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Enacting sustainable transitions: a case of biogas production and public transport in Trøndelag, Norway

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Abstract

The background for this paper was a wish to extend the understanding of how sustainable transitions in sociotechnical systems come about, especially the characteristics of processes and the role of actors. The empirical context was the case of developing biogas production and improving transport in the Trondheim region in Norway. The case consisted of two connected units; establishment of a biogas plant (production side) and development of a sustainable public transport system (use side). As a template for the analysis, the Multilevel Perspective (MLP) on sociotechnical transitions was applied. The core in this perspective is the (sociotechnical) regime level, where changes have to occur in order for sustainable transitions to take place. Central at the regime level is the interaction between actors, technologies and institutions. Transitions can take place if actors experience threats from the external world and have access to niche innovations. Analysis of the case showed that the development first went through a transformation phase (ca. 1990-2009) where R&D actors developed basic technical innovations. In the next phase (2009-2019) there was a reconfiguration process were politicians and market actors engaged. Over the years, this process resulted in significant sustainability outcomes (increased production of biogas and exchange of fossil for biofuels in transport). Three major lessons can be drawn: 1) the crucial role of leadership when it comes to interpreting external changes, timing of actions and coordination of resources, 2) the necessity of new technological innovations and their adoption on regime level, and 3) differentiated state support can develop demand for renewable products and is necessary for compensating extra costs for niche actors.

Keywords: sustainable transport; renewable fuel; bioeconomy; sociotechnical transitions; multilevel perspective

Highlights

Leadership is crucial in sustainable transitions

In leadership, timing of action and coordination of resources is paramount

Innovations take place and must be searched in special environments (niches)

State support can contribute to develop demand and compensate for extra costs

Interaction across regimes opens special possibilities for transition

1. Introduction

Gas produced from renewable biological material (biogas) is of importance because it can contribute to solve societal challenges, such as the need for clean energy and reduced GHG emissions, as well as waste treatment and sustainable business development (European Technology Platforms, 2017; The Lund Declaration, 2009). One reason for this is that biogas is an energy carrier with many possibilities both for production and use (Olsson and Fallde, 2015). However, the realization of these potentials builds on complex processes, which are only partially possible to plan and involve many social and technological factors (Fallde and Eklund, 2015). This is the case for most, if not all, sustainability transition processes (Lachman, 2013; Markard et al., 2012). Analysis of the empirical case in this paper contributes to the wider literature about the understanding of such sustainable transition processes.

Traditionally, biogas has been produced from waste from landfills with heat and electricity as byproducts (Olsson and Fallde, 2015). In recent years, attempts have been made to upgrade biogas to a main product. One of the use sectors is transport. Delivery to this sector requires upgrade of the biogas through various technical processes. Moreover, new types of raw material become available due to the need for waste handling in sectors such as aquaculture, forest industries and agriculture (Lindberg et al., 2016; Richardsen et al., 2015). This has opened business opportunities for entrepreneurial firms. Recent research has shown that business opportunities as well as GHG reductions can be most optimally met if various sectors, such as, waste, energy and transport are integrated, for example, through combining raw materials from different sectors (Lyng et al., 2018). On the other hand, such integration may lead to increased complexity and be demanding when it comes to innovation management (Van de Ven, 1988).

1.1. Aim of the study

This study seeks to fill gaps in the research literature concerning innovation processes leading to sustainable transitions, in particular the role of actors and their enactment in sustainable transition processes. As part of this, there is a need to better understand the role of interaction between multiple systems, such as between bioenergy provision and public transport, for the possibilities for sustainable transitions. As an empirical basis, we present a case story of a sustainable transition that has occurred on regional level over a medium time span (around 10 years). This contrasts with many earlier studies of sociotechnical transitions, which have examined changes over long time spans (50 years or more), often on a national or global scale (Geels et al., 2016; Geels and Schot, 2007). However, a shorter (and contemporary) time span in a more limited geographical setting offers good possibilities for relatively detailed observations and analysis of action aimed at sustainability outcomes across systems of production and use. By applying a sociotechnical multilevel perspective (MLP) to the case, it is possible to transfer lessons from the study to other situations of sustainable transitions. On these grounds, the study contributes novel information relevant not only for academics, but also business entrepreneurs, users of energy, policy makers and funders of research. In order to achieve this objective, two sets of questions were formulated:

1. Process—what characterized the sociotechnical processes leading to sustainable system changes in the case of production and use of biogas in transport?
2. Enactment—what was the decisive role of actors' actions and interactions in this process, and how did they handle challenges and utilize opportunities?

The rest of the paper is outlined as follows: In Section 1.2 the theoretical perspective is presented. In Section 2 the research material and method is described. Section 3 details brief background information on biogas, transport and sustainability challenges. The results are presented in Section 4 as a case story. These are then discussed and put in perspective in Section 5. Finally, Section 6 provides a conclusion with recommendations for research and policy.

1.2. Theoretical perspective

Transition processes involve social as well as technical aspects (Geels, 2004). This means that transitions do not occur only by way of technology, but also through actors' mobilization and adoption of technology. Hence, the interplay between technology and social elements of different kinds is crucial. On this basis, sociotechnical transition theory has emerged as a conceptual framework to analyze and make sense of instances of sustainable transition understood as fundamental shifts in resource use and provision of goods and services (Lachman, 2013; Markard et al., 2012). The multilevel perspective (MLP) in particular has gained much attention in the transition literature (Geels et al., 2016) and has been repeatedly applied in analyses of transitions in the bioeconomy (Bosman and Rotmans, 2016; van Dam et al., 2005).

To explain change mechanisms in transition processes the MLP highlights three levels: niche innovation, regime, and exogenous landscape (Geels et al., 2016). To be termed a transition, changes on regime level must have occurred. The two terms 'system' and 'regime' are related, but not identical. In the MLP, system refers to tangible and measurable elements, such as artefacts, market shares, infrastructure, regulations, consumption patterns, and public opinion. Regime denotes intangible and underlying structures, for example, engineering beliefs, heuristics, rules of thumb, routines, standardized ways of doing things, policy paradigms, visions, promises, and social expectations and norms (Geels, 2011).

The basic triggers of transitions are: a) innovations (e.g. new technologies) often developed in environments (‘niches’) outside regimes, in combination with: b) changes in the landscape external to the regime level (e.g. climate changes, international agreements), and c) interpretations of landscape changes and adoptions of innovations on regime level (Geels, 2004; Geels and Schot, 2007; Ibarra, 1992). Transition processes cannot be foreseen and only partially be planned for. A rough classification of processes can be made based on the “initial state” of niche innovations and landscape factors. For example, if moderate landscape change occurs, such as the gradual introduction of a new climate policy, in combination with the recent development of new types of low emission engine (niche level), actors in a public transport regime may initially react by adopting the niche innovations to solve local problems. This adoption may trigger further, cumulative learning and changes in the basic architecture of the regime. This type of transition has been termed ‘reconfiguration’ (Geels and Schot, 2007) and applies in particular to distributed sociotechnical systems, which function through interaction of multiple technologies as is the case for many sectors in the bioeconomy (Bosman and Rotmans, 2016) as well as the transport sector (Fallde and Eklund, 2015; Krishnan and McCalley, 2016). If niche innovations have not been sufficiently developed transition will follow a transformation pathway. If landscape changes are sudden or extensive (for example war or major migrations) the transition process will follow other pathways; substitution or dealignment/realignment (Geels and Schot, 2007).

To further pinpoint processes of transition this study recognizes that the regime level as well as the niche level are constituted by the three basic elements actors, institutions and technologies. Hence, a certain regime, for example public transport in a region, is a semi-coherent system determined by a certain configuration of institutions, technologies and actors. There are formal institutions (e.g. legal rules) as well as informal institutions (e.g. norms of behavior). Moreover, several technologies may have to be combined. These established configurations of actors, institutions and technologies lead to path dependency and challenges for actors who want to accomplish changes. That is why innovations often are developed by small networks of dedicated actors outside regimes (in niches such as R&D departments, incubators, and by entrepreneurs). Landscape changes in combination with new innovations may eventually lead actors into new pathways (Stack and Gartland, 2003), which may eventually result in regime changes (transition).

Understanding the prerequisites and processes of sustainable transitions obviously requires a systems perspective. Nevertheless, a system focus may lead to the role of the actor dimension in transitions being under-communicated. However, in recent years, transition processes have been studied with a specific eye on the actor dimension. For example, Geels et al. (2016) compared the role of different actors in low-carbon electricity transitions in Germany and UK, and introduced the concept of the ‘enactment of socio-technical transition pathways’. Hence, a crucial element for transition is the way regime actors accomplish institutional changes and connect with actors on niche level concerning technologies (Elzen et al., 2012). Nevertheless, since sociotechnical contexts and pathways vary, e.g. between sectors, there is need for further studies on the enactment of sustainable transitions.

Another observed research challenge concerns the regime level. In many studies one regime is assumed, whereas an investigation of two or more regimes may be required to develop sufficient understanding of the transition. For example, in the case of farmers switching from food to energy production, both the food regime and the energy regime must be included to explain the transition (Darnhofer, 2015). Hence, it seems more fruitful to analyze the *regime level* than regimes per se. Moreover, regimes consist of subregimes. Within a value chain, one can imagine subregimes related to production and use. Geels (2004) identifies five types of subregimes: user and market, technology, science, policy, and sociocultural subregimes. This means that for a transition to occur not only have actors to interact with niches and across regimes, but also within regimes. This may not be an easy task when interests differ (Avelino, 2017). However, through interaction actors from different regimes/subregimes may develop a common interpretation of landscape (exogenous) changes and adopt niche innovations that can benefit all partners (Villanueva et al., 2012) or as stated by Geels and Schot (2007, p. 402) “every transition becomes coordinated at some point through the alignment of visions and activities of different groups.”

2. Materials and methods

Langley (1999) described a number of strategies for the analysis of process data and pointed out that the central purpose was sensemaking. She also advised using multiple strategies and leave room for a “creative leap” in the analysis. This study is built on this advice. The main empirical material was a narrative; a single case consisting of two embedded units of analysis sharing a common context (Yin, 2003). One unit of analysis concerns a use system; development in public transport in the Trondheim region. The other unit of analysis regards provision of fuel, especially development of a factory for production of biogas from waste. In a narrative, the key anchor point is time. A narrative is also useful when the boundaries across cases are ambiguous and the temporal embeddedness is variable, which is typical for sociotechnical transition processes. Moreover, some other strategies were also used. Temporal bracketing was employed to clarify phases in the case story. A visual mapping strategy in form of a table was used to obtain an overview of events in the case. Finally, the analysis applied a templates strategy in that a certain theoretical framework (the MLP) was used to capture generic elements in the case. By combining these four strategies, we secured accuracy through a narrative with sufficient detail (Lincoln and Guba, 1985) and triangulation of different types and sources of data (Yin, 2003). Bracketing, visualization and templates increased the potentials for achieving generality from the analysis (Langley, 1999).

2.1. The case study

Case studies are useful when developing knowledge about complex, dynamic and contemporary phenomena (Yin, 2003). One important reason for this is the possibility to combine different types of data and provide information about the context within which events and outcomes occur. The case chosen for investigation concerned sustainable transition at a regional level with connections to a multitude of sectors: aquaculture, forest industries, biological waste, biogas production, transport, and agriculture. As such, within the MLP this case study can be characterized as a type 2 study, which offers "explanations of trajectories in terms of event-chains and rounds of moves and counter-moves" (Geels et al., 2016, p. 898). The narrative in the case was constructed in chronological order centered on the simultaneous development of a more sustainable public transport system and a new type of fuel production in the Trondheim region. Moreover, both these developments had connections to preceding developments nationally and internationally. On these grounds the story offers a holistic description of a certain development over time which makes it possible to pinpoint connections between seemingly independent events, decisions and outcomes in time and space. The case story was last updated in May 2019.

2.2. Analysis

The writing of the case story represented a first step in the analysis by organizing the various data (see below) into a narrative identifying logical phases in the story. Identification and ordering of main events, decisions and outcomes within the phases represented the next stage of the analysis. Through this, actors' meanings were revealed along with mechanisms and patterns in the transition process. The main part of the analysis consisted in making sense of the case through the application of concepts and models in the chosen theoretical framework (the MLP). This facilitated synthesis into theoretical propositions with general relevance for sustainable transitions (analytical generalization) (Yin, 2003). Based on the research questions, this involved; 1) interplay between landscape factors, niches and regimes over time, and 2) the role of key actors in transition processes. The analysis and theoretical implications of the study are presented in Section 5.

2.3. Data

To build the case, four types of data were used: informant interviews, media coverage, documents and web pages.

Three personal interviews were conducted. In November 2016 both authors interviewed a chief engineer at the Department of Environment in Trondheim municipality. In April 2017 the first author interviewed two managers in the transport company AtB in Trondheim. In October 2018 the first author interviewed the manager of the company Biokraft AS in Trondheim. Each interview lasted between 1 and 1.5 hours. All interviews were audio recorded and transcribed.

To uncover developments between 2009 and 2019, the authors searched for newspaper articles and popular articles in the media database Retriever. The key words 'Biokraft', 'biogass', 'Trondheim', and 'Skogn' were used, and from this 83 items were selected that were relevant to the case. Some reports referred to the same event, but with differing detail. Almost two-thirds of the news items were in the two regional newspapers, *Trønder-Avisa* (35) and *Adresseavisen* (17). The national newspaper *Nationen* had 5 items. The rest were in various local and national newspapers and in trade journals. Going through all the coverage key information was extracted into an Excel sheet sorted by year and date. Information included the title of the item and its key themes, such as descriptions of events, actors, resources, decisions, cooperation, investments, public support and R&D activities.

Relevant documents and web pages were identified through online searches. The first phase of the case story is based entirely on documents—a research report, a government report, and a parliamentary agreement—and web pages of various companies. The third phase is based on a combination of information from company web pages, public reports and interviews. Documents and web pages were also important in the second phase of the case story, in particular, annual reports from companies and the web pages of companies and public actors.

3. Biogas, transport and sustainability

Biogas can be produced from any type of organic matter through digestion. If the organic matter is digested without access to O_2 (anaerobic digestion) the gases CO_2 and methane (CH_4) are produced. Methane can be used for a variety of purposes such as heat, electricity and engine fuel (Olsson and Fallde, 2015). Used as engine fuel, the raw gas has to be upgraded through purification to isolate the methane and compacting through compression or liquefaction. The latter process is more demanding, but advantageous for distribution (Lyng et al., 2018). Furthermore, the rest-products can also be used sustainably and be of potential value; the CO_2 can be used to stimulate plant production in green houses, and the digestate from the fermentation process can be used as fertilizer. This is because the raw material for biogas is biological matter that is part of the carbon- and nutritional-cycle (Ghisellini et al., 2016).

The raw material can come from different sectors of the bioeconomy, such as manure from agriculture, rest-products from forestry, and byproducts from aquaculture. Hence, use of biogas produced from biological rest products opens possibilities for sustainable value creation in the bioeconomy (Geissdoerfer et al., 2018), which according to the EU: "… encompasses the sustainable production of renewable biological resources and their conversion and that of waste streams into food, feed, bio-based products such as bio plastics, biofuels and bioenergy" (Kovacs, 2015, p. 10). In the Norwegian climate policy, biogas produced from waste has status as a carbon neutral source of energy (Ministry of Climate and Environment, 2014). In reality the effect may not be absolutely carbon neutral, but the sustainability gain is clear in cases where biogas substitutes for fossil energy (Brynolf et al., 2014; Fallde and Eklund, 2015; Lyng et al., 2018), and even more so if the rest-products (CO_2 and digestate) are utilized (Vaneeckhaute et al., 2013).

Concerning the transport sector a major challenge in all economically developed countries is the high CO_2 emission levels. In the EU, the transport sector contributed 25.8% of total greenhouse gas (GHG) emissions in 2015 (European Environment Agency, 2018). In Norway, emissions from the transport sector constituted 31% of total GHG emissions in 2017 (Miljøstatus.no, 2018). These emissions increased by 24% from 1990 to 2016. Within the transport sector, road traffic is the source of around two thirds of the emissions and is particularly problematic in urban areas. However, transport is not included in the CO_2 quota system (European Commission, undated), so other measures have to be used to reduce its emissions. Biogas produced sustainably from waste can serve as one effective measure. On the user side this requires relevant technologies, such as buses with suitable engines (Olsson and Fallde, 2015). In addition, there has to be a distribution system for the biogas. In Norway the company AGA, an international distributor of gas, started to deliver biogas in 2008 and by 2014 operated 14 biogas filling stations in eastern Norway (AGA, 2019). Most of this biogas was produced in Sweden, where companies and researchers have worked to develop the use of biogas since the 1960s (Fallde and Eklund, 2015).

4. Case story: Establishing a biogas plant and changing a regional transport system

On September 2, 2018, the world's largest plant for producing liquid biogas (LBG) was officially opened in Skogn, 50 km north of Trondheim by the Norwegian prime minster, Erna Solberg. The plant is owned by the Trondheim based company Biokraft AS. In its first year, the plant will produce 12.5 million "Normal cubic meters" (Nm^3) of biomethane annually with an energy content estimated to 125 GWh. From 2019 the production will be doubled to 25 million Nm^3 of biomethane annually. When replacing fossil fuels, this amount of biomethane reduces GHG emissions on the order 60,000 tonnes CO_2 equivalents (Biokraft AS, 2018). As a residue, the plant produces annually 20,000 tonnes of biofertilizer, which is distributed to farmers in the region. As of May 2019 the raw materials for the production were category II byproducts from fish farming along the Norwegian coast (80%) (Richardsen et al., 2015), and organic sludge from the Norske Skog paper mill (20%) located on the same premises. As such, the factory contributes to handling waste from other bioeconomic producers. The LBG from Biokraft is bought and distributed by the company AGA and sold as fuel to companies operating public buses and, increasingly, heavy trucks for goods transport.

The complex and innovative production at Biokraft Skogn took several years to establish building on biotechnological developments, testing of new combinations of resources, adaptation and exploitation of institutional instruments, and networking with other actors. Development is ongoing. On both the supply side and the demand side, the search for and combination of suitable *technologies* as well as the use and adaptation of *institutional* instruments (such as financial support and taxes) were crucial.

4.1. Niche and landscape developments, ca. 1990–2009

Before the founders of Biokraft took the first steps in 2009, solutions for biogas production had been developing in various countries since the 1940s, mostly in connection to waste handling (Sørheim et al., 2010). Actors in Sweden were pioneers. Sewage plants in Stockholm were already producing biogas in the 1940s (Olsson and Fallde, 2015). Production of biogas as vehicle fuel did not start until the early 1990s. One of the early pioneers was Erik Danielsson who in 1996 founded the company UltraSonus in Öregrund north of Stockholm to test how ultra sounds affected fermentation of biomass for biogas production (ScanBio, 2019). Together with two partners, Danielsson in 2005 established the company later to be named Scandinavian Biogas, which in 2016 became majority owner in Biokraft (see Section 4.2.).

In Norway, the ample supply of renewable energy from hydropower and extensive extraction of petroleum, dampened actors' motivation to establish biogas plants. In addition, infrastructure and use of natural gas for cooking in for example households was never developed. Nevertheless, in the 1990s plants began to be established (Ministry of Climate and Environment, 2014). Most were part of waste handling programs in municipalities and produced heat and electricity for consumption at the plant (Sørheim et al., 2010). However, in 2001 Frevar (the communal waste handling company in the city of Fredrikstad) began producing upgraded biogas from drain mud and food waste for use in vehicles (Frevar KF, 2019). In 2010 BEVAS, the company operating Bekkelaget Renseanlegg (a treatment plant) in Oslo, began to deliver superfluous biogas to public transport (buses) in Oslo (Purac, 2019).

Although some tests of biogas production had been undertaken in Norway since the 1980s, the period 2007-2010 represented a turning point. In 2007 the Government launched a White Paper on climate policy (White Paper No. 34, 2006-2007), and in 2008 an agreement on national climate policy based on the White Paper was reached among all political parties (Akselsen et al., 2008). In 2010 a comprehensive report on biogas was published increasing the interest and strengthening the knowledge of biogas as a primary engine fuel product (Sørheim et al., 2010).

4.2. Production and use: niche innovations and regime changes 2009-2019

The company Biokraft AS was founded in 2009 by Anders Boot and three colleagues with a registered office in Trondheim (Biokraft AS, 2016). (Anders Boot is a fictive name for the real founder.) The founders of Biokraft envisioned creating a large-scale industrial company focused on the recirculation of biological resources and the production of renewable bioproducts. According to Boot, they were not experts in biogas production; rather, their competence was entrepreneurship and industrial organization. For example, Boot had a background as an entrepreneur in the ICT industry. One of the first things the founders did was to visit a farmer in the region, who for a long time had been experimenting with small-scale production of biogas from animal manure.

In 2009–2010 Biokraft mapped various byproducts and waste resources as well as identifying potential supply chains, leading to the establishment of the subsidiary company Biokraft Marin AS in 2010. At the same time, the regional energy company TrønderEnergi became a primary owner of Biokraft. Biokraft Marin built its first factory in 2011. This factory is located by the entrance of the Trondheim Fjord in Agdenes 30 km west of Trondheim and collects category II byproducts from fish farms along the Norwegian coast. Biokraft Marin produces bio oils and bio substrate from these byproducts. In 2013, Biokraft sold the factory to the Trondheim-based company Scanbio Marine

(ScanBio, 2019), with an agreement that Biokraft had the right to buy and use the bio substrate from all the activities in which Scanbio Marine was engaged.

Biokraft considered several locations along the Trondheim fjord for a factory producing liquid biogas. In 2013, the company decided to contract with the forest company Norske Skog to rent part of its plot next to its pulp and paper plant at Fiborgtangen in Skogn, which had a harbor on the fjord. Establishing the biogas factory in Skogn took significantly longer than the managers in Biokraft had anticipated. They planned that the factory would be the largest in Norway, producing 75 GWh of liquid biogas (LBG) annually. By 2013, Biokraft had contacted the public transport administration in the Trondheim region. Boot regarded the regional transport system as one of the factory's most important potential customers, since it served more than 200,000 inhabitants. The municipality of Trondheim, Sør-Trøndelag County, the Public Roads Administration, and the newly reorganized public transport company AtB had formed the state supported partnership "Greener Trondheim" (called "Miljøpakken" in Norwegian) in 2009, the same year Biokraft was founded (Greener Trondheim, 2019). One of Greener Trondheim's main aims was to develop more environmentally sustainable transport in the Trondheim region. Shifting from fossil to renewable fuel was a key element in the strategy, and biogas was to be one of three major types of fuel, along with biodiesel and electricity. In 2009 and 2010, the managers of Biokraft had been in contact with the mayors of Trondheim municipality and Sør-Trøndelag County to inform them about the company's plans for an LBG factory in the region. Boot regarded the responses from these public authorities as positive, and the county was especially interested because it had the overall responsibility for public transport in the region. Moreover, in light of Swedish examples, Boot foresaw trucks and private cars as potential future users of LBG. As raw material for the production of LBG, Biokraft planned to use sludge from Norske Skog's nearby pulp and paper factory and substrate from Scanbio Biokraft Marin's factory in Agdenes.

The particular combination of these two types of raw materials had never been used in the production of biogas before. Boot engaged technical researchers at the Norwegian University of Science and Technology (NTNU) in Trondheim and the company Scandinavian Biogas in Sweden (which later became the majority owner of Biokraft) to test the feasibility of this raw material combination. The testing also included other raw materials, such as straw and wood chips, in preparation for an eventual expansion of the plant.

The forest company Norske Skog was motivated to engage in the Biokraft project because a nearby biogas production would lead to increased value of its byproduct, organic sludge, compared to using it as fuel internally for heating purposes (Norske Skog AS, 2017). Moreover, coordination of the handling of byproducts from aquaculture and forest industry represented an innovation that could reduce the company's costs, according to Olav Dehli of Fiborgtangen Vekst. The site for the plant was a plot at Fiborgtangen with a concession originally given for building a factory for processing natural gas extracted beneath the Norwegian sea outside Trøndelag. Due to its unsustainability and the lack of state support, this factory was never built, but the plot's infrastructure included road, rail and sea access.

In mid-2011, Boot foresaw the start-up of biogas production in early 2013. In early 2012, Biokraft hired an expert on biogas plants as leader of the factory project, and construction of the building was scheduled for the first half of 2012. The planned capacity had now increased from 75 to 125 GWh of biogas annually. A major breakthrough occurred in 2014 when Enova decided to grant 37.5 million Norwegian kroner (around 4 million Euro) in economic support to the project. Enova is an institution established by the Norwegian state to provide economic support to businesses who adopt environmentally friendly technology, that would be unprofitable without financial assistance (Enova, 2019).

Nevertheless, Biokraft had to postpone the plant's start-up date several times, largely because of factors on the demand side. As a consequence of Greener Trondheim, from 2009 the collective bus transport in the Trondheim region became administered by a new, county-owned company AtB. AtB was not authorized to operate buses, but to coordinate the buying and operation of transport services delivered by other companies based on criteria specified in Greener Trondheim. One of the criteria concerned fuel. In 2010, AtB decided that the buses should change from petrodiesel to liquid gas in order to reduce air pollution. EU directives on fuel technology that Norway had to follow pushed for this shift. AtB knew that bus manufacturers could deliver motor technology that used liquid gas and that the same technology could be used for biogas and petrogas, since both burn methane. In 2009, AtB tested compressed biogas (CBG) from a waste disposal site in the region and found that it functioned less well as fuel for buses. The first gas driven buses in the Trondheim region ran on liquid natural gas (LNG) because little liquid biogas (LBG) was available. In contrast to biogas, such as LBG, LNG is produced from fossil (nonrenewable) sources (Soma and Otterlei, 2013).

After the first round of tender in 2011, AtB awarded contracts to three companies: Trønderbilene, Tide Buss and Nettbuss. In August 2011, the companies operated a total of 133 buses that could run on both LBG and LNG. Greener Trondheim financed the extra costs required to make the fuel competitive with petro diesel. The buses could fill up with fuel from a tanking station at the central depot. In the opinion of leading persons in AtB (interviewed on April 7, 2017), the shift from *municipally operated* buses to a *county owned purchasing company* was decisive for changing the fuel technology in the buses and the transition to renewable fuel, although the bus drivers at the outset opposed this organizational change. Eight years later, in 2017, the managers of the bus companies appreciated AtB for the conferences that they arranged before every round of tender, as the companies found the process had contributed to greater innovation and more efficient solutions.

Nevertheless, in October 2013, the chief officer of Sør-Trøndelag County advised that LBG would be too expensive and that the bus companies should continue to use LNG fuel in the public buses. By then around 90% of the buses ran on liquid gas, mostly LNG. The politicians did not approve the chief officer's proposal, however, and decided that Greener Trondheim should negotiate with state authorities to obtain compensation for the additional costs. Some days later, the executive board in Trondheim municipality made the same decision. Just before these decisions, Biokraft had been granted a discharge permit by the Environmental Authorities. Later in 2014, Enova granted an additional 82 million kroner to support Biokraft's planned biogas plant. In November 2014, after a budget compromise (*Budsjettforliket*) between the two ruling parties and their two supporting parties, the Norwegian parliament finally decided to end the tax exemption on LNG in transport (*veibruksavgift*) on January 1, 2016. This step made the price of LBG competitive to LNG. The Liberal Party (*Venstre* in Norwegian), which espoused environmentalism along with its long-time social liberalism, and The Christian Democrats (*Kristelig Folkeparti* in Norwegian) which added climate change to its Christian Democratic concerns were particularly active in effecting these tax changes. Norwegian authorities had to get approval from The EFTA Surveillance Authority (ESA) in order to introduce the tax changes. Given this change in road taxes, in early 2015, Greener Trondheim was willing to enter into a long-term contract with Biokraft to supply LBG. This was the last piece necessary to complete Biokraft's industrial puzzle. In April 2015, three years before the plant opened, Biokraft started to deliver LBG (obtained from a Swedish producer) to Greener Trondheim corresponding to 350,000 Nm^3 of gas annually. One of the operators (Trønderbilene) then proclaimed that it planned to shift to biogas on all its buses. Later in 2015, Biokraft signed a substantial sales contract with AGA. From then on, AGA would buy all the biogas produced by Biokraft and distribute it to customers in Scandinavia. Somewhat ironically, this led to most of the biogas that Biokraft later started to produce (in 2018) being delivered to bus companies in the Oslo region rather than the nearby Trondheim region.

Biokraft could now concentrate entirely on establishing production of biogas and leave the responsibility for distribution to another actor. In October 2015, the Norwegian government even introduced compensation for the extra cost of fueling public buses with biogas. In the following month, Innovation Norway granted Biokraft a low interest loan of 105 million kroner. This came in addition to the total grant of NOK 119.5 million given by Enova the year before.

Construction of the Biokraft plant in Skogn started in August 2015. Plant production involved three processual steps; 1) production of raw gas through anaerobic fermentation with organic bioresidue as the byproduct, 2) purification of the raw gas, removing CO_2 and extracting methane, and 3) concentration of methane through liquifaction by cooling it to –160 C, reducing its volume to 1/600. In dialogue with its financiers, Biokraft decided to contract the procurement of the whole building to Purac, the Swedish company operating among other things waste treatment plants in Oslo. As an expert on biogas fermentation, the Swedish company Scandinavian Biogas was engaged for constructing the first step. For the third step, Purac chose the Finnish company Wärtsilä as supplier. In cooperation with the oil and gas industry in Norway, this company had developed a cooling technology for fossil methane gas that was used in several hundred installations. A postponement of the plant's start-up date was mostly the result of unanticipated events rather than major problems with its technical design. In particular, the soil on the plot turned out to be not consolidated enough to bear the weight of buildings – leading to a need to strengthen the soil at a late stage in the project. Delays in deliveries from one of the subcontractors also contributed to the postponement.

In the case of Biokraft, the digestate from fermentation in step 1 amounted to around 100,000 m^3 of wastewater containing significant amounts of carbon and nitrogen. In 2017, Biokraft invested 30 million kroner in evaporation equipment, which dries the digestate into 20,000 tonnes of biofertilizer. The product has been approved by the Norwegian Food Safety Authority ('Mattilsynet') as fulfilling criteria related to content of environmental toxins, heavy metals and hygiene (Norwegian Food Safety Authority, 2019). In addition, the nutritional content has been determined. The biofertilizer is used by farmers in the area. The biofertilizer serves two functions (Biokraft AS 2018). First, it contributes to maintaining the carbon balance in the soil. Second, it reduces the need for mineral nitrogen fertilizer.

In January 2016, Scandinavian Biogas, the largest company in Scandinavia that plans and operates biogas plants, became the 50% owner of Biokraft. Scandinavian Biogas had already taken part in the testing of raw materials for Biokraft, and it sought to capitalize on the research findings by becoming a part-owner. The company foresaw an expanding market for solutions of the same type. Research and development plays a major role in the company. It has investigated the feasibility of more than 300 organic materials as substrates for biogas production and works on fine-tuning fermentation processes for stable and resource effective production of biogas (ScanBio, 2019). With Biokraft, Scandinavian Biogas was by 2018 involved in two research projects − one on the utilization of sludge from paper production and the other on the potential recirculation of byproducts from Biokraft for growing algae for processing into animal and fish feed.

The customer base that the Biokraft founders envisioned in the beginning (2009) changed over the period. In the beginning, Biokraft saw AtB in Trondheim as its main customer. While AtB still is a customer, the market possibilities widened considerably in 2015 when AGA became its sole buyer. According to Boot, AGA is not simply a customer, but also functions as an expert and guide for Biokraft as it maneuvers in the field of biogas production. Boot also expressed great appreciation for Enova. He recognizes Enova as a "heavy" professional institution, which contributes to the realization of quality sustainable energy solutions. He therefore regarded the grant from Enova in 2014 not only as a financial benefit, but also as form of a recognition that legitimated the fledgling company. As a general lesson, Boot sees it as crucial for the business to "work through others," staying informed and being prepared to take "timely action." He does not see the supply of raw material as critical for the future expansion of Biokraft, since the company has tested alternative types of resource inputs in cooperation with various research organizations. In addition, the Biokraft founders have developed an extensive network with various suppliers of raw material. In 2019 this led to two new agreements. In March 2019 Biokraft made an agreement with the dairy company Tine to deliver LBG to their fleet of trucks by 2020. The agreement also involves local dairy farmers who will deliver manure to the plant at Fiborgtangen. This represents a third type of raw material and requires a third fermentation tank. In May 2019 Biokraft entered into a multimillion kroner contract with Hurtigruten, one of the world's largest cruise companies, to deliver LBG to their ships from 2021. On their part, Hurtigruten will replace diesel motors with motors running on a combination of LBG, LNG and electric batteries on their ships. The ships will tank LBG in the harbor in Trondheim, 72 km from the production site. For Biokraft, this requires at least a doubling of the production. At the time of writing, the company is negotiating with Norske Skog which owns the premises at Fiborgtangen concerning utilizing more of the premises.

4.3. Fuel in public transport in the Trondheim region by 2019 and beyond

As a result of the merger of Nord-Trøndelag and Sør-Trøndelag into the county of Trøndelag in 2018, AtB became the administrative company for public transport in the whole new county. As AtB stated on its home page in October 2018: "AtB is a mobility company administrating the public transport in Trøndelag." (AtB, 2018). According to AtB, the customer and the environment are at their centre. As one of the managers expressed in an interview in April 2017: "We have no political opinion. We do what our owner, the county, decides." The county's latest strategy requires all public buses in AtB's domain to run on renewable fuel. As of 2019 the 290 buses operating in the greater Trondheim region ("Stor-Trondheim") were powered as follows: 12% electric battery, 40% biodiesel, and 39% biogas. Electric buses will be used on shorter and relatively flat routes within the city. Biodiesel buses (Weber and Amundsen, 2016) will be used on longer routes within the region and on large city buses (so-called metro buses). Biogas buses will be used on the other city routes.

The main advantages of using biogas is that it leads to quiet buses and produces very low emissions. AtB builds its "diversified fuel strategy" on the conclusions of the project "Framtidig rutestruktur for Stor-Trondheim 2019-2029" ['Future route structure for Greater Trondheim 2019-2029'] (AtB, 2016) carried out in 2014-2016. The project was commissioned by Sør-Trøndelag County as part of a larger study on the future of public transport in the region. One of the studies concerned "bus types, environment, fuel and installations" and was led by AtB. Other participants in the working group came from the municipality of Trondheim, the county of Sør-Trøndelag, the directorate of public roads, representatives from two of the regional transport companies, and two transport labor unions. Sør-Trøndelag County had set a target of fossil fuel–free public transport by 2019. The report documented that CO_2 emissions could be reduced by nearly 80% through a shift from petroleum fuels (gas and diesel) to biogas, biodiesel, and electric buses. On this basis, AtB recommended fully electric buses on four routes and biogas and biodiesel on the remaining routes to be implemented in 2019.

This strategy requires adequate buses. Over the past 20–25 years, various companies have developed buses that run on biogas, so the technology is available. Companies delivering buses powered by methane include large, well-established companies such as Volvo, Scania, MAN, Mercedes Benz and Solaris. In recent years, companies specializing in electric buses have emerged, for example the Dutch company Ebusco and the Finnish company Linkker. The manager of AtB regarded these two small companies as very innovative compared to the more established companies. He also pointed out the importance of national networks, such as Norsk Transportforum (Transportforum Norge, 2019), established in 2016, for exchanging experiences and making contact with authorities. Beyond Norway, he thought that directives from the EU are very important for promoting innovation and improved practices, for example, the Euro VI emission standard adopted in 2014 (EUR-Lex, 2018) with much tighter requirements on emissions of hydrocarbons (HC) and nitrogen oxides (NOx) for heavy vehicles. Finally, the manager estimated the additional operating costs of the transition from fossil to renewable fuels in public transport in the Trondheim region to be 6-7%. To a large extent, these additional costs are covered by the state through Greener Trondheim. "I think it is a reasonable additional cost given what we obtain in return in terms of better environment and more satisfied customers," he stated.

Table 1 summarizes the case story providing details of important events sorted on the dimensions actors, technology and institutions.

Table 1: A chronology of important events in the case.

Period	**Actors**	**Technologies**	**Institutions**
Ca. 1990–2009: Sporadic testing of production and use of biogas as engine fuel in Sweden and some other countries	Biological and technical researchers and business entrepreneurs in Sweden. AGA starts to distribute biogas as engine fuel in Norway delivered by Swedish producers.	Research actors in Sweden test various substrates for production of biogas. Prototypes of engines that can use biogas fuel is tested and used in public traffic in among others Sweden. Technologies for liquefaction of biogas already established in the oil- and gas sector.	Legislation on handling organic waste. Testing of production and use of biogas by some Norwegian Municipalities as part of waste handling.
2009-2019: Development phase for production and use of biogas as engine fuel in the Trondheim region	Business entrepreneurs establishing Biokraft. Local, regional and national politicians. AtB. ENOVA. Innovation Norway. Bus companies. Bus producers. Scanbio Marine Group. Norske Skog. Scandinavian Biogas. Purac. Wärtsilä.	Biokraft is testing a mixture of rest products from aquaculture and sludge from forest industries as substrates for producing biogas fuel. Biokraft makes agreements with companies on deliveries of production technologies for the new factory.	Reorganizing of public transport in the Trondheim region and establishment of the public company AtB as coordinator. Biokraft receives public support to the new factory. EU directives on fuel technology and adaptation of national road tax regulations.
2019-: Production and use of biogas as engine fuel established in the Trondheim region and beyond	AGA Scandinavian Biogas. NTNU (university) and NIBIO (research institute). Local farmers. Tine. Hurtigruten.	The various production technologies are set up at the factory (fermentation, cleansing, liquefaction). Biokraft is testing additional raw materials. AtB identifies routes suitable for biogas-fueled buses in the Trondheim region.	The technology company Scandinavian Biogas takes over as majority owner in Biokraft. The market for biogas from Biokraft is extended through an agreement with the distribution company AGA. Biokraft signs agreements with local farmers, the dairy company Tine and the cruise company Hurtigruten

5. Discussion

This study set out to contribute to the research literature concerning innovation processes leading to sustainable transitions. Within this purpose, this section draws lessons from the sociotechnical transition processes described in the case story and put them in a wider perspective. Before we go on to analyse the paper's main topics, processes and enactment, a few comments on sustainability outcomes is in place.

The most obvious sustainability outcome in the case was the exchange of around 80% of the fossil fuel with renewable fuel in the use system (public transport in the Trondheim region) from 2009 to 2019. Even if biogas was not the only contributor to this change, biogas contributed significantly and was the preferred solution for certain types of buses. Hence, the exchange of fossil fuel would have been lower without biogas in the renewable fuel "mix". When it comes to the production system, Biokraft produced in 2019 a significant volume of renewable fuel, while in 2009 it produced nothing. Whether this production represented a regime shift depends on where one sets the system borders. Compared to all production of fuel in the world, the contribution from Biokraft was minor. Compared to the use of fuel in heavy trucks in the Oslo area (the main market for Biokraft at the time of writing), the contribution of biogas from Biokraft was significant. This suggests that sustainable transitions are not absolute phenomena, but have to be analyzed as part of specific production and use contexts (Ghisellini et al., 2016).

The case also serves as a platform to comment on the concept of circular economy (CE). As the case was at the time of writing (2019), it was not an example of CE in the sense of a fully closed circular system (Ellen MacArthur Foundation, 2013), even if it had led to documented sustainanable transitions. These transitions were linked to the use of (biological) rest products from aquaculture (not allowed as food or feed) and (biological) waste from forest industry, and from this producing biogas exchanging fossil fuel in transport and biofertilizer exchanging mineral nitrogen and maintaining carbon balance in soils. In this way, one might say that one principle of CE was applied: Reclassifying materials so that technical materials are reused and nutrients are transformed to new uses (Ellen MacArthur Foundation, 2013). This principle is considered more efficient for obtaining sustainability than energy demanding recycling (Allwood, 2014; Ghisellini et al., 2016). Reduction of waste is a second principle in CE (Jawahir and Bradley, 2016; Winans et al., 2017; Yuan et al., 2006). In the case, this principle was applied on the use side (transport in the Trondheim region) by enhancing public transport and introducing vehicles running on renewable fuels. Nevertheless, the case as described does not contain real circles. However, with some further development it could be transformed into a circular economy system or even several circular systems. For example, feed produced through applying the actual biofertilizer could be used to feed the fish from which (part of) the biosubstrate used by Biokraft came from. Another example, in fact planned for by Biokraft, would be to use manure from animals fed by feed produced on fields fertilized by the actual biofertilizer, as input to the production at the Biokraft plant.

5.1. Transition processes

What then characterized the transition processes in the case story? Overall, it is clear that the transition processes were not linear and outcomes could not have been predicted beforehand. Nevertheless, in hindsight it is possible to pinpoint some patterns in the development. It is fruitful to acknowledge that there was not only one transition process in the story, but *several, connected transition processes*. First, during the whole period specific developments took place in, respectively, the production system (energy) and the use system (transport). Second, for both systems one can observe moderate landscape pressures and discern a period of *transformation* (ca. 1990-2009) and a period of *reconfiguration* (2009-2019) (Geels et al., 2016; Geels and Schot, 2007). This means that in the first period, there was a reorientation towards new technologies, experimentation and gradual development of such things as fermentation of biowaste (production system) and engines (use system). This transformation pathway was followed in the next period (2009-2019) by *reconfiguration*. In this period the pressure from landscape factors continued to be moderate, but innovations were now sufficiently developed, on both the production side and the use side. In terms of actors, the reconfiguration was characterized by several new alliances between incumbents and new entrants within regimes and among regimes, while in the previous period developments characteristically took place independently as a result of actions by actors, such as certain municipalities, vehicle producers and persons with a background in technical research. However, this does not imply that there was a sudden break in types of transitions over a single year (2009), only that the overall character of the transition shifted at this time.

The focus of the story on the reconfiguration period enables relevant observations to be made on technologies and institutions in this period. Concerning technology, biogas was initially an add-on to the existing fossil fuel based transportation. Through adoption of already developed engine technology, biogas fueled buses were introduced to Trondheim and, after a few years, were combined with buses run on other renewables (biodiesel and electricity). The Biokraft firm was initially developed based on application of certain rest products (waste from aquaculture), but went on to include other raw materials such as waste from forest industry. However, the combination of these existing raw materials required further development of existing production technology. This again demanded research and development, which led to discovery of new potential uses, such as growing algae for fish feed. In other words, from an initial rather simple resource base, a cascade of innovations followed, altering the system architecture of the fuel regime.

The decision by politicians in the Trondheim region in 2009 to establish a broad program ("Greener Trondheim") to deal with prospected challenges in transport was the culmination of societal debates taking place over previous years. Included in this was also a change to a 'buyer – performer' system for delivering public transport. The year 2009 marked a clear shift from a transformation pathway to a reconfiguration pathway. The program represented an institutional change that in the coming years facilitated new interactions and alliances between actors that previously had operated in "silos". These included road authorities, transport companies, municipalities and politicians in the region, as well as new connections to national authorities. On the production side, Biokraft could benefit from institutions established before 2009, such as the sustainable energy agency ENOVA. During the development process in the subsequent years, only minor changes in formal institutions were necessary. Moreover, it is likely that the establishment of Biokraft as well as the transport program in the Trondheim region benefitted from the agreement on national climate policy adopted by the Norwegian parliament the year before (Akselsen et al., 2008).

5.2. Enactment - role of actors

Analysis of processes after they have occurred is relatively simple, but to analyze the ongoing processes at the time and be able to rapidly identify and exploit opportunities to influence the process development is quite another matter. This is the role of actors in transition processes. The case story demonstrates actors' impact on processes and outcomes, both in the transformation period (1990-2009) and the reconfiguration period (2009-2019), and on the production side as well as on the use side. In both periods and on both sides processes can be characterized as unpredictable and incremental. Nevertheless, the processes resulted in outcomes that were not necessarily as originally planned. In what way did actors affect the processes? First, actors were crucial in *initiating processes*, some more than others. In the case story, the founder of Biokraft is one of several examples of a proactive actor. This actor was not a technical expert in the renewable energy sector which Biokraft entered, but introduced *organizational competence*, especially in the field of establishing new ventures. This competence was crucial for the development of Biokraft. More specifically, since this development occurred as part of a reconfiguration process, where building of new alliances was critical (cf. Section 5.1.), organizational competence was particularly relevant. Organizational competence was also crucial for the transition (reconfiguration processes) on the use side (public transport) in the same period. It was also important that the various relationships between actors that were established, for example on the production side (Biokraft) were motivated by broad objectives and not solely concerned short-term economic gains. This is in accordance with Villanueva et al. (2012) who found that resource flows to entrepreneurial ventures were dependent upon the *total dependencies* between parties rather than *dependence advantages*, and hence that joint resource mobilization was more effective than unilateral resource acquisition for determining the way new ventures accessed external resources. Also in our story actors' access to their own as well as external resources was crucial for developing new ventures, such as Biokraft and AtB, and hence for the transition processes. However, without actors with knowledge of how to find ways to combine resources in a productive way and willingness to act, the transition towards sustainable transport fuels would not have occurred.

Hence, the case suggests that actors are required who are able to combine resources in order for sustainable transitions to occur. Actors that have this ability can be seen as exercising *enabling* power (Villanueva et al., 2012). Other types of power were also exercised in the case and had consequences, such as *destructive* power (cf. termination of the old system for delivering public transport in the Trondheim region in 2009) and *systemic* power (cf. the system of "environmental packages" ("Miljøpakker") initiated by state authorities to secure sustainable transport in cities) (Avelino, 2017).

Other observations related to actors and enactment can be made concerning the unpredictable and incremental character of the transition processes in the case. One is the importance of *learning* during the process and taking action to secure resources at strategic points in time. This is obvious in the case of Biokraft, which successively established relationships with actors that could provide relevant input resources (e.g. Scanbio Marine Group, Norske Skog and Scandinavian Biogas) and secure sales (e.g. AGA, Hurtigruten and Tine). Also in the previous period there were examples of reflective practitioners (Schön, 1991), but in this period of transformation other types of actors were more in the forefront, such as technical researchers and inventors. More examples are provided in Table 1. Considering the whole period (1990-2019) and both the production side and the use side, we find examples of actors that explore and make discoveries on the one hand, and actors that search for opportunities to exploit on the other (March, 1991). The first type of action was most prevalent in the first period (transformation). However, in Biokraft exploration of new opportunities through for example research, was consciously also applied in the reconfiguration period. Nevertheless, this period was marked by more formal negotiations and contracts between actors. In the case of Biokraft, formal contracts were signed at every stage of the process when cooperation with new partners was established. Hence, successful enactment of sustainable transition processes seems to stem from actors' reflective *moves and countermoves* (Geels et al., 2016). Behind all this is also the importance of actors having a *vision*. In the case of Biokraft the vision was to establish and demonstrate an enterprise that could produce a sustainable product and at the same time be profitable. In the case of public transport in Trondheim the vision was to develop a cleaner city, with less car traffic and lower CO_2 emissions.

Overall, it is interesting to note with reference to the case, that once transitions have started to happen, they can be further developed. Both the Biokraft case and the case of public transport suggest that once actors have created a sustainability "path" (Garud and Karnøe, 2001), new outcomes can continuously be produced, within as well as across sociotechnical regimes (Konrad et al., 2008; Raven, 2007). This requires that there is a continued cooperation between regime actors and niche actors (Elzen et al., 2012).

6. Conclusions and recommendations

In this paper, action in two major sectors of society have been analyzed, the energy sector and the transport sector, through a case stretching over a period of around 30 years. The case has demonstrated that action in these sectors can be much more complex than, for example, individuals reducing meat consumption or using their car less, but there is a communality. Action happens when people take initiative and, as touched upon in the Discussion (Section 5), a multitude of actions by many actors has to be undertaken in order to "fix the climate".

Then is the question, of what can we learn about "climate action" from the study of a single case? Due to its empirical focus, the study is most relevant for public sector actors and private market actors. If not anything else, the study has demonstrated (and confirmed) three major factors behind successful sustainable transitions; leadership, technical innovations and institutional adaptations. These findings may be applied as recommendations by various actors in the public and private sectors, and may provide an inspiration for actors in the civic (voluntary) sector (Putnam et al., 2004).

First, in enacting sustainable transitions, *leadership* is crucial. One aspect is interpreting external developments and taking initiatives for change. Another is leading change processes after initiatives have been taken. Here two points seem especially critical. One is the *timing* of action; when to do what and how? One formula of success seems to be to develop some form of overriding general vision, and given this, split up action into shorter, "manageable" time horizons, and achieve sub-goals which can then be evaluated (learning), and provide a platform for further action. To wait for "the one, major action" seems futile. The other critical point is *power to manage resources* (material as well as immaterial). Resource management concerns both development of (new) resources and combination of (existing) resources. One must also mention with reference to the case, that a precondition for successful timing and resource management is to mobilize and interact with other actors. Hence, sustainability leadership is about developing conditions for *inter*action as much as individual action (Ibarra, 1992).

Second, *technical innovations* (broadly understood; methods, products, knowledge) are necessary for actors' enactment of sustainable transitions. The case story has confirmed research in the MLP that new technical innovations are often developed in niches outside existing sociotechnical regimes because innovation processes requires non-traditional approaches. The case story has also shown that developing new technical innovations takes time, and part of the "leadership timing" mentioned above is to identify and follow relevant innovation niches and decide if and when the time is ripe to act. That new technical innovations are required also helps to explain why sustainable transitions take time to accomplish. It is therefore not an option for an actor in a regime "to act at any time". On the other hand, the time it takes to produce new innovations can be shortened through interventions from the state.

Third, it is reason to believe from the case story that none of the two major developments (energy transition and transition in transport) would have been possible without *institutions* provided by the state. The case has also shown that a variety of different types of support from the state is necessary for different sustainable actions, in other words, differentiated institutional arrangements is a fruitful strategy. The role of ENOVA for the establishment of Biokraft is an interesting point in case, because not only did ENOVA contribute financial capital to the startup, but the agency also provided specific advice in relation to the establishment. Another example is the revision of rules for road taxes, which had direct consequences for the adoption of biofuels in transport and indirectly for the establishment of Biokraft. A third contribution from the state was by funding research and innovation, which Biokraft could capitalize on through its cooperation with university actors and research institutes. A fourth example of institutional innovation was the concept of "environmental packages" to larger cities developed by national authorities. Taken together these examples show that the state has a crucial role to play in laying the ground for sustainable transitions. Moreover, the state has the power to use an arsenal of policy instruments when it comes to supporting sustainable transitions; financial, legal, organizational and informational instruments (Howlett et al., 2009).

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