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RESEARCH FOR INNOVATIVE TRANSPORTS SET

Volume 1

# Energy and Environment

Edited by

Michel André and Zissis Samaras

ISTE

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**Research for Innovative Transports Set**

coordinated by
Bernard Jacob

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# Contents

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# Preface

The transport sector is very much concerned about environmental adaptation and mitigation issues. Most of these are related to the objective of curbing GHG emission by 20% by 2020, alternative energy and energy savings, sustainable mobility and infrastructures, safety and security, etc. These objectives require the implementation of advanced research work to develop new policies, and to adjust education and industrial innovations.

The theme and slogan of the Transport Research Arena held in Paris (TRA2014) were respectively: "Transport Solutions: From Research to Deployment" and "Innovate Mobility, Mobilise Innovation". Top researchers and engineers, as well as private and public policy and decision-makers, were mobilized to identify and take the relevant steps to implement innovative solutions in transport. All surface modes were included, including walking and cycling, as well as cross modal aspects.

Policies, technologies and behaviors must be continually adapted to new constraints, such as climate change, the diminishing supply of fossil fuels, the economic crisis, the increased demand for mobility, safety and security, i.e. all the societal issues of the 21st Century. Transport infrastructures and materials, modal share, co-modality, urban planning, public transportation and mobility, safety and security, freight, logistics, ITS, energy and environment issues are the subject of extensive studies, research work and industrial innovations that are reported in this series of books.

This book is a part of a set of six volumes called the *Research for Innovative Transports* set. This collection presents an update of the latest academic and applied research, case studies, best practices and user perspectives on transport carried out in Europe and worldwide. The presentations made during TRA2014 reflect on them. The TRAs are supported by the European Commission (DG-MOVE and DG-RTD),

the Conference of European Road Directors (CEDR) and the modal European platforms, ERRAC (rail), ERTRAC (road), WATERBORNE, and ALICE (freight), and also by the European Construction Technology Platform (ECTP) and the European Transport Research Alliance (ETRA).

The volumes are made up of a selection of the best papers presented at the TRA2014. All papers were peer reviewed before being accepted at the conference, and they were then selected by the editors for the purpose of the present collection. Each volume contains complementary academic and applied inputs provided by highly qualified researchers, experts and professionals from all around the world.

Each volume of the series covers a strategic theme of TRA2014.

Volume 1, *Energy and Environment*, presents recent research work around the triptych "transports, energy and environment" that demonstrate that vehicle technologies and fuels can still improve, but it is necessary to prepare their implementation (electromobility), think about new services and involve enterprises. Mitigation strategies and policies are examined under different prospective scenarios, to develop and promote alternative fuels and technologies, multi-modality and services, and optimized transport chains while preserving climate and the environment. Evaluation and certification methodologies are key elements for assessing air pollution, noise and vibration from road, rail and maritime transports, and their impacts on the environment. Different depollution technologies and mitigation strategies are also presented.

Volume 2, *Towards Innovative Freight and Logistics*, analyzes how to optimize freight movements and logistics; it introduces new vehicle concepts, points out the governance and organization issues, and proposes an assessment framework.

Volumes 3 and 4 are complementary books covering the topic of traffic management and safety.

Volume 3, *Traffic Management*, starts with a survey of data collection processes and policies and then shows how traffic modeling and simulation may resolve major problems. Traffic management, monitoring and routing tools and experience are reported and the role of traffic information is highlighted. Impact assessments are presented.

Volume 4, *Traffic Safety*, describes the main road safety policies, accident analysis and modeling. Special focus is placed on the safety of vulnerable road users. The roles of infrastructure and ITS in safety are analyzed. Finally railway safety is focused upon.

Volume 5, *Materials and Infrastructures*, is split into two sub-volumes, investigating geotechnical issues and pavement materials' characterization, innovative materials, technologies and processes and introducing new techniques and approaches for auscultation and monitoring. Solutions to increase the durability of infrastructures and to improve maintenance and repair are presented, for recycling as well as for ensuring the sustainability of the infrastructures. Specific railways and inland navigation issues are addressed. A focus is put on climate resilient roads.

Volume 6, *Urban Mobility and Public Transport*, highlights possible innovations in order to improve transports and the quality of life in urban areas. Buses and two-wheelers could be a viable alternative in cities if they are safe and reliable. New methodologies are needed to assess urban mobility through new survey protocols, a better knowledge of user behavior or taking into account the value of travel for public transport. The interactions between urban transport and land planning are a key issue. However, these interactions have to be better assessed in order to propose scenarios for new policies.

Bernard JACOB, Chair of the TRA2014 Programme Committee

Jean-Bernard KOVARIK, Chair of the TRA2014 Management Committee

March 2016

# Introduction

# Toward Cleaner, Efficient and Sustainable Transports: Context and Recent Research Works

## I.1. Introduction

Transport systems are facing an impossible dilemma today: on one hand they must satisfy an increasing demand of mobility for a growing world population and an intensification of the goods exchanges, while on the other hand, they are also supposed to decrease their energy requirements and shift to non-fossil fuels (rarefaction and climatic impacts), while preserving or even improving the environment, decreasing the impacts of noise and air pollution on living beings, fauna and flora, to be precise. Besides that, transports have a unique opportunity to evolve in a changing world, with new services (vehicle sharing or in self-service), technologies like intelligent transportation systems (ITS), communication, etc., and also requirements including fast delivery, reliability, improved accessibility, etc.

In this book, recent research and application works – that were presented during the 5th Conference of Transport Research Arena, Paris, France, held on 14–17 April 2014 – are reported around the triptych: "transports, energy and environment".

Successively, works will be reported on the progress and potential of electromobility and the conditions of its implementation (Part 1), the recent developments of vehicle and engine technologies for optimizing their operation while decreasing their energy needs and their environmental impacts (Part 2). Renewable and alternative energies are studied from both their technological and implementation points of view in Part 3.

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Introduction written by Michel ANDRÉ and Zissis SAMARAS.

The next three parts adopt rather an environmental perspective, with respect to climate change and of the mitigation of transportation-related greenhouse gases (Part 4) and the issues of air and noise pollution due to transports in Parts 5 and 6.

As a prelude to this scientific and technical reporting, we propose a brief contextual overview, regarding the energy, environment and transport sectors, and their connections taking into account appropriate and coherent policies, towards the development of sustainable transport systems. This overview will be followed by a brief summary of the research works reported in the following chapters.

## I.2. Context

### I.2.1. *Consistent and coordinated energy and environmental policies are needed in Europe*

One of the major European concerns is increased oil and gas prices due to geo-political instability that may endanger EU economic performance [BER 14]. This requires the development of sound energy policy which should take into account environmental issues such as climate change, air quality, noise and other related impacts. As underlined in the Green Paper on a European strategy for sustainable, competitive and secure energy by the European Commission in 2006, Europe has to put energy policy high on the EU agenda if it is to achieve its economic, social and environmental objectives. The EU must exploit its position as the world's second largest energy market and as a world leader in demand management and the promotion of renewable energy sources. Improving energy efficiency and focusing on regionally sourced renewables will also benefit energy security by leading to lower imports of fuel, making countries less reliant on foreign supplies. Moreover, it will result in a more diverse energy mix and improve the resilience of national or regional energy systems.

### I.2.2. *Co-benefits between energy and environment can be achieved*

It is important to note that significant co-benefits can be produced for health, quality of life, or even ecosystems and the economy by linking energy policies with those for climate change and environmental protection (on that subject, see for instance [WES 13, MCC 13, RAO 13, RAF 13, ALG 13]). Switching to clean energy would pay for itself, almost immediately, because actions to reduce greenhouse gas emissions reduce co-emitted air pollutants too, thus bringing co-benefits for air quality and human health, as well as for natural environment and ecosystems.

Overall, it seems that there is a strong incentive for countries to start cutting back on fossil fuels as soon as possible, as the co-benefits of avoided air pollution mortality alone can justify substantial reductions in greenhouse gases (GHG) emissions. Air quality and health co-benefits, especially as they are mainly local and near-term, can therefore provide strong additional motivation for transitioning to a low-carbon future.

### I.2.3. *Energy and environmental policies face a multiplicity of actors*

Energy and environmental policies face difficulties due to multiple layers of regulation, levels of governance, multiplicity of actors and, finally, complex interactions between multiple pollutants, pollutions and environmental impacts. Climate change policy is affected by multiple decision makers at local, sub-national, national and transnational levels [BON 12]. Usually, these decision makers are not fully coordinated with respect to goals and methods, and the existence of several layers of governance may encourage strategic behavior from powerful local actors trying to enhance their own positions. Multi-level climate change governance is also related to governance of local environment and quality of life since production processes often involve emitting several pollutants and harmful effects simultaneously. Environmental policies aiming at reducing $CO_2$ emissions might, therefore, create trade-offs. For example, a common strategy to reduce $CO_2$ emissions is switching the fuel mix from oil towards bio-fuels. However, while net $CO_2$ emissions do fall with biofuels, a darker side also exists with an increase in the levels of nitrogen oxides.

### I.2.4. *Transport: a vital sector with increasing energy and environmental concerns*

The transport sector is a vital component for fulfilling the three freedoms of the European single market: the free movement of persons, services and goods [KAL 15]. The demand for transport has been rising for many years at both national and European levels; and it accounts for the majority of all liquid fuel consumption. Therefore, air pollutants, GHG emissions, noise and other environmental damages caused by the transport sector are expected to increase, further contributing to pollution, adverse health effects and climate change. In this framework, the push to move toward energy efficiency and alternative fuels in the transport sector is expected to continue as well. The “EU-2020 strategy” includes the flagship initiative “resource efficient Europe” [EUR 11a] in which the European Commission presents proposals aiming at cleaner, more efficient and more sustainable transport through the adoption of measures such as research and innovation, setting current standards and developing the necessary infrastructure

support as well as regulatory measures such as pricing. The White Paper on Transport [EUR 11b] takes into account major policy initiatives for a competitive and resource efficient transport system under sustainable developments. Furthermore, the European Road Transport Research Advisory Group (ERTRAC [ERT 10]) sets out the following ambition: "Towards a 50% more efficient road transport system by 2030".

In that context of energy and environmental high-level requirements, a cleaner, more efficient and sustainable transport system should develop in the frame of coherent energy and environmental policies, but transport, land use and urban planning policies should also be oriented accordingly. In all, this means a highly integrated approach for successful development and the implementation of improved or alternative transport technologies and energies. Besides that, transports have today a unique opportunity to evolve in a changing world, with the development of new services (vehicle sharing or in self-service), technologies (ITS, communication, etc.) and also with changing requirements (fast delivery, reliability, improved accessibility, etc.). These opportunities can and should be seized for a possible renewal of our transportation systems and of our mobility practices.

### I.2.5. *Research and application works for cleaner, efficient and sustainable transport systems*

Evidently, research, innovation and application works should be the main driving forces of such an integrated development for clean and sustainable transports, considering technical but also organizational, social and human aspects of such evolution. These works are the basis of the related-knowledge production and of the technological development and demonstration, and should contribute to the understanding of organizational and governance interactions, their optimizations, the elaboration of pertinent and acceptable policies, and finally to the real-world implementation and assessment of these innovative transport technologies and services.

## I.3. Recent research results of the "transports, energy and environment" triptych: a summary

The 5th Conference of Transport Research Arena (Transport Solutions from Research to Deployment) held in Paris, France during 14–17 April 2014, was the opportunity to explore recent research works around mobility of people and goods with respect to energy, environment, safety, security and economic issues, considering all surface transport modes, including crossmodal issues.

The present volume compiles a selection of scientific and application papers related to recent and most significant research works around that triptych: “transports, energy and environment”.

The works in this book demonstrate that vehicle technologies and fuel can still improve (electromobility, hybrid, hydrogen/ fuel-cell, CNG, etc.), but it is necessary to prepare their implementation, to think of them as elements of new services, and to involve all actors early in the design of transports and services, in particular – besides the vehicles, fuels, infrastructures and big companies – a high number of small and medium-sized enterprises that operate the transport or that could be the new actors of innovation. Other works have already pointed out the importance of considering human aspects, for a better appropriation and to improve behaviour (eco-mobility).

Prevision, prospective and orientation in the development of transports are key elements for reaching increasingly high and mandatory expectations in regards to climate and environment. Conditions for the transport and energy mutations should be carefully analyzed, as a strong influence of the economical context (of which fuel and mobility prices) was demonstrated and could even defeat the expected effects, while incentives or bonus/credits were envisaged to promote new technologies.

Mitigation strategies are thus proposed here as combination of measures and policies under different prospective scenarios, to promote alternative fuels, new technologies and services, promote multi-modality, decrease GHG and environmental impacts, while creating “value chains”. For a better understanding and analysis of transport’s economic impact, research has worked on better and agreed evaluation tools, such as carbon footprint that is particularly challenging for the complex freight transport chains and the high diversity of shippers, as also demonstrated.

With respect to air pollution, research has progressed around non-exhaust pollution, re-suspension of particles, non-regulated compounds with high concerns, and estimation tools. But a robust assessment of mitigation measures still depends on input data at the very local scale of which vehicle–fleet composition and traffic conditions remain to be key factors. Some works examine depollution technologies and fuels to decrease particulates and NOx as well.

Finally, this book proposes a compilation of non-conventional research works regarding noise and vibration from transports, addressing the acoustical impacts on marine life by shipping, on terrestrial organisms by vibrations and noise caused by trains, and on the opposite, how additional warning sounds could be managed for

electric vehicles for safety while simultaneously optimizing their noise level, detectability and warning efficacy. Reduction technologies, assessment, (virtual) certification and perception (human and animal) are the main aspects of these works, which enrich the environmental noise problem by diverse application studies.

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PART 1

# Electromobility and its Implementation

# Introduction to Part 1

This first part covers a wide range of subtopics that assess different ways of implementing electromobility. Today, drive electrification represents a potent concept for achieving sustainable mobility. Electromobility is now the key technology for the replacement of fossil energy sources in the long-term, creating new markets and new technologies as the old energy order comes to an end and a new one begins.

One paper reviews the results of the first two years' work of the Green eMotion project, which aims at developing and demonstrating a commonly accepted and user-friendly framework that combines interoperable and scalable technical solutions with a sustainable business platform. Two papers address the issue of electromobility services in Italy demonstrating the effectiveness of and encouraging the deployment of intelligent vehicle systems, designed specifically for electric vehicles on European roads. Another paper outlines the development of the training programmes for safe eco-driving of clean vehicles, and describes the framework for evaluating their impact. The chapter concludes with some major results on improving the capacity of European SMEs to develop and implement products in the low-carbon transport sectors.

Introduction written by Zissis SAMARAS.

*Energy and Environment*, First Edition. Edited by Michel André and Zissis Samaras.

# 1

# Toward a Europe-Wide Interoperable Electromobility System

In March 2011, the European Commission kicked off a four-year Europe-wide initiative called Green eMotion. The aim of Green eMotion is to define and demonstrate an interoperable and user-friendly electromobility system based on existing installations and the experience thus gained. One of the goals of Green eMotion is to create an ICT system concept for the Europe-wide electromobility services marketplace (including definition of the requisite interfaces) and to demonstrate it. Almost all the 10 Green eMotion demo regions in Europe are using this business-to-business (B2B) marketplace, linking their IT systems to the marketplace via open standard interfaces. The test phase, which began in September 2012, comprises functions used for locating charging points and clarifying charging contracts with third-party providers (roaming). In addition to this key topic of ICT, Green eMotion is also working towards important developments in other areas:

1) improvements in standardization;

2) technical reports and policy recommendations;

3) extensive evaluation of static and dynamic electromobility data;

4) demonstration of a new approach to the sharing of electric vehicles in urban areas.

## 1.1. Background

Climate change and the reduction of greenhouse gas (GHG) emissions are one of the major challenges of our time. A growing world population is leading to higher demand for mobility and energy, aggravating the problem and pushing emission levels upwards. The transport sector faces serious environmental, economic and societal challenges, which in the short- and medium-term will necessitate the transformation of the system.

Chapter written by Gabriele GIUSTINIANI, Luca PERSIA, Heike BARLAG and Norbert VIERHEILIG.

*Energy and Environment*, First Edition. Edited by Michel André and Zissis Samaras.

There is a need to mitigate the negative impacts on the environment and transport that will seriously impede the goal of reducing GHG emissions by 20% before 2020, as well as the longer-term climate goals. Until now transport has been the only sector in which GHG emissions have increased since 1990.

Meanwhile, the proportion of European citizens living in urban areas is increasing steadily. It is expected that by 2050 some 84% of the population will live in cities. Urban transport accounts for 40% of $CO_2$ emissions and 70% of emissions of other pollutants from road transport. The congestion in urban agglomerations must be brought to tolerable levels, while a growing demand for mobility has to be satisfied in the near future.

For this reason, the decarbonization of road transport, starting from urban areas, is one of the top priorities of policymakers in Europe. Battery-powered electric vehicles are seen as one of the most promising long-term sustainable options. For a number of reasons, such as improved battery performance and changes in emission performance standards, sometime in the next ten years electric and plug-in hybrid vehicles (EV and PHEV)[1] are likely to begin to gradually replace vehicles using internal combustion engines. They offer advantages in energy efficiency and a number of environmental aspects, such as their potential contribution to reducing $CO_2$ and local emissions and other negative external effects of mobility (e.g. noise), but some conditions are still keeping EVs from a full rollout on the market.

In some niche markets, EVs are already performing well, and EVs are gradually being introduced to more markets thanks to a large number of national and local demonstration initiatives.

The extent to which EV and PHEV will contribute to reducing GHG emissions also depends on the energy mix used to recharge the battery. Theoretically, the driver can choose whether to run his EV using conventional electrical energy sources or strictly from renewable electrical energy sources. However, EVs also have the potential to contribute to the integration of renewable energy sources (RES) into the electricity grid as they provide storage and demand response options.

The implementation of alternative mobility concepts requires consumer acceptance, meaning that EV must provide car owners with the same kind of ease-of-use, safety and reliability at reasonable prices. A comprehensive and standardized recharging infrastructure is one of the aspects that will favor consumer acceptance of EVs.

1 For simplicity, the abbreviation EV will be used for both electric vehicles and plug-in hybrid vehicles.

## 1.2. The Green eMotion project partnership and objectives

To enable the mass market for electromobility in Europe, important players from industry, the energy sector, municipalities and universities and research institutions have joined forces in the Green eMotion project (henceforth, GeM), which was kicked off in March 2011. GeM is a four-year EU funded project with 43 partners, coordinated by Siemens AG. An overview of the partnership is provided in Figure 1.1; for a more detailed description, see http://www.greenemotion-project.eu/.

The GeM partnership is convinced that transport, as a network industry, must be approached as a system integrating the ICT elements, services, interoperable equipment (vehicles and recharging infrastructure), and grid infrastructure as well as policies, incentives, and urban mobility concepts to ensure smooth and efficient interaction and, ultimately, a self-explanatory overall market system.

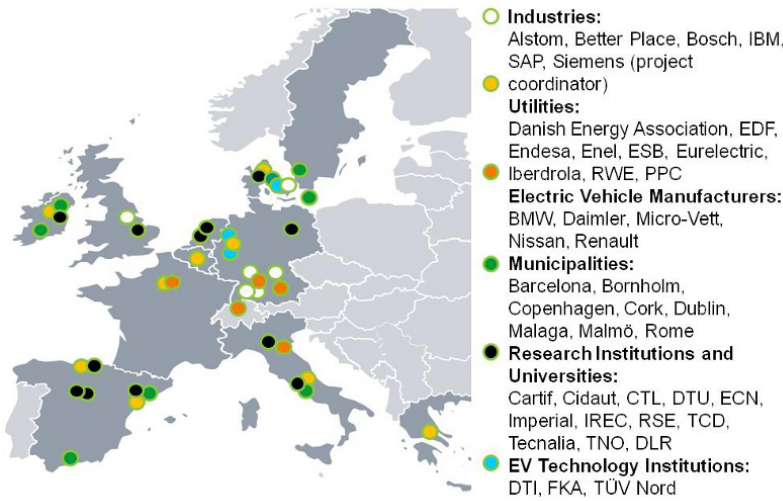


**Figure 1.1.** *The GeM partners. For a color version of the figure, see www.iste.co.uk/jacob/energy.zip*

GeM aims to establish a unique and user-friendly framework for green electromobility in the EU. Based on existing regional demonstration projects, feasibility and scalability of an interoperable and standardized mobility system including a clearing house[2] will be demonstrated to establish the best conditions to

2 Clearing house: this enables roaming for electricity customers across Europe (comparable with mobile phone services).

allow businesses and consumers to drive EVs and, thus, enable their mass-market introduction.

As a result, the user-friendly, interoperable, and scalable framework demonstrated will serve as a benchmark for further regions and their interconnection in Europe. In short, GeM will provide policymakers, urban planners, and electric utilities with the necessary tools to facilitate the Europe-wide rollout of EV.

## 1.3. GeM achievements so far

In the first two years of the project GeM partnership work covered four different areas:

– development of a marketplace as common innovative service platform: Europe-wide roaming and other services connecting the electromobility market players;

– improvement in standardization: highlighting and addressing the most urgent "new" needs;

– technical reports and policy recommendations: lessons learned in the practical implementation of electromobility;

– extensive amount of valuable electromobility data: use patterns, environmental impact (e.g. $CO_2$).

### 1.3.1. *Development of a marketplace as common innovative service platform*

GeM's first step was to create an ICT system concept for a European marketplace[3] for electromobility services and to demonstrate its operability in practice. For the first time, such a Business To Business (B2B) marketplace is bringing together all the actors involved in this segment: providers of charging services, charging station operators, power utilities, and suppliers of other electromobility-related services.

Such a marketplace permits associated service offerings – for instance, roaming between different charging point operators – to be provided on a pan-European

3 An electronic marketplace (for eMobility) is the virtual place where all participants in the ecosystem can connect and operate (process) their business (transactions). The marketplace in this proposal is not to be understood as the electricity or vehicle market. The "electromobility (mass-) market" refers to the whole set of products (vehicles, electricity and infrastructure) and services associated with electric vehicles and their operation.

scale, similar to current practices with cellphones. Furthermore, since the marketplace is open to other service providers, this would allow for innovative electromobility concepts to be made available more easily (see Figure 1.2). As the central technological component, the marketplace serves the following two functions:

– to reduce the number of interfaces between participants;

– to prove easy access to all offerings through standardized software services.

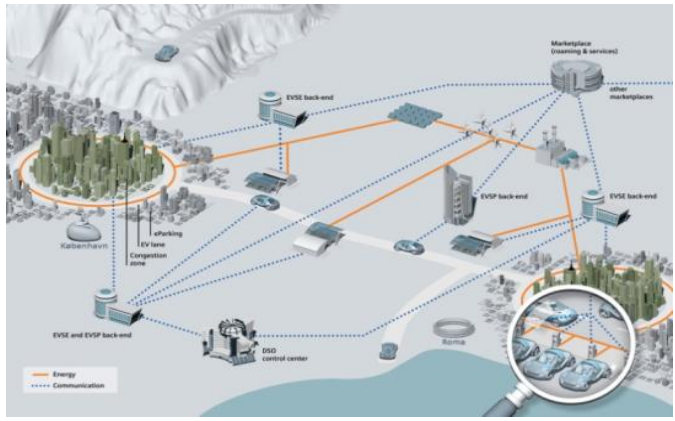


**Figure 1.2.** *The "Big Picture" of electromobility shows the complexity of a real interoperable system*

Right now, the first demo regions are connecting up. Subsequent phases will include energy-related services for optimizing grid utilization and new, added-value services for end customers, e.g. reservation of charging points.

Drivers of electric cars can make use of such services, which provide access to a variety of electromobility offerings. The result is a global system that allows for competition and individual solutions. Furthermore, the GeM marketplace for electromobility communicates with other marketplaces, such as pre-existing regional solutions, allowing broader integration beyond the GeM partners.

Currently two added value services are available through the marketplace:

– the roaming service allows the EV drivers who are customers of one GeM partner to access the charge points of the other partners easily. This is supported by a clearing house made available as a service on the marketplace. The clearing house service is in the background, transparently validating contracts of business partners involved in roaming;

– the search for EVSE service offers the charge spot data from most of the GeM demo regions. B2B partners connected to the marketplace can utilize this data and offer EV drivers to search for the charge spots through either a website, a mobile phone application or an in-car display.

The marketplace information hub is operational since August 2012 (see also Figure 1.3) and the integration of project partners using the enabled services is in progress. Successful tests between the first GeM demo regions have taken place.

The open ICT system architecture and the standardized interfaces and business objects enable all market participants to develop and offer the services in accordance with their own business models. If other marketplace operators follow the published IT architecture, the offering of services on different systems is enabled leading to enhanced competition.

### 1.3.2. *Improvement in standardization*

GeM partnership considers standardization as the key for an interoperable electromobility system, because this will allow convenient EV driving all across Europe, create new businesses and bring future-proof investments.

For this reason GeM focused the standardization work on identifiers and interfaces for the electromobility ICT systems, to enable roaming and allow a smooth system communication, independently from manufacturers, to allow an open competition.

**Figure 1.3.** *Commissioner Günther Hermann Oettinger (Energy) started operation of the first charging point at the European Commission on 19 June 2012*

To extend its results beyond Europe, GeM, with many other market players, initiated the electromobility ICT Interoperability Innovation Group (40 participants covering Asia, Europe and the Americas) to define industry standards for interfaces and user IDs for smooth communication between all the different electromobility ICT systems (for more information see www.eMI3group.com).

As the final standardization activity GeM proposed a New Work Item for the communication protocol between EVSE (EV Supply Equipment) and backend systems, leading to more competition for charging infrastructure and IT systems by avoiding proprietary protocols.

### 1.3.3. *Technical reports and policy recommendations*

Reports and recommendations were developed with the mass market for electromobility in mind. Obstacles encountered by the project partners in the electromobility policymaking process were described, as were the factors that made electromobility projects successful. This covers financial and non-financial incentives, infrastructure, EV issues and also the political environment.

Technical reports cover areas from infrastructure planning on different voltage levels to the performance of EVs in fleets.

### 1.3.4. *Extensive amount of valuable electromobility data*

GeM is also running an extensive data collection program in 10 demo regions, monitoring 600 electric vehicles and 1,800 charging points; 85% of the electric vehicles and 70% of charging points provide dynamic data sets today. These dynamic data are used by GeM teams to generate further results in the near future. Other external European mobility projects are being included in the data collection, and their data will be compared with GeM results.

Some results from the tests on site include:

– the mean distance run between EV charges is 37 km, but 75% of the users run a distance of up to 51 km;

– the maximum distance run between two charges has been 145 km;

– the mean battery level when starting a charging process is 65%, which means that most of the EV drivers charge their vehicle before the battery is drained;

– up to now, GeM EV drivers have run more than 65,000 km, saving more than 60 tons of $CO_2$.

### 1.3.5. *Developments in other areas*

In addition to building selected charging systems, infrastructure partners in GeM have issued preliminary findings on the effects of different charging strategies on the grid both in power quality and required reinforcement costs.

A deterministic network investment tool has been developed and successfully tested. It analyses the effects of different load charging profiles on real grids and calculates the total investment cost required in the network for hosting a specific percentage of EVs. The tool does not optimize the EV charging directly but is able to consider the value of control strategies by comparing the investment for different load profile shapes. For the first time, such a tool can be applied by the network operator itself. Furthermore, this tool will be publicly available.

GeM has also emphasized the design and development of EV-related hardware infrastructure.

This culminates in the completion of three important ongoing tasks:

– fast charging station, a novel charging station with second life buffer battery for integration of fast charging capability in weak grids;

– design and development of an inductive charger to provide wireless charging to a converted Nissan Leaf. This new design will allow easy conversion of EVs with CHAdeMO[4] interface;

– a 50 kW AC/DC/AC converter unit for grid re-enforcement application to support the grid in case of overloads due to a high number of charging EVs[5].

GeM is working on business models for electromobility. Key business model environments have been established, with all relevant interactions among actors defined. The goal is to evaluate the profitability of the different business models under various market considerations.

Concluding, GeM has done a broad set of measurements on various types of EVs. The goal is to evaluate the usability of EVs in everyday life. A new test setup for standard usage pattern (driving cycle) suitable for EVs was developed to show which range can be achieved realistically. Also, the influence of driving behavior on the driving range of EVs is under evaluation.

4 CHAdeMO is a standard for DC fast charging defined in Japan.
5 This project is running under the responsibility of one GeM partner. It is a grid buffering system realized with second life EV batteries to stabilize the grid and able to charge EVs.

## 1.4. Next steps

In the first two years of activities, GeM has already achieved important results and expects more of the same over the next two years, especially in:

– assessment of impact on EVs' diffusion of support/regulatory measures at local level;

– assessment of potential market penetration of EVs;

– demonstration of new forms of EV sharing and assessment of their transport and environmental impacts.

### 1.4.1. *Assessment of impact on EVs' diffusion of support/regulatory measures at local level*

The first activity is related to the understanding and assessment of the impacts on EVs' diffusion of support/regulatory measures that may be implemented at local level. In this regard, it is also important to understand and assess whether and how the impact of such measures varies according to local conditions such as population or gasoline prices. The assessment will be carried out by analyzing the support/regulatory measures already implemented on a sample of cities involved in GeM and the impacts they have had or are having on the diffusion of EVs. The methodology for the assessment has already been defined. Three main steps are foreseen for the assessment:

– survey of cities involved in GeM;

– analysis of data collected;

– review of the results and draft of a report.

The survey will be carried out by means of a questionnaire to the city representatives. The data collected will be of three types.

The first set of data is related to the city being investigated (population trends, area of the city and gasoline cost evolution).

The second set is related to the possible measures implemented to support the diffusion of EVs. The data will be related to how and when the measures have been implemented. Some of the measures considered in the survey are limited traffic zones in inner cities open/free for EVs, exceptions to road pricing for EVs in urban areas, the possibility for EVs to use bus lanes and reduction of local/national vehicle tax for EVs. In total, 11 possible measures will be investigated in the survey.

The third set of data is related to the evolution of EVs and internal combustion engine vehicles in recent years.

Once all the data are available, analysis will begin. Different analysis methods (e.g. time series analysis) will be used, and cities will be clustered according to selected data (e.g. population or area of the city). The results of the analysis were expected in summer 2014.

These results will be very important because the measures proposed can support the diffusion of electromobility at little or no cost to the local administrations. For this reason, these results will be used to support cities in selecting suitable support/regulatory measures to foster the diffusion of EVs according to local conditions and will be synthesized in a report available to the public.

### 1.4.2. *Assessment of potential market penetration of EVs*

To support full deployment of EVs in Europe, it is important to understand their potential market penetration, especially as regards recharging locations. To assess the driving factors, a study is underway in GeM Demo regions using a Stated Choice survey. The survey asks householders to indicate their most likely car purchase given multiple options, including lease of car or just batteries.

An efficient design is built and customized on the most likely next car purchase of each household. In particular, respondents are presented with different car classes and are asked to assume that they are in the purchase situation (previously defined in the survey) assuming that at the car dealership there are both the conventional vehicle and a comparable EV available with the characteristics shown for a given car class. Other than that, the respondent must assume that the two cars are identical.

The data collection is already complete in Denmark, and those results will soon be available. The survey is still in progress in the other GeM Demo regions.

### 1.4.3. *Demonstration of new forms of EV sharing*

Another interesting activity to be carried out within GeM is a small demo of micromobility in Rome. Micromobility is a new concept of EV sharing in cooperation with public transport. It aims to solve the last-mile problem for individual transport by integrating conventional collective PT with EV sharing. This represents a real opportunity for PT to compete with private transport. Micromobility stations spread over the area allow users to rent an EV (e-bike, e-moped or e-car) in A to reach B and leave the EV in the B station. This concept,

which integrates sharing of EVs with public transport, can completely alter the approach to urban mobility, and users can use conventional collective PT for covering the long part of the trip and cover only the last "mile" by e-vehicle. Moreover, although the business model of the micromobility has not yet been defined, micromobility e-vehicles will not pay parking fees and will be able to enter limited traffic zones.

An example of the potential coverage of such a service, integrated with the underground lines of Rome, is shown in Figure 1.4. Of course, it needs to be tested. Accordingly, Rome will implement a small demo with three stations and a total of 24 EVs (eight vehicles per station) of different types (e-bicycles, e-mopeds, quads and city cars). The demo aims to shed light on such aspects as:

– costs and financial sustainability of the service;

– user acceptance;

– technical and administrative problems that can hinder the diffusion of such a system.

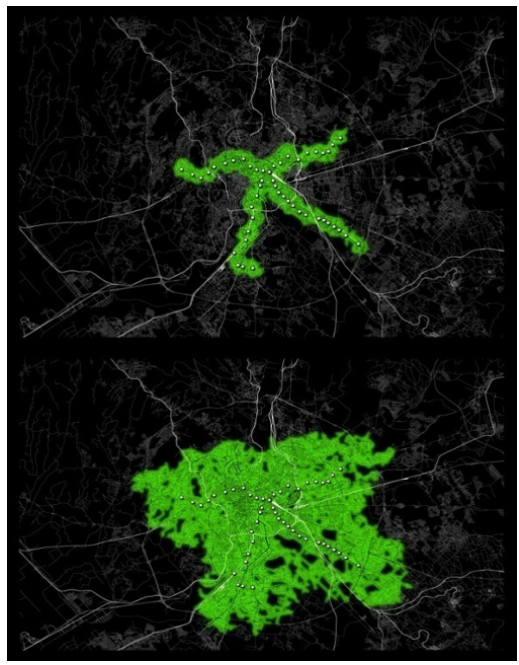

**Figure 1.4.** *Distance covered from underground station in Rome (above: distance covered by foot in 15 min; below: distance covered in 15 min with EVs, Vcom= kph)*

In parallel with the demo, which will provide important technical and financial information, a study will be carried out in Rome to:

– select the best area of Rome to deploy such a system and scale the system itself;

– estimate the number of private vehicle users that would shift to a combined use of PT and micromobility (considering also different scenarios of implementation);

– assess the potential reduction of pollutant emissions.

The results of this study are expected for autumn 2014 and will be used to evaluate a full deployment of micromobility in Rome.

## 1.5. Conclusions

In the first two years of work, GeM has already achieved important results. Its first step was to set up an ICT system concept for a European marketplace for electromobility services and to demonstrate its operability in practice. The marketplace is now open, and two added value services are available through the marketplace:

– the roaming service allows the EV drivers who are customers of one GeM partner to access the charge points of the other partners easily;

– the search for EVSE service offers the charge spot data from most of the GeM demo regions. B2B partners connected to the marketplace can utilize these data and allow EV drivers to search for charge spots through a website, a mobile phone application or an in-car display.

It is important to stress that the marketplace being developed is open. If more operators follow the published IT architecture, services can be offered on different systems, leading to greater competition.

To set up the marketplace and support the rollout of electromobility, GeM has carried out activities in:

– standardization of different protocols, procedures and tools;

– definition of recommendations to support policy makers and technicians in a successful rollout of electromobility;

– extensive data collection program in 10 demo regions;

– preliminary analysis on the effects of different charging strategies on the grid in power quality;

– design and development of EV-related hardware infrastructure;

– set-up of key business model environments with all relevant interactions between actors defined in order to evaluate the profitability of the different business models under various market considerations.

In the next two years, other important activities will be carried out:

– assessment of impact on EVs' diffusion of support/regulatory measures at local level;

– assessment of potential market penetration of EVs;

– demonstration of new forms of EV sharing and assessment of their transport and environmental impacts.

All these activities and the related results will allow the project to provide the EU, and elsewhere, with a wide and comprehensive set of tools, studies and measures to support the diffusion of electromobility, making Europe a leading area on the subject.

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# 2

# Advanced Services for Electromobility: the Integration of the SmartCEM Project Platform for the Reggio Emilia Pilot Site

This chapter presents the Italian test site currently in progress within the smartCEM project (www.smartcem-project.eu). The EC co-funded project smartCEM is aimed at implementing an ICT platform for the integration of five electromobility services (i.e. EV-sharing management, EV-efficient driving, EV-navigation, EV-trip management and EV-charging station management) to be piloted in four different pilot sites across Europe: Barcelona, San Sebastian and Gipuzkoa county, Newcastle and Reggio Emilia. Services in Reggio Emilia will be implemented on a fleet of 10 EVs and involving users among the municipality's employees. The smartCEM project provides added value by setting up a common framework for combining the five electromobility services into a more complex integrated system. The Reggio Emilia pilot site main objectives are focused on increasing stakeholder awareness and users' confidence in electric vehicles, by assessing the acceptance of efficient driving, navigation and monitoring management services designed for EVs.

## 2.1. Introduction

### 2.1.1. *Electromobility in Europe*

Electrification of transport (i.e. electromobility) is a priority in the Community Research Programme. It also figures prominently in the European Economic Recovery Plan presented in November 2008, within the framework of the Green Car Initiative.

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Electricity as an energy vector for vehicle propulsion offers the chance to substitute oil with a wide diversity of primary energy sources. This could ensure security of energy supply and a broad use of renewable and carbon-free energy sources in the transport sector, which could help the European Union targets for $CO_2$ emission reduction.

Electric vehicle "tank-to-wheels" efficiency is about a factor of 3 higher than internal combustion engine vehicles. Electric vehicles emit no tailpipe $CO_2$ or other pollutants such as $NO_x$, NMHC and PM at the point of use. Electric vehicles provide quiet and smooth operation and consequently create less noise and vibration. Global $CO_2$ emissions have been steadily increasing over the last decades [BRI 13, DOD 09, FRA 13] making environmental sustainability a major area of interest. About 25% of $CO_2$ global emissions are generated by transport and 75% of these emissions are specifically due to road transport [INT 09, UNI 09, NAT 09]. The use of electric vehicles in place of vehicles running on fossil fuel may considerably reduce $CO_2$ emissions worldwide in the forthcoming years. By 2050, electric vehicles, if recharged using renewable resources, may be expected to have their emissions ($CO_2$ eq/km) 50–75% lower than regular vehicles (NRC 2009 and GEA 2012).

Intelligent transport systems (ITSs) – including both safety and telematic applications – have been the subject of significant research and development in Europe in recent years. Several models of passenger cars are now equipped with these ITSs as options, such as adaptive cruise control, lane departure warning and blind spot monitoring. In this context, most of the world's developed countries and large technological companies have focused their research, trialling and deployment actions to facilitate more energy-efficient and fewer petrol fuel-dependent vehicles and transport systems.

In this context, the smartCEM research project started with the main aim to demonstrate the effectiveness of and encourage the deployment of intelligent vehicle systems specifically designed for electric vehicles on European roads. Through the combination of technology and electromobility, smartCEM intends to increase the awareness of EVs and encourage the use of electric vehicles as part of everyday life. The smartCEM services will be tested by means of field operational tests (FOT) in three different European countries, namely Italy, Spain and the UK.

### 2.1.2. The *SmartCEM project*

Four European cities/regions (Barcelona, Gipuzkoa-San Sebastian, Newcastle and Reggio Emilia) have gathered together to demonstrate the role of ICT solutions for