MIT Portugal

Power demand estimation and power system impacts resulting of fleet penetration of electric /plug-in vehicles

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Institutions/Research Centers involved: IDMEC/IST; INESC-Porto; IN+/IST; MIT	
Companies involved: GALP; EDP; APVE	
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1.Questions to be answered:

- What would be the impact on energy and emissions in the road transportation sector of introducing alternative powertrain technologies in Portugal, mainland and islands?
- What would be the impact of introducing vehicles requiring electricity on the electrical grid? What changes would be necessary to satisfy the demand?
- What would be the technology price evolution for Portugal, user point of view and society point of view?

2.Main models

Road transportation sector model: PATTS - Projections for Alternative Transportation Technologies Software to estimate the evolution of fleets along time, allowing the evaluation of the effect of introducing alternative vehicle technologies and alternative energy pathways in a full life-cycle approach.

Inputs: motorization curves over 2010-2050, mobility patterns in vehicle x kilometer over 2010-2050, scrappage rates, sales curve for EV, PHEV, FC vehicles, electricity mix over 2010-2050, biofuel incorporation (%) in fuel over 2010-2050, fuel consumption and emission factors for the different technologies.

Methodology: forecast/backcast with discrete modeling and linear programming.

Outputs: CO_2 in LCA, energy consumption in LCA, local pollutants in WTW, cost for the user, maximum and minimum border lines for multi-scenario analysis of the road transportation sector; regional versus overall impacts.

Application: Portuguese road transportation sector and specific island applications in the Azores.

Grid steady state analysis model*:* a Monte Carlo approach for simulating different scenarios of EV loads within a distribution network, during a given period. Power flow evaluations using the Newton-Raphson formulation will be performed for every time step, typically 0.5/1 hour, to evaluate grids' technical indicators.

Inputs: EV penetration, types of EV, mobility patterns (daily commute profiles), EV owner charging behavior, and conventional load diagram.

Outputs: Load diagram (EV+conventional load), voltage profiles, branches congestion levels, and energy losses.

Application: Flores island, S. Miguel island and typical networks from Portugal mainland.

Grid dynamic simulation platform: a primary frequency control model for EV in isolated grids, based on a droop control implementation, using a numerical integration method with a variable time step to perform the necessary simulations.

Inputs: EV penetration, types of EV, mobility patterns (daily commute profiles), EV owner charging behavior, conventional load diagram, generation units representations for dynamic studies,

disturbances on the network or on resource availability.
Outputs: voltage and frequency fluctuations, machines power and torque variations, EV and conventional generators active and reactive power production.
Application: Flores and S. Miguel islands.

3.Innovation

- Life cycle integration for energy, CO_2 emissions and local pollutants of different alternative vehicle technologies and energy sources pathways with forecast/backcast tool
- Monte Carlo application to scenario uncertainty, and estimation of maximum and minimum border lines for multi-scenario analysis of the road transportation sector in the time horizon 2010-2050
- Inclusion of trucks and buses
- Cost and price analysis in the time horizon 2010-2050 for Portugal
- Regarding power system analysis:
    - For steady state:
        - Impact evaluation tool considering the stochastic behavior of EV
        - Smart charging algorithm from different players' perspectives
    - For dynamic:
        - Scenarios with generation based only on renewable energy resources
        - Droop control implementation on EV
- Joint evaluation of LCA and power system analysis allowing a full extent study from the transportation and electricity sectors

4.Publications

Books/book chapters

1. F. J. Soares, P. M. Rocha Almeida, J. A. Peças Lopes, Rodrigo Garcia-Valle, "State of the Art on Different Types of Electric Vehicles," in "Electric Vehicle Integration into Modern Power Networks," Springer, 2012.
2. F. J. Soares, P. M. Rocha Almeida, J. A. Peças Lopes, "Advanced Models and Simulation Tools to Address the Impacts of Electric Vehicles in the Power System (Steady State and Dynamic Behavior)," in "Electric Vehicle Integration into Modern Power Networks," Springer, 2012.
3. P. M. Rocha Almeida, F. J. Soares, J. A. Peças Lopes, "Impacts of Large Scale Deployment of Electric Vehicles in the Electric Power System," in "Electric Vehicle Integration into Modern Power Networks," Springer, 2012.
4. Cristina Camus, Tiago Farias, Jorge Esteves, Chapter 8 INTEGRATION OF ELECTRIC VEHÍCLES IN THE ELECTRIC UTILITY SYSTEMS, In Tech Open access publisher "Electric Vehicles the Benefits and Barriers" Edited by Seref Soylu, 2011
5. Silva CM and Farias TL Evaluation of Energy Consumption, Emissions and Cost of Plug-in Hybrid Vehicles. Elsevier's book: "*Electric and Hybrid Vehicles*." editor Gianfranco Pistoia, 2010.

Master thesis

1. Published - João Ribau. Análise de factores de consumo eléctrico e de hidrogénio em veículos puramente eléctricos e Plug-in eléctricos. IST, 2009.
2. Published - Manuel Branco Nery Nina, Introduction of Electric Vehicles in Portugal - A Cost-benefit Analysis, Master thesis in Mechanical Engineering, IST, 2010.
3. Published - Cristina Falcão. Energy consumption and CO2 emissions of the Biohydrogen life cycle. Master thesis, IST, 2010.

4. Published - Luis Oliveira. Development of a model to control an Energy Box in the scope of V2G Technology.Master thesis, IST, 2010.
5. Published - Carlos Oliveira. Integração de Veículos Eléctricos em Redes Isoladas, FEUP, 2011.
6. Published - Manuel Valente. Cenários de evolução de preços dos combustíveis e das novas tecnologias para veículos rodoviários até 2050. IST, 2011.

PhD thesis

1. Cristina Camús. Economic, energy and environmental impacts of plug in vehicles in the electric utility systems. PhD thesis, IST, 2012.
2. Published - Patricia Baptista, Evaluation of the impact of new vehicle and fuel technologies in the Portuguese road transportation sector, PhD thesis, IST, 2011.
3. Filipe Soares. Impact of the Deployment of Electric Vehicles in Grid Operation and Expansion, PhD thesis, FEUP, 2012.
4. Pedro Almeida. Impact of vehicle to grid in the power system dynamic behaviour, PhD thesis, FEUP, 2012.

Per reviewed journal

1. Published - Cristina Camus, Tiago Farias, The electric vehicles as a mean to reduce CO2 emissions and energy costs in isolated regions. The são miguel (azores) case study, Energy Policy, Volume 43, Pages 153–165, 2012;
2. Published - Camus, Tiago Farias, Jorge Esteves, Potential impacts assessment of plug-in electric vehicles on the Portuguese energy market, Energy Policy 39 (2011), pp. 5883-5897;
3. Published - J. A. Peças Lopes, F. J. Soares, P. M. Rocha Almeida, “Integration of Electric Vehicles in the Electric Power System”, Proceedings of the IEEE, vol. 99, no. 1, pp. 168–183, Jan. 2011;
4. Published - Ana F. Ferreira, Ana C. Marques, Ana P. Batista, Paula A.S.S. Marques, Luísa Gouveia, Carla M. Silva. Biological hydrogen production by Anabaena sp. -Yield, energy and CO2 analysis including fermentative biomass recovery. International Journal of Hydrogen Energy 37(2012) 179-190;
5. Published - Ferreira AF, Ribau JP, Silva CM. Energy consumption and CO2 emissions of potato peel and sugarcane biohydrogen production pathways, applied to Portuguese road transportation, International Journal of Hydrogen Energy. 36(2011)13547-13558;
6. Published - Carla Silva. Electric and plug-in hybrid vehicles influence on CO2 and water vapour emissions. International Journal of Hydrogen Energy. 36 (2011) 13225-13232;
7. Published - P. Baptista, M. Tomás and C. Silva. Hybrid plug-in fuel cell vehicles market penetration scenarios. International Journal of Hydrogen Energy. Vol. 35, 18 (2010) 10024-10030;
8. Published - J. Ribau, C. Silva and T. Farias. Electric and hydrogen consumption analysis in plug-in road vehicles. International Journal of Energy and Environment. Volume 1, Issue 2, 2010, pp.199-220;
9. Published - P. Baptista, C. Silva, G. Gonçalves and T. Farias. Full life cycle analysis of market penetration of electricity based vehicles. World Electric Vehicle Journal Vol. 3, 2009;
10. Published - G. Gonçalves, J. Bravo, P. Baptista, C. Silva, and T. Farias. Monitoring and Simulation of Fuel Cell Electric Vehicles. World Electric Vehicle Journal Vol. 3, 2009.

Conferences (International)

1. Published-Ana F. Ferreira, Patricia Moura, Luísa Gouveia and Carla Silva. Cyanobacteria and microalgae biohydrogen production - Life Cycle Inventory approach and process improvements. WHEC2012 – 19th Word Hydrogen Energy Conference, Toronto, Canada, 3 to 7 of June 2012.
2. Published- Cristina Camus, Tiago Farias, ELECTRIC VEHICLES AS A MEAN TO REDUCE, ENERGY, EMISSIONS AND ELECTRICITY COSTS EEM 12 – The 9th International Conference on European Energy Market, Florence May 10-12, 2012.
3. Published- P. M. Rocha Almeida, C. L. Moreira, F. Soares, J. A. Peças Lopes, "Exploiting the Potential of Electric Vehicles to Improve Operating Conditions in Islanded Grids", CIGRÉ 2011, Bologna, Italy, September 2011.
4. Published - P. M. Rocha Almeida, J. A. Peças Lopes, F. J. Soares, L. Seca, "Electric Vehicles Participating in Frequency Control: Operating Islanded Systems with Large Penetration of Renewable Power Sources", Powertech 2011, Trondheim, Norway, June, 2011.
5. Published - F. J. Soares, J. A. Peças Lopes, P. M. Rocha Almeida, C. L. Moreira, Luís Seca, "A Stochastic Model to Simulate Electric Vehicles Motion and Quantify the Energy Required from the Grid", PSCC 2011, Stockholm, Sweden, August, 2011.
6. Published - Ana F. Ferreira, Joana Ortigueira, L. Alves, Luísa Gouveia, Patrícia Moura, Carla M. Silva – "Energetic and environmental evaluation of microalgae biomass fermentation for biohydrogen production". 4th Internacional Seminar: Advances in Hydrogen Energy Technologies, Viana do Castelo, Portugal, 10- 11 November 2011.
7. Published- João P. Ribau, Carla M. Silva. Conventional to Hybrid and Plug-In Drive-train Taxi Fleet Conversion. European Electric Vehicle Congress, EEVC, Brussels, Belgium, 26-28 October 2011
8. Published- Christos Ioakimidis, Jorge Borges, Dimitris Savvidis. The use of Electric Vehicles in Greece: A Case Study. 3rd European Conference SmartGrids & E-Mobility, Munich, October 17th – 18th, 2011.
9. Published- J. Borges, C. S. Ioakimidis, T. C. de Barros. Fast Charging Station Business analysis. 3rd European Conference SmartGrids & E-Mobility, Munich, October 17th – 18th, 2011.
10. Published - A.F.Ferreira, J. Ribau and C. Silva. Biohydrogen pathways for the Portuguese road transportation sector - Uncertainty in the LCA analysis. IAMF 2011 8-9 March 2011, Geneve, Switzerland;
11. Published - João P. Ribau, Ana F. Ferreira, Carla M. Silva, Hybrid vehicle alternative fuel converter, energy strategy optimization and application to a fuel cell plug-in hybrid vehicle. IAMF 2011, 8-9 March 2011, Genève, Switzerland;
12. Published - Cristina Camus, Tiago Farias, Jorge Esteves, IMPACTS OF ELECTRIC VEHICLES' CHARGING STRATEGIES IN THE ELECTRICITY PRICES EEM 11 –The 8th International Conference on European Energy Market, Zagreb May 25-27, 2011;
13. Published - Cristina Camus, Tiago Farias, Jorge Esteves, IMPACT OF THE INTRODUCTION OF PLUG IN ELECTRIC VEHICLES IN THE IBERIAN ELECTRICITY MARKET, EEM 10 - The 7th International Conference on European Energy Market, Madrid Jun. 17-19, 2010.
14. Published - J. A. Peças Lopes, P. M. Rocha Almeida, F. J. Soares, C. L. Moreira, "Electric Vehicles in Isolated Power Systems: Conceptual Framework and Contributions to Improve the Grid Resilience", CMTEE 2010 – Conference on Control Methodologies and Technology for Energy Efficiency, Vilamoura, Portugal,March, 2010.
15. Published - F. J. Soares, J. A. Peças Lopes, P. M. Rocha Almeida, "A Monte Carlo Method to Evaluate Electric Vehicles Impacts in Distribution Networks", 2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply, Boston, USA, September, 2010.

16. Published - R. J. Rei, F. J. Soares, P. M. Rocha Almeida, J. A. Peças Lopes, "Grid Interactive Charging Control for Plug-in Electric Vehicles", 13th International IEEE Conference on Intelligent Transportation Systems, Madeira, Portugal, September, 2010.
17. Published - F. J. Soares, P. M. Rocha Almeida, J. A. Peças Lopes, L. Seca, C. L. Moreira, "A Technical Management and Market Operation Framework for Electric Vehicles Integration into Electric Power Systems", 2nd European Conference on Smart Grids and E-Mobility, Brussels, Belgium, October, 2010
18. Published - C.S.Ioakimidis, J. Borges, P. Ferrão, Presentation 'Business Approach to Electric Vehicles Fast Charging Stations', Proceedings of´SGM-3515, 2nd European Conference SmartGrids and E-Mobility´, Brussels, Belgium, 20-21 October, 2010, p.52-59.
19. Published - L. Oliveira, C.S.Ioakimidis, P. Ferrão, Presentation 'The Energy Box – a Model for Optimizing the Electricity Management Decisions', Proceedings of ´SGM-3515, 2nd European Conference SmartGrids and E-Mobility´, Brussels, Belgium, 20-21 October, 2010, p.156-161.
20. Published - C.S. Ioakimidis, P. C. Ferrão, Presentation 'Pathways towards an Electric Vehicles Society', Proceedings of The 25thInternational Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition (EVS25 Towards Zero Emission), Shenzhen, China, 5-9 November, 2010, p.8.
21. Published - J. Borges, C.S. Ioakimidis, P. C. Ferrão, Presentation 'Business model for Electric Vehicles charging infrastructures', Proceedings of The 25thInternational Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition (EVS25 Towards Zero Emission), Shenzhen, China, 5-9 November, 2010, p.6.
22. Published - P.Baptista, C. Silva and T. Farias. Impacts in the Portuguese light-duty road transportation sector of increasing market electrification scenarios. Fisita 2010-Automobiles and Sustainable Mobility, 30 May – 4 June, Budapest.
23. Published - Ana Filipa Ferreira, Patricia Baptista and Carla Silva. Analysis of energy consumption and CO2 emissions of the life cycle of biohydrogen applied to the Portuguese road transportation sector. WHEC- World Hydrogen Energy Conference, May 16 - 21, 2010, Essen, Germany;
24. Published - A. F. Ferreira, P.Baptista and C. Silva. Bio-hydrogen pathways for the Portuguese road transportation sector. Fisita 2010-Automobiles and Sustainable Mobility, 30 May – 4 June, Budapest;
25. Published - P.Baptista, C. Silva and T. Farias. Energy and CO2 emissions scenarios of introducing new vehicle technologies in the Portuguese fleet. IAMF 2010 -International Advanced Mobility Forum, 9-10 March 2010;
26. Published - C. Camus, P. Baptista, C. Silva and T. Farias. Strategic marketing plan for battery electric vehicles. the Portuguese case. IAMF 2010 – International Advanced Mobility Forum, 9-10 March 2010;
27. Published -P.Baptista, C. Silva and T. Farias. Impacts on CO2 emissions of market penetration of new technologies/fuels in the Portuguese light-duty road transportation sector. WCTR 2010-12th World Conference on Transport Research,11-15 July 2010, lisboa;
28. Published - D. Livengood, F. Sim Sim, C.S.Ioakimidis, R.Larson, ´Responsive Demand in Isolated Energy Systems´ First International Conference on Island Sustainability, Brac Island, Croacia, 19-21 April, 2010.
29. Published - J.Borges, C.S. Ioakimidis, P. Ferrão, ´Fast charging stations for Electric Drive Vehicles infrastructure´ First International Conference on Island Sustainability, Brac Island, Croacia, 19-21 April, 2010.
30. Published - Patrícia Baptista, Cristina Camus, Carla Silva, Tiago Farias, Impact of the introduction of electric based vehicles in São Miguel island, 10th International Conference on Energy for a Clean Environment, Lisbon Portugal, 7-10 July 2009;

31. Published - Patricia Baptista, Carla Silva and Tiago Farias, Impact of the introduction of new vehicle technologies in the Portuguese road transportation sector, 1st Transatlantic NECTAR Conference 2009, Arlington, Virginia USA, 18-20 June, 2009
32. Published - P. Kadurek, C.S. Ioakimidis, P. C. Ferrão, 'Electric Vehicles and their Impact to the Electric Grid in S. Miguel', Proceedings of International Conference on Power Engineering, Energy and Electrical Drives, (http://ieeexplore.ieee.org/stamp/stamp.jsp? arnumber= 04915218, Paper 147), p. 49-54, Lisbon, Portugal March 18-20, 2009.
33. Published - P. Kadurek, A. Pina, C. Ioakimidis, P. C. Ferrão, 'São Miguel Island as a case study on a possible usage of Electric vehicle to store energy', Proceedings of The 24th International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition, Stavanger, Norway, May 13-16, 2009.

Conferences (National)

1. Published- Silva C. Research on Electric drive vehicles, 2º encontro de Jovens Investigadores do LAETA, 10-11 de Abril, 2012.
2. Published – Baptista, P. C.. Energy, environmental and economic impact evaluation of the massification of ICT solutions in urban mobility. GET 2012, 5-6 January 2012, Tomar, Portugal
3. Published - A.F.Ferreira, J.Ribau and C. Silva. Análise de Ciclo de Vida do Biohidrogénio – sua aplicação a transportes em Portugal. GET 2011, 5-6 January 2011, Estremoz, Portugal
4. Published - Silva, C.M , Life cycle assessment of alternative vehicles, 1º encontro de Investigadores do LAETA, 15 de Novembro 2010.
5. Green Feast 2009, Auditório do Estoril, Estoril, 18-25 Setembro 2009
6. MIT-Mid-Program Event, Centro Cultural de Belém, Lisbon, 7 July 2009

5.Role of MIT

Provided know-how. Professor J. Heywood contributed to the most probable visions within the fleet model PATTS and scenario's combinatory analysis

6.Role of Industrial partners

Provided industrial visions for fuels future possibilities and power plants data

7.Research impact/Expected benefits

Develop of new charging management strategies, always taking into account the drivers' requests concerning the foreseen use of the vehicles, assuming the existence of some smartgrid functionalities, like smart-metering and a reliable and efficient communication platform;

Quantify the maximum number of EV that can be safely integrated in a given distribution network;

Minimize the deviations between the energy bought in the markets by the aggregators and the energy sold to EV owners; and the renewable energy wasted in systems with a large integration of intermittent RES;

Flatten, as far as possible, the load diagram of a given network;

Assess the results (energy and CO2 in LCA) of a large number of scenarios through impact indicators applied to road transportation sector (LDV and HDV/Bus);

Develop new procedures to enable EV participation in primary and secondary frequency control schemes;

Assess the effects that a mass introduction and the different daily charging profiles of plug-in vehicles will have in electricity prices.