STUDENT AWARDS

Q-PARK Quality in parking

PARKING AND ELECTRIFICATION

CAR PARK POWER PLANT

Student information
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Graduation year: 2015

Exploring the operation of a Car Park Power Plant - Formalising the operation of a system innovation with the Actor-Option Framework

The Car Park Power Plant (CPPP) concept is in its essence a parking garage in which parked fuel cell vehicles (FCVs) are used for the generation of electricity.

On-site hydrogen production

By including on-site hydrogen production methods, the CPPPs could purchase electricity when it is cheap, store it, and convert it back to electricity when the electricity price is high.

System innovations such as the CPPP concept lead to large scale changes in infrastructure systems such as the electricity and the passenger transport infrastructure.

The infrastructural systems are complex systems in which designers of new elements are unable to control the use of these elements once deployed.

Knowledge is currently lacking concerning the influence of CPPP design choices and environmental uncertainties, on the possible future operational performance of the installation.

In order to aid in the delineation of the possible design space of CPPPs, we have set the objective of providing an approach that is capable of identifying possible barriers for the successful operation of a CPPP.

To structure our research we have used the following research question:

Which Car Park Power Plant design elements or environmental factors could form barriers for the successful operation of an introduced CPPP installation?

To answer this question a literature study was conducted to find an appropriate theory to guide the identification of a relevant but delineated system representation. The Actor Option Framework was selected to serve this purpose.

Six factors form possible barriers

The system delineation was used to construct an agent based model that has been explored for possible behaviours of the CPPP and its surroundings. With the aid of the model we identified six factors that in sets of three form possible barriers for a successful operation of a CPPP:

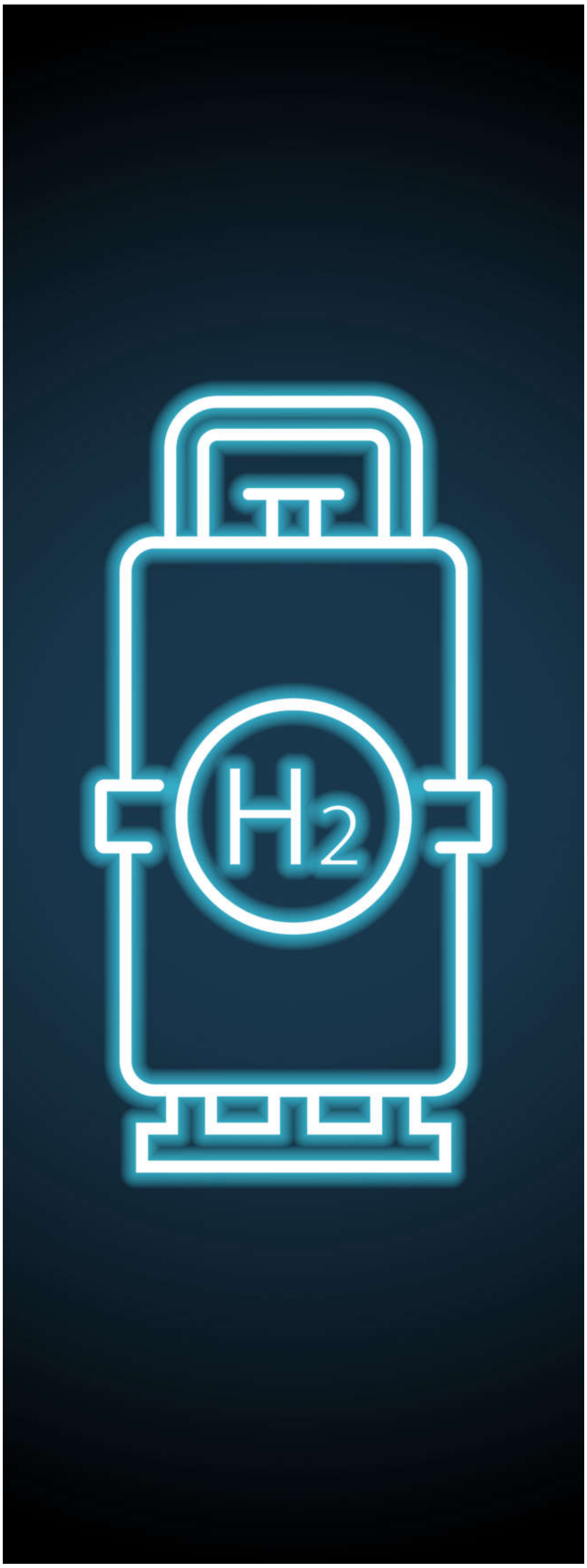
- The usage of simple CPPP operation tactics will result in CPPPs to produce electricity at all moments that satisfy the selected use-case. As a result the CPPP desires to produce electricity during many hours of the day.
- FCVs are expected to have production capacities of around 100 kW. If the conversion efficiencies of FCVs remain in the range of what they are now, the FCVs could require an amount of hydrogen per hour that comes close to the daily capacities of today’s on-site hydrogen production devices. Combined with the desire to produce electricity during many hours a day, an unsatisfiable hydrogen demand and a continuous hydrogen production emerges.
- Without the possibility to determine profitable hours of hydrogen production, the possibility of making use of the price differences of electricity during a day will no longer be present. As a result the value of storage becomes too small to compensate for the conversion losses within the

CPPP. In these cases the CPPP can be expected to make operational losses due to the absence of a positive profit margin.

- Choosing to reward motorists who park at a CPPP with a free refill of hydrogen is unlikely to have significant effects on their perceptions. Due to the fact that FCVs consume a small amount hydrogen per driven kilometre, the perceived monetary value of the received free hydrogen is insufficient to structurally persuade motorists to park at the CPPP.
- Also the effect of the existence of a CPPP on the decision of a motorist with respect to the choice between purchasing an FCV or a conventional vehicle could be limited. Benefits that a CPPP could offer for FCV owners are a reduction in fuel costs and an improved environmental performance of their vehicle. The valuation of these benefits by motorists is however insignificant when compared to the valuation of the purchase price of vehicles.
- If both the share of motorists with an FCV and the share of these motorists that park their car at a CPPP are low, the CPPP will have to rely on a very large motorist population. This would make it difficult to find a suitable location that such a large base population would consider to use as a daily parking location.

We observe that the approach as we have used it is capable of identifying possible operational barriers for CPPPs and possibly for system innovations in general.

The knowledge gained from this study can be used as a base to further explore the possible operation of CPPPs, as a base for discussion concerning possible CPPP designs or as substantiation for research towards the identified factors.



CHARGING EVS AT THE WORKPLACE

Student information
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Advancing sustainable transportation by charging EVs with PV power at the workplace: an optimal charging strategy

Arguably, the most important challenge of our time is climate change. In The Netherlands in 2014, 30% and 21.5% of total CO_2 emissions were emitted by the electricity producing and transportation sector, respectively.

Electric vehicles (EVs) have therefore gained interest as they do not emit carbon dioxide whilst driving and therefore do not pollute, at least directly.

Nevertheless, when EVs are charged with electricity produced by a fossil-fuel power plant there are indirect emissions. Additionally, high penetration of EVs will inevitably lead to increased stress on the grid and consequently capital expenditure.

A viable solution to mitigate both these disadvantages is by charging EVs at the workplace with locally produced photovoltaic (PV) power. The high level of coincidence between parking time and solar power paves way to charge EVs in a sustainable and cost-efficient manner.

Energy Management System

The thesis work presents the design of an energy management system (EMS) capable of forecasting PV power production and optimising power flows between PV system, grid and EVs at the workplace.

The aim is to reduce energy demand on the grid by increasing PV self-consumption while minimising charging costs and consequently increasing sustainability of the EV fleet.

The developed EMS consists of two components: an autoregressive integrated moving average (ARIMA) model to predict PV power production and a mixed integer linear programming (MILP) framework that optimally allocates power to minimise charging costs.

The EMS is designed such that it can be implemented in practice and moreover, is versatile, implying that it can be utilised for alternative purposes as well. Additionally, the predictive quality of the system enables it to anticipate and act accordingly, rather than solely react.

In order to perform sensitivity analyses, case studies will be formulated in which the effectiveness of the system can be ascertained.

The results show that the developed EMS is able to reduce charging costs significantly, while simultaneously increasing PV self-consumption and reducing energy demand from the grid.

Furthermore, during a case study analogous to one repeatedly considered in literature, i.e. dynamic grid tariff and dynamic feed-in tariff (FIT), the EMS reduces charging costs by 118.44% and 427.45% in case of one and two charging points, respectively.

Moreover, stress on the grid is alleviated through both load shifting and power injection during peak demand. In addition, the EMS proves that vehicle-to-grid (V2G) leads to optimality only in extraordinary cases.

The optimisation problem is modelled in GAMS, whereas the ARIMA process is modelled in Matlab and subsequently, the EMS is simulated in Matlab.

SOLAR CHARGING ELECTRIC VEHICLES

Student information
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Graduation year: 2020

Analysing the charging efficacy of an off-grid, solar powered electric vehicle charging system in long-stay parking applications

This thesis analyses the efficacy of off-grid solar powered EV charging systems, specifically for long-stay car parking at airports. The aim of such EV charging systems is to ensure that the EV is sufficiently charged for the return journey when the owner returns to retrieve their car.

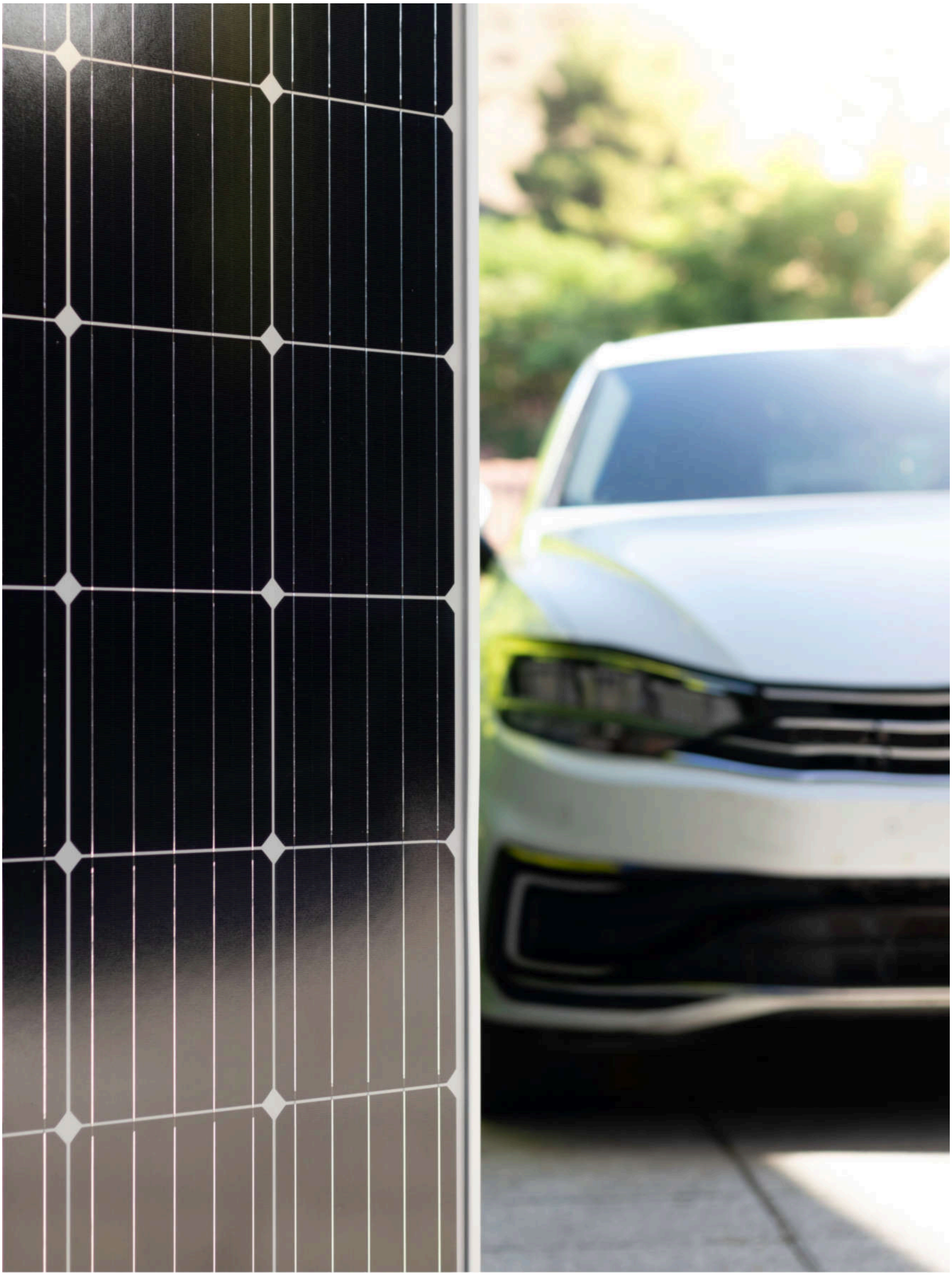
The research is based on a pilot study at Lelystad Airport long-stay car park. This facility includes 108 parking spaces for EVs under canopies fitted with solar panels. South-facing canopies covering four parking spaces, each with an EV charging point, are fitted with solar panels, 40 per canopy, 10 per parking space. Each parking space is equipped with a 3.7 kW charging point, which is powered only from the combined capacity of the solar panels. There is no top-up from the grid.

Arrival times were derived from information provided by Schiphol in November 2019, adjusted for the volume of the other months and assuming that flight arrival and departure times are comparable. The length of stay was derived from parking duration data provided by Boston Airport with a minimum of 48 hours, as the focus was on long-stay parking. The charging characteristics, including battery capacity and charging speed, of one of the ten most popular EVs sold in 2019 were then applied to each charging operation.

The simulations calculated that on departure, 85 percent of the cars would be sufficiently charged, in other words, with at least 75 percent of the battery capacity. Power generation was simulated based on weather conditions throughout the year: in the months April to August there was clearly overproduction. Throughout the winter months the charging efficacy dropped, to be expected for a location in the Netherlands at a latitude of 52°. In December and January, the simulation indicated that only 50 percent of the EVs leaving the car park had a sufficiently charged battery.

The underutilised generating capacity in the months April to August could be better used. A battery energy storage system is an obvious recommendation, and if sized and managed appropriately could offer reserve energy during the winter months and improve charging efficacy in the worst performing period.

Based on assumptions for installation costs and the price of electricity at € 0.36 per kWh, a payback period of 10 years was calculated. In the economic analysis, this basic case was compared with two alternatives: solar panels with top-up from the grid connection and powering the EV charging points only from the grid, without solar panels. The first alternative, solar panels with grid connection, requires the highest investment and has an estimated payback period of 15 years. The second alternative, where EV charging points powered from the grid without solar panels, has an estimated payback period of 9 years. However, there are disadvantages associated with the alternatives including grid connection, namely the capacity of the grid to incorporate new connections, and the associated risks regarding supply continuity.



Q-Park has assured a number of its activities under NEN-EN-ISO 9001.

Q-Park has received several ESPA and EPA awards.

For more details and up-to-date information about Q-Park's products and services please visit: www.q-park.com.

Quality in parking

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