentally compatible supply of power in the future, it is essential to optimize the generation, distribution, and consumption of electric energy. Modern information and communication technologies (ICT) allow for the operation of intelligent energy systems that efficiently use all resources available and optimize the entire power supply system.

E-Energy Funding Program

"E-Energy – ICT-based Energy System of the Future" is a funding program of the German Federal Ministry of Economics and Technology (BMWi) in interministerial partnership with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the primary goal being to increase the efficiency, security, and environmental compatibility of power supply.

The abbreviation "E-Energy" stands for electronic, efficient, or enhanced energy, comprehensive digital networking and computer-based control and monitoring of the entire power supply system. Initiatives and activities in this field are summarized by the term "Smart Grids".

The overall goal of the program is the development of efficient energy systems. Furthermore, the E-Energy project activities help finding the balance between weather-dependent power generation and fluctuating power demand.

The MeRegio project is one of the winners of an E-Energy technology competition along with five other model regions. The model projects selected for funding will develop an "Internet of Energy" that will intelligently control and monitor the electricity system by interconnecting all supply chain members – from generation and transportation to distribution and consumption. The model regions chosen shall develop their concepts to maturity and test their marketability in everyday life until 2012.

Due to itsrelevance to innovation and national economy, "E-Energy" was declared a national beacon project at the IT summit of the Federal Chancellor in December 2006 and 2007.

Supported by:

Federal Ministry
of Economics
and Technology

on the basis of a decision
by the German Bundestag

The Project

Smart Networking of Energy

The major goal of the MeRegio research project is to meet the demand for efficient, decentralized energy systems by intigrating advanced ICT in every part of the electricity chain of values added and thus, considerably enhance energy efficiency.

The core of the project is a marketplace created for the efficient and transparent coordination of energy supply, energy demand, and services, which will be coupled to the technical energy infrastructure by a powerful and lawful information and communication infrastructure. The integrated techno-economic concepts developed will be analyzed in a regional field study in the city of Göppingen and the rural municipality of Freiamt (state of Baden-Württemberg), with about 1000 private and commercial customers participating.

On the one hand, end customers of various groups, such as households or small and medium-sized enterprises, will participate in the field study. On the other hand, different types of decentralized power-generating systems, such as photovoltaic systems, (micro-) combined heat and power plants (CHP), or fuel cells, will be integrated. Advanced automation shall enable the test participants to operate on the energy market and to use novel services, such as energy efficiency or energy management consulting.

The Vision

The MeRegio project is aimed at an intelligent energy usage, increase in energy efficiency, and reduction of greenhouse gas emissions. Expensive energy can be saved during periods of peak demand by optimally utilizing the capacities of power stations and decentralized generation systems.

Intelligent networking continues at home. Household appliances communicate with the energy supplier and determine at what time power consumption is favorable based on customer preferences and a dynamic tariff.

Surplus power (for example, from a photovoltaic system) can be stored directly at home, for example, by an

electric vehicle or a stationary storage system. This also requires time-dependent tariffs.

Thus, the consumer has a clear idea of his consumption and the costs arising. It is up to him to decide whether he wants to buy the power from a central marketplace or produce it with his generator.

As renewable energies, such as solar energy, biogas, wind power, and hydroelectricity, will be promoted, concepts will be developed to economically operate and efficiently integrate such power-generating units in the energy system.

Key Aspects

Smart electricity meters, mobile price-indicating devices, and flexible power tariffs shall contribute to best possible energy usage.

1. Decentralized power generators
In the MeRegio project, the consumer can generate power with the help of decentralized systems using wind, sun, or water, sell it to others on a virtual energy marketplace, or use it himself.

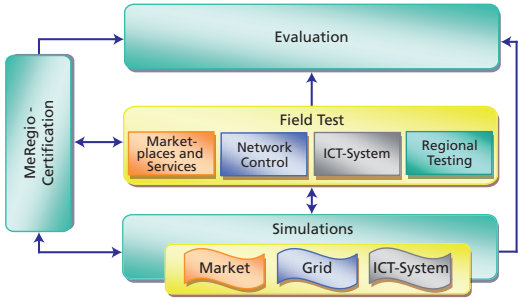
2. Smart storage systems
When the sun is shining or the wind is blowing, energy can be produced or bought at a particularly favorable price. Mobile or stationary storage systems make this energy available at the time it is needed.

3. Smart household appliances
They switch on automatically when energy is cheap, for example, when large amounts of renewable energy are available.

4. Smart electricity meters
Smart electricity meters record power consumption at short time intervals and send the consumption data to the respective metering service provider.

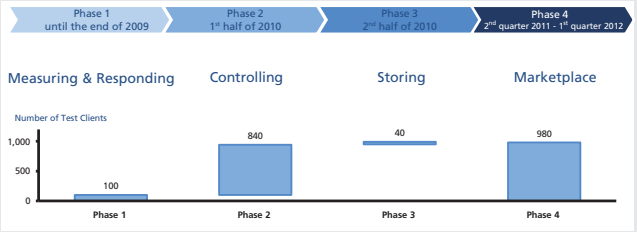
Project Structure

The project is divided into four large areas, as is shown in the illustration below:



Field Test

As part of the field test, a prototype of the marketplace, network control, and the ICT infrastructure will be established in four phases. KIT will act as an advisor and support its industrial partners in conception and evaluation later on. In the course of the project, a number of scenarios will be investigated and various concepts will be tested on the basis of the prototype and the model region.



Phase 1 (until the end of 2009): Measuring and responding
In this stage, it shall be found out how consumers respond to a dynamic price signal. Sensitivities of consumers with standard load profiles as well as price elasticity will be tested using energy price signals on an hourly basis.

Phase 2 (1st half of 2010): Controlling
A first, local optimization will be performed in phase 2. Consumers and decentralized providers will be controlled by means of control boxes combined with complex price and control signals and familiarized with the control of intelligent devices.

Phase 3 (2nd half of 2010): Storing
In this stage, (partly) flexible consumption and storage of energy produced by decentralized sources will be coordinated. The integration of all components will be tested and connection to the marketplace as well as trading will be prepared. Furthermore, network bottleneck situations will be simulated.

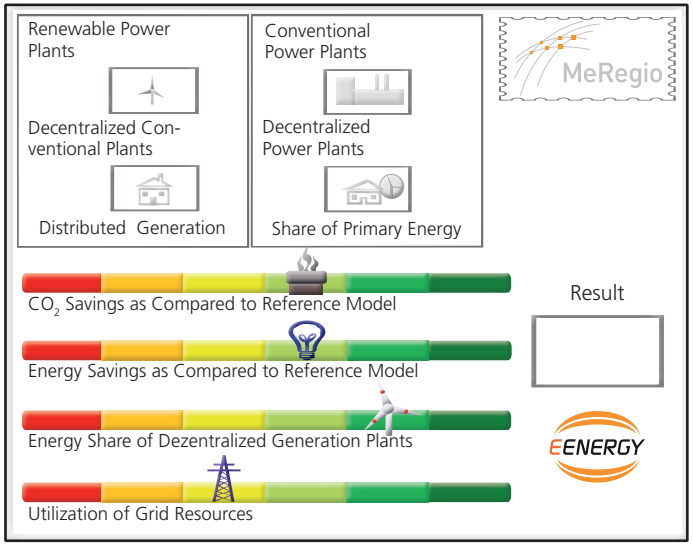
Phase 4 (2nd quarter of 2011 - 1st quarter of 2012): Marketplace
Finally, the project participants (consumers and producers) will be interconnected in phase 4 via the MeRegio marketplace. Additionally, MeRegio certification will be implemented.

Certification

An integral part of this project is a certificate for Minimum Emission Regions. KIT will develop the certificate and execute the certification process in the model region.

This certificate will help creating awareness for the need to act in an energy-efficient way in both the population and (regional) politics and economy. Furthermore, certification will allow for regions to be compared with each other. In addition, a catalog of actions to enhance energy efficiency in the model regions will be drawn up.

To obtain as comprehensive information as possible on the energy efficiency of regions, energy sources other than electricity will also be taken into consideration during the certification process.



Simulations

Within the MeRegio project, simulation components will be used to closely examine and analyze various features of the MeRegio concepts. KIT will develop the corresponding simulation components for use in scenario analyses.

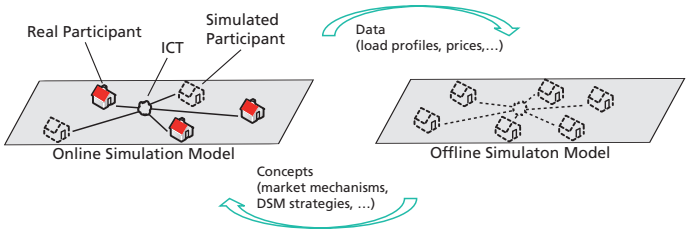
During the simulations, various levels and characteristics can be distinguished. As a part of the project, both offline and online simulations will be carried out in a real and a virtual model area.

The real model area comprises all participants in the field test residing in the model region. The virtual model area additionally covers other test participants distributed all over southern Germany. As the latter are not directly connected to the same low- and medium-voltage power grid as the participants in the real model area, integration will be simulated by means of software components.

Virtual connection allows to create model areas of any composition as a basis of online and offline simulations.

Online simulations allow for the testing of different scenarios, such as various market mechanisms, grid control concepts, and business models, with the participants in the virtual or real model area. The online simulations interfere with the existing prototype and, thus, influence the model area. For instance, it is possible to evaluate the participants' responses to certain situations, for example, high energy prices at noon, as well as the interaction between power grid and marketplace. The results obtained allow reliable statements to be made with respect to the concepts tested.

Offline simulations are necessary for the investigation of situations that cannot be induced in the real settings, such as power outages or consequences of extreme weather conditions. A purely virtual model allows to arbitrarily change and extend the influencing factors in order to draw conclusions regarding the scalability of the methods. Offline simulations allow for the evaluation of a considerably larger number of approaches than the field test that is subject to time and technical restrictions.



Interdependencies between offline simulations, online simulations and the real model region

- Coordination approaches based on regional energy and service markets are investigated with the help of **market simulations**.
- Simulation and evaluation of both centralized and decentralized **ICT concepts** allow to develop solutions for the efficient and secure handling of large amounts of metering and control data.
- By simulating various **control methods**, load and generation management strategies for the short-term balancing of deviations between power generation and consumption are developed and evaluated.
- **Grid simulations** help analyze load flows and plan grid extensions. Thus, they support the integration of renewable energy sources.

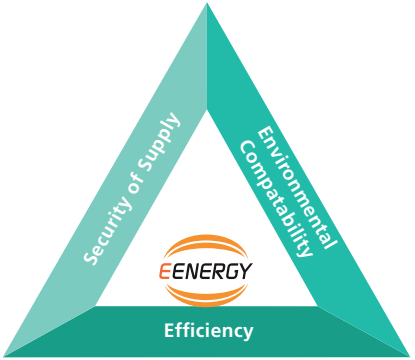
The results of offline simulations will be used in the next project phases to choose the most promising MeRegio concepts which will then be implemented in the field test.

Evaluation

Within the scope of the evaluation process, the concepts developed will be analyzed and assessed. The main focus will be on issues relating to the operation of the prototype implemented. This includes effects on energy efficiency and greenhouse gas emissions and possible approaches to improving the overall system. Interest concentrates on the three objectives of efficiency, environmental compatibility, and security of supply. Additionally, legal framework conditions have to be investigated.

To generalize, the results, they will be aggregated and scaled to a larger area (e.g. the whole of Germany). In addition, information concerning the long-term impact for the next 20 – 30 years will be supplied in order to forecast the development of the power plant park in the future, for instance.

Success of the concepts developed is determined not only by their potential, but also by the participants' acceptance. From the results of various test runs and simulations, conclusions will be drawn with respect to consumer behavior, acceptance, and other socio-economic effects.



Consortium

Industry and KIT

The interdisciplinary project consortium pools the expertise of five chairs of Karlsruhe Institute of Technology (KIT) in the areas of economics, informatics, and law with that of their industrial partners EnBW AG (consortium management), ABB AG, IBM Deutschland GmbH, SAP AG, and Systemplan GmbH.

The entire chain of values added from power generation (large power plants and decentralized generation) to mains operation (every voltage level), to the end customer will be considered. The analyses will cover the technical feasibility of the concepts, IT, and legal aspects as well as the acceptance of incentive models.

KIT Chairs Involved

Research Activities

Institute of Applied Informatics and Formal Description Methods (AIFB)

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 with self-organization capabilities. Their controllability and efficient use are major objectives of the Organic Computing initiative which is strongly influenced by this group, as it coordinates the priority program of the German Research Foundation on organic computing.

Along with fundamental research into architectures and methods of Organic Computing, the focus is put on concrete technical application scenarios in urban traffic, service-oriented architectures, and – based on previous work in the SESAM project – smart energy systems. Work is complemented by the development of nature-inspired methods for optimization and in particular for multi-objective and dynamically changing problem settings.

The interdisciplinary SESAM project funded by the German Federal Ministry of Education and Research and coordination of the Organic Computing program have enabled the group to acquire comprehensive knowledge in the field of controllability of self-organizing, adaptive systems. The generic architectures and methodological approaches developed bear a great potential for self-organizing energy systems as well.

Contribution to MeRegio

Within the scope of the MeRegio project, one major point of attention will be the development and evaluation of adaptive control strategies to compensate short-term imbalances of energy generation and consumption. Decentralized renewable power plants will be integrated in the grid by controlling both load and generation.

The focus in the domain of load management is on cooperative strategies. These strategies enable participants to

communicate with each other for coordinated load management. In the field of power generation management, control strategies for pools of decentralized plants (virtual power plants) will be analyzed.

For the control strategies to handle the uncertainties inherent in forecasted and measured load, price, and network data, models and algorithms will be developed to provide good and robust solutions despite the limitations mentioned above. Moreover, it will be investigated how errors caused by the interaction of various components can be identified and eliminated automatically. These phenomena known as emergence are due to the fact that the underlying system is too complex to be verified in its entirety during interaction.

Furthermore, the AIFB is involved in developing a MeRegio certification concept as well as in carrying out online simulations.

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Institute for Industrial Production (IIP)

The Chair of Energy Economics at the Institute for Industrial Production conducts techno-economic analyses of energy systems and material flows needed for the assessment of strategic and environmentally relevant issues. The working group "Energy System Analysis and Environment" traditionally concentrates on strategic problems, such as capacity expansion and deployment planning, supply chain optimization, and technology assessment as well as development of emission reduction strategies. The main objective of the newly created research group "Transport and Energy" is to determine the impact electric vehicles have on the energy system and material flows.

To conceive consistent power supply strategies, energy models have to be developed (further) taking into account the framework conditions of energy economy. The research activities are aimed at developing new methodological approaches in the energy sector to model the structure of energy systems as well as changing energy policy and environmental policy conditions. In recent years, Operations Research methods proved to be suitable for supporting decisions of political decision-makers and enterprises.

Depending on the topics to be studied and the given system boundaries, other methodological approaches, such as real option approaches, nodal pricing approaches, agent-based simulation systems, or System Dynamics approaches, are developed. Moreover, models are coupled (energy system models with models for the calculation of load flow, GIS models, or macroeconomic models). Implementation of these tools allows to analyze techno-economic systems on various levels of abstraction from local areas of single industrial enterprises to an urban energy system to an international energy system.

Contribution to MeRegio

A large part of the research within the scope of the MeRegio project will be dedicated to the development of a certification process of CO_2 and energy efficiency of regions. The first step will be to define the assessment criteria, parameters as well as efficiency classes, so that the certification proce-

dure developed can be tested in the model region later on. Furthermore, the simulation model developed can be used for further research in this field. The issues covered include model-based analyses of the impacts price and control signals have on power demand as well as model-based analyses of the impact of integration of decentralized power plants, storage systems, and controllable loads on the grid. Based on the results, a model will be designed for the evaluation of the transferability and the long-term effects of the concepts developed for e.g. the MeRegio marketplace and certification on the energy system. These research phases will be accompanied by socio-economic analyses, with the participants' acceptance playing a considerable role.

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Institute of Information Systems and Management (IISM)

The research group of Prof. Weinhardt at the Institute of Information Systems and Management analyzes and designs electronic markets for various sectors, for example, finance, energy, logistics, and emission certificates. Electronic trading platforms and market mechanisms are examined with regard to their quality of results and suitability. For this purpose, prototypical systems are designed and implemented. On this basis, it is possible to run simulations, business games, and experiments. The overall approach, which is at the center of the group's research, is called "Market Engineering".

Contribution to MeRegio

Within the framework of the MeRegio project, the IISM supports the development, implementation, and evaluation of the market platforms and their mechanisms. One of the research objectives is to reproduce model regions and their participants in simulation scenarios in order to investigate the interaction on a regional energy market. Software agents will be employed as representatives of real participants on the part of both consumers (for example, households, industry) and producers (for example, wind power, storage systems).

Within the scope of the analyses, possible approaches to implementing the regional marketplace shall be studied in due consideration of operational constraints, such as the available transmission capacity. This will set the course for the implementation of the regional energy market platform for an efficient and intelligent usage of the scarce resource energy.

Furthermore, the IISM participates in advanced socio-economic investigations as well as in the conceptual design of a MeRegio certificate. The latter is supposed to enhance the transparency of the use of energy within a region and characterize a particularly efficient handling of energy with low emissions. The regional comparability will provide incentives for the development of a low-emission, sustainable local use of energy in the future.

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Institute for Information and Economic Law (IIWR)

The research group headed by Prof. Dreier focuses on the legal issues raised by digitization and networking in the information society for the chain of information values added.

The institute and its researchers are renowned in Germany and abroad for numerous presentations 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 provided by legal rules. These issues might enable or hinder the development of useful and desirable information technologies and information services.

Contribution to MeRegio

Within the scope of the MeRegio project, all the legal requirements will be analyzed on the basis of the existing legislation, considering every particular level from basic communication and the middleware/platform to the business models. The results will be reported back to the project partners. At the same time, it will be worked towards an early opening of the present basic provisions of the energy law. For this purpose, statements and expert opinions will be issued for e. g. the Bundesnetzagentur (German Federal Network Agency).

Major research topics result from the regulations relating to message formats and process stipulations (interoperability) as well as from generic regulations of the law of evidence and data protection law. Technical concepts will be developed for the smart grid to implement legal conformity in the fields of technical data protection and data security.

Legislative adaptation requirements above all of the ICT-related energy law, law of evidence, data protection law, and the German standard weights and measures law will be identified. Domain-specific recommendations for the standardization of rules will be formulated and provided to political decision-makers.

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Institute of Telematics (ITM)

In the context of new services and applications, the group of Prof. Martina Zitterbart focuses on the research into and prototype development of novel communication infrastructures for today's as well as the future internet.

The topics covered range from signaling and management aspects of future networks to the implementation of distributed applications and services by means of overlay and peer-to-peer approaches, to communication protocols and applications for wireless sensor networks. Network security aspects, abstract modeling of processes, as well as network simulation play a major role in all areas.

The institute has acquired a high level of expertise through different research projects, such as ScaleNet and SpoVNet, funded by the BMBF and Baden-Württemberg State Foundation within the BW-FIT program, respectively. Both projects offer flexible architectures facilitating the execution of distributed services while considering quality of service and security constraints. With Oversim, ScaleNet additionally yielded a powerful ICT simulation tool. The findings of the SpoVNet project regarding distributed services can be incorporated in the development of distributed ICT systems in MeRegio and MeRegioMobil.

With his CoMoGrip young investigator group funded by the Excellence Initiative, Dr. Oliver Waldhorst additionally investigates the use of grid and P2P techniques in highly heterogeneous networks.

Contribution to MeRegio

Within the framework of the MeRegio project, the research group of Prof. Zitterbart concentrates on the development and simulative evaluation of both centralized and decentralized ICT concepts, paying particular attention to aspects of scalability and security. Specialized communication methods, such as Concast and Multicast, allow to develop solutions to efficiently handle the data traffic due to the acquisition of power consumption data of a large number of households.

In order to preserve the origin of the data and, by doing so, estimate the regional energy demand, novel methods are of great necessity especially when applying decentralized ICT concepts on a peer-to-peer basis, for example, for the adequate addressing of communication participants or their organization.

Security mechanisms play a fundamental role in this respect. They are required to protect the anonymity of the communication participants or to ensure integrity of the transmitted and exchanged data, for example.

The mechanisms designed will be evaluated in a simulative way in order to obtain information about the real level of scalability achievable. An appropriate simulation environment will be defined and implemented for this purpose.

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MeRegioMobil

ICT for Electric Mobility

As part of its second economic stimulus package, the Federal Ministry for Economics and Technology (BMWi) launched the technology competition "ICT for Electric Mobility". This initiative of the federal government that is closely linked to the E-Energy beacon research project of the BMWi is aimed at developing and evaluating ICT-based key technologies and services for the integration of electric mobility in the existing energy and transportation systems.

MeRegioMobil was chosen to be one of the winning consortia. Considering its research focus, the MeRegioMobil project perfectly complements the concepts that have already been developed within the scope of MeRegio.

Future developments in the field of electric mobility and new challenges for the power grid shall be analyzed. The major goal of the MeRegioMobil research project is to efficiently integrate mobile electric storages in vehicles in the existing energy systems by means of innovative ICT. With the help of ICT, batteries of electric vehicles might be used as mobile electrical storage systems in the future, which take up surplus wind and solar power from the grid and feed the stored energy back into the grid when necessary.

A major part of the project consists in the development of new services to integrate electric vehicles in the power grid in the most advantageous way. This includes pricing models, load management models as well as route and mobility planning. Furthermore, innovative business models in the field of electric mobility as well as incentive schemes to influence the clients' consumption behavior will be developed and tested.

It will be required to develop the corresponding electrotechnical and software components, and to adapt them to the model tests. Furthermore, a laboratory representing the prototype of a "smart home" with intelligent, controllable household appliances, decentralized generators, and electric vehicles will be constructed.

Further developments that cannot be implemented in the field test during the project will be demonstrated in laboratory experiments. In this way, the services and technologies

developed can be tested before they are applied in the model region.

The development of new business models and incentive schemes in the field of electric mobility, development of innovative telematics services on the basis of route planning techniques (GPS) for saving energy, consumption forecast as well as cooperative dynamic mobility planning (Car2X-Communication) will also be relevant to the project. In addition, online and offline simulations will be applied within the scope of MeRegioMobil in analogy to MeRegio. The simulation components developed will be designed such that they ideally complement the MeRegio components. Hence their further application after the project will be ensured.

Apart from the chairs already mentioned, six KIT chairs participate in the MeRegioMobil project:

- Prof. Dr. Rudi Studer (Knowledge Management, Institute of Applied Informatics and Formal Description Methods)
- Prof. Dr. Thomas Leibfried (Electric Energy Systems and High-Voltage Engineering, Institute of Electric Energy Systems and High-Voltage Engineering)
- Prof. Dr. Michael Braun (Electrical Engineering, Institute of Electrical Engineering)
- Prof. Dr. Ralf Reussner (Software Design and Quality, Institute of Programme Structures and Data Organisation)
- Prof. Dr. Hannes Hartenstein (Decentralized Systems and Network Services, Institute of Telematics)
- Prof. Dr. Peter Sanders (Algorithmics, Institute of Theoretical Computer Sciences)

EnBW

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Gefördert durch:

Bundesministerium
für Wirtschaft
und Technologie

aufgrund eines Beschlusses
des Deutschen Bundestages

Wir leben Autos.

SAP

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KARLSRUHE
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Published by

Karlsruhe Institute of Technology (KIT)
University Sector
Kaiserstraße 12
76131 Karlsruhe, Germany

Oktober 2010

www.kit.edu