Local energy innovators

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6

CONCLUSION

This chapter concludes my thesis on innovation for the energy transition by local energy initiatives. The empirical chapters highlight different aspects of such innovation processes, and this section gathers insights from all these chapters and presents an overarching perspective on the transformative potential of local energy initiatives. Subsequently, it discusses the theoretical and methodological reflections and the implications and recommendations to local energy initiatives, policy makers, and technology developers. Finally, as attempting to answer a question always leads to more questions, the thesis concludes with suggested avenues for further research.

6.1. Main conclusions

This section provides an overview of the main conclusions of the previous chapters, to use as starting point for answering the overarching research question:

What roles can local energy initiatives play in historical and current energy transitions through the development and embedding of socio-technical energy innovations?

This question was operationalized by splitting it up into four sub-questions. The sub-questions overlap with? knowledge lacunae regarding the characteristics of socio-technical innovation by local energy initiatives identified in the introduction. The sub-questions provided the focus for the empirical chapters:

1. How can local energy initiatives develop and implement **innovative technological configurations** by creating a supportive network? (CH2)
2. How do **value-sensitive multi-stakeholder processes** contribute to acceptable embedding of locally-owned energy technologies? (CH3)
3. What can be learnt about supporting local energy innovation from **regulatory experimentation**? (CH4)
4. How did **historical** energy initiatives contribute to socio-technical innovation during the adoption of electricity technology, and how was this influenced by the interplay between technologies, actors, and regulations? (CH5)

The answers to these questions will be discussed in the remainder of this sub-section.

6.1.1. Developing innovative technological configurations

Chapter 2 delves into the ways local energy initiatives develop socio- technological innovations by growing an actor network. They initially develop innovative configurations on an ad hoc and step-wise learning-as-we-go basis, in a process that becomes more structured as the projects progress. The research supports the hypotheses that innovation increases the difficulty of project development, and that the outcomes of the innovation processes are very dependent on the networking capabilities of the energy initiatives.

Initiatives developed innovative RE projects through seizing local opportunities for synergies and trade-offs with local actors and by linking to the systemic functions of the local landscape. Furthermore, they started from an awareness of the local circumstances and sought to develop their project to fit with these circumstances and to create synergies by aligning their goals with those of other local actants where possible.

To find partners to create synergies with, they needed to convincingly demonstrate the potential to create successful alignments and functioning innovation. Tangible products, such as studies performed by students or a feasibility report prepared by a recognized specialist, can function as strong interessement devices to get other actors with additional resources, such as knowledge, further networks, and capital, on board in innovation projects. Initially, resourceful actors came primarily from existing professional and personal networks. In the later stages, they come from a wider network in which contacts from the partnering actors' networks and unfamiliar actors are also engaged. Local government and intermediaries [16] are especially valuable partners in helping to build necessary ties between the members of the actor network that are hard to align. Commitment to the socio-technical network then needs to be established by being more of a beneficial point of passage than an obligatory one, which makes the interessement devices even more important.

During the innovation process, actors need to prevent invisible or hidden misalignments from emerging during and after implementation. As alignment is formed in an interactional process with incomplete information, an actor might think that certain parts of the innovation network are aligned, whereas in reality, they are not. In the case of the paper landfill site, the connection between the solar thin-film and the physical conditions at the landfill was such an invisible misalignment. The film did not react well to the weather conditions and soon started deteriorating.

6.1.2. Establishing value sensitive implementation processes

The empirical investigation in chapter 3 focuses on the role of values in implementation processes of local energy initiatives, particularly how a wide variety of stakeholder values could be integrated in the design of two locally owned wind projects developed by farmers. The case studies were a number of simultaneously initiated small-scale projects in Middag-Humsterland and a large-scale project in the Oostpolder, both in Groningen. The varying sizes of the projects enabled an analysis of the different possibilities for participative project design within the framework of extant regulation in the Netherlands.

Although the owners of the projects in the studied cases were local residents, differences in power and agency necessitated a levelling of the playing field in the participative planning processes that unfolded. Residents struggled to be kept informed about all procedures and to be seen as an equal stakeholder. In a participative planning context such as a sounding board, the help of a neutral mediator [1], or even supportive intermediaries [2], can help residents to have a more equal standing.

A second conclusion was that innovative processes and collaborations require intersubjectivity to create more widely shared value conceptualisations, and enable embedding in design. This is especially so when it comes to values that are hard or impossible to operationalize quantitatively.

Third, not all value conflicts in local wind energy projects can be solved through making design choices that align conflicting values. When multiple values or norms are involved, there is not a single norm that can function as a standard to resolve conflicts or make trade-offs. Furthermore, certain values or even conceptualisations of values are incommensurable. The pursuit of a certain value from the perspective of one or more stakeholders then inevitably comprises or limits the ability to pursue certain other values [3]. Therefore, a methodology giving guidance in resolving value conflicts would be beneficial.

Fourth, the cases show that value conflicts can also be productive. The ever-returning value conflict between landscape, economic, liveability and nature values that accompanies the implementation of wind on land has created a market for alternative designs such as the small-scale E.A.Z. turbine. Furthermore, in both case studies value conflicts led to design adjustments that made the wind project more aligned with local values or created a wider shared intersubjectivity on value conceptualisations. Thus, conflicts teach developers that an initial awareness of the values of all stakeholders leads to overall better solutions.

Fifth, the space for a supralegal degree of value sensitivity that was carefully constructed in both cases is by no means a norm and it is very dependent on efforts of local stakeholders such as a local government or residents. Policy that is more supportive of participation and representation of stakeholders other than the developer would boost the design of more value inclusive energy projects. Here, identification of values and mapping and discussing value conflicts could be a useful tool to better include situatedness and place-specificity in renewable energy planning.

6.1.3. Influence of new and existing energy regulations and policies

Chapter 4 studies the relation between regulations and local energy innovation, focussing on the EDSEP as an example of a regulatory sandbox. This decree creates a participatory experimentation environment for exploring the revision of the Electricity Act (In Dutch: Elektriciteitswet). When projects receive a derogation under the EDSEP, they can perform new tasks and combine roles that are otherwise legally separated and thereby deliberately unbundled to protect the consumer and safeguard security of supply, affordability, and safety. The first option is the development of a project grid. Here, local energy initiatives can act simultaneously as the supplier, producer, and distributor of energy, managing a mini grid. The other option is a large experiment, in which the grid remains owned by the grid operator, and the initiatives are concerned with flattening the usage profile and balancing supply and demand.

By taking on these tasks, experimenters become part of a polycentric energy system with decision-making units at several levels. This turned out to be a complicated procedure with limited attractiveness for local energy initiatives, which resulted in only 18 experiments of the potential 80 in a four-year period being executed. Experimentation under the EDSEP showed that inter-actor alignment was initially lacking and pro-active nurturing would have smoothened the implementation. Furthermore, EDSEP experimenters faced significant constraints (e.g. no financial aid tied to experimentation, double taxation of storage, financial risks, and the necessity of large investments to take on and benefit from supply/DSO tasks), had very limited political representation, and varying representation of the users within the experiment.

Thus, having the opportunity to take more control over the local energy system from a legal perspective does not always mean that all of this control can be taken over and all new roles can be enacted. For experimenters, it was not, or not yet feasible to take on some of the tasks, mostly due to financial, organisational, or other practical constraints. However, despite the fact that experimenters cannot take full control, the EDSEP provides end-user collectives with an incentive to balance their grid, e.g., enabling p-2-p supply without intervention of a DSO.

A more holistic approach of the regulator, inter-actor alignment, the availability of expert support by an intermediary, and facilitation of a close-knit learning community are expected to be beneficial to future regulatory sandboxes for local energy experimentation.

6.1.4. A historical perspective on collective energy experimentation

The role of historical electrification cooperatives as actors within the electrification niche during its development to a regime from 1900-1950 is central in the fifth chapter. It analyses how electrification cooperatives' emergence and decline was related to the dynamics in the forming proto-regime regarding rules, actor-constellations and technologies.

At least 83 energy cooperatives were founded between 1905 and 1929. The two types of cooperatives were distribution cooperatives and integrated production and distribution cooperatives. The cooperatives were founded by the societal upper and middle classes. The distribution-only cooperatives were often established by more diverse groups of citizens, also including working class citizens as they needed to guarantee a certain level of use from the start.

Large regional diversity existed in the cooperative electrification niche as the cooperatives predominantly emerged in the northern provinces Friesland and Drenthe. In the other provinces, early electrification was mainly carried out by the municipalities or, in a few instances, by other private companies.

The emergence of the cooperatives in Friesland took off rather early and happened in a regulatory vacuum. From 1910-1916, only the permission of the municipal government was required for a permit. Cooperative electricity was orchestrated by people used to take private initiative in the province’s remote rural communities. These often had no gas factory but were looking for modernisation of the energy provision. The cooperatives founded after 1916 were mainly distribution cooperatives that formed to guarantee sufficient demand to connect these localities to the expanding provincial grid.

In Drenthe, cooperative energy development was a way to realise electrification despite a lack of initiative from local and provincial governments, and the slow connection to the regional grids of the neighbouring provinces. Initiative mainly took place in the wealthy peat extraction area. Farmers in this area built on a history of cooperative enterprising in the agricultural sector, and had been able to collectively secure loans for sizeable factories for processing agricultural produce. The familiarity with the cooperative model in agriculture in both provinces may have made the step to cooperative electricity smaller.

Hence, the niche consisted of heterogeneous innovation environments in which the development, diffusion and embedment of niche technologies was performed by different actors, at different paces, and in different ways across different localities.

The electrification cooperatives started to disappear when the advantages of upscaling became larger and regulations put the mandate for energy provision with the provincial government. Some still functioned as a distribution cooperative for a period of time before being dissolved, and could negotiate better tariffs because they had their own grid. By the 1930s, nearly all energy cooperatives had ended their operations [4]. Their main roles had been to help the dispersion of electricity technology by making it accessible in rural areas and to familiarise society with this new energy source.

6.2. Reflection on analytical frames

This section reflects on the theoretical frameworks and approaches used in the thesis. First, the choice for these particular frameworks will be discussed, and then the contribution of the frameworks to the analyses performed in the chapters.

6.2.1. Understanding local energy innovation through complementary theories

This thesis analyses the interplay between technological configurations, actor constellations, regulations, and values to better understand which roles energy initiatives can play as experimenters within the Dutch energy transition. To understand the network that is shaped by energy initiatives while developing innovative socio-technical configurations actor-network theory (ANT) was used. This theory does not discriminate between humans and non-humans, and describes both as agents that resist or accept being embedded in a network, and are changed in the process. While this framework is excellent for describing an innovation as a configuration, and therefore as a construction and not just an outcome, it does not adequately capture the influence of policies and regulations. For this reason, the polycentrism concept from the work of Vincent Ostrom was chosen to study how an experimenting energy initiative can operate as part of a network with distributed decision-making power. This concept put institutional arrangements at the centre of the analysis, and has been helpful to show how a local energy initiative can steer the innovation process in a regulatory sandbox where they can play around but are, at the same time, bound to rules of many other actors. The dimension that was still missing from the analyses of the actor-technology configurations was that of the actors who were not directly involved in the projects but who were still impacted by innovative local energy projects. Value sensitive design was chosen to analyse how local energy innovation can support or conflict with values, especially those of stakeholders other than the local owners. Including a value-based perspective added a normative and reflexive dimension to this thesis and allowed for showing how an energy innovation can be designed more acceptably, and whether implementation is locally appropriate. Finally, the MLP and proto-regime concept were able to provide a structure that allowed for systems perspective analysis of the three central elements of technological configurations, regulations, and actor constellations. This framework works well for analysing developments over a longer period of time and captures changing system interactions at the level of a country or a region.

Thus, in this thesis, conceptual frameworks from multiple traditions are used: ANT from science and technology studies, VSD from ethics of technology, polycentrism from institutional economics and MLP from innovation studies. As a consequence, the relationship between the social and technical has been differently operationalized throughout the thesis.

As stated in the introduction, this research foregrounds the socio-technical dimension. This means that when it comes to local energy innovation, the position is taken that the social cannot be studied in isolation of the technical, and vice versa. The ANT framework used in chapter 2 most closely and purely resembles the view of a seamless web of socio-technical elements. It opposes social determinism and ascribes agency to both social and material elements.

However, in the other chapters, technologies and actors are differentiated on a conceptual level. This operationalization does not intend to deny the interwovenness of the social and the technical. Defining actors and technologies as separate categories was simply a more pragmatic operationalization. The use of fewer neologisms also makes the research easier to communicate.

Chapters 3-5 take a more social constructivist approach. This followed naturally from the centrality of the local energy initiatives in this study. Nevertheless, the influence of the technologies in shaping the interactions in actor-networks has never been forgotten--especially, because it was the socio-technical dimension that was the starting point of this thesis. There are abundant examples of how technological possibilities characterize the innovation processes by the energy initiatives throughout the thesis.

Thus, while the operationalization of the relationship between the social and the technical may differ, the underlying conviction throughout the thesis has been that social and technical are mutually constitutive and technological innovations (CH2), values (CH3), institutional arrangements (CH4), and energy systems (CH5) are not given, but constructed.

In the remaining sub-sections, the value of the theoretical frameworks to the sub-questions of the thesis is discussed.

6.2.2. ANT

The ANT conceptual lens used in chapter 2 allows for a rich and detailed analysis of local network dynamics in developing new technologies and configurations. Using this approach, it was possible to analyze local grassroots innovations and the specific ways they were connected, as each local context and each particular technology implies a specific constellation of networked social and material elements (actants). The translation dynamics highlight the changing roles and identities of these elements during network-building. The new technological configuration is understood as an outcome of translation dynamics shaped in the local process of alignment, stabilization, and destabilization of networks.

More concretely, ANT enabled following energy initiatives and the alignments that they established to engage actants who could fulfil roles such as site, energy generator, inventor, connector (e.g., intermediary), advocate, authority, or provider of various other resources. It showed that many actants were intentionally engaged by the initiatives, but others created a role for themselves, desired or undesired.

Furthermore, ANT was useful to show how translation processes can change the role of social and material elements during the development of an innovative socio-technical configuration. For instance, both case study sites changed their identity from useless wasteland to RE generation sites and symbols of local sustainability. This development highlights change in the identities of the actants, which should not be overlooked in network analyses as this aspect of translation is influential in the success of the socio-technical configuration.

In addition, using ANT enabled consideration of the roles of material and human elements equally in the network building processes of adjustment, molding, attempts at connection, and misalignment. The success or failure of local innovative configurations, and thereby their potential to contribute to local and supra-local energy transitions, is shaped through these processes. When advocates for energy transition start a project or technology development and are sensitive to the identity and agency of other material and social elements, innovative technological configurations of various kinds are more likely to have high potential for developing synergies with their implementation context. Because they are included in the local context, energy initiatives are well-positioned to contribute to the creation of such synergies.

6.2.3. Value sensitive processes

In analysing conflict about farmer-owned energy projects, the value perspective was beneficial in better understanding tensions because it highlights a need for fostering intersubjectivity, which enhances more widely shared value conceptualisations and facilitates the embedding of local values in design of RE energy projects. Furthermore, the value-centred approach also helped to point out that not all value conflicts in local wind energy projects can be solved through making design choices that align conflicting values, e.g. for political and financial reasons.

Moreover, the value-centred approach helped in understanding that these conflicts are about prioritisation, because in cases where multiple values or norms are involved, there is not a single norm that can function as a standard to resolve conflicts or make trade-offs. Furthermore, certain values or even conceptualisations of values are incommensurable. It is therefore impossible to represent all stakeholders' values in a design.

Furthermore, local ownership does not automatically imply that a project has an acceptable design. The precise influence of local ownership is affected by the parties who benefit from a project. The extent to which the impacted community of place intersects with the community of interest that benefits from the development is especially important [5]. In the case of Middag-Humsterland and Oostpolder, the benefits only or mainly accrue to a few individuals within the community, which may well limit acceptability.

Hence, the value approach underlined that ownership is not the only factor in acceptability. Values of local stakeholders are diverse and situated. What is acceptable is place-specific, and related to e.g. past locally unwanted land uses like in the Oostpolder case and the cultural heritage identity of Middag-Humsterland. History, context and geographic scale are key to acceptability [5].

6.2.4. Polycentricity

A merit of the concept of polycentricity used in chapter 4 is that an actor constellation can be described by four different actor characteristics (level, type, sector, and function), which provide helpful tools for understanding the context of experimentation. This concept provides guidance for this study in defining actor roles and their position in the energy system. Using the concept of polycentricity facilitates visualising a nested system of decision-making units and analysing the ways in which unites are layered.

Furthermore, the concepts for evaluating the role of actors in polycentric systems (local autonomy, control, efficiency, and political representation) help in understanding what is necessary for a decision-making unit in such a system to function well. They are especially useful in studying legal innovations due to the inclusion of the concepts of control and political representation. The same goes for studying participative bottom-up innovation due to the inclusion of local autonomy. Lastly, the concept of efficiency helps in understanding whether the decision-making unit can provide added value to the system, which is a useful indicator in assessing whether experiments contribute to an efficient process towards a more sustainable energy system.

However, it is important to note that the success of the experimenters in the polycentric context does not equal the value of the experiment for legal innovation. In evaluating the experiments, the question should also be whether the experiment has resulted in new insights for guiding the energy transition, and not only whether the experimentation constellation itself is efficient in providing added value. Learning potential, instead of replication potential, should be central in evaluating experimentation for legal innovation.

Furthermore, the analytical framework is focused on the functioning of the polycentric system, but does not give theoretical guidance on what actors can do to nurture experimentation, or how they can better work together and create alignment in the system. Applying frameworks to further explore these aspects of innovation management may be helpful (e.g. strategic niche management and actor-network theory).

6.2.5. MLP and the proto-regime

The MLP provides a structuring framework for understanding transition processes from one socio-technical system to another[6]. Like the concept of polycentricy, it takes a systems perspective and also distinguishes layers, but instead of institutional dimensions, it foregrounds how an innovation (often a niche technology) interacts with an established system.

In this chapter, the focus was on the development of the electrification niche to a regime within the wider energy sector (including e.g. gas, petroleum, and candles), and the role of the Dutch electrification cooperatives as a subniche during this development.

To analyse the development of electricity from a niche into a regime, further operationalisation of the development of a niche into a regime was needed for which the concept proto-regime was used. A theoretical contribution of the study was operationalizing the proto-regime as consisting of three interlinked elements, namely rules, actors, and technologies.

Furthermore, a contribution was made to understanding niches as heterogeneous innovation environments where the development, diffusion and embedding of niche technologies can be performed by different actors, at different paces, and in different ways across different localities[7]. This contrasts to MLP studies on contemporary local energy that have given a snapshot of the role of community energy in the national energy system[8]–[10] or analysed local case studies [11], [12]. These studies tend to either aggregate the data and describe the local energy niche from a country-level perspective, or focus on specific cases. As a result, they do not show nor explain the regional differences that can co-exist within a niche.

6.3. Methodological reflections

One important methodological observation drawn from the contemporary case studies is that socio-technical innovation processes are challenging for energy initiatives. They take several years and many innovation processes were not yet finished by the end of the 5-year period in which this thesis was written. Therefore, ideally, long-term relations with initiatives should be formed to capture the full innovation dynamic. Furthermore, the burden of cooperating in the research should be kept as low as possible for the initiative. If feasible, research participants should also be compensated for their input, either financially, through a reciprocal time investment, or by providing useful information in an accessible format, such as a toolkit or a roadmap.

Long-term reciprocal relations are especially important for future work on local energy innovations. If studies only engage with innovations that come to completion or have been completed, a significant bias towards the success stories of local energy innovation is chronicled in community energy and innovation literature.

It is hard to identify and follow innovations that do not succeed or have not yet led to an operational project. Yet, it is essential to monitor these to get a more realistic view of the circumstances under which local energy innovation can be successful and to see what the impact of being part of or leading innovation processes is for an initiative. This is especially important given that innovation projects become increasingly complex as community energy branches out to systems solutions such as smart grid and district heating.

Now that more and more work on local energy innovations is coming out, it will be possible to undertake a structured literature review of socio-technical innovation processes in the community energy sector. Such work could give a more rigorous and systematic perspective that builds on the case studies, such as those presented in this thesis. It could identify patterns and confirm or modify hypotheses raised about the possibilities and limitations of the new roles of local energy innovators, their collaborations, interactions with and shaping of new socio-technical configurations, and the influence of the regulatory framework on these processes.

6.4. The historical cooperative electrification niche and the current local energy niche compared

In this section, insights from the historical chapter are reflected upon and contrasted with developments in the current community energy niche. The focus is on the institutional space to embed energy innovations in a changing actor-constellation. What role community energy innovators can have in the future energy system is unknown, but here some reflections are given based on differences and similarities between both niches.

One similarity is the absence or limited presence of public or non-cooperative private action in combination with institutional space to operate[13]. Today, citizen collectives are motivated to take action to speed up the slowly progressing local and national energy transition to RE. These citizens are motivated by a combination of individual and collective drivers, including social, economic, and environmental ones [14], [15]. Yet, all initiatives aim to contribute to energy sustainability. During the electrification period, reasons for cooperative enterprising in the electricity sector were socio-economical. The members of these cooperatives wanted to improve their living and working conditions by creating access to electricity. Although their members were mostly upper and middle class, like the members of today's initiatives[16], they needed to bundle their capital in collectives to create access for themselves. Most initiators of today's initiatives would also be able to generate RE for their own household, and the collective interest is now motivated by a wish to contribute to solutions that surpass individual needs.

The second similarity between the historic and contemporary niches is the feasibility

6

of enterprising at a local level. In the early 20th century, various factors enabled cooperative enterprising in the electricity sector . The regulatory vacuum created an institutional space in which different actors could become active on the energy market. Furthermore, the low maturity of electricity technology meant that a small system could initially generate electricity for a similar cost per unit as a bigger system. The combination of these two reasons made it attractive to start a small-scale electricity provision system in the electrification period. Nowadays, niche development is supported by RE subsidies and a growing market segment containing a mix of sustainability, community, and investment-oriented citizens prepared to collectively contribute to the energy transition[14].

However, the conditions for development of the current energy cooperatives and the electrification cooperatives also differ in many ways. First, the electrification cooperatives developed in a regulatory vacuum in the energy sector as electricity was a novel, commercially available energy source. They were dissolved when this space disappeared with the introduction of national government policy that steered towards provincial monopolies. In contrast, today's initiatives have developed in a heavily regulated energy sector within a niche that was created by regulatory changes from the 1980s onwards to break monopolies and enable decentralised grid access and the electricity production [17], [18]. The market liberalisation and privatization created space for new players on the energy market and consolidated the political choice steer away from regional public monopolies in the energy sector[17]. Only the distribution system operators and the transmission operator TENNET remained in the public domain. At the moment, a turn back to centralization does not threaten the continued existence of energy cooperatives. The niche fits with the current narrative of decentralised sustainable energy to create a socially acceptable, place-appropriate integration of renewables, and avoid grid overload. As a result, there are national and provincial financial incentives to help the local energy niche develop further[19].

Second, in the electrification niche few actors other than the cooperatives were involved as an energy regime had not yet formed, and cooperatives could operate relatively independently. In contrast, today energy cooperatives have to function in a polycentric decision-making environment where their agency is limited and they need to collaborate with other actors in the energy sector[18]. Remarkably, the more they go in the direction of vertical integration of different tasks within the same organization, the more they are confronted with the need to align their activities with the organisational frameworks and rules of regime actors such as the distribution system operator, energy retail companies, local governments, and funders[18]. Establishing cooperative energy retailers and other local energy organisations is a way to further the own niche, and decouple vertical integration and becoming similar to the dominant electricity regime. Furthermore, since the vertical integration of the electrification production process has decreased, the diversity of activities and business models has increased tremendously compared to the time of the electrification cooperatives.

Third, electrification cooperatives formed only very limited actor networks. The cooperatives learned from each other's experiences as the Friesland case study shows. However, there were no intermediary or umbrella organisations, like today's regional umbrellas, or (supra-)national representative bodies such as national knowledge platform HIER opgewekt or lobby organization Energie Samen [11]. This may have been unnecessary as the electrification cooperatives operated rather independently in their own area. Furthermore, the institutional space for electrification cooperatives was already shrinking around ten years after the very first cooperative was founded. Hence, the period before the mandate for energy provision was transferred to the provincial governments may very well have been too short for an integrated network of cooperatives and supporting organisations to develop. Yet, such organisations could have helped the niche to grow and be resilient to changes in the newly forming electricity regime. The extensive actor constellation in today's cooperative niche, which facilitates learning and enhances the standing of community energy in national and international arenas, may help today's cooperatives to fulfil a longer lasting function in the current energy transition[2].

These differences and similarities raise some important questions about how the maturing of renewable energy technologies will impact today's niche for local energy. The historical niche shrunk when electricity became a more lucrative commodity for governments and private businesses. When renewable energy technology matures further, the rules and actor-networks in the electricity regime likely change, and this may impact the space for cooperative enterprising and require cooperatives to adjust in ways similar to agricultural and insurance cooperatives.

One positive outlook for the energy cooperatives is that the future of renewable energy that is shaped today is one with a need for local solutions. The experiments of today could become the obdurate systems of tomorrow, which may for once make path dependency an advantage for energy cooperatives[20].

6.5. Overarching integrative perspective and final conclusions

In experimenting with new socio-technical innovations, local energy initiatives take on new roles. They extend the role of the citizen as end user to active prosumer (production + consumption), and sometimes even prosumager (production + consumption + storage) or distribution network manager [18], [21]. Through the extension of the role of the consumer to provision tasks in the energy system, local initiatives are taking steps towards a more localised and vertically integrated energy system that is more similar to the systems that existed in the electrification period. In this concluding section, the insights from the empirical chapters have been integrated to answer the main question. This way, an overarching perspective can be provided on what roles local energy initiatives can play in the Dutch energy transition as experimenters that are developing and embedding socio-technical energy innovations.

I discuss three roles energy initiatives can play in the energy transition that nuance the importance of whether the upcoming movement has the potential to cause regime change by becoming a dominant player in the energy regime[6]–[8]. I do so, because less attention has been paid to other ways in which socio-technical experimentation by local energy initiatives can potentially contribute to energy transition [22].

1. Diffuser of innovative technology

The main role of historical electrification cooperatives during electrification was enhancing the diffusion of electricity technology and embedding it in rural contexts. Hereby, they made electricity available at an earlier point in time and in some cases more affordably than if electrification had been rolled out by other actors, such as municipal and provincial companies. Hence, one role of local energy initiatives as socio-technical experimenters during an energy transition can be to make energy more accessible to society. In the case of electrification, accessibility improved geographically, but contemporary cases show that local energy also has the potential to make renewable energy more accessible among different social groups. For instance, accessibility can be improved by developing projects in which less affluent groups can participate to benefit from RE without large upfront investments[23]. Such improved accessibility can lead to many positive social impacts [24].

2. Generator of locally and supralocally applicable lessons

A second role that local energy initiatives can play through experimentation is as small-scale inventors, testers and co-designers of potential and promising socio-technical solutions that can later be used by other initiatives but also by other actors, such as private project developers and social housing corporations. For instance, regulatory experiments such as those under the EDSEP decree can, under the right conditions, yield valuable learning experiences that are helpful in transforming the energy system. Furthermore, in the case of the solar thin-film on the landfill the foundation provided a testing ground for an innovation that was later commercially upscaled. In other studies on socio-technical experimentation by local energy initiatives, this role is also apparent (amongst others [10], [21], [25]–[28]).

Local energy initiatives' members are motivated to change the energy system in their community. Their members form a mostly voluntarily operating workforce, and are an asset for the energy transition. However, policy makers and technology developers or knowledge institutions working with energy initiatives and local communities should be cautious not to overtask experimenters. Experimentation is, by its nature, highly complex and represents a constant interplay with what is feasible. Generally, energy initiatives are small organisations with limited time and resources, although they often have willing, knowledgeable, and affluent members. Therefore, governments need to sufficiently enable initiatives and nurture innovation to ensure efficient learning processes, especially when it comes to legal sandboxes, and avoid creating legal but unworkable opportunities in which the market and society are forced to solve the problems of the energy transition.

3. Local antenna

Energy experimenters can use their local networks and spatial awareness to develop projects that are more acceptable to people who experience their impact[29]. Thus, a third role that local energy experimenters can play in transforming the energy system is being a local antenna, which picks up on and is sensitive to local values. In the cases of the innovative solar parks planned in Elst and Brummen, we see how synergy with local entrepreneurs is sought and locations where the spatial impact is minimal are chosen. However, sufficient integration of the values of all stakeholders should not be taken for granted in case of local ownership. The studies of Middag-Humsterland and the Oostpolder showed that acceptability was, and partly remained, low despite the initiation of the projects by individual farmers or local farmers' collectives. Consultation of direct neighbours about the project and the intendeddistribution of outcomes, as well as sensitivity to the context and history of the site remain important[5]. This is perhaps even more relevant for local developers, as they have a long-term connection with the community.

In sum, local energy initiatives can transform local and supralocal energy systems through socio-technical innovation in many more ways than only through becoming a dominant player replacing incumbents. This thesis has shown that the value of experimentation is evident in: diffusion of energy technology and making energy more accessible; creation of learning experiences that can be used to make technical, and legal implementation process reforms in the energy system, and being a local antenna, which picks up on local values to create synergies while embedding socio-technical innovations.

6.6. Implications and recommendations

This section contains suggestions based on the research findings. Specific recommendations are made for local energy initiatives, policymakers and technology developers.

6.6.1. Local energy initiatives

- Innovation requires an extensive learning process as there is no trodden path. It is more feasible for a cooperative to create an innovative technological configuration than to bring a technology that is developed as part of such a configuration to the market. It is very challenging and probably not even desirable for an energy initiative to professionalize and to create a suitable actor network with the required time, knowledge, and capital that could bear the risk of developing a technology and bringing it to the market. However, partnering in innovation projects proved to be feasible and interesting for energy initiatives that do not find a proven technology that fits their goals.

- For the innovation process to be successful, it is necessary to have or to develop an extensive network inside and outside the initiative. This is necessary to have technical, legal, and organizational knowledge at arm's length, create support by embedding local values, and look for synergies.

- In innovation and implementation processes, it remains important to elicit and make explicit values of local stakeholders to increase acceptability of the innovations and synergies between the energy project and its context.

6.6.2. Policymakers

- For local energy innovation projects, it would be beneficial to have a case manager at the level of the municipal government to smoothen and speed up the permit process as they have to deal with various departments within the local government.

- Local energy innovators can be valuable partners in realizing energy transition goals. Including local energy initiatives can be conducive of locally acceptable RE solutions. However, local energy initiatives' projects are not inherently acceptable. A more value-centred participative approach can help to elicit conflict between various local stakeholders, and help to resolve it by negotiating more intersubjectivity.

- The regulatory framework provides legal delineation of the range of activities that are possible within the community energy field. When formulating regulation that aims to facilitate local experimentation, it is important to make sure that the space for experimentation is not only a theoretically existing, legal space but that the experimentation niche is sufficiently facilitated. For example, this can be ensured by taking a project-centred holistic approach in assessing the constraints to innovation, or, if necessary, by providing financial support helping the business case, such as an innovation subsidy.

- It is important to facilitate knowledge production and exchange in experimentation environments, so that initiatives do not need to reinvent the wheel over and over.

6.6.3. Technology developers

- It can be attractive to partner with an energy initiative in order to work with a party that has local networks, knows which locations are likely to be acceptable for projects, and invests the necessary time and effort into a pilot project.
- In addition, it can be interesting to seek out a local energy initiative as a launch customer. Some innovation grants require working with a civil society organization.

- Creating energy innovations that are well aligned with the values of a local user group can help to enhance their diffusion and uptake. Values related to the implementation process, outcome distribution, and local history and context are all important to consider during the design of the innovation.

6.7. Avenues for further research

This research concludes by highlighting areas where future research can build on questions that have arisen from the work undertaken for this PhD thesis. The following topics could benefit from further research:

- Firstly, a comparative study of our case studies and other local technological innovation initiatives, preferably in other countries, would contribute to a larger evidence base of grassroots technological innovation dynamics, but would also allow for more insight into the location–innovation relation.

- As the focus of this thesis was predominantly on the emergence of innovations, transfer and diffusion of grassroots technological innovation was not within its scope. Mainstreaming grassroots innovation often involves input from, and hybridization with, more conventional research, development, and investment in institutions. Accordingly, recontextualization and up-scaling of local innovations may very well imply broadening networks. Studying these processes can contribute to a better understanding of the transformative capacity of local energy innovations.

- Institutional conditions appeared to be crucial for configuring the innovations studied in this thesis. Only few studies have explored the fit between the activities of local energy initiatives, and national and regional policies and governance. It would be interesting to see more research into policies that are specifically developed to enable more types of experimentation with novel local energy configurations.

- Transformative potential requires a level of resilience of community energy organisations. For future research, it would be interesting to research how energy-focused and other cooperatives have adjusted over time and have remained resilient as niches in differing energy regimes.

- Integrating values of stakeholders from the communities in which local energy initiatives operate was found to be important for acceptability of RE innovations, but difficult due to incommensurability of certain values. Research exploring how to come to a prioritisation of values is therefore a very fruitful avenue for further research.

I would like to end this thesis on a personal note. I have always been a firm believer in the power of bottom-up citizen-driven action. Still, after writing this thesis I stand amazed of what local energy initiatives can achieve. Not all experiments succeed at realising their desired outcomes, but that is expectable considering how they leave the trodden path. Still, there are plenty of initiatives that are successful. The sheer organisational power of this growing movement and the increase in the complexity of the innovation projects I have witnessed over a rather brief period of five years (e.g. recently, the foundation of cooperative project developer Bronnen VanOns), foreshadow that local energy initiatives can further extend their impact on the energy transition. Their potential will only be enhanced as Dutch policymakers increasingly recognize the importance of a localized approach to a well-supported and timely transition. My thesis ends here, but I am looking forward to research and be part of the next chapter in the development of local energy in the Netherlands.

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