Transition towards DC micro grids

From an AC to a hybrid AC and DC energy infrastructure

Evi Ploumpidou [1], Sjoerd Romme [1], Madeleine Gibescu [1], Arno Bronswijk [2], Harry Stokman [3], Pepijn van Willigenburg [3], Wil Paulus [3]

[1] *Eindhoven University of Technology*
[2] *ABB BV*
[3] *DC Flexhouse*

Abstract

Our electricity is predominantly powered by alternating current (AC), ever since the War of Currents ended in the favor of Nicola Tesla at the end of the 19th century. However, lots of the appliances we use, such as electronics and lights with light-emitting diode (LED) technology, work internally on direct current (DC) and it is projected that the number of these appliances will increase in the near future. Another contributor to the increase in DC consumption is the ongoing electrification of mobility (Electric Vehicles (EVs)). At the same time, photovoltaics (PV) generate DC voltages, while the most common storage technologies also use DC. In order to integrate all these appliances and technologies to the existing AC grid, there is a need for converters which introduce power losses. By distributing DC power to DC devices instead of converting it to AC first, it is possible to avoid substantial energy losses that occur every time electricity is converted. This situation initiated the concept for the implementation of the DC-Flexhouse project. A prototype DC installation will be developed and tested in one of the buildings of the developing living lab area called the District of Tomorrow (De Wijk van Morgen) which is located in Heerlen, the Netherlands. A neighborhood cooperative (Vrieheide cooperatie) is also part of the consortium in order to address the aspect of social acceptance. Although DC seems to be a promising solution for a more sustainable energy system, the business case is still debatable due to both technology- and market-related challenges. The current energy infrastructure is predominantly based on AC, manufacturers produce devices based on AC standards and people are using many AC products across a long life span. This Smart Energy Buildings & Cities (SEB&C) PDEng project is a contribution to the DC-Flexhouse project. The aim is to analyze the challenges in the transition to DC micro grids, assess the market potential of DC applications in the built environment and develop a framework that leads to a commercial success.

Keywords

DC micro grids; Smart Energy Buildings & Cities; DC-Flexhouse; De Wijk van Morgen; Vrieheide cooperatie

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Project scope and objectives

This project targets to support the transition to DC micro grids in the built environment by investigating enabling strategies for successful market introduction, while taking into account both technology and market aspects. More specifically, the following objectives are identified:

- Assessing the market potential: The market opportunities that arise within the DC innovation are investigated based on trends in the energy sector and relevant industries.
- Proposing a strategy for the transition to DC micro grids: Companies and organizations involved in the DC-Flexhouse project can use this proposition to steer activities towards the commercial realization of DC micro grids. The proposed strategy is intended to be applied not only to DC-Flexhouse project but also to future projects for the development of DC technology.

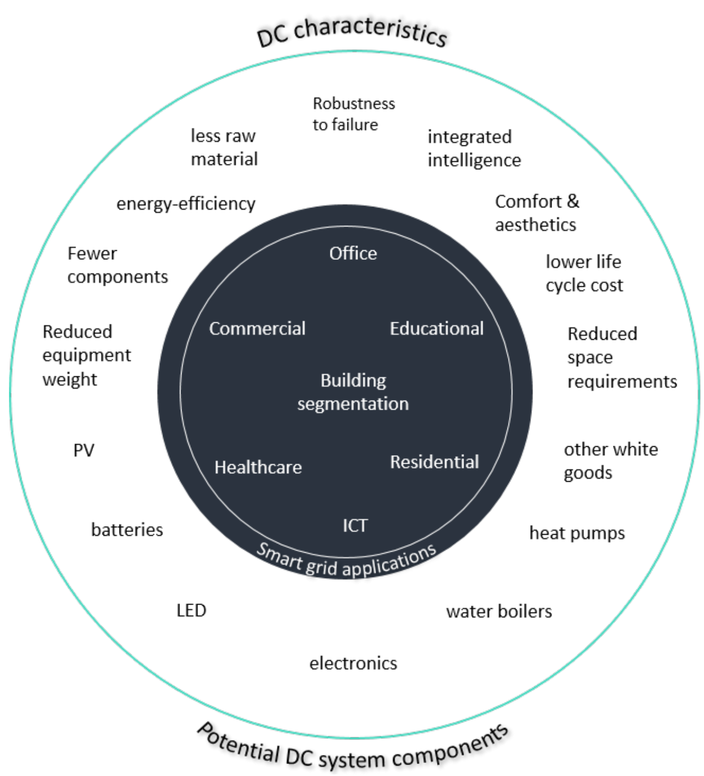

FIGURE 1 Graphical abstract

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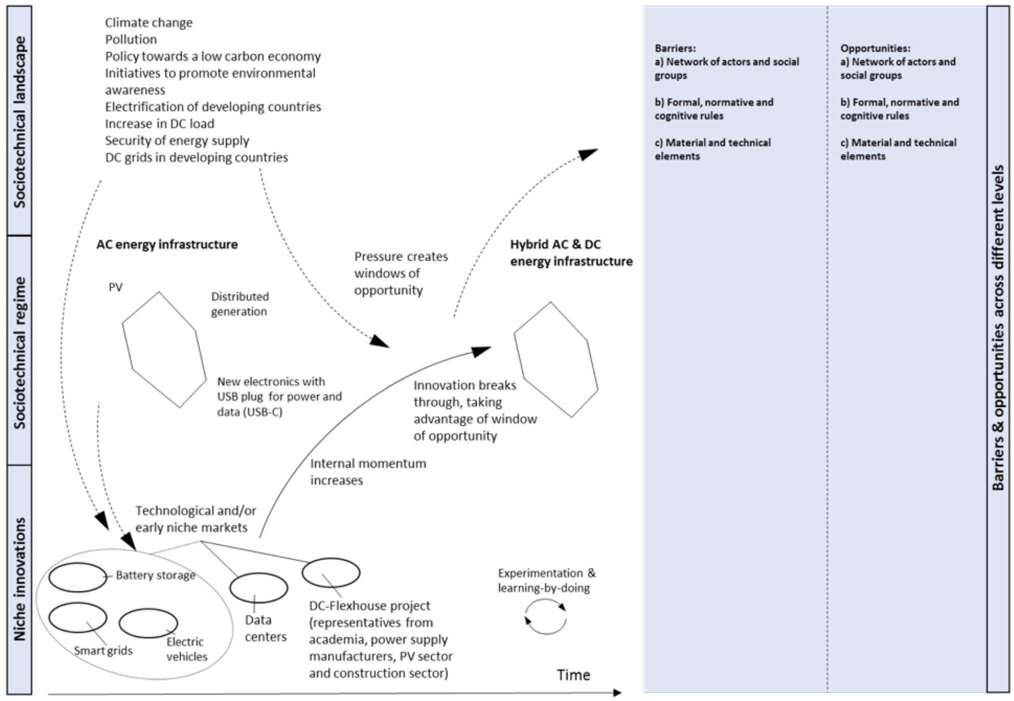
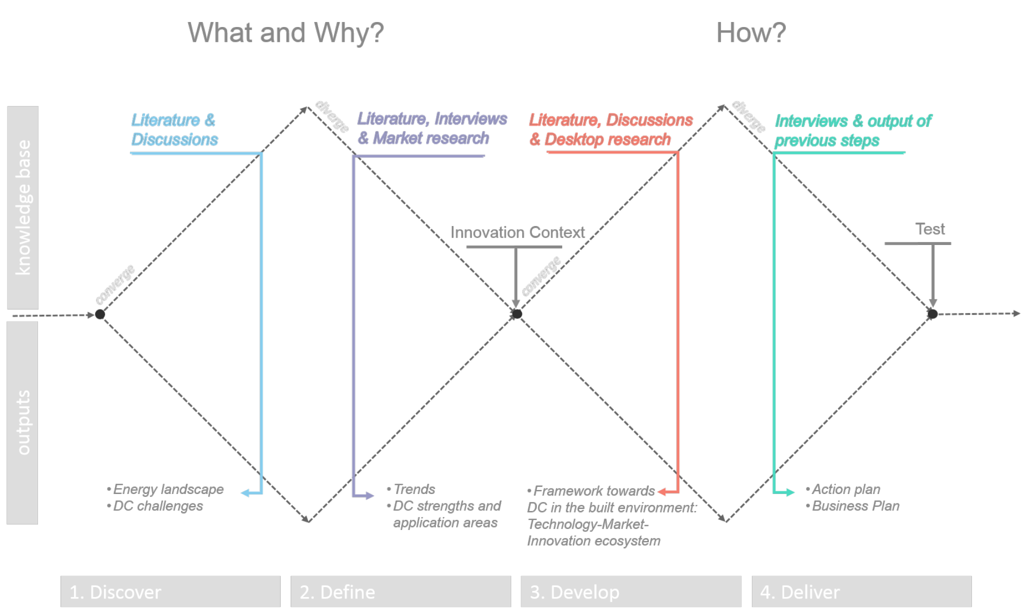


FIGURE 2 Graphical abstract



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Methodology

The methodology of this project combines principles grounded in research on innovation and transition management with guidelines from a more practical structured design process. More specifically, the implementation of this project was based on the combination of transition theories, the Multi-level Perspective (MLP) and Transition Management (TM) with the Design Thinking (DT) method. The MLP is used to analyze how transitions towards sustainable energy systems take place and identify how DC innovation can potentially challenge the current energy system, while TM provides guidelines aimed at facilitating and directing processes towards the commercialization of DC. DT offers a step-by-step guideline for developing innovative solutions for complex problems by deliberately incorporating the concerns, interests and values of stakeholders into the design process.

Background information

The prototype in-building DC micro grid that is being designed in the framework of the DC-Flexhouse project will integrate PVs, battery storage and DC loads. The goal is to provide direct DC power to DC loads, thus avoiding the otherwise necessary conversion steps. The key feature of the DC micro grid, however, is that it is a smart grid in itself, meaning that it comes equipped with an energy management system to monitor and manage energy use.

In addition to the benefits of energy savings and potential lower capital costs due to fewer components (elimination of converters), DC offers the advantage of high penetration rate of intelligent hardware thanks to electronic transducer technology. This feature allows smart grid services to be offered to all electricity market players, including the end-users (building owners/users) themselves.

Brief discussion of results

DC technology is a radical innovation that requires the transformation of the well-established AC energy system. At the time this PDEng project is conducted, there is no explicit market need for DC applications. Therefore, it appears to be difficult to gauge the market potential at this moment. However, building upon the MLP framework, the trends and drivers that can lead to the breakthrough of the DC innovation were identified.

The wider developments in the energy and building sectors, such as the increasing use of DC loads, growing penetration of PV, expected falling prices of battery storage technologies, potential change in net-metering policy for PV, and regulations for improved energy efficiency of buildings, point at the future market potential. In other words, it can be argued that DC innovation fits within the overall energy transition and can have a big impact if managed properly.

Based on my personal observations during my involvement in the DC-Flexhouse project and principles inferred from the innovation and transition management literature, a set of recommendations towards the commercialization of DC was developed. Following these recommendations increases the likelihood of commercial success in the future.

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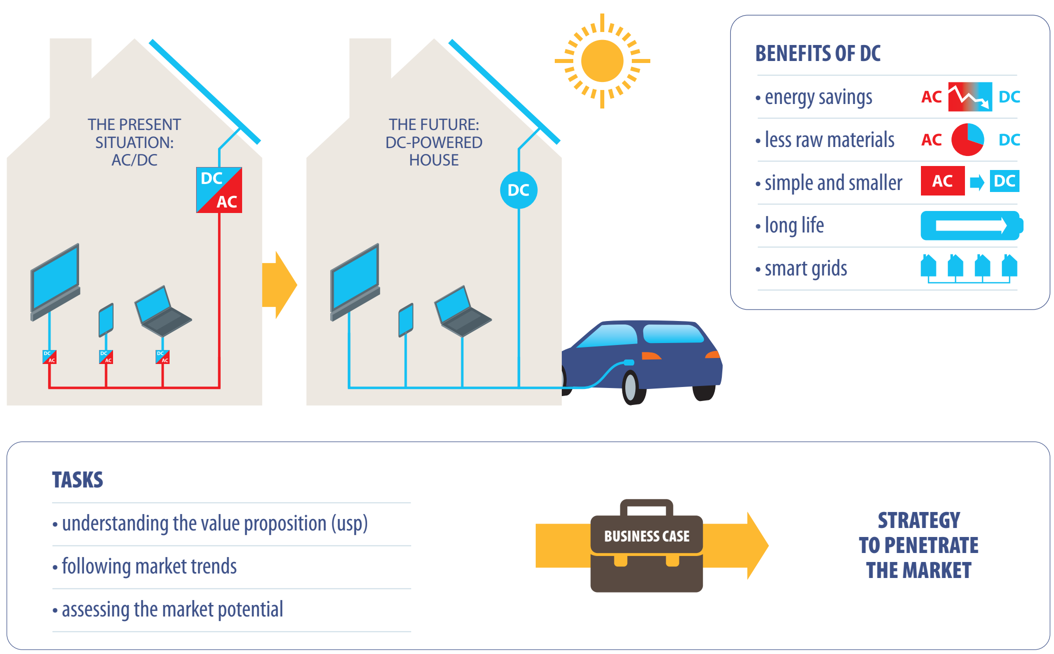
Parties that want to promote DC technology should first target to build strategic alliances with co-innovators and then find frontrunners that are willing to invest and adopt the innovation. A key co-innovator is grid operators. A financial analysis for residential buildings indicates that an in-building DC installation is an attractive business case for the building owner when the power supply is provided by a DC distribution grid. Therefore, the involvement of grid operators is crucial for the successful commercialization of DC applications. The frontrunners create the niche markets that facilitate the diffusion of the innovation into the mainstream markets. According to the transition management literature, the transformation of regimes starts from technological niches and/or early niche markets. In the DC case, potential niche markets or early adopters were identified by combining the value proposition of DC with needs and perceived values in different market segments. Potential groups of early adopters are office buildings with high lighting and computing demand, educational buildings and new neighborhoods. Niche markets might initially not generate a substantial level of profit for the actors in the value chain, but entering these niche markets will facilitate broader market development at a later stage.

Deliverables

In line with the project objectives, the key deliverables are:

- An assessment of the market potential of the DC innovation that is grounded on transition management literature
- A case study for residential buildings with a photovoltaic installation based on a cost-benefit analysis
- An action plan for companies and organizations involved in the DC-Flexhouse project towards the commercialization of DC technology
- A business plan for the development and market introduction of DC applications based on future trends and financial projections (pro-forma financial statements)



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Conclusions

Overall, this PDEng project demonstrates the future market potential of DC and provides a strategy that paves the way towards a commercial success based on examples of successful breakthrough of other sustainable innovations. Early involvement of actors within the value chain at this stage will help them capitalize on this market potential in the future and generate new revenues from the production of DC products. If the findings of the DC-Flexhouse project validate in practice the current theoretically validated findings for improved energy efficiency, reduced capital costs and robustness to failure, we can expect to see DC installations in the built environment in the near future.

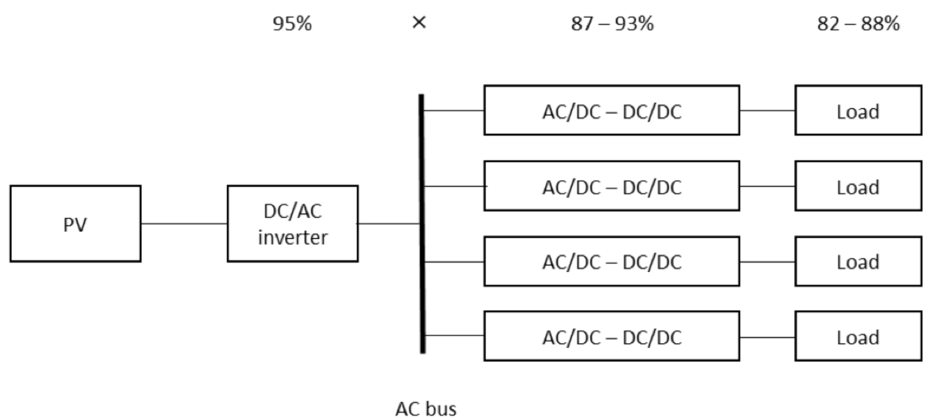

FIGURE 5 Conventional AC architecture with PV system

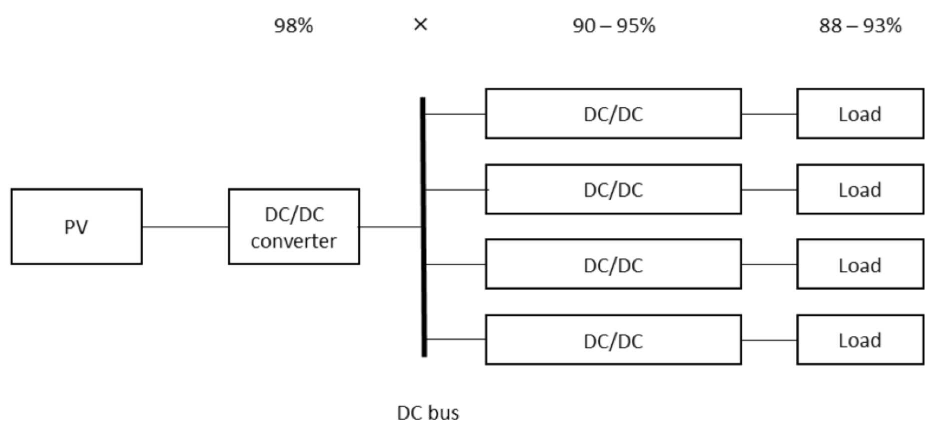

FIGURE 6 DC architecture with PV system

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