CaPP: Car as Power Plant*

with Plus Project in Amsterdam**

Team

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Partners

Delft University of Technology ▪ GasTerra ▪ Eneco ▪ Stedin ▪ BAM ▪ Q-Park ▪ HyTruck ▪ The Green Village ▪ Shell

Period

1 September 2014 – 31 October 2018

* **Full title:**
Car as Power Plant – Fuel cell cars creating an integrated, efficient, reliable, flexible, clean, multi modal and smart transport and energy system

** **Full title:**
Modelling and designing 'Car as Power Plant' systems in a real life environment at Shell Technology Centre Amsterdam and at the Amsterdam Arena Stadium

Integrating transport and energy systems

The Car as a Power Plant (CaPP) project envisioned an integrated transport and electricity system, in which wind and solar power dominate the electricity production mix, hydrogen is a key energy carrier, and Fuel Cell Electric Vehicles (FCEV) play a key role in energy storage and flexible power production. The CaPP project investigated the feasibility of a hydrogen fuel-cell car system by designing a detachable, decentralized multi-modal energy system, combined with policy recommendations for stimulating the transition to a clean, reliable and affordable CaPP system.

* Three design concepts

Three system design concepts have been developed: Car as Power plant in Smart City Areas, the Car as Hospital Power Plant, and the Car Park Power Plant. These system designs can function as blueprints for future national and local energy and transport systems.

* Model Predictive Control approach

A robust Model Predictive Control algorithm has been designed for a CaPP microgrid system that is able to guarantee the power balance condition in presence of the uncertainty in the load and generation of renewable energy sources. To test the algorithm, a hybrid model of the microgrid is developed in the standard form of a mixed logical dynamical model. The algorithm will enable the operation of electrolysers and FCEVs at minimum costs.

* Institutional arrangements based on modelling operational schedules

To investigate the performance of CaPP systems from the perspectives of fairness and self-sufficiency, various computer models have been developed and used.

Read more

1 E. Park Lee, F. Alavi, Z. Lukszo (2017): *Fuel cell cars in a microgrid for synergies between hydrogen and electricity networks*, *Applied Energy*

2 E. Park Lee, Z. Lukszo (2017): *Complex Systems Engineering: designing in sociotechnical systems for the energy transition*, *EAI Endorsed Transactions on Energy Web*

3 Z. Lukszo, P. Herder, E. Park Lee (2018): *Conceptualization of Vehicle-to-Grid Contract Types and Their Formalization in Agent-Based Models*, *Complexity*

The research programme Uncertainty Reduction in Smart Energy Systems (**URSES**) aims to make a quick transition to a reliable, affordable and sustainable energy system possible. It is a joint initiative of several departments of NWO, Shell, AMS and the TKI Urban Energy.

A scheduling mechanism of a CaPP-based microgrid with a fair scheduling mechanism for FCEV vehicle-to-grid operation can be used to support the self-sufficiency of a small neighbourhood while fairly distributing the number of start-up times of FCEVs. Several institutional arrangements in an agent-based model have been studied.

Business concepts

The economic potential of CaPP systems has been explored through the development of a few business concepts central to CaPP: energy storage through water electrolysis and V2G operation, the car park as balancing power plant, and hydrogen production and transport as an alternative to power transmission line investment. High-level cost-benefit analyses have been performed for these concepts, the related business models have been worked out for different actors, and prerequisites and other influential system and market conditions have been formulated and considered through sensitivity analysis.

Insights & recommendations

[1] A community microgrid with photovoltaic systems, wind turbines, and fuel cell electric vehicles can be used to provide vehicle-to-grid power when renewable power generation is scarce.

[2] A framework has been developed accounting for technology, institutions and actors' perspective to design in socio technical systems, and has been applied to (a) biodiesel production in Germany and (b) vehicle-to-grid contracts in a Car as a Power Plant microgrid. This framework can contribute to the performance improvement of these systems.

[3] To integrate Fuel cell electric vehicles (FCEVs) through vehicle-to-grid (V2G), new kinds of agreements and contracts are needed between the FCEV owners and the actor that coordinates V2G on behalf of them, usually considered the aggregator. Modelling and simulations have shown how price-based contracts can be applied for selling V2G in the wholesale electricity market and how volume-based contracts can be used for balancing the local energy supply and demand in a microgrid. The models can provide a base for exploring strategies in the market and for improving performance in a system highly dependent on V2G.

NWO Netherlands Organisation for Scientific Research

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

TKI URBAN ENERGY Topsector Energie