Insights from the Darmstadt Energy Lab for Technologies in Application

THE DARMSTADT ENERGY LABORATORY FOR TECHNOLOGIES IN APPLICATION

OVERVIEW PAPER – LIVING LAB DELTA

DELTA Darmstadt Energy Laboratory for Technologies in Application

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Authors

Institute for Production Management, Technologies, and Machine Tools (PTW), Technical University of Darmstadt

www.ptw.tu-darmstadt.de

Prof. Dr.-Ing. Matthias Weigold, Thomas Kohne, Stefan Seyfried

Institute for Stuctural Mechanics and Design (ISM+D), Technical University of Darmstadt

www.ismd.tu-darmstadt.de

Prof. Dr.-Ing. Jens Schneider, Dr. Nadja Bishara

ETA-Solutions GmbH

www.eta-solutions.de

Martin Beck

Editors

Technical University of Darmstadt

Karolinenplatz 5, 64289 Darmstadt

www.tu-darmstadt.de

Prof. Dr.-Ing. Matthias Weigold, Thomas Kohne,
Stefan Seyfried, Martin Beck, Dr. Nadja Bishara

Contact: info@delta-darmstadt.de

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Living Lab DELTA

The Darmstadt Energy Laboratory for Technologies in Application (DELTA) serves as a showcase for the urban energy transition to demonstrate interacting energy-optimized districts. The living lab DELTA aims to demonstrate that the technically proven potential for increasing energy efficiency and flexibility in urban districts is economically feasible and socially accepted.

Abstract

In the living lab DELTA, energy system methods are applied, and energy technology systems are installed to transfer successful pilot projects of the urban energy transition to a broad application. The focus is on the consistent improvement of energy efficiency in all sectors, which is already considered to be the largest usable potential of the urban energy transition. In addition, the potential for shifting electrical loads over time to optimize the integration of renewable energy sources will be identified. Energy efficiency and flexibility will be achieved by intelligently linking individual districts of the urban energy system and by sector coupling. The development of a holistic innovation ecosystem is essential to enable all stakeholders in the energy system to participate in the energy and economic potential. To this end, the project pursues a multi-level, cross-sectoral approach.

Keywords: Living Lab, Urban Energy Transition, Energy Efficiency, Energy Flexibility, Darmstadt

Kurzfassung

Titel: Das Darmstädter Energie-Labor für Technologien in der Anwendung

Im Reallabor DELTA werden energiesystemische Methoden angewendet und energietechnische Anlagen errichtet, um erfolgreiche Pilotprojekte der urbanen Energiewende in die breite Anwendung zu überführen. Im Mittelpunkt steht die konsequente Steigerung der Energieeffizienz in allen Sektoren, die bereits heute als größtes nutzbares Potenzial der urbanen Energiewende gilt. Darüber hinaus sollen Potenziale zur zeitlichen Verschiebung elektrischer Lasten identifiziert und zur optimalen Einbindung erneuerbarer Energiequellen genutzt werden. Energieeffizienz und -flexibilität werden durch die intelligente Verknüpfung einzelner Quartiere des betrachteten städtischen Energiesystems sowie durch Sektorkopplung erreicht. Wesentlich ist dabei die Entwicklung eines ganzheitlichen Innovationsökosystems, um alle Akteur:innen des Energiesystems an den energetischen und wirtschaftlichen Potenzialen teilhaben zu lassen. Hierzu wird im Projekt ein mehrstufiger, sektorübergreifender Ansatz verfolgt.

Schlagwörter: Reallabor, Urbane Energiewende, Energieeffizienz, Energieflexibilität, Darmstadt

DELTA

1 Living Labs for Energy Transition

The *living labs for the energy transition* are an innovative format of energy research launched by the Federal Ministry of Economic Affairs and Climate Action (BMWK, former Federal Ministry of Economic Affairs and Energy, BMWi) in 2019. As collaborative research projects, the living labs pursue the approach of testing technical and non-technical innovations in a real environment and on an industrial scale. In addition to research on technical innovations, this includes the development of innovative operating and business models, the consideration of socio-economic and societal aspects, as well as regulatory learning and, ultimately, the increase in demand for energy technologies. The living labs not only test new technologies, but also investigate their applicability and social and economic impact in practice. In this way, the energy transition can be advanced in a comprehensive way, ensuring that it is both technically and socially successful. [1]

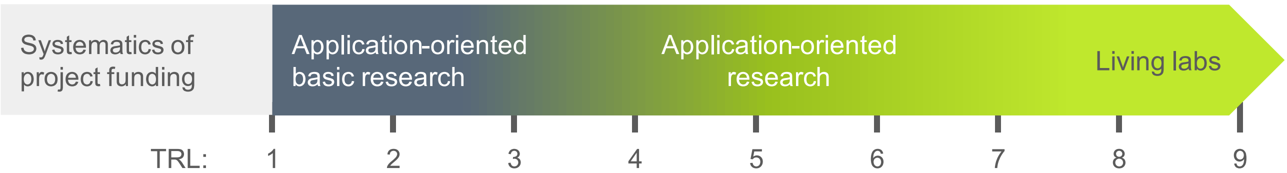

Figure 1-1: Technology Readiness Level (TRL) in the context of project funding in the 7th European Energy Research Program. Graphic follows [2].

The Darmstadt Energy Laboratory for Technologies in Application (DELTA), led by the Technical University of Darmstadt (TUDa), is one of the 20 winners of the first ideas competition for living labs for the energy transition in the German government's 7th Energy Research Program [2]. The aim of the ideas competition was to initiate and promote the first living labs in the two areas of *sector coupling and hydrogen technologies* as well as *energy-optimized districts*. Twelve real-world laboratories (as of November 2023) from the first ideas competition have been launched so far, with the living lab DELTA being one of them. The BMWK is now continuing the funding format in the 8th Energy Research Program [3], as it closes technological and non-technological development gaps for innovations between application-oriented research and broad implementation in practice (Figure 1-1).

Figure 1-2: Living Lab DELTA against the backdrop of the Mathildenhöhe World Cultural Heritage Site in Darmstadt. Graphic: Nikolaus Heiss+TUDa (Jan Leuwer).

2 Project Overview

The living lab DELTA acts as a showcase for the urban energy transition by demonstrating interacting energy-optimized districts [4]. The project aims to demonstrate that the technically proven potential for increasing the energy efficiency and flexibility of urban districts is economically feasible and socially accepted. Energy system methods will be applied, and energy technology systems will be installed to transfer successful pilot projects of the urban energy transition to a broad application.[1]

2.1 Initial Situation

Due to the limited space available, cities typically act as energy sinks for the centralized renewable energy supply in the German energy system [5]. They consist of many individual district types, which can be divided into industrial, commercial, and residential districts, but can also be a mix thereof. The district types differ in terms of the energy infrastructure, the timing of energy use and the useful energies required. Within district types, there are other characteristics, such as different proportions of new and old buildings in residential districts. Within urban centers, these different districts are connected by network structures. These include energy networks, such as electricity, gas, and heat, as well as supply and disposal networks, mobility networks, and communication networks.

The technical potential for increasing the efficiency and energy flexibility of districts has been demonstrated by a large body of research [6]. This applies to energy systems in industrial districts as well as residential and commercial areas. In addition, technologies already exist that can reduce greenhouse gas emissions in urban energy systems through sector coupling. Examples include the use of centralized and decentralized heat pumps and hydrogen electrolysis. When heat pumps are used to produce heat and cooling simultaneously, the energy efficiency of the technology can be significantly increased [7]. Similarly, the decentralized use of electrolysis processes in the district enables the use of renewable electricity surpluses with simultaneous use of the generated waste heat [8]. Both measures thus allow for the substitution of conventional energy sources. Furthermore, the measures create flexibility on the electricity side, responding to short-term peaks in the electricity grid and temporarily reducing demand at times when the supply of renewable electricity is low.

In this context, the living lab DELTA is pursuing the following questions on achieving urban climate targets:

- What are the short, medium, and long-term achievable energy efficiency goals of a typical medium-sized city?
- How can locally available energy sources contribute to reducing the CO_2 emissions of the city's energy system?
- How can the capacities of the local energy infrastructure be optimally utilized?
- How can the energy system be operated and what new business models will emerge?
- What regulatory incentives does such an energy system require?
- How can technological learning be embedded from implementation back into basic research?

[1] The content of this overview paper is largely based on the project description of the project.

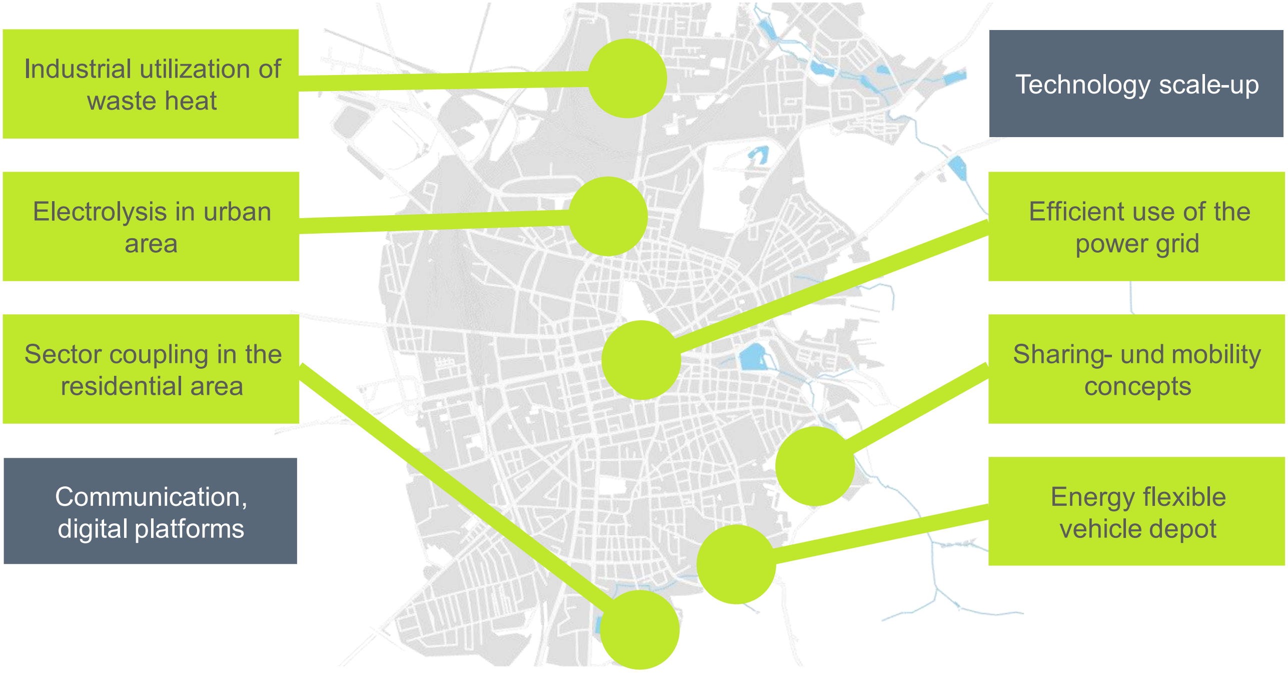

Figure 2-1: Map with different locations of the implementations in the living lab DELTA. Graphic: Shutterstock + TUDa (Jan Leuwer).

2.2 Approach

To answer the questions described above, the project will select different locations in and around the city of Darmstadt and test various technological innovations on a real scale (Figure 2-1). These include:

- The retrofitting or new construction of industrial buildings with a focus on energy efficiency and flexibility, as well as the provision of industrial waste heat to a district heating network.
- The optimized allocation of commercial energy consumers to optimize heat loss and the use of innovative technologies (e. g., electrolysis in district cells with high heat demand).
- Integration of power-to-heat systems (especially heat pumps) into the urban energy system and upgrading it for electricity flexibility.
- The integration and networking of decentralized generation and storage concepts.
- The largely climate-neutral energy supply of residential buildings with optimized use of available and low-emission sources of electricity, heat, and waste heat.

The living lab DELTA takes a multi-level, cross-sectoral approach (Figure 2-2). In the first stage, the energy efficiency of individual systems or buildings is increased through individual measures. In the second stage, the energy system in the district will then be intelligently networked. Finally, in the third stage, district wide integration for optimal use of energy sources and sinks needs to be explored. The focus is on a consistent increase in energy efficiency in all sectors, which is already considered to be the greatest usable potential of the urban energy transition. Additionally, the potential for shifting electrical loads over time will be identified and used to optimize the use of renewable energy sources. Energy efficiency and flexibility will be achieved through the intelligent linking of individual districts of the urban energy system under consideration of and through sector coupling. Synergies will be exploited considering a broad and holistic view of energy flows within and between the different districts. The development of a holistic innovation ecosystem is essential for enabling all actors in the energy system to partake in the energetical and economic potentials.

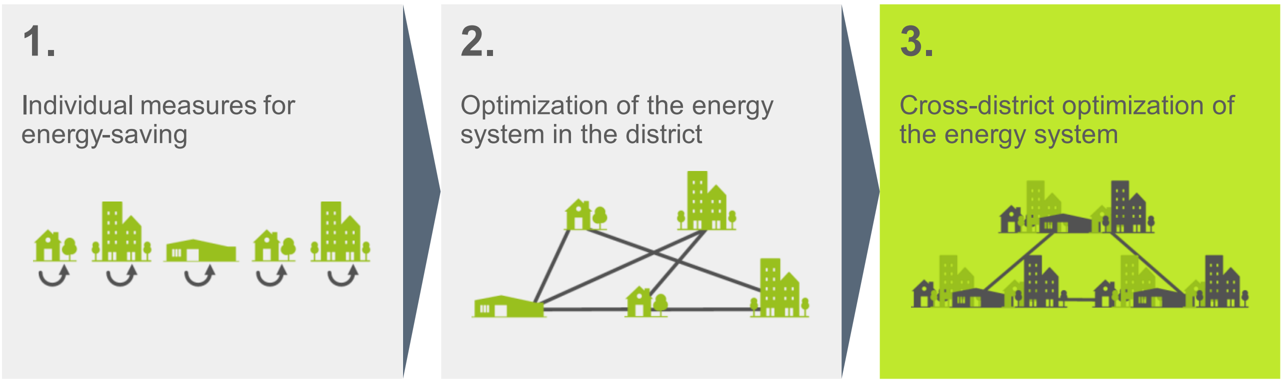

Figure 2-2: Three-layer approach of the living lab DELTA. Graphic: TUDa (Jan Leuwer).

3 Project Layout

In order to develop holistic synergetic solutions and successfully implement its ambitious goals, the DELTA project brings together companies and institutions from different sectors, such as urban development, urban economy, industry and commerce, research, and technology start-ups. To explore the issues and technical applications described in the living lab DELTA, the project also consists of a complex project structure and strategic coordination at various levels of the project.

3.1 Project Structure

The living lab DELTA consists of several subprojects and clusters (Figure 3-1). In the subprojects, technological innovations are planned, implemented, tested, and operated. The aim is to research the optimized energetic implementation and use of the technological innovation (research on the real object) as well as the investigation of specific business models and regulatory barriers. Finally, the technical systems will be put into operation. The focus is on increasing energy efficiency and flexibility by considering and interacting with the three types of districts (industrial, commercial, and residential) as well as the connecting elements of energy networks (electricity, gas, and district heating and cooling), mobility (traffic routes, public transport), and digital infrastructure (digital platforms):

- In subproject 1, various measures to increase energy efficiency and sector coupling are implemented in a newly developed residential area.
- Subproject 2 analyzes the comprehensive improvement of energy efficiency and waste heat utilization at an industrial site and beyond.
- In subproject 3, an electrolysis unit is integrated into the energy hub of the local energy supplier in an energy flexible and multi-sectoral way.
- Subproject 4 further develops a mobility depot against the background of fleet electrification.
- Subproject 5 focuses on the optimal utilization of the urban power grid, e. g., using battery storage.
- Subproject 6 develops and investigates urban sharing models and practices.
- Subproject 7 enables three start-ups to carry out large-scale field trials of innovative technologies.

It is essential that all actors involved can pursue their respective specific goals and simultaneously achieve the overarching goal of minimizing the city's greenhouse gas emissions. To embed the subprojects in the context of the energy synergy utilization of a typical medium-sized city (in this case Darmstadt), three overarching clusters are defined - Energy Data, Energy Innovations and Energy Academy. The clusters serve the integrative research of the cooperation in the project as well as the development of a digital connecting structure to enable an ordered knowledge transfer. Furthermore, insights from selected scientific disciplines (e. g., innovation management, supply chain management, institutional economics, geographical urban development/urbanity research, and transformation research) will be integrated. The overall project will be coordinated and supported by a multi-project management team to guide and support the scientific and technical outputs.

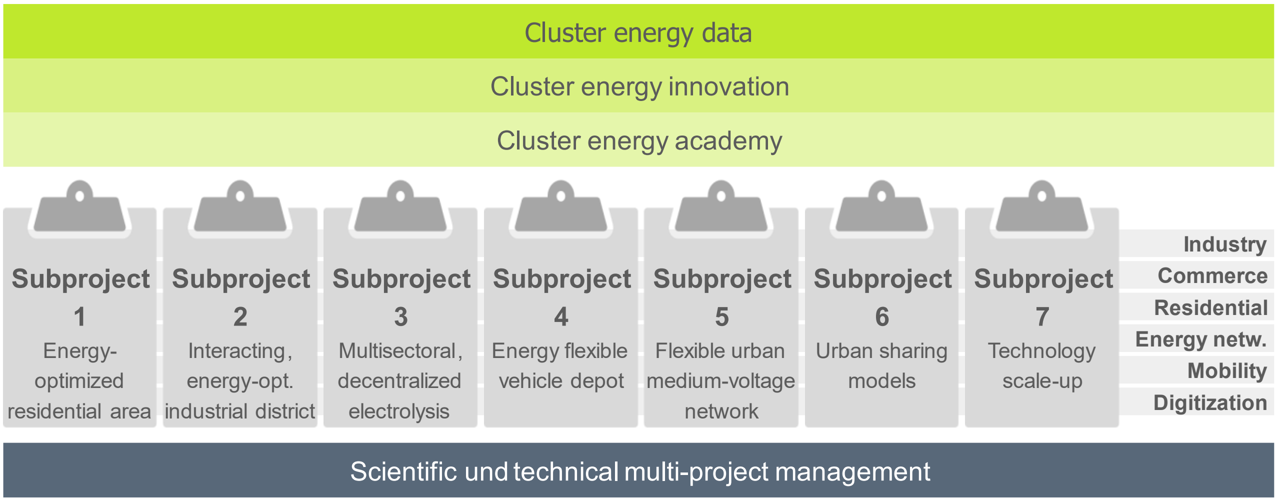

Figure 3-1: Project structure of the living lab DELTA. Graphic: TUDa (Jan Leuwer).

To structure innovation processes and overall course of the project, and to ensure a targeted exchange of knowledge and experience between the various project participants, there is a management and governance structure with centralized and decentralized coordination that is appropriate to the level of complexity (Figure 3-2). Multi-project management plays a central role, both at the academic and technical/economic levels; its responsibilities include key coordination tasks such as the implementation of an internal and external project communication system, innovative and adaptive project structure planning, as well as stakeholder activation and transfer performance. In addition to project management, the management and governance structure also includes the respective coordination of subprojects and clusters. These are responsible for the implementation of the individual measures and their coordination in the overall context. One of the main tasks of the management and governance structure is to ensure communication between all project participants in the transdisciplinary innovation and learning ecosystem, and to guarantee the success of the project through planned implementation and agile adaptation.

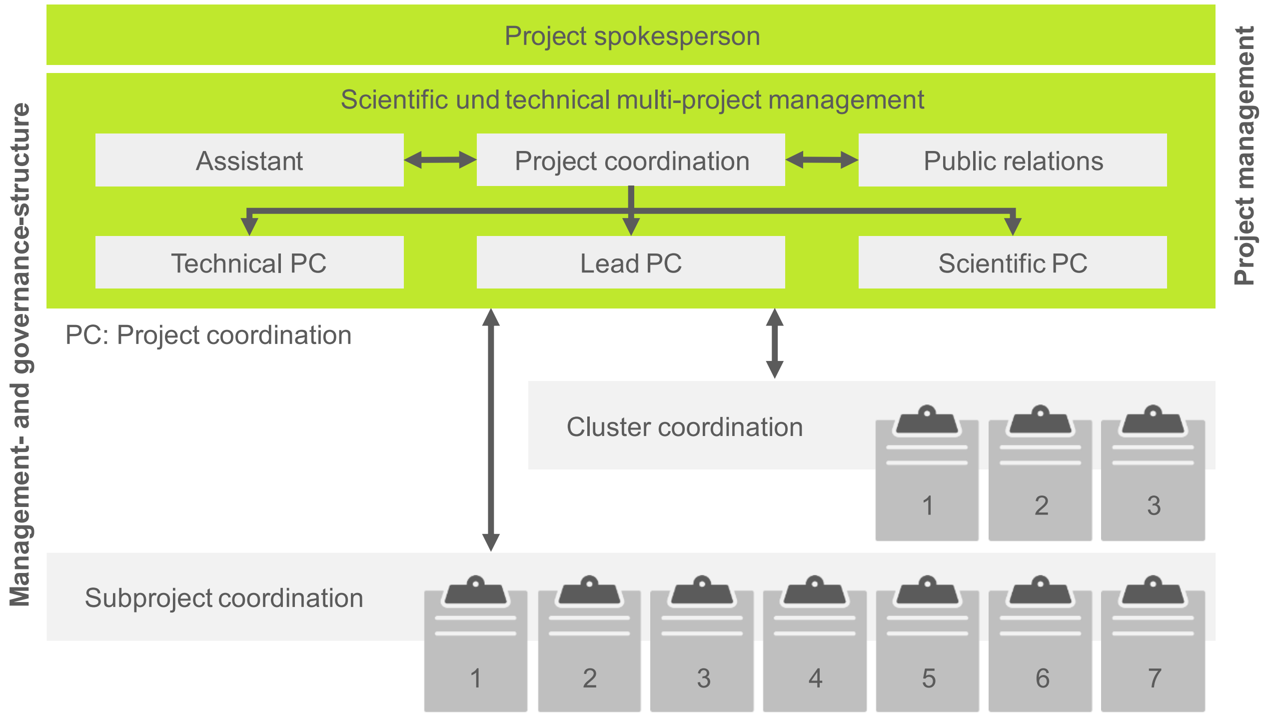

Figure 3-2: Management and governance structure of the living lab DELTA. Graphic: TUDa (Jan Leuwer).

3.2 Consortium

The City of Darmstadt is a typical medium-sized city in Germany, whose district structure is exemplary for numerous other cities in Germany. As it holds the title of City of Science, Darmstadt is characterized by important research institutions, in particular the Technical University of Darmstadt and Darmstadt University of Applied Sciences. The topics of sustainability and energy efficiency are a cross-institutional component of the activities. An increasing number of innovative technology companies, start-ups and research-related institutions are settling in the region, creating a cluster of expertise in the field of energy efficiency and flexibility. In addition to educational institutions, the city is characterized by large industrial companies (including Merck KGaA) with ambitious goals in sustainability. The local energy supplier (ENTEGA AG) and its direct cooperation partners (COUNT+CARE GmbH & Co. KG, Zweckverband Abfallwirtschaft Südhessen) also follow the clear orientation of an ecological regional supplier and contribute a diverse generation and energy storage structure to the project via the electricity, gas, and district heating network. Through the municipal holding company (HEAG Holding AG), both the public transport mobility structure (HEAG mobilo GmbH) and the municipal housing association (bauverein AG) are formative for sustainable urban development. As a digital city, the city of Darmstadt is also characterized by its innovative drive for the future and research with a variety of initiated projects. Finally, smaller companies such as mobility service providers (Hy2Serv GmbH) and technology start-ups (SMART-KLIMA GmbH, etalytics GmbH) are also contributing their expertise to the DELTA consortium, further developing technologies and testing them on a real-life scale. All the companies and institutions mentioned are consortium partners under the leadership of the Technical University of Darmstadt.

In addition to the consortium partners, the living lab DELTA offers space for innovative start-ups to introduce and test technologies – driven by hardware and software – for Germany's urban energy transition on a large scale (ETA-Solutions GmbH, etalytics GmbH, Green Mobility Solutions GmbH, DATAbility GmbH, vilisto GmbH, Kraft-block GmbH). Major industrial partners (Evonik Operations GmbH) and network operators (e-netz Südhessen) are also supporting DELTA with system and technology expertise. In addition, the City of Science Darmstadt is also involved as an associated partner through close dialog and exchange to ensure the success of the project in Darmstadt.

Figure 3-3: Consortium of the living lab DELTA

4 Mission Statement

The mission statement of the living lab DELTA was developed with the full project team and reflects the consortium's drive to actively shape the urban energy transition.

Vision – Where are we headed in the long term?

We strive for the vision of developing the city of Darmstadt into a sustainable innovation ecosystem for the energy transition.

- Initiating social change
- Transforming the energy system holistically
- Developing and testing scalable solutions

Figure 4-1: Vision, mission, and values as elements of the mission statement. Graphic: TUDa (Jan Leuwer).

Mission – What is our purpose?

- We contribute to reducing emissions in Darmstadt with cross-district and cross-sector implementations.
- We create communication structures and thus social acceptance for an innovation cluster of the urban energy transition.
- We prepare scientific and socio-techno-economic findings and thus create a broad knowledge base for the transfer of solutions.

Values – What unites us?

Our self-image is the combination of sustainability, future orientation, and responsibility. Our work is characterized by innovation, expertise, and team spirit.

Strategy – How do we intend to achieve this?

- Implementation with real experimental facilities: technological implementations based on the approaches in the project proposal are realized and analyzed.
- Communicating with familiar structures: target group-oriented formats for communication and discussion of scientific and technical findings are established.
- Transfer as a basis for new projects: a consolidation of the innovation ecosystem is initiated with the involvement of society.

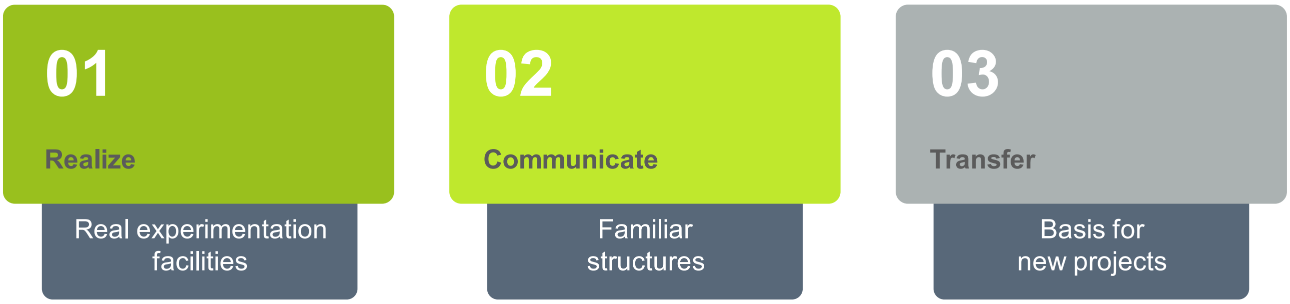

Figure 4-2: Strategy for implementing the mission statement. Graphic: TUDa (Jan Leuwer).

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