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# Enablers and barriers to the sustainable transformation of urban districts

(Interim) results from six lighthouse projects

## 1 Introduction

'How can we make energy both clean and affordable?' asked *+3* magazine (https://plus-drei.de) in February 2022. Answers were provided by, among others, meteorologist Sven Plöger, who advocated 'getting rid of fossil fuels'. Economist Claudia Kemfert described 'the magic triangle of renewables, based on the three pillars of energy transition, electrification and efficiency'. In contrast, Axel Gedaschko, President of the German Housing Industry Association, argued for 'socially just solutions – instead of more and more demanding and expensive efficiency standards'. Finally, Lukas Köhler from the FDP parliamentary group in the German Bundestag also contributed to the discussion; his credo was 'open competition for the best $CO_2$-saving solutions'.

The Federal Ministry for Economic Affairs and Energy (now the Federal Ministry for Economic Affairs and Climate Action, or BMWK) and the Federal Ministry for Education and Research (BMBF) had announced a similar competition for the best ideas in April 2016: the funding initiative 'Solar Construction/Energy Efficient Towns'.[1] Here, too, the aim is to transform the energy supply towards environmentally friendly, safe and cost-effective energy. The call was for 'lighthouse projects in the form of living labs and comprehensive neighbourhood projects that pioneer an integrated energy concept from research to implementation with the involvement of all relevant stakeholders' (BMBF announcement of 23 April 2016). They explicitly welcomed 'experimental spaces' in which new technologies could be tested and institutional structures changed, but also where stakeholders could work together in new partnerships. In other words, they called for 'transformative research' (ibid.) with the aim of further developing established research approaches and testing out new ones.

This article is about the six winners of this call. A panel of experts selected them from more than 60 competing consortia. The key evaluation criteria were 'the level of scientific and technical innovation or risks', 'the professional competence of the partners, the participation of small and medium-sized enterprises (SMEs), a balanced and

**1** https://www.fona.de/en/measures/funding-measures/funding-initiative-solar-construction.php (Accessed 09 June 2022).

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https://doi.org/10.1515/9783110777567-205

binding cooperation between the partners involved', but projects were also assessed on 'the prospects of realising the project plan' and the 'scientific-technical and economic prospects of success', as well as the 'social significance' of the project (ibid.). Such a catalogue of evaluation criteria leads one to expect extraordinary things from the winners – as does the amount of funding on offer, around 100 million euros with which, in the period from 2017 to 2023, the six lighthouse projects are to demonstrate how 'urban districts successfully act as local drivers for the energy transition' (BMBF 2017).

To produce the 'transformative research' (WBGU 2011, Schneidewind/Singer-Brodowski 2014) postulated in the call for proposals, the consortia are not only faced with the task of developing innovative solutions to the concrete social problems of the energy transition at the district level together with (local) stakeholders, but also to provide proof of concept in the field, or at least demonstrate in principle the feasibility of particular concepts. Therefore, a prerequisite for (socio-technical) solutions to be both viable and accepted is the involvement of societal stakeholders in the research process: their expectations, experiences and know-how are brought together with scientific and technical knowledge – with the aim of ensuring that the results of the research process bring benefits for science and society alike.

The following sections describe to what extent the ministries' goal to generate 'socially robust knowledge' (Nowotny/Scott/Gibbons 2001) and to help shape social reality in living labs has succeeded after almost five years of funding. The second section describes the projects and their scope. The third section deals with how the projects typically unfolded and the delays and feedback loops that occurred. Sections 4 and 5 look at the central actors involved and the external conditions that had an impact on the projects. The last section asks to what extent the projects fulfil their claim to be 'lighthouse projects', and what the coordinators assess as the key findings from the initiatives. Put more systematically, and again from the logic of the transformative research process (cf. Schneidewind/Singer-Brodowski 2014, Jahn/Keil 2016), we ask:

- To what extent has it been possible – in the beginning of the projects – to 'construct' a common problem out of the different social perceptions and the academic descriptions of the problem and to combine it into a unified plan?
- Did the partners from practice and research succeed in jointly implementing a solution, and to what extent does this correspond to the goals they set?
- Which actors were particularly important to this process and what specific expectations, motivations and interests emerged, and to what extent were conflicts baked in as a result?
- To what extent was it necessary to adapt the plans due to existing and evolving conditions guiding decision-making within projects, and what barriers have emerged on the road to climate-neutral districts?
- Can the projects live up to their claim of being 'lighthouse projects' despite the repeated adaption of plans, and how do new, sometimes surprising, results contribute to their status as lighthouse projects?

Empirical studies, for example of 'smart grid experiments' (Lösch/Schneider 2017) or 'urban labs' (Scholl/de Kraker/Hoeflehner et al. 2018, Reusswig/Lass 2017), show that transformation processes by no means follow a simple, linear model – from problem construction to idea generation to implementation and knowledge transfer. Rather, they usually proceed in recursive loops, are characterised by numerous breaks and therefore resemble the 'fireworks model of innovation' (Van de Ven/Polley/Garud et al. 1999). That is, they are subject to non-linear dynamics, surprises are inevitable, and the process is therefore neither stable and predictable, nor random. We contend that innovations are unpredictable not because they are at the mercy of chance, but because they are subject to a complex interplay of all actors involved in the process. The course of such interactions therefore represents an experiment with an open outcome, both for the participants themselves and for any observers. We will refer to these findings throughout the article.

The empirical basis of the article consists of guided interviews with the coordinators of the six lighthouse projects, but also with other key actors, named by the coordinators, in order to gain even deeper insights into critical events, difficult underlying conditions or the parties involved in the project. A total of ten of such interviews were conducted; they lasted an average of 70 minutes, were recorded, transcribed and analysed with the methods of qualitative content analysis (Mayring 2008) using software tools (MAXQDA). In addition, the minutes of the meetings between the lighthouse projects were also included in the analysis; not only were (interim) results from all six lighthouse projects presented at these meetings, but workshops were also held on the topics of 'Technologies of regenerative energy supply', 'Regulatory challenges' or 'Participation in the living lab'.

## 2 The Six Lighthouse Projects

The two ministries expect the six lighthouse projects to address various energy-related and socio-economic questions from a systemic perspective – from basic research to technology development and implementation in living labs (announcement of 23 April 2016). Table 1 provides an overview of the project consortia, the amount of funding awarded, the size of the living labs and the central objectives of each project.

- The largest lighthouse project, with 21 collaborative partners, is 'ENaQ: Energetic District Quarter – Oldenburg Air Base'. The redevelopment consists of converting of one of Lower Saxony's largest former military sites to residential use, and a 3.9 ha area with about 110 residential units has been explicitly designated as a 'living laboratory' for testing new smart city concepts.
- Providing innovative solutions for a completely new district is also the goal of 'ES-West-P2GP: Neue Weststadt Esslingen': An innovative energy supply concept based around the use of an electrolyser for hydrogen generation and utilisation

of waste heat is being developed and implemented by 13 partners in an urban quarter with over 600 flats, office and commercial spaces.
- In Kaiserslautern, the 9 partners of 'Living Lab Pfaff' are showing how a climate-neutral urban quarter with new and listed buildings can be created from an industrial wasteland. The consortium aims to lay the foundations of an energy plan for a district of about 40 ha, with more than 40 buildings to be built. The concrete demonstration of use cases and the starting point of the energy infrastructure centres around two existing buildings and a living lab centre, where stakeholders can test and develop further innovations.
- In Stuttgart and Überlingen, 11 partners are working together on the project 'STADTQUARTIER 2050', which involves redeveloping two urban residential districts with a total of about 960 households in a socially responsible, climate-neutral way and transferring the concepts to other quarters. The plan is to use local district heating, supplied mostly from renewable sources, such as geothermal, wastewater, biomass and solar heating. In addition to the implementation of the energy plan, the project partners are working on technological issues such as developing four different tools that can be applied in other city districts as well. Furthermore, the whole process is supported by social research.
- The 20 collaborative partners on the 'QUARREE 100' lighthouse project are laying the foundations for the transformation of an existing district ('Rüsdorfer Kamp') with around 220 households into a sustainable district. Like in the other projects, the partners are focusing on several goals, such as power-to-X technologies, a district heating network, renewable energies and the integration of the heating, electricity and transport sectors.
- The lighthouse project 'ZED: Zwickauer Energiewende Demonstrieren' (Demonstrating (the) Zwickau Energy Transition) is seeking to create a 'zero-emissions quarter' incorporating existing buildings. 13 collaborative partners want to advance digitalisation in the energy supply network for around 800 households in the Zwickau-Marienthal living lab, with the aim of shaping the energy transition in a way that is acceptable to residents with the help of innovative (information) technologies and participatory formats.

These six lighthouse projects were selected in 2017 and represent a broad spectrum of different energy plans, energy carriers, installations or management systems in the respective living labs. All the lighthouse projects are seeking to show how energy consumption can be reduced in the individual urban districts, how the smart coupling of electricity, heat and transport can succeed, and how renewable energies can be integrated into the energy supply in a way that is acceptable to residents. In short: How

**Table 1:** The 6 lighthouse projects – amount of funding, partners, district size and central goals.

| Lighthouse project | Amount of funding | Coordinator and number of partners | District size, Number of residential units | Central goals |
|---|---|---|---|---|
|  <br>*Energetisches Nachbarschaftsquartier Fliegerhorst Odlenburg*<br>(www.enaq-fliegerhorst.de) | approx. 19.6 m € | **City of Oldenburg with OFFIS – Institute for Computer Science**<br>21 predominantly regional partners from business, research and municipal administration | 3.9 ha,<br>110 residential units | Establishment of a Smart City test and trial field for:<br>– Technical and non-technical innovations<br>– Communal living projects<br>– Innovative supply and transport concepts<br>– Networking of industrial and R&D projects<br>– Pilot projects bringing together stakeholders |
| NEUE WESTSTADT<br>KLIMAQUARTIER<br>*Klimaneutrales Stadtquartier in Esslingen am Neckar*<br>(www.neue-weststadt.de/klimaquartier) | approx. 12.5 m € | **Steinbeis Innovation Centre Energy, Building and Solar Technology**<br>13 partners from research, business and municipal administration | approx. 12 ha,<br>600 residential units | – Climate neutrality and local energy cycles<br>– $H_2$-generation with waste heat utilisation in the district<br>– Coupling the electricity, heating, cooling and transport sectors<br>– Living lab: networking of agriculture, energy, transport, industry and buildings<br>– - Accom<br>-panying the transformation process through social science monitoring |

(continued)

**Table 1** (continued)

| Lighthouse project | Amount of funding | Coordinator and number of partners | District size, Number of residential units | Central goals |
|---|---|---|---|---|
| Reallabor PFAFF<br>*Innovationen für nachhaltige Stadtquartiere*<br>*Erneuerbar. Effizient. Digital.*<br>(www.pfaff-reallabor.de) | approx. 23 m € | **City of Kaiserslautern with Fraunhofer Institute for Solar Energy Systems**<br>9 network partners from research, business and municipal administration | approx. 19 ha,<br>423 residential units | Development and implementation of a climate-neutral district:<br>– Innovative technologies (e.g. agent-based energy management, bidirectional charging of e-vehicles).<br>– Dovetailing planning processes through new 3D city models or data exchange platforms<br>– - Simulation of planning processes and monitoring tools |
| QUARREE 100<br>*Quartiersentwicklung mit 100% Regenerativer Energie*<br>(www.quarree100.de) | approx. 24.4 m € | **Heide Region Development Agency**<br>20 partners from research, business and municipal administration | approx. 20 ha<br>200 residential units | Development of a post-war settlement into a model district:<br>– Living and working (small businesses, home office)<br>– Energetic refurbishment<br>– $H_2$ and waste heat supply<br>– System-serving, resilient energy concept in the district<br>– Sector coupling (electricity, heat, transport)<br>– - Plans to support multigenerational living |

| | | | | |
|---|---|---|---|---|
|  <br>STADTQUARTIER 2050 – Herausforderungen gemeinsam lösen (www.stadtquartier2050.de) | approx. 13.5 m € | **State capital Stuttgart with Fraunhofer Institute for Building Physics (IBP)**<br>11 partners from research, business and municipal administration | approx. 4 ha (Stuttgart)<br>approx. 5 ha (Überlingen)<br>A total of 960 residential units | Climate-neutral energy supply of 2 districts, in Stuttgart (conversion of a former hospital site) and Überlingen (peripheral area redevelopment with building site expansion):<br>– Direct use of local renewable energy sources<br>– Greenhouse gas emissions from the energy sources used for building operation = 0 in annual balance (heat and electricity supply incl. user electricity)<br>– - Socio-economy: Motivation of communities of apartment owners to participate in the district rehabilitation; development of a bonus system for conscious energy consumption; socially acceptable and rent-neutral renovation |
|  <br>Zwickauer Energiewende Demonstrieren (www.energiewende-zwickau.de) | approx. 16.1 m € | **City of Zwickau**<br>13 partners from research, business and municipal administration | approx. 5.6 ha, 800 housing units | Holistic innovations in the Zwickau-Marienthal district:<br>– Development of electrical-thermal compound systems for zero-emission supply<br>– Storage technologies for renewable energies and cross-trade ICT networking<br>– Sector coupling of transport, electricity and heat<br>– - Sustainable and user-oriented technology and district development |

can urban districts become climate-neutral?[2] To this end, the consortia not only involved numerous actors from municipalities, the private sector, research institutes and civil society, but also developed a wide range of different modes of participation. These draw on a variety of methodological approaches, ranging from district apps and design-based solutions to simulations, gamification, usability tests, the establishment of living-lab centres and citizen science.

# 3 Project Progress

All six lighthouse projects address specific social and technological problems associated with the energy transition and aim to develop sustainable energy plans for the selected districts, as well as to test these solutions in a 'living lab' approach. By demonstrating the effectiveness of the concepts, the aim is also to show how districts can be made climate-neutral under the given conditions. Even though all the projects shared the same goal of sustainable district design, the specific starting conditions differed greatly.

## 3.1 Initial Conditions

> *We've been on this mission for a while, looking at how we get a handle on the issue of integrated energy transition in the region, because of course we're a real renewable surplus region, and all the citizens see wind turbines shut down day in and day out.*

The focus in the project to which this quotation relates was to use surpluses from the local generation of renewable energies and thereby address a problem that has been visible in the region for a long time. In another project, on the other hand, the goal was primarily to integrate an already existing proposal for a technological solution into a district whose planning was largely complete and thus to demonstrate the importance of the technology as a building block for climate-neutral districts:

> *The entire district is not the goal of this project now, the development of the district would have taken place in any case. It would also have taken place in a 'climate-neutral' way: via conventional methods with a combined heat and power plant and similar hardware. The new contribution that the municipality can make to the energy transition is this specific design for a renewable energy supply infrastructure.*

2 None of the projects had a definition of a 'zero-emission' or 'climate-neutral' district that could be used as a general standard. Because it probably was clear to most project partners from the very beginning that complete climate-neutrality could not be achieved within five years, the implicit goal was rather to reduce emissions as much as possible under the current conditions and with the means available, and with a strong focus on a sustainable heat and electricity supply.

Yet another project wanted to lay the foundation for the longer-term development of its' district by formulating a sustainable energy concept that linked to local authority plans to develop existing brownfield sites into sustainable districts.

> *We had already drawn up a master plan for 100% climate neutrality for the city. So there was a working context as a background. And the site had been lying fallow for a very long time and then there was a framework plan and efforts to create a development plan. At some point, the city and the environmental protection agency wanted to develop a sustainable district and talked to various actors to get an energy plan funded.*

In several cases, existing plans served as the impetus to seek funding to drive forward the development in question and to test innovative concepts. Thus, while some consortia were able to link up early on with an urban planning framework and therefore had the opportunity to help shape district development from the very beginning, in other cases the project itself provided the impetus for the city and the actors involved to address issues of sustainable district development in the first place.

> *And in this energy transition context, the university has already done a lot, together with different partners from the housing industry, but also from other areas. So, in principle, this project should take this topic to the next level. The idea was taken to the city, to the mayor and we were really kicking at an open door. And also the municipal companies, the housing company and the energy supplier, were very enthusiastic.*

In the example mentioned, the consortium came up with a completely new idea, for which a comprehensive plan had yet to be developed and a suitable district had yet to be found. The same was true in another case, where the consortium had a history of cooperation going back many years, but the project idea itself had its origin in the call for proposals.

> *We have a long-standing cooperation with the city, especially in various BMWi demonstration projects. It was certainly from this cooperation that the idea of taking part in the competition was born. Then we sat down together here and chose a district, or rather one was suggested to us by the city.*

## 3.2 Real Labs And Districts

Despite the differences in the specific starting conditions and although, from the very beginning, all the projects were pursuing the goal of designing sustainable districts, all participants soon realised that complete districts cannot be transformed within 5 years, especially when some of them occupy an area of up to 40 ha.

> *Today it is even more obvious to us that this implementation obviously needs a lot more time, but well, if you have five years, then you can't somehow do three months of research and the rest implementation, that's not possible either.*

District developments, in which many of the lighthouse projects are embedded, often take place over a period of much more than 10 years, from the first conceptual urban planning discussions and the architectural competitions, the definition of the development plans, and the ground-breaking ceremony to the completion of the development. Another thing the projects have in common, therefore, is that they are limited to more restricted demonstration cases – for example, by first designating a core area for which existing buildings are to be redesigned in such a way that the sustainable energy plan can be implemented. From these starting points, the plans would then launch the development of the wider district.

Thus, these demonstration cases are not to be dismantled after the end of the project period, as is often the case in research projects, but rather serve as a starting point for further development in the district or represent self-contained building blocks for sustainable energy supply in the districts. One of the goals of some projects is therefore to lay the groundwork for climate neutrality to become a central feature of future development in the districts by establishing relevant structures and specifications.

> *That's where we see ourselves, as having the task of developing and establishing this infrastructure, these formats, in order to establish a breeding ground for further research projects (. . .). So this development of the living lab, but not the development of the energy transition, that was a second very large component of our project, yes.*

## 3.3 Developing a Common Understanding of the Problem

In addition to the different starting conditions of the various lighthouse projects, different expectations and interests on the part of the project partners and stakeholders came to light, often early on in the project, which were not always adequately addressed and communicated. Such disagreements often begin with the description of the problem and the definition of common goals. Even if all stakeholders roughly agree on sustainable district development as a common goal and commit to a specific formulation of the problem in the project proposal, in many cases, the various actors first had to develop a common understanding of the problem after the start of the project.

> *Because if you are completely honest, the first year is a search for a common understanding, where arguments are exchanged, partners are motivated, ideas are generated, and then a plan is created.*

At the beginning of the project, generating a common understanding that everyone could support was necessary simply because the research proposal was often pushed forward by a single research partner. This partner then looked for other collaborators, including the relevant partners from the municipality, civil society and business. However, these partners from practice would often not have had a precise idea of what they were actually facing.

> *We had to work several night shifts to get this project up and running in such a tight timeframe. The city was not particularly involved at this stage. The coordinator did all that. And then all of a sudden the city was there: 'We now have jobs, okay, now we'll take a look at the project.'*

After the start of the project, therefore, there was often an increased need for communication and a period of orientation.

> *We also spent the entire first two years creating a level of communication where the different partners could talk to each other properly – not just the partners from research and business, but sometimes those from business sector A and business sector B as well. That's a huge point, but in my view these kinds of research projects are very, very well suited for this, because they make the risk manageable and give all the participants at least some opportunities to deal with such things independently of their usual capacities.*

The high need for communication was due in particular to the different experiences and working cultures that the project suddenly brought together.

In one project, the differences between the partners were so pronounced that the city would have preferred to start implementation immediately, while the research partners had to insist on developing plans before proceeding to implementation.

> *At the city's insistence, we decided on the concept much earlier, after about a year. We actually wanted to develop a concept from the different clusters over two years, bring them together and discuss them, and then make a decision. But we scaled that down, because there was such strong potential for conflict with the city and other actors, because they wanted to go straight to implementation. Their attitude was: we'll build something there and implement it and then we're done. You do some research.*

In order to develop a common understanding of the problem space, differences in ways of thinking and acting, as well as in forms of communication, must first be bridged in order to mediate between the different expectations of the project and the further process.

## 3.4 From Understanding the Problem to Developing the Plan

At the beginning, the core of all projects consisted of the development of a basic energy plan – often for the entire district, whose overall development extended far beyond the actual project duration. An initial implementation and demonstration of the feasibility of the concepts was, in most cases, supposed to be carried out at least in a core area of the district and for either some of the existing buildings or a smaller number of buildings that had yet to be constructed. This approach was intended not only to demonstrate the basic building blocks of sustainable district development by using the buildings as models, but also to enable the active involvement (participation) of residents in district development. The idea was to develop and test various modes of participation, community district design or digital housing services together with residents. In addition to some core actors who were necessary for the develop-

ment of the energy plan, other partners with expertise in community research and development were also involved from the beginning.

As part of the energy plan and in addition to the solarisation of the buildings in the core area, all projects also developed a proposal for some kind of central supply or transfer station and a district heating network, the implementation of which was to begin during the course of the project. Because heat represents the largest proportion of the total final energy consumption in residential areas, the transformation of the heat supply is of great importance for sustainable development. Therefore, from the beginning, the focus of the projects was on energy sector integration (sector coupling) in order to ensure a sustainable heat supply:

> *The focus is of course on heat. That is not surprising, because heat is the main energy driver in a district. Even if we have also looked at transport and electricity consumption, you can see that heat is still the big energy driver in districts. Now, how do I find solutions that meet this demand to move towards $CO_2$ neutrality, or at least build a path towards it?*

Accordingly, in four of the projects, the consortia had the idea of extending the basic concept of a central supply or transfer station and a district heating network – alongside solarisation and increasing the energy efficiency of the buildings in accordance with the plans developed – to the entire district. For example, some partners, together with the participating municipalities, succeeded in introducing criteria into the development plans or purchase agreements with future investors that are designed to ensure the sustainable development of the district beyond the project period. Alternatively, others were able to implement an obligation for compulsory connection and usage for the heating networks.

More than half of the projects also show that one should not be too narrow-minded when defining the district boundaries. In the professional community, it has often been said that if a city is to successfully transition towards a sustainable energy supply, it is no longer sufficient to look at individual buildings, but instead districts should be considered as a whole. This basic idea of a district approach was also incorporated in the 'Gebäudeenergiegesetz' of 2020 (Deutscher Bundestag 2020). Yet the projects additionally show that a consideration of districts alone is sometimes not sufficient to develop sustainable solutions. Instead, in the course of the projects, the consortia often resorted to structures outside the district to ensure the viability of the energy plans. This included, for example, extending the boundaries of the search for consumers of the hydrogen produced, suppliers of industrial waste heat, or existing district heating networks that one could connect to outside the district.

> *Fortunately, here, it isn't like it is in urban development funding. There, you designate a district and it is very strictly defined. And you're only allowed to do things within the defined boundaries. We have a major client a little outside of here, who has signalled that he wants to join us. That is very important for us. At this point, we need an anchor customer, who has a relatively high demand. We once said that we need at least a 30 percent connection rate at the beginning, before investing actually starts.*

This extension of the search for producers or consumers of energy outside the district can not only help to guarantee minimum connection rates and thus ensure the economic viability of the proposed solutions, but also to enhance the sustainability of the development plans.

> *We did the energy plan, analysed the heat supply and came to the conclusion that using the industrial waste heat from a site that is in the immediate vicinity, but still four hundred metres away, would be the most ecologically and economically favourable option to realise the whole thing.*

Nevertheless, economic efficiency is the main motivation to look for connecting points in the wider environment, i.e. connections to existing infrastructures as well as synergies with entities outside the defined project area. In order for investments to be feasible, the infrastructure that exists within the framework of such projects must be connected to the larger system of energy supply and demand. In a broader sense, this is also described by some interviewees as the need for the developed solutions to serve the system or the grid.

> *Rather, the aim was to create this system that connects to and serves the wider energy system, and that is actually something that later turned out to be extremely complex, even from a purely legal point of view – how do you link it to the wider supply system?*

In principle, the interviews showed that three elements are essential for all the projects' district plans to ensure they meet the demand for sustainable supply structures. Firstly, it is important to ensure a certain building efficiency standard so that the heat generated is sufficient to meet demand. Secondly, it is necessary to tap into all local energy sources as completely as possible, e.g. by using available sources of waste heat or geothermal energy and completely solarising the roofs to provide enough green electricity for household use or for the heat supply. And thirdly, there is a need for cross-sectoral thinking, wherein the coupling of electricity and heat is ensured in most cases via various generators such as heat pumps, or via the use of waste heat from other plants and distribution through a district heating network.

> *In terms of learning from these approaches with the goal of climate neutrality, there are three or four simple truths. A first key element is solarisation, with photovoltaics as a basis. Then we need buildings with a good thermal insulation standard (. . .), in order to get the renewable energies into the buildings to a sufficient extent. Because environmental heat or renewable energies are only available to a limited extent in districts, demand must be correspondingly low. And then I have to use synergies by taking a cross-sectoral approach. That is also something that applies in general. (. . .) What does heat and electricity supply look like? How can I integrate the topic of transport? And can I create added value beyond that? And if we look at all sectors, then the energy sector and industry are also involved. That's why we say: 'This holistic thinking ultimately has to include all sectors.'*

A fourth component in almost all the projects is the provision of storage capacity for energy, be it in the form of electrolysers or battery storage. For the moment, building up storage capacity is currently only a small aspect of most projects, in part because

there are not enough surpluses generated in the districts themselves that could be stored, and in part because there are regulatory and economic hurdles to the efficient storage of renewable energy generated at other locations. Therefore, the question of how well the local energy infrastructures can serve the efficiency of the whole grid becomes an issue again.

These basic elements of the energy plan can be found in some form in all projects and were therefore referred to as the “three or four simple truths” that can ensure the transferability of the results to other districts. In many projects, plans for transport, district apps and a variety of participation formats are included alongside the energy plans.

## 3.5 From Concept to Implementation

Initially, most actors seem to assume that after a prolonged concept phase for the development of the energy supply structures, an implementation phase will follow in a strictly linear sequence. While in the concept phase, the actors develop solutions, for which, among other things, they have to gather information, convince external actors (such as the city council or possible operating companies) and initiate approval procedures; once a final decision is made, ‘only’ the implementation itself remains. Implementation then ‘only’ means that previously developed concepts are built and thereby demonstrated in previously defined core areas. Most coordinators, therefore, had firmly expected a more research-oriented concept phase of usually two to three years at the beginning, after which the projects would go into implementation.

In fact, however, all the projects show that considerable difficulties arise during this process and that the ensuing course is anything but linear, especially when it comes to moving from concept development to implementation. Instead of a linear sequence, there are always feedback loops and redefinitions. Partners drop out partway through, or change their role because the direction the concept development has taken does not fit with their own ideas. Particular difficulties have arisen for the energy suppliers originally envisaged as operators of the energy systems and involved as project partners. In four of the six lighthouse projects, the original energy supplier has left the consortium or has relinquished the role of operator.

> *We probably had a very special case in our project. We started in 2017 with the same team as now, except for the one exception that we had this company with us for the operation and planning of the system. They left after about a year. There were certainly staff shortages or deficiencies, which is why they had difficulties with the planning and coordination with the small team. And on the other hand, I think they had other internal specifications or ideas for the systems, so they pulled the plug. Because we focused very strongly on the operation of this specific system, this could of course have been the downfall of our entire project.*

Such a change can be quite threatening for the whole project and leads to significant delays even where the partners are able to successfully adapt. When partners drop

out, a new operator has to be found within a relatively short time if the remaining partners are to have any chance at all of implementing the plans. This happened in half of the projects. Some took steps to establish new operating companies for this purpose, while in others, the decision is still pending.

> *It's not quite as trivial as you might think. Because first of all, until such a municipal company is actually founded (which involves municipal supervision and everything that goes along with that – it's a very big process), it is not easy. The second thing is that not everyone is on board and behind us.*

In addition to the extreme case of a partner pulling out, the project partners also faced a variety of hurdles in trying to get their concepts implemented that they could not have foreseen at the beginning. These included regulatory challenges (for example, in the establishment of a 'customer system'), economic barriers that resulted primarily from competition with existing, conventionally operated supply systems, or environmental problems such as soil contamination. The concepts therefore had to be tailored to the specific conditions that prevailed in the local area, which is perhaps why the concept as originally envisaged turned out not to be feasible:

> *So the core objective of the application is: How can I supply the district with 100 per cent renewable energy from the region? We can already say that we have failed. We have a concept, but we haven't actually managed to achieve our goal of using the power from wind farms that would otherwise be switched off. Because the regulatory system, as it still is today, makes it impossible for me to use the electricity that is switched off five kilometres away in such a way that you can make it viable economically.*

Often, the research partners only realise in the course of putting the project plans into action, after working on a topic for some time, that the implementation is harder than initially thought. Delays also occur due to unforeseen barriers. A good example is the contamination of soils, the negative effects of which were additionally exacerbated in one case due to restrictions on gathering introduced during the COVID-19 pandemic.

> *Apart from that, we are currently having a hard time building up the area as a living lab, because the development is just so far behind the plan. We underestimated this unexploded ordnance clearance (UXO), especially in connection with Corona. UXO, assembly bans – what do you do if you find unexploded ordnance? So it had to be suspended completely, because then you can't get people together in a hall somewhere. Therefore, the exploratory work was stopped for about half a year. Then there were other contaminants in the existing buildings, so more of the existing buildings were demolished and more new construction was planned.*

Major social developments and crises can also cause hardship for projects that are scheduled to be completed within a certain period of time.

> *A large number of the buildings were to be demolished and redeveloped. But along the way, planning had to adapt to changing conditions. For example, the need for social housing keeps increasing, the school enrolment date changed mid-project which led to the need for more kindergartens.*

> *The refugee crisis in 2015 led to the need for interim accommodation, which was in part found in the site we are working on.*

In other cases, however, social developments can also have positive effects by providing important support for the partners.

> *Of course – this is one of the general conditions – the climate situation has changed in the last five years. That helps with participation, where people suddenly have more understanding of why such solutions are needed. It helps when comparing the price of heat, i.e. the developments of the last six months.*

Due to a stronger environmental movement and, more recently, sharply increased gas prices, concepts can become attractive when they were not before and thus give the projects additional impetus. In the course of time and as the project progresses, it can happen that external conditions change or are assessed differently and can thus have positive, as well as negative, effects. In extreme cases, as in one project, it can even happen that a partner who had previously dropped out rejoins the project.

> *And in the meantime, it turns out that the power supply company, which had left the project, is now interested in building a low-temperature heating network in the district and in fact is wiling to do this. It's partly because there was a change in the board of directors – it always depends on people. So at least we have achieved that.*

While such external developments are taking place, actors are constantly searching for solutions, continuing to develop the concepts, and rethinking or recomposing them in other ways.

> *When we started, we wanted to realise this hydrogen utilisation, either through a station for trailer filling, in order to bring the hydrogen from there to the industrial customers with trucks, or through a hydrogen filling station. However, a filling station is not economically viable at all because of the demand situation, even when considering the subsidies. And as far as the industrial supply is concerned, we started out with the aim of accommodating this plant technology in a new showcase district. There were many difficulties and challenges involved in doing this in a way that interfered as little as possible with the exterior design, which is why we had to refine or change the conceptual approaches, and which is why this filling station does not exist now. But of course we are still looking for solutions.*

In the end, the success of a project depends largely on whether the various actors involved in it can succeed in developing a basis of trust, cooperation and common objectives within the context of the diverse feedback processes that primarily take place between the idea generation phase, the decision-making phase and the implementation phase. And it also depends on whether the actors can enforce these concepts in light of the intricacies and uncertainties of the given conditions. In Sections 4 and 5, we look in more detail both at the actors who are indispensable for this process from the point of view of the interviewees and at the decisive internal and external conditions. The next subsection briefly recapitulates from a temporal perspective what the

essential key points of the projects are and what the projects have in common in terms of content and organisation.

## 3.6 Temporal Dimension

Almost all the projects needed more time than was originally estimated (at least 6–7 years instead of 5 years) in order to be able to implement at least the main features of the project envisaged in the project proposal. All coordinators agree that the complete (re)development of a district is not feasible in such a short time.

> *I mean, we all know that the limited duration of these research projects is not sufficient to follow a district from the conceptualisation and planning stages, through the implementation and then to the monitoring phase. That is too short a time.*

It is precisely this temporal dimension – i.e. the differences between long-term district development, which can extend well over a decade, and the comparatively short project durations of five years – that repeatedly gives rise to difficulties in the course of the project. In particular, the implementation phase causes the greatest difficulties for the consortia and most often forces them to repeatedly jump back to earlier phases ('feedback loops').

> *At the beginning, it went pretty well and things also pretty much followed the timetable that had been set. With respect to two or three aspects of the project, maybe even a little faster. However, particularly when it came to the switch from research and concept development to implementation, that's where it suddenly becomes difficult (. . .). Some researchers don't necessarily realise what implementation means. The people in charge of implementation don't know what research is.*

All the projects face a synchronisation problem, regardless of where they stand with respect to further district planning: in order to significantly advance the planning for the wider district and possibly, as has happened in many projects, to be able to also define standard requirements for development plans and purchase contracts, the projects must start early in the planning process. This, however, makes it less likely that implementation will be completed within the timeframe of the project.

The more the actors focus on establishing an energy plan for the whole district, the more important it becomes to be able to contribute to the development of the building plans – and the more difficult it will be to finish the implementation within the time allotted to the projects, let alone to carry out an evaluation of the infrastructure implemented.

> *The timeline is a very decisive one and dealing with it is also a major problem in such projects. On the one hand, energy plans should be prepared as early as possible because they are related to urban land use planning and the development of the zoning plan. The project therefore started relatively early in relation to the overall district development. (. . .) Furthermore, everyone who does district development knows that first you have a development plan, then the plots have to be put*

> *out to tender, and then it takes several years until the building actually takes place. So it was absolutely clear that the realisation of the wider district development plan was not going to be possible within the framework of the project.*

Conversely, when planning is already at an advanced stage and many decisions have already been made, this makes it difficult for the lighthouse projects to influence the design of the district and, at the same time, to accommodate major technological innovations in the district.

> *So the problems that gave us the biggest headaches were actually always due to the fact that everything was already planned and set in stone.*

However, at the other extreme – namely when the impetus for sustainable district planning essentially came from the project itself and there was no larger plan for the development of the district that the project could slot into – things were not necessarily any easier for the actors. This is particularly the case in projects located in existing districts. Here, the key actors must be convinced of the necessity of a redesign and persuaded to shift the priorities of the district development to align with the goals of the lighthouse projects in the first place.

> *This overarching theme, which we are now also always hearing about on a supra-regional level, i.e. $CO_2$ neutrality and climate issues, is also relevant on a small scale, but more for the end users. And for the municipality, for research, where this was at the top of the agenda. But for the companies that actually implement it in the end, that also pay for it, that finance it, one simply has to say that there are other priorities at the top.*

This synchronisation problem is also due to the fact that business partners, who are entrusted with implementation, e.g. investors, housing companies or power supply companies, do not usually base their time planning on research requirements and the duration of the concept development.

> *You can't take it for granted that when you suddenly come up with something like this, the investor will go along with it. They said, 'We'll do anything you want. The only restriction is that we won't wait for you. We have a fixed schedule. We have to deliver to our owners.'*

However, despite all these obstacles, the long duration of the projects seems to be conducive to their success, as it allows for an intensive examination of the concepts. On the one hand, the public perception of the projects and the participation of the municipalities create pressure to deal with the issues and not to reject the proposed ideas lightly. On the other hand, the projects create the opportunity for plans to be worked on intensively and repeatedly and for alternative options to be considered – a procedure that would, under different circumstances, likely not happen due to the material and time requirements in normal everyday life.

> *Constant dripping wears the stone and we tried out a lot of things. Solutions were always looked at and corrected. (. . .) And that's why we needed this initial year, and although we were already known in the consortium and there were lots of connections with each other, it still tookone and a*

*half years to get there, to really work constructively with each other. A few partners held back a bit and could have been much more involved, they could have implemented much more if they had simply been more open from the beginning. But all in all, I think that with the compromise we reached there is something in it for everyone.*

# 4 Actors and Key Influencing Factors

All six lighthouse projects involve a large number of actors from municipalities, the private sector, research or civil society who had quite different motives, expectations and interests. However, according to the interviewees, some actors are particularly 'critical to success'. If the consortia do not succeed in seeing that the interests of these critical stakeholders are safeguarded, or if these stakeholders are not prepared to support the implementation or even leave the consortium altogether, the success of the projects is seriously at risk. This also explains why the interviewees focus on the creation and implementation of sustainable energy concepts and why topics such as participation, mobility services and other components of the projects often only play a secondary role in the interviews. In the following, the most important actors, and especially their motives and interests, their behaviour and their competences, will be discussed. First, however, we will discuss the fundamental differences between research and practice and social dynamics in the transdisciplinary process.

## 4.1 Research and Practice

Most interviewees make a fundamental distinction between research partners and partners from practice such as municipal or industry partners as well as civil society actors in terms of their respective roles in the project, their expectations and behaviours, and, last but not least, their goals. Nevertheless, it is rather unusual in district development for cooperation between research and practice in the consortia to be relatively close.

*Normally, there aren't any discussions between researchers and practitioners. Usually, an investor talks to an engineering office or a planner, who then have a different argumentation. In the project, however, we noticed a big discrepancy in the communication between research partners and partners from practice, and there are not only investors to think about, but also the city administration, city planning, the power supply company, etc. It's a different language. It's a different approach. And above all, I would say that there is a big difference: for an investor or for a city administration, at some point, a development plan must be available or the investment decision must be made. So it's about delivering a product.*

In order to establish a common understanding between partners with such divergent perspectives, there seems to be a considerable need for communication and reflection on their respective roles and expectations. However, some interviewees are not con-

vinced whether it should be part of the researcher's role to convince practitioners of the validity of their concepts, and how much distance they themselves should have from objectives such as sustainability. Some interviewees tended towards a position where researchers neutrally develop concepts and are as unbiased as possible. They then repeatedly emphasise different perspectives on, and aspects of, a project to the practitioners so that the latter can make a sensible and sustainable decision.

> *Researchers have a bit of a role to play in presenting the breadth of innovative concepts. To remind the business partners of the concepts that exist and of the fact that it is important to be aware that the projects touch on different aspects, aspects that we as scientists are relatively impartial about because we bear little responsibility and few risks afterwards. In other words, if someone is only looking at the economy, then we have to say that there are other things, such as regulation. Or we have to look at the ecology or the social component.*

With these mentions of researchers' (supposed) impartiality and the differences in attribution of responsibility between researchers and business partners, the interviewee describes important reasons why participants have different perspectives and behaviour patterns: because it is the business partners who ultimately have to bear risks, and if the new solutions fail technically or do not pay off financially, they have to take responsibility for it. In contrast, it seems rather easy for the research partners to push for the implementation of more far-reaching measures – without bearing any entrepreneurial risks themselves.

> *At the end of the day, we as researchers come up with more or less innovative concepts, and ultimately a mayor or a city council or an investor has to decide what to do with them.*

Such differences are also reflected in the actors' expectations and assessments. For example, what a industry partner may judge as a highly innovative solution, may not even correspond to 'standard technology' for a research partner. Bringing together such different perspectives and linking them to a common solution is therefore at the core of the projects. Several interviewees think that it is precisely the 'scientist's distance from practice' that is decisive, by allowing for the development of concepts that go far beyond the status quo. Partners from practice, on the other hand, shy away from 'the risk of the new' and therefore often prefer to resort to familiar and tried-and-tested solutions.

In order to resolve this dilemma, according to most of the interviewees, the research partners in the living lab projects could not simply be neutral, but would also have to have an interest in the implementation of the concepts and therefore give up their 'distance' to a certain extent. The researchers had to engage with the interests and needs of the practitioners and also adopt a communicative attitude appropriate to transdisciplinary cooperation:

> *When a researcher gets involved in a living lab project, he must also have a stake in it and be prepared to work to ensure that what he develops tastes good to the fish and not just to the angler who hooks the result."*

While practitioners are required to be open-minded to new solutions, researchers have to strike a balance between being too close to practice and their professional distance from the project. Overall, the practitioners seem to be much more reserved about the objectives, while their participation in the projects seems to be essentially shaped by their specific (business) interests. From the coordinators' point of view, the practitioners therefore need more motivation to get involved and to commit to the objectives.

> *"And this thinking simply has to be there, the willingness to also think about what it means to take part in such a project: What am I getting myself into? Am I prepared to deal with new solutions? Of course, there are always risks involved. The question of legal issues. The question of commitment, the question of funding. Who bears the additional costs? How much acceptance is there, etc.?*

In particular, the prioritisation of different objectives, some of which were not openly formulated at the beginning of the projects, reflects the different attitudes of partners from research and partners from practice. While all actors agree that the security of the energy supply has the highest priority, they differ quite a bit in their assessments of other objectives. For the research partners, the lighthouse projects are primarily about new integrated solutions for districts that are as climate-neutral as possible. Aspects such as economic efficiency or 'warm rent neutrality' (meaning that rents including heating cost should stay the same after investments in energy efficiency or renewable energy supply) are important, but the decisive factor is that the solution is in line with the objective of climate-neutral supply, even if this means that energy prices have to increase or that less profit can be made compared to conventional solutions. However, partners from practice look at this differently; they expect the new energy concepts not to result in higher overall costs for housing and energy for the residents. In addition to their margins and return on investment, it is precisely this aspect that investors give priority to over climate neutrality. From this point of view, a new energy concept may well save less $CO_2$ if the rent including heating costs and potential returns remain the same.

> *After some time, we realised that we had not defined these goals clearly, neither among the project partners nor in discussions with the city or the municipal utility companies. And that naturally leads to the fact that if I have the goal of realising a climate-neutral district, and I then find out in the calculations that the heating price cannot remain at the usual heating price, but that a surcharge is necessary, then you have to go with it. But if at the same time you set another goal, that heating must not get more expensive, then I might have to say that that goal is not achievable.*

Such different logics and quite diffuse definitions of goals not only determine the actions of those involved, but, according to the interviewees, permanently become an issue within each project and have to be bridged again and again.

> *The goals that may be at the top of the list for researchers and also for the municipality are of course in the end not the top priority for the investors, who are also somewhat entrenched in their established models of thinking.*

In fact, industry partners prioritise the financial viability and economic efficiency of the developed solutions over sustainability, thus remaining oriented towards the current external conditions – current energy prices, their customers' demands and expectations, as well as existing technological concepts. From most coordinators' point of view, this perspective is strongly rooted in the status quo and lacks a longer-term orientation towards climate goals, legal and social developments and technological trends (including energy price developments). Conversely, practitioners often do not understand the disciplinary 'blindness' of the research partners and the large amount of time needed to develop the plans. Therefore, the researchers have to defend themselves against the impression that their proposals are too far removed from practice and cannot be implemented in reality.

## 4.2 Cities

One, if not the most essential, actor in all the lighthouse projects is the municipality itself, with its different political bodies and organs such as the environmental department, urban planning or licensing authorities. Therefore, it does not speak with one voice, and within the municipality, there are many different groupings with different agendas:

> *When you talk about the city, the question, of course, is who are you actually talking about? There is the environmental department, which manages the project, the urban planning department, which is responsible for the development of the land-use plan, and the mayor, who is ultimately responsible for everything. Then there is also the development company as a project developer and subsidiary, which acts independently. This means that when you talk about the city, you have to look closely at who it actually is, because of course there are also different opinions and attitudes within the city and its subsidiaries. As a result, you have to look carefully who you are talking to about what.*

In addition to the environmental departments, which are responsible for project coordination and/or public relations in more than half of the projects, the political structures, and in particular the mayor and the city council as central political bodies, play an essential role in the progress of the project. Mayors can achieve a lot through their prominent position and their generally good networking and can support the project considerably when it comes to clearing obstacles out of the way:

> *In the end, it is always a matter of political or public discussions. What counts, of course, are decisions. And so far, of course, after intensive preparatory work, they have always been initiated and adopted in the sense that we had proposed. From that point of view, there has always been support, both from the mayor and from the city council as a whole.*

Such support can make it much easier to solve problems – for example, if other actors are fundamentally opposed to implementation plans. Good networking and deep-rooted support from the city authorities is therefore a plus point in the implementation of these projects. In addition to the mayor, the municipal council also plays a significant

role. The city council not only decides on development plans and purchase contracts – e.g. the topics of compulsory connection and the use of heating networks, or the decision about the solarisation of roofs – it also determines other political guidelines and guiding principles. Thus, the municipal councils also give the projects important political backing in negotiations with other administrative bodies or municipal subsidiaries.

> *The different departments can sometimes be a challenge, as different departments have different tasks or topics as their responsibility. For example, even when the environmental department sets high goals for energy efficiency, other departments might recoil and hesitate to prescribe high efficiency standards for investors, as they fear that they then won't find anyone who is willing to invest. The education authority, for example, has the job of providing education for children, the wastewater treatment plant has the job of cleaning the water. That's their primary objective, and energy reduction comes second. Similar things happened in our project and it was sometimes difficult to reconcile the different objectives (fresh air corridors, urban green spaces, noise protection, etc).*

The support of the city council must therefore be taken into account as an essential factor in such projects, even if its presence or absence is difficult to influence, and the city council should therefore, according to many interviewees, ideally be involved at an early stage and regularly informed about the progress of the project.

Since departments such as urban planning or the office responsible for building regulations, which are also needed for approvals and have to make project-relevant decisions at many points, are usually not directly represented in the project itself, fundamental political decisions can therefore make negotiations much easier.

## 4.3 Housing Associations

In addition to the political and administrative levels of the municipality, it is primarily the energy suppliers and the housing associations that are essentially responsible for the implementation of the projects. In most of the lighthouse projects, these actors are also fully or partially municipal companies. The question of what energy supply in general, and a secure and sustainable energy supply in particular, may cost, and thus the question of whether – and if so, in what form – it will be implemented in the projects, is decided to a large extent by these actors.

> *It is still the local actors that need to be involved as much as possible. I think that's important, whether it's housing associations or, very importantly, the municipal utilities with their focus on energy. If you meet with resistance from them, then it is very, very difficult. But if they are taken on board at an early stage and perhaps even won over as operators of parts of the project, then at least – often because they are also subsidiaries of the city – you have two important players who speak with one voice.*

In particular, the housing associations have to decide to what extent they are prepared to impose burdens on their tenants and possibly also whether to take on extra communications work or, alternatively, to bear the costs of implementation themselves.

Especially when it comes to the generation and supply of renewable energy, but also to the question of the appropriate level of energy efficiency in buildings, the housing industry is an indispensable partner, but often quite a reluctant one. This is particularly evident in projects where the building stock plays an essential role. Since there are few regulatory requirements regarding energy efficiency standards for the existing building stock, the housing associations are free to make their own decisions. Their interest in investing in the energy efficiency of their own building stock is largely determined by the landlord/tenant dilemma. If housing associations cannot pass the costs of efficiency measures on to their tenants and the tenants are not willing to pay, the housing companies themselves have no incentive to invest in efficiency measures, because they will only increase their investment costs, while the positive effects in the form of energy savings will exclusively benefit the tenants (Melvin 2018). For housing associations, this means that either they have to be able to pass costs to tenants or there should be funding from the government, e.g. in the form of subsidies.

> *At the end of the day, put simply, it is a closed system. It is true that housing associations have to look at becoming more efficient. On the other hand, the cost will always remain with the final consumer. Even the obligation to pay a $CO_2$ price must be generated by the housing industry from its income. In the end, it is either subsidised or borne by the final consumer. There is no other way.*

Nevertheless, housing associations do have room for manoeuvre. Examples of this are housing associations that set up their own energy subsidiaries or even operate their own heating networks. Others install their own power grids on their premises, only to operate their own 'customer system' when it is worthwhile. From the coordinators' point of view, a housing association's willingness to take unfamiliar paths depends on the one hand on whether it has the necessary resources and knowledge to apply for funding. On the other hand, the association's experience with the relevant building standards and renovation measures, and above all, the attitude of the key decision-makers such as the managing directors, seem to play a major role:

> *If you take the housing industry, there too it depends on the people involved. I don't think that our housing association has exploited the full potential of the project. On the one hand, I can see that looking at the funds they have used, but on the other hand, it is also evident in the way they have contributed. So there is clearly still potential there. I also have to say that it really depends on the people involved and how forward-looking the organisations are. And yes, what their own goals are.*

However, a lack of willingness to invest may also be related to a certain mentality, a lack of long-term perspective and limited subjective rationality.

> *We have now had the experience that, even when things like the $CO_2$ levy are already fixed and do directly develop a price pressure, the head of our housing association then still says in the end. 'Well, nothing is fixed yet. I'll talk to our housing industry associations first, it'll take another year or so'. (. . .) This mentality, this sitting out, is something we have unfortunately had to observe a few times with one decision-maker or another.*

Overall, under the given conditions, it therefore often seems more attractive for housing associations to rely on a supply of renewable energy than to strive for higher efficiency standards in order to save energy. Therefore, one coordinator also sees the housing association in their project as the clear 'winner' of the proposal, as it does not have to make any investments itself in order to benefit from a better primary energy factor. However, this also makes certain energy plans that rely on a low heat demand in order to supply the buildings more difficult to implement. In new buildings, on the other hand, efficiency standards are now so high that the integration of renewable solutions is much easier. In addition, for new buildings, specifications for necessary measures can be defined to a greater extent through development plans or purchase agreements, although the decision lies with other actors such as the municipality.

Overall, this shows the contradiction between the goals of achieving climate neutrality and avoiding social burdens. With reference to both the affordability of housing and the cost burden on tenants, as well as their lack of interest in sustainability, it is therefore easier to reject stricter specifications and requirements for higher efficiency standards than to expect residents to pay higher, but sustainable, energy prices.

## 4.4 Energy Suppliers and Plant Operators

The situation with energy suppliers is somewhat different, but no less difficult. In the case of most lighthouse projects, the municipal utility companies are involved. Every solution – usually a district heating network coupled with various suppliers (waste heat from industry or from electrolysis, heat pumps, a connection to the wider district heating network etc.) – also requires a company that is responsible for operating the supply systems, as well as for marketing and selling the energy. Municipal utility companies bring both the appropriate resources and the necessary experience to take on this task and are therefore the natural choice of partner.

> *If you want to realise a climate-neutral district, then first of all, it's a question of energy supply, and then of course you talk to the municipal utility companies. It's about electricity and heat. They, or a subsidiary of theirs, will also have data. So it was quite natural that the supply should actually come from the public utility company, especially since they are also a subsidiary of the city. The fact that a lot of things were done without them is simply because in many respects they were not cooperative or the economic side was not attractive enough for them.*

However, this natural choice of partners often does not go very far. While for the researchers and, in some cases, also the municipal partners, a sustainable energy supply is the primary goal of the projects, this looks different for the power supply companies. Not surprisingly, their priority, as with the housing associations and other practical partners, is above all the economic efficiency of the solutions to be implemented. Other goals, such as the avoidance of emissions and the alignment of the supply systems with the climate goals of the German government, have to be subordinated to

this goal. However, what also surprises the coordinators over the course of the projects, and is clearly expressed in the interviews, is how narrowly economic efficiency is often understood in this context and by which factors it is influenced.

> *'Not economic' means below the expected return of a gas plant.*

Accordingly, economic efficiency usually means economic efficiency *at the present time and under the present conditions*, whereby existing and conventional solutions are always used as the reference. The lack of a long-term perspective and a strong orientation towards the status quo are striking. In addition, opportunity costs are usually not considered. From the coordinators' point of view, power supply companies do not sufficiently take into account possible price increases that would make a fossil fuel plant more expensive in the future and therefore would justify investment in a renewable solution. Conversely, they are quick to assume that the new plants, due to a lack of experience, will lead to high costs, e.g. for personnel, which will in turn negatively affect the economic viability of the plans under consideration.

While some energy supply companies take decisive steps towards the transition to a renewable energy supply, many still seem to be inclined to see the problems rather than the opportunities. This industry sector is therefore often seen as rather innovation-shy. While some interviewees maintained that being in the black would be a good result for the new district energy plans under prevailing conditions, some companies are still aiming for profit margins that make the implementation of climate-neutral concepts under these current conditions difficult. However, with regard to economic efficiency, one interviewee also points out that in the end it is less the specific calculations than the personal views of the decision-makers, their foresight and willingness to take risks, as well as their trust in the statements of the project partners, that make the decisive difference.

> *And as I said, money is of course important, but I don't think it's really just a question of how many cents something costs or how much additional cost there is in percentage terms, but whether the actors are convinced that this is necessary in the future and whether they are willing to take risks. And every new solution has risks, of course, because it is simply unknown.*

Getting involved with proposed solutions where the economic viability of an operation has yet to be proven is apparently also an option if managing directors expect to build up competencies and gain experience. This view is also supported by the fact that in some projects a change of operator or the willingness of various actors to establish a new company eventually ensured the implementation of innovative concepts, albeit partly at the expense of the original goals and with certain limitations in terms of emission savings.

As was the case with the housing associations, power supply companies faced difficulties in supporting implementation under the business and regulatory conditions that prevailed at the beginning of the project. Therefore, some lighthouse projects applied for an extension in order to be able to ensure even partial implementation. One

important reason for this seems to be that the factors governing whether a plan is economically viable have changed considerably in the meantime, particularly with sharply rising prices for fossil fuels in 2021 and after the Russian invasion of Ukraine in 2022. Finally, the duration and intensity of the joint work obviously pay off if the projects can contribute to learning effects and a change in values.

## 4.5 Coordinators, Project Developers and Development Agencies

At the centre of all projects stands the coordinator: he or she keeps an eye on the different issues, mediates between the partners' different interests and drives the project forward. It is the coordinators who ultimately have the task of bringing together all the different interests, expectations and competences and using them to develop a proposal. In almost all the interviews, the conclusion was that project management was much more important than had been assumed at the beginning and that more resources were needed for communication and coordination at the beginning than usually estimated for research projects.

However, since the expansion of the energy plan and the operation of the plants are to continue beyond the project period, this coordinating role also needs to be guaranteed in the longer term. In the view of some interviewees, however, some cities could be overburdened by this role, as a city's main influence on a district usually ends with the conclusion of the development plan and therefore many cities lack the corresponding resources to continue guiding district development. Therefore, project developers or development companies have an important role. Due to their experience with such projects and the necessary competences in the area of planning and approval procedures, as well as the acquisition of funding, they seem to be more able to push the projects forward and, in the best case scenario, ensure sustainable district development beyond the project period. However, there can be negative effects if this role is not occupied or the corresponding commitment is lacking, as one interviewee reported:

> *In addition, there needs to be a timetable and development plan (. . .) for the district. Here, the development company is responsible for coordination. It has coordinated the soil remediation and is taking care of road planning, development planning, and so on. But now, there are some open questions. At the moment there is no timetable (. . .). And obviously the project developer is either not able or not willing to (. . .) make a schedule and plan, which street building plots etc. can be built on in the next five years, and when and how this can happen. And of course this causes difficulties for all actors who now have to make a plan, because they don't know what they will be able to make happen. (. . .) There is a deficit here.*

At the time the interviews were conducted, i.e. in the fifth year of the projects, most consortia found that it was still an open question as to how the development of a district could be continued in accordance with the intended goals after the end of the project and how the continued operation of individual solutions could be ensured.

## 4.6 Citizens

In addition to the actors who are directly involved or at least associated with the projects, there are also actors who are not part of the consortia, but who should nevertheless be involved. These include in particular the wider public, the citizenry and the current or future residents of the district. These people are involved in the lighthouse projects through either the city or other project partners, such as social science institutes. A key challenge here is the question of the right form of participation, as well as how to deal with the imponderables of the planning process.

> *So of course we have the citizens, with whom we have been in contact from the very beginning. We have always involved them from a very early stage. We did all kinds of things, including an information container and events. They don't understand the timeline and, of course, they don't understand the funding issue at all. They hear about a large sum of money and then want to see something happening for that money. The excavator should start rolling right away. Yes, it's the excavator that counts, nothing else counts, no development plan or anything. It has to be visible, which makes the whole thing extremely difficult.*

Likewise, in the case of internal communication, the participation of the broader public and the demand to be as transparent as possible in planning create further difficulties when it comes to building trust among project partners and their ability to develop and discuss solutions together without putting pressure on the partners from practice by prematurely going public with plans.

> *And then there is this factor of uncertainty. Maybe we were very cautious or too cautious in many places, so that we simply didn't communicate things we weren't sure about. But we have seen for ourselves how often the project was already dead and then took another turn. You really can't communicate so openly in the process, because you always step on the toes of a stakeholder in the end. And that makes it difficult.*

One challenge in many projects was that many of the new districts were to be built from the ground up and thus no residents were there to discuss the plans with. Therefore, alternative methods of participation had to be found, e.g. by communicating with other residents living close by. However, what the project partners planning the participation see as particularly difficult is a lack of interest and understanding on the part of the residents – especially over a longer period of time – when it comes to participating in the developments. The right form of participation and involvement, as well as public relations work, is therefore an ongoing challenge for all projects.

## 4.7 Funding Agencies, Project Executing Agencies

Finally, among the external actors, the ministries and the project executing agency (as the funding body) naturally play a prominent role. As the considerations regarding the typical course of projects above have shown, the funding agency must be pre-

pared to go along with the recursive loops and the resulting delays and to allow the partners a high degree of flexibility in the face of the imponderables that arise. It was repeatedly emphasised by the interviewees that the organisation in question has fulfilled this role to an extraordinary degree. This especially applies in circumstances when partners have dropped out or the concepts had to be largely rescheduled due to unforeseen events.

> *I can say with certainty that there was never a lack of goodwill on the part of the project executing agency. We looked for solutions together and they were always very sympathetic in examining the proposed solutions or making suggestions.*

The willingness to keep looking for creative solutions with the coordinators was rated extremely positively by all interviewees. However, as will be discussed below, certain hurdles resulting from the funding regulations could not be removed and these sometimes represented major barriers to successful implementation.

> *Of course, we experienced this cooperation as very constructive and solutions-oriented on the part of the project executing agency, particularly the way that this support and supervision takes place. We feel that we are really being supported in order to make solutions possible. Nevertheless, there is a clear definition of the framework.*

## 4.8 Interim Conclusion

Overall, it can be said that different actors are pursuing very different interests. Especially with regard to their goals, they have very different expectations of the projects and bring different competences to the table. These differences must be absorbed and channelled through skilful coordination and the management of the logistics of the projects. What conclusions the coordinators therefore draw for project management is discussed in more detail in the last section.

For all actors, however, it is not only the institutional environment that plays a prominent role, but above all the specific individuals, their views, their relationships and their willingness to cooperate.

Trust is the decisive currency here. It is no coincidence that project consortia often consist of groups of actors who have worked together successfully on projects before or that they only come into being because of a pre-existing network between crucial actors. However, in each project there can be a change of personnel and without certain actors the success of the project can be endangered. Often, therefore, trust has to be built first and it is this trust-building work that plays a decisive role in the projects, consuming a lot of time and resources for communication.

Trust is also particularly important when it comes to taking risks and going down unusual paths, which is a basic requirement for projects that are seeking innovative solutions. A lot of information and data is not readily verifiable. It requires trust in the researchers that their calculations are correct, which is more easily achieved if

there is an understanding of what they do. Both can often only be acquired in the course of the projects. Conversely, on the part of the researchers, there must be an understanding of the needs and perceived scope for action of the practitioners in order to be able to work constructively with each other at all.

> *Why does it work or not work? Of course, this depends a lot on the willingness of the individual actors. And I think that there are very different actors. Many of the difficulties we have had, and still have, are related to the fact that individual actors, consciously or unconsciously, have – might I say? – simply pushed back many innovations. Or they have not supported them, or have only constantly mentioned the counter-arguments, or withheld information, or used killer arguments. And, of course, networks are also used to prevent changes and the like. So it is all these things that play a role and that often are only assessed under the conclusion that change brings about insecurity. (. . .) When people like that are in unfavourable positions or in important positions, then of course the question of credibility is a problem.*

# 5 External Factors

However, it is not only the actors, their goals, their competences and their behaviour that have a significant influence on the course of the projects, but also a number of different external conditions. Among many relevant factors, we can identify three key ones from the interviews. In addition to the regulatory environment, the existing structures, as well as the debates and events surrounding climate change itself, seem to have a big impact on the living labs.

## 5.1 Regulatory and Funding Environment

*"Regulation is one of the biggest obstacles, not only with the laws as they are, but also with the element of uncertainty that they bring to a project."*

Regulatory issues and, as part of this, funding conditions are among the most frequently mentioned factors on which, although they can hardly be influenced, a project's chances of success depend significantly. Every project also has to deal with lots of legal issues that, even if these can often be resolved, tie up many resources and take up a considerable amount of time along the way, starting with questions of data protection and how to obtain certain information, e.g. from the population register, and leading all the way to approval processes.

> *I mean, data collection in our district was not a trivial matter either, of course, with so many players, and then you have the issue of the General Data Protection Regulation. It takes a lot of effort to get energy consumption data, but also to find out things like how many people live there. Registration data are among the worst. Of course, this data is held by the city, but even there it is not shared internally.*

The legal issues are further complicated by the fact that the lighthouse projects are meant to be innovative. This means in particular that there is often little to no experience with the solutions envisaged. It is therefore very difficult for there to be complete legal certainty, which is why certain risks have to be taken if implementation is to be successful.

> *If the regional council had said: 'You need a safety zone', then that would have been it for the project. It was tense, because the approval process is a lot of work. And we were lucky that there were people in the regional council who were willing to go along with it and were a bit experimental. There was no blueprint. If someone is sitting there who is a little less courageous, then that may be it. Because if something goes wrong, someone takes the responsibility. And in cases where there's doubt, it's those who approved it.*

One example that appears in various projects and combines many of these problems is the establishment of customer systems – a concept that seeks to connect consumers and producers within a defined area in their own electricity grid, whereby one can generate and sell the electricity produced in the district cheaply and exempt from various fees. The realisation of a customer system is therefore sometimes decisive for business models and their economic viability. However, many legal questions have to be clarified and even then, a residual risk often remains:

> *Unfortunately, you don't apply for this status anywhere. You can just take it, but then you're vulnerable, that's the problem, until someone sues. That's why you have to have legal certainty. Well, in any case, we have obtained legal certainty with an expert opinion.*

The legal environment in particular often determines a project's economic viability. In one project, for example, the combination of a customer system with the concept of mini-photovoltaic systems, which the residents could hang on their balconies to become prosumers, would not have been economically viable due to the requirement for medium-voltage meters associated with the customer system. These and other hurdles then led to a decision not to introduce the customer system. In other cases, such hurdles could be removed through the intervention of other actors, e.g. by stipulating construction requirements or even a connection and use obligation in development plans and purchase contracts. However, this also required impositions, for example on the part of investors and residents, and was therefore accompanied by a great deal of persuasion and discussions about legal issues. An even greater effort was made in those projects where there were plans to found a new operating company.

However, some hurdles cannot be overcome even with the most risk-tolerant actors because the legal framework completely undermines economic viability.

> *Technically it's possible, but you can't make it economically viable. Switched-off wind power, if it is no longer switched off, with all the levies and charges, is no longer green as soon as it is in the grid. Even if you say it comes from the wind turbine, it is still only one-third green, because then the federal mix counts.*

Even though there may be good reasons for many regulations, they still can make things very difficult for actors who are looking for innovative possibilities for local energy supply and trying to find economically viable alternatives to existing technologies. It is therefore not enough to develop technical solutions; very often, a host of difficult legal questions must be clarified along the way.

An essential approach to compensate for a lack of economic efficiency is to provide the actors with sufficient funding for implementation as well. As far as the legal funding framework is concerned, however, the coordinators' assessment is equally ambivalent. For even if the basic material equipment of the projects is assessed as positive, the necessary conditions for investors essential for implementation are not attractive enough to sufficiently lower typical barriers to innovation. Respondents see the main cause of this as related to EU state aid regulations (EU 2014, in particular Articles 25, 36 and 38). According to the funding regulations for the lighthouse projects, only 50% of the depreciation of investments during the timeline of the project is subsidised. This means that for technologies and infrastructures with long life spans (for example, of 25 years), only 50% of the depreciation over the project period – i.e. a maximum of 5 years – was financially supported, reducing the funding in this hypothetical example to 10% of investments. Therefore, it remains unattractive for investors to invest in systems and facilities with long amortization periods, such as district heating networks or energy control centres.

> *When investments are funded in research projects, only depreciation is funded. Of course, this has to do with the EU's state aid framework. However, the state aid framework also allows for other approaches, if one were to take them into consideration. But then one would not be allowed to promote according to Article 25, but would have to take Article 36 or 38 as a basis. As a rule, however, these were not included in the research funding guidelines.*

In the application phase, the business partners from the field usually did not yet have a detailed awareness of the funding conditions, either because they did not yet have an eye for them or because the consequences of these regulations for project investments might have been difficult to assess beforehand. The EU regulation, for example, was relatively new and only was implemented in the year 2014, just three years before the projects actually started and therefore it is possible that not all the partners knew about it or completely understood its implications. The crux of the matter, identified in all projects, is that the funding conditions for research are good, but those for implementation were not seen as equally as good – and yet implementation, according to all interviewees, is at the core of the living labs and the lighthouse projects. Therefore, implementation faces major hurdles even with funding. For successful implementation, the partners are not only dependent on other funding sources, such as Germany's Kreditanstalt für Wiederaufbau (KfW), they must also be familiar with the corresponding regulatory framework and administrative procedures. Consequentially, the project consortia often had to reduce their goals of climate neutrality from

their original aims, which was, among other reasons, often a combination of insufficient compensation from funding or other sources and risk aversion.

## 5.2 Existing Structures, Energy Prices and the Question of What a Sustainable and Decentralised Energy Supply May Cost

Another significant aspect in all projects is the competitiveness of innovative energy concepts relative to established supply infrastructures. Innovative technologies are at a disadvantage compared to established systems in many respects, which is also evident in the projects. Just as the legal framework is not yet adapted to the new systems, the wider environment and existing infrastructures are not yet aligned with the innovative concepts. Among other things, this is in some instances discussed as a chicken-and-egg problem when it comes to the question of whether one first has to establish supply structures or whether there first needs to be sufficient demand. A good example is the production of green hydrogen. Although from at least one coordinator's point of view there is a broad consensus among experts that this is an indispensable component of the energy transition, even though not necessarily within residential areas, the demand in general is often still lacking. Furthermore, there are not only questions of economic efficiency, but also questions about connection to existing infrastructures.

> *And there are certain conditions that we set. In the regional context, I really need demand for hydrogen, or at least the prospect that this local demand will emerge in the future. Only then does it make sense. Because otherwise I have to think about how I'm going to transport the hydrogen over long distances. And then it's not justified. I also have to make sure that the hydrogen plant has a heat sink, either a district heating network or connected buildings. And there are restrictions here, too, because the consumers must also be able to use a corresponding temperature level.*

Special attention must be paid to the coupling with existing structures in existing districts, as here the entire district cannot be planned anew, but the existing structures must be worked with. The matter is further complicated if existing facilities have not yet been fully depreciated and amortized. Since the funding is usually not sufficient to compensate industry partners sufficiently for the existing hurdles, it is necessary to look for other synergies to overcome the concerns:

> *In addition to the residential buildings that are included in the district, we also have a school that is included. A primary school that is owned by the municipality, which is due for energy refurbishment anyway, and this was a good opportunity to find synergies there.*

However, the main problem in all the lighthouse projects, which concerns both new construction and existing buildings, is that from the viewpoint of the intended operators, the innovative systems do not always fit their business model and it is often difficult to operate them economically. On the one hand, certain approaches, such as the

idea of saving as much energy as possible through efficiency measures, contradict the business models of the power supply companies, who earn their money and recoup their investments by selling energy.

> *A major conflict where we tried to bring the actors together was that the more energy I save to become green – for example, by using building systems technology to increase efficiency – the more difficult it is, of course, to recoup the costs of the entire system. Because in the end, I have to recover the same costs with less energy consumed, which therefore has to be more expensive.*

On the other hand, due to their lack of experience in dealing with the innovative systems, operators anticipate risks that are then reflected in the costs, while they usually do not take into account the opportunity risks of existing systems, such as rising fossil fuel energy prices.

> *But the risk factor for the established system is never considered anywhere. For me, it also has a risk. That is, the risk that, for example, gas prices explode or gas no longer arrives at all. They do not take this risk into account at all, even if it is only an opportunity risk.*

These two factors contribute significantly to the view that systems based on renewables mostly cannot guarantee a price for heat that would be comparable to prices from conventional systems. The high investment costs, which cannot be entirely cancelled out by the subsidies, undermine the economic viability of renewables, because even if the energy costs through renewable energy are low in some cases, the apportionment of the necessary investment costs increases heating costs considerably. Due to the competition with existing systems, which are assessed to be cheaper in this respect, and due to both tenants' and housing associations' lack of willingness to pay for green energy, the operators make it in basically every project a condition for their participation and investment that the implementation is quasi neutral with respect to rent, including heating costs.

Even with stipulations of compulsory connection and use of the district heating networks, nevertheless, neutrality of rent (including heating) was in several cases declared a condition for implementation. A major problem here is that the current prices for fossil fuel energies are usually taken as a reference, which have changed only very moderately since 2017 and for most of the project term. It was only towards the end of the project term, from 2021 onwards, that the prices of fossil fuel energy began to rise sharply, partly due to the $CO_2$ price, but much more significantly due to the global economy picking up after the COVID-19 pandemic.[3] The fact that the additional costs are always compared to costs that prevail at the present time is therefore tantamount to a lack of a long-term orientation on the part of the actors.

**3** In the meantime, Russia's war against Ukraine and the associated sanctions have been added as a further factor. However, this development was not yet foreseeable at the time of the interviews and therefore did not play a role in the project evaluation at that time.

> *It is true that the question of additional costs is a very variable story, in that one must of course estimate the associated reference costs and the fossil fuel costs. Look at the development of gas prices and heating prices now. Under today's boundary conditions a profitability calculation is very different from what it was two years ago.*

The expectation in the projects was therefore that the government funding would completely close the gap between the economic viability of a fossil fuel and a sustainable energy supply, but this proved to be unrealistic. In the search for a compromise, therefore, most consortia ultimately considered solutions that moved away from the goal of climate neutrality instead of abandoning the idea of keeping energy prices the same.

> *The [housing associations] are very tough, according to the motto 'What's the price? We'll take another look at that. We aren't going to connect our buildings if it is more expensive than district heating or something like that.'*

The comparison with existing systems also makes the evaluation of the innovative solutions difficult. The sharp rise in energy prices since 2021 certainly played into the hands of the partners to some extent, especially since the players have become aware that there is no simple 'business as usual'. However, at the same time, other costs, such as construction costs, have also continued to rise sharply, so that even with the sharp increase in gas prices (before the war in Ukraine), fossil-fuel-based solutions were considered more attractive by many energy suppliers. An almost grotesque effect of the increases in oil and gas prices was the impairment of utility companies' ability to invest, because they were not able to pass the prices on to their customers at the same rate. This has reached such extremes that in one project a partner originally intended to be the operator of the energy systems actually had to file for insolvency.

> *There are two stories here. On the one hand, the increase in gas prices means that renewable energy solutions are suddenly becoming more competitive. And it is also the case that the power supply companies and customers naturally see that alternatives must also be developed. That's positive, but it's also true that the power supply companies are now under much more economic pressure and, even if they wanted to – as a result of these initial effects, they can no longer do what they want.*

All this shows that little attention is paid to future price developments. Instead, the strong adherence to the status quo makes it very difficult for projects that are trying to bring about a long-term transformation to keep their promises. And this also raises another question that is lurking under the surface of all the interviews, namely the question of what a sustainable and decentralised energy supply may actually cost and who should bear these costs. Because, in the end, it is either the state or the end consumer who has to pay the costs for this sustainability transformation, and as long as neither party is willing to do so and new business models hold too much risk and provide too few gains, the players' hands remain tied from a business point of view.

*But the managing director's hands are also a bit tied. And he also emphasised yesterday that people are now desperate to buy gas connections everywhere. And this makes him happy economically, but actually it is not the right signal. In this way, he also made it clear that he theoretically has a different mindset. But if the shareholders make a different decision, then they make a different decision. Then he has to take it and implement it.*

## 5.3 Climate Change and What Sustainability May Cost

This also brings us to the question of what role the climate discourse and the environmental awareness of citizens play in the projects. As a factor that affects the projects, all actors assess the increasing debate around climate change as very positive. The debate changes the attitudes of individual actors, and leads to a changed dynamic in which, for example, city councils adopt 'climate action master plans', 'integrated climate action plans' and 'climate action targets'. Additionally, new regulatory instruments are being introduced, such as the $CO_2$ price. However, there is another side to this, of which the $CO_2$ price is also a good example. While the trend is going in the right direction, the individual steps are, in the view of the interviewees, far from sufficient to support the desired transformation of the districts, just as the level of the $CO_2$ price is far from sufficient to bring about significant changes.

However, in addition to citizens' insufficient interest in sustainable behaviour, they often also lack the willingness to pay for sustainability. Furthermore, for some social classes there is also a limited ability to pay for sustainable energy provision – especially for people living in social housing, which accounts for many residents in the projects in question here, due to the frequent involvement of municipal housing associations. This in turn serves as an argument for all stakeholders for not allowing prices to rise too far.

*Many don't have the money. But many don't bother with it either, that's another thing. That means that the electricity comes out of the socket and somewhere I have a heating regulator, I turn it on and it gets warm. Thus, if someone says that you can somehow reach 60, 70, 80 percent of the population because you have a green image, you won't have that.*

Even though many project partners, especially those involved in participation and public relations, were afraid that the fear of certain technologies and the lack of acceptance among the local population would hamper the projects, these aspects proved to be not very decisive, which could, however, also be an effect of the participation efforts. However, what was a huge barrier is the fundamental lack of willingness to pay for a sustainable energy supply – this inhibits a sustainable transformation.

*And then people say, yes, we don't want to pay. There is natural gas, which is cheap if it comes from Russia, or let's see where it will come from.*

Another ambiguous effect lies in the public perception of the projects. Generally, the visibility of the projects is rated as very high by the coordinators, which also benefits

the projects' claims to be lighthouse projects and can have a motivating effect on actors such as the city, who see themselves as responsible for generating visible results from the funding. However, according to the coordinators, this visibility can also lead to negative effects among the local citizens – e.g. when citizens perceive the projects as heavily funded but not very productive, because they have problems understanding the research logic, they have difficulties staying motivated and interested over a period of five years, and in the end it is mainly the visible changes that are perceived. Particularly in the case of less visible successes, such as the design of a development plan or the conversion of hidden infrastructure, it is not to be expected that there will be storms of enthusiasm and therefore also no increased willingness to pay.

# 6 Transfer and Lessons Learned

To what extent do the lighthouse projects live up to their name and have an impact beyond the district? How does the transfer of knowledge take place? Moreover, what concrete lessons can the coordinators draw from the projects?

## 6.1 Knowledge Transfer

On the purely technical level of developing a plan for a sustainable and local energy supply, it becomes apparent that, depending on the local conditions, a few elements must be combined in order to generate added value in the sense of an energy supply that is as cheap as possible, accepted by residents and adapted to its context. This includes, firstly, the fullest possible usage of local energy sources, such as through the solarisation of roofs or even façades in order to generate enough green electricity within the district, but also through the use of geothermal or waste heat energy, depending on the local context and the availability of different energy sources. Secondly, buildings have to have certain efficiency standards to ensure a sustainable heat supply. The higher the efficiency standards of the buildings, the lower the heat demand that needs to be met and the easier it is to apply low-temperature systems such as heat pumps or low-temperature district heating. Thirdly, synergies must be exploited by coupling the different sectors, such as electricity, heat generation and transport, e.g. by supplying district heating networks via heat pumps, powering combined heat and power plants with biogas or using waste heat from industry or electrolysers. The presence of heat sinks that can cope with lower supply temperature and the supply of renewable electricity, as well as the possible economies of scale and the location of a project – e.g. in the middle of an urban area vs. on its outskirts – then determines whether individual modules such as electrolysers are profitable within a certain setting. Fourth, the possibility of storing energy surpluses from fluctuating renewable

energy generation and the integration of the district network into the wider grid, in order to balance differences in the supply and demand of renewable electricity between regions, are needed.

These various elements are always necessary in one form or another to supply districts with sustainable energy, but the specific system modules have to be flexibly coupled depending on local conditions. Depending on these conditions, one then has to choose whether to use, for example, geothermal energy, industrial waste heat, solar or wind energy for supplying electricity, heat and electric vehicles.

> *Everything else is scalable in principle. Depending on the orientation of these buildings, you could then integrate more or less solar heating or PV. Geothermal energy is a big topic in various areas. But if you go to the sea or to somewhere with open space, you might have instead a wind turbine. Or you could consider using industrial waste heat. Thus, this basic system is so scalable that it can really react to most circumstances.*

In addition to the structural-technical background, a number of other factors (discussed in detail in Section 5) are essential for the success of the project, especially with regard to legal issues, financing questions and questions of acceptance. However, the projects also show very clearly that one of the biggest hurdles that sustainable district solutions need to overcome is that they are currently not economically feasible – the necessary requirements are simply not met. As long as none of the actors is willing or obliged to accept higher heating prices than they have been used to in the short term, these plans will have a hard time competing with gas and oil.

Even if the general conditions – after the interviews were conducted – have changed considerably as a result of the war in Ukraine and are likely to contribute to a further rethink, the development of heating infrastructure in Germany clearly shows that there is still a long way to go before climate-neutral supply will be achieved. In 2020, the share of energy sources for the heating structure in the German housing stock was still 49.5% gas, 25% heating oil and 14.1% district heating (BDEW 2022), with 75% of district heating being supplied by fossil fuels (dena, 2022, p. 47). Less than 10% of the energy for heating comes from renewable sources. Moreover, it is way too early to interpret the efforts to become independent from Russian gas as a more fundamental shift away from fossil fuel energy sources. Rather, it is likely that in the medium term, policy-makers will focus more on a return to former price levels than on a forced conversion to sustainable structures.

In view of these hurdles, it is quite uncertain whether all the projects will see the implementation of the envisaged concepts by the end of the project terms, even with the extensions. What seems certain, however, is that large parts of the plans could not be implemented as envisaged at the beginning of the projects, whereby adjustments were often made at the expense of climate neutrality.

Nevertheless, all the coordinators rate the projects as on balance successful, even if there were disappointments, and they mention a number of results that contribute to this success and a successful knowledge transfer. Overall, one should not forget

that, from the coordinators' point of view, the projects are living labs, and a crucial aspect of living labs is to show what is possible under the existing conditions if only one is given resources and time to look intensively at different options.

> *For me, a living lab project is successful when I deal with the real problems that are there within the project, understand them and help to solve them or develop them further and learn something from them. And here, like all the projects probably did, we have had many experiences that made it much more difficult than expected.*

Four dimensions can be extracted from the interviews that constitute a successful knowledge transfer.

1) At the level of the districts in the six lighthouse projects, it is the decisions that particularly paved the way for further district development, such as concrete guidelines. This includes, for example, the adoption of guiding principles in the municipal council, the co-design of development plans or the definition and specification of criteria in purchase contracts.

   > *On the plus side, we have a good development plan, which has become better through our work. We have a mission statement, we have a requirement to install solar panels, we have low-temperature heat. We have set a course that is definitely there. From that point of view, there are things that are really visible.*

2) The lighthouse projects provide learning effects; because the actors involved accumulate knowledge, refine their solutions and adjust them to consumers' needs, this knowledge then becomes the basis for every future project. Some actors, however, also experience a change in attitude. Awareness of sustainable development is heightened and old certainties are questioned.

   > *All these soft factors, knowledge gain etc., they definitely also came about for all the partners in the project. We also had a few partners, from pump manufacturers to developers of information technology solutions. Of course, they all benefited greatly. Simply because the systems are much more sophisticated or more oriented to actual needs.*

3) The participating stakeholders pursue the concepts developed in the lighthouse projects in subsequent projects, in which they further refine and develop the solutions and where they can refer to and even demonstrate the results. Therefore, the lighthouse projects act as catalysts for the partners to get new projects, for example, because they can show concretely what they have achieved and let other actors share their experiences, including pointing out which mistakes should not be repeated.

   > *We are already preparing this in other projects. In one project, for example, they are building a new district for sixteen thousand inhabitants. Since we've now tested our system on a small scale, we're rethinking it so we can repeat it on a much larger scale in the new project.*

4) Lastly, successful knowledge transfer means that projects test the limits of what one can achieve under current legal, regulatory and financial conditions using current technology – they should also show what is not possible and where the concepts fail. The living lab projects show how laborious coordination processes can be and how important it is to deal with processes and structures. Learning from this experience and presenting these experiences is crucial, which is why we have publications like the current one.

   *We also learned what barriers and obstacles there are: What are the real problems? What are the fears? What are the legal or financial hurdles? What are the lines of argumentation? And afterwards it is also important that it's not just me personally or a handful of others who have learned this, but that it is also more widely analysed and communicated.*

These various points also clearly reflect the importance of living labs as research projects (as opposed to pure implementation projects). Living labs provide resources and time to pursue ideas that otherwise would not have been pursued and to make things happen that otherwise would not have happened, even if these things were often not planned from the beginning. And during the process, actors have also had to take on different loops and deal with many insecurities. Thus, the goal for many actors is to reach the point where research funding is no longer needed, because the pitfalls are then sufficiently known, but where funding for projects is only required to sufficiently compensate for the lack of profitability of sustainable systems compared to existing ones.

## 6.2 Findings for the Implementation of Research Projects

In addition to these four dimensions, there is also another class of experience, namely that which relates to the organisation of such transformation processes and even more narrowly to the organisation of living lab projects.

*One should clearly separate these classes of experiences in this presentation. One experience is in terms of implementation, technical solutions and processes. The other one is: How do you organise something like that? Or what are the obstacles, so to speak, in terms of process and organisation? Perhaps you could even add a third level: What does this actually mean for the organisers of living lab projects? On the one hand, we want to disseminate findings that work in a project development without a funding framework. But what we have just discussed rather relates to: What experience do I have in a funded framework?*

Especially on this procedural level, the coordinators cite many insights regarding what they believe coordinators in similar projects should pay attention to in the future. Even though some of the following aspects are difficult to influence, they still serve as warning signs and can be essential starting points to avoid unnecessary feedback loops and delays.

The interviewees raised the following points in particular:

1) An intensive and trust-building cooperation between the different actors within a project is crucial for the success of research projects: partners on the ground should be heavily involved as early as possible in the development of the concept, but without losing sight of the fundamental objective of sustainability and without unnecessarily narrowing the search for new solutions. For it is precisely by pursuing supposedly unattractive paths that new possibilities arise and ultimately lead to surprising results. However, it is essential to actively involve the addressees in the process and thus create trust, understanding of the process and solutions that meet actual needs.

2) To build this trust, communication is key: many coordinators seemed surprised at how much communication was ultimately required. They therefore recommended making sure from the very beginning that the partners regularly communicated their results to each other in an addressee-appropriate and descriptive manner, in order to avoid individual research partners silently working on their own. On the other hand, close bilateral exchange could not be overrated, because within large groups individual partners could easily withdraw from responsibility and progress is usually made in smaller settings.

3) In order to build better bridges between research and practice, a dual leadership with one research project leader and one representative from the practice side, often the municipality, would be beneficial for project administration; this would make it easier to mediate between the different styles of thinking and acting, for example between public administration, research and companies.

4) Coordinators must always be aware that the progress of a project ultimately depends on specific people. A lack of trust or the existence of hidden agendas, especially among people who sit at crucial interfaces, could severely disrupt any project, no matter how ambitious. Trust is therefore the key factor. However, even though there are many possible ways to establish and promote trust, there is no guarantee of a trusting cooperation. From the point of view of almost everyone involved, it is therefore a great advantage if there are caretakers or decision-makers in the projects, well-connected mediators who support the project's objectives but also have the power to resolve deadlocked situations. These are the kind of people who, if they are not sufficiently involved from the beginning, coordinators should try to engage in the course of the projects.

5) Coordinators should also deal with the necessary external conditions as early as possible. On the one hand, this concerns questions about the space needed for installations, but also for public relations work, which needs to be organised at an early stage. It also concerns questions about who will ultimately operate the energy supply systems or whether there are possible anchor customers who already cover a large part of the demand and could thus facilitate implementation. Because the search for a suitable oper-

ating company has proven particularly difficult in basically all of the six projects, the experience of the lighthouse projects also shows that being prepared means that the consortia should consider looking for ways to set up their own operating companies early on. Alternatively, another idea would be to regularly inform a number of potential operators about the plans and thus establish a wider circle of interested but competitive parties. And when looking for anchor customers, one should also broaden one's view beyond the district boundaries, as actors in neighbouring commercial areas or other city districts can also make the decisive difference.

6) The legal framework is considered one of the main factors influencing the various projects. Due to the abundance of legal topics on which sustainable and innovative energy plans often depend, several interviewees therefore rate it as very helpful to be able to fall back on local legal expertise for certain aspects. Legal advice, be it with the involvement of a designated partner or through subcontracting, could therefore be beneficial in the development of the energy plan.

7) In general, it is of great advantage if the partners know important nodes of decisions in advance and can also think about strategies for how they could influence them. This applies in particular to districts where the development is starting from scratch and where it is possible to incorporate specifications into development plans and purchase contracts, and thus set the course for sustainable development early on. In a slightly different way, it is also important for redevelopments of existing districts, e.g. when resolutions of the municipal council have to be sought in order to be able to refer an issue to the political decision-making level in the case of difficult decisions. Project goals such as climate neutrality should be defined in sufficiently concrete terms as a basis for decision-making and delineated from other goals so that they are not too easily softened in retrospect.

Beyond these seven lessons learned, a final point to be considered – although it can hardly be influenced by the coordinators themselves – concerns the project duration: in almost all the lighthouse projects, there were plans for a cost-neutral extension of up to two years. Even though concept development should usually not take much more than three years from some coordinators' point of view, it is the coupling with implementation and the resulting feedback loops that lead to delays and make implementation – not to mention a monitoring and evaluation phase – within five years so difficult. However, the projects also show that it is only the prospects for funding for implementation, and the persistent attempts to get into implementation, that lead to repeated refinements of scientific concepts and that make implementation possible at all. It therefore seems crucial to have a prospect for the funding of the implementation from the very beginning of a project. However, in the eyes of some coordinators, it could also make sense to have some interim evaluation, after which the consortia should then more easily be able to apply for extended time and resources for implementation and even an additional evaluation phase.

For the implementation – and this has also been clearly shown by the projects – improved conditions for supporting practice partners are also needed; funding of long-lasting infrastructures is definitely not sufficient under the current conditions (see Section 5) to really motivate the practice partners to an implementation.

Although there have been some disappointments for the interviewees, especially concerning the implementation of the sustainable concepts, the overall results show how much the different partners have benefited from the projects, the different ways one can learn from such projects, and how different the results and knowledge transfer such projects can look. Even if it is impossible in the planning of research projects to ensure compliance with all the criteria that were assessed as helpful by the interviewees, these experiences can nevertheless provide important impulses. They show that one should expect and can anticipate corresponding developments and that it is better to start dealing with these issues sooner rather than later. What else can be learned for sustainable district development in terms of technical implementation and the various processes is dealt with in detail in the other contributions to this anthology.

## Bibliography

BDEW (2022) Beheizungsstruktur des Wohnungsbestandes in Deutschland (online). Available at: https://www.bdew.de/service/daten-und-grafiken/beheizungsstruktur-wohnungsbestand/ (Accessed: 29 June 2022).

Bundesministerium für Bildung und Forschung (BMBF) (2016) *Bekanntmachung zur Förderung von Forschung, Entwicklung und Demonstration auf dem Gebiet energieeffizienter Gebäude und Quartiere*. Bundesanzeiger, 11 April 2016.

Bundesministerium für Bildung und Forschung (BMBF) (2017) *Urban districts as local drivers for the energy transition*, press release 084/2017 (online). Available at: https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/stadtquartiere-als-lokale-impulsgeber-fuer-die-energiewende.html (Accessed: 29 June 2022).

Deutsche Energie-Agentur (ed.) (dena) (2021) *DENA-GEBÄUDEREPORT 2022 – Zahlen, Daten, Fakten*.

Deutscher Bundestag (2020) *Gebäudeenergiegesetz*. Bundesgesetzblatt I, S.1728.

EU (2014) 'Commission Regulation (EU) No. 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty', *Official Journal of the European Union*.

Jahn, T. and Keil, F. (2016) 'Reallabore im Kontext transdisziplinärer Forschung', *GAIA*, 25(4), pp. 247–252.

Lösch, A. and Schneider, C. (2017) 'Smart-Grid-Experimente im Macht-Wissens-Dispositiv der Energiewende' in Böschen, S., Groß, M., Krohn, W. (eds.) *Experimentelle Gesellschaft – Das Experiment als wissensgesellschaftliches Dispositiv*. Baden-Baden: Nomos, pp. 163–184.

Mayring, P. (2008) *Qualitative Inhaltsanalyse – Grundlagen und Techniken*. 10th edn. Weinheim/Basel: Beltz.

Melvin, J. (2018) 'The split incentives energy efficiency problem: Evidence of underinvestment by landlords', *Energy Policy*, 115, pp. 342–352.

Nowotny, H., Scott, P.B., Gibbons, M.T. (2001) *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Malden: Polity Press.

Reusswig, F. and Lass, W. (2017) 'Urbs Laborans: Klimapolitische Realexperimente am Beispiel Berlins' in Böschen, S., Groß, M., Krohn, W. (eds.) *Experimentelle Gesellschaft – Das Experiment als wissensgesellschaftliches Dispositiv*. Baden-Baden: Nomos, pp. 311–340.

Schneidewind, U. and Singer-Brodowski, M. (2014) *Transformative Wissenschaft – Klimawandel im deutschen Wissenschafts- und Hochschulsystem*. 2nd edn. Marburg: Metropolis.

Scholl, C., de Kraker, J., Hoeflehner, T., Eriksen, M.A., Wlasak, P., Drage, T. (2018) 'Transitioning Urban Experiments: Reflections on Doing Action Research with Urban Labs', *GAIA*, 27(1), pp. 78–84.

Van de Ven, A., Polley, D., Garud, R., Venkataraman, S. (1999) *The Innovation Journey*. Oxford: Oxford University Press.

Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WGBU) (2011) *Welt im Wandel – Gesellschaftsvertrag für eine Große Transformation*. Berlin: WBGU.