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LOCAL ENERGY INNOVATORS: COLLECTIVE EXPERIMENTATION FOR ENERGY TRANSITION

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Local energy innovators

Collective experimentation for energy transition

PhD thesis

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by

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born on 5 June 1992
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The rising hills, the slopes,
of statistics
lie before us.

The steep climb
of everything, going up,
up, as we all go down.

In the next century
or the one beyond that,
they say,
are valley, pastures,
we can meet there in peace
if we make it.

To climb these coming crests
one word to you, to
you and your children:

stay together
learn the flowers
go light

- For the Children, Gary Snyder

Acknowledgements

Already since my childhood, I dreamt of doing Ph.D. research. Surrounded by books, whilst contemplating in merry solitude, I would expand my knowledge and contribute to the progression of science. As I furthered my education, my view of a doctoral thesis became more nuanced. I learnt that it is certainly not a walk in the park. Yet, my wish to take on this certainly challenging and potentially very satisfying journey remained. By the end of my master in spatial planning, I had decided that I would try to get a Ph.D. position if an opportunity would present itself on a topic that I truly loved and felt I could contribute to. That opportunity came when I was made aware of a vacancy at the University of Groningen on exploring the role of community energy initiatives as socio-technical innovators. A topic that seamlessly aligned to my master research project. Delighted that I got hired, I started the journey of this PhD. A journey with ups and downs that I could not have completed without the support of numerous people: my supervision team, my partner, family, friends, colleagues, academics and energy professionals I met, research participants, and many others.

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Wetenschappelijke samenvatting

Tijdens de energietransitie nemen steeds meer burgers de regie over hun eigen energievoorziening. Zij verenigen zich dikwijls in burgercollectieven zoals Grunneger Power of BrummenEnergie en zoeken naar manieren om hun lokale energiesysteem duurzamer te maken. Niet zelden verlaten zij daarvoor de gebaande juridische, sociale en technische paden en vinden zij innovatieve oplossingen. Daarmee doen zij nieuwe kennis en kunde op over de energietransitie. Overheden zijn zich in toenemende mate bewust van de waarde van deze kennis en kunde, desalniettemin is er weinig bekend over wat die waarde precies is. Daarom beschrijft dit proefschrift de rollen die lokale energie-initiatieven spelen bij de ontwikkeling en inbedding van energie-innovaties in de Nederlandse energietransitie en doet het aanbevelingen om innovatieve burgercollectieven het beste tot hun recht te laten komen.

Centraal bij de onderzochte collectieve innovatieprocessen staat zowel het sociale als het materiële aspect van innovatie. Deze aspecten zijn in hoge mate met elkaar verweven omdat de innovaties aan de ene kant betrekking hebben op het fysieke energiesysteem en daarmee een technische, materiële component hebben, en aan de andere kant actoren zoals lokale energie-initiatieven invloed uitoefenen op de vormgeving hiervan. Een derde aspect dat centraal staat in dit onderzoek is regelgeving, omdat die de institutionele ruimte voor innovatie afbakent en daarmee grotendeels het speelveld bepaalt waarbinnen innovaties ontwikkeld worden en moeten functioneren. De nadruk in de empirische hoofdstukken van dit proefschrift ligt dus op de aspecten technologieën, betrokken actoren, regulering en hun onderlinge interactie tijdens innovatieprocessen.

Om de centrale onderzoeksvraag te kunnen beantwoorden over de rollen die lokale energie-initiatieven kunnen spelen in de energietransitie ben ik tot vier deelvragen gekomen. De eerste drie deelvragen zijn gerelateerd aan de hierboven genoemde en onderling samenhangende aspecten technologieën, actoren en regulering. Voor de vierde deelvraag geldt dat ook, maar hier wordt een historisch perspectief gekozen. De uitkomsten van deze historische analyse zijn gebruikt voor een vergelijking met de rol van initiatieven als innovator in de huidige energietransitie.

De vier deelvragen die elk in een empirisch hoofdstuk van dit proefschrift aan de orde komen, zijn:

1. Hoe kunnen lokale energie-initiatieven komen tot een ondersteunend netwerk voor het ontwikkelen en implementeren van innovatieve technologische configuraties? (H2)
2. Hoe kunnen multi-stakeholder ontwerpprocessen waarin uiteenlopende waarden een rol spelen bijdragen aan een aanvaardbaardere inbedding van lokaal beheerde energietechnologieën? (H3)
3. In welke mate kan lokale energie-innovatie ondersteund worden door experimenten met regelgeving? (H4)
4. Hoe droegen historische energie-initiatieven bij aan sociaal-technische innovatie tijdens de invoering van de elektriciteitstechnologie, en hoe werd dit beïnvloed door de wisselwerking tussen technologieën, actoren en regelgeving? (H5)

In hoofdstuk 2 staat het ontwerp van nieuwe socio-technische configuraties door lokale energie-initiatieven in de schijnwerpers. Hier wordt onderzocht hoe deze initiatieven technologische innovaties kunnen ontwikkelen door lokale actoren samen te brengen en hun activiteiten af te stemmen op contextgebonden omstandigheden. Met behulp van actor-netwerktheorie (ANT) en gestructureerd door concepten uit de translatiesociologie van Callon werden twee technologisch innovatieve projecten van Nederlandse energie-initiatieven bestudeerd: het drijvende zonnepark van Stichting Betuwe Energie en de zonne-installatie op de papierstort van BrummenEnergie (beide in de planningsfase ten tijde van het onderzoek). Door middel van documentanalyse en interviews werd onderzocht hoe deze initiatieven hun innovaties ontwikkelden door netwerken te vormen van sociale en materiële elementen. De uitkomsten van de innovatieprocessen blijken erg afhankelijk te zijn van de netwerkcapaciteiten van de lokale energie-initiatieven, en ook van hoe goed men weet af te stemmen op externe omstandigheden, en kan werken met de zich voordoende kansen en beperkingen. In het geval van het drijvende zonnepark moest bijvoorbeeld bedacht worden hoe een constructie gemaakt kon worden die geen gevolgen zou hebben voor de archeologische resten in de bodem van het meer. Later werd er juist een cruciale kans voor de ontwikkeling van de technologie geboden door Rijkswaterstaat die het project uitnodigde om mee te doen aan een pilot na het zien van het project bij een televisie-uitzending. In het geval van het zonnepark op de papierstort werd er succesvol afgestemd met de eigenaar van de stort die erg in duurzaamheid geïnteresseerd is, maar bleek het lastiger om een voldoende competitieve aanvraag te doen om SDE+ subsidie toegewezen te krijgen. Uit deze cases komen vijf lessen naar voren voor initiatieven die nieuwe socio-technische configuraties willen vormgeven: (i) creëer verbinding met doelen van de lokale actoren, (ii) neem plannen uitvoerig onder de loep om de haalbaarheid vast te stellen, (iii) vergaar tastbaar bewijs van haalbaarheid omdat startende organisaties zich meer moeten bewijzen, (iv) positioneer het project zo gunstig mogelijk voor zoveel mogelijk actoren en (v) pas het ambitieniveau aan de kracht van het netwerk.

In hoofdstuk 3 staat het belang van nieuwe regelgeving en beleid om socio-technische innovatie door lokale energie-initiatieven mogelijk te maken centraal. Geanalyseerd wordt de toepassing van de het Besluit Experimenten decentrale duurzame elektriciteitsopwekking. Deze algemene maatregel van bestuur fungeerde tussen 2015 en 2018 als een zogenaamde regulatieve "zandbak", waarbinnen verenigingen van huiseigenaren en energiecoöperaties konden "spelen" met nieuwe regels omtrent het beheren en balanceren van kleinschalige distributienetwerken. Ze konden projecten voorstellen die afwijken van bepaalde artikelen van de Elektriciteitswet en bijvoorbeeld peer-to-peerlevering organiseren en hun eigen tarieven voor energietransport bepalen. Theoretisch is dit hoofdstuk geworteld in de institutionele economie en het gebruikt Ostroms concept polycentriciteit. Dit concept is geschikt om de invloed van een actor te analyseren binnen systemen, zoals de energiesector, waarbinnen de besluitvormingskracht verdeeld is over meerdere actoren. Het concept is gebruikt om de dynamiek te bestuderen tussen actoren die betrokken zijn bij en invloed hebben op de participatieve experimenten. Empirisch werden vier projecten onderzocht door middel van interviews en documentanalyse. Uit de analyse bleek dat er een hoop werd verwacht van de deelnemers aan de regeling zonder dat veel actieve begeleiding werd geboden vanuit de overheid of netwerkbeheerders. Ook was de aantrekkelijkheid van de experimenteren beperkt omdat de ontheffing weinig kans bood om een werkend verdienmodel te creëren aangezien er bijvoorbeeld nog dubbel energiebelasting werd geheven op door het initiatief opgeslagen energie. Verder komen bij de nieuwe rollen risico's kijken, zoals het risico op uitblijvende betaling bij de rol van leverancier dat kleine organisaties moeilijk kunnen dragen. Daarom kon eigenlijk bij invoering al verwacht worden dat de voortgang van de projecten relatief traag zou verlopen en dat de belangstelling om een nieuwe rol te spelen beperkt zou zijn. Een holistischere benadering waarbij naar alle beperkende regelgeving wordt gekeken (dus ook de belastingwetgeving) zou bevorderlijk zijn voor toekomstige experimenten. Ook afstemming tussen actoren (bijvoorbeeld tussen RVO en de netwerkbeheerders), verdergaande beschikbaarheid van deskundige ondersteuning, en facilitatering van een hechtere leergemeenschap zouden positief zijn.

In hoofdstuk 4 staan nieuwe ontwerpprocessen en samenwerkingen tussen lokale energie-ontwikkelaars en andere lokale belanghebbenden centraal. Onderzocht wordt hoe lokale energie-initiatieven, in dit hoofdstuk met name boereninitiatieven, de aanvaardbaarheid van hun energieprojecten kunnen verbeteren door middel van procesinnovatie die tot stand komt via inclusievere planningsprocessen. De nadruk in dit hoofdstuk ligt op het belang van een brede vertegenwoordiging van de waarden van lokale belanghebbenden in het projectontwerpproces, waaronder het verdienmodel, keuze voor de technologie en plaatsing van de technologie. Het hoofdstuk maakt inzichtelijk hoe de initiatiefnemers van de projecten en de andere belanghebbenden inter- en intra-waardenconflicten over leefbaarheid, economie, landschap en natuur probeerden op te lossen of te verzachten. Op basis van literatuur over waardegevoelig ontwerpen werden twee tegengestelde casussen in de Nederlandse provincie Groningen geanalyseerd: de implementatie van mini-turbines in een nationaal landschap en een grootschalig multi-MW windproject in een geïndustrialiseerd gebied nabij het Werelderfgoed Waddenzee. De waardenconflicten bleken vruchtbaar te zijn voor het identificeren van sleutelproblemen en het creëren van breder gedeelde waardenconceptualisaties en ontwerpprioriteiten. In het geval van het Oostpolderproject betekende dat bijvoorbeeld dat er na overleg voor werd gekozen om de waarschuwingsverlichting voor luchtverkeer op de turbines continu te laten branden in plaats van flitsen. In het geval van Middag-Humsterland werd er op gemeenteniveau nieuwe regelgeving geformuleerd die ervoor moest zorgen dat de mini-turbines alleen op een ruimtelijk ondergeschikte locatie in het bouwblok geplaatst mochten worden (bijvoorbeeld naast een stal). Uit dit hoofdstuk kan worden geconcludeerd dat waardenconflicten productief kunnen zijn als er zorgvuldig mee wordt omgegaan en er geanalyseerd wordt hoe ze precies in elkaar steken. Echter blijven er bij het verminderen van waardenconflicten uitdagingen bestaan zoals de ongelijke machtsverdeling tussen belanghebbenden in het planningsproces, de onverenigbaarheid van sommige perspectieven en het creëren van intersubjectiviteit.

Hoofdstuk 5 biedt een historisch perspectief op socio-technische innovatie door Nederlandse energiecoöperaties en bespreekt het ontstaan van elektriciteitscoöperaties tijdens de elektrificatie aan het begin van de 20e eeuw. Dit hoofdstuk bespreekt op basis van primaire en secundaire bronnen het bijna vergeten en grotendeels onbekende coöperatieve deel van de vroege geschiedenis van elektriciteit in Nederland. Met het concept proto-regime uit de onderzoeksliteratuur over het multi-level perspectief op duurzame transitie wordt de rol duidelijk van deze elektrificatiecoöperaties tijdens deze periode waarin elektriciteit haar intrede deed.

De markt voor elektriciteit ontwikkelde zich van een nichemarkt naar een steeds stabieler wordend regime met zijn eigen actor-constellaties, regels en materiële en technische elementen. De gemaakte analyse draagt bij aan een beter begrip van niches als heterogene innovatieomgevingen waar de verspreiding en inbedding van nichetechnologieën regionaal op verschillende snelheden en op verschillende manieren kan plaatsvinden. De elektrificatiecoöperaties werden vooral opgericht in Friesland en Drenthe. In Friesland kwam de coöperatieve elektrificatie eerder op gang dan in Drenthe, en gedeeltelijk ook om andere redenen. In Friesland waren de coöperatieve pioniers al vroeg in de ban geraakt van elektriciteit. De eerste coöperaties kwamen daar vooral op in de gemeenten die nog geen gas hadden en werden opgericht terwijl er nog nauwelijks regels waren. In Drenthe kwam de coöperatieve elektrificatie echter later pas op gang, omdat er geen provinciaal bedrijf werd opgericht en de aansluiting op de Groningse en Overijsselse netten traag vorderde. Vooral in de rijkere veendorpen wilde men graag al wel profiteren van de voordelen van elektriciteit. De coöperaties verdwenen langzaam maar zeker toen het mandaat voor de elektriciteitsvoorziening bij de provincie kwam te liggen. Bij gevolg konden ze niet meer buiten de eigen gemeente werkzaam worden en daardoor niet concurrerend blijven toen opschaling van productie schaalvoordelen met zich mee begon te brengen. Ondanks dat de coöperaties kleine spelers waren en geen dominante speler in het regime werden, blijkt uit de analyse dat ze een belangrijke rol speelde in de transitie naar elektriciteit. De elektrificatiecoöperaties creëerden via hun experimenten niet alleen leerervaringen binnen het proto-regime, maar verbeterden ook de toegankelijkheid van een nieuwe ontwikkeling die niet alleen letterlijk maar ook figuurlijk het werk op het platteland verlichtte. De resultaten uit dit hoofdstuk zijn gebruikt in het conclusiehoofdstuk om de rol van de coöperaties tijdens de elektrificatie te vergelijken met de rol van de energie-initiatieven binnen de hedendaagse energietransitie.

Uit deze hoofdstukken komen naast hoofdstukspecifieke conclusies drie verschillende rollen naar voren die lokale energie-initiatieven kunnen spelen als innovator binnen de energietransitie. In alle gevallen zijn zij degenen die experimenten opzetten of uitvoeren.

De eerste rol is verspreider van innovaties. Als we kijken naar de historische elektrificatie-coöperaties was hun belangrijkste rol het bevorderen van de verspreiding van elektriciteitstechnologie en deze in te bedden in rurale gebieden. Door coöperatief initiatief werd elektriciteit eerder en soms betaalbaarder beschikbaar dan wanneer elektrificatie zou zijn uitgevoerd door andere actoren, zoals gemeentelijke en provinciale bedrijven. In het geval van de elektrificatiecoöperaties verbeterde de bereikbaarheid geografisch, maar hedendaagse cases laten zien dat lokale energie ook het potentieel heeft om hernieuwbare energie toegankelijker te maken voor verschillende maatschappelijke groepen. Een voorbeeld zijn projecten waarin minder welvarende groepen kunnen deelnemen om te profiteren van duurzame energie, zonder grote investeringen vooraf.

Een tweede rol die experimenterende lokale energie-initiatieven kunnen spelen is het creëren van leerervaringen. Hun innovaties helpen bij het benutten van lokale potentie voor duurzame energie en ze kunnen in sommige gevallen later worden gebruikt door andere initiatieven. Ook andere actoren zoals ambtelijke regelgevers, particuliere projectontwikkelaars en woningcorporaties kunnen hun innovaties gebruiken. Zo kan lokaal ervaring worden opgedaan die elders weer gebruikt kan worden in de energietransitie.

Tijdens het experimenteren kunnen lokale energie-experimentatoren hun netwerken en kennis van de lokale situatie gebruiken om projecten te ontwikkelen die acceptabeler zijn voor degenen die de impact ervan ervaren. Een derde rol die experimenterende energie-initiatieven kunnen spelen is dan ook die van een lokale antenne die gevoelig is voor lokale waarden en synergiën kan creëren tussen activiteiten van verschillende lokale actoren. Echter moet lokaal eigenaarschap niet gezien worden als een garantie voor energieprojecten die door een groot deel van de gemeenschap gedragen worden. Ook in geval van lokaal eigenaarschap blijven raadpleging van directe betrokkenen zoals omwonenden en een eerlijke verdeling van de kosten en baten belangrijk, evenals een gevoeligheid voor de context en de geschiedenis van de plaats. Misschien geldt dat nog wel meer voor lokale ontwikkelaars dan voor andere projectontwikkelaars, aangezien ze een langdurige band met de gemeenschap hebben.

Kortom, via hun experimenten kunnen energie-initiatieven ook als bescheiden speler in de energiesector een belangrijke bijdrage leveren aan de transitie binnen lokale en bovenlokale energiesystemen. Dit kunnen ze doen in hun hoedanigheid als verspreider van innovaties, door het creëren van lokaal en supra lokaal inzetbare leerervaringen, en door het fungeren als een lokale antenne die context gebonden kansen en waarden oppikt. Het haalbaarst en meest geslaagd bleken de innovatieprocessen waarbij samenwerkingen werden aangegaan tussen lokale energie-initiatieven en andere actoren met parallelle belangen. Ook een goede inschatting van wat zelf gedaan kon worden en wat beter uitbesteed droeg bij aan succes. De kracht van het (te vormen) netwerk van een initiatief is dus van groot belang.

Tenslotte is het belangrijk om in het oog te houden dat lokale energie-initiatieven in eerste instantie innoveren om lokaal op nieuwe manieren te kunnen verduurzamen. De inzet van initiatieven moet daarom vooral niet zuiver als een instrument voor overige belanghebbenden bij de energietransitie opgevat worden. Vooral de initiatieven zelf zullen er zorg voor moeten dragen dat hun innovatieprojecten de lokale wensen waaruit ze ontstaan zijn voldoende blijven dienen als ze samenwerken met o.a. beleidsmakers, technologieontwikkelaars, en kennisinstellingen.

List of abbreviations

ACM	Authority for Consumers and Markets
ANT	Actor network theory
BRP	Balance responsible party
Chw	Crisis and Recovery Act
DC	Direct current
DSO	Distribution System Operator
E.A.Z.	Enschede Aan Zee
EDSEP	Experiments decentralized, sustainable electricity production
EMS	Energy Management System
EU	European Union
HOA	Homeowners association
KEMA	Inspectorate for Electrotechnical Materials
kWh	Kilowatt-hour
LTO	Land- en Tuinbouworganisatie
MLP	Multi-level perspective
NGO	Non-governmental organization
NMFG	Natuur- en Milieufederatie Groningen
PV	Photovoltaic
RE	Renewable energy
RVO	Rijksdienst voor Ondernemend Nederland
SDE+	Stimuleringsregeling Duurzame Energieproductie+
SER	Social and economic council
SEP	Collaborating Electricity Production Companies
SNM	Strategic niche management
VDEN	Association of Directors of Electricity Companies in the Netherlands
VSD	Value sensitive design
W	Watt
Wp	Watt peak

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1

INTRODUCTION

This chapter forms the introduction to my PhD thesis on the role of local energy initiatives as socio-technical experimenters for energy transition. It will first set the scene by introducing local energy initiatives as innovators, leading up to the research question. Afterwards follow the aims and scope, and an overview of main concepts and focal areas of the research. Consecutively, an introduction to key aspects influencing socio-technical innovation by local energy initiatives are presented, together with the sub-questions that laid at the basis of the empirical chapters. The methodology is introduced after this, and the chapter is concluded by an outline of the further thesis.

1.1. Local energy initiatives as innovators

Several pressures are globally fuelling the development of policy agendas stimulating a transition towards a more sustainable energy system. Among these pressures are global climate change, environmental degradation, threats to human health, and not least the impending event of peak oil and related concerns about longer-term energy security. However, not only governments are undertaking action to future-proof their national energy systems. In many north-western European countries, also citizens are re-taking control over their own energy provision, leading to a rapid growth of the number of citizens' collectives in the energy sector [1], [2].

The uniqueness of this community energy sector is not chiefly defined by the applied technologies, but by the particular 'social arrangements through which a given technology, irrespective of its scale or cost, is being implemented and made useful' [3, p. 498]. Community projects are characterized to ideally be open and participatory on the process dimension, and local and collective on the outcomes dimension[3, p. 497]. Seyfang et al. define the sector as including projects 'where communities (of place or interest) exhibit a high degree of ownership and control, [and are] benefiting collectively from the outcomes'[4, p. 978].

These community energy initiatives are far from homogeneous, and are undertaking a broad set of activities, including:

- renewable energy (RE) production,
- collective purchase of renewable energy,
- collective purchase (and installation) of RE technologies,
- collective purchase (and installation) of energy storage technologies,
- promotion of energy efficiency (energy efficiency scans and measures),
- smart grid development and other grid balancing activities,
- participation in R&D and pilot testing of energy technologies,
- and local development efforts.

Community energy can be framed as a niche development potentially able to be one of the steppingstones in realising a transition to renewable energy [5], [6]. Consequently, while aiming to reach climate targets, governments have shown a largely instrumental interest in community energy as potential means for enhancing larger-scale sustainable energy transitions[7] On the one hand as contributors to RE generation, and on the other hand as facilitators of energy related attitudinal and behavioural changes top-down policies cannot deliver[7].

While the work of Hicks and Ison concluded that making a contribution to a more sustainable energy system was the most common motivation among local energy initiatives[8], the rationales of participants themselves are often much broader in scope than energy sustainability. Recent research has identified an extensive overview of motivations for, and benefits of, community energy projects [8]–[11], revealing a list of social, technical, political, environmental and economic impetuses to start a local energy project. Identified drivers for citizen action on decentralized energy systems include increasing local environmental benefits and behaviour within the community; striving for energy self-sufficiency; fostering regional development and income diversification; local empowerment and skills development, and creating actors in a renewable powered future [8]. Oftentimes a combination of projected benefits is found to inspire a project [8], [11], reaching from the personal to the community and the system level.

Even though part of the motivations for starting an energy initiative is supra local, it has been recognised that community energy projects develop in a specific context to meet the particular needs of their local initiators [1]. Hence, searching for societal change through technological change, local energy projects are conceptualised as a social niche. In a social niche 'innovative activities and services are motivated by the goal of meeting a social need and [...] are predominantly developed and diffused through organisations whose primary purposes are social' [12, p. 8]. Such social niches are also characterised in the literature as grassroots innovation environments (e.g. [13]). They represent a bottom-up approach to socio-technical change within the energy system, mainly involving people 'who are intrinsically motivated citizens with a more than average degree of environmental commitment', because of which they use a different set of criteria to select a technology and they are also less interested in future profitability [14, p. 733].

Focused on realising their own local goals, most local energy groups would not be actively concerned with how their innovative practices and the used technologies could be further developed and disseminated [15]. However, there are traces of evidence that citizen's collectives do contribute to technological development and embedment of RE technologies [15]. For instance, the renown wind energy development in Denmark was strongly led by local energy cooperatives [16], [17]. Also, home-insulation policy for socially disadvantaged households in the UK evolved from models that were developed by community activists[18]. Furthermore, similarly, the Austrian solar collector do-it-yourself movement emerged from civil society [19]. Thus, while primarily designed to meet local needs, it has been argued that community projects, frequently unintentionally, still can be conducive of socio-technical change in the larger energy system [13], [15].

For this reason, the community energy sector has been defined by Doci et al. as an internally-oriented niche with a local focus in which technological and social innovations go hand in hand[15]. They argue that community energy stimulates technological development and dissemination of energy sustainability innovations, and they portray technologies as 'tools for actors to reach their special purposes' [15, p. 87]. Hence, community energy could be seen as a social niche in which niche technologies get a platform to develop. Such an interaction and partial overlap between the chiefly internally-oriented social niche for community energy and the predominantly externally-oriented clean tech niche makes for interesting research, since little energy transition research looks at how community energy initiatives help to develop and embed renewable energy innovations.

This is an especially interesting research area as studies on user-involvement in other technical fields show that user communities, such as community energy initiatives, can be significant contributors to innovation [20]. User involvement can take place at different levels of intensity[19]: early users can design completely new technologies (e.g. a specific type of self-built solar collector; they can find and test new applications of a product (such as solar space heating); they can be the source of incremental changes (like the control system or additional security components in biomass heating systems); and they can appropriate unconventional building technologies and design solutions in the course of collective planning processes.

Furthermore, Ornetzeder and Rohracher found that strong participation of prospective users can lead to 'a series of innovations leading to specific design features of these technologies that has been highly functional to a wide dissemination' [19, p. 139]. Thus, involvement of energy initiatives in innovation processes could lead to wider dissemination of energy technologies, as well as technological innovation and design adjustment.

So far, little is known about the interaction between community energy initiatives and energy sustainability technologies. However, ostensibly, contacts between community groups and developers go beyond feedback through necessary monitoring and maintenance of deployed energy technologies, as various examples can be identified of communities actively participating in testing and optimisation of energy sustainability innovations.

Recent multiple case study research conducted by Koppenjan and Hufen describes how some of the Dutch energy cooperatives are actively involved in research and innovation of RE technologies [21]. They show that energy collectives are innovating by gradually renewing their RE systems and expanding the range of services – an example can be found in the wind cooperative Deltawind that branched out to solar [21]. Some initiatives go one step further and are actively taking part in research to develop and improve innovative energy solutions for local application, such as smart grids, smart energy displays, or storage solutions- including amongst others TexelEnergie and LochemEnergie [21]. An international example of local energy initiatives' participation in RE research and development (R&D) can be found in the Scottish Local Energy Challenge Fund projects, which show 'a local energy economy approach linking local energy generation to local energy use' by stimulating collaborative working, innovation and local added value[22].

Hence, indications exist that local energy initiatives can act as socio-technical innovators facilitating energy transition. Based on the current state of literature, this thesis departs from the hypothesis that the community energy niche can help to shape the development of technological niche innovations for energy sustainability in its search for new solutions for various local issues. Furthermore, is hypothesized that the development of locally oriented innovations can increase the transformative capacity of local energy initiatives. Therefore, the following research question is central in this thesis:

What roles can local energy initiatives play in the Dutch energy transition through the development and embedding of socio-technical energy innovations?

1.2. Research aim and scope

This research contributes to innovation studies literature on localised, bottom-up socio-technical innovation by exploring new socio-technical configurations of local community-based sustainable energy systems. Energy collectives combine technological and societal innovations, developing new business and organizational models while embedding innovative RE systems. A better understanding of local energy initiatives as socio-technical innovators contributes to better insight in their transformative capacity as actors in the energy transition. Therefore, the preconditions to and dynamics of their innovativeness are analysed. Furthermore, their future role in the sustainable energy transition can be better understood and potentially also strengthened by carefully aligning new legal, organizational and technological innovations to the needs of local energy initiatives.

The focus in the thesis is on the socio-technical innovation potential of local energy initiatives in the Netherlands specifically, because local energy initiatives' dynamics are heavily influenced by country-specific factors such as energy and planning policy[23], the economic climate and presence of a history of cooperative and other collective enterprising. We focus on the Netherlands specifically because this is one of the few north-western European countries with a flourishing community energy sector. Currently, over 500 local energy collectives are active in The Netherlands, many of them produce their own sustainable energy or undertake a large variety of other energy related activities. Due to the richness and diversity within the Dutch community energy sector sufficient examples of socio-technically innovative energy collectives can be found to study their innovation dynamics.

1.3. Local energy

Local energy is a focal concept in this research. This section operationalises what is meant by local energy in this thesis, and introduces the history of the Dutch community energy sector as well as its state today.

1.3.1. Defining local energy initiatives

Together, local energy initiatives are often labelled as the community energy sector. Neither academic researchers nor policy makers have a clear definition of the multi-faceted concept of community energy[1]. It has proven difficult come to a clear delineation of the field [3], because 'one of the most notable features [of the sector] is the diversity of forms associated

[1] The discussion of the concept community energy that follows in this section is a lightly adapted version of an unpublished section of my 2015 MSc thesis "Towards a methodology for the assessment of the social impacts of community-owned renewable energy projects: A wind of change for Shapinsay?" I wrote at the Radboud University.

with the term', encompassing 'different technologies and scales of deployment in a range of ownership structures and policy contexts, involving many actors and their various motivations' [8, p. 524]. Local energy projects range from off-grid micro-renewables on remote Scottish islands, to wind guilds in Denmark, to bio-energy villages in Germany, to small-scale behind the meter solar in Australia, distribution cooperatives in Canada, and are also taken up by communities outside the Western world [8].

Due to the large variation of local energy initiatives, Hicks and Ison state that a 'singular definition is unlikely to be possible or even useful' [8, p. 523]. However, particularly since funding and other policy support is involved, failing to set proper boundaries also poses a risk. On the one hand, a too narrow definition can constrain the community energy sector's adaptability to 'develop in contextually appropriate ways, sensitive to the needs and desires of local communities'[8, p. 523]. On the other hand, too broad a definition 'leaves openings for charlatans to take advantage of the community brand, when in reality the community element might be little reflected' '[8, p. 523].

To come to a delineation of local energy within this research, two descriptions that are often cited in the community energy literature have been used for conceptual guidance. They are those of Walker and Devine-Wright [3] and Seyfang et al. [4]. Both influential works do not set clear boundaries, but aim to progress the understanding of the distinctive "community" element of community energy.

Walker and Devine-Wright suggest that it is the 'processes' and 'outcomes' that differentiate community projects from commercial projects [3, p. 497]. Accordingly, the uniqueness of the sector would not be defined by the technology, but by the particular 'social arrangements through which a given technology, irrespective of its scale or cost, is being implemented and made useful' [3, p. 498]. Process refers to 'who a project is developed and run by, [and] who is involved and has influence' [3, p. 498]. Outcome is concerned with 'how the outcomes of a project are spatially and socially distributed – in other words, who the project is for; [and] who benefits particularly in economic or social terms' [3, p. 498]. They indicate that community projects are the projects that are open and participatory on the process dimension and local and collective on the outcomes dimension. Figure 1.1 shows three viewpoints on community energy resulting from different positions of projects along the process and outcome axes. Walker and Devine-Wright found that some see a project as community energy if local people participate (A), some when the benefits are distributed locally(B), and some are not really concerned with a precise definition as long as a project is somewhere in the circle of C.

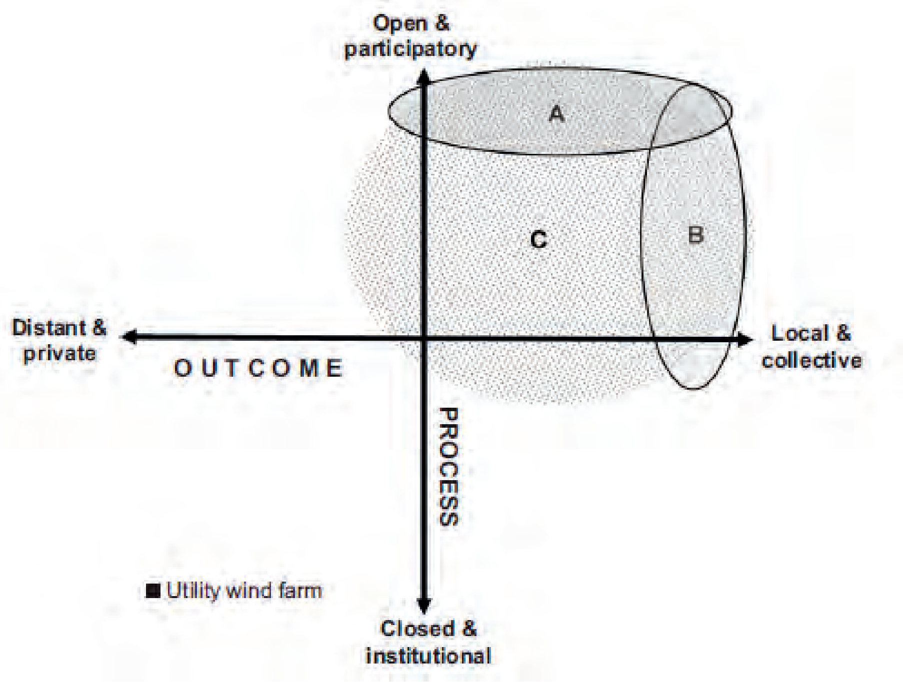

Figure 1.1: Understanding community energy in relation to process and outcomes dimension [3, p. 498].

Seyfang et al. also offer some grip on the slippery concept. Following Walker and Devine-Wright's lead, they point to the process and outcome dimensions of community energy, defining the sector to include projects 'where communities (of place or interest) exhibit a high degree of ownership and control, [and are] benefiting collectively from the outcomes' [4, p. 978].

Thus, analysis of the definitions of Walker and Devine-Wright and Seyfang et al. suggests that projects within the community energy sector are characterised by a degree of local and/or collective ownership and control (1), an extent of an open and participatory process (2), and local and/or collective benefits (3). A combination of the first aspect and at least one of the other two aspects is taken as the delineation of community energy in this thesis. This delineation closely resembles the C sphere in figure 1.1.

It is common to describe the local energy movement as the community energy sector and this research will do so as well. Yet, a deliberate choice has been made in this thesis to refer to the initiatives themselves as local energy initiatives and not community energy initiatives.

This decision has been made because the term community energy embodies 'implications and assumptions about the nature and quality of relationships between people and organisations' that are part of the community [24, p. 2655]. Especially within the contemporary discursive politics of governance, the community label is 'much used' and 'readily attached' to projects and policies to give them a warm glow and increase public support [24, p. 2657]. Also, within academia such positive assumptions are part and parcel of the community energy discourse.

Walker et al recognise that such narratives and claims about amongst others openness, inclusivity, and distributional justice 'are clearly predicated on the basis that communities can and do exist, in an unproblematic form and within many of the positive qualities with which they are readily associated' [24, p. 2657]. However, during their research the authors found that 'communities' were not always experienced as places where people are 'willing to support and work for the common welfare and good', and where 'people live together in harmony with different cultures and interests' [24, p. 2657]. More sceptical views on community showed that people felt that communities either 'are not really existing', or were not as inclusive as they might seem. Whilst appearing inclusive, a community was also found to be potentially 'deeply exclusionary' and 'marginalising those who are seen as not fitting' [24, p. 2657]. Therefore, community energy researchers should ask themselves who the community is, how inclusive it is, how it is involved in a community energy project, and how it benefits [25, p. 3].

Furthermore, when addressing communities of place, it is important not to assume that communities and places necessarily coincide [26, p. 337]. There can be 'multiple overlapping communities in a place and extended and constructed communities of interest that transcend physical delineations' [24, p. 2657]. Given these observations, it is important that a researcher critically asks him- or herself what the community is.

Hence, while recognising the potential and the promise of community energy projects to deliver various local benefits, the more neutral term local energy initiatives has been used. This term stresses locality, which is the most important element in this research as it looks into the innovativeness and transformative potential of local energy initiatives that operate and therefore, embed energy technologies in their own living environment. As a result, this means that the focus is on civic energy communities that are bound to a geographic community.

It is still recognised that energy initiatives with a local basis do in certain cases act supra-locally too.

1.3.2. A brief history of Dutch community energy

The documented history of community energy within the academic research community comprises developments from the 1980s onwards[23], [27]–[29]. Oteman et al. gives a comprehensive overview describing four partly overlapping waves [27], which we here use to provide a brief overview of the Netherlands' history with local and collective energy provision.

They explain how the seedbed for the first wave lies in the 1970s, when the oil crises and anti-nuclear protests challenged the national government's approach to energy. Dissatisfaction arose because national energy policy depended on import and focused on economic interests only. The first wave that developed at this time consists of twenty-five wind projects that were developed in the 1980s and 1990s. This wave was enabled by a legal change that allowed for decentral access to the grid to break regional monopolies, and later also the 1989 Electricity Act, which obliged energy suppliers to buy decentrally produced electricity for a standard price and guaranteed grid access. Some of these organisations, such as the Windvogel and Noordenwind, are still active and help starting initiatives with financing or advice.

After this wave, came a wave of nine Frysian village turbines, that arose under the same institutional conditions as the earlier wind cooperatives. The Frysian villages built a discourse coalition with provincial and municipal governments based on community revitalization. Based on this, the province made resources available that convinced local banks to provide loans. These village organisations also benefited from tightly-knit communities where people know and trust each other.

When the energy market liberalized between 1998 and 2004, few local initiatives developed because of the instability and unpredictability of the energy system. This third wave includes the pioneers in the liberalized market at the time that the Dutch government had embraced a transition to RE as a policy goal, but followed a broad and inconsistent approach. This approach was characterized by series of experiments, subsidies, pilot projects and policy platforms. It was a hostile climate for energy initiatives as the liberalized market was still a new territory, the investment climate uncertain, and policies changed rapidly.

Yet, climate change gained legitimacy through amongst others influential popular scientific documentaries and IPCC reports. In the period from 2006-2009 a new wave of local energy initiatives emerged inspired by the energy sustainability activities of NGOs and initiatives from fields such as neighbourhood development, housing construction and existing collaborations between farmers and citizens. These initiatives had a broad focus and a local approach. They opted for low risk and relatively simple projects that could yield short-term visible results, including resale of green electricity and collective purchase of privately-owned solar panels and information provision on energy saving and production. Enabling factors were the 2008 net metering regulation that allowed household energy producers to deduct the energy they produced that from their energy bill, and the dropping price of solar panels.

The fourth wave consists of the current boom of local energy initiatives from 40 in 2009 to over 500 today, and is still ongoing. Inspired by the pioneers from the third wave, this take off mainly started through emulation of the third wave's new activity: collective purchase of solar panels. Especially, during the economic crisis, solar panels were seen as an investment that would save money in the long run. Like the third wave these "follower" initiatives have a broad range of motivations ranging from environmental, to economic and societal.

From 2010 on, the movement started to grown and mature. It increasingly extended its network and professionalized. Two important financial support mechanisms have been playing a key enabling role. The 2013 postal code rose scheme enables small-scale users who are located in a pre-defined area around the collective production installation to get restitution of energy tax. Energy initiatives interested in developing larger energy projects can opt for the more secure but highly competitive SDE+ subsidy, which was introduced in 2011 and is targeted at companies.

1.3.3. Dutch community energy today

Over the last few years, community energy in the Netherlands has been experiencing a rapid growth. The Dutch local energy monitor shows that during the last four years number of community energy initiatives in the Netherlands has doubled from 248 initiatives in 2015 to 582 in 2019 [29]. During this period, the capacity of the most popular technologies-- solar and wind-- grew from 83,4 MW to 311,2 MW. The electricity use of a quarter million households is now supplied by these initiatives, and the movement has been estimated to have around 85.000 members and participants.

The most common legal entity for an energy initiative in the Netherlands is a cooperative association with excluded liability (*in Dutch: coöperatieve vereniging U.A.*). The members set out the goals of the cooperative association in the memorandum and articles of association, and govern the cooperative via a one member one vote system. Excluded liability means that only the capital brought in can be lost, and the members have no further liability. A few initiatives are incorporated as a charitable foundation and use this entity as an umbrella organization that owns the cooperatives or private limited companies set up for specific projects.

When it comes to the activities of the Dutch cooperatives, many of them started out with energy saving and energy production projects. In energy savings projects, cooperatives offer advice on energy saving behaviour and technologies, and facilitate their implementation (e.g. through setting up collective purchase deals, promoting smart meters or LED lights, or organizing a saving competition). This requires less time, resources and expertise than the development of an energy production installation, creates visibility for a starting cooperative, and every kWh that has been saved does not have to be generated. The second main activity of most cooperatives in the Netherlands is energy production. When it comes to production, 80% of the cooperatives develop solar, 24% wind, and a small but growing number (5) produces and manages heat (e.g. from biomass, geo-thermal sources, or heat from industry, sewerage or surface water)[29]. A third type of activity is support of and collaboration with local and regional policy makers regarding policies such as gas-free neighbourhoods and regional energy strategies. Last but not least, energy cooperatives exceedingly expand their activities and work on energy sustainability from a more holistic and integrative perspective, branching out to amongst others shared automobility, green gas, hydrogen, storage, smart grid solutions and flexibility services. In doing so, they act as partners or initiators in innovation projects with knowledge institutions, DSOs, companies, and funders, and use their living environment as a testing bed for new innovations, such as new technologies or technological configurations, or business models [29], [30]. Thereby, the local energy movement may start or enhance new developments [29].

The community energy sector in the Netherlands is not only growing but also professionalizing, and building and extending an own network of support platforms, supra local umbrella organisations, intermediary organisations, and a lobby organisation. The most important actors in this network are:

- HIER opgewekt: national knowledge platform facilitating a learning community;
- EnergieSamen: lobby organization at national level for local energy;
- Cooperative energy companies: VanOns, AGEM, and om I nieuwe energie buy energy

from local cooperatives and act as supplier. Furthermore, they sometimes take on administrative tasks and function as back-office. Before, the cooperative energy companies were founded these tasks outsourced to regular energy companies, and some energy initiatives still use their services;

- Regional umbrella organisations of cooperatives: cooperatives of cooperatives, which are province-based such as Groninger Energiekoepel, Ús Koöperaasje and Drentse Kei;
- Nature and environment federations take on a supportive role in many provinces;
- Energy cooperatives increasingly partner up and collaborate with DSOs and other established energy sector players;
- The municipalities and provincial governments are also part of the network. They provide knowledge, permits and sometimes subsidies. By times, the energy initiatives provide services to the municipality as well, such as staffing an energy information office. Some energy cooperatives also managed to get European Union subsidies for their projects (as part of a consortium).

Dutch local energy initiatives have greatly benefited from financial support schemes for RE. Main supportive policies are: net metering (salderen), the regulation lowered tariff (postal code rose regulation), and the stimulation regulation sustainable energy ++ (SDE++) feed in tariff. Here is explained how these support schemes work as well as which percentage of cooperatives is using these.

- Net metering: the kWhs renewable energy supplied to the grid can be subtracted from the kWhs on the energy bill. Can only be used when the installation is connected to one's own electricity meter (household level incentive). An example of use in the cooperative movement is a cooperative that helps arranging solar panels for renters, who then use the net metering policy. Twelve percent of energy initiatives uses this. From 2023, the energy that can be net metered will gradually be reduced, as the government assumes that the solar energy will be competitive enough due to the decreased price of the panels.

- Regulation lowered tariff (postal code rose regulation): This regulation enables restitution of the energy tax during 15 years for user-participants that live in the so-called postal code rose area around the production installation (see figure 1.2). The administrative centre of the postal code rose can also be located in one of the leaves to increase the number of potential participants. The regulation has been revised, and entered a new phase in 2021 (structured more like a feed-in tariff now). This resulted in insecurity, which made that some energy initiatives rather waited because they were unsure about their ability to realise their project before the revision. 60% uses this regulation.

Figure 1.2: Postal code rose area in which a project can look for participants[31]. The dark red area is the administrative centre, where the installation is often located, and the lighter areas are the leaves.

- SDE++: This is a biyearly allocated feed-in tariff. There is a fixed budget for several renewable energy categories (technology-based). The local energy initiatives and other project developers send in a bid for the subsidy they require and the lowest bids will be granted the subsidy. This subsidy is fairly competitive and the auction is always heavily oversubscribed. 26% uses this regulation.

Also non-financial supportive policies exist. An important one is a measure supportive of local ownership. The local energy movement successfully lobbied for a target of 50% local ownership of renewables for 2030 to be taken up in the 2019 Climate Agreement. Currently, the implementation of the Climate Agreement takes place via an area-based approach with regional energy strategies. Local energy initiatives are seen as important stakeholders and are actively involved in the co-design of these strategies with other stakeholders.

Furthermore, the executive order 'experiments decentralized, sustainable electricity production' enabled derogation from certain articles of the Electricity Act on experimental basis (case by case) to facilitate grid balancing. Applications could be made from 2015-2018, and it was only for energy cooperatives and owners' associations. In the proposed but cancelled next round, more stakeholders could have proposed a project.

Also on the provincial level various supportive policies exists. For example, in Groningen the provincial government offers a subsidy for start-up costs.

To sum up, local energy specific and general renewable energy policies are supportive of the growth of the local energy movement. Due to the development of the movement, community energy reached a stage at which it can function as stakeholder that is part of energy policy design and has had a limited but demonstrable positive impact on the creation of supportive policy.

1.4. Socio-technical innovation

The second focal concept in this research is socio-technical innovation. Doci et al. present describe how civic engagement with RE can be understood as an intricate system of social and technological development[15]. When civil society actors set up collective RE projects, they create spaces for societal experimentation with new forms of energy consumption and production that have a potential for widespread participation and a focus on social learning[32]. Local energy initiatives develop new forms of organisation and collaboration as well as new technological constellations. Hence, socio-technical innovation was taken as a conceptual starting point in this thesis to research the transformative potential of their innovative activities.

Socio-technical innovation can be defined as a process of simultaneous and interwoven social and technological innovation. These two types of novelty are understood to co-evolve within sustainability transitions literature [14], [33], [34]. Social innovations can incentivise technological innovation, and technological innovation can simultaneously affect social organisation [35], [36].

While acknowledging the impossibility and undesirability of attempting to either fully or cleanly separate the social from the technical, the two dimensions of socio-technical innovation are briefly introduced here. Starting with the social dimension, social innovativeness can be understood as a new way of doing business, while pursuing a social goal [37]. In the energy field, it entails new ways of organising energy production and consumption being set in motion by heterogeneous and changing groups experimenting with new modes of social organisation, such as novel business models and financing schemes. Technological innovativeness, on the other hand, can be seen as the array of technological change ranging from the diffusion of novel technologies, to incremental changes in processes, product reformulation, product substitution and the development of new processes [38]. Technological innovation typically entails the emergence of social innovation, such as new practices, generic rules and lessons. However, social innovation does not necessarily require the presence of technological innovations (e.g. bio-agricultural communities, community development) [15]. Thus, social and technological innovations are often closely connected, and social innovation is not just a requirement, side-effect or result of technological innovation.

These definitions of social and technical innovativeness have been used to further operationalise socio-technical innovation by local energy initiatives for this research. Initiatives can differ in social and technological innovativeness. Initiatives can be highly technologically innovative but limitedly socially innovative, vice versa, or can be innovative in both or none of the dimensions. The initiatives that are focused on in this research range from modestly to highly technologically and socially innovative.

1.5. Aspects influencing socio-technical innovation by local energy initiatives

To narrow down the research and define the scope for the empirical chapters of the thesis, three interlinked, focal elements were identified from the literature that are important to further understand socio-technical innovation by local energy initiatives: technological configurations; policies and regulations; and multi-stakeholder processes. The remainder of this section will discuss these elements as they have been used to underpin the choice for the sub-questions of the thesis.

1.5.1. Technological configurations

Much of the influential early work on community energy used an innovation studies approach and explored whether or not community energy had potential to facilitate regime change through its role as embedder of new energy technologies via innovative socio-technical configurations. Research tended to focus on the upcoming movement's potential to cause regime change through becoming a dominant player in the energy regime[6], [15], [39].

However, less attention has been payed to other ways technical experimentation by local energy initiatives can potentially contribute to energy transition. This part of the thesis continues on work such as Verkade & Höffken[40] and De Vries et al.[41], who look at how local energy initiatives or their members shape and interact with novel technological configurations.

Verkade and Höffken looked at the piloting of an online platform supporting the use of community-generated solar electricity by members of a cooperative. They found that the interlinked nature of the energy consumption practices can prevent the monitoring insights from changing use patterns. The members of the local energy initiative helped the development of smart software by enabling research on domestic users of energy technologies and their behaviours.

De Vries et al. focused on novel activities in the community energy sector and framed them as configurational user innovations, i.e. user-designed arrangements of loosely related sets of components. They show how innovative energy initiatives combine off-the-shelf technologies with novel technical and non-technical ideas, rather than try to make clear-cut changes to existing devices. Their work shows how the value of the innovations, referred to as tinkering with technology, lies in how initiatives naturally embed these technologies into their wider business, social and community context. Other authors also point to how such configurational work with novel technologies leads to new business models, collaborations, and place-based solutions for local energy transition that are more aligned with local interests (e.g. [15], [42]–[44]).

Conceptualising innovations as configured networks of socio-technical elements, paves the way for analyzing the development process of socio-technical innovations, instead of only seeing them as an outcome that can or cannot be upscaled. Planned and unplanned impacts on the energy transition can be better traced when framing innovation as a configurational process of networking.

These understudied networking processes are particularly interesting, because energy initiatives are often voluntary organizations, have limited resources and have few existing structures to guide their innovative endeavors. In addition, innovating requires experimentation and creates uncertainty, which exerts pressure on the relationships that need to be formed and maintained for a working configuration.

Hence, the first sub-question central in this thesis is how do local energy initiatives develop and implement ***innovative technological configurations***?

1.5.2. Policies and regulations

Enabling regulation and stimulating policies have been very important for community energy to take off [23], [45]. It creates the institutional space for collective, civic entrepreneurship in the energy sector.

As mentioned earlier, in the Netherlands the first opportunities were created by the national government in the 1980s by opening up the grid to decentral access, and through the 1989 Electricity Act which obligated energy suppliers to buy decentrally produced electricity for a standard price and guaranteed grid access[27]. Later, energy transition incentives such as feed-in tariffs and other RE subsidies helped the movement expand[45]. Even policies specifically aimed at the community energy movement were developed, such as the postal code rose incentive[46] and an experimentation decree for piloting more integrated grid management[47].

Not only national policy and regulations are important for the community energy movement. Municipal and regional level policy is also important in governing the transition to a more decentralized and locally embedded energy transition [48]. Active civic engagement with the energy transition requires policy innovation to support this at the local level. Hoppe et al. show how the success of local energy initiatives is to a great extent influenced by close interaction and mutual trust between local government and representatives of the local communities. Such a working relationship can be established through proper process management and strategic, responsive, community serving, and reflexive leadership[48].

At the European Union level, local energy is also on the agenda and specific policy has been made to stimulate its development. The EU's ambition is to establish an 'Energy Union' that empowers citizens to actively interact with the energy market as self-consumers or prosumers[49]. The Clean Energy for All Europeans Legislative Package (CEP) provides a legal framework that will not just help the EU meet its 2030 climate and energy targets. It also requires Member States to ensure certain rights for "renewable energy communities" and " citizen energy communities" that help level the playing field and stimulate their development [50]. This can create opportunities for local energy initiatives but how this legislation will exactly be transposed remains to be seen.

Hence, policy and regulations at the local, national and international level determine the institutional space, and, thereby, what roles initiatives can legally enact when it comes to energy provision. Yet, previous experiences with novel regulations show that merely having a legal space to innovate does not mean new activities can be easily undertaken with success [46], [47], [51]. New regulations are not always sufficiently aligned with existing regulations, can be complex, or limited in usefulness due to practical constraints such as the lack of a feasible business model. More insight in how energy policy can better facilitate bottom-up energy innovation requires further research.

Therefore, the second sub-question central in this thesis is what can be learnt about constraints and opportunities of new and existing energy ***regulations and policies*** with regard to local energy initiatives' bottom-up experimentation.

1.5.3. Multi-stakeholder processes

Embedding of and experimentation with RE technologies requires process innovation and new collaborations[15]. To realise their increasingly complex projects, energy initiatives collaborate within the cooperative energy sector, but also reach out to other actors.

Within the cooperative sector, local energy initiatives learn from each other. Furthermore, they institutionalised learning and knowledge sharing by setting up regional umbrellas, a national platform, and a lobby organization. This multi-leveled system makes for cross-scale interactions where insight flows bi-directionally[43]. Also, the cooperative energy supply companies, and supportive intermediaries such as certain environmental NGOs, can be counted as part of this growing network that aims to stimulate the growth of the niche for local energy.

In order to make possible or extend their activities, cooperatives also forge alliances with actors outside the cooperative movement. Some cooperate with incumbent or recently founded energy companies. They collaborate by outsourcing some of their activities (e.g. back office for administration, supply, and billing). While the initiatives in principle have a let's do it ourselves attitude [11] and are keen on their grassroots values, they can overcome hurdles such as lack of financing, marketing, professionalization, and legal constraints by collaborating with commercial parties and creating hybrid business models [44]. In other projects, such as under the experimentation decree, they also cooperate with technology developers, DSOs and knowledge institutions[47]. Last but not least, energy initiatives look for synergy with local businesses, associations, and other organisations in realising their projects[43].

Not only do local energy initiatives need to include the ones they need for developing their project, but they should also not forget to engage the ones impacted by their projects (human and non-human). As raised earlier while problematizing the term community energy, there can be multiple groups with different interests and values in one place[52]. More research on how prospective local owners of energy installations can include other local stakeholders, such as neighbours and representatives of nature and landscape NGOs, would add to the literature on social acceptance of local energy projects[53]. Especially, now the impact of renewable energy on the landscape is increasing as the energy transition progresses.

Hence, because of the increasing complexity of the projects of energy initiatives and the increase of the landscape impact of RE, multi-stakeholder processes are becoming even more important. The third sub-question in this thesis is how innovative ***multi-stakeholder processes*** can contribute to acceptable embedding of locally-owned energy technologies.

The aspects technological configurations, regulations and multi-stakeholder processes are central to better understanding roles local energy initiatives can fulfill by experimenting with socio-technical energy innovation. Figure 1.3 shows how they relate to each other. This figure provides a simplified representation of the ways in which they are related. Central to the socio-technical innovation process are the development of novel RE energy technologies and the processes of embedment of these technologies through interaction and collaboration with actors in and beyond the local energy initiative. The roles that a local energy initiative can play in the energy transition are heavily influenced by the regulations and policies, and these delineate the institutional space for innovation.

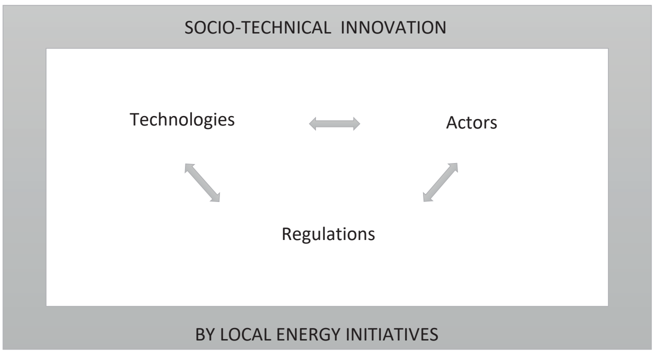

Figure 1.3: Three interdependent aspects influencing socio-technical innovation by local energy initiatives.

1.5.4. Sub-questions

To be able to answer the main research question about the roles local energy initiatives can play by experimenting with socio-technical energy innovations, I came to four sub-questions. The first three sub-questions are identified based on the previously introduced and interrelated aspects of socio-technical innovation by local energy initiatives. The fourth sub-question takes a historical stance. This sub-question aims to gain insight into the interplay of technological development, the actor-constellation, and regulations during another period in time. This will be discussed in relation to today's involvement of energy initiatives in the transition.

So, the four sub-questions addressed in this thesis are:

1. How can local energy initiatives develop and implement ***innovative technological configurations*** by creating a supportive network? (CH2)
2. What can be learned about supporting local energy innovation from **regulatory experimentation**? (CH3)
3. How do value-sensitive **multi-stakeholder processes** contribute to acceptable embedding of locally-owned energy technologies? (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)

1.6. Methodology

This section introduces the case-based approach followed in this thesis and explains the case selection process. More detailed information on methodology can be found in each of the empirical chapters.

1.6.1. Case-based approach

Data for the empirical chapters were collected through a case-based approach. One chapter focuses on historical cases and the three others on contemporary cases. All of these studies cover multiple case studies (2-4) and describe socio-technical innovations over a time period ranging from a couple of years to a few decades in the historical study.

By using a case-based approach, a phenomenon can be investigated in relation to its context. That way contextual conditions that might be highly pertinent can be taken into account[54].The strength of the case study is that it can provide a rich and in-depth understanding due to its ability to deal with a full variety of evidence, such as documents, artifacts, interviews, and observations[54].

The case-based approach allows to add to knowledge by analyzing, understanding, and then to an extent generalizing from the cases [55]. This should not mistakenly be interpreted as nomothetical universalizing, but as developing an understanding with explanatory power that goes beyond the unique instance of the case as object of inquiry.

Explanatory power in case study research is ascribed to the interplay of a plurality of events, factors, mechanisms, and contributors. Therefore, it is important to recognize that different contexts result in different outcomes, and that different mechanisms even may produce similar outcomes[55]. Hence, the applicability of the findings and the limitations to this applicability need to be precisely specified based on the characteristics that have been used as selection criteria. Thus, the characteristics of the case and the extent to which these are similar to other cases are in direct relation with the range of applicability.

1.6.2. Case selection process

Representativity of the Dutch local energy movement has not been used in this thesis to select the cases. In all chapters the cases have been selected for information-oriented sampling to offer insight in specific innovation dynamics of local energy initiatives. These cases are specifically chosen for their explanatory power due to interesting, unusual or particularly revealing characteristics[56].

For this thesis about innovation dynamics, the average local energy initiative, or typical case is generally not the richest in information since few energy initiatives are highly innovative in terms of social-technical characteristics. The cases in the empirical chapters were selected based on extraordinarily high socio-technical innovativeness and represent in that sense extreme cases with respect to other local energy initiatives.

The identification of innovative local energy initiatives for the chapters was an iterative and multi-phased process. The interest was in recent innovation projects in the Dutch community energy sector. It was positive for this research that the Dutch community energy movement has significantly grown and developed over time, and started experimenting more and more with new technologies and configurations, processes and collaborations, and regulations and policies.

At the start of this research, identifying recent innovative projects that are high in social and technological innovativeness was rather difficult as such projects were often not announced online, especially if they were not operational yet. If they were announced online, they were often already part of a consortium of researchers and technological developers, and, due to the limited time these initiatives have to engage with researchers, it was not always possible to include their projects. Hence, it was critical to reach out to contacts in the several professional networks available within this research project to identify case studies.

1.7. Outline

This thesis explores the three previously identified aspects of socio-technical innovation by local energy initiatives: technologies and configurations, multi-stakeholder process and policies and regulation. Innovation dynamics as observed during the current transition to renewable energy (CH2-4), and the electrification period (CH5) are both covered.

In chapter 2, the spotlight is on the design of new technologies and socio-technical configurations by energy initiatives. It explores how they can develop technological innovations by bringing together local actors and creating a fit with local circumstances. Grounded in actor network theory (ANT) and structured by concepts from Callon's sociology of translation, two technologically innovative projects were studied. Through document analysis and interviews was researched how these initiatives developed their innovations by forming networks of social, material, and discursive elements.

In chapter 3, the importance of new regulations and policies for enabling socio-technical innovation by local energy initiatives has a central position. It analyses the Dutch executive order 'experiments decentralized, sustainable electricity production' (EDSEP) that functions as a regulatory sandbox and invites homeowners' associations and energy cooperatives to propose projects that are prohibited by extant regulation. Local experimenters can after approval of their project plan derogate from the Electricity Act, and, for instance, organise peer-to-peer supply and determine their own tariffs for energy transport in order to localize, democratize, and decentralize energy provision. Theoretically, this chapter is rooted in institutional economics and uses Ostrom's concept of polycentricity to study the dynamics between actors that are involved in and engaging with the participatory experiments. Empirically, four approved EDSEP experiments were examined through interviews and document analysis.

In chapter 4, new processes and collaborations between local energy developers and other local stakeholders have the centre stage. It explores how local energy initiatives, in this chapter farmers' initiatives, can improve the acceptability of their energy projects through process innovation brought about via more inclusive planning processes. The emphasis in this chapter is on the potential for broad representation of local stakeholders' values in the project design process, including amongst others business model, choice for the technology, and placement. The study analyses how the initiators of the projects and the other stakeholders attempted to resolve or ameliorate inter- and intra-value conflicts regarding liveability, economy, landscape and nature. Informed by value sensitive design literature, two contrasting cases in the Dutch province of Groningen were analysed: the implementation of mini-turbines in a national landscape, and a large-scale multi MW wind project in an industrialized area close to a World Heritage nature reserve.

Chapter 5 offers a historical perspective on socio-technical innovation by Dutch energy cooperatives, and discusses the emergence of electricity cooperatives during the electrification in the early 20^{th} century. This chapter brings a nearly forgotten, and largely unknown part of the early history of Dutch cooperative electricity back from the margins of historical work on electrification: the emergence of electricity cooperatives in the early 20^{th} century. By using the concept proto-regime from the multi-level perspective on socio-technical transitions, the role of these electrification cooperatives during the development of electricity from niche market to a regime with its own actor constellations, rules, and material and technical elements is studied. Through this analysis is contributed to an understanding of niches as heterogeneous innovation environments where diffusion and embedding of niche technologies can take place at different paces and in distinctive ways across localities. The results from this chapter are used in the conclusion chapter to compare to the development of the current community energy movement and its role within the energy transition to sustainable energy.

Finally, chapter 6 concludes this thesis. It revisits the findings from the empirical chapters and discusses the transformative potential of local energy initiatives as innovators in the transition to a renewables-based energy system. Besides addressing the main research question, the chapter contains a theoretical and methodological reflection, comparison between the electrification niche and current community energy niche, and recommendations and suggestions for future research.

1

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2

HOW LOCAL ENERGY INITIATIVES DEVELOP TECHNOLOGICAL INNOVATIONS: GROWING AN ACTOR NETWORK

Abstract

Local energy initiatives are of growing interest to studies of grassroots innovation for sustainability. Some of these initiatives have developed novel technological solutions to fulfil local demand for renewable energy. However, whereas the upscaling and diffusion of grassroots innovations has been extensively discussed in the literature, their emergence has received very little attention so far. We will therefore focus on how energy initiatives can develop technological innovations by bringing together local actors and creating a fit to local circumstances. Grounded in actor network theory (ANT) and structured by concepts from Callon's sociology of translation, we studied two technologically innovative projects of a Dutch energy initiative. Through document analysis and interviews, we researched how these initiatives developed their innovations by forming networks of social, material, and discursive elements. We found that the outcomes of the innovation processes are very dependent on the networking capacities of the energy initiatives, as well as how well they fit with external circumstances and opportunities. The paper concludes with five lessons for grassroots technological innovation: form links with the local, extensively scrutinize plans, create tangible proof of alignments, position the project as beneficial to as many actors as possible, and adjust the level of ambition to the strength of the actor network.

Keywords: grassroots innovation; energy cooperatives; local energy initiatives; community energy; technological configuration; sociology of translation; actor network theory.

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2.1. Introduction

Many of the changes required to transform the energy system start with modifying existing configurations of technologies, services, or practices for use at a smaller scale [1]. Some of these innovations are developed by people and organizations located at the bottom of a system's pyramid, such as users, community groups, voluntary associations, and cooperatives. These bottom-up innovators create grassroots solutions for sustainable development that respond to the local situation and the interests and values of the communities involved [2,3], usually as matters of necessity and in response to challenges that are not addressed adequately by actors with more power [4].

The focus of this paper is on grassroots technological innovation by local energy initiatives that want to transition further towards a more sustainable energy system. Previous well-known examples of such grassroots innovations in the energy sector include the Austrian solar collectors and the Danish turbines developed by do-it-yourself builders and local craftsmen. Studies of these cases [1,5,6] and of other user-designed and managed energy systems [7–12] demonstrate how energy consumers can take up new roles going far beyond passive consumption, and can be initiators, managers, developers, and co-developers of new technological solutions that are better adjusted to local values, needs, and desires, and that have a widespread impact on energy provision.

Some Dutch energy initiatives have also produced innovative technological solutions. Examples include an experimental church heating and ventilation system that increased energy efficiency as well as comfort, and a hydroelectric power station that has been integrated into a sluice gate [13]. These cases show that local energy initiatives tinker with technologies and methods for their implementation, leading to innovative arrangements of localities, actors, and technologies. De Vries et al. conceptualize these outcomes as "*configurational user innovations*," which they define as "*user designed arrangements of loosely related sets of components*" [13] (p.51). Innovation can thus be understood as the alignment of technical components, people, organizations, policies, business cases, physical characteristics of the site, skills, and local goals and values in a network.

Portraying innovations as networks of social, material, and discursive elements enables us to study how local energy initiatives connect these diverse elements into innovative configurations [3]. These networking processes are particularly interesting to study, because energy initiatives, which are often voluntary organizations, have limited resources and have few existing structures to guide their innovative endeavors. They need to find a way to develop from idea to implementation without a pre-existing innovation management structure as would be the case in many commercial environments, i.e., a systematic process from strategy building to implementation [14]. In addition, innovating requires experimentation and creates uncertainty, which exerts pressure on the relationships that need to be formed and maintained for a working configuration.

Accordingly, local energy initiatives have to build the structure to facilitate innovation almost from scratch and under challenging conditions. We therefore expect that the innovation process largely depends on how the energy initiatives engage in networking and we consider the following questions: how do local energy initiatives create a network that enables the development and implementation of innovative technological configurations? What conditions facilitate, and what conditions hinder, network building?

With a focus on network dynamics, we aim to contribute to a deeper understanding of how grassroots energy innovations emerge and gain robustness. A wide array of scholars use the multi-level perspective (MLP) and strategic niche management (SNM) to analyze grassroots innovations as niche dynamics [2,9,15–18]. Quite often these studies address how grassroots innovation niches can be strengthened by, e.g., sharing information and facilitating learning processes through intermediaries [9,16,17,19].

In these studies, local energy initiatives are depicted as a niche, opposing and challenging the powerful actors in the prevailing energy regime. However, until now only limited attention is given to how innovations emerge from within local energy niches [20]. For addressing this question, the MLP and SNM framework are less suitable as they primarily focus on meso and macro level dynamics, whereas this paper aims to contribute insight into the local micro level network dynamics through which an innovative technological configuration is being shaped. Therefore, this paper takes a novel approach and uses actor network theory (ANT) as the theoretical lens. As we will argue in the next section, a micro level ANT analysis can add new insights to existing work on grassroots innovation dynamics.

2.2. Theoretical lens

This paper analyses network construction from an ANT perspective to obtain a better understanding of how energy initiatives can align various elements into a network that enables the realization of an innovative technological configuration [20–23]. The ANT framework permits the interpretation of power and influence in networks at a micro level. It does not dichotomize structures and agents, nor humans and non-humans, but includes people, institutions, and the non-human realm as the scope for analysis [24]. Especially, because of the socio-technical nature of local energy projects, it is valuable to not only focus on human interaction, but also take into account the technical and other material aspects in the innovation process.

More specifically, we will use Callon's sociology of translation [21] as this framework provides us with concepts to study how energy initiatives can develop innovative energy configurations by building a network. A core concept is "translation," which Callon defines as the interactional process of connecting during which the actors' identity and their margins of manoeuvre are negotiated and delimited [21]. Callon has conceptualized this interactional process of connecting as phased (see Section 2.2.2) and these phases are particularly useful to understand various stages of network development within an innovation process. In this section, we will further introduce our theoretical lens.

2.2.1. ANT and energy initiatives

ANT follows actors during the development of a network [20]. As energy initiatives are the focus of our research project, we used their interactions as a starting point. Furthermore, ANT regards all elements in the socio-technical network as actants that possess agency. Possessing agency here means making or stimulating change in another entity or network [25]. The agency in a socio-technical network is shaped by the connections that constitute the network, and the durability and stability of these connections.

Agency can be exerted by human and other actants. In the case of a community energy project, human actants can, for instance, be the owners of a potential site for renewable energy (RE), and municipalities that can issue or deny building permits to energy initiatives or change land zoning plans. The category of non-human actants is diverse, including nature, technical, and material structures and texts (such as scientific accounts and laws) [25]. For example, a protected bat species living at the site of a proposed RE installation exerts agency through environmental protection laws and mechanisms for environmental impact assessment built into permit procedures, as well as through environmental non-governmental organizations (NGOs) representing its interests. The qualities of a site, such as its dimensions, soil type, and location relative to other infrastructure, impact the design options. For example, having a grid connection with enough capacity available at the site saves costs and makes it easier to achieve a viable business model. As these examples show, non-human actants possess agency and influence the success of a community energy project. They need to be taken into account as actants to be followed during network construction, just like human actants.

2.2.2. Analysing network development

In following network development, ANT is not primarily concerned with mapping only the interactions between actors, but rather with mapping "*the way in which they define and distribute roles, and mobilize or invent others to play these roles*" [22] (p. 285). ANT characterizes this process of actors struggling over inclusion within particular networks as translation. Translation is the process of making connections between a multitude of elements involved in a system and their meanings, such that they can be related in a socio-technical network [23]. It is therefore about relating things that were previously unconnected. Consequently, the identities of the actants involved and the meanings that they attach to various aspects of the project are fluid and can be intentionally influenced by actors in the translation processes. Callon [21] argues that such translation dynamics occur in four phases: problematization, interessement, enrolment, and mobilization. We will elaborate on these terms below, using examples from the community energy context.

The first phase of network building is the ***problematization*** phase. As the initial network builder, the energy initiative needs to problematize the situation and make itself indispensable to other actants by creating an obligatory passage point. This obligatory passage point can be established by firstly defining a problem with a certain urgency and importance, and then convincing the desired partners that this problem can only be resolved by cooperating with the energy initiative. An important means through which energy cooperatives can do this is by defining themselves as a necessary partner to meet sustainability targets.

After creating a shared problem definition, an energy initiative needs to create ***interessement***, which is a series of processes by which the energy initiative can lock actants into the roles that it proposes. In this phase, the interest of the actant is defined, and potentially also redefined if the actant succeeds in negotiating inclusion in the network on different terms than the energy initiative proposed.

Interessement is realized by the initiative through interposition, which means putting itself or a third party between two actants, often to intervene in their activities and bend their actions to another cause. This is realized with the help of so-called interessement devices, which can be technologies but also policies, laws, or resources such as money. These devices are used to stabilize the connection between the energy initiative and the actant that it wants to engage, and weaken possible links between the actant and entities which may threaten the alliance. The interessement device is of particular importance to the energy initiative with respect to actants for whom the energy initiative cannot truly be an obligatory passage point.

Subsequently, if interessement is successful, the energy initiative has to ***enrol*** actants in the network by interconnecting the various roles into a productive network. Interessement devices are powerful tools for structuring the relationships in a socio-technical network. An example of an interessement device is a grant, which connects the government that allocates it, the recipient energy initiative, and the actants, such as a project developer or a consultancy firm conducting feasibility studies that the energy initiative pays for using the grant money.

Finally, ***mobilization*** refers to making "entities mobile, which were not so beforehand" [21] (p. 14). For actants that first need to be detached from other actants, this phase also refers to this displacement and necessary changes in alliances. However, the connections made in a socio-technical network can be contested at any moment, making the mobilized state a potentially volatile one [21].

2.3. Methodology

Using a case study design, we empirically studied the translation dynamics of two local energy initiatives that were in the process of developing an innovative energy configuration in their municipality. From beneficial and unbeneficial moments of translation along the project development process, we can learn how and under what conditions energy initiatives can engage with potential facilitators, align them with their innovation projects, and keep themselves dissociated from actants that obstruct their progress.

2.3.1. Conceptualization of core concepts

This paper focuses on the development of *innovative technological configurations* in which *local energy initiatives* play a key role. It is therefore important to elaborate on how we will conceptualize the two core concepts.

We use the conceptualization provided by Boon to define *local energy initiatives*, and characterize them as initiatives "initiated and managed by actors from civil society, that aim to educate or facilitate people on energy use and efficiency, to enable the collective procurement of renewable energy or technologies, to provide, generate, treat or distribute renewable energy derived from various renewable resources for consumption by inhabitants, participants or members who live in the vicinity of the renewable resource or where the renewable energy is generated" [26] (p. 10).

Based on the work of Peine and Fleck, we define *innovative technological configurations* in this research as new and productive alignments between local actors, RE technologies, and localities made under prevailing socioeconomic, spatial-physical, and institutional circumstances [27,28]. In line with Fleck, we use the notion of *technological configurations* instead of *technologies* to emphasize that local energy projects do not focus on purchasing RE technology and using it off the shelf; instead, we center on the setup or configuration shaped by the energy initiative to serve the local context [27]. Therefore, the identity of a technology gets shape during the configuration process, and evolves during project development as a result of learning processes. Other parts of the configuration, such as the actors executing project development and the site where the configuration is implemented, also evolve [28].

We consider a technological configuration *innovative* when it yields any kind of value (social, economic, or environmental) "in the form of new or improved functionality or quality, reduced cost, better or more widespread availability (i.e., bringing a new tool or capability to a location where it had not been available before), … [price], or some combination of any or all of these" [14] (p. 12).

2.3.2. Case study method

To analyze how energy initiatives create a network with the agency for the implementation of an innovative technological configuration, we looked closely at two projects through a case study design. The case study design allowed us to research the project-level network construction processes during project development, and to identify beneficial and less beneficial translation attempts: the events in which connections are made and lost. The cases illustrate how energy initiatives can organize agency by defining and distributing roles and making other parties play these roles, to build a technologically innovative energy configuration.

We increased the external validity of our findings by selecting energy initiatives that had to start their innovative projects from scratch (neither finance nor location were provided upfront, which is the starting point for most local energy initiatives). By doing so, we gained insight into the whole process of network construction and translation and captured a set of common steps that virtually all technologically innovative energy projects need to go through: invention, testing the technological configuration, securing a location, finding investors and other partners, and obtaining the necessary permits and grants.

As a first exploratory step, an expert in the field of community energy was interviewed to identify potential cases. After a round of initial conversations with representatives from several of the suggested energy initiatives who were contacted by email, two projects were then selected for the richness of their networks and their interactions in these networks: the *BrummenEnergie* solar park, which is under development at the paper landfill site in its eponymous municipality, and the planned floating solar park of *Stichting Betuwe Energie*. These two cases represent two different ways that a new technological configuration can be realized: one case shows how improving an existing technology can start within a community initiative, and the second case shows how an innovative configuration can be achieved by collaborating with the developer of an innovative technology in a pilot study (these ideas are introduced further in Sections 2.3.2.1 and 2.3.2.2).

While neither of these two projects have reached the implementation phase, both have been through almost the entire project development process and are now at the point where they only need to secure their feed-in tariff Stimulation regulation Sustainable Energy production+ (in Dutch: Stimuleringsregeling Duurzame Energieproductie+, SDE+), which is allocated twice a year. Our analysis of the translation dynamics therefore focuses on the initiating and developmental phase of the two innovative technological configurations and leaves out the implementation phase. However, the most important alignments have to be made before implementation. Once the subsidy is allocated, the energy initiatives can activate the actants needed for implementation relatively easily, as the project has then truly proven its economic viability.

2.3.2.1. BrummenEnergie: a solar park on a local landfill site

BrummenEnergie is working on a solar park to provide energy for approximately 1200–1400 households. It occupies 12 ha situated at a paper landfill site in Eerbeek, a settlement in the municipality of Brummen. Developing a solar park on a landfill site poses legal challenges as this complementary land use initially conflicted with the Landfill and Soil Protection Decree 1993 (*Stortbesluit bodembescherming*), but besides the legal dimension, the technical dimension of this project is also complex. Instability of the ground due to subsidence of the paper waste meant that regular solar PV panels and a lighter and more experimental solar film were both considered from an early stage. The first option was a 15,000 panel and roughly 4.5 MW PV installation with a stabilizing foundation. The alternative was an experimental solar film generating about 100 kWh/m^2/year, consisting of lightweight and flexible thin-film silicon solar cells on long foil substrates. This film is very flexible, making the technology applicable for covering rooftops and facades, for instance, and potentially also a landfill site. The amorphous nanocrystalline silicon tandem cells yield product efficiencies exceeding 10% (commercial solar panels yield from 9% to 21% [29]). Although the yield would not be very high, thin-film is less expensive per m^2 and could cover a greater surface than solar panels, which would partly make up for the efficiency difference with the panels. The difference in the potential yields would also be nullified because of a grid limitation. The socio-technical network developed while working on this project was therefore strongly focused on finding the combination of an appropriate technology and a viable business model that could fit within the regulations for managing the landfill.

2.3.2.2. Stichting Betuwe Energie, a floating solar park in a sand excavation lake

Stichting Betuwe Energie is in the process of developing a 1.4 ha floating solar installation consisting of 10,800 panels on lake Eisenhower in Elst, a settlement in the municipality Overbetuwe. Its calculated capacity is 1.9 MW and the electricity will be supplied to local industries. The project was started by a retired bank manager, who cooperated closely with the municipality for years as a sustainability consultant, advising residents on solar panels for their homes through his solar collective Overbetuwe foundation. The technology for this floating solar field was developed by an acquaintance of his, a retired engineer, who developed the concept of floating solar PV by adding an innovative mechanism permitting the installation to follow the sun, to increase its yield by about 35%. The installation normally turns 180 degrees (with a maximum of 270 degrees) in twelve hours, while also continuously adjusting the angle of the panels to obtain perpendicular irradiation during the daytime.

While the bank manager worked towards the establishment of a cooperative to develop the project, the engineer continued improving the technology and established a start-up company. The floating solar project is therefore dependent on the development of two partly interwoven socio-technical networks: one around the implementation of the project and one concerned with the development and marketization of the solar tracking technology.

2.3.3. Data collection and analysis

The empirical data was retrieved from three types of sources: local energy initiative websites (e.g., various online news updates), internal documents provided on request by the local energy initiatives, and semi-structured interviews. As displayed in table A1 in appendix A, a total of thirteen semi-structured interviews were conducted with actors involved in the development of the two projects (either by phone or face-to-face). The role of non-human actants has been analyzed from the perspective of the various human stakeholders in the project.

The interviews explored the various moments of translation during project development. They were structured to answer the following questions regarding the translation processes within the cases and also informed the structure of the results section:

1. Problematization: (i) which problem definition underlies the project and (ii) how has it been formulated?
2. Interessement: (i) what roles were identified by the local energy initiative, (ii) what are the resources associated with these roles, (iii) at which stage did these roles need to be fulfilled, (iv) which interessement devices were used by the local energy initiative and other actors, and (v) how were the actors persuaded by the various interessement devices to play the roles proposed to them?
3. Enrolment: (i) how were alignments achieved between the human and non-human members of the network to further the innovation process, and (ii) how did interessement devices help to interrelate parts of the network?
4. Mobilization: (i) which actants were mobilized, (ii) how durable was the mobilization, and (iii) are there any future threats to this mobilization?

All of the data were analyzed thematically using the translation phases as guiding concepts. Where possible, the data were triangulated by using various sources to collect specific information (interviews, websites, and documents) and by repeating the same semi-structured interview with multiple interviewees. Moreover, the interpretation of the data was checked with the interviewees.

2.4. Results

In this section, we describe the evolving socio-technical networks developed by *BrummenEnergie* and *Stichting Betuwe Energie* to create an innovative technological configuration using the sociology of translation as a lens. The reconstruction of the translation dynamics is based on the operationalization of the translation phases in the methodology and the empirical data obtained from documents and interviews.

2.4.1. BrummenEnergie: A solar park at the paper landfill

2.4.1.1. Problematization

Within a year of its foundation in 2012, the cooperative and the municipality began a series of meetings with other municipalities and cooperatives in the region to identify locations for developing RE projects co-financed by available provincial funds. The 12 ha paper landfill site presented itself as a potential location to the chairman of the Brummen cooperative when he passed it on his racing bike. He explained: "If you did not know it was a landfill site, you cannot really see it because of the overgrowth. I was aware of the landfill and thought that it was a shame that it was not covered with solar panels."

Shortly afterwards, he approached the director of the landfill. Because he had worked for the paper industry in Eerbeek earlier in his career, he knew the company that managed the landfill, and which person to approach. The landfill director was interested in the idea of developing a solar park at the landfill site, not only because it would contribute to local sustainability, but also because a solar project at the landfill site could possibly play a role in solving the technically complicated and very costly problem of covering the landfill site. Owing to waste disposal regulations implemented in 1995 [30], the landfill site had been closed for over fifteen years. As part of the post-closure care guaranteeing the safety of the environment, the Landfill and Soil Protection Decree[31]—a national decree implemented by the provinces—requires that the landfill site be covered. Even though the waste is non-hazardous, according to this Decree, the Eerbeek landfill site must be fully closed off to stop the infiltration of rain in the waste materials that could lead to contamination of groundwater, soil, and air. Such an impenetrable cover consists of various layers of high-tech materials and represents a multimillion-euro investment, and the landfill director was investigating possibilities to create an alternative and preferably less expensive cover.

Furthermore, the covering of the paper landfill site was also still pending, because the paper waste at the landfill was still settling, and because of significant but unpredictable and variable subsidence, varying between 1 and 3 m, extra stabilization measures were required before it could be covered. Otherwise, the subsidence might well cause the covering layers to tear, making it impossible to guarantee an impenetrable cover in the long run.

Facing the obligation to comply with the Landfill and Soil Protection Decree, the opportunity to develop a solar park at the landfill site was an argument for its director to strengthen his case in favor of alternative and less expensive coverage. The opportunity to install a large solar park could be used to connect with other policies and regulations to provide a new way to approach finding legal space for alternative covering.

As a result of the collaboration between the cooperative and the landfill director in the problem definition, the role of the solar panels was therefore broadened from merely increasing local RE production to also covering the local landfill.

2.4.1.2. Interessement and enrolment

The chair of *BrummenEnergy* and the director of the landfill site identified the roles that were needed to continue the project successfully in the next phase. They then tried to enrol actants corresponding to these roles in their network.

Bringing in knowledge: A university and an innovation platform

First, they sought a source of knowledge capable of outlining the legal, technical and economic feasibility of ordinary solar panels and a new lightweight solar thin-film developed in the region.

Before retiring, the chair of *BrummenEnergy* had worked at the University of Applied Sciences of Arnhem and Nijmegen as a business economist. He continued to be in contact with his former colleagues, so he contacted them to see whether they could have students explore their questions regarding the feasibility of the two options for a solar park on the landfill as graduation projects. This resulted in four graduation projects in 2013: one project in business economics, one in mechanical engineering, and two legal projects.

Alongside the students, the chairman of *BrummenEnergy* and the director of the landfill approached a starting solar thin-film company that they knew for information on the technical and economic specifications of the product. The students' feasibility studies based on these figures showed that this film would be technically simple and would make a good return on investment. However, the legal research showed that the Landfill and Soil Protection

Decree was an obstacle to establishing a solar park on the paper landfill site. As the landfill director stated: “The Landfill and Soil Protection Decree has been designed so strictly that new developments do not get a chance.”

Not long after these studies were completed, further opportunities for a pilot project were explored as part of a strategy by the Province to promote the solar thin-film company. The solar thin-film company was the anticipated centerpiece of the Energy Valley campus for innovative companies in the field of environmental technology that the province of Gelderland was developing near Arnhem. The solar film had just reached the point of being ready for market entry, and the company was looking for a launch customer to scale up production and begin making a profit. The solar project at the landfill site had the potential to be such a launch customer that would justify the extension of the thin-film production facility. To aid the development of its business, the solar thin-film company was in contact with the Kiemt foundation. This is a platform financed by the Province of Gelderland to transform the province into the Dutch center for energy and environmental technology and bio-based economy. Kiemt had received the students’ reports, which acted as interessement devices, binding Kiemt to the project in the role of external mediator and facilitator. Kiemt thought in terms of “chances and developments” and helped to smooth the cooperation by mediating the project development from an external perspective, which helped to overcome difficulties encountered when the project was in danger of stalling (interview municipality of Brummen).

From this point onwards, the case manager from Kiemt, the director of the landfill site, the chair of the cooperative, the solar thin-film company, and at times representatives of the Province and municipality, held regular meetings. Moreover, thanks to the project’s good prospects, the cooperative received a municipal subsidy to hire a project developer experienced in supporting cooperatively developed solar parks. As a group, they identified opportunities to get the legal permission and finance for a pilot.

Towards a pilot: Legal permission and funding

To avoid the strict coverage regulations of the Landfill and Soil Protection Decree, the group started a process proposed by Kiemt to fast-track the project via the Crisis and Recovery Act (*Chw*) [32]. The *Chw* was developed in response to the economic recession in the late 2000s and early 2010s and aims to stimulate the economy and employment in the construction sector and the economy in particular. It shortens the approvals process for infrastructure projects and facilitates innovative projects by providing them with exemptions from regulation, where possible. As a large solar park at the landfill site would justify expanding the production of the solar thin-film, the project would stimulate the economy by creating up to 30 jobs at the solar thin-film company[33]. Furthermore, this method for covering landfill sites was estimated to have a replication potential of 10,000 ha across Europe, which offered the prospect of further growth for thin-film production[33].

The municipality now adopted an advocating and connecting role and took up the *Chw* application with the Province. The Province subsequently applied to the Ministry of Infrastructure and Water Management for an exemption to the relevant sections of the Landfill and Soil Protection Decree. A policy officer from the municipality of Brummen illustrates: "We did need to persuade the permit allocation division at the Province. …The Provincial deputy has helped to get the parties [permit allocator and inspection division of the Province] on the same page."

After a process of lobbying, the project was included in the tenth tranche of the *Chw* Implementation Decree in September 2015, as an innovative combination of electricity generation and waterproof landfill site covering. As a result, the *Chw* created an interposition between the landfill site and the Landfill and Soil Protection Decree. Provided that the groundwater quality does not deteriorate, the Province must now propose a new deadline for the covering, required by the Decree by 2040.

Parallel to this legal process, grant options for a pilot were explored. After missing out on a national grant to encourage innovative energy technologies, the project was selected for a provincial grant of EUR 160,000 for a pilot in late 2015. This grant came from a program called Gelderland's dimensions (in Dutch: Gelderse Maten), which targeted pilot projects exploring energy generation or savings in local projects including citizens, companies, municipalities, and non-governmental organizations. The grant functioned as an interessement device to further lock the partners into the project development network and strengthened the ties between parties through financial agreements regarding the pilot.

Implementation of the pilot

For the pilot, 4000 m^2 of the landfill site was cleared, levelled, and stabilized with waste material from blast furnaces (clinker). The director of the landfill site consulted an earthworks company, which was included in the growing support network, for knowledge on stabilization of the landfill site. After preparation of the surface, 5 kWp solar thin-film and 3 kWp lightweight solar panels were installed. These newly available lightweight solar panels were expected not to sink into the waste. For this application, the solar thin-film was combined with a geo-textile that had been developed in cooperation with the thin-film company for a previous project. The geo-textile would stop rainwater infiltration and provide an alternative way to seal the landfill. The pilot would run for two years and would test the performance of the solar thin-film as well as the stability of the foundation that the solar panels and thin-film were placed on. The test site was officially opened in June 2016.

After a year, the solar thin-film was found to have already degraded severely, and was not advanced enough to be adapted effectively with the physical conditions at the site. Another setback was that the solar thin-film company had disassociated itself from the pilot in the meantime, which excluded the possibility for cooperating further on a more durable hybrid of the geo-textile and the solar thin-film. The reason for the disenrolment was the film producer's dissatisfaction with the opportunities that it had obtained from the Province to develop its business. During the pilot, the company had found an opportunity to upscale and to move production of the thin-film abroad. At this point, the role of the Kiemt innovation platform in the project also ended because the project was no longer about testing and eventually helping to upscale an innovative energy technology. However, the pilot had shown that the foundation method tested using blast furnaces clinker supported the lightweight solar panels, and thus locally, the innovation process to establish a solar park on an unstable landfill site could continue. However, as the solar thin-film production and its foreseen economic benefits were no longer part of the project, it was unclear whether the exemption to the Landfill and Soil Protection Decree through the *Chw* could still be used.

2.4.1.3. Mobilization

To the surprise of the project group, the Province now identified an article in the Decree which could be read as supporting alternative coverings, making the project legally viable. Ultimately, the Province was able to create alignment between the Decree and the solar park and created legitimacy for the project through the Decree.

With this uncertainty resolved and the environment permit granted by the Province after a shortened procedure approved by the municipality, the project group was able to apply for the SDE+ tariff in the autumn of 2018. If this RE subsidy is allocated, the construction of the solar park will be able to commence, as the project developer has the available investment capital to secure a bank loan for the project. Not obtaining this feed-in-tariff is the biggest threat to the project at the moment, as it is not viable without it. Because the scheme is substantially oversubscribed, projects that use a form of technology (e.g., solar) that needs the lowest subsidy/energy output are the first to be funded. The scheme can thus achieve an economically efficient transition and maximize the capacity installed. The allocation of this subsidized feed-in tariff is only done biannually, so an initial rejection might cause tension within the network because it would cause significant delays and it would continue to be uncertain as to whether the subsidized tariff would be allocated on the next attempt. However, the time, effort, knowledge, and money that have already been invested and the contracts that are in place (e.g., for use of the site and the project development contract) make it unlikely that the cooperative, landfill manager, or the project developer would disassociate from the network unilaterally. Finally, the solar thin-film developer has shown that disenrolment need not be permanent, as it has renewed its interest in the landfill site to test a new prototype of its film.

2.4.2. Betuwe Energie: A floating solar tracking installation on the lake

2.4.2.1. Problematization

The idea for an innovative floating and rotating solar installation arose in 2011 during the implementation of the municipality of Overbetuwe's climate plan, which aims for 14% RE by 2020 (on par with the national target). A retired sustainability consultant from the municipality volunteered to investigate options for the solar park. As wind turbines face resistance in the municipality, a considerable surface area was needed to generate the RE required to realize the climate plan mainly using solar.

In a meeting with the municipality about the implementation of the climate plan, an alderman mentioned Lake Eisenhower to the sustainability consultant. The lake is owned by the municipality and an earthworks company located next to the lake. It is not currently in use as it is polluted by past industrial activities. This suggestion started a process of redefining Lake Eisenhower from a useless, polluted lake into a large area available for solar RE generation. Looking online at floating solar systems, the sustainability consultant reckoned that it should be possible to get a solar panel installation to rotate from east to west during the day to maximize yield. As he lacked the technical knowledge to explore how to implement such a system, he contacted an acquaintance, a retired mechanical engineer with whom he sang in a choir. As a technical enthusiast, the engineer was up for the challenge and started what he called a "project of combination and deduction," in which he integrated his professional experience with floating objects and other technical knowledge that he had gained over the years. Within a short time, he had designed a structure that rotates during the day and also tilts to maximize yield by creating perpendicular irradiation. Furthermore, the engineer added two more features: a fish-pond-like bubbler system to keep the water from freezing in winter and rollers to prevent birds from landing on the installation and soiling the panels.

From this point onwards, the engineer worked on refining the design, and the sustainability consultant started to further explore the requirements for developing a floating solar park and institutionalizing the initiative.

2.4.2.2. Interessement and enrolment

The municipality was positive about the plan to use the lake but did not want to take on the role of landowner in this project. It wanted to avoid potential accusations of providing state aid and having its procurement procedures challenged, and therefore suggested that the quickest and easiest solution would be to develop the solar park on the lake owned by the dredging company, with their permission.

Concretizing plans: Confirming the location and assessing feasibility

Through their professional backgrounds, the two initiators were both already in contact with the dredging company. The sustainability consultant was part of the sustainability committee for the industrial area and the engineer was still active as a consultant to the company after having retired from working there. The dredging company responded positively to the plan because it was aligned to their vision for adding social value to their projects. As a representative of the company illustrates: “We would like to offer our resource- sand- CO_2 neutral. Therefore, we are exploring renewable energy [in various ways].” Moreover, the dredging company owns various excavations where the project could be replicated if successful.

After various talks, the dredging company decided to make the site available for free to facilitate a more attractive business model. A normal profit margin was needed for this project because the sustainability consultant knew from experience that most businesses would only invest if some return on investment could be expected. As the businesses in the local industrial area were expected to adopt both the role of investors and electricity consumers, their participation was an important condition for project development.

With the location secured, the sustainability consultant and the engineer applied for a provincial grant of EUR 25,000 to finance pre-development costs in early 2015. They noticed that it is hard to secure a subsidy as a newcomer: “There are many like-knows-like networks in which subsidies are allocated and it is hard to enter these networks. … [Having relevant contacts in your own network] helps" (interview SBE #2). However, they were successful, and hired an external agency to verify the engineer's design and to perform an economic feasibility study. This study was completed in nine months and showed that the project was both technically feasible and economically viable.

The environmental permit: A facilitative municipality

In autumn 2015, the consultant and engineer applied for an environment permit at the municipality. As the municipality was supportive, it established a special committee to consider all of the aspects of the project that needed to be reviewed at once. They first needed to prove that the RE installation would not harm the wildlife in and around the water. With the money left over from the provincial grant, the sustainability consultant and the engineer had an ecological study performed that demonstrated that local wildlife, such as the ducks and fish, would not suffer from the solar park. Second, the lakeshore and surrounding area contained archaeological remains from the Roman period, and any building activities involving pile driving would require an archaeological study. The initiators did not want to be delayed and inquired of the municipality whether an archaeological study would also be necessary if the required piles were to be located a few meters offshore. As a permit to use the sand excavation site had already been given, this solution avoided the need for an archaeological study. Finally, the municipality requested a visual impression of the solar park because it was such a novelty that they could not assess the expected spatial impact. The sketches and 3-D designs prepared by a graphic designer showed that the 1.4 ha installation would be barely visible from the shore, as it was fairly flat and would rest a couple of hundred meters offshore. This productive collaboration with the municipality led to the very rapid completion of the permit procedure, which happened within two months. The sustainability consultant stressed the benefits of the municipality's support: "Lingewaard Energie [a cooperative from a neighboring municipality] has already been working for a year on getting the permit for their floating solar park. Here, the municipality's various departments are all on the same page."

The publicly announced permit application sparked a fair amount of media attention, even before the environment permit was granted. This started with an article in a regional newspaper, which was picked up by a number of national newspapers and led to an invitation for the engineer and the sustainability advisor to discuss the project on national television. Because of the media attention, the Dutch government Department for Waterways and Public

Works (RWS) learned about the project and invited the engineer to include the technology in a pilot project with three other floating solar technologies. This pilot was realized through a consortium initiated for testing the performance of floating solar technologies in semi-open water with higher waves at the Port of Rotterdam dredging depot. This consortium, called the National Consortium Solar on Water (In Dutch: Nationaal Consortium Zon op Water), consists of government bodies, knowledge institutions (Energieonderzoek Centrum Nederland and Toegepast Natuurwetenschappelijk Onderzoek, joining as the Solar Energy Application Centre), and energy and water sector incumbents, and has invested in the pilot as it foresees a future in which solar parks at sea will be technically and economically feasible and can be combined with wind parks. Therefore, the announcement of the application for the environment permit unintentionally acted as an interessement device linking the solar tracking technology to the pilot, which started in September 2017 and is still ongoing. The pilot installation has since survived several heavy storms (Bf 10 and 12), and a few modifications to the installation have been made to further improve its functioning.

Institutionalizing: A start-up, a foundation, and a cooperative

At this point, the floating solar panel technology had become part of a start-up established by a turnkey solar installation company and a family business in winches, special-purpose machines, and hydraulics. The engineer felt that a commercial environment was needed to bring the technology to the market. However, he wanted to enjoy his retirement and was not interested in a role as developer. The hydraulics company was interested in the solar tracking technology because of its regional roots, the company's belief in bottom-up innovation, and the technological concept itself. These factors convinced them that it was possible to scale up and bring the technology to the market. Furthermore, they added that it was also about having the guts to invest in an idea that feels promising: "At a large company such innovations often strand in the bureaucracy. You will get all kinds of tables and ratios to calculate the risk and potential benefits. Even the brightest ideas will then strand if they are not well quantifiable. You need to dare to become part of it and invest."

After the transfer of the intellectual property, one engineer remained involved as a consultant but entrusted the start-up with developing the pilot in Rotterdam's harbor and the further marketization of his technology.

Meanwhile, the sustainability consultant looked for a way to institutionalize the project. He brought together a group of acquaintances with backgrounds as varied as accountancy, law, and local politics. Contrary to some other initiatives they had seen, the group wanted to work on the solar project as volunteers. One of the members stressed: “We have seen projects in which initiators paid themselves and the project stranded when the subsidy was finished. We do it unpaid and because we like it.” In December 2015, they decided to establish a foundation to pursue energy sustainability in the Overbetuwe municipality, to create a subsidiary cooperative for the floating solar installation and, later, to establish new cooperatives for potential future projects. The rationale behind this umbrella construction was that people could participate in a specific cooperative and corresponding project. Members of the cooperative were not required to be engaged with all the foundation’s activities.

With the site secured, the feasibility studies performed and the environmental permit granted, the foundation was ready to apply for an SDE+ feed-in-tariff on behalf of the cooperative. Having the subsidy would further strengthen the network, as the subsidy could function as an interessement device. It would enable a financial tie between the cooperative and the start-up, and would further activate investing businesses. However, a subsidy was not granted in the first two attempts. The first time, the paperwork was not completed on time despite outsourcing part of the preparation to a subsidy advisory consultancy. The second time, the feed-in tariff that the foundation applied for was too high to create enough interposition between the project and its competitors to have the subsidy allocated. The foundation aims to remedy this in the next attempt.

2.4.2.3. Mobilization

Whether the elements in the actor network will be mobilized to start implementation depends on the allocation of the SDE+ subsidy. At the time of writing, the foundation is working on its third attempt to secure this subsidized feed-in tariff and will learn whether the SDE+ will be allocated in the summer of 2018. The chair of the foundation expects that the cooperative will receive the subsidy this time, but estimates that it will then take roughly another eighteen months to finish the project. The investors that have promised to contribute financially must be mobilized to actually provide the promised funding.

In the meantime, the start-up keeps developing the technology and its business model and exploring projects with potential future clients. It is therefore not entirely certain whether the technology will be available at the moment that the cooperative is ready to proceed, which might cause it to need to find alternative floating solar options on the market.

Other parts of the innovation network, however, are more stable. The municipality and the dredging company are securely mobilized, and the environment permit and the contract with the dredging company regarding the use of the lake are tangible legal documents. However, it is uncertain whether the future cooperation between the foundation and the municipality will be as smooth as it was within this project. Recently, the relationship between the foundation and the municipality has cooled considerably because of political changes.

2.4.3. Overview of the case studies

In this section, we will provide a schematic overview of the main findings from the two case studies. The translation phases have been used to structure the overview presented in table 2.1.

Table 2.1. A schematic overview of the main findings from the case studies per translation phase. Abbreviations of the phases: PD (problem definition), I & E (interessement and enrolment), and M (mobilization).

<table>
<tr><th></th><th>Case 1: Solar on the Landfill Site</th><th>Case 2: Floating Rotating Solar</th></tr>
<tr><td rowspan="2">PD</td><td colspan="2">Aspects:</td></tr>
<tr><td>• Increasing local RE production (municipality and cooperative)
• Unlocking a space for large-scale solar (municipality and cooperative)
• Covering the landfill site (landfill director)</td><td>• Increasing local RE production (municipality and sustainability consultant)
• Unlocking a potential space for large-scale solar (municipality and sustainability consultant)
• Improving an existing technology (engineer)</td></tr>
<tr><td rowspan="3">I & E</td><td colspan="2">Resources:
Policy and regulation, personal and professional networks, knowledge, financial means, legal and governance authority, space, communication skills, networking skills, and time.</td></tr>
<tr><td colspan="2">Interessement devices:</td></tr>
<tr><td>• Student studies (linking innovation platform, cooperative, landfill company, province and municipality, and solar thin-film company in a working group)
• Municipal and provincial grants (enrolling project developer, and strengthening interlinks in working group)
• Exemption to Landfill and Soil Protection Decree via the Chw (exempting landfill side from the Decree)</td><td>• Feasibility study (linking technology, engineer and start-up, and further institutionalization by developing into foundation and cooperative)
• Provincial start-up subsidy (linking graphic designer and the agency performing the feasibility study to the consultant and engineer)
• Public announcement of application environment permit (linking the start-up and engineer to the floating solar pilot test)</td></tr>
<tr><td rowspan="3">M</td><td colspan="2">Durability:
• The initiators were mobilized at all stages and the other actants were only mobilized during a certain phase or from a particular moment.
• Some actants remained mobile after the mobilization (e.g., the project developer in the landfill site case) and others disassociated after they fulfilled their role (e.g., the graphic designer in the floating solar case).</td></tr>
<tr><td colspan="2">Threats:</td></tr>
<tr><td>• Rejection of application for the SDE+ subsidy</td><td>• Rejection of application for the SDE+ subsidy
• Development of the start-up and floating solar technology
• Mobilizing investors</td></tr>
</table>

2.5. Discussion and conclusions

In this final section of this paper, we draw conclusions and core lessons for successful socio-technical network development by technologically innovative energy initiatives from the empirical results.

From the development of the actor networks in the case studies, we can conclude that local energy initiatives initially develop innovative technological 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 our 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. We will explore this in more detail in this section. We present and discuss our five main conclusions on how local energy initiatives can create actor networks in which the alignments between actants build up to functional innovative technical configurations. While the explanatory power of the two cases is certainly limited, we researched the literature on grassroots innovation to see whether our conclusions fit with what has previously been found.

2.5.1. Innovating by linking to the local

Local energy initiatives develop RE projects through seizing “local opportunities for synergies and trade-offs with local actors, such as entrepreneurs, public bodies or citizens,” and by linking to the systemic functions of the “local landscape such as agriculture, water treatment, social care, housing and leisure” [34] (p. 175). The energy initiatives studied also 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. At various points in the translation process, this encouraged other actants to support the planned innovation. Furthermore, while we do not want to imply that this is by any means a necessary result of grassroots innovation, in both cases, the resistance of users of the area to the project played no role (and is therefore absent from the results). Other works have also found a positive effect of local involvement on RE attitudes [35,36].

2.5.2. Unknowns require increased scrutiny

Rigorous feasibility assessments that can convincingly demonstrate the potential to create successful alignments and functioning innovation are required within projects in which an innovative technological configuration is developed. 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.

Strategic niche management literature has already shown that resourceful networks are key to the development of energy innovations [15]. In the case of the energy initiatives studied, such resourceful actors primarily come from existing professional and personal networks in the early phases of the innovation process. In the later stages, they come from a wider network in which contacts from the partnering actors' networks and unfamiliar actors are also engaged. In addition to landowners, investors, and experts of various kinds, local government [37] 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.

2.5.3. Making alignments visible is key

When experimental technologies or set-ups are used, assessing their feasibility through calculations and drawings alone is often insufficient, meaning that a proof of concept is needed to prevent invisible or hidden misalignments from emerging after full-scale 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.

However, when discussing alignment, it should be noted that alignment does not exist a priori, but is made, optimized, weakened, or found to be unrealizable in the interactional translation process between both human and non-human actants. Alignment is made tangible in documents such as a feasibility study, a change in the land zoning plan, or an environment permit.

2.5.4. More of a beneficial than an obligatory passage point

An energy initiative does not have much leverage over other parties when it starts its innovation project because, as a new and developing organization, it generally does not have much power or resources. This dependence is often one-sided, and the initiative can therefore be used instrumentally by others in the actor network. When better opportunities occur, interest in the local energy project may fade, as happened with the solar project at the landfill site when the thin-film developer encountered better opportunities abroad and the pilot test results were disappointing.

In general, it appears to be challenging for local energy initiatives to make themselves indispensable to the entities that they need to develop and implement their technological innovation, i.e., to be an obligatory passage point that others in the network need to cross to achieve their goals. It is often not possible for initiatives to present themselves as an obligatory point of passage to, for instance, the owner of a potential project site or a bank. 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.

2.5.5. Place-based versus up-scalable innovative technological configurations

The case studies show that it is more feasible for a cooperative to create a local innovative technological configuration than to bring a technology that is developed as part of or for 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 can be interesting for energy initiatives that do not find a proven technology that fits their project. For technological developers, it can be equally attractive to partner with an energy initiative in order to work with a party that will actively consider the specifications required for their innovations and implementation to succeed, and which has local networks, knows which locations are likely acceptable for projects, and invests the necessary time and effort into a pilot project. In addition, it can be interesting for technology developers to seek out a local energy initiative as a launch customer. Some innovation grants require working with a civil society organization, as was the case for the innovation grant that the solar project consortium for the landfill site was granted.

2.5.6. Reflections on the value of ANT for understanding the dynamics of grassroots technological innovations

The ANT conceptual lens allowed for a rich and detailed analysis of local network dynamics. Following the actants is useful for analyzing local grassroots innovations, as each local context and each particular technology implies a specific constellation of networked actants. The translation dynamics highlight the changing roles and identities of these actants during network-building. The new technological configuration is understood as an outcome of translation dynamics shaped in the local process of alignment, and stabilization and destabilization of networks.

More concretely, ANT enabled us to follow energy initiatives and the waxing and waning of the actor networks 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. Many actants were intentionally engaged by the initiatives, but others created a role for themselves, desired or undesired. Sometimes this concerned human actants, such as the RWS, who invited the floating solar start-up to run a pilot project, and other times these were non-human actants such as the lake wildlife, archaeological remains, and the weather conditions that damaged the energy generation technology. Moreover, it is typical of translation processes that actants are changed. For instance, both sites changed their identity from useless wasteland to RE generation sites and symbols of local sustainability, and the Landfill and Soil Protection Decree was translated by the efforts of the grassroots innovators and finally the Province from being an inhibiting actant to an enabling one.

Furthermore, using ANT, we were able to consider the roles of material and human actants equally in the network building processes of adjustment, molding, trying to connect, 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 a project or technology development is started by advocates for energy transition, and has a heightened sensitivity to the identity and agency of other material and social actants, 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.

2.5.7. Suggestions for further research

Our study has analyzed how local technological innovations are shaped through micro level socio-technical network dynamics. We specifically aimed to enrich the literature on the project-level processes of building networks that give rise to and stabilize new innovative configurations. Here we want to raise three topics that, in our opinion, are worthwhile for further study.

The first topic is to compare our cases with other cases of local technological innovation, preferably in other countries. This would contribute to a larger evidence base of grassroots technological innovation dynamics, but would also allow for more insight into the location–innovation relation. Due to the large role of local actants and local conditions in the innovation process, literature on frugal innovation could offer useful concepts for such research [38]. Grassroots innovation too starts off resource-constrained and asks for smart solutions to make the most of what is available.

Second, as we focused on the emergence of innovations, transfer and diffusion of grassroots technological innovation was not within our scope. Mainstreaming grassroots innovation often involves input from, and hybridization with, more conventional research, development, and investment in institutions for science, technology, and marketing [2,39]. Accordingly, recontextualization and up-scaling of local innovations may very well imply broadening networks. The triple and quadruple helix model of innovation could offer conceptual guidance in understanding relationships that are formed between civil society actors such as energy initiatives, businesses, governments, and knowledge institutions [40,41].

Third, the institutional conditions appeared to be crucial for configuring the studied innovations. A few studies have explored the fit between the activities of local energy initiatives, and national and regional policies and governance [42–44]. 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 [45].

Appendix A. Key actors and method of interviewing

This appendix presents table A1 with the key actors and interview methods.

Table A1. Key actors and interview methods.

Case 1: Solar at the Eerbeek Landfill Site	Type of Interview (F = Face to Face, P = Phone, X = Not Interviewed)	Case 2: Floating, Rotating Solar in Elst	Type of Interview (F = Face to Face, P = Phone)
Local government	F	Local government	P
Local energy initiative	F	Local energy initiative (2×)	F
Distribution system operator *	F	Distribution system operator *	F
Provincial government *	P	Provincial government *	P
Landfill site manager	P	Start-up	F
Innovation platform	P	Initiator pilot test	P
Project developer **	X	Lake owner	P
Thin-film developer **	X	Manager industrial estate	P

* Same actor, as the cases are in the same province and in the area of a single distribution system operator. Both cases were covered during the same meeting. ** These actors were not available for interview due to their busy schedules. The information about their roles has been recovered from interviews with the actors with which they interacted.

2

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3

BEING A BETTER NEIGHBOR: A VALUE-BASED PERSPECTIVE ON NEGOTIATING ACCEPTABILITY OF LOCALLY-OWNED WIND PROJECTS

Abstract

We pose that instead of problematizing negative attitudes of local stakeholders, such as citizens and NGOs, wind energy implementers should be more focused on scrutinizing the acceptability of their projects. The emphasis in this study is on the potential for representation of local stakeholders' values in the project design, including amongst others business model and placement. Informed by value sensitive design literature, we analyzed two contrasting, locally-owned wind projects in the Dutch province of Groningen: the implementation of mini-turbines in a national landscape and a large-scale multi MW wind project in an industrialized area close to a World Heritage nature reserve. The study analyses how the respective farmer-developers and other local stakeholders attempted to resolve or ameliorate inter- and intra-value conflicts regarding livability, economy, landscape, and nature. The value conflicts turned out to be fruitful to identifying key issues and creating more widely shared value conceptualizations and design priorities. Hence, from this study it can be concluded that value conflict can be productive if carefully unpacked and managed. Uneven power distribution among stakeholders in the planning process, overcoming incommensurability of perspectives, and creating intersubjectivity remain challenges.

Keywords: value sensitive design; wind energy; local energy; social acceptance; acceptability.

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3.1. Introduction

In many European countries' energy policies, wind energy is an important means for realizing a transition to a sustainable energy system. However, frequently a main bottleneck to smooth implementation of wind energy is the lack of support of local stakeholders—such as local resident communities, landscape organizations, and environmental NGOs. This resistance has been described as a lack of social acceptance of a project [1] and has been much researched for over a decade. A synthesis of this work can be found in several reviews with varying focuses (e.g., geographic [2], community-ownership [3], and planning guidelines [4]) and in reviews of social acceptance of renewable energy technologies more generally (such as [5]).

Framing a lack of social acceptance as a problem invites problematization of resistance by local stakeholders to wind energy projects. Yet, instead of problematizing lack of acceptance, the wind energy projects themselves could be scrutinized. Project developers could ask themselves the question of whether they are behaving like a good neighbor: Do I design my project mindful of the other users of this area? Is the project acceptable to them, and if not, can I alter the design of my project to improve this?

In this paper it is argued that project developers should pay more attention to whether and in what way a wind project is desirable in a certain local context. A focus on the fit of a wind project with the values and interests of the local stakeholders shifts the stress from acceptance of a project design to acceptability of the very plans that need to be accepted by the impacted stakeholders.

This difference could be described as the difference between social acceptance and acceptability. Taebi characterizes social acceptance as the acceptation or mere toleration of a new technology, while he describes acceptability as a reflection on a new technology that takes into account the issues that emerge from its introduction [6]. Hence, by focusing on acceptability, the normative dimension concerned with the acceptability of the wind project to its local environment becomes central, and so do the value perspectives of and conflicts between the stakeholders in this environment. Thus, it brings in a more local, and therefore territorial, focus[7], stresses ex ante acceptability instead of ex post acceptance of a development [8], and goes beyond recommending process participation by putting inclusion of key values of local stakeholders at center stage [9].

Key within the acceptability perspective is the desirability of the process and outcome for all local stakeholders [10–12]. Gross has shown how that acceptability is influenced by a combination of the perceived fairness of the process and the outcomes, as well as the favorability of the outcomes[12]. Hence, even if the process and outcomes are perceived to be legitimate, a lack of favorability of the outcomes of a project can make it unacceptable to local stakeholders.

We pose that resistance due to perceived unfavourability of outcome should no longer be dismissed as selfish not-in-my-backyard motives [10], but as an impetus to look at wind energy implementation more holistically, take the local context into consideration [11], and strive for better alignment between wind projects and their implementation environment [13].

Such alignment between the interests of turbine developers and other local stakeholders could lead to the design of more desirable, and so more acceptable, wind projects. In line with Oosterlaken, we hypothesize that designing locally desirable wind projects could speed up implementation in a morally acceptable way, and could thereby foster long-term support for wind farms [9]. Therefore, we are interested in analyzing how acceptability can be realized through a process of embedding outcome-related values of local stakeholders in the design of a wind project.

Previous research looking at responses to wind projects from a value point of view has described the values involved in wind energy development [14], theoretically explored the merit of value sensitivity [9], empirically analyzed the values represented in the physical and institutional design of offshore wind [15], and looked into the situatedness of value conflicts of onshore wind [16]. However, to our knowledge, no previous empirical research has put the focus explicitly on design attempts to make wind projects more sensitive to the values of local stakeholders and improve their acceptability, while a focus on design may have unused potential and could be a welcome addition to participative planning strategies.

Hence, we are specifically interested in which mechanisms exist to embed local values in wind energy projects, and how value sensitivity can affect the acceptability of locally-owned wind projects and reduce value conflicts. Therefore, our central question is:

How can wind projects be made sensitive to the values of local stakeholders by integrating them in project design?

To answer this question, we use concepts from Value Sensitive Design as a heuristic framework, which can be used to analyze a design for values, value conflicts, and trade-offs between values [17]. A strength of VSD is that it responds to the need for moving beyond conceptual accounts of values and towards the development of practical applications informing energy and planning practices [17].

An interesting contribution to the development of VSD itself is that we do not exclusively focus on how the values in the design of a technology affect its development [18], but we go broader and look at how values of local stakeholders are affected by design choices in the whole project development process, including, for instance, the placement and business model. Thereby, we expand the range of application to the design of wind projects.

Apart from this theoretical contribution, we also want to contribute to planning praxis by showing what a value-based approach can mean for wind energy development. The potential of a value-based approach for wind energy planning will be illustrated by a comparative case study of two farmer-owned wind projects of varying scales to contrast the opportunities of design for acceptability in different types of planning processes. The farmer-developers, to varying degrees, try and are pressured to be better neighbors to the other stakeholders within the area and make their projects more desirable.

Because of the central focus on farmer-ownership, we can contribute more insight into the relation between local ownership and acceptability. In the community energy literature, which predominantly foregrounds projects of citizens' collectives, this relation has been described as potentially positive but not uncomplicated [18,19]. Through this research, we can explore whether the same holds true for farmer-owned projects.

The remainder of the paper has the following structure: Section 3.2 introduces the value-based perspective inspired by value-sensitive design literature and outlines the conceptual framework used for the analysis of the empirical findings. Subsequently, Section 3.3 gives an overview of the case study methodology and introduces the two farmer-owned case study projects. Then Section 3.4 contains the results and gives an overview of the value perspectives of the stakeholders in the case studies and the ways in which they tried to negotiate the inclusion of their values in the project design. Finally, Section 3.5 concludes the paper by discussing five observations regarding how wind projects can be made more value sensitive and a reflection on the influence of local ownership on acceptability.

3.2. A value-based perspective

A strand of literature that is helpful to analyze what and whose values are involved in the design of a wind project and can provide pointers on how to create a broader representation of local stakeholders' values is value sensitive design (VSD). VSD literature assumes that a design, whether it is about placement, business, or the design of a technology itself, is not value-neutral. It supposes that several alternatives for design decisions exist, which have to be compared and assessed on how well they resemble the values of different stakeholders [9]. VSD does not rank or compare values in a normative way, but it assumes that broad value inclusion contributes to understanding and improving decision-making by articulating and comparing the way values are taken into account.

When it comes to the methodology, VSD is in principle a proactive approach to systematically including values in design [9]; the full methodology includes a tripartite approach involving conceptual, technical, and empirical investigations [18]. We will describe the approach and explain how we adapted it to fit our purposes.

The first phase is the conceptual phase, during which it is determined which values are relevant, how they should be understood, and which trade-offs between conflicting values are acceptable. In our research, the choices about trade-offs are made via the planning process by the provincial and local government. Hence, our conceptual phase will only cover identification of relevant values and operationalization. The second phase is the technical phase that assesses how technological properties affect values and looks at how design can support relevant values. The empirical phase looks at the perception of the users and other stakeholders and assesses their perception of which values are embedded in the design and which are not. As this research does not focus on the design process of a technology but of projects using existing technologies, we introduce the technologies in the case description but apart from that, skip the second step and fully focus on the empirical dimension. We choose to do so as we are interested in the negotiation of value inclusion during local implementation of the wind technologies.

Our empirical analysis focuses on the values the wind projects represent and impact according to the stakeholders. This includes values ascribed to the technology, such as profitability or efficiency, but also and especially the situated values impacted by its implementation in the specific local context, such as landscape values. By constructing stakeholders' value perspectives, we can identify value conflicts in the empirical phase of this project. We then analyze how value inclusion is negotiated in the cases. Finally, we use the insights from this analysis to formulate suggestions on the usefulness of value inclusive planning. Hence, we use VSD as a heuristic frame to do an ex post analysis of value conflict, negotiation, and inclusion to reach recommendations about using it proactively during project development of wind energy projects.

As part of the conceptual phase, we will now go into more detail about how values can be understood when it comes to designing wind energy implementation processes. According to Feather, values are in essence “general beliefs that people hold about desirable and undesirable modes of conduct and end states of existence” [20] (p 130). This can be concretized to what people consider as important to their lives. This understanding is broader than the conceptualization of values in philosophy as moral values governing right and wrong, and extents to concepts that can be associated with desirability, such as natural and economic value. Examples of values in the context of onshore wind energy are profitability of the project and the aesthetic quality of the landscape of which a project becomes part.

During the design process of a wind project, different stakeholders can have a different understanding of what a value means. They may find spatial quality important, but operationalize it differently. Values can, therefore, be split up into two levels, using a distinction that has been made by Rawls [22], which differentiates between the concept of a value and the conception of a value. The concept, on the one hand, is the general idea of a value, such as livability or inclusivity. The conception, on the other hand, is a specific interpretation or understanding of the meaning of that value. One stakeholder might consider the implementation process of a turbine project inclusive when other local parties have been consulted, while another may consider a project inclusive only if it enables ownership of the neighboring community. When two different values conflict at a conceptual level, this is called an inter-value conflict, and when two conceptions conflict, it is called an intra-value conflict. When looking for value conflicts, planners and developers should be sensitive to both types during the design process.

By synthesizing literature reviews of values in wind energy projects [4], [7], [23], [24], we made an overview of values relevant to the outcome dimension of the implementation of wind energy projects. We operationalized these categories and gave examples of values that fall under these categories (see table 3.1).

Table 3.1: Value categories.

Value categories	
Livability	Values related to quality of living in the direct surroundings of the technology, which can comprise, e.g., safety, noise, flicker and other visual impact.
Economic	Monetary value related to financial benefit or loss, e.g., affordability, productivity, reliability, touristic value of the area, property and land values, profitability of ownership, community benefit scheme, financial participation, and local job creation turbine industry.
Landscape	Value of the attachment or emotional bond that people develop with a place and its specific visual characteristics, e.g., cultural heritage value and visual beauty.
Nature	The value of ecosystems, e.g., value of plants, animals, and other elements of the ecosystem.

During the empirical phase, the value categories from table 3.1 are used as sensitizing concepts to reconstruct the value perspectives of the stakeholders involved in the case studies. By comparing and contrasting stakeholder value perspectives, we analyzed if conflicts occurred at inter- or intra-value level. We then analyzed which procedural mechanisms have been used to attempt to ameliorate these value conflicts and better integrate values of local stakeholders. Hence, we chose to exclude procedural values such as inclusivity and transparency, but instead included the procedural aspect of project development by carefully analyzing how the design is negotiated.

3.3. Case study methodology

3.3.1. Case study design

To answer our research question, we made use of a case study design, which allows for in-depth analysis of a contemporary phenomenon in a real-life context [25]. It allowed us to research value conflicts that came up in specific projects and analyze the ways in which these were dealt with.

The main case selection criteria were the presence of value conflicts among local stakeholders and variation in scale of the studied wind projects. We wanted to represent the two very contrasting types of wind energy development that are possible in the Dutch province of Groningen: small-scale < 15 m turbines for local use and large-scale concentration areas to minimize spatial impact. Both types of wind turbines have very different planning procedures: the first a notice to the municipal government followed by a spatial quality check and the second an extensive planning process including securing a location and permit application (requiring, among other things, a feasibility assessment and environmental assessment).

Secondly, we selected two locally-owned projects, which we deemed interesting as the developers of these projects are not only figurative neighbors, but also have a local connection beyond the project as residents of the area. Just like community energy initiatives [26], farmers or farmers collectives can be more receptive to the need for place-based renewable energy integration. Furthermore, much less research looks into the response to locally but not community-owned projects [3].

Based on these criteria, we selected wind park Oostpolder and the implementation of E.A.Z. mini-turbines in Middag-Humsterland.

3.3.1.1. Wind park Oostpolder

As an introduction to this case, we give some further information about the proposed project and the area.

Project Oostpolder

In 2015, a group of farmers started the development of a jointly owned windfarm situated on their lands in the Oostpolder (see figure 3.1). Their plan is to install approximately 60 MW of wind energy. Thirteen 4.65 MW Enercon turbines with a hub height of 155 m and a rotor diameter of 136 m will provide this capacity [27]. The project is part of an extension of the wind capacity in the Eems Harbor concentration area. The total extension would mean an addition of 170 MW to the already operational 276 MW [28]. Recently, the project has gotten a green light to start construction, and the planning is that it will be operational in 2021.

The farmers work without a professional developer, which is a special situation. Even though the farmers were limited to commercially available largescale turbines, they could decide upon the project design, instead of the conventional way where a professional developer or company dominates the process and decisions.

After the basic design of the project was made, a sounding board was established in September 2016 on the recommendation of local governments to involve the community and other local stakeholders in the development process of this wind park and a second nearby park. This sounding board consists of local governments (province of Groningen and municipality Eemsmond), an environmental NGO (Natuur en Milieufederatie Groningen, NMFG), and representatives of the residents and farmers of Oostpolder.

Figure 3.1: Impression of the current landscape in the Oostpolder [29].

Concentration area Eems harbor

When it comes to concentration area, Eems Harbor, where the project is implemented, a first important characteristic is the proximity to the Wadden Sea, a UNESCO world heritage as well as a Natura 2000 area (part of EU nature protection regulation). This area has specific landscape qualities and houses protected species that are affected by wind turbines. Especially its birds and bats can become victims of the wind turbines due to the moving rotor blades.

A second characteristic of the area is the Eems Harbor, a storage and transshipment sea port. Energy production is an important industry in the Eems Harbor. Gas fired power plants, a coal fired power plant, and 90 wind turbines are generating approximately a third of all Dutch energy [30] (see figure 3.1). Moreover, Google is building a data center for approximately 100,000 servers in the region, and new transmission towers are constructed for the transportation of the generated electricity. Furthermore, a helicopter port is planned in the Eems Harbor to facilitate the transport of employees to (future) offshore windfarms. Altogether, the inhabitants of the sparsely populated Eems Harbor area have endured many impactful spatial developments, and new developments are still contributing. Therefore, creating alignment between project Oostpolder and the values of local stakeholders was central to the farmers in avoiding being yet another negative development in the area.

3.3.1.2. E.A.Z. turbines in Middag-Humsterland

As an introduction to this case, we will introduce the type of wind technology proposed and the characteristics of the case study area.

E.A.Z.-12 turbine

The small-scale wind technology that has been implemented in the case study area is the 15 kW E.A.Z.-12 turbine, the product of the company E.A.Z., which is specifically designed to fit the values of its users and other local stakeholders in the Groningen landscape. From its start in the stables at the farm of the parents of one of the founders to an own production hall, the product has been by and large developed and produced in the province of Groningen with the specificities of that area in mind.

To make their product more aesthetically pleasing, E.A.Z. designed their turbine together with a landscape architect, a father of one of the founders. They consciously gave their turbine a friendlier and more natural appearance, so it could blend in with the rural landscape of their first market, the province of Groningen. They gave the turbine wooden rotor blades (6 m), a tail vane, and a thin tall green mast (15 m) (see figure 3.2).

The company is still improving its product based on feedback from users and other stakeholders who experience the turbines' effects. For instance, based on user feedback, they have reduced the noise of the blades. Furthermore, E.A.Z. is in close cooperation with Libau (the provincial committee for quality of the built environment) about the placement of the turbines and even tours with them through the landscape to discuss where they see or do not see fit for mini-turbines. Libau has also done some recommendations concerning the design of the turbine to make it less obtrusive, such as the reduction of the size of the tail vane.


Figure 3.2: A Groningen farm with two E.A.Z. turbines, up close and from a distance (pictures author's own).

Middag-Humsterland

Wind energy implementation is a sensitive and controversial issue in Middag-Humsterland. Even though the E.A.Z. developers took the characteristics of the Groningen landscape into consideration, some stakeholders feel turbines inevitably detract from the beauty of the landscape.

The Groningen region Middag-Humsterland is a so-called National Landscape. A Dutch National Landscape is a cultural landscape with rare mix of characteristics. Middag-Humsterland got its cultural heritage status due to its wide views over the meadows and characteristic villagescapes. Reminiscent of the past influence of the sea on the landscape, the farmland north of the Dutch city of Groningen is embossed by mounds, dikes, and salt marshes. This area is considered to be the oldest cultivated landscape in Europe, with a history dating back to the early Iron Age. It is mainly valued for its openness, quietness, organically shaped landscaped elements, and the presence of cultural heritage.

The status National Landscape dates back from the 2004 Land Use Memorandum Space (*in Dutch: Nota Ruimte*), in which the Dutch national government assigned 20 areas the status National Landscape to help safeguard and strengthen their core qualities [31]. However, today the status National Landscape is not accompanied by a special landscape conservation policy. Since the national government stopped its support in 2012, no special landscape policy has been made for Middag-Humsterland. Yet a foundation has been recently founded to change this and facilitate cooperation between the municipality Westerkwartier, the Province of Groningen, and some private initiatives.

3.3.2. Data collection and analysis

The data for the case studies consist of online available newspaper articles in Dutch newspapers including the local ones (via LexisNexis), policy documents, council notes, online news on websites, and face-to-face and phone interviews that are carried out with the main stakeholders in both cases. In total, six semi-structured interviews have been carried out for the E.A.Z. turbines in the Middag-Humsterland case and 12 for the Oostpolder case. The difference in the number of interviews is related to the different number of stakeholders involved (see table 3.2).

The interview transcripts and the digitally retrieved documents have been thematically coded to elicit value perspectives with the concepts from table 3.2.

Table 3.2: Overview of interviewees.

Case 1: E.A.Z. in Middag-Humsterland	Case 2: Windpark Oostpolder
Interviewed actors: 1. Representative of E.A.Z. 2. Farmer using E.A.Z.-12 3. Two residents critical of E.A.Z. 4. Alderman of municipality Zuidhorn 5. Representative of Libau 6. Representative of farmers' representative body LTO	Interviewed actors: 1. Province of Groningen (2x) 2. Municipality Eemsmond 3. Four residents of Oudeschip 4. One of the farmer-developers 5. Two companies active in the Eems Harbor region 6. Three different NGOs which are active nature protection organizations in the Wadden Sea region

3.4. Results

In this section, we present the results of the case studies. We show how and what values were included in the development process of the studied wind projects in Middag-Humsterland and the Oostpolder. For each case, we first discuss the value perspectives of the local stakeholders, and then the procedural mechanisms through which values were integrated, or not, in the design of the projects.

3.4.1. Case 1: Wind park Oostpolder

3.4.1.1. Value perspectives

The local stakeholders involved in the value deliberation about improving the desirability of the Oostpolder project are the farmer-developers, the residents of the neighboring village, a few environmental NGOs, and the provincial government. The value perspectives of the local stakeholders are displayed in table 3.3.

Table 3.3: Value perspectives stakeholders.

Stakeholder: Farmer-developers
Liveability values: When developing the plans for the wind farm, two alternative designs to deal with the noise (*quietness*) the residents experience were made. The first construction plan, where new turbines would be added to existing turbines, leads to a higher noise emission, but due to legislation there is no need for mitigation, because including the noise of existing wind turbines in the noise impact calculation is not a legal obligation. In the second construction plan, some older turbines would be replaced by newer ones with higher capacity. Here, the noise level is lower in practice, but might exceed the legally permitted level for nine houses, because the impact from all the new turbines needs to be included in the assessment. Therefore, mitigation measures might be necessary.
Economic values: The farmers value the *profitability* of the project, but also want to have some extent of *economic distributive justice*. A community benefit fund of 1050 EUR/MW/year is installed by the farmers to enable the community to profit financially from the wind park. Depending on the actual annual production, they will receive money for approximately 200 MW wind energy capacity, resulting in about € 210,000 annually for the 179 households in the region.

Stakeholder: Residents
Liveability values: Residents living nearby the wind park are concerned about the nuisance due to noise and shade, and the nuisance from the flashing air traffic warning lights (*quietness* and general *tranquillity*). The nuisance due to noise and shading is restricted to the legally permitted amounts. The government will not give permits to a project developer if the windfarm would exceed the legally permitted amount of noise and shade. The residents are still worried, especially about the amount and effects of noise from the wind turbines, because the noise and shading are calculated by using models and not field measurements. Finally, flashing lights on top of the wind turbines are perceived as very annoying by the residents. **Economic values:** Many residents still prefer a higher extent of compensation than the community benefits, and especially a buy-out arrangement for their devaluated properties (*loss of property value*) is seen as the solution to escape from all the unwanted negative effects of the economic developments and the earthquakes in the region. The provincial and municipal government do not support this solution, as it would be a very costly measure and would create a precedent for other similar communities.
Stakeholder: Environmental NGOs
Nature values: The production of wind energy in the Eems Harbor is perceived by nature organisations as a development compromising nature values, especially protected bird and bat species. **Landscape values:** The lighting, and more broadly the visibility of the wind turbines and their landscape impact, is also an important subject for the NGOs, as they are close to the Wadden Sea. The construction of current wind turbines in the harbor area of the Eems Harbor itself is acceptable to the NGOs, but they feel the *openness* and *wideness* of the Wadden Sea as a Natura 2000 area should be protected. Additionally, the spatial development strategy of the national government includes the objective to protect the Wadden Sea as a nature area and to retain the *openness* of the landscape. Therefore, the NGOs would like to make clear agreements about areas in which the construction of wind turbines is permitted and areas which should be kept free from wind turbines.
Stakeholder: Province
Nature values: The Province protects the *nature values* in the Eems Harbor region, as it enforces the relevant nature protection regulation, especially protected *bird* and *bat* species.

The values that are threatened to be compromised in the Oostpolder are nature, economic, and livability values. Landscape values play less of a role here, because the landscape of the Oostpolder is already highly industrialized, and stakeholders are accustomed to the sight of wind turbines and other economic activities with a large visual impact.

Looking at inter-value conflicts, the *economic profitability* of the wind project for the farmer developers is at conflict with the nearby residents' *quietness* and general *tranquility* and the *property value* of the houses. Furthermore, the *economic profitability* of the wind

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park for the farmer-developers is also in conflict with the value of the presence of protected *birds* and *bats* in the Wadden Sea region, represented by the environmental NGOs and the Province.

When it comes to intra-value conflicts, most prominent in the case study is the conflict about what *economic distributional justice* entails. The farmers are willing to provide a community benefit fund to ameliorate adverse economic effects such as loss of property value and other negative effects, but the residents feel that this is not sufficient compensation and would prefer to be compensated through a buy-out arrangement offered by the government.

3.4.1.2. Value deliberation

This section discusses how stakeholders attempted to have their values better represented in the design of the wind project in the Oostpolder.

Sounding board

An important mechanism for the farmer-developers in identifying and integrating values of local stakeholders has been the sounding board that has been installed by the Province. Through monthly meetings of the sounding board, the farmers are trying to create transparency and representation of the relevant stakeholders. They indicate that it is important to avoid distrust by the community and to take the input from the community seriously. They perceive good communication and adequate information provision as necessary to avoid both unexpected decisions for the community and opposition. However, the residents expected that they could actively collaborate from the beginning of the development processes, but this did not happen until the plans for placement were already in the stage of finalization. Furthermore, some of the residents indicated that, to their knowledge, none of the agreements or decisions made during the sounding board meetings are formally put on paper, and they doubt their influence. Additionally, a lack of clarity remained regarding the steps in the development trajectory, so residents did not know what to expect after a certain decision was made.

The involvement of the municipality, Province, and the NGO NMFG facilitated the communication within the sounding board, as they could act as intermediaries between the farmers and the residents during value deliberation. Especially, progress could be made towards ameliorating the intra-value conflict about the conception of *economic distributional justice*. A financial construction has been developed within the sounding board to increase the economic benefit for the community near the turbine. First, it was planned to use all the projected earnings from the community benefit as an investment, so the community can cooperatively own two of the turbines in the park. Unused capacity from the provincial repowering policy of the Province provides the legal opportunity for this. As not many owners of older wind turbines wanted to participate in Oostpolder, it has been decided by the Province that the residents of Oudeschip should have an opportunity to invest in the wind park and become co-owners. However, despite facilitation of such a construction by the NGO NMFG, this was too ambitious for the energy cooperative Oudeschip formed in 2018, and therefore a compromise has been decided upon. The cooperative gets 10% of the profits of the Oostpolder: 80% for distribution over the households and 20% to invest in projects.

One-on-one discussions

One-on-one discussions were used to reduce the inter-value conflict between the *economic profitability* of the project and the deterioration of *tranquility* for the residents in Oudeschip. The farmers of Oostpolder visited the owners of the houses that were in the area where the noise of the turbines would exceed legal limits and had consultations with these owners to investigate if additional compensation could result in approval for replacing some of the existing turbines during the extension to increase capacity. Additional compensations can be found in insulation of the houses, additional monetary compensation, or maybe even a buy-out arrangement. Residents agreed to additional measures (the exact extent of the measures is unknown to the authors). An example of the additional measures is reducing the nuisance from the air traffic warning lights on top of the wind turbines. The lights of windfarm Oostpolder will be constantly burning instead of flashing, which attracts less attention. The farmers of Oostpolder also requested the wind turbine suppliers to investigate the usage of lamps with narrow beams of light, which are less visible from the ground.

Another design change resulting from the agreement between the farmer-developers and the respective residents is that the zoning plan of some houses has to be changed from residential property to business property of the windfarm. This step is necessary to receive the permits for the wind farm, because the legally allowed amount of noise for conventional residential houses is exceeded.

Enforcing legal authority

The measures the Province takes to enforce the Natura 2000 legislation to protect the *nature value of the presence of protected birds and bats* are based on the total of all the activities in the Eems Harbor region, not only the Oostpolder project. The protection measures that are taken by the Province are the declaration of a mandatory standstill provision during moments with many migratory birds or bats passing the wind turbines and the construction of a bird nesting island co-financed by the companies in the Eems Harbor.

These measures were adopted relatively easily, as the Province has the authority to protect nature values and can also ask for a financial contribution of the companies in the Eems Harbor, as their economic activities affect these values. For the companies involved, it is a trade-off: they are given the opportunity to operate in the area if they contribute to the conservation of its nature.

3.4.1.3. Case conclusion

The case of wind park Oostpolder shows that the opportunities to influence the design of a larger wind park can be rather constrained, even in this project where initiators are looking for a dialogue with other stakeholders. One reason is the inequality between the developer and the other local stakeholders. Furthermore, in general, the local governments have no legal instruments, such as the repowering policy, to enforce resident participation.
However, at the same time, the case shows that when an effort is made to involve residents in the design process, this can result in modest changes to the design of the project, such as the modifications to air traffic lighting and larger financial compensation.

Furthermore, this case shows that the resolution of value conflicts is quite dependent on financial resources, and that design solutions through which a financial benefit can be realized for a limited cost can be implemented most easily.

Finally, the values that are enshrined in hard, legal norms, such as noise regulations and nature conservation, are easier to embed in the design than non-legal norms that resemble stakeholders' preferences.

3.4.2. Case 2: A small-scale wind solution in a National Landscape

3.4.2.1. Value perspectives

The local stakeholders involved in the value deliberation about the desirability of E.A.Z. turbines in Middag-Humsterland are the farmer-developers and their representative body LTO, residents concerned about the turbines, and Libau, the independent provincial committee for aesthetics of the built environment. E.A.Z. did not take an active role in the controversy. The value perspectives of the local stakeholders are shown in table 3.4.

Table 3.4: Value perspectives of stakeholders.

Stakeholder: Farmers and LTO
Landscape values: The farmers see the E.A.Z. turbines as a renewable energy (RE) technology with spatial quality that fits within the landscape. Due to their natural appearance, with wooden blades and a green mast, they can better blend in with the landscape (*similarity*). Furthermore, because of their mast size, which is comparable to a mature tree or a stable, they can be easily integrated with the other farm infrastructure (*proportionality*). Furthermore, spatial quality is defined relative to the alternative of largescale RE as well. A farmer poses that if the starting point is that RE should be produced as much as possible at the place of use (*locality*), no largescale landscape polluting infrastructure is needed to transport energy. Hence, spatial quality is not only associated with the particular look of the technology, but also assessed at system level.
Economic values: E.A.Z. turbines are perceived as an *effective* way to provide renewable electricity. For an average farm in the region, one E.A.Z. turbine can provide all the electrical energy This means that the total yearly electrical energy demand can be produced with an E.A.Z. turbine; however, energy that is not used at the moment of production will be exported to the grid, and shortages will be bought back from the grid). Bigger farms need two or three. By owning a turbine (*ownership*), farmers save the costs of buying the electricity and the electricity tax over all generated power (*cost efficient*). The energy that they do not use at their farm is sold to an electricity supplier. Furthermore, wind energy is often cheaper than solar energy, because solar panels require a grid connection with a higher capacity, as they have a higher peak production. The network provider costs of such a bigger connection are higher. For wind energy, you do not need such a connection, because its production is more regular. However, many farmers who have an E.A.Z. turbine also produce solar energy, as these sources have a largely complimentary generation profile. Another economic reason why using renewable energy is interesting for farmers is because they have noticed that their consumers are increasingly critical as to whether their products are produced environmentally sustainably (*commercial advantage*). For them, therefore, having their own source of energy fits with the circular economy thinking they are already familiar with when it comes to efficient resource use. Using RE also results in a small sustainability bonus from their dairy cooperative (*profitability*). Finally, the LTO as representative of the farmers considers the region as an excellent location for the new small wind turbines. He feels that through a combination of wind and solar, the area could become the first energy neutral National Landscape of the Netherlands, and that an area can get no better regional marketing than to have the label of being a touristic attraction without CO_2 emissions (*tourism).*

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Stakeholder: concerned residents
Landscape values: In terms of landscape values, the concerned residents feel that, despite its size and design, the E.A.Z. turbine is a disturbance in the *open, wide, organically shaped landscape* with its characteristic mounds, ditches, and dikes, and monumental villages (*cultural heritage*). A resident expresses it in the following way: “This National Landscape is unique in the province (*uniqueness*). The turbines, no matter how small, impair the appearance of the landscape and do not fit in the area” [32]. The “modern turbine” with its moving blades takes away from the clear view on the horizon. Another concerned resident stresses: “Formally, they are, with their hub height of 15 m, a little higher than the maximum height of a barn that is at maximum 14 m. However, in practice most stables and barns are around 8 m high”[33]. **Economic values**: Furthermore, the concerned residents deem the turbine to be an *ineffective* solution. A resident describes them as a “feel good subsidy turbine” [34] (*cost inefficient*) and another resident says that they are “very charming” and that it is a “nice company” selling the product, but that the production per turbine is too low (*effectiveness*) [35]. She would prefer taking care of renewable energy supply by investing jointly in a larger wind turbine or solar on roofs of houses and stables rather than acting independently and in a dispersed fashion (*efficiency*). Finally, they fear that E.A.Z. turbines also negatively affect the economic value of the area by leading to a reduction of tourists (*tourism*). They feel that Middag-Humsterland should focus more on monetizing the beauty of the landscape (*aesthetic quality*) than on wind energy. **Liveability values**: When it comes to liveability, the quality of the living environment, within the direct surroundings, it is mainly the sound of the E.A.Z turbines that concerns the residents, as it disturbs the *quietness*. They pose that it is not only the blades, but also the generator that makes quite some noise at low wind speeds.
Stakeholder: Libau
Landscape values: For the same reasons of similarity and proportionality as the farmers, Libau feels that the turbines have spatial quality. It recognises the energy transition will have a large spatial impact, and, consequently, only very exceptionally should an area be excluded. However, to safeguard the *cultural heritage value, uniqueness, quietness, openness, wideness,* and *organic shapes*, the organisation deemed it necessary to investigate the suitability of placement in Middag-Humsterland and create more detailed placement criteria for mini-turbines.

In this case study, economic, livability, and landscape values are at play. Nature values do not play a role here, because the E.A.Z. turbines do not affect the nature in the region.

Looking at inter-value conflict, the farmers’ economic values *profitability* and *ownership* are perceived by concerned residents to threaten the livability value *quietness,* and the landscape values *cultural heritage value, uniqueness, quietness, openness, wideness,* and *organic shapes.*

The landscape aspect of the inter-value conflict is largely fed by intra-value conflict. The main intra-value conflict at stake is the interpretation of the norms similarity and proportionality.

While the farmers feel that the mini-turbines are proportional to other elements in the built environment of the farmscape, the concerned residents disagree and point out that the total height, including the blade length, is much higher than the stables and silos at the farms. Regarding similarity, the farmers feel that the turbine blends into the landscape due to the material choice and the size, which they compare to a large tree, whereas the concerned residents do not agree due to the movement of the blades and the modern look of the turbine.

Resultantly, the residents conceptualize *touristic value* as stemming from original landscape values that are diminished by the presence of E.A.Z. turbines, while the farmers feel that the mini-turbines strengthen the *touristic value* of the region by contributing to a change towards a *sustainable* agricultural landscape and can function at the farm as a *cost-efficient, own* energy source. Libau postponed judgement and recognizes both perspectives.

3.4.2.2. Value deliberation

This section discusses how stakeholders attempted to have their values better represented in the implementation process of wind energy in Middag-Humsterland. The deliberation mainly focused on whether the value of the landscape could be sufficiently conserved if E.A.Z. turbines would be implemented, and livability and economic values played a smaller role. The section outlays the different steps of the process by which it was decided if and under which conditions mini-turbines could have a place in the region.

Awareness raising through local media

In the summer of 2016, a few villagers from Niehove, a mound village in the National Landscape Middag-Humsterland, read in the local newspaper about the announcement of four planned mini-turbines at farms. As their farmer-neighbors had not consulted them, and they felt confronted with a fait accompli, they expressed their concern in the local media and demanded the municipal council more clarity regarding the exact criteria for placement. The existing policy allowed for mini-turbines, but stated that intertwinement between characteristic landscape elements and turbines should be avoided. They doubted whether this would be possible at all in the National Landscape that was valued for its wideness and openness.

Agenda setting in the local political arena

At the next council meeting, the farmers and concerned residents were invited to present their arguments. After a short political swordplay, the mayor and aldermen of Zuidhorn, the municipality responsible for the permits, decided to take about five months for deliberation. In the deliberation period, the municipality looked into the impact of the E.A.Z. turbines with Libau, the visualization department of the nearby University of Groningen, and a sounding board.

Sounding board

The municipality founded a sounding board to get input from different actors, and asked farmers, residents, and environmental and agricultural organizations to participate and a mediator to lead the process. E.A.Z. was requested to respect the societal discussion and not file new applications, which the company did. The sounding board was a good vehicle to facilitate an inclusive process. However, for concerned residents, it was hard to be informed about the ins and outs of the procedures. They feel that support from a professional adviser or an officer from the municipality would have been beneficial to level the playing field. Furthermore, within the sounding board, it was unclear how the advice to the local government would be constructed. The process evolved into preparing an advice by giving weight to the values of the majority, which led to a positive advice. This was not perceived to be fair by all stakeholders, as not all stakeholder groups were represented by an equal number of people.

Stakeholder consultation to inform decision-making in local political arena

At the end of the deliberative process, the municipal government held a consultative meeting where stakeholders could express their thoughts, a positive advice of the sounding board was presented, and a visualization of the landscape effects was shown. A week later, the council decided that the landscape impact was acceptable, as the majority agreed with the farmers' that the turbines were proportional and similar enough to the other landscape elements. Therefore, the policy remained supportive of mini-turbines.

However, as a result of the deliberative process, the council, advised by Libau, sharpened the design criteria that mini-turbine projects need to meet and installed a monitoring group. The new design criteria dictate that the mini-turbines should be placed at a spatially subordinate position and as a logical part of a farm to secure the values *cultural heritage value, uniqueness, quietness, openness, wideness,* and *organic shapes*. In short, this translated to concrete rules such as no placement of turbines in an open landscape, only as part of the building block (e.g., next to a stable).

Monitoring group

A monitoring group with local stakeholders (consisting of a representative of LTO, one of the concerned residents, a representative of a local energy working group, and some vacant seats) was installed by the municipality to evaluate the policy in a year's time.

When it comes to the implementation of the new placement criteria, the resident in the monitoring groups feels that the new stricter criteria are not followed rigorously enough. Furthermore, due to conflicting value perspectives and lack of trust because of an incident within the group, the monitoring group did not function well and has been terminated by its participants. Having or not having a mediator with no personal interest seemed to make a large difference between the sounding board and the monitoring group.

3.4.2.3. Case conclusion

This case indicates that value sensitivity during the design phase of the technology needs to go hand in hand with value sensitivity of the implementer. Even in the case of a supposedly landscape and environmentally friendly wind turbine, new alignments are required if it comes to a specific new context such as a national landscape. The lack of consultation led to a societal discussion, which resulted in a deliberative process steered by the municipal government.

Quickly, the full value deliberation centered on whether the mini-turbines were deemed acceptable in terms of their effect on the landscape values in the region. The other value conflicts were side-lined and tied to the outcome of the decision regarding impact on landscape values. The landscape effects were mainly assessed in terms of similarity and proportionality, which were differently conceptualized by the farmers and the concerned residents.

During the deliberation, process was worked towards enlarging the sense of intersubjectivity. A main vehicle in the deliberation process was the sounding board. Despite perception of lacking a level playing field, this arena offered a chance to build a more broadly shared conception of whether the turbines were similar and proportional to other landscape elements or not. This led to new, sharpened design criteria for spatial integration of mini-turbines. While this did not resolve disagreement fully, conflict still helped to incentivize processes that contributed to enlarging the intersubjectivity required for a more concrete planning policy.

3.5. Conclusions and discussion

We analyzed how a large-scale and a small-scale farmer-owned wind project were scrutinized by local residents and other stakeholders in the area. We used a value perspective to analyze perspectives of local stakeholders and conflicts. Here we present the conclusions to the research question of how wind projects can be made more sensitive to the values of local stakeholders by integrating these in project design.

We discuss our answer through five observations of how wind projects can be made more sensitive to the values of local stakeholders by integrating these in project design. These insights about negotiating acceptability through value sensitivity can also be used for implementation of other controversial energy technologies where developers, local owners or not, face potential opposition of the local stakeholders (e.g., largescale solar PV on fields or biogas).

Finally, we end the paper with a reflection on the influence of local ownership on the acceptability of the studied wind projects.

3.5.1. Levelling the playing field in participative environments

In these cases, negotiation of more value inclusive designs took place in various ways, such as through a sounding board, one-on-one stakeholder discussions, enforcement of legal authority, societal and political mobilization, stakeholder consultation, and a monitoring group. However, due to the difference in agency and power, co-design was only possible to some extent. In both cases, residents struggled with being informed about all procedures and with being seen as an equal stakeholder.

In a participative planning context such as a sounding board, the help of a neutral mediator [36], or even supportive intermediaries [37], can help. In the Oostpolder case, the NGO NMFG took on the support of the resident community in Oudeschip and facilitated the embedding of their values. In Middag-Humsterland, on the other hand, residents lacked a supportive intermediary that helped them voice their values and stated that such an intermediary could have helped them have a more equal standing.

3.5.2. Creating intersubjectivity

Protecting some values and integrating them in design is complicated by the degree of subjectivity involved, such as landscape values and certain livability values [16]. Some of these values are very much individually, and sometimes elusively, conceptualized. Especially if values are hard or impossible to operationalize quantitively, some stakeholders could feel that the value is not sufficiently integrated in a design, whilst others may be satisfied based on the operationalization of the same qualitative criterium. Creating intersubjectivity through participative planning processes is important to create more widely shared value conceptualizations and enable embedding in design.

3.5.3. Overcoming incommensurability

Our two cases show that value sensitivity can make wind projects more acceptable to local stakeholders, as more of their values get embedded in the design through consultation and negotiation. However, value sensitivity is no panacea for acceptance of outcome. It has to be recognized that not all value conflicts in local wind energy projects can be solved through making design choices that align conflicting values for various reasons, e.g., political or financial. Especially 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 conceptualizations 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 [38].

Therefore, a methodology giving guidance in resolving value conflicts would be helpful. Research which explores how to come to a prioritization of values is therefore a very fruitful avenue for further research. For instance, Van de Kaa et al. uses the best–worst method, in which users or decision makers decide on the most and least important value and compare the rest of the values to these reference values [39].

3.5.4. Creating a space for constructive conflict

Value conflicts between the stakeholders involved in local wind energy projects should not only be perceived as negative. Certainly, value conflicts require deliberation and can slow down or even stop projects that can contribute to sustainability. However, our cases show that value conflicts can also be productive. The ever-returning value conflict between landscape, economy, livability 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 and thereby expands the range of options for sustainable energy solutions. Furthermore, in both cases value conflicts led to design adjustments that made the wind project more aligned to local values or created a wider shared intersubjectivity on value conceptualizations. Cuppen found constructive conflict can even be used as a design tool to facilitate diversity of perspectives and avoid consensus being reached before diverging viewpoints are fully explored and understood [40]. Thus, our value analysis showed that conflicts teach developers that it leads to overall better solutions to start from an awareness of the values of all stakeholders that have to deal with the planned development.

3.5.5. Making "neighbors" more integral to the planning process

The space for a supra-legal degree of value sensitivity that was carefully constructed in both cases is by no means a norm and very dependent on efforts of local stakeholders such as a local government or the residents. For instance, it is easier for a stakeholder such as the Province to protect nature values that are enshrined in regulations than it is for residents of Middag-Humsterland to protect the landscape values, as these are not protected by hard norms.

Policy more supportive of participation and representation of stakeholders other than the developer would boost the design of more value-inclusive energy projects. In the Netherlands, steps towards better inclusion of local stakeholders are currently being experimented with. In the Dutch climate agreement, the ambition is formulated to realize a national average of 50% local co-ownership by 2030 for large RE projects [41]. This facilitates inclusion of local stakeholders from the start of the project on. However, this is only a partial solution, as it focuses mainly on potential co-owners. Hence, procedural innovation is also required to include values of non-owners in the planning process. Figuring out how this can be achieved is currently high on the agenda within the development of regional energy strategies, where various local stakeholders are involved in the planning process and invited to contribute to area-based plans for renewable energy integration. Here, identification of values, and mapping and discussing value conflicts, could be a helpful tool to better include situatedness and place-specificity in renewable energy planning.

3.5.6. A reflection on the relation between local ownership and acceptability

We end this paper with a brief reflection on the influence of the local ownership component in the response to the studied farmer-owned wind projects. Generally, local ownership has been depicted as counteracting some of the objections to wind energy projects. Local owners could use their local network to reduce the scale of planning controversies [42]. Additionally, the contribution to local economic development through farmer income, and potentially also community benefit, can in some cases generate support [43].

However, in the studied locally-owned cases, conflict was still present. This can be partly explained by the observation that support is also affected by who benefits from local ownership, especially the extent to which the impacted community of place intersects with the community of interest that benefits from the development [3]. In the case of Middag-Humsterland and Oostpolder, the benefits only or mainly accrue to a few individuals within the community, which may limit acceptability.

Furthermore, and most importantly, our paper underlined that ownership is just one factor in acceptability. Values of local stakeholders are diverse and situated. What is acceptable is place-specific, e.g., past locally unwanted land uses such as in the Oostpolder case and the cultural heritage identity of Middag-Humsterland. Hence, our case studies confirm the importance of history, context, and geographic scale to favorability, and thereby, acceptability of outcome [3].

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4

PARTICIPATORY EXPERIMENTATION WITH ENERGY LAW: DIGGING IN A ‘REGULATORY SANDBOX’ FOR LOCAL ENERGY INITIATIVES IN THE NETHERLANDS

Abstract

To facilitate energy transition, regulators have devised 'regulatory sandboxes' to create a participatory experimentation environment for exploring revision of energy law in several countries. These sandboxes allow for a two-way regulatory dialogue between an experimenter and an approachable regulator to innovate regulation and enable new socio-technical arrangements. However, these experiments do not take place in a vacuum but need to be formulated and implemented in a multi-actor, polycentric decision-making system through collaboration with the regulator but also energy sector incumbents, such as the distribution system operator. Therefore, we are exploring new roles and power division changes in the energy sector as a result of such a regulatory sandbox. We researched the Dutch executive order 'experiments decentralized, sustainable electricity production' (EDSEP) that invites homeowners' associations and energy cooperatives to propose projects that are prohibited by extant regulation. Local experimenters can, for instance, organise peer-to-peer supply and determine their own tariffs for energy transport in order to localize, democratize, and decentralize energy provision. Theoretically, we rely on Ostrom's concept of polycentricity to study the dynamics between actors that are involved in and engaging with the participatory experiments. Empirically, we examine four approved EDSEP experiments through interviews and document analysis. Our conclusions focus on the potential and limitations of bottom-up, participatory innovation in a polycentric system. The most important lessons are that a more holistic approach to experimentation, inter-actor alignment, providing more incentives, and expert and financial support would benefit bottom-up participatory innovation.

Keywords: polycentricity; local energy initiatives; community energy; smart grid; legal innovation; socio-technical innovation; bottom-up.

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4.1. Introduction

Perhaps one of the most critical issues for the energy transition is matching sustainable energy supply and demand, and especially managing the local peak loads and the influx of prosumer energy since many renewables are intermittent resources. For now, the existing grid is used for balancing, but when renewable electricity production and use further increase, the grid capacity will not be sufficient and reinforcement will be very expensive. New options for grid management that have been explored are smart meters, smart grids, demand response, and storage technologies to reduce peak loads and manage congestion. These technological developments create opportunities for new roles in the energy system, such as aggregators [1–3]. New technological developments are also relevant from a prosumer perspective [4,5]. Until recently, project partners in smart grid projects perceived users primarily as a barrier [6], or as passive subscribers to grid services [7]. Planko et al. show that end-users are scarcely represented in the system-building networks that are active in the development of the Dutch smart grid sector [8]. Yet, times are changing with the increase of local energy initiatives [9], which increasingly broaden their activities that aim to further influence the direction and pace of the energy transition [10]. Potentially, local energy initiatives can extend their role from energy generation to performing active functions within the smart grid. They could ‘actively offer services that electric utilities, transmission service operators or other prosumers have to bid for’ [11] (p.4), such as offering storage capacity for balancing, or avoiding grid reinforcement through flattening the usage profile and increasing real-time use and local storage [12].

Local energy initiatives or other local actors would need to be enabled to organise a more integrated resource management at the local or regional level to extend and optimise such services. For instance, peer-to-peer supply and flexible tariffs could increase local use. However, the extant law is sometimes a limiting factor for energy management innovation towards a renewable energy (RE)-based system that needs matching demand and supply both in terms of available energy and grid capacity [3]. For instance, for household consumers, law might need to enable pricing of grid services based on actual loads instead of connection capacity.

Several countries’ regulators have devised ‘regulatory sandboxes’ to create a participatory experimentation environment for exploring revision of energy law to overcome such legal obstacles for energy transition. A main characteristic of these sandboxes is that they allow for a two-way regulatory dialogue between an experimenter and a regulator to innovate regulation and enable new socio-technical arrangements. For instance, in the Netherlands, the executive order 'experiments decentralized, sustainable electricity production' (EDSEP) allows for the implementation of innovative energy services at the local level [13,14]. Another example is the UK, where innovators can get a temporary derogation of some rules in order to run a trial if the proposed product or service is considered to be genuinely innovative and able to deliver consumer benefits [15]. Importantly, new actors, such as local energy initiatives, take centre stage in these sandbox experiments, and they are seen as a locus of agency, in contrast with 'business as usual' in smart grid experiments, as described above [6–8]. What is especially interesting about these experiments is that, while experimenters can take on new roles due to exemptions, they do not operate in a vacuum, but experiments need to be designed and implemented in a multi-actor, multi-centered decision-making system. Such a system was coined by V. Ostrom et al. as a polycentric system [16] and was further elaborated by E. Ostrom [17,18]. In the particular polycentric system in this study, the experimenters need to collaborate with the regulator, but also energy sector incumbents, such as the distribution system operator.

Little is known regarding the functioning and innovative potential of local energy initiatives as experimenters in polycentric actor-constellations [19], while they are earmarked as potential providers of new grid services in such a system by governments creating these experimentation environments [11]. Our central question, therefore, is: What can be learnt about local energy initiatives' bottom-up experimentation with smart grids in a polycentric energy system? By answering this question, we aim to provide policy relevant insights regarding the preconditions for and obstacles to using end-user collectives as innovators informing new energy regulation, which is more facilitative of the integration of renewables within the limits of the grid. Furthermore, we would like to introduce the polycentricity concept to the community energy literature and demonstrate its value to better understand the relationality and interdependencies in governing energy.

To research this, we focus on the aforementioned case of the Dutch EDSEP, which invites homeowners' associations and energy cooperatives to propose projects that are prohibited by extant energy regulation. Local experimenters can, for instance, organize peer-to-peer supply and determine their own tariffs for energy transport in order to localize, democratize, and decentralize sustainable energy provision. We further introduce our case in Section 4.2. Subsequently, we elaborate on our theoretical framework, in particular the concept polycentricity, in Section 4.3. In Section 4.4, we describe the used case study methodology and introduce the four EDSEP projects that are analyzed in-depth. Afterwards, we will describe the polycentric configuration under the EDSEP, and the functioning of the experimenters in this configuration in Section 4.5. Finally, Section 4.6 concludes the article with a discussion of our findings in a broader context and the value of the polycentricity literature for studying the potential and limitations of bottom-up, participatory innovation in a polycentric system.

4.2. Policy background and introduction EDSEP

In this section, we introduce the policy developments that led to the EDSEP, and the EDSEP itself.

4.2.1. Policy background

The direct reason for the EDSEP is the 2013 Social and Economic Council (SER) energy agreement for sustainable growth between over 40 Dutch organizations and supported by the Dutch national government [13]. In the text of the energy agreement, it is stated that: “To realize the energy transition the legislation needs to be providing a consistent framework to provide investors with long-term security. In addition, the legislation needs to facilitate innovation. This means that the legislation needs to provide sufficient space to enable desired new developments, specifically when it comes to the production of RE. To this end, the Gas and Electricity Acts will be revised”[20]. For the revision, the Dutch government had established the legislative agenda STROOM (abbreviation of streamlining, optimizing and modernizing, in Dutch: STROomlijnen, Optimaliseren en Moderniseren), which had achieving clearer and simpler rules to reduce bureaucracy, streamlining with European legislation, and being facilitative of a competitive economy and transition towards as sustainable energy system as its goal.

This legislative proposal offered a merger of the Electricity Act 1998 and the Gas Act [21]. However, instead of waiting for the new Gas and Electricity Act, the parties in favor of local, sustainable energy lobbied to make use of article 7a sub 1 of the Electricity Act 1998. This article states that, through executive order, in accordance with European Union legislation, the Electricity Act can be derogated from by the experiment [22]. The article intends to enable relatively small-scale, localised, RE experiments for which the strictly regulated separation between the commercial activities production and supply, and the publicly managed distribution side of the energy system can be relaxed, to a certain extent under specified conditions for a particular target group of homeowners associations (HOAs) and cooperatives.

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Such derogation has to be laid down in an executive order (in Dutch: Algemene Maatregel van Bestuur) and it has taken the shape as the EDSEP, which entered into force on the 28th of February 2015. The objective of the EDSEP is stated in its explanatory memorandum and it is to observe whether it is necessary to strictly apply the rules of the current Electricity Act for decentrally produced renewable electricity.

4.2.2. Executive order 'Decentral, Sustainable Electricity Production Experiments'

To informedly revise the Electricity Act, the Dutch government strives to obtain more knowledge regarding grid stabilization by prosumers and obstacles that are created by present regulations. For this reason, the Executive order 'Decentral, sustainable electricity production experiments'(in Dutch: Besluit experimenten decentrale duurzame elektriciteitsopwekking) was designed [23]. The goals of the executive order are stimulation of more renewable energy (RE) at the local level, more efficient use of the existing energy infrastructure, and more involvement of energy consumers with their own energy supply. It provides energy cooperatives or HOAs the opportunity to get an exemption from the Electricity Act and carry out the functions of the grid operator. The cooperatives and HOAs can carry out two main types of experiments:

- the project grids up to 500 users. In this case, the grid is owned by the project and has only one connection to the public grid;

- the larger experiments up to 10,000 users and 5 MW generative capacity, usually in cooperation with the grid operator. The grid operator remains owner of the grid. These experiments are concerned with balancing the electricity grid through peak shaving, and dynamic electricity tariffs.

The size of the experiments is chosen, so that the projects remain manageable and the general security and safety of the electricity provision on the regional grid will be guaranteed. Safeguarding provision within the projects is the responsibility of the participants of the projects. Thus, the protection of the consumer is partly taken care of through the assumed control that the participant can exert in the cooperative or HOA. The members should hold each other accountable for the responsibilities of the local energy initiative regarding production, supply, and transport. Initiatives that are willing to make use of the EDSEP need to apply at the Netherlands Enterprising

Agency (in Dutch: Rijksdienst voor ondernemend Nederland, RVO) for the derogation of the Electricity Act. Yearly, 10 projects of both types could be admitted, but only a total of 18 projects have been approved (see appendix B), and only few are actually being implemented. The admission started in 2015 and ended in 2018. The experiments will be evaluated in early 2020.

4.3. EDSEP experimenters as decision-making unit in a polycentric system

The EDSEP is designed to identify the obstacles that the extant Electricity Act presents to the development of local collective solutions to the production of more RE and its more efficient use. When experiments receive derogation under the EDSEP, this means that they become part of a system with decision-making units at several levels, with whom they have to cooperate, or by whom they are supervised or even opposed. These include, amongst others, grid operators, energy companies, the Netherlands Authority for Consumers and Markets (ACM), the Ministry of Economic Affairs and Climate and its executive organization RVO.

A polycentric approach is suitable for analysing the functioning of these experiments as part of such a larger system in which decision-making power is distributed [24], and it has been used for previous work on smart grids [25,26]. Polycentricity means that there are "many centres of decision-making which are formally independent of each other" [16], but which in practice often need to collaborate with others to execute what they are formally allowed to do. For instance, in the case of the EDSEP experiments, experimenters pursuing a project grid only formally need to discuss their plans regarding grid design and distribution with the regional distribution system operator (DSO), as they are allowed to take the role of DSO in their mini-grid, but in practice the approval of the regional DSO is important for obtaining the exemption.

Polycentric systems are characterised in the literature as being multi-level, multi-sectoral, multi-functional, and multi-type, as displayed in Table 4.1 [26,27]. We will use these concepts to describe the polycentric setting in which the experiments operate in (see Section 4.5.1), as the authority of a decision-making centre in energy regulations is defined by these characteristics. For instance, a locally functioning energy initiative is a private sector initiative and has therefore previously been excluded from the function grid management, as it was deemed a public good.

Table 4.1: Aspects of polycentric constellations based on [26,27].

Aspects	Definition
Multi-level	Geographical level of scale (e.g. local, regional, provincial, national, and global)
Multi-sectoral	Actors are active in different sectors (e.g. public, semi-public, voluntary, community-based, private, and hybrid kinds)
Multi-functional	Different functions are performed by different actors (i.e. specialized units for different functions, such as production, provision, sale, financing, etc.)
Multi-type	Several types of jurisdictions are present at the same time (e.g. territorial jurisdictions: nested, multi-purpose jurisdictions; and organizations with functional jurisdiction: specialized, cross-territorial organizations)

We rely on Ostrom et al. [16] for the analysis of the polycentric system, who propose four criteria to evaluate the well-functioning of a polycentric system: control, political representation, efficiency, and local autonomy. We briefly define these criteria in table 4.2.

Table 4.2: Criteria for evaluating the functioning of polycentric decision-making systems [16].

Criteria	Definition
Control	Formal powers of the decision-making unit within the applicable legal frameworks;
Efficiency	Whether the collaboration between the multiple decision-making centres has advantages for getting to the desired outcome;
Local autonomy	The power of local stakeholders to be a decision-making unit;
Political representation	Inclusion of the political interests of the decision-making unit within the decision- making arrangements.

4.4. Methods

4.4.1. Case study

We study the EDSEP as a multiple case study. Case study research allows for in depth analysis of a contemporary phenomenon in a real-life context and the combination of various complementary research methods [28]. Our sample of cases includes four projects that were approved under the EDSEP: Schoonschip, Endona, Collegepark Zwijsen, and Aardehuizen. All of these started relatively early (in 2015 or 2016) and their projects have reached an advanced stage. Two of these are so-called large experiments and two are project nets, so both types of experiments that are possible within the EDSEP are equally well represented.

Many (web-)documents that describe the four cases are available, and for each case the project initiators or other participants heavily involved in the development have been interviewed in a semi-structured face-to-face interview. Although these representatives provided us with key information for this research, we acknowledge that other participants to the experiments could have different perspectives. Furthermore, we conducted interviews with other relevant actors in the polycentric system related to the EDSEP, mostly telephonic. Appendix C presents an overview of the interviewees.

This information has been analysed through reflexive thematic analysis, starting with the criteria indicating the functioning of polycentric systems as analytical framework. The coding has been based on the six-step methodology of Braun et al. [29], which consists of the steps: familiarisation, generating codes, constructing themes, revising themes, defining themes, and writing the report. We used the qualitative data analysis software Atlas.ti for our analysis.

4.4.2. Cases

Via table 4.3–4.6, we will shortly introduce all four of our case studies based on their project type, delineation of the experiment, its organization and governance, its energy system, and the use of the EDSEP.

Table 4.3: Case study description Endona.

Aspects	Description
Project type	Large experiment
Delineation	The first pilot is in the village of Heeten, but eventually Endona wants to supply the medium voltage grid (part Raalte) with locally produced RE as well as increase the region's real-time electricity use.
Organisation and governance	Endona is an energy cooperative, with the board members registered as its members. This structure has been chosen to keep the decision-making with its day-to-day management. Endona has a large portfolio of projects and is part of several collaborations with grid operators, technology developers and knowledge institutions.
Energy system	With some of its partners, Endona installed sea salt batteries. It also implemented household level energy management systems (EMSs)[2] in a neighbourhood with 47 households [30], and an overarching EMS that uses the inputs from these EMS for neighbourhood level optimisation. Furthermore, Endona developed a solar park with 7200 photovoltaic (PV) panels on 3.5 ha of former agricultural land.
Use of EDSEP	The derogation has not yet been effectuated. The cooperative only acts as producer and does balancing experiments that are allowed within the framework of the current Electricity Act. At present, the electricity sale is through a cooperative energy company. Endona has not found a suitable business model for being energy supplier, and is investigating the financial risks. In the long run, it wants to take on this role so both the costs and benefits of the energy system are local, and they can possibly offer a lower price to their users because of the integrated management.

[2] An EMS is a system of computer-aided tools used by to monitor, control, and optimize the performance of the energy system.

Table 4.4: Case study description Aardehuizen.

Aspects	Description
Project type	Large experiment
Delineation	The location is at the outskirts of the village of Olst, and is situated in a rural landscape. Incidentally, it is near Heeten, where our first case, Endona, is located. Aardehuizen is in contact with Endona. 23 houses have been built, of which 3 rental social houses, and a community house.
Organisation and governance	The project is operated by a HOA and part of a worldwide movement, Earth Ships, which wants to build houses with little environmental impact built from recycled and regionally sourced material. The project's decision-making system is a sociocracy, which means everyone is involved and informed, although decisions are not made by consensus. The occupants of the rental houses are also a member of the HOA.
Energy system	Electricity generation in Aardehuizen is realised by PV-panels on individual houses, while at a later stage collective PV may be placed at a parking lot. The PV panels are privately owned, but the battery will be collectively owned. A collective battery is under investigation, in cooperation with a different higher education institution. No gas connection is present, and because the energy performance coefficient of the buildings is almost zero, the little auxiliary heating that is required is done with heat pumps and wood stoves. Next to the direct current (DC) grid, in the future, an inverter will be placed, to make storage possible. Some of the houses have a private EMS. An investigation is ongoing to place EMSs in all houses, which can be connected to a higher level collectively owned EMS. Not all households are connected yet, because not all participants are certain about their privacy. Smart appliances and smart connectors are under investigation.
Use of EDSEP	At present, the HOA acts as producer. Once the collective smart grid is in place, peer-to-peer supply based on dynamic tariffs is planned. At this moment, every household has its own energy supplier. Later, an external cooperative energy company will buy and sell electricity, and handle the administration of the project. Ownership of the grid was not feasible financially as the grid was already in place and the grid was too expensive compared to the benefits of having Aardehuizen managing it.

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Table 4.5: Case study description Collegepark Zwijsen.

Aspects	Description
Project type	Project grid
Delineation	The project consists of a HOA for 115 apartments built in a monumental, former school building in the village Veghel, in the south of the Netherlands.
Organisation & governance	The derogation for a project grid has been arranged by the project developer before the houses were sold. The HOA has been set up by the developer so that the residents can use it as a vehicle to decide on matters related to their energy system.
Energy system	Collegepark Zwijsen has solar PV and solar collectors. These installations are jointly owned (in Dutch: mandeligheid). All households are connected to one shared large-scale use connection to the national grid. Grid balancing measures will be achieved through individual EMSs for each household. No smart appliances are involved in the project for reasons of privacy. The EMSs, in combination with dynamic tariffs are expected to incentivize the apartment owners to better align demand to supply. Storage will be as heat, not as electricity.
Use of EDSEP	The HOA acts as supplier, producer and distributor, but is not a balance responsible party (BRP). Project grid management, management of the energy technologies and the administration of energy use for billing are done by an external organization affiliated with the project developer. The apartment owners will pay a fee for these services commissioned by the HOA. The initial tariff structure is in place and approved by regulator ACM. The occupants are guaranteed to a 3-year zero energy charge, provided their consumption remains within a certain bandwidth. Later on, grid balancing is seen as a way to negotiate better tariffs, and then the HOA will be involved in deciding upon tariffs and new investments.

Table 4.6: Case study description Schoonschip.

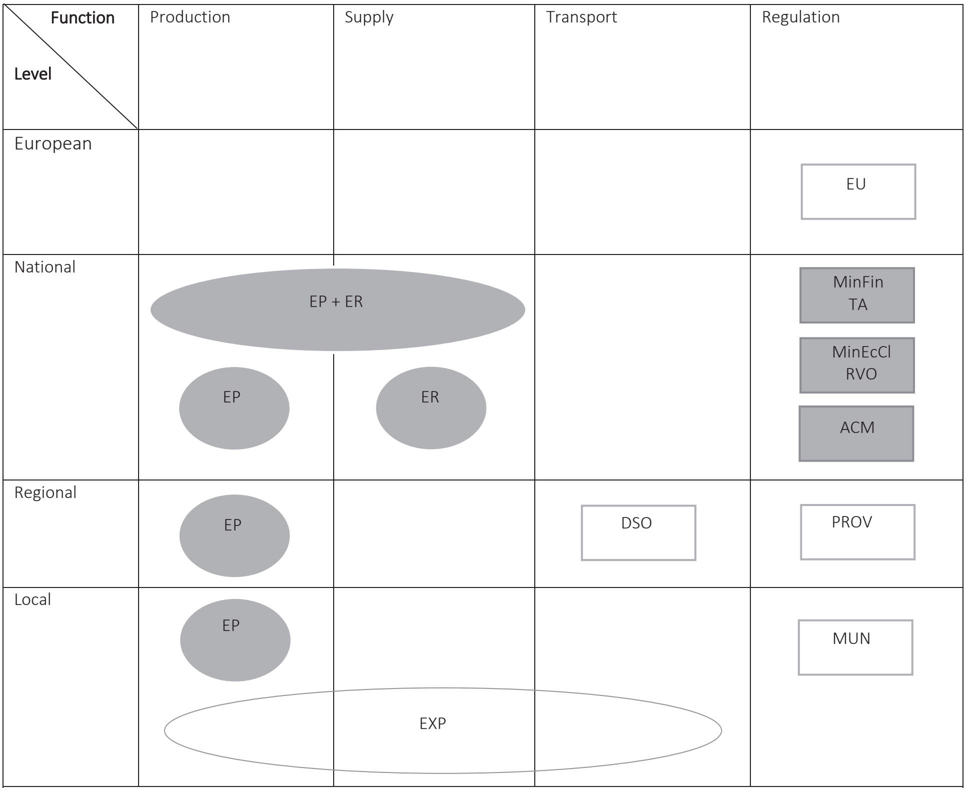
Aspects	Description
Project type	Project grid
Delineation	Schoonschip is an HOA of the owners of 46 houseboats and one communal boat in the Amsterdam quarter Buiksloterham, which is a city quarter that develops all kinds of sustainable building projects.
Organisation & governance	The project was started by a group of friends, who were later joined by other friends and acquaintances. There are other goals than RE, e.g. wastewater treatment, and the use of recycled building materials. The board of the HOA is responsible for daily decisions. Working groups have been established, e.g. in supervising the building process. These working groups may give presentations about their findings, to keep all members involved. For some decisions it is necessary for all members of the HOA to be present.
Energy system	The boats are all-electric, part of a project grid, and connected to the national grid via one connection. The HOA generates electricity through individually owned solar panels. Batteries are placed on each boat, but collectively owned. Shared electric vehicles are part of future plans. The administration and some of the maintenance are done collectively. A smart grid is in place, and every household has an EMS. The smart grid is part of a project of a consortium with external expertise, which researches the optimization of smart grid technologies and algorithms [31]. Dynamic tariffs are not foreseen as part of demand management. Efficiency should occur through the smart grid: using and storing electricity when production is high. Eventually, the energy management should result in providing electricity to the main grid at the highest price.
Use of EDSEP	The HOA acts as supplier, producer and distributor. The administration of electricity use and supply is outsourced to a commercial electricity company, which acts as BRP and provides electricity when a shortage occurs, and buys surplus electricity.

4.5. Results

In this section, we first discuss the polycentric constellation of actors that EDSEP experimenters need to function in, and thereafter we analyse the well-functioning of the experiments in this context.

4.5.1. The polycentric constellation of actors under the EDSEP

In this section, we will introduce the polycentric energy system that EDSEP experimenters are part of and function within (see figure 4.1 for an overview). The selection of the actors that we discuss here is limited to actors that are directly involved in EDSEP experiments, and therefore does not include actors, such as the high voltage system operator.



Legend:
Sector → square = public; oval = private.
Type → grey = functional; transparent = territorial.

Abbreviations:

ACM: Authority for Consumer and Markets
DSO: Distribution system operator
EP: Energy producer
ER: Energy retailer
EU: European Union
EXP: Experiment
MinEcCl: Ministry of Economic Affairs and Climate
MinFin: Ministry of Finance
MUN: Municipal government
PROV: Provincial government
RVO: Netherlands Enterprising Agency
TA: Tax authority

Figure 4.1: Overview of polycentric energy system under the EDSEP.

- Energy supplier

Dutch energy companies are traditionally large, nationally operating, private companies. In recent years, some cooperative energy companies have been founded that are closely related to local energy initiatives and seek to return at least part of the benefits to the region.

The functional energy companies receive surplus electricity from the projects and deliver electricity when the projects do not meet demand with their own production. They take care of the administration and billing for the electricity produced and consumed.

Energy suppliers that supply to small scale users, such as households, need a supply permit. This permit is given by ACM when the supplier can show amongst others that supply will be reliable, tariffs are reasonable, and the company is financially, organisationally and technically compliant with the conditions of the Electricity Act. Under these conditions, it is not feasible for local energy initiatives to act as the supplier. However, a few cooperative energy suppliers exist that supply energy that is produced by a growing number of local energy initiatives. These suppliers are cooperatives of cooperatives, of which local energy initiatives producing energy are member.

Furthermore, an energy supplier needs to have balance responsibility (in Dutch: programma-verantwoordelijkheid) or have a contract with a balance responsible party (BRP). The BRPs share the responsibility of balancing and they have to inform grid operators about their planned injections, offtakes, and transports. At the moment, experimenters are not able to take up balance responsibility and they rely on the larger national energy companies to provide this function for them.

- DSO

The DSOs in the Netherlands are territorially organized, monopolist utility companies that operate regionally. They are specialised in the transport of electricity and the maintenance and extension of the grid.

As utility companies, they are subject to forms of public control and regulation. The Authority for Consumers and Markets yearly determines the tariffs that the DSOs can charge to their clients to connect them, be connected and transport energy, and how much profit they can make on their investments.

In the large projects, the DSO remains the owner and manager of the grid, but, in the project grids, the grid is part of the project, and is built and maintained by the experimenters.

The DSOs are asked by RVO to give a reaction on the project grids, and they try to be involved in the design of these grids. They want to be formally involved in the process towards the derogation.

The DSOs have considerable experience and they are well equipped to build and maintain grids. However, as the regulatory focus in the Netherlands is primarily on the public values of affordability and availability of supply, the safeguarding of sustainability is prioritized at a much lower level [4,32]. While DSOs can benefit from the sustainability experiments, they are concerned about the knowledge that is present among the experimenters to perform DSO tasks. After the 10-year-derogation, the project grid has to be potentially handed over to the DSOs, and they wonder whether the quality of these grids will be sufficient, and who must pay the costs if this is not the case.

- ACM

The ACM is a nationally and functionally operating, independent public organization. It is a business regulation agency, which is charged with competition oversight, sector-specific regulation for several sectors, and enforcement of consumer protection laws. In the context of the EDSEP, the ACM checks the calculation method for the energy and transport tariffs if the energy experiment wants to take over the task of the supplier and the DSO.

- Tax authority

The tax authority is a nationally and functionally operating public organization. It is tasked with the tax collection and customs service of the Dutch government and it is part of the Ministry of Finance. It levies and collects the energy tax on electricity (in Dutch*:* Energiebelasting elektriciteit). This is a type of environmental tax that disincentivizes use. The energy tax per kWh for 0–10,000 kWh electricity was in 2019 € 0.09863 [33]. This is a large share of the average electricity price in the first quarter of 2019 of € 0.203 per kWh for households using 2.5–5 MWh [34]. In the experiments, it is dependent on the circumstances within each project whether energy tax needs to be paid, and no special conditions exist. Another tax that needs to be paid is for the storage of renewable energy (in Dutch: Opslag duurzame energie), which is € 0.0189 per kWh until 10,000 kWh [33]. In addition, a payment of 21% VAT is charged over supply costs, transport costs, and levies.

- RVO

RVO is an executive organization of the ministry of Economic Affairs and Climate, which operates nationally in the public domain with a functional agenda targeted at executing policies that support Dutch enterprising. RVO provides the derogation to the projects and supervises its implementation.

Once or twice a year it organizes meet-ups for the experiments, together with the national platform organisation for community energy, Hieropgewekt. Here, projects can create a community of practice and share learning experiences.

The types of experiments under the EDSEP are left rather open to see what kind legal changes are required to facilitate energy transition. This meant that some of the problems that the projects encountered were not foreseen, e.g. whether energy tax needed to be paid was first also not clear to RVO.

- Experimenting HOA or cooperative

The experimenters are locally operating, territorial decision-making units. The HOA's and cooperatives themselves are voluntary bodies, but a hybrid sometimes develops where a private party is the main developer and is either founding the HOA or cooperative, or paid by it to take on an important role in the design of the experiment. The functions that an experiment can fulfil under the EDSEP in the energy system can be any type of activity in the domain of energy production, supply, or grid management for projects grids, whereas large experiments are more constrained (see section 4.2.2).

- Municipality, provincial government, and European Union

The governmental bodies are, similarly to the previously described departments of the national government, public, territorial bodies, which operate at their respective scales. In the context of the EDSEP, these governments have played various roles in the polycentric energy system, such as subsidizer and provider of permits. This will be discussed in more detail in Section 4.5.2.4 regarding political representation.

4.5.2. The functioning of the experiments in their polycentric environment

We will now discuss the functioning of the EDSEP experiments within the afore-described Dutch, polycentric energy system, based on the criteria from our conceptual framework: control, efficiency, local autonomy, and political representation.

4.5.2.1. Control

Under the EDSEP, experimenters can carry out several tasks that were not permitted under the current Dutch model. Energy transport and grid management are considered to be a public utility, and production and supply are commercial activities. Without the EDSEP, the experiments can only be active in production and supply. However, supply requires a specific permit and it is not feasible for most local energy cooperatives or HOA's due to the required scale of customer base and financial risk. Before 2014, most of the energy cooperatives that acted as supplier sold electricity through energy companies as reseller, while using a so-called white label construction [35]. Others outsource tasks, such as administration and balance responsibility, to a back office of one of these companies while still using their own brand and image [36].

With a derogation, experiments can take over the tasks of both the energy supplier and the DSO, to the extent that they deem to be most beneficial for their projects. Note that derogations only apply to specific articles of the Electricity Act [23]. Other laws and regulations, such as the General Data Protection Regulation, continue to be applicable. In short, the derogation presents the following opportunities to derogate from the Electricity Act:

- derogation from the prohibition to carry out DSO tasks;
- derogation from the obligation to have a supply permit;
- freedom to determine grid tariffs, tariff structures, and requirements as set by ACM. ACM only checks the method by which the tariffs are determined, not the tariff itself;
- derogation from certain specific rules that apply to data processing (which are mainly about the requirement to participate in sector-wide discussions to align data related procedures to the benefit of the consumer);
- derogation from certain specific rules regarding transparency and liquidity of the energy market (which are mainly about the right of the government to create additional requirements regarding supply conditions and information provision in case of an illiquid market); and,
- derogation from rules regarding metering device requirements.

There are regulations that limit the control of the experiment. One of these that poses a particular threat to the experimenters is the European Union (EU) legal obligation to provide third-party access to a network whether it is a public or a private network (see article 32 Third electricity directive, 2003/54/EG. Pb EU L 211/55.). This means that participants need to be able to choose another energy supplier. From the perspective of the experimenters, this third-party access is a threat, because it can undermine the business model, as only as much energy

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is allowed to be generated as the projected use of the participants [23]. Moreover, collective energy management and storage are at risk when the user group decreases. The installations are dimensioned to supply for the initially projected users, and part of the production capacity can potentially not be used anymore if the user number decreases. A reason for this is that the government wants to keep the experiments as self-contained as possible to minimize the risk of blackouts or safety issues in surrounding areas.

Secondly, the prohibition of a flexible transport tariff limits the control of the experiments. Currently, it is only allowed for the DSO to charge a fixed daily transport tariff that is proportional to the capacity of the grid connection [37]. This limits the attractiveness of balancing, as the DSO cannot vary the costs based on the actual used capacity.

inally, non-energy legislation can also limit the control of experiments over their project. For instance, project grids are only attractive when there is no existing grid and, therefore, go along with the development of houses or apartments. The experimenters then need to obtain a building permit and might need to obtain permission from an aesthetics committee of the built environment. For instance, for Collegepark Zwijsen it was hard to get the design with solar collectors on the façade approved, as it was first deemed to negatively affect spatial quality.

4.5.2.2. Efficiency

Having an experiment under the EDSEP can lead to a number of cost savings for the participants. We list the most important below [38] :

- Grid connection and DSO transport costs for project grids: A one-time saving on the grid connection costs can be realized. Experimenters that newly construct a grid can save costs, because one high-volume connection to the regional grid is cheaper than the sum total of connections for individual dwellings to the regional grid. This is a financial incentive to balance the energy on project grids, because, the smaller the connection with the regional grid required, the lower the connection costs. Furthermore, the periodical transport costs that need to be paid to the DSO are also lower when the capacity of the connection is lower. This can result in a rather significant saving as the DSO costs are about 1/3 of the total electricity bill. To give an example: The total of the DSO tariffs for a household with an average 3 × 25 A connection at the DSO Stedin € 230.36 (other DSOs do not differ much in their tariffs) [39]. Schoonschip annually pays € 6759.74 according to their business model, which comes down to an average of € 225.32 per dwelling. As this is an all-electric neighborhood, where the electricity consumption is higher, the balancing brings these dwellings back to rather average DSO costs). However, if dwellings do not have their own connection to the grid, they miss out on the annual levy rebate for a part of the energy tax.

- DSO transport costs for large grids: the periodical transport costs on a large grid can be reduced by creating a virtual connection through a shared code for a group of participants that cooperate to create balance. The lower the required peak capacity, the lower the transport costs. Additional costs can be saved by helping the DSO to realize a flat usage profile (using the same capacity of the grid throughout the day), because this has value to the DSO. However, sufficiently adjustable capacity is needed for this.
- Energy tariff of large net: If the experiment can realize the aforementioned flat usage profile, it can potentially negotiate a lower tariff for the energy that it does not generate with its own capacity and needs to buy from an external supplier.
- Fixed supplier costs: Most energy suppliers charge a fixed supply tariff. If the experiment (project grid or large experiment) has one connection, these costs are lower than when each individual user would need to conclude a contract with the supplier. However, costs need to be made to measure the usage within the project and bill the participants.

When the EDSEP started, not all of the decision-making units were familiar with the regulation, because RVO did not prepare them for working with the EDSEP. This led to various instances when the experimenters needed to explain the regulations to the DSOs, ACM, and the tax authority. The compartmentalization of DSOs had a negative impact on the progress of projects, because the functioning of decision-making units within DSOs was not always well aligned. Accordingly, after informing and convincing the civil-servants in one unit, experimenters met with resistance of the executive staff, and had to re-explain their plans. RVO has asked organizations that have dealings with EDSEP-experiments to assign a case-manager with whom the projects can communicate at an early stage to improve this situation.

The scale is another efficiency related factor. It is questionable whether the experiments are an interesting party for the DSO to do business with for grid balancing. Grid operators could for example contract experimenters to make use of their storage capacity, or compensate them for the investment costs of grid reinforcement that are avoided by the experiment. However, some grid operators prefer to deal with larger parties and find projects with a size of up to 10,000 households too small and not very interesting to buy flexibility from. The creation of a legal requirement to buy balancing services through tendering could be a solution here, giving priority to small-scale providers. Or oblige DSOs to buy local balancing services for a price that reflects their value. Historically, such a similar obligation has been embedded in the law for DSOs regarding grid connection to make sure energy production and consumption would be accessible at any location in the country. Furthermore, energy tax needing to be paid twice for stored energy is a major inefficiency[40] (once when the electricity is uploaded in a battery and once when it is taken out again). As the energy tax is a high proportion of the energy price (see footnote 5), this limits experimentation with storage solutions. Unfortunately, alignment between the Ministry of Economic Affairs and Climate and the Ministry of Finance to avoid this double taxation has been lacking. In the near future, this problem will no longer occur, because the EU has adopted the 'Clean Energy for all Europeans' package, which states that owners of storage facilities should not be subject to any double taxation [41].

Additionally, the interpretation of current energy tax rules makes the experiments less efficient. Energy tax can be saved if the ownership structures make sure that there is no supply to third parties, and the participants make use of their own production and distribution capacity. However, a third party is a party with a different real estate valuation tax object, according to the taxation criteria (REV-object, in Dutch: woz-object). Each house or apartment is a REV tax object, and, therefore, energy tax on electricity needs to be paid when a participant uses energy from the production installation of another participant. A possible solution would be for the municipal government to register the houses as one REV-object (this has no consequences for the REV-tax and the procedure is the same as for other REV-tax objects with multiple owners). Moreover, whilst DSOs embrace the goal of the EDSEP to keep production and consumption local, they fear that private project grids threaten the socialization model that underlies Dutch grid management. The DSOs have the perception that some experiments are motivated by the evasion of the energy tax, as it appeared at first to some participants that this tax would not apply for the experiments.

Last, but certainly not least, the experimenters need to fully comprehend a whole gamut of complicated energy related regulation to be successful. Misinterpretation can lead to a worsening of the business model and can, ultimately, lead to an inviable project. Experimenters progressed slowly despite some support from RVO and Hieropgewekt due to this complexity. Slow progress even led to the strange situation that the government has decided to draft a follow-up EDSEP without waiting for the formal evaluation of the present experiments.

4.5.2.3. Local autonomy

Formally, for experimenters, the two structures to self-organize and function as a decision-making unit in the polycentric energy system are HOA and cooperative. While HOA and cooperative seem to be structures that are explicitly designed for high commitment of the involved households, these do not, per se, imply a high level of participation of all participants. For example, Endona is a cooperative, but only its board members are members to keep decision-making with the daily management. The organizational structure is primarily set up to run the sub-projects efficiently, it is not geared to involve many local participants.

A second example is Collegepark Zwijsen, which was designed without input from its future inhabitants. The derogation was applied for by its project developer, but assigned to the HOA, which was not yet in existence at that time. The HOA only started its regular meetings after the residents started living in the apartments. From then on, the autonomy of the HOA will be larger, as it will decide on topics, such as maintenance and tariffs.

The other two HOA's, Aardehuizen and Schoonschip, functioned from the beginning of the projects as decision-making units run by the future inhabitants. Both outsourced tasks to professional parties, but took the decisions about project design themselves. The working groups prepared proposals about e.g. sustainability, but these decisions were then taken collectively.

All of the projects, except Zwijsen, which is entirely professionally developed, mention that working as a HOA or a cooperative with participation based on the input of volunteers, who are mostly not professionals in the field of energy, has made it harder to function as a local decision-making unit, because they need to invent the wheel by themselves and it was not always easy to acquire all of the required information for informed choices. Additionally, in the communication with other decision-making units such as DSOs, the tax service and ACM, the status as cooperative or HOA was by times a disadvantage and they needed to first convince the other parties of their know-how and professionality.

4.5.2.4. Political representation

The municipal government was the political body that was most involved in the projects. Sometimes the relationship with the local government depended on the political tide, but most projects had a productive working relationship with the municipality and felt supported. Two projects got a municipal subsidy: Endona for a feasibility study for its solar park, Schoonschip a contribution per household for the high energy efficiency of the houses. Additionally, motions at the local council functioned as a mechanism to realise political representation of the interests of projects in local politics. Aardehuizen and Collegepark Zwijsen both benefited from political motions. Aardehuizen benefited from a motion about sustainable building prior to the project, which helped to increase the support for the project. The project developer of Zwijsen successfully lobbied for a motion that would reduce the fee for the building permit, which is proportional to the building costs and was high due to the costs of the energy sustainability measures and techniques. The project developer was also successful in lobbying to overrule the negative advice of the aesthetics committee for the built environment, so Zwijsen could have its solar collectors. Furthermore, Endona, Aardehuizen, and Schoonschip received a provincial subsidy, e.g. to hire an architect or for feasibility studies. Aardehuizen also received a European subsidy for the community building, although this had to be partly paid back, as the building could not be realised in time.

At the national level, no specific representation of the experiments exists. RVO reports on their progress to the ministry of Economic Affairs and Climate, but only from their position as an executive organisation, not as lobbyists. For this reason, it is unlikely that the experiences of the experimenters will be influential in the revision of energy law, especially because the experimenters were not asked for their input during the consultation for the draft of the follow-up executive order.

4.6. Conclusion and discussion

We studied the EDSEP as an example of a regulatory sandbox, a participatory experimentation environment for exploring the revision of the Electricity Act. 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. On the one hand, the project grids can act at the same time as the supplier, producer, and distributor of energy, managing an own mini grid. On the other hand, the large experiments cooperate with the DSO, while the grid remains owned by the grid operator, and 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. Interested in their functioning, we asked ourselves the question: What can be learnt about local energy initiatives' bottom-up experimentation with smart grids in a polycentric energy system? In this section, we conclude on our findings and discuss our conceptual framework, and then put these in a broader perspective of legal innovation for energy transition.

4.6.1. Lessons learnt from participative experimentation under the EDSEP

For potential experiments, the EDSEP has shown 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. We want to make four main points, related to the four criteria for the well-functioning of polycentric decision-making structures.

- Efficiency: Combining exemptions with a pro-active nurturing of experimentation

The EDSEP's exemptions should make the integration of RE and grid balancing more attractive, which adds to the overall efficiency of the energy system. The EDSEP enables taking on new roles, but taking on these roles is hardly attractive or facilitated in the polycentric constellation. First, our case studies show that the EDSEP provides only a modest improvement for the business case of smart grids at the project grid level, and that for the large experiments we studied a good business case has not yet been found due to the limited financial attractiveness and the large organizational capacity required for taking on the balancing and supply roles while they come with considerable financial risks. Second, for developing the experiments, there is no financial support available and, therefore, the experimenters have to rely solely on their own political efficacy and networking capacities to attract subsidies, or partners with knowledge or capital to invest. RVO has an important task to distribute subsidies for energy innovations, especially for innovations in the early stages. Hence, a special fund or subsidy for experiments would fit in seamlessly in the overall aims of the RVO. In addition to this, we suggest that more support should be created to overcome knowledge differences in small-scale volunteer organizations.

Third, alignment between decision-making units, such as the DSOs, ACM, and the experiments, was initially lacking due to poor communication with the other actors about the regulation by RVO, which made it harder to establish a productive collaboration with these decision-making units. This reduced the efficiency of experimentation, as enrolling such established actors in their network is very beneficial for bottom-up technological innovation projects [42].

Hence, our findings suggest that the smart-grid niche that the EDSEP provides lacks sufficient nurturing to function efficiently [43]. Nurturing can take place through assisting learning processes, articulating expectations, and helping networking processes [43]. All of these could be strengthened to increase the efficiency of the polycentric constellation that is created under the EDSEP.

- Control: the benefits and limitations of the new roles

The EDSEP fulfills a need to explore regulation that better facilitates the integration of intermittent resources. By making use of the EDSEP, the experimenters can take on new roles as grid managers (for project grids even the role of grid owners is possible) and as energy suppliers. For project grids, we saw that this incentivizes grid balancing through providing the opportunity to bring down the DSO costs by minimizing the exchange of energy (import or export) between the project grid and the regional grid. Additionally, the exemption from getting a supply permit is used for the project grids, but, in both cases, the administration has been outsourced to either an energy company or a company related to the project developer. These tasks require more time and expertise than the local initiatives could give and, therefore, they chose to outsource the tasks to commercial organizations. Taking on the roles of supplier and balancing agent is more difficult when it comes to extra control for the large grids. First, when it comes to supply, the customer base is bigger than for the small projects, so the risks of, for instance, late payments are also higher, but the company is still not big enough (or not sure whether it is in the case of Endona) to carry these risks. Second, when it comes to taking the role of grid manager for a larger area, this is complicated due to the fact that for flattening the usage profile, adjustable capacity is required to create a good business case, which is expensive for experimenters, as it has to come largely from storage because they cannot use industrial partners' capacity, as their participants have to be mainly households. Furthermore, as only the local experimenters could experiment with tariff structures and the regional DSOs not, business opportunities regarding balancing are limited. Lastly, the supplier role of the BRP is out of reach for the experimenters, as the software for this is too expensive and the risks too high for the small-scale experiments. 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. Some of the tasks are not (yet) feasible, mostly due to financial, organizational, practical, or sometimes legal 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.

- Political representation: approach sustainability more holistically in policymaking

Experimentation would have been more effective if the Dutch tax authority was enabled by the ministry of Finance to co-experiment and to, for instance, exempt the experiments from double taxation on storage. However, communication regarding the EDSEP between the ministries of Economic Affairs and Climate and Finance was lacking. Some projects have tried to come up with project designs to pay less energy tax. However, no exceptions or reduced tariffs were granted to these relatively small energy cooperatives, in contrast to the tax rulings for large international companies. Hence, similarly to the work of Kooij et al. on niche–regime interactions between the tax authority and collective PV producers, our case also ‘illustrates the political and power-laden nature of sustainability transitions, going beyond the focus on organizational and technological challenges’ [44] (p.10). Ultimately, the EDSEP-sandbox shows that an experiment is not always fully a two-way regulatory dialogue between an experimenter and a regulator.

Furthermore, the lack of alignment between ministries shows that the development of policies that affect sustainability evolve in parallel worlds, and a more holistic approach is needed [1]. Stepping away from silo thinking and strengthening inter-ministerial alignment would be helpful in designing effective energy transition policies. Stronger political representation of a lobby organizations or intermediaries [45,46] at the national level would also be useful in this case. For instance, EnergieSamen, a Dutch lobby organization for local energy initiatives, could take on such a role.

- Local autonomy: a legislative balance between self-responsibility and the protection of consumers

The experiments show that, while the HOA and cooperative seem to be structures that are explicitly designed for high commitment of the involved households, these do not, per se, imply a high level of participation by all participants. In the context of smart electricity, energy legislation needs to strike the balance between opportunities for self-responsibility and the protection of consumers [1]. Options for users to shape their own energy system are desirable in the context of energy democracy [26], but consumer protection against high prices could be threatened, e.g. when making tariffs flexible. Therefore, further experimentation with legal innovation should not only explore how legalislation can be facilitative of technological innovation, but also of social innovations to create an energy system that represents the interests of its users and is acceptable to them. Involving local energy initiatives or users cannot function as the sole mechanism of user involvement, because our cases show that such a characteristic does not always guarantee high participation. Furthermore, adequate insight of end users in the experiment necessary to protect their interests might be lacking.

4.6.2. Theoretical reflection on polycentricity

The advantage of the concept of polycentricity 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. We find that this concept provides more guidance for our study in defining actor roles and their position in the energy system than e.g. the multi-level perspective (MLP), which predominantly focuses on levels and rather general dimensions, such as science, market preferences, technology, socio-cultural, and policy [47]. With the concept of polycentricity, it is easy to see what a nested system of decision-making units looks like and in which ways it is layered, whereas MLP puts more focus on which sectors (market, science, policy, etc.) are represented in a system.

Furthermore, the concepts for evaluating the role of actors in polycentric systems (local autonomy, control, efficiency, and political representation) help to understand what is necessary for a decision-making unit in such a system to function well. They were especially helpful when 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 efficiency helps to understand whether the decision-making unit can provide added value to the system, which is a useful indicator in assessing whether sustainability experiments contribute to an efficient progress towards a more sustainable energy system.

However, it needs to be realised that, while using these concepts, the success of the experimenters in the polycentric context does not equal the value of the experiment for legal innovation. When evaluating the experiments, the question should also be whether the experiment has resulted in new insights for guiding energy transition, in this case study for revising energy law, 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. Strategic niche management and actor-network theory may be helpful frameworks to further explore these aspects of innovation management.

4.6.3. Final remarks

For the Dutch legislators, learning from the EDSEP experiences is important, because the EDSEP is only the start of experimentation informing revisions of energy law. A follow-up of the EDSEP has already been drafted, being based on the 2018 Law Progress Energy Transition. This executive order expands the size of experiments, experimenting actors, and also enables experiments under the Gas Act. The new regulation has been presented to the parliament in May 2019 and new experiments can apply once the new executive order has received positive advice of the Council of State, which is expected early 2020.

We would like to briefly summarize the conclusions of this study, so they can be taken into account for the evaluation of the EDSEP as well as for future experimentation. Experimentation under the EDSEP shows us that inter-actor alignment was initially lacking and pro-active nurturing would have smoothened the implementation.

Furthermore, EDSEP experimenters faced significant constraints, had very limited political representation, and varying representation of the users within the experiment. As a starting point to improve both the well-functioning of the experiments and the quality of the learning process, an intermediary could be more of a bridge between national and regional actors and the locally operating experimenters, and take a more active role in developing a knowledge base, providing project development support, spreading knowledge in the polycentric experimentation system, and extending the learning community. A first option for this could be an extension of the role of the executive organization, RVO, as it is already involved in the derogation process. In the Scottish context, Community Energy Scotland, which provides such support, also grew from a governmental initiative. Alternatively, the national community energy platform Hieropgewekt could take on this role, or even the regional umbrella organizations for energy cooperatives. Yet, to realize this, such intermediaries should pro-actively follow developments in energy legislation relevant for local energy initiatives and attract or train expert staff that can assist experimenters with their project development. As many of such organizations do not have the financial means for this, a government that truly wants to support inclusive innovation and transition processes should allocate budget to them for staff time.

Thus far, a lot has been expected from the experimenters without much active facilitation. Resultantly, the distribution between the risks of and incentives for experimentation is rather uneven and, therefore, it could have been expected that experimenters' progress was relatively slow and interest in new roles limited. This decreased the potential of the sandbox for generating lessons for revising energy regulation to facilitate energy transition. A more holistic approach, inter-actor alignment, the availability of expert support by an intermediary, and facilitation of a more close-knit learning community would bring benefits to the bottom-up participatory innovation.

Appendix B. Overview of EDSEP projects

Table B1 presents an overview of EDSEP projects.

Table B1: Overview of EDSEP experiments.

Year	Name	Type (project/ large)	Legal Entity	Project Goals	Scale
2015	Parq Green	P	HOA	Collective PV, sustainable heat	292 recreational houses
	Black Jack/ Withdrawn	L			
	Experiment DDE Collegepark Zwijsen	P	HOA	Generations, EMS, tariff differentiation, cogeneration	115 apartments in renovated school
	Endona EXP	L	Coop	Generation, cooperation with biodigester, supply to members, increasing direct usage, EMS, storage.	47 with EMS and towards 5000 members in 10 years
2016	Schoonschip	P	HOA	EMS, generation, batteries, heat pumps, heat storage in buffer and smart appliances	46 water houses
	Noordstraat 111 Tilburg	P	HOA	EMS, generation, smaller grid connection	3 houses in old office (owned)
	Villa de Verademing	P	Coop	Insulation, generation, smart grid connected to the neighborhood, storage.	18 apartments and 1 city residence
	Groot Experiment Aardehuizen e.o.	L	HOA	Community battery, EVs, EMS, generation, no gas, smart software dynamic electricity tariffs and demand response, p-2-p.	3 rental and 20 owned

	Kringloopgemeenschap Bodegraven-Reeuwijk	L	Coop	Generation and determining own tariff	2500 households
2017	Republica Papaverweg	P	Coop	EMS, generation, own grid, smart charging with EVs, thermal storage and batteries	Newly built housing block with various accommodations
	Micro Energy Trading Eemnes	L	Coop	P-2-P , EVs, blockchain, storage, generation, smart software.	100–200 social houses; scaling up to 1500
	Micro Energy Trading Amersfoort	L	Coop	P-2-P, smart software and block chain	400–600 social houses
2018	Duurzame Wijkenergiecentrale Trudo	L	Coop	Generation, EMS, batteries, EV chargers, and tariff differentiation	260 apartments in old industrial building(owned/ rental)
	Smart Grid Groene Mient	L	HOA	Generation, heat pumps, no gas, battery and EVs	33 newly built houses (2017) with communal garden
	Zeuven heuvels Wezep	P	Coop	EMS, generation, no gas, own grid.	57 newly built houses
	Smart energy grid Bajeskwartier	L	Coop	Generation, neighborhood battery, EVs, heat pumps and thermal storage, smart grid software platform EMS	950 apartments, school, hotel, 340 student houses and various other services
	Kleine Duinvallei Katwijk/ Gave Buren	P	Coop	Balancing, joint electricity purchase and distribution, generation.	80 ecological houses
	Shared energy-mobility community Amersfoort	L	Coop	P-2-P, car sharing with EVs	400–800 houses of housing cooperation
2019	Cooperatie zonnepark Bad Noordzee U.A.	P	Coop	Heat pumps, P-2-P, PV, battery storage.	322 recreational houses and a few large use connections

Appendix C. Overview of interviewed actors

Table C1 displays an overview of interviewed actors.

Table C1: Overview of interviewed actors.

Interviewed Actor	Type of Interview
Resident of case Schoonschip	Face-to-face
Resident of case Aardehuizen	Face-to-face
Project developer of case Collegepark Zwijsen	Face-to-face
Resident board member and advisor of case Endona	Face-to-face
Grid operators from the different territorial jurisdictions, who engage with experiments (3)	Phone (all 3) and one also face-to-face
Energy company staff member: EnergieVanOns & Nuts&co. (2)	Phone
RVO	Phone
Policy maker ministry of Economic Affairs	Phone
Tax authority staff member Consultant in legal, technical and fiscal aspects of renewable energy and energy efficiency. Focus on complex projects and political processes.	Phone Face-to-face
Employee regional umbrella cooperative for supporting local energy cooperatives	Phone
Management, ICT, energy and sustainability advisor, creator of web environment with information overview for EDSEP experimenters	Face-to-face

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5

LIGHTENING THE WORK: THE HETEROGENEOUS DEVELOPMENT OF THE DUTCH COOPERATIVE ELECTRIFICATION NICHE IN TERMS OF SPATIALITY AND PACE

Abstract

The cooperative energy movement has been defined as a socio-technical innovation. Socio-technical innovation implies a process of simultaneous change of the structure of the energy system and relationships among the actors in the system, which affect its technical as well as societal and behavioural dimensions. However, framing energy cooperatives and their interaction with the energy system as socio-technical novelty prompts the question: have cooperatives played a role in energy transitions before, and if so, how? This study brings a nearly forgotten, and largely unknown part of the early history of Dutch cooperative electricity back from the margins of historical work on electrification: the emergence of electricity cooperatives in the early 20th century. By using the concept proto-regime from the Multi-level perspective on socio-technical transitions, we explore their role in the development of electricity from niche market to a regime with its own actor constellations, rules, and material and technical elements. Through this analysis we would like to contribute to an understanding of niches as heterogeneous innovation environments where diffusion and embedding of niche technologies can take place at different paces and in distinctive ways across localities. From the analysis, we also conclude that energy cooperatives can still have a transformative role in an energy transition without becoming a dominant player in the regime. The electrification cooperatives did not only inform learning in the proto-regime as experiments, but also improved accessibility of a novel development that not only literally but also figuratively lightened the work in rural areas.

Keywords: multi-level perspective, electrification, local energy, historical, proto-regime, niche heterogeneity.

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Gij, lichtbron van den nieuwen tijd,
Door ons met zooveel vreugd verbeid,
Blink ons uw schijnsel tegen,
Verhelder d'arbeid, noeste vlijt,
Verlicht om 't dagelijksch brood den strijd,
Gemeente en dorp ten zegen.

Thou, light source of the new time,
Awaited by us with so much joy,
Shine your glow on us,
Brighten the work, unremitting diligence,
Lighten the struggle for the daily bread,
Blessing for municipality and village.

~ Festive song composed for the opening of the cooperative energy plant in Bergum.

5.1. Introduction

Today, local civic initiatives are playing a growing role in national energy transitions. Especially in north-western European countries such as the Netherlands, the UK, Denmark, Germany and Belgium, such energy initiatives have been establishing themselves as a community energy sector with their own rules and actor-networks [1], [2]. The sector is expanding its activities, professionalizing, and creating regional, national and even supra-national institutional structures. In some cases, initiatives are enrolling incumbent energy regime actors such as distribution system operators and energy companies in their networks[3], and even creating hybrid business models[4], [5].

The precise growth of local energy initiatives has been country specific and far from linear, with phases of waxing and waning. The latest take-off of community energy in many north-western European countries was during the last 10 to 15 years, and the number of European energy cooperatives already exceeds 1500 [6]. This development has mainly been facilitated by a combination of the liberalization and privatization of the energy markets, dropped prices of solar panels due to rapid technological development, introduction or extension of financial policies for renewable energy, and a societal wish to accelerate the transition to renewables. Especially, a fit with the regulatory framework and supportive financial policy turned out to be important for their growth [7], [8]. Periods with less favourable conditions in those respects had a slower growth pace, which has been seen in Denmark, the UK and Germany [7], [8].

Due to this recent growth of community energy in north-western European countries, community energy has largely been perceived as a novel phenomenon, even described as a socio-technical niche innovation [9]–[14]. However, collective, civic action in the energy sector is not as new as it may seem. For countries with an established community sector today, the roots of the collective local initiative goes back much further than the last 15 years. A few country-based studies provide a wider historical perspective on community energy[7], [15]–[17]. These studies describe how from the 1970s and 1980s, community energy sprouted from a combination of social, political, institutional and environmental factors.

Yet, we found even earlier community energy initiatives in the Netherlands. We discovered that similar to for instance North-America and Germany[18], [19], the Netherlands had a wave of cooperative energy provision much earlier on, at the start of the 20th century. Just like today's initiatives, these cooperatives were part of an energy transition. This study focuses on how a niche market formed for cooperative energy and how it developed in relation to a changing energy regime. Such information provides a background that can be used for later work involving systematic comparison with today's community energy sector.

Thus, interested in what role electrification cooperatives played in the historical energy transition towards electricity, we focus on the following main questions:

How did electrification cooperatives develop and why did they disappear? What was their role during the Dutch electrification?

We explore these questions through a historical analysis based on archive study and secondary data. As framework for analysis we have chosen concepts from the literature on the multi-level perspective (MLP) on socio-technical transitions. This framework has been used for analysing systems interactions in contemporary and historical transitions. The MLP highlights co-evolution and multi-dimensional interactions between various involved actors, amongst others industry, technology, markets, policy, culture and civil society[20]. We characterise the electrification cooperatives as part of the electrification niche, and describe what role these initiatives played during the shift of electricity from niche market to part of the energy regime.

By doing so, we aim to contribute to an understanding of niches as heterogeneous innovation environments where the development, diffusion and embedding of niche technologies can take place by different actors, at different paces, and in different ways across different localities[21]. 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 at a certain point in time[2], [10], [11] or analysed local case studies [12], [22]. 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.

Hence, we want to show how concepts from the MLP body of literature can be used to show regional diversity. In this paper, we explore and explain the heterogeneity of development pace and the regional diversity of cooperative electrification.

5.2. Theoretical framework

The MLP has been used for understanding contemporary and historical transitions to new socio-technical systems, and has been helpful in furthering the understanding of the dynamics of system innovation. In MLP, transitions are defined as changes from one socio-technical system to another through the co-evolution of technology and society[23]. Historical MLP transition studies have, for instance, been done on the transition from cesspools to integrated sewerage systems [24], from horse-drawn carriages to automobiles[25], from manual to mechanized unloading of ships in the port of Rotterdam[26], and on the co-evolution of water supply and personal hygiene[23].

The MLP's analytical framework to analyse transitions is constructed around the core concepts niche, regime and landscape (see figure 5.1). When innovations emerge at the lowest level in niches [27], rule structures are not yet in place and actors improvise and experiment to come to grips with what their (prospective) target group needs. Networks around the innovation are at this stage rather small and precarious, and the innovation does not threaten the existing regime.

If an innovation catches on, it will get used in small niches of the market, resulting in more interaction with users and other regime actors, providing resources to further develop and specialise the technology. In this second stage, the innovation starts to develop its own trajectory and the rules and actor constellations are getting increasingly stable. The structure of the niche develops increasingly in the direction of that of a regime, and forms an early stage regime like proto-regime[28].

Either the innovation remains a niche product, or it enters a breakthrough phase in which the technology starts to compete with and make changes to the established regime. Both internal niche dynamics, and external regime and landscape developments are earmarked as important for replacement of existing regime structures[27]. This will be accompanied by creative destruction: the collapse of some incumbent actors, and introduction of new actors from the support network of the innovation. Finally, once a transition has taken place via a crooked process of acceleration and slowing down[23], the new constellation settles to a state of dynamic stability and reproduction, forming a regime with a new balance and structure.

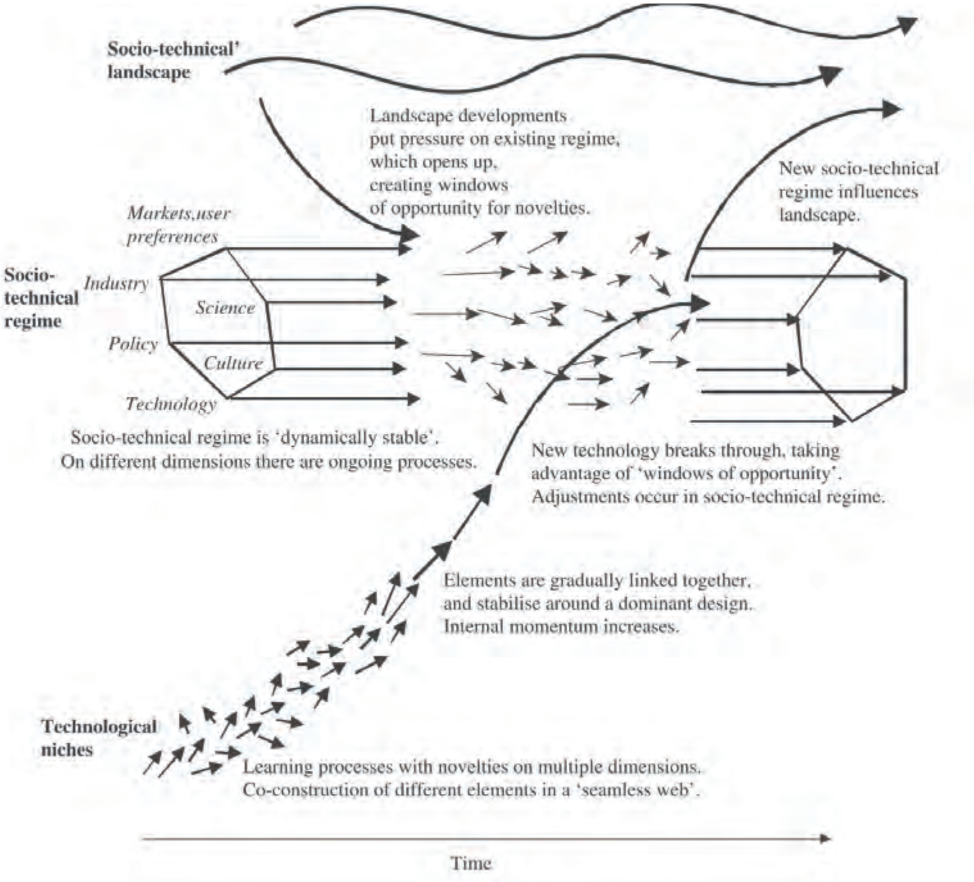

Figure 5.1: The multi-level perspective on socio-technical transitions [27].

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In this study, the focus is 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, we need further operationalisation of the development of a niche into a regime, and for this we use the earlier mentioned concept proto-regime.

Niches have been described to be similar in structure to regimes, but less stable and operating on a lower scale [29]. As a niche matures, it evolves towards a proto-regime that has a similar structure to a regime [30]. The proto-regime comes slowly into being when rule structures and actor-networks start to take shape during niche development [28] (see figure 5.2 for a schematic overview of steps).

Smith and Raven propose five steps for the development of a proto-regime [28]. First, regimes and landscape inform experimentation, and shape the conditions for innovations to arise (T1). Second, a variety of local experiments arises and gets supported by local networks, generating locally applicable lessons. Third, these local lessons are negotiated and translated and some get selected and start to act as rules in the entire niche. Fourth, there is retention of knowledge, and the developing actor-network and the new rules become useful resources for new experiments. Finally, it starts to change prevailing regimes or becomes a viable competitor (T2).

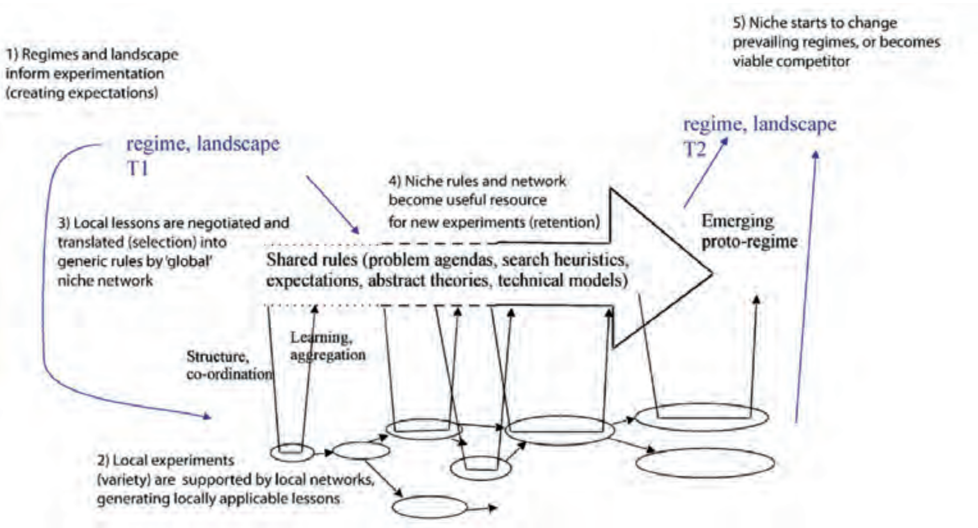

Figure 5.2: Emergence of a proto-regime [28].

Since a niche is in structure similar to a regime, we can use the three interlinked elements of the regime proposed by Verbong and Geels [32] to analyse the increasingly stabilising electricity niche and the role of the electricity cooperatives in it:

- Actors: a network of actors and social groups, which develops over time;
- Rules: regulations that guide the activities of the actors who reproduce and maintain the elements of the energy system;
- Material and technical elements: the tangible elements such as infrastructures and technologies.

After analysis of the emerging electricity regime, we study the cooperative electricity niche in more detail. We focus on the spatial and temporal trends of emergence.

5.3. Methodology

This historical research uses a mixed methods approach and combines qualitative and quantitative data.

For establishing an overview of the electrification cooperatives, we used the yearly supplements of the *Staatscourant (*the Netherlands Government Gazette*)* with an overview of the all cooperative associations founded in that specific year. The supplements include a list of the founded cooperatives, and memoranda and articles of association. These supplements are available from 1904 onwards, and we have searched the period 1904-1935. The delineation of the search era was data-driven and was an iterative process. We set the search limit to 1935 as in the five previous years no new cooperatives were found.

The data sheet we created by using this source includes the names of the cooperatives, their year of foundation, the location (place name and the province), and whether they were started as a distribution or generation and distribution cooperative. Are mark that needs to be made about the reliability of the data of foundation from the Staatscourant is that for a few Frisian cooperatives, this source gave a later year than Jansma [33]. Hence, the cooperatives may not always have incorporated in the year they started operating. However, we expect that the trends in the data will not be affected much by this.

Furthermore, a methodological limitation to this research is that the dates of dissolution of the cooperatives could not be retrieved. It was not yet required to register dissolution of a cooperative. This information is incomplete and scattered over regional archives. In the Drenthe archive information about only 4 of the at least 26 cooperatives could be found, and therefore, we have concluded it was not possible to trace this information for each cooperative individually. However, some global data on the decrease of cooperative energy could be found in provision overviews from governmental organisations and encyclopaedias covering the history of electrification and utilities.

To obtain qualitative data for interpreting and explaining these trends, we used various approaches. We used historical search engine Delpher to search for newspaper articles featuring electricity cooperatives. In addition, we searched via archieven.nl, which is a collaboration of 87 organisations and more than 51.000 archives. We also used a regular web search to find content from for instance local historical associations to triangulate the data from the Staatscourant.

Furthermore, two contrasting types of cooperatives have been portrayed in more detail as historical cases, and to give a more in-depth understanding of the functioning of these differently motivated electrification cooperatives.

5.4. The developing electricity regime

In this section, the conditions under which electrification cooperatives developed will be sketched. The focus is on how the actors and network, rules, and technologies and material elements changed between 1900 and 1950 while electricity developed from a niche to a regime, and became an increasingly stable part of the lighting and power sector.

5.4.1. Technologies and material elements

After the International electricity exhibition in Paris in 1881, European engineers started to experiment with electricity. The first practical application was lighting, which meant competition for the gas factories.

In 1907, the Netherlands had 131 gas factories, of which 108 municipally-owned companies[34]. The gas was produced out of coal and transported via pipelines. As gas was more expensive than petroleum and candles, it was only affordable for the societal upper class. Initially, owners of gas factories did not perceive electricity to be a threat as they thought it would be only suitable for lighting large public spaces and would stimulate the demand for lighting. Gas light had just gotten an impulse in the 1890s and 1900s because of the invention of the Auer von Welsbach gas mantle, which used less gas and did not require a very specific gas quality[34]. Furthermore, gas was less expensive than electricity. With time gas became more accessible to lower- and middle-class households because of the introduction of coin meters which avoided an unexpectedly high bill at payment time. However, because of the high costs of the development of a gas grid and techno-economic limitations of transport over larger distances, gas remained for use in more densely populated areas, and grid expansion was limited.

While gas was still generally more attractive than electricity, an early niche market for electricity of self-generating factories using electricity for their production processes formed[34]. These factories possessed already a steam engine that could be connected to an electricity generator. The advantage for these factories was that they did not require a central drive shaft because of the possibility to use electricity cables. However, the gas engine improved during this time as well, increasing the attractiveness of gas, and was still attractive for small- and medium-sized companies for which a steam engine was too expensive.

Although gas had its advantages from about 1905 onward, the gas engine started to lose its competitive advantage to the maturing electro-engine that was smaller and more versatile than the steam engine, and had lower purchase and maintenance costs, easier installation, smaller size, and was cleaner than the gas engine[34].

Especially when the price of electricity went down due to upscaling that was enabled by technological developments electricity started to prevail over gas for lighting and propulsion purposes. An important technological development was connection in parallel of alternating current generators. This enabled extension of production of alternating current that could be transported with high voltages for minimal losses through thinner, and therefore, more economical electricity cables[35]. Until about 1910, the number of gas engines still increased in smaller cities, but because of the quick expansion of electricity these were soon replaced by electric equivalents[34].

However, despite their success, electricity plants were barely making a profit. This was a result of the quick technological advancements, and of the constant need for investments and high depreciation[35]. The electricity providers started experiments with attractive tariff systems to stimulate the demand. However, the success of the plants was determined by a combination of the potential for labour, capital, used technology, the extent of industrialisation, population size, and bargaining power[35]. The population size and the market composition were the most important.

By about 1914, upscaling meant lower production costs, and therefore, bigger plants turned out to be more successful [35]. Between 1883 and 1914, 19 plants already closed again, of which most were smaller, private, direct current plants. Eleven of these were located in localities with fewer than 10.000 inhabitants[35].

In sum, due to progress in electricity technology and market dynamics, gas started to lose its competitive advantage to electricity from about 1905. An important development was connection in parallel of alternating current generators, which enabled extension of production of alternating current that could be transported with high voltages. A decade later, economies of scale could be realised with bigger plants, which led to centralisation of production. This made it harder for cooperatives to remain competitive as around this time rules changed and their institutional space became limited to one municipality only.

5.4.2. Policies and regulations

At the start of the electrification period, rules and regulations for electricity technologies and infrastructures regarding e.g. safety, durability, and organisation of the emerging electricity system were largely absent. Until 1912, the municipal government could decide whether or not to give a concession and allow a private electricity company or to start a municipal company[36]. The prospective concession holder only needed to ask the national government (ministry of water works) permission if the electricity grid came near to telegraph or telephone cables or along waterworks or railroads[36]. In 1912 (Groningen) and 1913 (Noord-Brabant) provincial regulation that obliged prospective electricity companies to get a provincial concession was approved per Crown Decree[36], [37], and soon after this most other provinces applied for this right and started a provincial electricity company.

National policy and regulations developed slowly. It was only in 1938 that the first Electricity Act was passed, whereas the first policy preparations by installing various state commissions started already more than 35 years earlier[38]. In 1903, the Commission Tidemann explored safety and measurement standards. In 1910, the Commission IJsselstein was installed to look into promotion of the electrification of the country side. It recommended to divide the country into districts and to give out concessions based on this classification. The concession system did not yet find its way into regulation, but the provinces North-Brabant and Groningen still successfully applied for a provision concession for their province, which was soon followed by most of the other provinces. An advice of Commission IJsselstein that did make it into law (i.e. to the Belemmeringswet) was expropriation of unbuilt properties for electricity infrastructure, if for the common good. In 1919, Commission Lely made a plan to bring the electricity provision in the hands of the national government. However, parliament downvoted this, after which the proposal was withdrawn. In 1921, Commission Graaf van Lijnden van Sandenburg was installed, which brought out an advice report in 1925 that was used to create a first draft of the first Electricity Act. This proposal did not make it, but led to the installation of an Electricity Council that would advise the ministry of Water works on electricity matters. In 1937, another draft of the first Electricity Act was presented, which was accepted by parliament in 1938. At this point, the importance of coupling the network at the national level to improve security of supply overrode the doubts about the desirability of government intervention and the negative effects of forced collaboration between the electricity companies.

This Electricity Act provided a legal basis for the arrangement of the electricity provision via a state concession system. Concessions that had been given out prior, by e.g. the municipalities, were not ended but needed to be harmonized with the new regulations to be turned into state concessions. The only exception were municipalities that only serviced their own territory, which could continue as before. Furthermore, the Electricity Act provided a legal ground for the Electricity council. Hence, it mainly consolidated ongoing practices, and added the possibility to later prescribe conditions for effectiveness, safety, and solidity of electrical installations per executive decree[38].

Before the Electricity Act the only regulation in the energy sector was self-regulation of the quality of electric installations and devices via the in 1927 founded Inspectorate for Electrotechnical Materials (KEMA). This organisation secured a high standard in terms of solidity and safety of electronics.

In conclusion, when electricity technology was introduced, no regulations other than concession rules of the local government applied. Only in 1938 national legislation was passed to provide a legal framework and enshrine in law what had become common practice. However, this Electricity Act confirmed what had been reality for nearly two decades: the provincial concession system meant the end of the institutional space for energy cooperatives.

5.4.3. Actors and networks

The first actors in the Dutch electrification niche were small-sized private companies[38], which were mostly self-generating factories (often already in possession of a steam machine) and so-called block centrals that serviced a continuous housing block and did not cross streets. The first example of an electricity plant servicing private users in an area larger than a housing block was the Electrische centrale Kinderdijk that became operational in 1886 and had 350 connections (every lamp counted as a connection).

The municipal government was initially only involved in granting concessions. It did not become active on the developing electricity market as it was not yet confident about the future of electricity. Furthermore, in localities that had been connected to a gas grid, it feared competition for the (municipal) gas factories[39].

However, soon when electricity technology matured and demand grew, the local government became gradually more interested, and in 1895 Rotterdam first started a municipal electricity company. Between 1900 and 1910, nearly all larger cities started a municipal electricity company. From this time on, the number of municipalitie energy companies grew and municipalities became the main player on the electricity market. Yet, between 1895 and 1914, most electricity companies were actually established in small cities under 10.000

inhabitants. Main reasons for this twofold development were that an electricity grid was more viable for vast municipalities, but smaller municipalities more often did not have a gas factory, which constrained concession possibilities and created competition as gas was still cheaper.

Among these smaller municipalities were some where the first electrification cooperatives were established. This development electrification cooperatives was part of a wider reaction between 1880 and 1920 to Liberalism and the strong market economy that dominated in Europe at landscape level [40]. Cooperatives, and other types of collective action initiatives such as cultural and sports associations and trade unions, witnessed a steep rise due to discontent with the power of capitalistic producers and resultant inequality[40].

In the period with municipal electrification, few common interests existed among electricity companies. However, when the electricity provision became more widespread a need developed to organise collectively and explore aspects important to future of the energy system in committees. To this end, the Association of Directors of Electricity Companies in the Netherlands was founded in 1913. Its members were the directors of the larger electricity companies. Small electricity companies such as first electrification cooperatives were no member of this association and functioned relatively isolated within their territory.

The take-off of use and the rapid advancement of electricity technologies stimulated upscaling and concentration of energy production[39]. This led to the development of regional grids that were fed by a central larger-scale production facility. At this point, the provision of electricity started to shift from municipal (private company, cooperative, municipally-owned) to provincial companies.

Between 1914 and 1925, all provinces except Drenthe and Zuid-Holland established a provincial energy company[39]. Drenthe was serviced partly from Overijssel and partly from Groningen. In Zuid-Holland, several large municipalities collaborated and set up regional provision. North-Holland, Friesland, and Groningen had provincially owned companies. In Overijssel, the two most important facilities were in the hands of the Province and a few municipalities. In the remaining provinces, a private company (N.V.) was set up, of which the shares were held by the provinces.

As a result of the increased activity of provincial governments in the energy sector, the number of municipal energy companies and private and cooperative initiatives decreased. The private companies, such as the cooperatives, were increasingly sold to a governmental energy company or their concession did not get extended when the local government wished to start their own electricity company. Table 5.1 shows the development of the distribution of municipal electricity providers between 1922 and 1949, and shows how private and cooperative initiatives declined when regional energy provision by the provinces became more common.

Table 5.1: Overview of energy suppliers (adapted from [38]).

Year	Total number of municipalities	Municipalities where the municipality supplies (and % that outsources technical or administrative work)	Municipalities where the provincial government holds the concession	Municipalities where a private company or cooperative holds the concession	Municipalities without supply of electricity
1922	1073	588 (42%)	96	52	337
1931	1077	464 (38%)	629	17	27
1940	1050	285 (26%)	743	16	6
1949	1014	242 (30%)	756	11	5

At the end of the 1920s, the actor constellation was expanding as the urge to regulate electric power grew. To secure the quality of electric installations and devices, in 1927 the Inspectorate for Electrotechnical Materials (KEMA) was founded[39] by the VDEN. Furthermore, in 1933, the electricity council was installed by the minister of Water works and was tasked with advising the ministry about electricity provision[38].

In the early 1940s, the upscaling slowed down and the focus shifted to coupling regional grids into a national grid. In 1948, the organisation Collaborating Electricity Production Companies (SEP) was established to promote a national interconnection network[39].

All in all, electrification started as the effort of relatively locally operating actors such as cooperatives, private companies and municipalities. Over time the electrification niche went beyond local experiments and when electricity became a viable competitor the actor-network expanded. Enabled by national legislation provincially-owned companies increasingly pushed the local players out of the market. When electricity became a viable competitor on the energy market, the part of the emerging proto-regime with municipal level actors, such as the cooperatives, ceased to exist.

5.5. The cooperative electrification niche

Established for the electrification of their locality, many of the cooperatives had names such as “cooperative association electricity plant (place name)”, or “cooperative association for electric lighting”, “cooperative association for the provision of electricity in (place name) and its surroundings”, or “cooperative association electricity plant for lighting in (place name)”.

Many of the cooperatives’ names underline that the electricity they provided was initially, primarily used for electric lighting of their members’ properties. The members of these cooperatives were mainly households and sometimes also local businesses. Therefore, these cooperatives can be defined as consumer cooperatives, which are enterprises owned by consumers and managed democratically, aiming at fulfilling the needs and aspirations of their members. The ones that produced electricity for use by their members can be described as prosumer cooperatives.

We found that, between 1905 and 1929 at least 83 electrification cooperatives were established, mainly concentrated in the provinces Friesland and Drenthe. The temporal and geographic trends of the development of this part of the electrification niche are discussed in the remainder of this section.

5.5.1. The emergence of electrification cooperatives (1905-1929)

In this study, we found that between 1905 and 1929 at least 83 electrification cooperatives were established (see figure 5.3). Their names, year of foundation, and location are listed in appendix D. The development of these cooperatives was part of a wider reaction between 1880 and 1920 to Liberalism and the strong market economy that dominated in Europe at landscape level [36]. Cooperatives, and other types of collective action initiatives such as cultural and sports associations and trade unions, witnessed a steep rise due to discontent with the power of capitalistic producers and resultant inequality[36].

The majority of these were founded between 1910 and 1920 (see figure 5.4). The small dip between 1915 and 1917 was likely due to the political and economic unrest at landscape level caused by World War I, in which the Netherlands remained neutral. In 1918, at the end of the war, the number of cooperatives boomed with 32 newly founded cooperatives. A possible explanation for this boom is that the preparations for these cooperatives had been taken in the previous years, or they were possibly already operational, and the cooperatives were incorporated after stability improved when the war ended. After 1929, no new electricity cooperatives were founded.

Figure 5.3: Spatial distribution of Dutch electrification cooperatives.

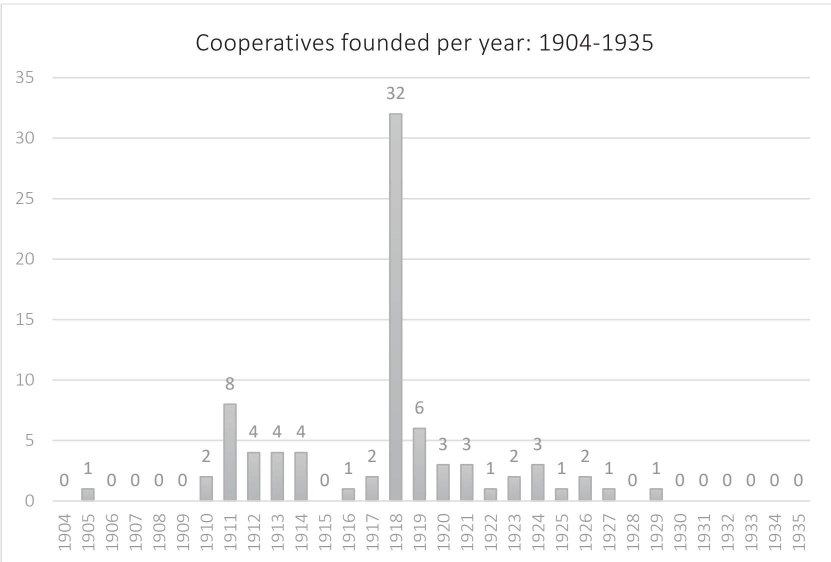

Figure 5.4: Emergence of electrification cooperatives.

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A distinction can be made between cooperatives that both generated energy and distributed it, and the ones that only did distribution[1] (see figure 5.5). Based on the statutes of the cooperatives, at least 68% of the cooperatives established an energy production installation and a distribution grid. These cooperatives were founded by collectives of wealthy farmers, peat extractors and the local middle and upperclassmen such as craftsmen, hotel owners, publishers, directors of factories, salesmen, teachers, bakers, doctors, and mayors. Another 27% functioned only as distribution company and bought electricity from another company. These cooperatives either had a contract with a designated electricity plant (cooperative or private) or with a factory. The other cooperatives had a contract with a (cooperative) factory that dimensioned its system to provide electricity for own use as well as for broader electrification of the locality. The distribution cooperatives were often established by larger groups of villagers, also including gardeners and workers, as they needed to guarantee a certain use from the start. Of the last 5% we cannot be sure whether their activities encompassed both production and distribution, or distribution only (based on their memorandum and articles of association).

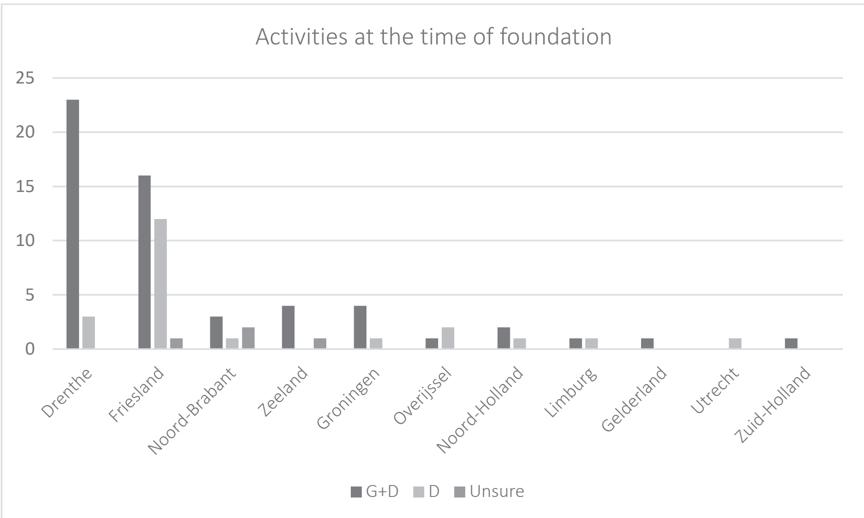

Figure 5.5: Activities of the electrification cooperatives at the time of foundation, as found in the memoranda of association.

Interestingly, the electricity cooperatives were not evenly spread over the Netherlands (see figure 5.6). Of the then eleven provinces, Friesland (29) and Drenthe (26) had by far the most

[1] Some of the generation and distribution cooperatives stopped generation at some moment, but kept operating the distribution grid for a longer period of time (see section 5.5.1.2). This development is not included in this graph as no complete data is available on which cooperatives made this change and when they made this change.

electrification cooperatives. Followed by Noord-Brabant (6), Zeeland (5), and Groningen (5).

Why electrification cooperatives developed mainly in Friesland and Drenthe is discussed in detail in section 5.5.1.1 and 5.5.1.2. In the other provinces, early electrification was mainly carried by the municipalities and, in a few instances, by private companies other than cooperatives. Later, the Provinces became the main electricity provider due to regulatory and technical developments in the developing proto-regime (as discussed in section 5.4.3)

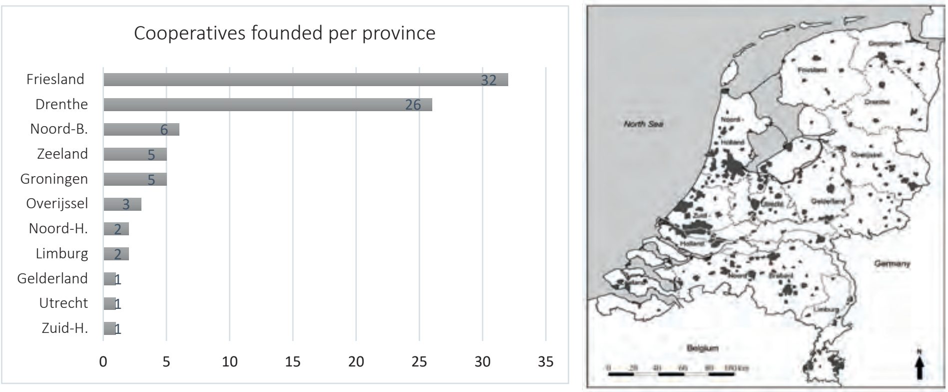

Figure 5.6: Distribution of cooperatives over the Dutch provinces (left), and map of Dutch provinces (right)[41, p. 570].

Between the five provinces with most cooperatives also slight differences in period of emergence of the cooperatives can be seen (see figure 5.7). Over half of the cooperatives in Friesland (62%) was founded before 1915, whereas only 12% of the cooperatives in Drenthe was founded before that year. In Noord-Brabant and Zeeland, the emergence of cooperatives was later still, and took place from 1918 on. Groningen had the first electricity cooperative with the "Cooperatieve verlichtingsfabriek Helpman" (*In English: cooperative lighting factory Helpman*). In appendix E, a small in-depth history of this first electrification cooperative can be found. Groningen's second and third cooperatives were founded five years later, and the province did not experience the emergence of a comparable number of cooperatives as Drenthe and Friesland, the other two northern provinces.

In Zeeland and Groningen, no cooperatives were founded anymore after 1918. In the 3 provinces with the most cooperatives, the emergence of cooperatives continued up to over a decade longer. Noord-Brabant's last cooperative was founded in 1927, and Friesland's in 1925. The last electricity cooperative from this era was founded in Drenthe's Dalerveen in 1929.

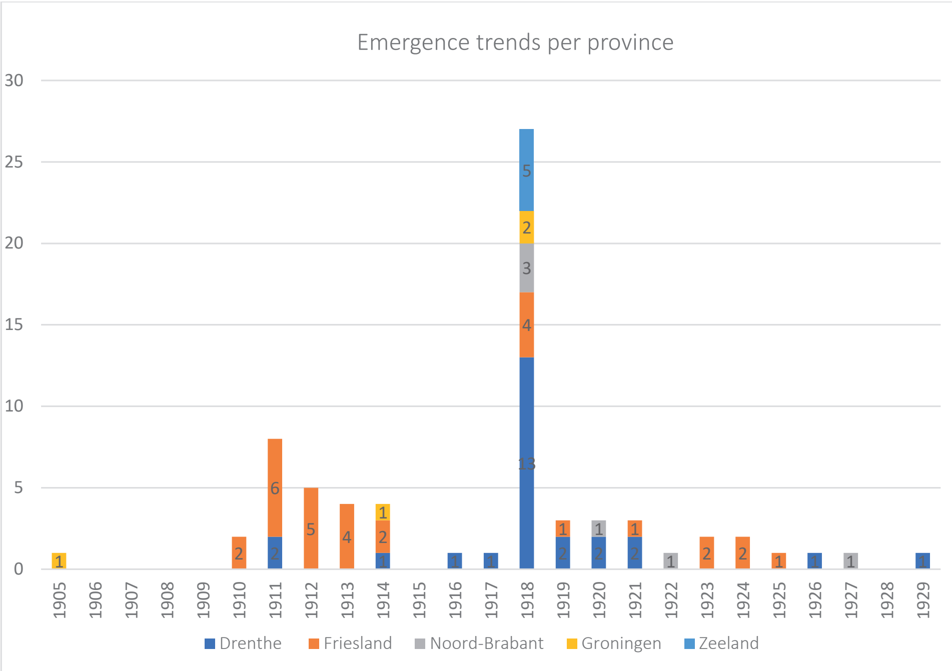

Figure 5.7: Number of cooperatives founded per year in the five provinces with most cooperatives.

Below, we will describe and discuss the dynamics in the two provinces with most cooperatives, Friesland and Drenthe, by placing it in a regional context of grid expansion and other relevant socio-economic, technical and legal developments.

5.5.1.1. Friesland

In Friesland, the first municipal-level, electrification initiatives were cooperatives. Their development sprouted from an anarchistic regional culture. Furthermore, a wish for modernisation of the energy system played an important role, especially in villages that did not have gas yet. Later, distribution cooperatives were founded, which bought electricity from the provincially owned company.

Two cooperative, direct current energy plants were founded in 1910 (Oosterwolde and Kimswerd). Both cooperatives' installations were supplied by the engineering company Doyer & Co. from Rotterdam (after 1910 N.V. Electriciteits Maatschappij Electrostroom), which would later also supply installations to cooperatives in Makkum and Bergum[33].

It started with Oosterwolde. Doyer & Co. wanting to expand its market and had come into contact with a progressive resident of Oosterwolde via touristic promotion this resident did for the local tourist information centre. Furthermore, Oosterwolde had an enthusiastic mayor who was not satisfied with the petroleum lighting in the village. A lighting committee was installed and it was swiftly agreed upon that Doyer & Co. would build the energy plant and get a monopoly position for electricity supply to a designated cooperative that guaranteed a minimal use. After ten years, the Oosterwolde cooperative would get the opportunity to take over the energy supply. When the production started on the 12th of February 1910, the residents of Oosterwolde were so positive about the quality of the light that Oosterwolde provided a boost for the electrification of Friesland[33].

In the next year, six more cooperatives were founded, of which three operated three-phase current plants [42]. One of these was the plant in Bergum, which was described in the local newspaper as ‘a wonderful expression of private initiative, because till today only a few rural municipalities are privileged to have a board, enabled by the government to execute this common goods issue’ [33, p. 61]. That electricity production was perceived as a privilege was not only due to the novelty of the energy source, but also to the limited possibilities for electrification in municipalities with gas production. Many of the early pioneers were among the municipalities without a gas factory, because private gas factories often had a permit that excluded competition with other energy factories for a certain time and municipally-owned gas factories were reluctant because they did not want to compromise municipal income[33].

In 1912, the municipality of Leeuwarden (Friesland’s provincial capital) started generating electricity, and soon started a collaboration for grid extension with the municipal governments of some neighbouring rural villages and the distribution cooperative Noorderlicht from Oudebildtzijl[42].

Around this same time, Friesland got under the spell of electrification. Electrification cooperatives and committees were sprouting in various villages. However, not everybody was pleased with this private initiative. A deputy of the provincial government perceived the proliferation of small plants as a threat to profitable operation due to the limited size of the plants[33]. While a kWh costed 18 cents in Leeuwarden, it cost 44 cents in Oosterwolde. Research commissioned by the provincial government confirmed that it was better to coordinate the electrification. A district-level approach was advised, because a central plant for the entire province was not technically feasible. Still it was estimated that over the coming 6 years 425.000 fl needed to be made available to offset the losses and settle the accounts. Hence, the anarchistic Frisian culture which enabled the rapid spread of electricity in Friesland did not come without a price tag[33].

In 1916, a provincial electricity company was founded and took over from the municipal company of Leeuwarden. In the same year, the provincial government decided that the province would preferably generate electricity and develop and operate a high-voltage transmission grid, and that the municipalities would take on the distribution and install local grids[42]. Hence, in general, from this time on, electrification was done by municipalities and cooperative electrification became more of an exception.

In 1918, the cooperative association for electric lighting of Witmarsum, Pingjum, Arum, and Achlum decided to connect to the provincial grid, stopped its own generation and only continued distribution. Due to the connection, a grid extension was necessary, which provided Tzum with the opportunity to connect. For this, a distribution cooperative was established. In the same year, the cooperatives in Kollum and Kollumerpomp also switched to the provincial electricity company, and stopped the generation in Kollum. Shortly thereafter, they transferred the distribution companies to the municipality. As the Groningen provincial grid was closer than the Frisian, an agreement was made between the two provincial companies to connect these cooperatives to the Groningen grid.

From 1920 until 1922, the provincial high-voltage transmission grid was extended rapidly. The electricity production capacity of the provincial electricity plant was at the time 6500kW. In 1923, it slowed down due to the lack of financial means of municipalities because of the economic downturn caused by the German hyperinflation crisis (landscape development). By the end of 1924, the electrification by municipalities speeded up again.

All in all, the largest and strongest municipalities were connected first, and when the connection movement slowed down, only parts of villages were connected. The exploitation of the distribution grids was not easy at the countryside. The dispersed living residents created a need for vast networks that were expensive in maintenance and operation. The actual use was initially low, and therefore, the fixed costs of interest and depreciation made up a large share of the kWh price, and led to high electricity prices.

At times, the provincial energy company took the administrative and technical responsibility (after an agreement with the concerning municipality) for the distribution grids. However, the provincial electricity company generally only took on the exploitation of distribution grids after the municipality or a specifically for this purpose established cooperative guaranteed a certain minimum use, that guaranteed the profitability[33].

5.5.1.2. Drenthe

In the province of Drenthe, the first energy companies were also cooperative initiatives. Other than in Friesland, electrification progressed rather slowly compared to the rest of the Netherlands. The Province was not interested in having its own electricity company, which resulted in electrification from other provinces. As this process took some time, cooperatives were well positioned to supply electricity in the meantime.

The first two cooperatives were in founded in 1911 in Beilen and Dalen[43], [44]. In the provincial capital, Assen, some companies and institutions already had their own electrical installations[45], but the cooperatives were the first suppliers that serviced a small municipal market of households and local businesses. From 1901, there had been requests to build an electric plant in Assen, but these were turned down by the municipality that feared competition with the municipal gas factory.

The province of Drenthe was not interested in a concession from the national government. Therefore, its territory was split among two concession holders[46]. In 1913, the province of Groningen received a concession for Groningen based on the condition that the sparsely populated part of the northern part of Drenthe and the eastern part of Friesland would also be electrified where profitable. This happened through a distribution grid company to which all municipalities in the concession area, save a few exceptions, outsourced the electrification. The provinces initially financed the infrastructure and later offered loans to the municipalities. The municipalities only needed to finance the operation of these distribution grids and carry the risks. Due to this attractive construction and the impossibility to establish electricity companies without a permit of the Province of Groningen from 1913 onwards, only few electricity cooperatives were established in the north of Drenthe.

Only five years later, in 1918, the N.V. Electriciteits-Maatschappij Ijsselcentrale from Overijssel, was bound to expand its concession area with the south of Drenthe when its national concession from 1914 for the province of Overijssel expired and had to be renewed[46]. In the same year, the Province of Drenthe became shareholder of this company. The company initially only slowly expanded its grid in the direction of Drenthe, because the disappointing financial results that prohibited extension.

Because of the long wait for connection, quite a few cooperatives were established in the north of the concession area in the relatively wealthy peat colonial area[37]. The step to cooperative electricity in this area was not a large one due to the history of cooperative enterprising. This area had a group of well-organised, wealthy farmers who could collectively get loans for financing cooperative factories of considerable size due to their land possession[47].

Many of these cooperative companies ended production when they were connected to the regional grid[46]. Some even had this condition specifically in their memorandum of association. The cooperative in Dalen was one of the exceptions that remained operational for a longer time, and functioned as distribution cooperative until 1959 and profited of the economic advantages of owning the local distribution grid. Appendix E contains a short history of this cooperative as it must have been one of the longest surviving cooperatives: We cannot be sure it was the last operational electrification cooperative as we do not have dissolution dates for most cooperatives. We do know only 11 cooperatives/private companies were still in charge of municipal energy provision by 1949 [38]).

Thus, the cooperative electrification niche in the Netherlands was not a homogenous part of the wider electrification niche. Motivations to form a cooperative differed from early enthusiasm, to a wish to be connected sooner than the regional grid would reach the locality, and guaranteeing minimal demand to be connected to the provincial grid. Furthermore, the cooperative electrification niche also developed very heterogeneously in terms of temporal and geographical patterns depending on a combination of, amongst others, local enthusiasm for electricity, pre-existing local collective action capacity, regional familiarity with the cooperative model, demand for electricity (based on socio-economic status of residents as well as the presence of electrifiable economic activities), presence of a competing gas factory, interest of the respective provincial governments to become involved in electricity production, direction and pace of first municipal and later provincial grid extension.

5.6. Conclusions and discussion

The electrification cooperatives were central actors within the electrification niche during its development to regime. We analysed how their emergence and decline was related to the dynamics in the forming proto-regime regarding rules, actor constellations and technologies. We focused on the time period 1900-50 as during this period electricity technology evolved from newly commercially available to matured and well-embedded in an own regime within the energy sector. Here we conclude on how the cooperative electrification niche developed and how it disappeared, as well as its role during the Dutch electrification. Furthermore, we reflect on the theoretical implications of the study for the MLP literature.

5.6.1. Emergence and decline of electrification cooperatives

Among the 83 energy cooperatives founded between 1905 and 1929, we found distribution cooperatives and integrated production and distribution cooperatives. The cooperatives were established by the societal upper and middle class. The distribution only cooperatives were often founded by more diverse groups of villagers, also including gardeners and workers, as they needed to guarantee a certain 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 in this period by the municipalities or, in a few instances, by other private companies. From about 1914 onward, the Provinces or provincially-owned companies were increasingly in the lead.

The emergence of the cooperatives in Friesland took off rather early in the electrification of the Netherlands in a regulatory vacuum. From 1910-1916, only the permission of the municipal government was required for a permit. Cooperative electricity was orchestrated by villagers used to undertake collective action in the province's remote rural communities. Many of early electrifying villages did not have a private or municipal gas factory yet, and therefore, were not inhibited by competition restriction clauses or the threat of municipal income loss. The cooperatives founded after 1916 were mainly distribution cooperatives that formed to guarantee enough 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 of local and provincial governments, and the slow connection to the regional grids of the neighbouring provinces. Initiative took mainly place in the wealthy peat extraction area. Farmers in this area had a history with cooperative enterprising in the agricultural sector, and were able to collectively secure loans for significant factories processing agricultural produce. The familiarity with the cooperative model in agriculture in both provinces will have made the step to cooperative electricity smaller.

The electrification cooperatives started to disappear when the advantages of upscaling became larger and the regulation put the mandate for energy provision with the provincial government. By about 1914, production by larger energy plants became more economical and reliable due to technological development of electricity technology[35]. Due to the exclusive right of provision the provinces got via national government concessions, it was impossible for the electrification cooperatives to remain competitive by upscaling their production capacity and supply beyond their own municipality. Hence, when their permits ended, or earlier, they stopped their activities and sold or handed over their infrastructures to a provincial company. Some still functioned as a distribution cooperative for a period of time before being dissolved, and could negotiate better tariffs due to their own grid. By the 1930s, nearly all energy cooperatives had ended their operations for these reasons[38]. The cooperative in Dalen was one of the exceptions that remained operational for a longer time, and functioned as distribution cooperative until 1959 and profited of the economic advantages of owning the local distribution grid.

5.6.2. Role of energy cooperatives during the electrification

The electrification cooperatives mainly played a role in the dispersion of electricity systems during the development of commercially usable electricity from a niche market to a more stabilized regime with wider networks, more regulation and matured technologies. In Friesland, the pioneering energy cooperatives from before 1916 enabled rather early accessibility of electricity for small villages. The later Frisian distribution cooperatives functioned to shift risk of installation and operation of a distribution grid to the users by requiring minimum use. The cooperatives in Drenthe also helped the dispersion of electricity within this rural area, and resulted in earlier provision of electricity than if had been waited for grid extension of the regional grid from the neighbouring provinces.

Whereas these cooperatives were not involved in technological advancement of the technologies, they were very much experimenting with the domestication, the embedding of this new source of energy in the daily life. Electricity changed many existing production and household routines, and enabled many new practices for its users who previously used petroleum, candles or gas. For instance, time was saved to light a lamp, less frequent cleaning was needed, and household activities such as ironing became simpler. On the other hand, reliability of provision was not always high, availability of electricity especially in the evening limited, so limiting use was highly encouraged and sometimes some applications were even forbidden during certain hours. Furthermore, like with other energy sources electricity needed to be handled safely and also new practices for this needed to be developed by its users.

Thus, the electrification cooperatives mainly helped the dispersion of electricity technology, improved the accessibility of electricity in rural areas, and helped the familiarization with this new energy source.

5.6.3. Theoretical contribution and reflection on proto-regime concept

From our study, we can conclude that niches can function as heterogeneous innovation environments where the development, diffusion and embedding of niche technologies can take place by different actors, at different paces, and in different ways across different localities.

The concept proto-regime that we operationalised as consisting of the three interlinked elements rules, actors and technologies was useful to study the development of electricity from niche market to a regime. It showed how the niche for electrification was characterised by a lack of regulations that provided institutional space, technologies that were suitable for the local level without potential for economies of scale. Resultantly, actors were at first local players such as the cooperatives, and private and municipal companies. By mapping out the development of the proto-regime it became apparent why the number of electrification cooperatives began to decrease. Mapping showed how due to the provincial concession system that was enshrined in national legislation the provinces became the designated actor for energy provision. Also, the rapid technological developments made it difficult for energy cooperatives to remain competitive as production at a larger scale started to equal lower energy prices. Hence with this operationalisation, the proto-regime concept is useful to explain the emergence, development and decline of niche phenomena.

When reflecting on the development of the cooperative electrification niche in relation to proto-regime development as described by Smith et al. in figure 5.2[28], we can furthermore conclude that the electrification cooperatives played an important part in the first two steps: the start of experimentation by the regime and landscape and local experimentation supported by local networks. However, when local lessons got translated into generic rules, these rules did soon not favour small-scale systems anymore but stimulated provincially sized companies and centralized production. So, when these newly developed rules such as the provincial concession system informed new experiments, the niche developed in another direction, leading to the downturn of cooperatives.

An important theoretical insight that can be derived from this observation is that local experimentation energy cooperatives still played an important role in the historical energy transition towards electricity. Hence, without becoming a dominant player in the regime, energy cooperatives can still have a transformative role in an energy transition. As aforementioned, the electrification cooperatives did not only inform learning in the proto-regime as experiments, but, thereby, also improved the accessibility in rural areas of an innovation that not only literally but also figuratively lightened the work.

Appendix D. Overview of electrification cooperatives

Table D1 presents an overview of the year of foundation, location, province, and activities of the identified Dutch electrification cooperatives.

Table D1: Overview of electrification cooperatives

#	Year	Name	Location	Province	**Activity** (generation/ distribution /unknown)
1	1911	Coöp. ver., „Electr. Centr. Beilen”	Beilen	Drenthe	G
2	1911	Coöp. Ver. Electr. Centr. Dalen	Dalen	Drenthe	G
3	1914	Coöp. Ver. voor Electr. Centr. Verl. van het dorp Emmen en omgeving	Emmen	Drenthe	G
4	1916	Coöp. Ver. Electra te Emmercompascuum	Emmer-Compascuum	Drenthe	G
5	1917	Coöp. ver. Electr. Centrale Sleen	Sleen	Drenthe	G
6	1918	Coöp. Electrische Centrale	Borger	Drenthe	D
7	1918	Coöperatieve Vereniging Electrische Centrale voor Klazienaveen en Omstreken	Klazienaveen	Drenthe	G
8	1918	Coöp. Ver. voor Electr. Centrale verlichting van de omgeving derde Kruismond Nieuw-Weerdinge	Nieuw-Weerdinge	Drenthe	G
9	1918	Coöp. Ver. Electr. Centrale “Noordbarge”	Noordbarge	Drenthe	G
10	1918	Coöp. Ver. Electrisch Licht gem. Norg	Norg	Drenthe	G
11	1918	Coöp. Electrische Centrale Odoorn	Odoorn	Drenthe	G
12	1918	Coöp. Vereeniging ,,Electrisehe Centrale Oosterhesselen”	Oosterhesselen	Drenthe	G
13	1918	Cooperatieve electrische centrale voor de gemeente Schoonebeek	Schoonebeek	Drenthe	G
14	1918	Coöp. Electr. Centrale Valthe	Valthe	Drenthe	G
15	1918	Coöperatieve Vereniging Electrische Centrale te Valthermond en omstreken	Valthermond	Drenthe	G
16	1918	Coöp. ver. Electr. centrale Weerdinge	Weerdinge	Drenthe	G
17	1918	Coöp. Ver. voor Electrische Centrale verlichting ,,De Eersteling’” van het dorp Weerdingerveen	Weerdingerveen	Drenthe	G
18	1918	Coöp. Ver. Electr. Centrale Westerbork	Westerbork	Drenthe	D
19	1919	Coöperatieve vereniging electrische centrale Koekange	Koekange	Drenthe	G
20	1919	Coöp. Ver. Electrisch Licht gem. Smilde	Smilde	Drenthe	G
21	1920	Coöp. Ver. „Electrische Centrale Nieuw-Weerdinge Een”	Nieuw-Weerdinge	Drenthe	G
22	1920	Coöp. Ver. voor Electrische Centrale Verlichting Van het dorp Westenesch	Westenesch	Drenthe	G

#	Year	Name	Location	Province	Activity (generation/ distribution /unknown)
23	1921	Coöp. Ver. Electr. Centrale „Eerste Kruisdiep en Omgeving" te Nieuw-Weerdinge	Nieuw-Weerdinge	Drenthe	G
24	1918	Coöp. Ver. voor Electr. Centrale Verlichting van het dorp Roswinkel	Roswinkel	Drenthe	G
25	1918	Coöp. Ver. Electrische Centrale Wachtum W.A.	Wachtum	Drenthe	G
26	1929	Coöp. Electriciteits-Maatsch. „Dalerveen en Omstreken" G. A.	Dalerveen	Drenthe	D
27	1910	Coöp. Ver. voor Electr. Centr. Verlichting	Kimswerd	Friesland	G
28	1910	Coöp. Ver. voor Electr. Centr. Verlichting	Makkum	Friesland	G
29	1911	Coöp. Ver. voor Electr. Centr. Verlichting	Kollum	Friesland	G
30	1911	De Coöp. Electrische Centrale „Bergum"	Bergum	Friesland	G
31	1911	Coöp. ver. voor electrische centrale verlichting „Witmarsum Pingjum Arum"	Witmarsum	Friesland	G
32	1911	Coöp. Ver. voor Electr. Centr. Verlichting	Luinjeberd	Friesland	G
33	1911	Coöp. ver. voor electr. verl. te Ee en Engwierum en omstreken	Ee	Friesland	G
34	1911	Electra, coöp. ver. tot levering en gebruik van electr. stroom	Rauwerd	Friesland	G
35	1912	Coöp. zuivelfabriek	Langweer	Friesland	G
36	1912	Coöp. Ver. voor electr. verlichting, te Kollumerpomp, Warfstermolen, Burum, Munnekezijl en omstr.	Kollumerpomp	Friesland	D
37	1912	Coöp. Ver. ,,het Noorderlicht"	Oudebildtzijl	Friesland	D
38	1912	Coöp. Vereeniging ,,Electra"	Ijlst	Friesland	?
39	1912	Coöp. Electrische centrale Woudsend	Woudsend	Friesland	G
40	1913	Coöp. ver. voor het leveren van Electr. stroom voor verlichting en voor krachtwerktuigen in het dorp Heeg	Heeg	Friesland	G
41	1913	Coöp. Ver. voor Electr. Centr. Verlichting	Boornbergum	Friesland	G
42	1913	Coöp. electr. centr. Oosterwolde	Oosterwolde	Friesland	G
43	1913	Coöp. Ver. voor Electr. Centr. Verlichting de drie dorpen	Terwispel	Friesland	G
44	1914	Coöp. Ver. voor Electr. Verlichting te Buitenpost, Twijzel, Kooten en omstr.	Buitenpost	Friesland	D
45	1914	Coöp. Ver. ,,Electra" ter verkrijging en verdere expl. van electr. stroom	Scharsterbrug onder Nijega	Friesland	D
46	1918	Coöp. ver. tot expl. van Electriciteitsvoorz.	Oosterlittens	Friesland	G
47	1918	Coöp. ver. voor Electrische Verlichting Tzum	Tzum	Friesland	D
48	1918	Coöp. ver. voor electrische verlichting te Anjum en omstr.	Anjum	Friesland	D
49	1918	De Coöp. werkende Ver. tot levering van Electriciteit	Koudum	Friesland	G

#	Year	Name	Location	Province	Activity (generation/ distribution /unknown)
50	1919	Coöperatieve Vereniging tot Electrische Verlichting te Ameland	Nes	Friesland	G
51	1921	Coöp. Ver. ,,Electra"	Barradeel	Friesland	D
52	1923	Coöp. Ver. voor Electriciteitsvoorziening van het dorp Oldeberkoop en omgeving	Oldeberkoop	Friesland	D
53	1923	Coöp. Ver. voor de Electriciteitsvoorziening in den Kring Oranjewoud	Oranjewoud	Friesland	D
54	1924	Coöp. Ver. voor de Electriciteitsvoorziening te Beneden- en Bovenknijpe en 't Meer	De Knijpe	Friesland	D
55	1924	De Coöp. Electrieiteitsvoorziening in het dorp Akkrum	Akkrum	Friesland	D
56	1925	De coöperatief werkende vereeniging. Licht en Kracht, W.A.	Hemelum	Friesland	D
57	1918	Coöp. Ver. Electriciteitsvoorziening	Oldebroek	Gelderland	G
58	1905	Coöp. verlichtingsfabriek, Helpman	Haren	Groningen	G
59	1914	Electr. Centrale Ter Apel	Ter Apel	Groningen	G
60	1918	Cooperatieve vereeniging electrische centrale Barnflair	Barnflair	Groningen	G
61	1918	De coöp. ver. voor electrische centrale verlichting	Holwierde	Groningen	D
62	1918	Coöp. Ver. Electrische Centrale Vlagtwedde	Vlagtwedde	Groningen	G
63	1919	Coöp. Electr. Distributie Centrale	Baarlo	Limburg	D
64	1919	Coöp. Ver. Electrisch licht	Roggel	Limburg	G
65	1918	Coöp. Electrische Centrale	Baarle	Noord-Brabant	G
66	1918	Coöp. Electr. Noodverlichting	Drimmelen	Noord-Brabant	G
67	1918	Coöp. Ver. tot verschaffing van electrisch licht te Wouw	Wouw	Noord-Brabant	G
68	1920	Coöp. Ver. tot verschaffing van electr. licht	Chaam	Noord-Brabant	?
69	1922	Coöp. Electrische Stroomvoorziening	Zevenbergschenhoek	Noord-Brabant	D
70	1927	Coöp. Ver. tot Electrificatie van Den Hout (G. A.)	Den Hout	Noord-Brabant	?
71	1917	,,Electra", Coöp. ver. ter voorziening in de electrische verlichting van Edam	Edam	Noord-Holland	D
72	1918	Coöperatieve Vereniging Electrische Centrale Verlichting	Oosterend	Friesland	G
73	1918	Coöp. Ver. tot stichting en instandh. eener Electr. Centrale te Hippolytushoef op Wieringen	Wieringen	Noord-Holland	G
74	1918	Coöp.Ver.voorelectrischeverlichting	Ambt-Vollenhove	Overijssel	G
75	1919	Coöp. Ver. Electriciteitsbedrijf	Tubbergen	Overijssel	D
76	1924	Coöp. Electriciteits-Onderneming „Gramsbergen en Omstreken"	Gramsbergen	Overijssel	D
77	1918	Coöp. ver. „Electra" voor Kockengen en Laag-nieuwkoop	Kockengen	Utrecht	D

#	Year	Name	Location	Province	Activity (generation/ distribution /unknown)
78	1918	Coöp. Ver. voor Electr. Centrale Verlichting te Nieuwedorp en omgeving	Nieuwedorp	Zeeland	G
79	1918	Coöp. Electriciteits-Bedrijf voor Kapelle	Kapelle	Zeeland	?
80	1918	Coöp. Electriciteeitsmaatsch. Scherpenisse	Scherpenisse	Zeeland	G
81	1918	Coöperatieve Electriciteits Maatschappij	Sint Maartensdijk	Zeeland	G
82	1918	Coöp. Electriciteitsmaatsch. St.-Pliilipsland	Sint-Philipsland	Zeeland	G
83	1926	Coöp.Electrische Centrale W.A	Stellendam	Zuid-Holland	G

Appendix E. Two detailed examples of electrification cooperatives

In this appendix, we provide a detailed description of the development of two forerunners from our sample of cooperatives on which detailed information is available. By providing short histories of these cases, we would like to provide a better understanding of the functioning of the Dutch electrification cooperatives. The first case is the earliest electrification cooperative located in Helpman, and the second one of the longest operational cooperatives located in Dalen.

1. A risky novel product: Cooperative lighting factory Helpman

The first electrification cooperative "lighting factory Helpman" is an example from the early stage of electrification when electricity was still a high-cost and rather unreliable good, because the electricity technology was still in its infancy. Yet, at the same time, electricity had already acquired the status of a luxury good. It was perceived as a beacon of progress and modernity, because it was cleaner and safer than petroleum and candle lighting which were more common at the time.

The cooperative lighting factory Helpman was established on the 21st of April 1905 [48]. The initiative was founded because the municipality energy company of Groningen (the province of Groningen's eponymous capital) did not want to supply energy to Helpman, fearing that it would encourage commuting [42]. The initiators of the cooperative were Jan Evert Scholten, owner of the agro-industrial Scholten-group, and Willem Albert Penaat, chief executive officer of the Sikkens paint factory. Their ambition was to electrify 1000 villas and houses of the bourgeois in Helpman, among which the houses of the initiators themselves. Hence, the target group were the most affluent residents of Helpman, at the time part of the village Haren. Friends and business acquaintances of the initiators were enthused to buy shares of 100 f, which translates to about €1.267,84[3] [48].

They requested a building permit at municipality of Haren to build an electricity plant nearby in the Emmastraat [48]. A complaint was filed by a resident living nearby, because the plant would disturb the peace in the neighbourhood and might increase the chance of lightning strikes. The labour inspection declared the complaint ungrounded, and the municipal government provided a concession for electricity supply for 10 years.

The total of the starting costs for the electricity plant were f 42.000,-, or about € 532.

493,74 euro [48]. With this capital, two piston engines of 28 HP were bought to power two Swiss generators with a joint capacity of 54 kWh. Furthermore, a room with accumulators and a dynamo for storage of the electricity was built.

In 1906, supply started to many of the monumental villas and an inn, which together represented 55 connections [48]. The electricity net then had a length of about 1200 m, and could hardly be extended because the concession specified that the voltage could not be higher than 110V. At 110V thicker cables are necessary to avoid energy loss, which is expensive.

The supply was not that reliable, and especially in the winter months, the users were regularly left in the dark, and needed to return to candle and petroleum lighting. Thus, many users who needed a new connection turned to the municipal electricity company of Groningen when it became possible, because the municipal electricity company had a higher performance reliability[48].

Not only did the cooperative lighting factory have a competitor early on, but it faced other obstacles as well [48]. Due to the rapid developments in the field of electricity technology, the factory soon got outdated. Furthermore, it could not compete with the municipal, and from 1914 also the provincial, electricity company. Finally, in 1915 Helpman had become part of the municipality of Groningen, and the chance of renewal of the concession was therefore very low.

All these factors led to the decision to sell the grid and the then 68 connections, meters, and street lighting to the Groningen municipal electricity company for f 10.000,- [48]. A share in the electricity cooperative was by then worth only f 17,50,, in contrast to the f 100,- at its start. After the public sales of the factory in café-restaurant De Passage, the machines and the inventory, the shareholders celebrated that a part of the industrial revolution had become history over a festive meal.

2. A rural location: Cooperative association electric plant "Dalen"

The cooperative association electric plant "Dalen" (in Dutch: Cooperatieve vereniging electrische centrale "Dalen" W.A.) is an example of a cooperative that was established in a locality that was deemed too unprofitable for private investors. Dalen was at the time a small, agricultural village (3900 inhabitants in 1925[49]).

The cooperative association electric plant "Dalen" was established on the 9th of August 1911[44]. According to its statutes, the aim of the cooperative was realising lighting in- and outside the house, and supplying electricity to power units in the village of Dalen. It had permission to function for 30 years, to be extended if desired by the cooperative[44].

The cooperative association in Dalen had been founded by its first board that consisted of an alderman of the municipality, the director of the local, cooperative dairy factory, a farmer, a baker/shop holder, and a carpenter/contractor, who was also electrician and installer. At its start it had 41 members, who were mostly local shop holders and craftsmen [50].

The electricity was generated in the engine room of the local diary factory. The already present steam engine powered a dynamo. Furthermore, there was an accumulator to store energy for night-time use. To distribute the energy, the cooperative constructed an above-ground grid, for which a permit was granted by the ministry of Water management. Furthermore, the cooperative was responsible for installing the meters and checking the usage, but the infrastructure at the properties of the users such as power lines came at the users' expense. The infrastructure the cooperative owned was financed through a loan of f 18.000 [50].

The opening of the plant took place on the 22th of December 1911 in a hotel with a festive, yet modest celebration with the mayor and the city council, the minister of the church, and the board of the steam diary factory. After this, the electric street lights were put on and the board of the cooperative went around in the village and destroyed the old petroleum lights with stones [50].

Over the years the number of members grew steadily. An annual report describes how after 20 years the cooperative had 263 members to whom it supplied electricity for light, and 7 users to which it supplied power for electrified production processes (such as threshing, baking, and forging)[51].

To reduce the cost of the electricity and make it possible to extend the grid, several technological improvements were implemented [50]. To improve the ratio coal used to energy generated, the chimney of the factory was enlarged. In 1918, the voltage was increased to 220V, which enabled grid extension at a lower price because less cables with a smaller diameter could be used for transmission. In the same year, a switch was made to a gas-fed piston engine, because the price of coal increased and thereby the electricity price. In 1923, the accumulator-battery was replaced.

In the 1920s, there had been several discussions with the large plant IJsselcentrale in the neighbouring province Overijssel to buy their electricity instead of keeping generation in their own hands [50]. The advantages of this would be better light and more reliable provision of three-phase electric power. The costs of the extension of the cable needed to be borne by the cooperative, so the cooperative considered it more attractive to continue generating. However, at the end of the 1920s, due to the bad condition of the battery which would require costly repairs, moving generation to the IJsselcentrale was reconsidered. In 1930, the members of the cooperative voted to buy electricity from the IJsselcentrale and pay the estimated costs for the required grid extension and infrastructural adjustments of f 21.000,-. This was also the moment that the switch to alternating current was made.

The cooperative was from then on solely a distribution cooperative. The transition had been successful and Dalen had an exceptionally low electricity tariff for that time. For instance, light was 25ct per kWh, threshing power 8ct per kWh, and power for the diary factory 5ct per kWh [50].

The cooperative led a quiet life, and only returned to generating electricity for a few months during the second world war [50]. At this time, the transmission losses were very high due to the copper action of the occupier[4]. However, after the war, the cooperative prospered again. It was fully debt-free in 1948 and could extend the grid a few times in the next years.

However, in 1949 disagreement with the municipality arose over the distribution of the costs for a grid extension outside the village [50]. The municipality did not want to pay for the cables and the cooperative appealed to the terms in the concession that did not specify that the municipality could dictate extension. The municipality wanted to solve the problem by selling the distribution grid to the IJsselcentrale.

It became a long-winded affair that was resolved only by the end of 1959 by the sale of the grid and further infrastructure to the IJsselcentrale [50]. In line with the statutes, the profit of the sale was distributed equally among the members. After 48 years, the cooperative the distribution of electricity by the cooperative to its members ended on the 31st of December 1959 by midnight.

[4] During World War II, the German occupier confiscated metal objects for production of weaponry.

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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 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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