i-RESEV NEWSLETTER

ISSUE No. 1 - September 2012

i-RESEV Project

BASIC FACTS

i-RESEV is an acronym for the research project entitled **"ICT-aided integration of Electric Vehicles into the Energy Systems with a high share of Renewable Energy Sources"**. This three-year project started in January 2012, and it has been supported by the Croatian Science Foundation, with the total budget of approximately €180,000.

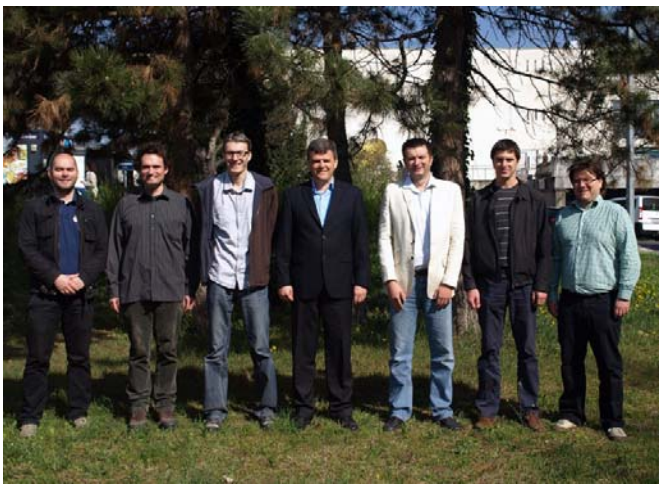
SCOPE AND OBJECTIVE

The growing presence of electric vehicles (EV), such as plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV), brings a substantial distributed battery storage that can be connected to the grid during long vehicle-parking intervals, thereby opening significant new opportunities for the grid load levelling and integration of intermittent Renewable Energy Sources (RES).

In this regard, the main objective of the project is to provide a basis for full integration of EVs into the RES-based energy systems, through extensive use of Information and Communication Technology (ICT) tools in: (i) modelling, optimisation and control of EVs; (ii) modelling, simulation and optimisation of Transport and Energy System (TES); (iii) energy system strategic planning; and (iv) supporting services such as those related to EV smart charging.

PROJECT TEAM

To achieve the above objective, the project assembles a multidisciplinary team of automotive control and energy system planning researchers with a significant international experience. The project is led by Prof. Joško Deur, Ph.D. (www.fsb.hr/acg/jdeur). The energy system planning activities are sub-coordinated by Dr. Goran Krajačić.



PROJECT ADVISORY BOARD

The project has formed an advisory board that includes the following, key Croatian industrial, electric-utility, telecommunication and retail companies, small and medium enterprises, and agencies, which work on different R&D, application and regulatory aspects of future electrified transport and RES systems: AVL-AST, DOK-ING, DURA, HEP, HT, Končar and Konzum.

DISSEMINATION

Dissemination of the research results is conducted through the project website

http://powerlab.fsb.hr/iresev/

at least one workshop per year, and publications and media announcements. Also, the project team will organise a summer school for PhD students/postdocs as a side event of the UNESCO-sponsored SDEWES conference to be held in Dubrovnik in 2013, as well as a Mini Track on Integrated Energy and Electric Vehicle Transport Systems at the same conference.

PROJECT NEWS

INTRODUCTORY PROJECT PRESENTATION

At the beginning of project, in January 2012, Prof. Deur gave an introductory presentation describing the

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project scope, main objectives, work plan and methodology, as well as expected outcomes and potential users.

PROJECT ADVISORY BOARD MEETING

Upon the aforementioned introductory presentation, the first meeting of the Project Advisory Board (PAB) has been held at the University of Zagreb-FMENA. The project team and the PAB members discussed the mutual opportunities that can emerge from the project activities, possible cooperation, data support to the project team, communication channels, and possibilities for joint participation in EU projects.

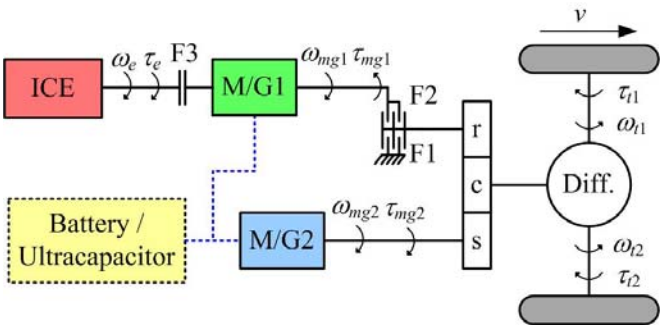
Afterwards, a number of bilateral meetings have been organised, where the project team presented the relevant research results and the possibilities of cooperation were discussed. PAB members that own large vehicle fleets have agreed to provide large-scale data sets on naturalistic driving cycles of passenger and delivery vehicle fleets, which will be used for the purpose of EV transport system characterisation and modelling, and TES system planning.

PROGRESS TO DATE

The main work tasks of the ongoing, first research year relate to EV modelling, optimisation, and control; collection and analysis of naturalistic driving cycles of vehicle fleets; and development of energy planning modelling and optimisation tools that take into account lumped EV transport features.

MODELING OF ELECTRIC VEHICLES (EVs)

BEVs have a limited travel range which depends on the battery capacity. In order to increase the EVs travel range, an internal combustion engine (ICE) can be added as another power source. With this modification, the BEV is transformed into a PHEV, which is also known under the name of Range Extended Electric Vehicle (REEV). The considered PHEV/REEV transmission consists of an ICE, two electrical machines (M/G1 and M/G2), a planetary gear used as a power split device, friction clutches (F1-F3) responsible for switching operating modes, and an electrochemical battery.



Schematic of REEV powertrain.

REEV Modes of operation	F1	F2	F3
Electric Vehicle operation (EV)	1	0	0
Two Motor Electric Vehicle operation (TMEV)	0	1	0
Series-Parallel Hybrid Electric Vehicle operation (SPHEV)	0	1	1
Series Hybrid Electric Vehicle operation (SHEV)	1	0	1
Battery Charging in park position (BCH)	0	0	1
Idle/Park	0	0	0

The REEV transmission can operate in various operating modes ranging from the electric-vehicle and series-hybrid modes to the series-parallel mode. In electric vehicle operating modes (EV and TMEV), which are predominantly active during the Charge Depletion (CD) period, all propulsion power is obtained from the battery. On the other hand, in hybrid vehicle operating modes (SPHEV, SHEV and BC), which are activated during the Charge Sustenance (CS) period, the propulsion power is obtained mostly from the engine, while the battery can be charged or can also provide additional power for electrical machines in order to boost the overall transmission power.

The transmission power flow has been analyzed and a mathematical/simulation model has been derived using the bond graph methodology. The below figure shows the transmission kinematics bond graphs, which illustrate the power flow in the SPHEV and SHEV mode. The SPHEV mode should be preferred to maximise the power flow over efficient mechanical transmission path. The bond graphs also provide the kinematic model speed and torque equations, and when extended with inertia and compliance elements they give minimum-realization dynamic models.

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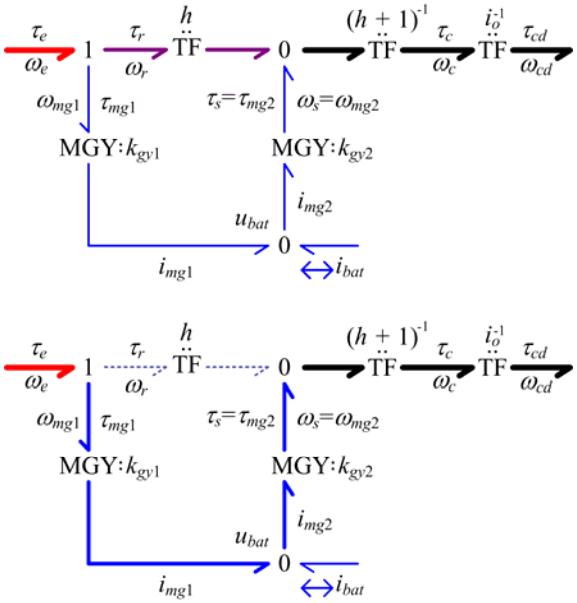
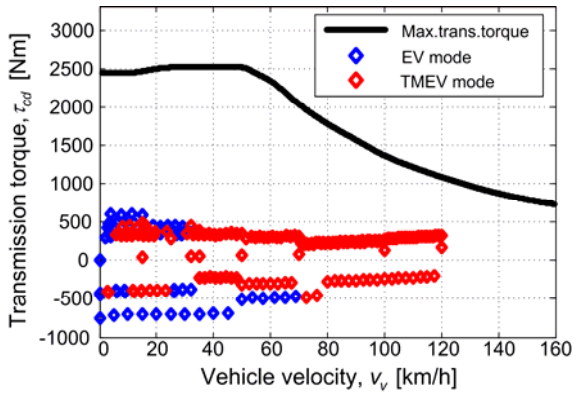


Power flow in SPHEV (upper figure) and SHEV (lower figure) operating mode.

PHEV CONTROL VARIABLE OPTIMISATION

The optimisation problem is to find optimal time responses of the transmission machines torque and speed variables and the control mode variable, which minimise the fuel and electric energy consumption, while satisfying battery state of charge (SoC) constraints and physical limits of the transmission variables. The PHEV control variable optimisation has been carried out by using the dynamic programming (DP) algorithm. These optimised control variables are then used as a benchmark for developing and verifying more realistic feedback controllers, such as traditional PHEV rule-based controllers.

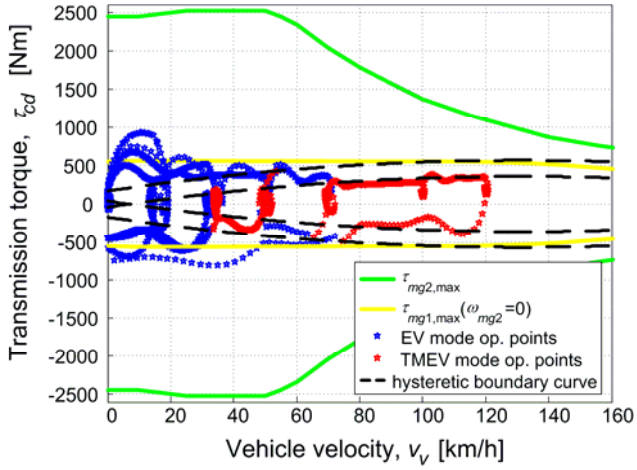


Optimisation results for New European Driving Cycle (NEDC): Operating points for CD mode.

PHEV CONTROL STRATEGY

PHEV control strategy consists of low-level and high-level subsystems. The low-level control subsystem is responsible for providing proper system transient and steady-state behaviours, in order to bring the powertrain components into operating points requested from the high-level controller. The high-level control subsystem consists of two parts: (i) optimal operating mode determination (optimal boundaries between modes are determined from offline efficiency analysis); and (ii) instantaneous optimisation of powertrain operating points for the chosen operating mode and the given vehicle velocity, driver torque demand and physical constraints. Instantaneous optimisation is combined with rule-based controller and battery SoC controller in order to avoid frequent ICE switching and to keep the battery SoC in its predefined range. The mode boundary curve hystereses are introduced to avoid deterioration of drivability due to frequent operating mode change.

The below figure indicates that the real electric driving (CD mode) control results are in a good agreement with the previously described off-line optimisation results. The controller uses TMEV mode for low-torque and mid-high velocity region (cruising, coasting and modest accelerations/decelerations), in order to reduce the electric power consumption compared to EV mode.



Control results for NEDC: Operating points for CD mode.

COLLECTION OF DRIVING CYCLE DATA

Standardized vehicle driving cycles (used for conventional vehicle certification) are generally not appropriate for verification of PHEV or BEV powertrain configurations and control strategies, especially for variable-duration vehicle missions and a wide range of driving styles. Therefore, the project team has established cooperation with the PAB partners in order to collect comprehensive sets of real-life driving cycle data from commercial vehicle fleets (including personal vehicles and urban delivery vehicles). The data include 24h time series of 3D GPS vehicle coordinates, vehicle velocity and engine speed, where the data sampling time is 1 second.

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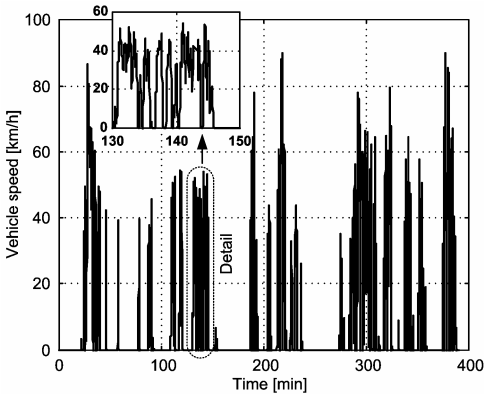


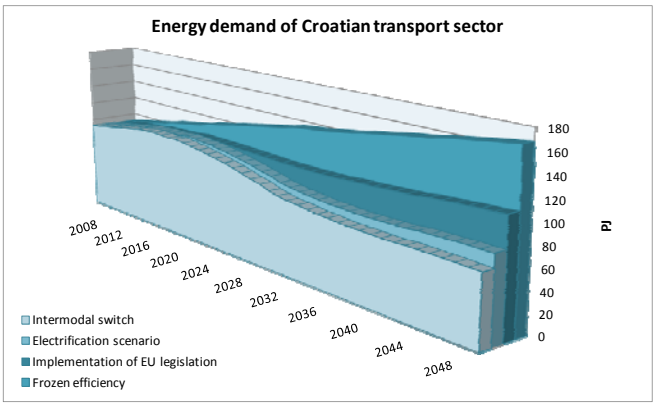
Typical driving cycle of urban delivery vehicle.

LONG TERM ENERGY DEMAND MODELING OF CROATIAN TRANSPORT SECTOR

One of the focuses of the ongoing energy planning research has been on developing a model capable of predicting long term energy demand of Croatian transport sector. First version of the model (EDT Model – Energy Demand for Transport sector) calculates total yearly energy demands, with special emphasis on vehicle population dynamics. Main intention was to show how different mechanisms, in particular energy policy and technological development, influence energy demands till the year 2050.

The EDT model is based on a bottom up methodology which turned out to be the most suitable for describing the transport sector. This approach combines and processes a large number of input data, but at the same time it allows all future energy policy and technological impact on energy demand to be quantified and compared. The EDT modelling results were compared with the Croatian national energy strategy and certain differences and conclusions were drawn. One of the major conclusions points to significant possibilities for energy efficiency improvements and lowering the future energy demand, based on a careful and rational energy planning. Namely, different financial, legal and technological mechanisms can lead to significant savings in the whole transport sector, thus resulting in lower GHG emissions and reduced dependence on foreign fossil fuels.

EDT model works as a scenario approach tool allowing users to compare different paths for future transport system. Four different scenarios are highlighted below. First scenario is the one with frozen energy efficiency throughout the modelling period. This is done solely for the purposes of comparing possible energy savings in the case of different energy efficiency mechanisms. Next scenario is the one with the implementation of EU legislation regarding energy efficiency of internal combustion engines. The third scenario presents an option of electrification of personal vehicles till the year 2050. Finally, the fourth scenario presents even more energy-efficient solution since it implies further intermodal switch from the road and air transport to the rail transport in the forthcoming period.



EDT modelling results.

The obtained results (see the graphical illustration below) predict that, if left with no technology development, energy demand of Croatian transport sector would reach 168 PJ which is an increase of 82% compared to the referent year of 2008. If we apply increase in energy efficiency of personal vehicles according to the EU regulation on CO2 emissions we can lower the energy consumption in the year 2050 by 33%. Further improvements, which are in line with the electrification of personal vehicle fleet, could lead to additional 26% energy savings. Finally, by adding the intermodal switch to the electrification scenario, additional 15% of energy can be saved. Comparing the zero efficiency scenario with the intermodal switch scenario indicates that the total possible energy saving in the Croatian transport sector in the year 2050 can be almost 99 PJ or 59%.

The more recent EDT activities have been focused on modelling hourly energy demand curves for EV transport, which represent a key input into the energy system planning and analysis tools for optimal integration of EVs into the energy systems.

ENERGYPLAN AND DEVELOPMENT OF *H2RES* ENERGY PLANNING SOFTWARE

The EnergyPLAN model is an input/output model that performs annual analyses of an energy system in steps of one hour. The model inputs are demands and capacities of the considered technologies, including the demand distributions and variable renewable energy distributions. A number of technologies can be included enabling the reconstruction of all elements of

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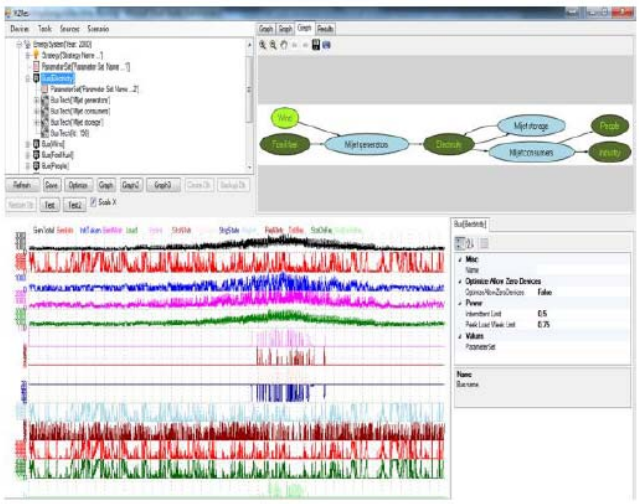
an energy system and allowing analyses of integration technologies. The model is specialised in making scenarios based on a large amount of renewable energy sources in all sectors (electricity and heat production, transport, industry and households). EnergyPLAN is free software, which can be ordered at the website http://energy.plan.aau.dk/.

EnergyPLAN has been used to model the Croatian energy system in accordance with Directive 2009/28/EC. The obtained results suggest that by promoting the RES and EV application, and by increasing the EV's consumption to 0.83 TWh (corresponding to "exported excess of RES production" in year 2020 with installed 2000 MW of wind turbines), the RES share in the gross final consumption of energy for transport could be increased to 15.3%, which is 53% above the mandatory target of 10% share. This means that the amount of biofuels on the market could be reduced by 1.2 TWh (almost a half of envisaged biofuels in calculations) or 131 million litters of biodiesel, while still fulfilling the mandatory target.

Besides running calculations in EnergyPLAN model, the i-RESEV project team is working on the development of its own H2RES energy planning software. The existing version of H2RES is being transferred to a new architecture, thus producing a standalone version of the tool running on Windows OS using the existing array of MS tools, including Visual Studio (VS), SQL Server (MSSQL) and Windows Server Operating System (OS). The new version of model is implemented in C# programming language and it extensively uses the .NET framework. The application is based on the Object-Oriented Programming (OOP) paradigm in the process, thus creating robust layers of data, logic and presentation code, which provide a framework for further expansions of different layers such as different type of consumers and supply and energy storage technologies.

An important new option that is being implemented in the software is optimization algorithm. The current approach of optimizing only according minimal installation costs will be expanded to create a best-case energy system based on environmental impact of greenhouse gas emissions, financial costs of acquisition, operation and maintenance, and in the future, demographic impact in terms of job creation given the implementation of newer, more environmentally friendly technologies. This will also allow for a much higher degree of automation in the energy planning processes, since much of the analytics can now be included directly into the application. The H2RES graphical User Interface (GUI) has also been significantly upgraded. The below figure shows the main screen display including the scheme of a modelled energy system and related graphs.



Main display of substantially upgraded H2RES energy planning software.

ENERGY POLICY AND EU DIRECTIVES

The Republic of Croatia is expected to become the full member of the European Union in July 2013. By this action, beside the rights that are belonging to each member state, Croatia will also take all obligations from EU directives and regulations. For I-RESEV project the most interesting is Directive 2009/28/EC (www.energy.eu/directives/pro-re.pdf) of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. The Directive 2009/28/EC is prescribing two important goals to be achieved by each member state by 2020. The first one relates to the RES share of energy in the gross final consumption of energy, which equals 20% for Croatia (the same share applies as the total goal for EU). The second goal is that the RES share of energy, coming from different forms of transport in a member state in 2020, equals at least 10% of the total consumption of energy in transport in that member state.

According to the directive, electricity obtained from RES could also be included in the final consumption of RES energy in the electrified transport, but then it shall be deducted from the calculations for gross final consumption of electricity from RES. Furthermore, when calculating the contribution of electricity

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produced from RES and consumed in all types of electric vehicles, the member states may choose to use either the average share of electricity from RES in the Community or the share of electricity from RES in their own country as measured two years prior to the year in question. Another important issue is that for the calculation of the electricity from RES consumed by electric road vehicles, that consumption shall be considered to be 2.5 times the energy content of the input of electricity from renewable energy sources. This rule allows countries with high share of electricity produced from renewable sources (0.4 or higher) to benefit by charging EV as every kWh of electricity consumed in transport will have the same or bigger contribution as kWh of biofuels in achieving the mandatory 10% share of RES in transport.

PUBLICATIONS

The main research results have been published in the below conference papers. The paper #6 won the Third Best Paper Award at the ICBGM Symposium. The authors of paper #5 have been invited to submit the paper for possible publication in Special Issue of the well-respected journal *Energy*. At least one more journal paper and a couple of conference papers will be submitted in this first research year.

1. Škugor, B., Pavković, D., Deur, J., "A Series-Parallel HEV Control Strategy Combining SOC Control and Instantaneous Optimisation of Equivalent Fuel Consumption", European Electric Vehicle Congress (EEVC 2012), Brussels, Belgium, 2012.
2. Škugor, B., Pavković, D., Deur, J., "A series–parallel hybrid electric vehicle control strategy including instantaneous optimization of equivalent fuel consumption", IEEE 2012 MSC conference, Dubrovnik, Croatia, 2012.
3. Cipek, M., Kasać, J., Pavković, D., Petrić, J., Deur, J., “Optimisation of Control Variables of a Series-Parallel Hybrid Electric Power train”, IEEE 2012 MSC conference, Dubrovnik, Croatia, 2012.
4. Deur, J., Cipek, M., Škugor, B., Petrić, J., "Modeling and Low-level Control of Range Extended Electric Vehicle Dynamics", 1st International Conference on Powertrain Modelling and Control (PMC 2012), Bradford, UK, 2012.
5. Pukšec, T., Lulić, Z., Mathiesen, B.V., Duić N., "Energy Policy and Long Term Energy Demand of a Transport Sector: Case Study Croatia", The 7th Conference on Sustainable Development of Energy, Water and Environment Systems Conference (SDEWES 2012), Ohrid, Macedonia, 2012.
6. Cipek, M., Deur, J., Petrić, J., "Bond Graph Modeling and Power-flow Analysis of Range Extended Electric Vehicle Transmission", 10th International Conference on Bond Graph Modeling and Simulation (ICBGM 2012), Genoa, Italy, 2012.

UPCOMING EVENTS, WEB PORTALS AND PROJECT CALLS

1st i-RESEV WORKSOP

The i-RESEV team will organise a workshop at the Faculty of Mechanical Engineering and Naval Architecture, I. Lucica 5, Zagreb, on 7th December, 2012. The main goal of the workshop is to promote the results and project achievements of the first research year. Workshop will bring together various stakeholders coming from domestic industry, academia and government, which are interested in further promotion of electric vehicles and renewable energy sources.

The workshop is anticipated to be organized in three main sections:

1) **Plenary lectures** of the project leader and the sub-coordinator of energy system planning activities, which will outline the main project outcomes in the 1st research year and the plans for 2nd and 3rd research year
2) **Panel discussion** on the importance of EV integration in future energy systems and the corresponding role of ICT technologies.
3) **Individual presentations** of the team members, concerning the results of the above-described ongoing project activities, and including demonstration of developed software tools, as appropriate.

The final schedule of the workshop will be announced in due course.

Please contact us in the next 30 days if you would like to present your R&D initiatives, activities, and results in the field of EV and their system integration to the workshop participants.

2ND MEETING OF PROJECT ADVISORY BOARD

Immediately after the workshop, the representatives of the project team and the PAB member companies will hold their second meeting to discuss the project results and mutual interactions during the first research year, and outline the plans for cooperation in the next research year.

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8th SDEWES CONFERENCE, Dubrovnik, Sep 2013

The 8th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES Conference, www.dubrovnik2013.sdewes.org), to be organised in Dubrovnik in 2013 by the University of Zagreb-FMENA, is dedicated to the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from natural resources and replacing them with knowledge based economy, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding energy, transport, water, environment and food production systems and their many combinations. At the beginning of the 21st century, SDEWES Conference has become a significant venue for researchers in those areas to meet, and originate, discuss, share, and disseminate new ideas. The last, 2011 SDEWES conference in Dubrovnik had more than 450 participants from 55 countries.

SPECIAL SESSION ON 2013 SDEWES

As a part of the 2013 SDEWES conference, i-RESEV team will organise a Special session or a Mini track on the topic of **Integrated Energy and Electric Vehicle Transport Systems**. Details of the Special session including the paper submission procedure will be announced soon on the i-RESEV and SDEWES webpages.

I-RESEV 2013 International Summer School

In order to further facilitate cooperation among young researchers and provide a wider dissemination of the project results, I-RESEV team will organise an international summer school for PhD students and other interested parties from industry/government as a side event of the 2013 SDEWES Dubrovnik conference. Respectable scientists will be invited to give lectures at our summer school.

More information on the summer school including the registration details will be announced soon on the i-RESEV and SDEWES webpages.

CONFERENCES

The following forthcoming conferences are closely related to the topic of i-RESEV project.

- Intelligent Transportation Systems Conference, 16-19 September, 2012, Anchorage, USA
  http://www.itsc2012.org/
- The 8th IEEE Vehicle Power and Propulsion Conference (VPPC 2012), October 9-12, 2012, Seoul, Korea
  http://www.vppc2012.org/info/about.php
- Transmission and Distribution – Smart Grids Europe, 9-11 October, 2012, Amsterdam, Netherlands
  http://www.td-europe.eu/
- Third IEEE PES Innovative Smart Grid Technologies (ISGT) Europe Conference, Berlin, Germany, October 14 – 17, 2012.
  http://www.ieee-isgt-2012.eu/
- The fourth Conference on Innovative Smart Grid Technologies (ISGT 2013), 24-27 February, 2013, Washington DC, USA
  http://ieee-isgt.org/
- Power and Energy Conference at Illinois (PECI 2013), 22–23 February, 2013, Urbana, IL, US
  http://peci.ece.illinois.edu
- Society of Automotive Engineers' International World congress (SAE 2013), 16 - 18 April, 2013, Detroit, Michigan, USA
  http://www.sae.org/congress/2013/
- 1st IEEE Workshop on Electric Vehicle Networks for Smart Grid Applications (EVN-SGA 2013), 2-5 June, 2013, Dresden, Germany
  http://www.nprg.ncsu.edu/evn-sga/index.html
- The 2013 IEEE Intelligent Vehicles Symposium, Gold Coast, 23-26 June, 2013, Broadbeach, Queensland, Australia
  http://www.iv2013.org/
- The 8th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2013), 22-27 September, 2013, Dubrovnik, Croatia
  http://www.dubrovnik2013.sdewes.org/
- The 27th World Electric Vehicle Symposium and Exhibition (EVS27), 17-20 November, 2013, Barcelona, Spain
  http://www.evs27.org/

FP7 INITITATIVES AND PROJECT CALLS

Smart Cities is a target research and innovation area of the European Framework Programme for Research and Innovation (currently FP7), which is closely related to the topic of i-RESEV project. In order to prepare the constituency, the FP7 Themes ICT and ENERGY are launching this Cross-thematic call. More detail on the Smart Cities and other related European Industrial Initiatives can be found on the SETIS web page http://setis.ec.europa.eu/implementation/eii. Among the related initiatives, from the standpoint of i-RESEV project theme it is important to mention the European **Green Cars** Initiative (www.green-cars-initiative.eu), as one of three Public Private Partnerships in research.

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The ICT contribution to Smart Cities initiative aims at improving the cost and energy-efficiency of the fully electric vehicle and its value chain through the application of advanced ICT. Interesting open topics in FP-7-ICT-2013 are under the Objective **GC-ICT-2013.6.7 Electro-mobility**.

There are also two interesting Topics open in the FP-7-ENERGY-2013. These are:

- Topic **ENERGY.2013.7.3.1**: Planning rules for linking electric vehicles to distributed energy resources
- Topic **ENERGY.2013.7.3.2**: Enhanced inter-operability and conformance testing methods and tools for interaction between grid infrastructure and electric vehicles.

The Deadline for project application under FP7-SMARTCITIES-2013 is the 4th December 2012 at 17.00.00 (Brussels local time).

WEB PORTALS

There are a number of web portals, magazines and libraries that deal with electrified road transport and its integration into energy systems. Here are some of the most relevant ones.

- Society of Automotive Engineers (SAE)'s International Global Technology Library – Electric Vehicle
  http://saegtl.org/ev/
- Vehicle Electrification (SAE)'s Magazine
  http://ev.sae.org/
- Information and Communication Technologies for the Fully Electric Vehicle
  http://cordis.europa.eu/fp7/ict/micro-nanosystems/docs/brochure-ict-for-fev-2nd-edition-2011_en.pdf
  http://www.ict4fev.eu/public/
- European Green Cars Initiative
  http://www.green-cars-initiative.eu/public/
- The IEEE Transportation Electrification Initiative
  http://electricvehicle.ieee.org/
- E-mobilnost
  http://www.e-mobilnost.hr/

DISCLAIMER

The opinions, findings, conclusions and/or recommendations included in this newsletter are of sole responsibility of the project team, and they do not necessarily reflect standpoints of the Croatian Science Foundation.

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