Borderstep Institut

# Governance of Radical System Transitions

## Effects of political strategies and instruments on the transition of socio technical systems

### Evaluation of the case studies from work package 1

Jens Clausen | Klaus Fichter

# Imprint


**Authors**

Jens Clausen (Borderstep Institute) | clausen@borderstep.de

Klaus Fichter (Borderstep Institute) | fichter@borderstep.de



**Project implementation**

Borderstep Institute for Innovation and Sustainability gGmbH

Clayallee 323

14169 Berlin

**Citation suggestion**

Clausen, J. & Fichter, K. (2020). Governance of radical System Transitions. Effects of political strategies and instruments on the transition of socio technical systems. Evaluation of the case studies from work package 1. Berlin: Borderstep Institute.





**Translation**

Translated with www.DeepL.com/Translator (free version)

**Funding agency**

Federal Ministry of Education and Research (BMBF)

Innovation- und Technology Analysis (ITA)

SPONSORED BY THE

Federal Ministry of Education and Research

# Content

# List of figures



# List of tables

# 1 The Problem

*"The greatest enemy of the new order is he who took advantage of the old."“*
*Niccolò Machiavelli (1469 bis 1527), Italian philosopher, politician and writer*

Sustainable development requires a change in the way natural resources are used and places high demands on the performance and transition capacity of national economies. These ambitious goals make it necessary to link environmental policy requirements with innovation policy issues. What distinguishes "eco-innovations" as defined in the EU Eco-Innovation Action Plan (European Commission, 2011) from "normal" innovations is their contribution to reducing environmental pollution, strengthening resistance to environmental stress and the sustainable use of natural resources.[1]

For many years, environmental innovations have played an important role in German politics when it comes to the question of how ambitious environmental protection goals can be achieved while at the same time taking advantage of employment and growth opportunities. The discussion often takes place in individual lead markets in which environmental innovations are intended to contribute to the achievement of environmental and economic goals. To this end, the German government regularly updates the German sustainability strategy, first published in 2002 (Die Bundesregierung, 2017). However, the actions of the federal government under Merkel are often inconsistent and changing environmental and economic policy objectives have led to an exodus of the German photovoltaic industry at the beginning of the decade. The number of people employed in solar energy fell from 156,700 in 2011 to just 42,800 in 2017 (Umweltbundesamt, 2019).Several times the number of jobs in lignite was lost here. The wind power industry is also currently struggling to survive (Zu Klampen, 2019). The number of jobs in this sector has also already fallen significantly from its maximum of 161,000 in 2016 (Umweltbundesamt, 2019).

However, as research on environmental innovations shows, German environmental innovation policy faces two central challenges:

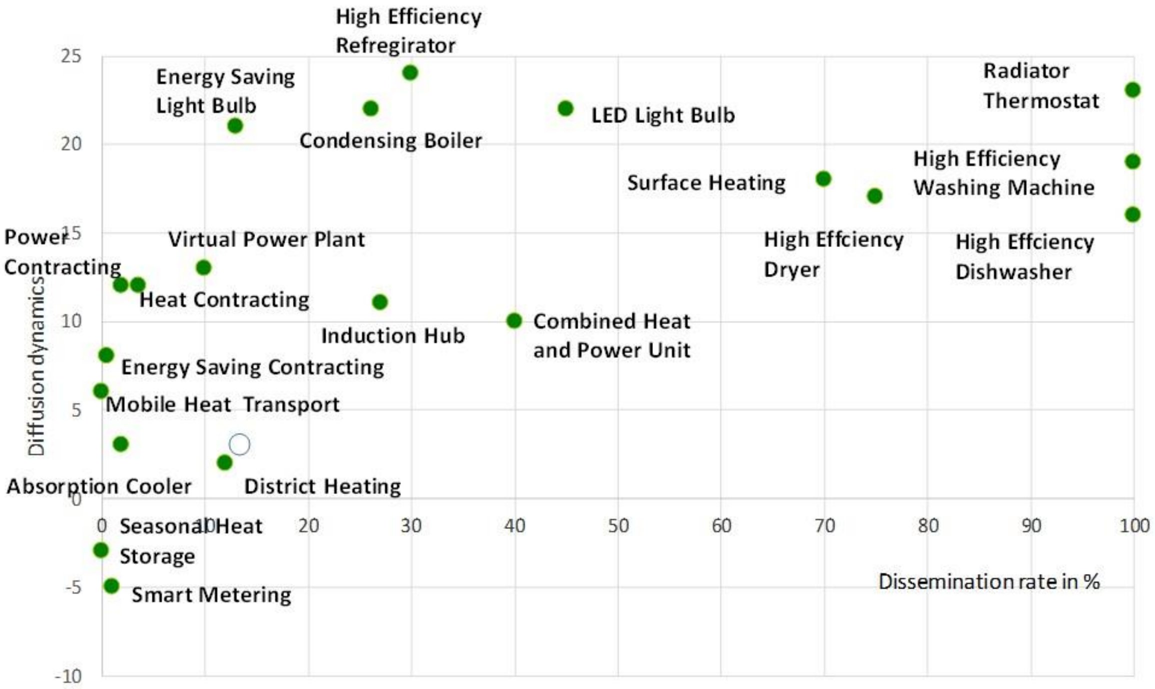
(1.) The diffusion of environmental innovations is often slow and environmentally friendly new products and services often do not achieve a high market share.

Approximately two thirds of all environmentally friendly product and service innovations launched on the market in recent years have only a small degree of diffusion of up to 15%. Thus, they only achieve a fraction of the environmental relief that would be possible with high or complete diffusion. A sample of 130 environmental innovations shows this in relation to the indicator "diffusion dynamics", which measures the promoting and inhibiting factors of diffusion (Clausen & Fichter, 2019a). In

[1] The terms "eco-innovation" and "environmental innovation" are used synonymously here. They include technical as well as social, institutional, organisational and business innovations.

the field of energy efficiency, for example, both diffusion dynamics and the degree of diffusion could be determined for 21 products and product-service systems (Clausen & Fichter, 2018, S. 120):

**Figure 1: Diffusion of environmental innovations in Germany in the field of energy efficiency**




Source: Fraunhofer ISI (Clausen & Fichter, 2018, S. 120).

As the figure clearly shows, only a few innovations promoted by the European Union's Ecodesign Directive, which is effective in terms of regulatory policy, achieve high levels of dissemination. In particular, system innovations such as heating networks or their components such as mobile heat and smart metering diffuse slowly and show only a low diffusion dynamic.

(2.) The diffusion problem arises above all with radical system innovations

“Radical system innovations" (cf. Section 2) refer to those that involve fundamental changes to entire supply systems (electricity generation, distribution and usage systems, building-related heat supply systems, etc.) or product-service systems (PSS) such as electromobility. The realisation of such system innovations is characterised by significantly higher technical, social and institutional complexity and stronger path dependencies than is the case, for example, with individual technical component innovations such as highly efficient washing machines or LEDs for room lighting. It is therefore not surprising that fundamental system innovations are more difficult to implement and generally spread much more slowly or not at all. However, since fundamental system innovations in particular promise high contributions to emission reduction, climate protection and resource conservation, eco-innovation policy needs effective strategies and governance mechanisms to stimulate them and ensure rapid and broad diffusion.

The implementation of environmentally harmful radical systemic innovations is not limited to the diffusion of individual product or service innovations, but includes the fundamental change of entire supply systems (electricity, heat, food, etc.) and product-service systems (e.g. in the area of mobility). This requires an orchestration of the systemic interaction of different environmental innovations, requires the identification of complementarities, synergies and competition between individual solutions and their placement in an effective transition concept.

The project "Governance of Radical Environmental Innovations (Go): New Governance Mechanisms in Eco-Innovation Policy: The Role of the Activating State in Radical System Innovations" starts at this point and aims to answer the following research questions:

(1.) What insights do previous cases of governmental activation attempts for environmentally friendly radical system innovations provide with regard to the conditions of success and failure?

(2.) What was the role of the state in the case studies examined and which political instruments prove to be particularly effective in the context of which lobbying structures?

(3.) Which context- and actor-related conditions and factors are central and to what extent can these be transferred to a transformative environmental policy in Germany?

(4.) Against this background, how are concepts of the activating and coordinating state on the one hand and of transition field-related innovation communities on the other to be assessed?

(5.) How must an orchestration of policy strategies, policy instruments and actor roles look like, so that a radical environmentally friendly system transition of the building-related heat supply in Germany can succeed?

The present paper builds on the theoretical study of the "Go" project presented in spring 2019 (Clausen & Fichter, 2019b) and further develops the transition approach presented there against the background of the findings of the seven case studies also prepared and published in 2019 (see Table 1 ). The case studies focused on steering attempts by various states to implement radical system innovations in political, social and economic terms.

## 2 Radical system innovations that reduce environmental impact

The literature distinguishes different types of innovations. The project "Go" focuses on innovations in market-related goods, i.e. on product and service innovations and their combinations. In the first instance, it is essential to differentiate between incremental innovations that do not fundamentally change a product or service, and basic or radical innovations. We define radical innovation as

- a completely new or materially substantially altered product or service, or
- a fundamentally new business model used in connection with it, which is associated with fundamental institutional or organisational discontinuities.

Other terms have emerged around the concept of radical or fundamental innovation. Freeman and Perez (1988), for example, describe the change of technological paradigms as technological revolutions, a term that corresponds to Schumpeter's theory of long waves and can also be linked to the idea of Kondratieff cycles.

The diversity of innovative (and non-innovative) products and services is embedded in socio-technical systems. Already Nelson and Winter (1982) introduced the concept of technological regimes, which referred to common cognitive routines in an engineering community and explained the development of innovations along "technological trajectories". However, scientists, policy makers, users and other interest groups also contribute to shaping technological change. Bijker (1995) therefore developed the concept of the socio-technical regime. As an example of a technical system, Unruh (2000, S. 822) mentions cars and individual transport, a system that includes many other technical components in addition to the supply industry, the oil industry and road construction. Understood as a socio-technical system, individual transport is expanding to include its users and interest groups, such as the General German Automobile Club (ADAC), as well as policy-related lobby groups such as the German Association of the Automotive Industry (VDA) and their close ties to politics.

In our understanding, the term system innovation refers to a socio-technical system and describes significant changes or innovations of these systems. They usually affect several industries and can also lead to the emergence of completely new sectors (Freeman & Perez, 1988). The fundamental change of the system requires not only the diffusion of individual product or service innovations, but also the orchestration of the systemic interaction of different product and service innovations and the identification of complementarities, synergies and competition between individual solutions and their placement in an effective transition concept.

As a third component of the definition of radical system innovations that relieve the environment, the concept of environmental relief should be defined. We consider any innovation to be environmentally friendly "which brings about or aims at substantial and verifiable progress towards the goal of sustainable development by reducing environmental pollution, strengthening resistance to environmental change or achieving a more efficient and responsible use of natural resources" (Clausen & Gandenberger, 2018).

A radical system innovation that reduces environmental pollution can thus be described as follows:

- It is environmentally beneficial because it brings about substantial and demonstrable progress towards the achievement of environmental objectives of sustainable development,
- it involves major changes in the technological knowledge base and materialises in completely new products, services, business models or combinations thereof and,
- it alters socio-technical systems such as supply systems (electricity, heat, proximity) or product-service systems such as mobility to a significant extent and possibly beyond the boundaries of sectors and can also lead to the emergence of completely new sectors as well as the disappearance of previously established technologies, behaviour or cultures (exnovation).

The term "radical system innovation" is equated here with the term "radical system transition" and used synonymously, even though the terms "innovation" and "transition" come from quite different theoretical discourses and research directions.

In the course of the project we have investigated the following cases of transition, whose character as an environmentally friendly radical system innovation is shown in the following table:

**Table 1: Case studies of the transition of large supply and product use systems**

| **System innovation** | **Radicality** | **System character** | **Environmental relief** |
|---|---|---|---|
| Power generation from renewable energies in Germany (Clausen, 2019a) | Completely new technologies for the generation of wind power, solar power, etc. completely replace established technologies such as electricity from coal. | The previous centralised and often oligopolistic structure is being replaced by decentralised production, storage and distribution with often new ownership structures. | The greenhouse effect of burning fossil fuels is avoided. |
| Heat supply Sweden (Clausen & Beucker, 2019a) | Previously less used energy sources like biomass, but also completely new technologies like heat pumps are replacing established technologies like oil heating. | The free choice of heating technology for each building is no longer necessary, the market for individual heat generators is significantly reduced, and new markets for heat pumps and heat networks are emerging. | The greenhouse effect of burning fossil fuels is avoided. |
| Heat supply Denmark (Clausen & Beucker, 2019b) | Previously less used energy sources such as biomass, but also completely new technologies such as large solar thermal systems with seasonal storage etc. are completely replacing established technologies such as oil and gas heating systems. | The free choice of heating technology for each building is no longer necessary, the market for individual heat generators is significantly reduced, and new markets for heat pumps, heating networks, large solar thermal systems and seasonal storage are emerging | The greenhouse effect of burning fossil fuels is avoided. |

| System innovation | Radicality | System character | Environmental relief |
|---|---|---|---|
| Car electromobility in Norway (Clausen, 2019b) | The complete fossil drive train of previous passenger cars will be replaced by battery and electric drive. | The role of suppliers, OEMs and start-ups in the automotive industry is changing significantly, gas stations will disappear in the long term and both car handling and charging will have to be relearned. | The greenhouse effect of burning fossil fuels is avoided. |
| Conversion of the city of Copenhagen into a bicycle city (Clausen, Warnecke & Schramm, 2019) | Car traffic, which increased strongly until the 1970s, was reduced by, among other things, the reduction of parking facilities. | The systematic development of bicycle lanes with the aim of shifting the modal split, but also of increasing safety and speed, is systematically changing mobility in Copenhagen. | The greenhouse effect of burning fossil fuels is avoided and the health of the population is demonstrably promoted. |
| Promotion of the expansion of renewable heat supply in Baden-Württemberg (Clausen & Warnecke, 2019) | Stronger increase in the proportion of renewable heat in Baden-Württemberg than the German average. | The funding programmes include solutions for individual buildings as well as heat supply systems for entire villages. | The greenhouse effect of burning fossil fuels is minimally reduced. |
| Organic farming in the Indian federal state of Sikkim (Clausen & Olteanu, 2019) | Instead of intensive agriculture with its integrated technology systems, organic farming is being applied to 100% of the agricultural land in the entire state. | By breeding and spreading robust varieties and promoting closed nutrient cycles, agriculture is being developed and ecotourism is being established in parallel. | The harmful effects of pesticides and fertilizers on biodiversity and water quality are being significantly reduced and biodiversity is maintained. |

Source: Authors.

Behind each of the system innovations listed here are a variety of technical innovations, some of which have the character of radical innovation. The ecological effects of the system innovations listed here have been investigated in many different ways. The degree of diffusion of the respective product and service innovations was used as a measure of the ecological success of the system transition through governance mechanisms. The case studies focused on the development of governance mechanisms for the dissemination and implementation of these system innovations.

# 3 Method

## 3.1 Working steps

The evaluation of the case studies is done in four steps:

Step 1: Characterisation of the examined system innovations on the basis of essential parameters of the system size (number of people affected by the change of the system, economic volume of the transition) and the temporal development of the transition (cf. chapter 4).

Step 2: Analysis of the strategies and instruments used by state actors to initiate and manage system transition (cf. Chapter5). The classification of state strategies and instruments used, developed in section 3.2, is used here.

Step 3: In the third step, a reflection on the research questions of the project is carried out, with particular emphasis on the orchestration of the use of political instruments as presented in the theory study (Clausen & Fichter, 2019b, S. 52ff) (cf. chapter 6). In this analysis, not only the activities of state transition, i.e., change-oriented action, are considered, but also various counter-strategies with which interested parties seek to hinder change (Clausen & Fichter, 2019b, S. 39, 55). Furthermore, it is analysed how the different levels of governance can support or hinder each other. It also addresses the connections between the object of transition, i.e. radical system innovation, and the course of transition.

Step 4: In the last step, a summarising assessment is made and consequences for eco-innovation policy are derived (cf. Chapter 7).

## 3.2 Classification of public policies and instruments used

For the analysis of the state strategies and instruments used in system transition, an appropriate classification is necessary. Building on the theoretical preliminary work (Clausen & Fichter, 2019b), we refer to Kivimaa and Kern (2016), who base their systematization of the political instruments on work on multi-level perspectives, techno-logical innovation systems and strategic niche management. In several aspects, they expand the classical understanding of state intervention (Kivimaa & Kern, 2016, S. 208) and consciously use Schumpeter's concept of "creative destruction":

- They subdivide the state's options for action according to the fundamental objective of promoting the emergence of innovations and niches on the one hand ("creative niche support") and the destabilisation and dismantling of established non-sustainable systems ("de-construction / regime destabilisation)" on the other (Kivimaa & Kern, 2016, S. 208).
- They emphasise the fundamental importance of a clear framework and direction, which should guide thinking and searching strategies towards sustainable solutions on a fundamental level. Furthermore, they establish a connection to support and legitimise new solutions.
- In addition to the importance of financing possibilities and risk capital, which was already emphasized in Rubik (2002, S. 331), they integrate the promotion of entrepreneurship and start-ups,

which has been repeatedly emphasized as an important element since the beginning of the millennium (Clausen, 2004; Petersen, 2003; Schaltegger, 2002; Schaltegger & Petersen, 2000; Weiß & Fichter, 2013), into the spectrum of niche management instruments.

- Furthermore, like Clausen and Fichter (2019a), they emphasise the importance of the cost-benefit ratio of innovations and see R&D activities aimed at developing learning effects and reducing costs also as an instrument for preparing transition.
- They extend the spectrum of instruments for destabilisation via the economic instruments of taxes, levies and subsidies for changing relative prices to the possibilities for changing basic system rules (such as the change in the rules of the electricity market in 1998 (Kivimaa & Kern, 2016, S. 209) as well as the targeted modification of network structures by the state, which can relate, for example, to the targeted reduction of the influence of lobbyists from established regimes in political advisory circles.

For their analysis of the political spectrum of action in the context of transition processes towards sustainability, they use the following analytical framework with 11 categories of possible state action.

**Table 2: Analytical framework by Kivimaa & Kern for the analysis of „policy mixes for transition“**

| **„Creative (niche support)“** | **„Destruction „regime destabilisation“** |
|---|---|
| C1: Knowledge creation, development and diffusion | D1: Control policies |
| C2: Establishing market niches/market formation | D2: Significant changes in regime rules |
| C3: Price-performance improvements | D3: Reduced support for dominant regime technologies |
| C4: Entrepreneurial experimentation | D4: Changes in social networks, replacement of key actors |
| C5: Resource mobilisation | |
| C6: Support from powerful groups/legitimation | |
| C7: Influence on the direction of search | |

Source: Kivimaa & Kern 2016, S. 208/209.

The analytical framework developed by Kivimaa & Kern (2016) is very well suited for the purpose of our research project and the cross-case evaluation of the "policy mixes for transition". However, in view of the specific systemic character of our research object and the technical infrastructure necessary for the development of supply and product-service systems (electricity grids, heat grids, logistics infrastructure, etc.), we see the need to extend this framework by a 12th element and add a further function or class of instruments, namely "infrastructure development" as a transformative instrument of political action.

Furthermore, in view of the seven case studies carried out, we see the need to divide the instrument group "D.1 Regulatory Law, Taxes and Charges" ("control policies") into two independent groups. Our case studies show that the use of "regulatory law" on the one hand and "taxes and duties" on the other hand can be analytically recorded separately and that these groups are used differently in our cases, so that an explicit distinction seems justified.

A further adjustment of the analytical framework of Kivimaa & Kern seems to us to be useful for the instrument group "D3: Reduction of support for dominant technologies", as this group concerns different policy areas. While the option of reducing R&D support for selected established technology lines, which is included in this group, concerns research and innovation policy, the area of subsidy reduction in the use of these technologies (production, product use), which is also assigned to this group by Kivimaa & Kern, is more likely to be assigned to economic policy and is usually used in other phases of a technology or product life cycle. For the purposes of our analysis, we assign the reduction of subsidies for the use of certain technologies identified as unsustainable to the functional class "taxes and duties" and retain a separate instrument group "reduction of R&D funding for unsustainable technologies and systems".

For our analysis purposes, we also change the order in which the instrument/functional groups are listed, as this seems to us to be only partially consistent at Kivimaa & Kern. We now assume an ideal-typical chronological order of the use of instruments from the perspective of the state. It is clear to us that the functions/state measures do not usually have to be sequential, but in some cases parallel and recursive. Therefore, this "ideal-typical" sequence has a rather fictitious character.

For the cross-case analysis of our case studies, we therefore use the following analytical framework:

**Table 3: Classification of possible policy instruments in system transitions**

| „Creative (niche support)“ | „Destruction „regime destabilisation“ |
|---|---|
| C1: Influence on the direction of search | D1: Changes in social networks, replacement of key actors |
| C2: Resource mobilisation | D2: Significant changes in regime rules |
| C3: Knowledge creation, development and diffusion | D3: Taxes, duties, including reduction of subsidies |
| C4: Entrepreneurial experimentation and entrepreneurship support | D4: Regulatory law |
| C5: Support from powerful groups/legitimation | D5: Reduced support for dominant regime technologies |
| C6: Establishing market niches/market formation | |
| C7: Deployment of Infrastructure | |
| C8: Price-performance improvements | |

Source: Authors based on Kivimaa & Kern (2016).

# 4 Differences between the cases examined

## 4.1 Size of the investigated systems

It seems plausible that systems that cover a large population and involve markets with very high turnover are more difficult to transform than small systems that involve fewer people and in which smaller amounts of money are moved. In the following, therefore, an attempt will be made to describe the size of the seven systems studied using two leading indicators:  Firstly, the number of people affected by the change in the system and, secondly, the market transaction value (turnover volumes) that is implemented in the respective system within a defined time (per year). In particular, the question of turnover volumes is difficult to clarify in detail, which is why only a rough estimate of the magnitude is given below.

In Germany, approximately 650 TWh of electricity are generated annually (Statistisches Bundesamt, 2019a). In recent years, the stock exchange price for electricity has fluctuated around an average value of approx. 40 €/MWh (Fraunhofer ISE, 2019), which corresponds to a production value of approx. 26 billion €. However, the turnover of the industry is much higher. The German Federal Statistical Office reports a turnover of 450 billion € for the electricity supply companies in 2017 (Statistisches Bundesamt, 2019b, S. 8). We use the latter figure as an indicator of the market transaction volume of the electricity supply system in Germany. The core of this immensely large market is being transformed by the energy system transition and industry turnover is thus a measure of the volume of the transition.

In 2017, the 11 million people in Baden-Württemberg consumed approx. 7.26 MWh of energy each in the form of heating oil, natural gas and other heating gases (Statistisches Landesamt Baden-Württemberg, 2019). Across the state this amounts to approx. 80 TWh, which at an average price of 8 cents/kWh (Forum Energii, Agora Energiewende & DBDH, 2018) corresponds to a turnover of approx. 6.4 billion €.

In Sweden, the heat consumption for heating and hot water is stated as 80 TWh (Clausen & Beucker, 2019a, S. 6). The average heat price is approx. 8 cents/kWh (Sköldberg & Rydén, 2014, S. 43), which results in annual sales of approx. € 6.4 billion.

In Norway, approximately 150,000 new passenger cars were registered in 2018 (Carsalesbase.com, 2019). At a pre-tax price of approx. €25,000 per vehicle, this would correspond to an annual turnover of approx. €3.75 billion before tax - although this could be the same amount in Norway.

Danish households consumed approx. 40 TWh of heat for heating and hot water in 2016 (Danish Energy Agency, 2018). Based on an average heat price of 8 cents/kWh (Forum Energii et al., 2018), this results in a turnover of heat to end customers of about € 3.2 billion.

It is difficult to estimate the expenditure of the 1.3 million inhabitants of Greater Copenhagen on local transport. Although there are indications of the share of mobility costs in average incomes, there is no indication of what share is spent on local mobility. In view of the jungle of local public transport tariffs in Copenhagen, a yearly ticket Hamburg AB at a monthly subscription cost of 89.50 is used as a substitute. This results in an annual cost of 1,074 € per person. With 1 million paying persons, this would result in a quite theoretical volume of the local transport market of approx. 1.1 billion €.

Sikkim generates a gross domestic product of 12 billion rupees in agriculture (KNOEMA Weltdatenatlas, 2019), which at an exchange rate of 1 rupee = 1.3 cents equals about 150 million €. This is the only non-OECD area where the magnitude of this figure is not comparable locally due to differences in purchasing power. The incentive to become self-employed with regard to the locally emerging market in Sikkim, e.g. by founding a trading company specialized in organic goods, is therefore not correctly reflected by the market transaction value given here. It is different with the value that the agricultural market of Sikkim has for example for the international agricultural companies with their pesticide and fertilizer offers. From this perspective, the size of the market is again correctly indicated.

**Table 4: Size of the investigated systems in comparison**

| System innovation | Number of people affected in million | Considered system | Market transaction value (sales volume) of the system to be transformed per year in billion € |
|---|---|---|---|
| Power generation from renewable energies in Germany (Clausen, 2019a) | 83 | Power generation in Germany | 450 |
| Promotion of the expansion of renewable heat supply in Baden-Württemberg (Clausen & Warnecke, 2019) | 11 | Heat supply in Baden-Württemberg | 6,4 |
| Heat supply by renewable district heating or heat pumps in Sweden (Clausen & Beucker, 2019a) | 10,2 | Heat supply in Sweden | 6,4 |
| Car electromobility in Norway (Clausen, 2019b) | 5,3 | New car sales in Norway | 3,75 |
| Heat supply by renewable district heating in Denmark (Clausen & Beucker, 2019b) | 5,7 | Heat supply in Denmark | 3,2 |
| Conversion of the city of Copenhagen into a bicycle city (Clausen et al., 2019) | 1,3 | Local mobility in Copenhagen | 1,1 |
| Organic farming in the Indian federal state of Sikkim (Clausen & Olteanu, 2019) | 0,6 | Farming in the Indian federal state of Sikkim | 0,15 |

Source: Authors.

The scale of the various systems that were the subject of transition policies varies greatly. They range from the number of people affected, from 600,000 inhabitants in Sikkim to 83 million in Germany.

With regard to the different measures of the markets, the spectrum even ranges from 1:3000 from 150 million € gross domestic product in the agricultural sector in Sikkim to a turnover of 450 billion € in the electricity sector in Germany.

These very different scales may be one of the explanations for the fact that the instrumentation of the "big" transition processes is much more differentiated than that of the "small" ones, and that the debate about lobbying interests over the electricity markets in Germany is also much tougher than over bicycle traffic in Copenhagen.

## 4.2 Temporal development of the transition

The seven transition processes that we are investigating for the implementation of radical environmentally beneficial system innovations are only a small sample. Nevertheless, a few facts can be deduced from them. A central finding is that the speed of transition of such large systems is limited.

**Table 5: Status of transition and speed of change**

| System innovation | Transition status 2018 | Progress in percentage points in X years | Progress per year in percentage points | Unit |
|---|---|---|---|---|
| Organic farming in the Indian federal state of Sikkim (Clausen & Olteanu, 2019) | 100% | 100 in 10 years | 10 | Share of organic farming on of total agricultural land |
| Heat supply by renewable district heating or heat pumps in Sweden (Clausen & Beucker, 2019a) | 88% | 63 in 30 years | 2,1 | Share of non-fossil energy in district heating networks |
| | 99% | 54 in 30 years | 1,8 | Share of renewable and district heating in energy consumption for heating and hot water |
| Power generation from renewable energies in Germany (Clausen, 2019a) | 41% | 34 in 20 years | 1,7 | Share of renewable energy in total electricity generation |
| Car electromobility in Norway (Clausen, 2019b) | 14% | 14 in 10 years | 1,4 | Share of BEV and PHEV in the Norwegian car fleet |
| Heat supply by renewable district heating in Denmark (Clausen & Beucker, 2019b) | 62% | 29 in 30 years | 0,97 | Share of renewable heat in the heated area |
| | 50% | 25 in 30 years | 0,83 | Share of heat networks in the heated area |
| Conversion of the city of Copenhagen into a bicycle city (Clausen et al., 2019) | 36% | 12 in 45 years | 0,27 | Share of the modal split in the core city |

| System innovation | Transition status 2018 | Progress in percent-age points in X years | Progress per year in percent-age points | Unit |
|---|---|---|---|---|
| Promotion of the expansion of renewable heat supply in Ba-den-Württemberg (Clausen & Warnecke, 2019) | 16% (Ba.-Wü.) 14% (federal) | 0 in 15 years | 0 | Share of renewable energies in final energy consumption for heating and cooling as opposed to the national av-erage (percentage points) |

Source: Authors.

The fastest process seems to have taken place in the Indian state of Sikkim. In only 10 years, the entire agricultural area there was certified as organic, i.e. at a rate of 10% p.a. It should be noted that in Sikkim, never much artificial fertiliser and pesticides have been used, as these were sold at a price hardly affordable for the farmers and were therefore subsidised. Ultimately, Sikkim has not carried out a transition of the agricultural cultivation system in the narrower sense, but has instead "turned weakness into strength", removed the already low consumption of artificial fertilizers and pesticides from the system, completely certified the areas as organic and skilfully used this as a national strength in the development of eco-tourism. The comparability of the Sikkim case with the other cases must therefore be judged as limited.

In Denmark and Sweden, a rate of expansion of the heating networks and renewable heat sources of 1% to 2% p.a. was achieved. The German energy system transition in the electricity supply sector has progressed at a rate of approx. 1.7% p.a. since 2000, but currently seems to be coming to a standstill. In the second slowest case, the conversion of Copenhagen into a bicycle city, the "speed of transition" is just 0.27% p.a. shift of the modal split towards bicycle traffic. Norway, with an increase in the share of battery electric and hybrid cars in the car fleet, achieved a transition speed of about 1.4% p.a.

At the bottom of the list is the case of Baden-Württemberg, which was unable to change its lead (from 8% to 16%) over the national average (from 6% to 14%) of 2 percentage points in 15 years despite additional state-specific programmes. It can be assumed that under the "glass lid" of an not ambitious policy of the CDU-led federal government since 2005 it has not been possible to achieve additional progress at state level. Measured by the difference to the federal average (in percentage points), the additional state-specific programmes have apparently not been able to develop any further effects worth mentioning.

It would still be critical to ask whether the speed of transition could possibly have been reduced by a change of political course. One might mention the effect of deregulation and the lowering of climate protection ambitions by the neoliberal Danish government under Rasmussen between 2001 and 2006, which, however, had hardly any dampening effect on the transition of the heat supply, but rather had an impact on electricity generation (Eikeland & Inderberg, 2016). Already in 2006, due to broad public resistance, Rasmussen's second cabinet fundamentally changed its policy and returned to an ecologically ambitious agenda (Eikeland & Inderberg, 2016). In Sweden, too, power generation was more the subject of political changes, especially a recurring back and forth about the future of nuclear power (Clausen & Beucker, 2019a, S. 20), which obviously had a dampening effect on the development of wind power, but hardly on the switch to renewable heat.

Changes of course can be observed in Germany in the form of the re-entry into nuclear power from 2010 to 2011 as well as the photovoltaic amendment of the EEG from 2012, the introduction of distance rules for wind turbines and the tendering procedure for renewable energy projects introduced in 2017. Their effectiveness in delaying the transition can be rated as extremely high, particularly in the case of the photovoltaic amendment, the tendering procedure and the current threat of collapse of the wind energy sector (Umweltbundesamt, 2019; Zu Klampen, 2019).

However, a look at the development over time reveals clear findings. The radical transition of large supply systems will take decades. Once a new path has been chosen, it must be followed for 50 to 100 years to transform the entire system. It may also be faster, but an example of such a process, which is still much faster, has not yet been documented. Here a contradiction to the hesitation of the governments with clear measures appears. Because far greater speeds of transition are needed to limit climate change. Depending on the beginning of a trend reversal of global emissions, Wicke et al. (2010) calculate necessary reduction rates of $CO_2$ emissions of up to 9% per year. Based on the residual budget approach, Rahmstorf (2019) also believes that reduction rates of about 7% are necessary.

# 5 Analysis of the use of political instruments in transition cases studied

The following chapter first provides an overview of the use of different types of instruments in the governance efforts of state actors and identifies basic patterns of interaction between different policy measures (policy mix). Subsequently, the different types of instruments are discussed in detail.

## 5.1 Overview of the use of different instrument types

The cross-case evaluation of the seven transition cases shows that 12 of the 13 instrument types on which the analysis is based have been applied in state transition efforts. Only policy instrument D5 (reduction of R&D funding for non-sustainable technologies and systems) could not be identified in any of the seven cases (see Table 7).

In all cases, clear long-term objectives and plans (C1) as well as measures to legitimise the new technologies or systems in question (C5) play an essential role and thus ensure directional security. Another type of instrument that can contribute significantly to creating and maintaining directional security, namely the change of network structures and key actors (D1), can be found in four of the six successful transition cases. The instrument type Establishment of fundamental new regulatory systems (D2), which can contribute to long-term institutional directional stabilization, can be found in four of the six successful transition cases.

Measures of government support for research and development and knowledge dissemination (C3) can also be identified in all cases studied. In most cases (five out of seven), this also involves the targeted mobilisation of resources (usually financial and promotional funds). On the other hand, the use of entrepreneurship and start-up support (C4) does not play a significant role in the cases examined, with the exception of the electricity transition in Germany. Even in the context of the transition of the electricity system in Germany, targeted start-up support geared to this transition project has so far been of a rather marginal nature.

Government measures to establish market niches and targeted market formation (C6) can also be found in all cases studied. Furthermore, the instrument types improvement of the cost-benefit ratio of new supply and product-service systems (C8) and taxes and duties (incl. reduction of subsidies for technologies that are recognised as unsustainable) (D3) play a central role in all six successful transition cases. There are indications that instrument types that specifically support the economic framework conditions and incentives for the implementation and dissemination of new sustainable systems (C2, C6, C8 and D3) appear to play a fundamental role in the success of fundamental system transitions.

Changes in regulatory law (D4) also play an explicit role in almost all cases. Only in the case of the conversion of Copenhagen into a bicycle city did no change in the regulatory law need to be made, but it was obviously sufficient to make consistent use of the existing regulatory framework. The change or consequent use of the regulatory law thus played a prominent role in all cases examined.

The following basic policy mix patterns can be identified across cases:

(1.) In all cases, clear long-term objectives and planning (C1) and measures to legitimise the new technologies or systems concerned (C5) play a major role and thus provide directional certainty.

(2.) All successful examples are characterised by an interplay of "creative" and "destruction" instruments, i.e. they create a synchronisation of innovation or its diffusion on the one hand and exnovation on the other.

(3.) All successful cases take "hard" economic measures (D3) and use regulatory instruments (D4). They thus rely on economic incentives and clear regulations.

(4.) In all successful cases the accompanying infrastructure development (C7) plays a central role.

**Table 6: Overview of the use of different instrument types in transition cases studied**

| | | | | | Creative | | | | | | | | Destruction | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System innovation** | **Transition status 2018** | **Unit** | **Period under review** | **Progress per year in percentage points** | C1 Goals / direction | C2 Resources | C3 R&D / knowledge | C4 Entrepreneurship | C5 Legitimacy | C6 Niches | C7 Infrastructure | C8 Cost-benefit ratio | D1 Networks | D2 Basic new rules | D3 Taxes & duties | D4 Regulatory law | D5 Reducing R&D |
| Organic farming in the Indian federal state of Sikkim | 100% | Share of organic farming on of total agricultural land | 10 Years (2009 - 2019) | 10 | J | J | J | N | J | J | J | J | J | J | J | J | N |
| Heat supply by renewable district heating or heat pumps in Sweden | 88% | Share of non-fossil energy in district heating networks | 30 Years 1989 - 2019 | 2,1 | J | J | J | N | J | J | J | J | J | N | J | J | N |
| | 99% | Share of renewable and district heating in energy consumption for heating and hot water | | 1,8 | | | | | | | | | | | | | |
| Power generation from renewable energies in Germany | 41% | Share of renewable energy in total electricity generation | 20 Years (1998 - 2018) | 1,7 | J | J | J | J | J | J | J | J | N | J | J | J | N |
| Car electromobility in Norway | 14% | Share of BEV and PHEV in the Norwegian car fleet | 10 Years (2009-2019 | 1,4 | J | J | J | N | J | J | J | J | N | N | J | J | N |
| Heat supply by renewable district heating in Denmark | 62% | Share of renewable heat in the heated area | 30 Years Von 1985 – 2015 | 0,97 | J | J | J | N | J | J | J | J | J | J | J | J | N |
| | 50% | Share of heat networks in the heated area | 30 Years 1985 – 2015 | 0,83 | | | | | | | | | | | | | |
| Conversion of the city of Copenhagen into a bicycle city | 36% | Share of the modal split in the core city | 45 Years 1976 – 2016 | 0,27 | J | J | J | N | J | J | J | J | J | J | J | N | N |
| Promotion of the expansion of renewable heat supply in Baden-Württemberg | 16% (Ba.-Wü.) 14% (Bund) | Share of renewable energies in final energy consumption for heating and cooling as opposed to the national average (percentage points) | 15 Years (2003-2017) | 0 | J | J | J | N | J | J | N | N | N | N | N | J | N |

J = The cross-case evaluation identified policy measures in this instrument group.

N = The analysis could not identify any policy measures in this group of instruments.

On the basis of the patterns described above, the 13 instrument types shown in Table 3 can be grouped into four subgroups within which particularly intensive relationships can be identified. In the light of the findings we also fine-tuned some of the terms used by Kivimaa and Kern. These are the four instrument types or activation fields:

C 1: Goals and influence on search and development strategies

C 5: Legitimacy of new technologies, practices and visions

D 1: Change in network structures and key players

D 2: Fundamental institutional changes.

In the following, findings on and interactions between these four types of instruments are summarized under the heading "Creating and maintaining directional security".

Four other types of instruments are located at the interface between innovation promotion and scientific development and have an important preparatory function as a prerequisite for diffusion and transition processes:

C 3: Research and development, dissemination of knowledge

C 4: Entrepreneurship and start-up support

C 6: Establishment of market niches and market formation

D 5: Reduction of R&D support for non-sustainable technologies and systems

The examples we have found on the importance of these four types of instruments can be summarised under the heading "Innovation policy and niche development".

The central control of transition takes place through the instrumentation of further activity types. These are:

C 2: Resource mobilization

C 8: Improvement of cost-benefit ratio

D 3: Taxes, duties and subsidies

D 4: Regulatory law

Findings on these instrument types are summarized under the heading "Synchronization of Diffusion and Exnovation".

As a last, also important, but nevertheless discreet instrument type we focus on the

C 7: Infrastructure development.

Often we have found activities here to transform state infrastructures, e.g. the conversion, extension or dismantling of roads or energy infrastructures such as heat or gas networks. We document findings on this point under the heading "Infrastructure Development".

## 5.2 Creating and maintaining directional security

An essential factor for the success of a transition is to give it a clear goal and to steer it in a direction that is reliable over many decades. The political goal may have been achieved in different ways. Scientific findings, such as those on the climate crisis, can be just as much a starting point for goal-setting as politically negotiated agreements such as the Paris Climate Change Convention (UN FCCC, 2015) or national foresight processes. In order to establish targets, it is necessary to set and frame them positively. Schneidewind (2018, S. 10) speaks of an identity-giving and transdisciplinary narrative, which condenses *"ecological, technological, economic, social and cultural science findings into a hopeful design programme".*

In order to anchor goals credibly in society, it is necessary to underpin them with a consistent strategy and a feasible action programme. Consistent action by the state is helpful in providing social legitimacy for goals and strategies. The implementation of the strategy plays just as much a role here as the participation of the state itself in the transition, e.g. by changing the procedures and processes of state institutions and through public procurement. Legitimacy can also be built up through the broad participation of consumers and companies in the transition.

However, it should not be forgotten that the upcoming major transitions in energy supply, mobility, agriculture and food are not only "hopeful" aspects, but also entail material disadvantages for all those who have so far benefited from the functions of the established non-sustainable regime. Diverse economic interests as well as institutional and use-related path dependencies (Kahlenborn, Clausen, Behrendt & Göll, 2019) lead to the "losers of transition" defending their interests with strong pressure. Since these actors represent the established regime, they usually have ample financial resources, while on the winner side of transition, on the other hand, there are often institutions and companies whose successful future is still ahead and whose financial resources are therefore limited.

So while on the one hand goals are set, strategies and plans are developed and narratives are created in order to facilitate the change to a sustainable path, on the other hand the scientific basis of the motivation for change is doubted, e.g. by climate change scepticism (Clausen & Beucker, 2020) up to the highest decision-making bodies of politics and companies, the effectiveness of strategies and the achievability of goals is questioned and alternative transition paths are designed using "alternative facts". The beneficiaries of these actions are often the actors of the established regime.

### 5.2.1 Goals and influence on search and development strategies

Most of the case studies show that the transition processes examined are for the most part associated with demanding objectives.

- Denmark is aiming for 100% renewable district heating by 2035, which already supplies 2/3 of all households with heat (Clausen & Beucker, 2019b).
- Copenhagen is aiming for a 50% share of cyclists on their way to work or schools in 2025 (City of Copenhagen, 2017).
- In Norway, the sale of all cars with combustion engines, including all hybrid models, is to be discontinued in 2025 (Stortinget, 2017).

- Germany has the goal of reducing greenhouse gas emissions from the energy sector by approx. 38% by 2030 compared with 2020, as well as the long-term goal of achieving extensive greenhouse gas neutrality by 2050 (Die Bundesregierung, 2019).
- The Indian state of Sikkim has already achieved its goal of organic farming and certification of 100% of its agricultural land by 2014 (Avasthe, Singh, Babu, Pashte & Sharma, 2019).

The only exception is Sweden. Although the $CO_2$ tax introduced in 1991 led to a successful change of course, it was not until 2009 that Sweden formulated targets for energy supply and climate protection.

All six case studies succeeded in maintaining the target orientation over several decades. However, there were isolated setbacks. These include an attempt to change energy policy in Denmark under the neoliberal Rasmussen government from 2001 onwards, which was abandoned after a few years (Eikeland & Inderberg, 2016). In Sikkim, an attempt was made to ban the import of non-organically produced food into the state from April 2018, which resulted in a shortage of key agricultural products and drastic price increases (Clausen & Olteanu, 2019). The ban was lifted again in autumn 2018 and the initiator of the Sikkim Organic Mission, Shri Pawan Chamling, was voted out of office as Prime Minister in May 2019. In Germany, resistance to the energy turnaround from 2012 onwards became tangible. Since then, the CDU-led federal government has led the photovoltaic industry into crisis and is currently instigating further problems in the wind industry. No setbacks were noted in the transition processes in Copenhagen, Norway and Sweden.

### 5.2.2 Legitimacy of new technologies, practices and visions

In all cases, the legitimacy of the transition processes is based on a broad political coalition, at least in phases, and public support. In Denmark, the alternative energy perspective of an energy supply strongly based on nuclear power was finally put to rest as early as the 1980s. In the course of research, no plans from Copenhagen that deviated from the development of a bicycle city were found. Following a consensus reached at the beginning of the millennium between politics, business and society, the consistent implementation of the electric car strategy also dominates the field in Norway, which also fits in well with natural energy potentials due to the abundant resources of hydropower. Energy policy disputes in Sweden were more concerned with the question of what power the energy companies can achieve and how far they can dictate heat prices. In Sikkim, the food crisis in 2018 shook the consensus around the Sikkim Organic Mission, which is also being actively pursued by the new Prime Minister (AgroSpectrum, 2019). And in Germany, although the majority of the population has long been supporting the energy turnaround, the process of transforming the power supply system seems to be coming to a halt at the moment due to widespread climate change scepticism and a lack of willingness to change in many circles, as well as due to the effective articulation of lobbying interests of the established (fossil) energy companies.

### 5.2.3 Change in network structures and key players

Over the decades, the proponents of the transition to a sustainable society have developed technologies, implemented demonstration projects such as the Tvindkraft wind power plant (CICD, 2002), and created endearing niches in which production and consumption were to some extent different.

In some cases, they have asserted themselves against the established companies, supported by coincidences or contingent events, as for example in the resolution on the Electricity Saving Act (Clausen, 2017). However, while the studies on the transition processes in Scandinavia give the impression that sooner or later the companies will also accept the socially negotiated and agreed compromises and "participate", this seems to be different in Germany. Essential lines of conflict in the implementation of a renewable electricity supply were traced in the corresponding case study (Clausen, 2019a).

As the example of Germany shows, it can take decades to deal with lobbies, just like the restructuring of systems. It is only likely to come to a definitive end with the disappearance of the last enterprise of the established regimes. Different discourse strategies are used by lobbyists (Geels, 2014), each requiring a different knowledge base:

- **Diagnostic framing**, which attempts to influence or redirect the identification of the problems and whose application requires extensive knowledge of the nature of the problems,
- **Prognostic framing**, which is intended to influence the selection of problem solutions and for which detailed knowledge of alternative solutions is required, and
- **Motivational framing**, which questions or changes the rationale for action and essentially represents an argumentative challenge for PR.

In the context of diagnostic framing, the denial of climate change is of importance, which was discussed in depth in the case study on the Building Energy Act (Clausen & Beucker, 2020). As a second topic, a distorted concept of personal freedom is increasingly being sought, which is also intended to refer to the right to drive oversized cars with combustion engines and to the free choice of energy source for heating, and which denies the state the right to regulatory intervention with reference to the German Constitution (Clausen & Beucker, 2020)

The method of prognostic framing consists in creating uncertainty about the solution of the problem. This can be done either by denying the preferred solution the ability to solve the problem (Hirschl, 2007, S. 130), or by proposing additional alternatives that reduce the clarity of objectives and effectively delay the process, such as the current debate on the Power-to-X option as the universal solution to all energy problems (Power to X Allianz, 2019).

Both a change in the diagnosis of the problem and increased uncertainty about the goal orientation then affect the motivation to bring about change. Kivimaa and Kern (2016, S. 208) therefore suggest actively questioning network structures such as the representation of established industries in political advisory bodies or at least establishing a balance by representing the possibly newly founded associations of "new solutions". However, the subject of discussion must also be the sometimes outrageous studies and arguments of the lobbyists (Institut für Wärme und Oeltechnik e.V. (IWO) & MEW

Mittelständische Energiewirtschaft Deutschland e.V., 2018) as well as the question of what part of lobbying takes place below the surface of visibility. Transparency rules are therefore a very important element in the preparation of the transition.

In the cases of the bicycle city of Copenhagen and electric mobility in Norway, we did not find any significant evidence of lobbying activities.

An attempt by neo-liberal circles to question the transition to renewable electricity generation and the heat turnaround in Denmark was abandoned after a few years due to fierce resistance from the population.

In Sweden, the energy companies successfully challenged the implicit rule of the non-profit status of heat supply in the course of the liberalisation of the heating market and managed to abolish it, which led to the takeover of a substantial part of the heating networks by commercial operators.

In Sikkim, following the failure of the import ban on non-organic fruit and vegetables, a candidate for the office of Prime Minister criticised the Sikkim Organic Mission. He was then also elected and continues the policy for the time being, but uncertainties remain (Singha, 2020).

In the case studies we encountered the most intensive and continuous activity of lobbies in the period from the early 1980s until today in the case of the German energy system transition.

New network structures around new solutions have formed in several countries. However, there is almost no evidence of state involvement in the genesis of such network structures. An exception are model farms and consultant networks in Sikkim and also the Swedish procurement groups provide new networks in a certain way. It remains unclear, however, whether they provide a significant political impetus.

None of the case studies showed any evidence of deliberate and effective change in network structures on the part of policymakers.

### 5.2.4 Fundamental institutional changes

Kivimaa and Kern (2016, S. 208) see structural reforms in legislation or important new overarching laws as fundamental institutional changes. They cite the privatisation and liberalisation of the electricity markets in the 1990s as a historical example of major regulatory changes. Such fundamentally new rules have not been established in the case of the bicycle city of Copenhagen or in the case of electric cars in Norway.

The Danish turnaround in the heat market was initially made against the background of the (regulatory) decision not to enter into the use of nuclear energy (1986) and to exclude the construction of new coal-fired power plants (1986). This created an effective foundation on which renewable energy technologies could be built. The principle of heat pricing, which stipulates that the heat supply is to be calculated on a non-profit basis according to the actual costs, also represented a fundamentally new rule.

In Sweden, on the other hand, the implicit rule of non-profit status of the heat supply, which had previously resulted from municipal law, was abolished in the course of the liberalisation of the heating market.

Sikkim has declared itself a 100% biological state, which has only indirect effects, but has proved to be extremely beneficial for tourism.

Not only the feed-in priority and the remuneration regulation introduced fundamentally new rules in the German electricity market, but also the market liberalisation in 1998 represents such a fundamentally new rule. The nuclear phase-outs in 2002 and 2011 and the planned coal phase-out will create further new rules.

In addition to economic governance and regulatory law, basic new rules appear to be a backbone of the governance of transition.

## 5.3 Innovation policy and niche development

At the beginning of transition processes, fundamental key innovations form the starting point for new technology paths. For example, the development of the first wind power plants, and especially the wind power plant in Tvind, built by teachers from an alternative school, SMEs and people from the scientific community, marked the turning point in Danish energy policy (Clausen & Beucker, 2019b). Numerous inventors and tinkerers, together with start-ups for supplier products, also marked the beginning of the renewable energy sector in Germany (Clausen, 2019a; Clausen & Loew, 2009; Oelker, 2005).

In the case of electromobility in Norway, a number of company start-ups in the electric car sector play a role in addition to the high-profile conversion of a Fiat Panda by Professor Harald Rostvik and the pop band aha. Especially the electric car manufacturer Think was supported with public and private funds, later taken over by the Ford Motor Company and finally went bankrupt in 2011 (Figenbaum & Kolbenstvedt, 2013). Today, the only remaining company is Buddy Electric, which also went bankrupt in 2011, but was bought by Norwegian investors and continued (Norsk elbilforenning, 2019). The significance of these foundations for the transition process lies in the fact that at the beginning of the process the technical feasibility of the vision was proven and thus contributed to the motivation for the change.

However, neither the first wind turbines nor the first solar thermal apparatus from the 1970s nor the first electric cars from the 1990s were ready for serial production. Through a process that lasted several decades, these basic innovations became more powerful, more durable, easier to use and repair, and ultimately cheaper. All these improvements are part of the Economy of Scale and are of great importance, but will not be discussed in detail here.

Instead, with a view to the change of large societal supply systems, we will take a look at innovations whose significance sometimes only becomes clear as the transition progresses. Examples of such solutions include demand side management, which aims to at least partially compensate for fluctuations in the supply of renewable electricity over time and improve grid stability. Such solutions, whose necessity is only recognised parallel to the ongoing transition or for which only basic innovations from other sectors create the possibility, are often necessary for the large-scale implementation of transitions. The transition process must therefore be accompanied by an active promotion of the innovation system that produces such complementary solutions.

### 5.3.1 Research and development, dissemination of knowledge

In all cases studied, we found examples of support for research and development and/or instruments for knowledge dissemination that accompanied the respective transition process.

In the context of the transition of the heat supply in Denmark, biofuel boilers, large solar thermal systems and efficient heating pumps have been further developed with public funding (Danish Energy Authority, 2005; Heller, 2000). Work has also been carried out on low-temperature heating networks (Diget, 2018) and sector coupling with large heat pumps (Lund, Ilic & Trygg, 2016).

Sweden investigated the feasibility of heating networks in low-density areas (Werner, 2017), and promoted the development of complex methods of biomass use with little success (Ericsson, Huttunen, Nilsson & Svenningsson, 2004), which was ultimately primarily burned. In particular, the development of the procurement groups' tool has been successful in inducing improvement innovations (Swedish Ministry of Environment and Energy, 2019).

In the case of Copenhagen, the exchange of information on bicycle-related innovations was promoted, suppliers of cargo bikes established themselves and automatically changing traffic signs for cyclists were developed (European Cyclists Federation, 2017).

The Norwegian Transport Research Institute has conducted numerous studies on the use and costs of and experience with electric vehicles in order to identify and address concerns of potential users (Clausen, 2019b, S. 9). Furthermore, demonstration projects were carried out on new fields of application for electric cars, e.g. as taxis or postal delivery vehicles (Figenbaum & Kolbenstvedt, 2013).

R&D projects on effective and approved organic pesticides have contributed to the successful spread of organic farming in Sikkim (Ministry of Agriculture and Farmers Welfare, Govt. of India, 2018; Rao, 2017) and research has also been conducted on the supply of nutrients through farm manure and multi-field farming methods (Rao, 2017; Singh, Babu, Avasthe, Yadav & Ngachan, 2017). The main challenge, however, was the diffusion of knowledge, techniques and methods of organic farming, with which all 65,000 family farms in Sikkim had to be familiarized.

In Germany, high budgets for energy research programmes supported numerous projects to further develop and improve renewable electricity generation technologies until 2019 (Clausen, 2019a, S. 9). New topics whose importance has been recognised, such as sector coupling and research into energy storage systems, have also been included in energy research. At present, significant cuts are being made in the energy research programme (Ehlerding, 2020), which raise the question of the extent to which the implementation of energy system transition can still be seen as a goal of the Federal Ministry of Economics.

The transfer of knowledge played a key role, particularly with regard to the craft trades, since thousands of craft enterprises had to learn to install and maintain decentralised PV systems, electricity storage systems, solar thermal systems or pellet boilers (Clausen, 2009). New solutions are being tested on a small to medium scale in the "real laboratories of the energy turnaround" as well as in the SINTEG projects (Bundesministerium für Wirtschaft und Energie, 2017).

It is becoming clear that both research and development and knowledge transfer play an important role in the transition process.

### 5.3.2 Entrepreneurship and start-up support

In the case studies examined, support for entrepreneurship and start-ups that consciously and explicitly aimed at the system transition in question only played a noticeable role in Germany. Even in the case of the transition of electricity generation from renewable energies in Germany, however, this is of a rather marginal nature. Measured against the large number of start-up and innovation support programmes and their financial volumes in Germany, the targeted inclusion of start-ups within the framework of the energy research programme[2] is an important step, but measured against the transition needs it is a rather small one. A possible reason for the lack of political use of the instrument type of entrepreneurship and start-up support for the transition of large supply and product use systems can be cited that start-up support in particular has so far been practiced politically and institutionally very separately from targeted transition policies (energy system transition, etc.) and is primarily focused on the technology and supply side and not on the demand or mission side. While, for example, the Federal Government's High-Tech Strategy 2025 (BMBF, 2018) identifies priority "societal challenges" and formulates so-called "missions" to which research and innovation are to make a targeted contribution, this has not yet been the case for start-up funding.

### 5.3.3 Establishment of market niches and market formation

The establishment of a market niche usually represents the first step in the transition of the mass market, but "stabilization in the niche" (Kahlenborn et al., 2019, S. 174) is also possible. From the perspective of transition, a niche market can therefore also be a dead end.

Numerous market niches were established in the case studies examined. For example, Sikkim experimented with 100 "bio villages" at first, then with 400 in order to transfer the experience to the whole country. Sweden has promoted the establishment of a group of first biomass CHP plants.  Germany has created niche markets in wind power as well as in PV and bioenergy, which were later effectively scaled up by the EEG. In Denmark, niche markets for biofuel boilers and low-temperature heating networks were created, and in Copenhagen for cargo bicycles. Norway in a sense represents a niche market for electric cars as a whole, which functions as a test market for the automotive industry worldwide.

[2] See https://www.forschungsnetzwerke-energie.de/start-ups (assessed 09.01.2020).

In niche markets, innovations are tested for the first time in small or medium quantities. In the process, weaknesses may be revealed and function, performance, costs and quality are optimized. Such steps are important, but the successful establishment of a niche market must not be confused with successful transition. Many environmental innovations have been limited to sales in niche markets, sometimes for decades (Clausen & Fichter, 2019a; Fichter & Clausen, 2013), so that their potential for environmental relief could not be tapped.

### 5.3.4 Reduction of R&D support for non-sustainable technologies and systems

Kivimaa and Kern (2016, S. 209) point to the consequence of ending R&D funding for technologies that are to be substituted by better ones in the process of politically desired change. The targeted political reduction of R&D activities for technologies and systems identified as unsustainable could not be found in any of the seven transition cases examined. For example, neither Norway nor Denmark had an automotive industry in recent decades that could have been supported with public R&D funds. Nor were there any major manufacturers of chemical pesticides or artificial fertilizers in Sikkim.

This finding also applies to the German energy turnaround in the electricity sector. Although the Federal Report on Energy Research 2018 (Bundesministerium für Wirtschaft und Energie, 2018a, S. 6) shows that funding for research into renewable energies and energy efficiency has increased significantly since 2006, research activities on nuclear energy have not been discontinued even eight years after the decision to phase out nuclear power. Following the path taken in the 1950s and 1960s, this research today is concerned on the one hand with nuclear safety and disposal, but on the other hand, as it has been for decades, with fusion research. With regard to fusion research, it is argued: *"The rising demand for energy against the background of the growing world population and the need to reduce $CO_2$ emissions make it necessary, in the view of the Federal Government, to continue to research long-term concepts for energy research in the field of basic research, open to new technologies"* (Bundesministerium für Wirtschaft und Energie, 2018a, S. 39). Since the work is integrated into the European fusion research programme of Euratom, it follows not only a German but also a European research agenda. However, the current sharp cutbacks in energy research (Ehlerding, 2020) raise doubts as to whether this research is still pursuing the main goal of a climate-neutral energy supply.

Research is also continuing on coal-fired power plant and CCS technologies, with small volumes. The reason for this is, on the one hand, that in view of the fluctuating feed-in of renewable energies, conventional power plants have to be ramped up and down more quickly in the last few years of their operation, which requires development work. But the major players in the energy regime are thinking ahead: *"Most German power plants are currently operated with coal or natural gas. In the future, however, fuels such as hydrogen and regeneratively produced methane should also be used"* (Bundesministerium für Wirtschaft und Energie, 2018a, S. 18). Between 2012 and 2017, public funding for research into fossil power plant technologies has thus increased successively from approx. 27 million

€ to approx. 32 million € (Bundesministerium für Wirtschaft und Energie, 2018a, S. 19). These activities can easily be connected to the current main project of fossil energy companies, the large-scale power-to-gas technology (Institut für Wärme und Oeltechnik e.V. (IWO) & MEW Mittelständische Energiewirtschaft Deutschland e.V., 2018; Power to X Allianz, 2019).

## 5.4 Synchronization of Diffusion and Exnovation

As our case studies suggest, both the targeting and maintenance of directional security and the development of innovations and niche markets are central strategies for managing radical system transition. They seem necessary, but they are obviously not sufficient. The cases studied suggest that these strategies are essential in accompanying and preparing the transition, but that the central transition must be carried out by a further strategy, which will be described here as the synchronization of diffusion and exnovation. The following section deals with central instruments for this.

The radical transition of large supply and product use systems requires a clear change in the economic framework and incentives. The instrument type "resource mobilisation" is fundamental for this. Without the provision or relocation of financial resources, the transition cannot be achieved. Furthermore, it is then a matter of designing taxes and charges in such a way that new and sustainable solutions become more economical than old and unsustainable offers of the established regimes. In addition to taxes and levies to shape economic efficiency, however, there is also the possibility of changing the cost-benefit ratio in favour of new solutions through targeted promotion of cost-cutting activities. The reduction of subsidies for non-sustainable technologies must also be addressed, which in turn affects the advantages or disadvantages in terms of economic efficiency. A clear advantage of such approaches is that they make it easier for private or public actors to finance the change, because the new technologies to be procured and applied become at least relatively cheaper, and thus decisions made on the basis of economic considerations are more often made in favour of the sustainable alternative.

It is also a matter of regulatory law, which makes the use of certain technologies possible, mandatory or impossible.

### 5.4.1 Resource mobilization

For Kivimaa and Kern (2016, S. 208), the financing of the transition involves both public and private sources of money and capital. Both the promotion of research and development and the promotion of testing and dissemination usually lead to costs for public budgets. Low-interest loans and risk capital can be provided by public funding banks, but also by private donors.

In Copenhagen, costs are incurred for the public budget due to the need to expand bicycle roads. In the long run, however, the construction of paths for pedestrians and cyclists proves to be cheaper than building additional motorways. In addition, lower costs of health care will reduce the burden on public social security funds, as cycling is beneficial to health. Furthermore, there are revenues from the high tax on cars, which also leads to a smaller car stock and thus to lower costs for the construction of roads and parking spaces.

In the Danish and Swedish heat supply systems, several renewable heat technologies, such as the use of biomass, large solar thermal systems with seasonal storage, and waste heat recovery with heat pumps, have proven to be economically viable in individual cases because the competitive pressure is less intense due to higher gas and oil prices. As a result, only a small amount of funding is required, some of which has been documented for R&D funding. The burden on national budgets is low.

The introduction of electric cars in Norway and tax incentives for them are associated with high costs for the state and, due to special conditions on fees, also for municipalities. Due to the robust Norwegian state finances, the loss of revenue through reduced taxes and charges on electric cars has so far been politically enforceable. At present, however, consideration is beginning to be given to revising the promotion strategies (Figenbaum, 2018, S. 22). It has already been decided that local authorities will again be able to levy fees on a pro rata basis for electric cars (Clausen, 2019b, S. 11).

The elimination of subsidies for conventional agriculture has relieved the Sikkim state budget. New subsidies, research measures and knowledge transfer are financed from the national budget. Consolidated figures of the burden on the state could not be determined.

The German energy turnaround in power generation was financed on the one hand from the national budget (research funds, promotion programmes) and on the other hand by electricity customers (EEG levy). Due to the volume of the transition, the differential costs of electricity generation under the EEG, which peaked at around €25 billion in 2018 (Bundesministerium für Wirtschaft und Energie, 2018b, S. 10), have repeatedly been on the political agenda and are also being used as an argument by opponents of the transition. Thus, they were not only the basis for the electricity price brake staged by Minister Altmaier (Anonym, 2012), but are permanently used as an argument (DICE Consult, 2016).

The critical debates on the costs of transition in Norway and especially in Germany indicate that the cost argument is of central importance for the success of transition not only at the level of the cost-benefit ratio for the individual user, but also with regard to its impact on the state budget or state-imposed pay-as-you-go systems. In addition to activities to reduce additional costs, a possible counter-financing as a political tool must also be considered. Such counter-financing can take the form of additional taxation of unsustainable products or behaviour.

### 5.4.2 Improvement of cost-benefit ratio

The cost-benefit ratio is a central factor that can promote or even inhibit the diffusion of new solutions. As a rule, however, the cost-benefit ratio is only indirectly the object of transformative activities. From the case studies the following activities can be compiled, which have an impact on the cost-benefit ratio or its perception.

The bicycle city of Copenhagen benefits from the fact that cycling is significantly cheaper than driving on the motorway, which is made even more expensive in Denmark by an extremely high registration tax. The subject of targeted improvement is the benefits of cycling. The average speed at which cyclists move around Copenhagen is continuously increased by the development of bicycle superhighways, green waves for bicycles and the overall good condition of the cycle paths. The fact that 76% of all Copenhageners who cycle feel safe when cycling (City of Copenhagen, 2017a, p. 5) is just as important as the fact that 53% of Copenhageners consider cycling to be faster and 50% to be easier than driving (City of Copenhagen, 2017a, p. 18). The success of the City of Copenhagen Bicycle Project is therefore largely due to the fact that cycling has been and continues to be made as pleasant, fast, easy and safe as possible by the city planners.

In general, all common forms of heat supply in Denmark satisfy more than 90% of the customers, although this is only the case with electricity heating for 83.9% of the customers and oil heating for 73.9% (FIF Marketing, 2016, S. 15). In the district heating supply, the 94.7% satisfied customers are most convinced by the perfect function and price (FIF Marketing, 2016, S. 22), which also indicates a good cost-benefit ratio.

The cost-benefit ratio of the heat supply is also good for the majority of Swedish heating customers. The price for district heating is - taking into account the high level of consumer prices - in the lower range of the heating prices in other EU countries

A favourable cost-benefit ratio is also important in the Norwegian car market. The consistent orientation of the political instruments towards cost advantages for electric cars has generally made it possible to achieve full competitiveness since 2010 (Figenbaum, 2018, S. 15f). The increasing number of buyers since then clearly shows the importance of this factor.

In the German electricity market, different generation prices for different types of electricity are redistributed by electricity market regulation and, to a very large extent, by the provisions of the EEG in such a way that cost differences are not visible to the end customer. The competition problem is thus only visible at the national level through the constantly increasing EEG levy. According to the type of planned economy, cost shifts are being fought for by excluding certain sectors from the obligation to pay the EEG levy. This has had an impact on the course of the transition in that in 2013, Minister Altmaier brought up the issue of the electricity price brake and, with this argument, plunged the prospering photovoltaic industry into the abyss and, in a populist manner, "capped" the expansion of photovoltaics in terms of regulatory law.

In Sikkim, it has been demonstrated for some crops that production in organic farming is somewhat more cost-effective, even taking into account lower yields (Rao, 2017). However, after the import ban on conventional vegetables was imposed at the beginning of 2018, the prices for nationally produced organic products rose significantly, not least due to shortages. The fact that the import ban had to be withdrawn after strong protests points to the importance of the cost-benefit ratio as a control parameter for transition.

In most examples, the cost advantages of sustainable products are the effect of internalising external costs in the form of taxes and charges on non-sustainable products. In addition, for a number of technologies there are considerable cost reduction effects through economies of scale. Targeted research and development activities with the primary goal of reducing the costs of sustainable products were not documented in any of the case studies, but are evident, for example, in a Dutch project to improve and cheapen building refurbishment (Clausen, 2019c).

### 5.4.3 Taxes, duties and subsidies

For proactive government action, Jänicke (2012) sets the following maxim: *"Ambitious targets plus monetary trend control plus detailed regulatory control plus supporting instruments. Supporting instruments are usually indispensable in the policy mix of innovation promotion"* (Jänicke, 2012, S. 19).

In the case studies, we found economic control instruments that affect the sales prices of certain products, measures that increase operating costs primarily through taxes on energy, and the reduction of subsidies on non-sustainable products.

In the case of Copenhagen, a purchase tax on cars up to a net price of €24,000 affects 85% of the car value, and even 150% for the price portion above that (Danish Customs and Tax Administration, 2019). The high purchase tax leads to a 20% lower car stock of 429 cars per 1,000 persons in Denmark compared to 555 in Germany (Eurostat, 2019) and increases the necessity to use other forms of mobility due to the lower availability of cars.

As a result of a change in tax law since 1993, the prices for natural gas in Denmark today are about 45% higher than in Germany, and those for heating oil are even about 67% higher. On the other hand, the principle of heat pricing stipulates that the district heating supply must be invoiced according to actual costs and that the district heating suppliers must be non-profit companies that are not allowed to make a profit. Wood pellets are tax-free.

In Sweden, a $CO_2$ tax was introduced in the early 1990s. Today, the tax is 120 € per tonne of $CO_2$, reduced to 100 € for certain industrial plants. Heating oil in Sweden is thus approx. 63% more expensive than in Germany, natural gas is not available at all due to non-existing gas networks and electricity for operating the numerous heat pumps is sold at a much lower price than in Germany at a retail price of approx. 20 cents/kWh.

In Norway, the sales price for cars with combustion engines is driven up by various taxes ($CO_2$ tax, NOx tax, weight tax, a disposal fee and a value-added tax of 25%) in such a way that electric cars are regularly cheaper to buy, as only the disposal fee is charged for them. The operation of electric cars is also significantly cheaper due to significantly higher prices for petrol and diesel compared to Germany and lower electricity prices for private customers of approx. 19 cents/kWh. A large number of fee reductions for the use of tunnels, ferries, bridges and parking spaces create further cost advantages for users of electric vehicles, which, however, reduce the income of the municipalities.

In Sikkim, subsidies for fertilisers have been gradually reduced since 2003. Transport and handling subsidies and commissions to retailers were also cut from 2006 onwards. The subsidies, which were reduced in steps of 10%, led to a collapse in the artificial fertilizer market after only a few years. Investments in irrigation systems were promoted and certain seeds were made available to farmers free of charge.

With the cost-covering feed-in tariffs under the Electricity Feed-In Act (1990) and the Renewable Energy Sources Act (2000), an instrument was used in the German electricity market that developed strong economic effectiveness. The feed-in tariffs, which were made binding for 20 years, made it possible to calculate the expected revenues of renewable energy projects in a comprehensible and credible manner, thus facilitating investment decisions on the one hand and simplifying access to credit on the other. The statutory feed-in tariffs were allocated to the electricity price via a levy system, whereby individual consumers such as "energy-intensive industries" were exempted from paying the EEG levy. The high costs of the widespread introduction of technologies that would not have been competitive in the free market became the subject of ongoing political debate, including the debate on the electricity price brake.

In the cases of the Danish and Swedish heat supply systems, as well as the bicycle traffic in Copenhagen, the transition took place in a form that had little impact on the costs for the end customers and did not lead to high expenditures for the state either. In addition, the state generates revenues through increased taxes and charges on non-sustainable products. The transition to electric cars in Norway was also largely cost-neutral, if not cost-cutting for the end customer, but led to high losses of taxes and fees for the state and municipalities. Recently, therefore, some fee reductions have been reduced in order to avoid financing problems for municipalities as the number of electric cars increases. In Sikkim, the effects of economic control are unclear. The only case in which the costs of transition are passed on to end customers to a significant extent is Germany. In Germany, the possibility of passing on cost shares to non-sustainable products was also not used. Instead, the EEG levy is even to be paid proportionately on self-generated renewable electricity. The economic management is thus carried out in a way that hinders the transition itself.

A major effect of economic management is the change in the cost-benefit ratio for customers of products from the transformed markets. In addition to the effect of economic management, the effect of activities to improve the cost-benefit ratio will increase the impact.

### 5.4.4 Regulatory law

In all cases examined, the state used regulatory provisions to achieve certain transition goals. In six out of seven cases, regulatory provisions were changed to this end. In the case of the transition of the city of Copenhagen into a bicycle city, which was apparently possible on the basis of the existing road traffic law (Clausen et al., 2019, S. 14), the regulatory law was not changed, but was consistently used for the transition.

In the course of the Danish heat turnaround, certain heating systems were banned in principle or significantly restricted in their applications. This was the case for electricity heating (1988), oil and gas heating in new buildings (2013) and oil heating in existing buildings (2016). Another key provision required municipalities to draw up energy plans (1981). The obligation of about 2/3 of the municipalities to connect individual buildings to heating networks is also an effective regulatory regulation.

In Sweden the number of regulatory interventions is low. But district heating is considered a natural monopoly in Sweden and market participation is regulated in detail in the District Heating Act (Nordic Council of Ministers, 2017, S. 36). Every district heating company must ensure that information on prices for district heating and for connection to district heating is easily accessible to customers and the public. The Energy Market Inspectorate monitors this. Customers can complain to the District Heating Authority (Nordic Council of Ministers, 2017, S. 36).

In Norway, a special number plate has been introduced for electric cars so that they can be clearly identified, for example, by automatic image recognition systems that are used for toll payment that can. Furthermore, from 2005 electric vehicles were allowed to use bus lanes, but this was discontinued in 2016 due to the increasing number of BEVs. Very small BEVs were allowed to park orthogonally. Since 2019, holders of a class B driving licence have also been allowed to drive class C1 electric vehicles.

The "Sikkim Agricultural, Horticultural Input and Livestock Feed Regulatory Act" (Government of Sikkim, 2014) regulates numerous details concerning the form of agriculture.  For example, the Act contains detailed and very restrictive regulations for the import, sale and use of inorganic agricultural and horticultural inputs in the cultivation of plants and the use of inorganic animal feed in poultry and livestock farming. In practice, it led to a ban on artificially produced fertilisers and pesticides. The law gave the state government the power to appoint inspectors for organic farming. The law also made the possession and use of unauthorised chemical fertilisers and chemical pesticides a criminal offence. Violations can be punished with 3 months imprisonment or a fine (Government of Sikkim, 2014, S. §11e).  This provision was intended to ensure that artificial fertilizers and pesticides are not purchased and imported on an individual basis outside the state (Rao, 2017, S. 17). As of April 1, 2018, a law temporarily prohibited (it was repealed in October 2018) the import of conventionally produced fruit and vegetables into Sikkim (Geier, 2019, S. 37).

Already in the 1980s, regulations for the approval of wind power plants were put into force in Germany. The Stromeinspeisungsgesetz (1990) obliged electricity supply companies to purchase renewable electricity in their supply area and to pay a fixed minimum price (Bruns, Köppel, Ohlhorst & Schön, 2007, S. 43). The nuclear phase-outs of 2002 and 2011 were of great importance for the confidence of companies to continue the expansion of renewable energy (Rogge, 2015. The 2008 amendment of the Renewable Energy Sources Act (EEG) provided for initial grid management measures to avoid overloading the electricity grids. Individual plants now had to be taken off the grid in case of grid overload. Since 2014, a country-opening clause has enabled country-specific rules on minimum distances between wind turbines and residential buildings to be introduced, which should prove to be an effective measure to limit the expansion of wind energy in the medium term and have brought the expansion of wind power almost to a complete standstill in 2019.

It has been shown that, on the one hand, regulatory rules regulate numerous processes of transition so clearly that they can be handled with legal certainty even in groups of many actors, e.g. in matters of permits. But also prohibitions with penalties create clarity in some places about the direction in which the transition should move.

## 5.5 Infrastructure development

Except for the unsuccessful case of the heat turnaround in Baden-Württemberg, the targeted development of relevant infrastructures is an essential element of the transition in all (successful) cases. However, the role of the state in this process must be viewed in a differentiated manner:

A strong intervention in Copenhagen's urban structure is due to the fact that the municipality provides its service "construction and maintenance of roads" differently today than in the days of the "car city". This is because the central infrastructure measure in the development of the bicycle city is the maintenance and construction of new cycle paths. For the year 2016, the current Bicycle Account shows 375 km of cycle paths (City of Copenhagen, 2017, S. 5). Bicycle Superhighways, Desire Lanes and Green Bicycle Routes already provide diversification for different user groups. Central to this transition was the training of urban planners. They had been specialised in the construction of motorways in the times of the car city and had to be trained with a view to the requirements of cycling.

The Danish natural gas network is owned by the state-owned company Energinet. The heating networks are often owned by municipal and non-profit organisations. The policy of separating the supply areas has made it possible to keep the investment costs for building the networks low. Competing network structures were thus largely avoided and infrastructure costs were limited.

In Sweden it is important to note that a natural gas network is virtually non-existent - the total length is 600 km. The heating networks, which were in public ownership at the time, were greatly expanded in the 1960s to 1980s, but were later privatised.

In Norway, state or municipal roads, bridges, tunnels and ferries were actively used as a policy instrument through the differentiation of charges. Charging stations are being built on the main roads and their number is increasing as the number of electric vehicles increases.

Sikkim provides essential government services through public experimental organic farms and through government officials who provide training and supervision for farmers.

Since all electricity grids in Germany are privately owned, changing the way in which government services are provided was not an option for the German energy turnaround. However, influence is exerted by energy law and the Federal Network Agency. The municipal utilities, some of which are still in municipal ownership, give individual municipalities limited regional influence on the transition processes.

Especially in road transport, whose infrastructures are almost everywhere in state ownership, the changed provision of state services is likely to be a major option for action. With regard to the change in energy supply, there is only limited state ownership of energy networks in some countries or regions, and more so in the case of heat than electricity, and thus the possibility of actively shaping them.

## 5.6 Interaction and orchestration of the instruments

In the cases studied, the types of instruments discussed above do not usually act individually and in isolation, but in interaction with other instruments. In the context of the present study, the interaction and interplay cannot be analysed in detail, but a number of basic relationships and rough patterns of interaction between the instruments can nevertheless be clearly shown:

The connection between the long-term maintenance of target orientations and changes in networks is striking. Thus, in the history of both the Danish and the German energy system transition, phases can be identified in which the opponents of the energy turnaround have taken the political helm again. In Denmark, however, the change of course initiated at the beginning of the new millennium met with resistance not only in the environmental movement but also in the economy. Since the 1980s, the business community had been focusing on the technologies needed as part of the renewable energy strategy. The fossil energy networks had become weak and so the renewable energy strategy was ultimately retained. However, even 20 years after the Renewable Energy Sources Act came into force, the networks of the fossil energy sector, which are still particularly strong in Germany, still manage to bring the energy turnaround to a standstill and to call it into question. A strong policy of influencing networks thus seems helpful, if not even necessary, to stabilise a transition path once it has been embarked upon. However, since political intervention in private association structures according to democratic standards is unlikely to be permissible, and since the case studies did not find any strong interventions to form new network structures, a consistent exnovation strategy that reduces the economic power of non-sustainable sectors and thus weakens their political influence is apparently necessary to weaken the networks of actors in non-sustainable technologies.

Another clear connection exists between the instruments of innovation policy and niche development and progress in transition. This connection is most clearly demonstrated by the "largest" transition process, the German energy system transition. After the weather-dependency of the growing quantities of wind and PV electricity led us to expect problems with grid stability in the long term, a major R&D programme was launched in 2012 to develop new forms of energy storage to cope with the fluctuating generation of electricity by storing it. The Copernicus projects of the "Sinteg" focus also aim to improve grid stability. Within the framework of Sinteg, for example, digital market platforms for the exchange of energy are being developed with which small battery storage units in private households can be bundled in order to stabilize the grid. In addition, intelligent control technology is being tested in industrial companies so that they can produce more flexibly and automatically adapt their production to the availability of electricity and save costs (Bundesministerium für Wirtschaft und Energie, 2020).

The example of electric mobility in Norway also demonstrates the importance of research to stabilize the transition. In particular, the Norwegian Transport Research Institute conducted projects on the usage behaviour of electric cars in order to better understand and address the concerns of certain target groups, but also to tap into new target groups.

The focus of the hot phase of transition is then the interaction of instruments for synchronizing diffusion and exnovation. Here, too, the German energy turnaround is a clear example of poor orchestration. In the case of wind energy, for example, the mobilisation of huge financial resources through the instrument of feed-in tariffs and the resulting opportunities for long-term optimisation through economies of scale improved the cost-benefit ratio to such an extent that the technology is now economically viable virtually without support from the EEG. At the same time, the regulatory law was changed from 2014 in such a way that the expansion of the now economic technology came to an almost complete standstill in 2019. The collapse of the leading German market does not bode well for the export opportunities of German manufacturers either. Even in the case of photovoltaics, inconsistent policies had already led to huge financial resources being mobilised via the feed-in tariff, but the benefits of the technology scaling up, which ultimately became economic, ultimately benefited other countries. Ultimately, it must be concluded that economic instruments and regulatory law must be coordinated in such a way that long-term goals are also achieved. A populist to and fro of politics using a contradictory set of instruments obviously leads neither to the achievement of ecological nor economic goals. Furthermore, the linking of regulatory and economic instruments with infrastructure policy is of obvious importance. For example, the Danish policy of dismantling gas networks where district heating is laid leads to sustainable shifts in the use of these forms of energy, just as the conversion of parking strips into cycle paths clearly links the promotion of the diffusion of bicycle traffic with the exnovation of automobile traffic. Moreover, once an infrastructure has been converted, it is very durable and thus resistant to abrupt policy changes.

# 6 Reflection of the research questions of the project Go

The project "Governance of Radical Environmental Innovations (Go): New Governance Mechanisms in Eco-Innovation Policy: The Role of the Activating State in Radical System Innovations" has taken a number of research questions as the starting point for the study. The state of knowledge on these questions achieved so far will be reflected in the following. The findings from the case studies will be drawn upon and the feasibility of their implementation in German politics will be repeatedly questioned.

**Research question 1: What insights do previous cases of governmental activation attempts for environmentally friendly radical system transitions provide with regard to conditions of success and failure?**

First of all, it should be noted that radical system transitions can in principle be realized successfully at all. However, the successful cases also show that the transition processes generally extend over long periods of time, from one decade to several decades, and that the rates of change per year are usually in the low single-digit percentage range. In the seven cases studied, we cannot see a clear connection between the "size" of the supply or product use system to be changed and the speed of transition.

The cross-case analysis reveals four basic patterns or basic strategies that can be assumed to be essential for the governance of radical system transitions:

(1.) *Creating and maintaining directional security:* In all cases, clear long-term objectives and planning (C1) and measures to legitimise the new technologies or systems concerned (C5) play an essential role and thus ensure directional security. In successful transition cases, the creation and maintenance of directional security is also flanked by changes in network structures and key actors (D1) and in some cases by the establishment of fundamental institutional changes (D2).

(2.) *Innovation policy and niche development:* A fundamental change in supply and product use systems depends on the interaction of various technical, social and institutional innovations. R&D policy thus plays just as important a role as the development of new markets or the establishment of new market niches. As a rule, these represent the first step in the transition of the mass market. In niche markets, innovations are tested for the first time in small or medium quantities. In the process, weaknesses may be revealed and optimizations of function, performance, costs and quality are made. Two types of instruments at the interface of innovation promotion and niche development played a central role in the government activities observed in the cases studied. Research and development / knowledge diffusion (C3) and the establishment of market niches and market formation (C6) were used here. So far, support for entrepreneurship and start-ups (C4) and the targeted reduction of R&D funding for non-sustainable technologies and systems (D5), whose governance potential can be suspected but has hardly been used by the state to date, have played a minor role here.

(3.) *Synchronization of diffusion and exnovation:* The focus of the hot phase of transition is then the interaction of the instruments for the synchronization of diffusion and exnovation. All successful examples are characterized by an interaction of "creative" and "destructive" instruments. This supports the assumption postulated by Kivimaa & Kern (2016, S. 207) that the sustainable transition of socio-technical systems not only dependent on the functions of innovation systems and strategic niche management, but that attention must also be paid to the "destruction side" if the new solution is to prevail and diffuse. All successful cases take 'hard' economic measures with the help of tax and duties policy (D3) and thus maintain an effective 'monetary trend control' supplemented by regulatory measures (D4) (Jänicke, 2012, S. 19). In the successful cases we examined, this also leads to an improvement in the cost-benefit ratio (C8) of new products or services. In addition, it is possible to systematically support or promote follow-up innovations based on basic innovations that lead to significant cost reductions, functional improvements or application and target group-specific adjustments. The creation of clear economic framework conditions and incentives usually requires a considerable mobilisation of resources (C2), which can be observed in most of the cases investigated in the form of the provision of funding or financial resources. This includes the reduction of subventions for established technologies and systems that have been identified as unsustainable.

(4.) *Infrastructure development:* Instruments and measures for infrastructure development have so far played a minor and subordinate role in the analysis of "policy mixes for transition". In the study by Kivimaa & Kern (2016, S. 207 ff.), for example, they do not represent an independent field of state action or an independent type of instrument and function. In the case of our specific focus on product-service systems, support for the development of necessary infrastructures (electricity grids, heating networks, cycle paths, etc.) is of fundamental importance for the success of radical system transitions in the transport and energy sector.

A central factor for the possible success of the four strategies is a cross-party consensus, preferably in society, on the need for change. Even small groups that doubt the problem or question social or technological goals or create confusion through a multitude of seemingly problem-solving alternatives can considerably delay or even bring transition processes to a complete standstill. In addition to the active control of transition, a permanent examination of counter-strategies is therefore recommended. Especially in large systems, where considerable values are implemented, successful transition is first and foremost a question of political power.

**Research question 2: What was the role of the state in the case studies examined and which political instruments proved to be particularly effective in the context of which lobbying structures?**

On the one hand, democratic structures are at work in the state, i.e. public party programmes of the parties elected by a majority in the parliaments and entrusted with the government or their coalition agreements are implemented. In addition, individual actors both within and outside the government follow non-public and often economically conditioned power interests, which are, however, only partially brought into the government and into democratic public processes by lobbies. Other goals and programs are pursued in a covert manner.

In the case studies, especially in the Scandinavian case studies, a comparatively viable political consensus about the desired change could be observed. Objectives were set consensually, their implementation was regularly reported on and, if necessary, measures were taken to correct deviations from objectives. The influence of lobbies was barely discernible in some case studies, although industries that might have had an interest in influencing the plans in the cases investigated are also only weakly represented or not represented at all in the respective countries.

The fact that a successful redirection can be achieved by means of a sophisticated economic trend control is clear and has already been discussed under Research Question 1. This steering must make the new sustainable solutions economic and ensure that old, non-sustainable solutions become uneconomic. Detailed regulations of regulatory law promote change where economic efficiency has little influence. It is also important whether a political majority is able to push through the introduction of demanding economic interventions and regulatory regulations in society, but also within the ministerial administrations, and to maintain the speed of change. Against this background, the provisions of the Climate Protection Act (Die Bundesregierung, 2019) for regular review and follow-up in the event of failure to meet the targets may be an important instrument. Although the resolutions on economic incentives and regulatory provisions in this Act, which were passed in September 2019 and amended in December, are absolutely inadequate from the point of view of critical science and do not show any understanding of the problem situation (Götze, 2019; Rahmstorf, 2019), the Act itself, with its provisions on target monitoring, may under certain circumstances offer the opportunity to sue for stricter regulations if targets are not met. In this way, however, the Act nevertheless achieves a core objective of the climate change sceptics' agenda: it further delays the necessary change of course and, from the perspective of science, to a point in time that is finally too late for effective action (Rahmstorf, 2019).

**Research question 3: Which contextual and actor-related conditions and factors are central and to what extent can these be applied to a transformative environmental policy in Germany?**

The absence of conflicting economic interests is undoubtedly helpful for the speed of transition. However, this finding cannot be applied to German core sectors of the transition to sustainability, namely energy, mobility, and agriculture, because there are powerful economic counterforces that draw an economic advantage from the previous non-sustainable systems. Rather, Germany is the seat of globally active companies in all these sectors, which derive considerable benefits from delaying or avoiding the transition to a sustainable economy. The Volkswagen Group with its increasingly convincing strategy for entry into electric mobility could be a first exception here. However, it remains to be seen whether it will be able to maintain its role as a "transitional leader" in the long term and how this will affect other established players in the automotive industry.

In addition, a culture of cross-party political cooperation and consensus-building is obviously of great importance for successful transition. Such a culture is also not to be found in Germany, with its pronounced particular interests and strong lobbying structures, to the same extent as in the Scandinavian countries, for example.

**Research question 4: Against this background, how are concepts of the activating and coordinating state on the one hand and of transition field-related innovation communities on the other to be assessed?**

The application of concepts of the activating and coordinating state is based on trust in the personal responsibility and honesty of economic actors and uses instruments such as negotiation and voluntary commitment. We did not find the application of this concept in the case studies, and it does not appear to be recommendable for Germany either. Instead, in all cases of successful transition a combination of effective economic incentives and regulatory provisions played a major role. An economic incentive is "effective" in cases where it makes sustainable solutions more economical than non-sustainable ones. Economic instruments must therefore throw a switch. Just as a lamp is either on or off, a new solution may or may not be economical.  So, since economic instruments are switches, they have to be used effectively. Undersized economic incentives do not work and ultimately place an unnecessary burden on the actors. If, for example, certain $CO_2$ prices are exceeded, Edenhofer et al. (2016, S. 207), for example, expect "significantly stronger volume reactions".

The concept of promoter networks or so-called "Innovation Communities" (Fichter, 2009; Fichter & Beucker, 2012) focuses on the close cooperation of key persons, called “promotor”, who want to jointly advance an innovation and was developed to describe and explain the implementation of radical innovations. The concept focuses on the development and implementation process up to the market launch or the first successful application. Although the concept of promoter networks can also be applied to later phases such as the diffusion of innovations, it was not explicitly used in our empirical studies. However, as the case studies have shown, changes in network structures and key actors play a central role in the transition process. For further research on the governance of radical system transformers, the concept of promoter networks can play an important role, but must be adapted to the phase of diffusion. It should be examined to what extent this key-person concept can be combined with other approaches, such as so-called "communities of practice" (Wenger, 2008) and with the theories and approaches of network and lobby research and can be condensed into an approach called "diffusion communities" or "transition communities". These could ensure the formation of strong alliances and, together with social stakeholders and NGOs, science and parties close to them, could bring about the decisions for the political implementation of the transition and thus ensure the directional security of the further actions of the actors in business, politics and administration.

**Research question 5: How must an orchestration of policy strategies, policy instruments and actor roles look like, so that a radical environmentally friendly system transition of the building-related heat supply in Germany can succeed?**

First steps towards the development of structures within the instruments of transition listed by Kivimaa and Kern (2016) were taken by grouping them into four basic strategies (see chapters 5 and 6). On the basis of this work, ideas for orchestrating policy strategies, policy instruments and actor roles will be developed in greater depth in the further course of the project.

The question of multi-level governance will also play a role in this. The investigated cases from Baden-Württemberg and Copenhagen already show that at lower levels of governance only a limited range of instruments is available and that goals that are beyond the scope of federal policy are hardly attainable.

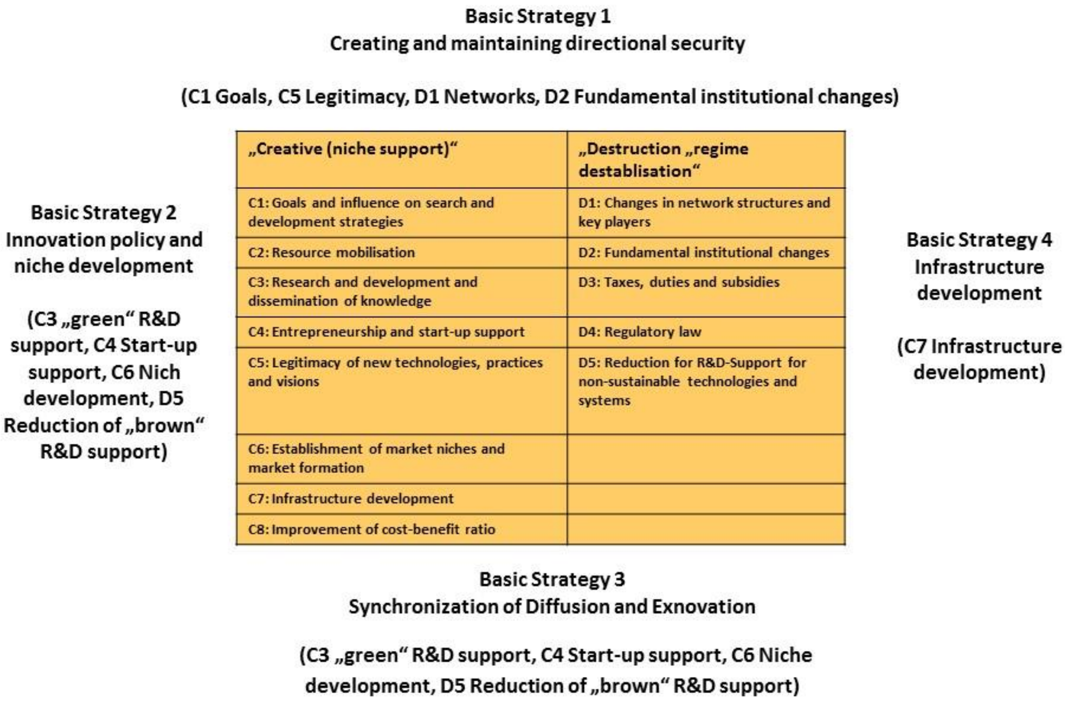
# 7 Consequences for eco-innovation policy

## 7.1 Policy strategies and policy instruments

The concept developed by Kivimaa & Kern (2016) for the study of policy instruments and policy mixes in transition processes (Table 2) was slightly extended and adapted by us for the study of the governance of radical system transitions. This classification framework of policy instrument types has proven its worth in the analysis of the seven transition cases studied and can thus be used as a basis for the further work steps of the project, but also generally for the development and implementation of a transition-related eco-innovation policy.

The empirical analysis of successful cases of radical system transitions reveals four basic patterns or basic strategies which can be assumed to be essential for successfully managing the fundamental change of large supply and product use systems. The four basic strategies were presented in Chapter 6. As a conceptual framework, the following presentation is the basis for further work in the project:

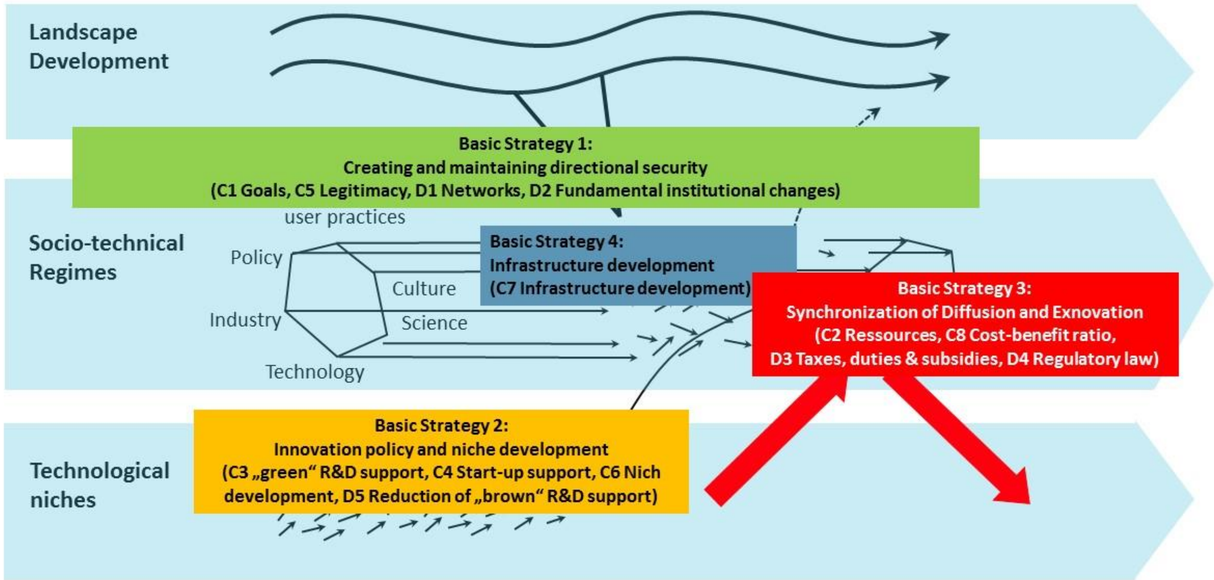
**Figure 2: Conceptual framework for the study of policy strategies and policy instruments in radical system transitions**




Source: Authors.

Figure 3 below shows the basic strategies and Figure 4 the political instruments of transition in a process-related classification and orders them over time.

**Figure 3: Ideal-typical use of basic strategies for the transition of large supply and product-service systems**




Source: Authors.

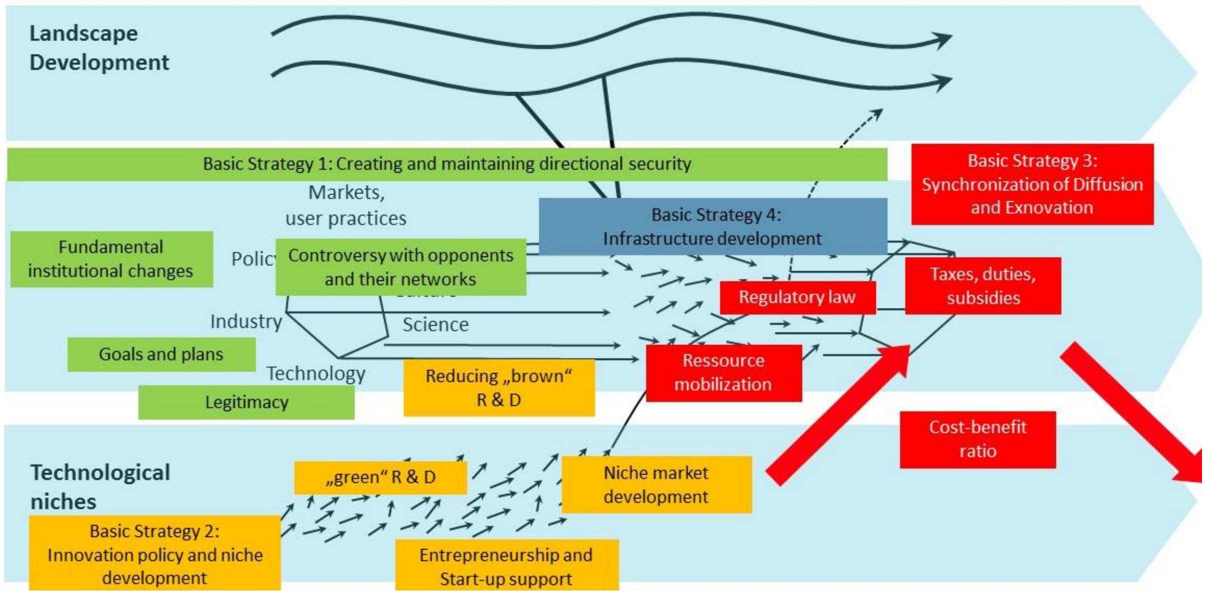
The starting point is always a political goal of the transition, which is the basis for developing and maintaining directional security (Basic Strategy 1). There should be agreement on goals and they should be socially legitimized. Reliability of direction can be questioned in the early phase of transition through diagnostic framing by questioning the reason for the need for change. Prognostic framing can also be used to question the direction of change and thus delay the transition process. Network structures of the established regime will tend to hinder the transition, which is why not only legitimacy and support for the transition idea must be built up in this phase, but in parallel with this, awareness of transition-critical structures and networks must be developed and they must be dealt with consciously and actively.

If the technical basis for a transition is not given, e.g. reliable technologies for the production of renewable energy as well as automobiles with alternative drives simply did not exist in the 1970s and 1980s, the availability of a functional, cost-effective and scalable alternative must be created by society through research and development, the promotion of start-ups and entrepreneurship and the development of niche markets (Basic Strategy 2). In parallel to the implementation of innovation in the mass market, research and development must also continuously drive improvements in the performance, quality and costs of key innovations.

In the hot phase of transition, strong instruments are at the forefront of policy, which, through high subsidies or the internalisation of external costs, establish the economic viability of the better alternative and, in parallel, accompany the dissemination of the alternative solution through regulatory provisions, e.g. in licensing law, and initiate the exnovation through targeted bans. The diffusion of the alternative solution into the mass market is inseparably connected with organizing the disappearance of the established but unsustainable solution from the mass market (exnovation) and ensuring a synchronization of diffusion and exnovation (Basic Strategy 3). Implicitly, the presentation indicates that it is significant to enter the "hot phase" of transition with the instruments of regulatory and economic control when external events open a political window of opportunity (Kahlenborn et al., 2019).

In the hot phase of transition, considerable resistance from the established regime must be expected. On several occasions, for example, the progress of transition processes has been effectively impeded by a questioning of the path switching costs, e.g. by the electricity price brake in Germany (Anonym, 2012), but also in the context of the Norwegian transition to electric cars (Clausen, 2019b). Continuous efforts to reduce costs represent a counterstrategy to the counterstrategy here. The argument of personal freedom is often cited against bans of any kind, justifying the continued use of oil heating systems and diesel engines (Clausen & Beucker, 2020; Pausch, 2020). An effective counterstrategy is also to tolerate prohibitions, but at the same time to ensure that no enforcement takes place and thus the prohibition remains ineffective.

**Figure 4: Ideal-typical application of the instruments of the basic strategies for transforming large supply and product-service systems**



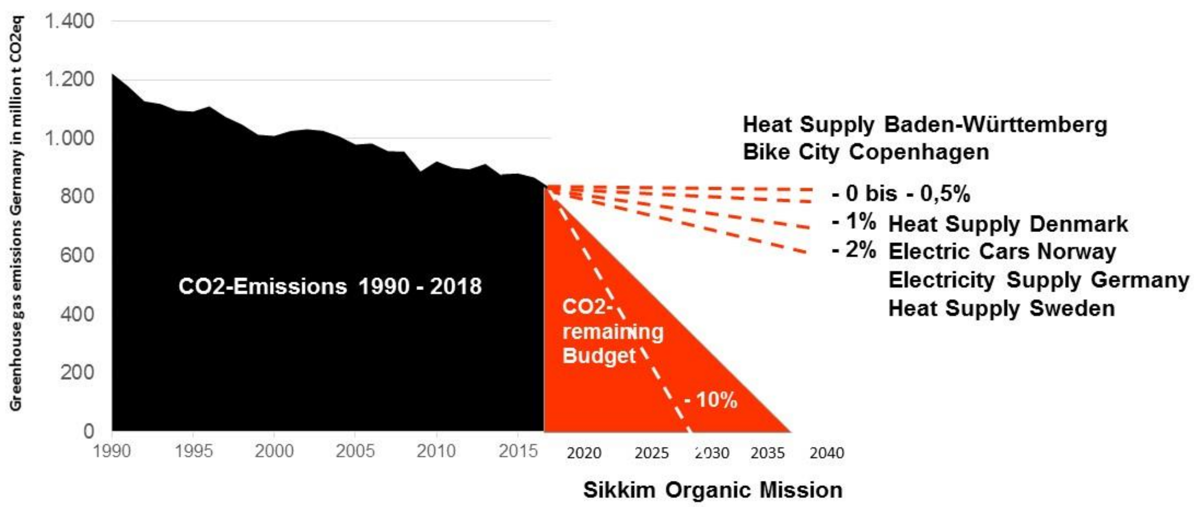

Source: Authors.

As our case studies have shown, radical system transitions also always depend on the targeted development and creation of the necessary infrastructures (electricity, heat, water networks, railways, testing and certification institutions, etc.) through government action and government support (Basic Strategy 4).

## 7.2 Taking the speed of transition into account

Throughout the entire process of transition, in addition to the continuous development and improvement of the alternative, the question of counter-strategies must be permanently examined and included in the planning of transition policy. For it must be remembered that we are under time pressure with regard to climate change. This can be seen if we relate the "transition speeds" observed in the case studies to the reduction of greenhouse gas emissions that will be necessary in the future.

**Figure 5: Emission trajectories until 2040 and transition speeds**




Source: Authors based on Rahmstorff (2019).

The curve corresponds to a remaining residual budget for Germany of 7.3 Gt $CO_2$ and represents an emissions budget for Germany that is compatible with the Paris Agreement. The lines marked with 0 to 0.5%, 1%, 2% and 10% represent the spectrum of transition speeds of the cases studied.

The findings on the speed of transition alone suggest that governments worldwide are irresponsibly hesitating to take effective measures. And every year that does not bring about a turnaround further increases the pressure to act.

One of the central mistakes in the governance of radical system innovations is therefore likely to be to follow wrong paths, to fail to achieve the necessary speed of transition, and to hope that too weak measures will have too strong an impact.

If only to get a clearer idea of the temporal sequence of major system transitions, it should be noted at this point that further case studies of the kind created in "Go" would be helpful to increase knowledge of these processes that are central to the survival of mankind.

# 8 Sources


AgroSpectrum. (2019, Dezember 30). IFFCO ties up with Sikkim Govt for largest organic processing unit. Zugriff am 10.1.2020. Verfügbar unter: http://agrospectrumindia.com/news/26/259/iffco-ties-up-with-sikkim-govt-for-largest-organic-processing-unit.html

Anonym. (2012). *Energiewende sichern – Kosten begrenzenVorschlag zur Einführung einer Strompreis-Sicherungim EEG*. Berlin. Zugriff am 20.5.2019. Verfügbar unter: https://web.archive.org/web/20130203035722/http:/www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Erneuerbare_Energien/Strompreissicherung_20130128.pdf

Avasthe, R., Singh, R., Babu, S., Pashte, V. & Sharma, P. (2019). Organic farming for doubling farmers income by 2022: Sikkim model, Pathway and strategies. *Technological Interventions in Organic Farming for Doubling Farmers' IncomePublisher*. Gangtok. Zugriff am 7.5.2019. Verfügbar unter: https://www.researchgate.net/publication/330900370_Organic_farming_for_doubling_farmers_income_by_2022_Sikkim_model_Pathway_and_strategies

Bijker, W. E. (1995). *Of Bicycles, Bakelites and Bulbs: Towards a Theory of Sociotechnical Change*. Cambridge MA, London: The MIT Press.

BMBF (Hrsg.). (2018). *Forschung und Innovation für die Menschen: Die Hightech-Strategie 2025*. Berlin: Bundesministerium für Bildung und Forschung (BMBF).

Bruns, E., Köppel, J., Ohlhorst, D. & Schön, S. (2007). *Die Innovationsbiographie der Windenergie unter besonderer Berücksichtigung der Absichten und Wirkungen von Steuerungsimpulsen. Endbericht zum Forschungsprojekt im Schwerpunkt „Innovationsprozesse in Wirtschaft und Gesellschaft"*. Hannover: Volkswagenstiftung.

Bundesministerium für Wirtschaft und Energie. (2017). Förderprogramm SINTEG: „Schaufenster intelligente Energie - Digitale Agenda für die Energiewende". *BMWi*. Zugriff am 20.2.2018. Verfügbar unter: https://www.bmwi.de/Redaktion/DE/Artikel/Energie/sinteg.html

Bundesministerium für Wirtschaft und Energie. (2018a). *Bundesbericht Energieforschung 2018. Forschungsförderung für die Energiewende*. Berlin. Verfügbar unter: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/bundesbericht-energieforschung-2018.pdf?__blob=publicationFile&v=15

Bundesministerium für Wirtschaft und Energie. (2018b). *EEG in Zahlen: Vergütungen, Differenzkosten und EEG-Umlage 2000 bis 2019*. Berlin. Zugriff am 15.11.2019. Verfügbar unter: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/eeg-in-zahlen-pdf.pdf%3F__blob%3DpublicationFile

Bundesministerium für Wirtschaft und Energie. (2020). SINTEG – das Programm. Zugriff am 7.1.2020. Verfügbar unter: https://www.sinteg.de/programm/

Carsalesbase.com. (2019). Norway car sales data. Zugriff am 14.11.2019. Verfügbar unter: http://carsalesbase.com/total-market-sales-country/norway-car-sales-data/

CICD. (2002). Tvindkraft Windmill. Zugriff am 24.4.2019. Verfügbar unter: https://www.cicd-volunteerinafrica.org/activism/tvindkraft

City of Copenhagen. (2017). *Copenhagen City of Cyclists. The Bicycle Account 2016*. Kopenhagen.

Clausen, J. (2004). *Umsteuern oder Neugründen? die Realisierung ökologischer Produktpolitik in Unternehmen*. Norderstedt: Books on demand.

Clausen, J. (2009). *Feldvermessungsstudie Klimaschutzregion Hannover Überblick über das Praxisfeld und die Fokusbereiche Solarthermie und Ökostrom*. Hannover. Zugriff am 16.9.2016. Verfügbar unter: http://www.fk2.uni-oldenburg.de/wenke2/download/Feldvermessungsstudie-Energie3-1.pdf

Clausen, J. (2017). *Stromeinspeisungsgesetz und EEG. Fallstudie im Rahmen des Projekts Evolution2Green – Transitionspfade zu einer Green Economy*. Berlin. Zugriff am 28.3.2017. Verfügbar unter: https://evolution2green.de/sites/evolution2green.de/files/documents/2017-03-e2g-fallstudie_eeg_borderstep.pdf

Clausen, J. (2019a). *Verbreitung radikaler Systeminnovationen Fallbeispiel Stromversorgung Deutschland*. Berlin: Borderstep Institut.

Clausen, J. (2019b). *Verbreitung radikaler Systeminnovationen. Fallbeispiel Elektromobilität Norwegen*. Berlin: Borderstep Institut.

Clausen, J. (2019c). *Industrie 4.0 im Kontext von Umweltinnovationen.* CliDiTrans Werkstattbericht 3-4. Berlin: Borderstep Institut. Zugriff am 20.11.2019. Verfügbar unter: https://www.borderstep.de/wp-content/uploads/2019/09/IndustrieVierNull-CliDiTrans20190912.pdf

Clausen, J. & Beucker, S. (2019a). *Verbreitung radikaler Systeminnovationen. Fallbeispiel Wärmeversorgung Schweden*. Berlin.

Clausen, J. & Beucker, S. (2019b). *Verbreitung radikaler Systeminnovationen. Fallbeispiel Wärmeversorgung Dänemark*. Berlin: Borderstep Institut. Zugriff am 20.6.2019. Verfügbar unter: https://www.borderstep.de/wp-content/uploads/2019/06/W%C3%A4rmeversorgung-Daenemark-Go-19-6-2019.pdf

Clausen, J. & Beucker, S. (2020). *Verbreitung radikaler Umweltinnovationen: Fallbeispiel Gebäudeenergiegesetz*. Berlin.

Clausen, J. & Fichter, K. (2018). *Umweltinnovationen 2: Faktoren und Dynamiken der Verbreitung grüner Dienstleistungen und Produkte in der Gesellschaft. Unveröffentlicht*. Dessau-Roßlau: Umweltbundesamt.

Clausen, J. & Fichter, K. (2019a). The diffusion of environmental product and service innovations: Driving and inhibiting factors. *Environmental Innovation and Societal Transitions*, *31*, 64–95. https://doi.org/10.1016/j.eist.2019.01.003

Clausen, J. & Fichter, K. (2019b). *Governance radikaler Umweltinnovationen: Theoretische Grundlagen und Forschungskonzeption*. Berlin: Borderstep Institut. Zugriff am 19.11.2019. Verfügbar unter: https://www.borderstep.de/wp-content/uploads/2019/07/AP1Theorie-und-Methoden-31-07-2019.pdf

Clausen, J. & Fichter, K. (2020). *Governance radikaler Systemtransitionen. Wirkung politischer Strategien und Instrumente in der Transition großer Versorgungssysteme.* Berlin: Borderstep Institut.

Clausen, J. & Gandenberger, C. (2018). *Umweltinnovationen 1: Grundlagenanalysen. Unveröffentlicht.* Dessau-Roßlau: Umweltbundesamt.

Clausen, J. & Loew, T. (2009). *CSR und Innovation, Literaturstudie und Befragung. Untersuchung im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit*. Verfügbar unter: www.4sustainability.org

Clausen, J. & Olteanu, Y. (2019). *Verbreitung radikaler Systeminnovationen. Fallbeispiel Sikkim Organic Mission*. Berlin: Borderstep Institut.

Clausen, J. & Warnecke, N. (2019). *Governance radikaler Umweltinnovationen. Fallbeispiel Erneuerbare Wärme Baden-Württemberg*. Berlin: Borderstep Institut. Zugriff am 19.11.2019. Verfügbar unter: https://www.borderstep.de/wp-content/uploads/2019/09/Fallstudie-BaW%C3%BC_20190912.pdf

Clausen, J., Warnecke, N. & Schramm, S. (2019). *Verbreitung radikaler Systeminnovationen. Fallbeispiel Fahrradstadt Kopenhagen*. Berlin. Zugriff am 2.7.2019. Verfügbar unter: https://www.borderstep.de/wp-content/uploads/2019/06/Fahrradstadt-Kopenhagen-Go20-06-2019-1.pdf

Danish Customs and Tax Administration. (2019). Registration tax. Zugriff am 6.6.2019. Verfügbar unter: https://skat.dk/skat.aspx?oid=2244599

Danish Energy Agency. (2018). *Energy Statistics 2016*. Kopenhagen. Zugriff am 14.11.2019. Verfügbar unter: https://ens.dk/sites/ens.dk/files/Statistik/energy_statistics_2016.pdf

Danish Energy Authority. (2005). *Heat Supply in Denmark. Who What Where and - Why*. Kopenhagen. Zugriff am 24.4.2019. Verfügbar unter: http://www.seas.columbia.edu/earth/wtert/sofos/DEA_Heat_supply_in_denmark.pdf

DICE Consult. (2016). *Kosten der Energiewende. Gutachten im Auftrag der Initiative Neue Soziale Marktwirtschaft*. Düsseldorf. Zugriff am 15.11.2019. Verfügbar unter: https://www.insm.de/fileadmin/insm-dms/text/soziale-marktwirtschaft/eeg/INSM_Gutachten_Energiewende.pdf

Die Bundesregierung. (2017). *Deutsche Nachhaltigkeitsstrategie - Neuauflage 2016*. Berlin: Die Bundesregierung. Zugriff am 27.2.2017. Verfügbar unter: https://www.bundesregierung.de/Content/DE/_Anlagen/2017/01/2017-01-11-nachhaltigkeitsstrategie.pdf?__blob=publicationFile&v=5

Die Bundesregierung. (2019). *Gesetzentwurf der Bundesregierung: Entwurf eines Gesetzes zur Einführung eines Bundes-Klimaschutzgesetzes und zur Änderung weiterer Vorschriften*. Zugriff am 24.10.2019. Verfügbar unter: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Gesetze/gesetzesentwurf_bundesklimaschutzgesetz_bf.pdf

Diget, T. (2018, 12.6). How to inclued supplus energy from Apple. Gehalten auf der Deutsch-Dänischer Dialog Wärmenetze, Stuttgart. Zugriff am 26.4.2019. Verfügbar unter: https://www.energiekompetenz-bw.de/energiekompetenz-bw/veranstaltungen/rueckblick/detail/?tx_ttnews%5Btt_news%5D=523&cHash=3375a14e27c607cde0f95b25db67b963

Edenhofer, O., Flachsland, C., Kalkuhl, M., Knopf, B. & Pahle, M. (2019). *Optionen für eine CO2-Preisreform*. Potsdam.

Ehlerding, S. (2020, Januar 8). Starke Kürzungen bei der Projektförderung der Energieforschung. *Tagesspiegel*.

Eikeland, P. O. & Inderberg, T. H. (2016). Energy system transition and long-term interest constellations in Denmark: can agency beat structure? *Energy Research & Social Science*, *11*, 164–173.

Ericsson, K., Huttunen, S., Nilsson, L. J. & Svenningsson, P. (2004). Bioenergy policy and market development in Finland and Sweden. *Energy Policy*, *32*(15), 1707–1721. https://doi.org/10.1016/S0301-4215(03)00161-7

European Commission. (2011). *Innovation for a sustainable Future - The  Eco-innovation Action Plan (Eco-AP)*. Brüssel.

European Cyclists Federation. (2017). Smarter Cycling Series: City of Copenhagen introduces variable message signs – exclusively for cyclists. Zugriff am 8.3.2019. Verfügbar unter: https://ecf.com/news-and-events/news/smarter-cycling-series-city-copenhagen-introduces-variable-message-signs-%E2%80%93

Eurostat. (2019). Number of passenger cars per 1000 inhabitants, 2016. Zugriff am 28.2.2019. Verfügbar unter: https://ec.europa.eu/eurostat/statistics-explained/index.php/Passenger_cars_in_the_EU

Fichter, K. (2009). Innovation communities: the role of networks of promotors in Open Innovation. *R&D Management*, *39*(4), 357–371. https://doi.org/10.1111/j.1467-9310.2009.00562.x

Fichter, K. & Beucker, S. (Hrsg.). (2012). *Innovation Communities: Teamworking of Key persons - A Success Factor in Radical Innovation*. Berlin, Heidelberg, New York: Springer.

Fichter, K. & Clausen, J. (2013). *Erfolg und Scheitern „grüner“ Innovationen*. Marburg: Metropolis.

FIF Marketing. (2016). *Fjernwarmens Image*.

Figenbaum, E. (2018). *Electromobility status in Norway. Mastering long distances – the last hurdle to mass adoption*. Oslo. Zugriff am 4.5.2019. Verfügbar unter: https://www.toi.no/publications/electromobility-status-in-norway-mastering-long-distances-the-last-hurdle-to-mass-adoption-article34903-29.html

Figenbaum, E. & Kolbenstvedt, M. (2013). *Electromobility in Norway -experiences and opportunities with Electric vehicles*. Oslo. Zugriff am 15.11.2016. Verfügbar unter: https://www.toi.no/getfile.php?mmfileid=33828

Forum Energii, Agora Energiewende & DBDH. (2018). *Good heating practices from Denmark and Germany.  Conclusions for Poland*. Warschau. Zugriff am 25.4.2019. Verfügbar unter: https://www.agora-energiewende.de/fileadmin2/Partnerpublikationen/2018/Forum_Energii_Good_heating_practices_from_Denmark_and_Germany/Good_heating_practices_en_final.pdf

Fraunhofer ISE. (2019, November 14). Monatliche Börsenstrompreise in Deutschland in 2019. Zugriff am 14.11.2019. Verfügbar unter: https://www.energy-charts.de/price_avg_de.htm?year=2019&price=nominal&period=monthly

Freeman, C. & Perez, C. (1988). Structural crises of adjustment, business cycles and Investment Behaviour. *Technical Change and Economic Theory* (S. 38–66). London/ New York.

Geels, F. W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society*, *31*(5), 21–40. https://doi.org/10.1177/0263276414531627

Geier, B. (2019). Willkommen in Sikkim. *Böll Thema*, (2), 36–38.

Götze, S. (2019). Gute Nacht. Vor 30 Jahren wären die Klima-Eckpunkte der Koalition eine Revolution gewesen. Heute sind sie ein Desaster. Experten bewerten die Einigung als „klares Politikversagen“. *Spiegel Online*.

Government of Sikkim. (2014). *The Sikkim Agricultural, Horticultural Input And Livestock Feed Regulatory Act*. Zugriff am 8.5.2019. Verfügbar unter: http://www.lawsofindia.org/pdf/sikkim/2014/2014Sikkim10.pdf

Heller, A. (2000). 15 Years of R&D in central Solar Heating in Denmark. *Solar Energy*, *69*(6), 437–447.

Hirschl, B. (2007). *Erneuerbare Energien-Politik: Eine Multi-Level Policy-Analyse mit Fokus auf den deutschen Strommarkt (Energiepolitik und Klimaschutz. Energy Policy and Climate Protection)*. Berlin.

Institut für Wärme und Oeltechnik e.V. (IWO) & MEW Mittelständische Energiewirtschaft Deutschland e.V. (2018). *Synthetische Energieträger - Perspektive für die Deutsche Wirtschaft ndden internationalen Handel*. Berlin. Zugriff am 13.1.2020. Verfügbar unter: https://www.frontier-economics.com/media/2504/frontier-iw-studie_ptx_markt_und_beschaeftigungsperspektiven.pdf

Jänicke, M. (2012). *Megatrend Umweltinnovation zur ökologischen Modernisierung von Wirtschaft und Staat*. München: Oekom.

Kahlenborn, W., Clausen, J., Behrendt, S. & Göll, E. (Hrsg.). (2019). *Auf dem Weg zu einer Green Economy. Wie die sozialökologische Transition gelingen kann*. Bielefeld: transcript.

Kivimaa, P. & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, *45*(1), 205–217. https://doi.org/10.1016/j.respol.2015.09.008

KNOEMA Weltdatenatlas. (2019). Sikkim - Net state domestic product at factor cost in agriculture at current prices. Zugriff am 14.1.2019. Verfügbar unter: https://knoema.de/atlas/Indien/Sikkim/Net-state-domestic-product-in-agriculture

Lund, R., Ilic, D. D. & Trygg, L. (2016). Socioeconomic potential for introducing large-scale heat pumps in district heating in Denmark. *Journal of Cleaner Production*, *139*, 219–229. https://doi.org/10.1016/j.jclepro.2016.07.135

Ministry of Agriculture and Farmers Welfare, Govt. of India. (2018). *Transition from Conventional farming to Organic Farming*. Odisha. Zugriff am 8.5.2019. Verfügbar unter: https://www.mstcindia.co.in/DMS/TRANSAITION_FROM_CONV_TO_ORGANIC_FARMING.pdf

Nelson, R. R. & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, MA.: Belknap Press of Harvard University Press.

Nordic Council of Ministers. (2017). *Nordic heating and cooling. Nordic approach to EU's Heating and Cooling Strategy*. Kopenhagen. Zugriff am 2.7.2019. Verfügbar unter: https://norden.diva-portal.org/smash/get/diva2:1098961/FULLTEXT01.pdf

Norsk elbilforenning. (2019). Norwegian EV policy. Norway is leading the way for a transition to zero emission in transport. Zugriff am 3.5.2019. Verfügbar unter: https://elbil.no/english/norwegian-ev-policy/

Oelker, J. (2005). *Windgesichter. Aufbruch der Windenergie in Deutschland.* Dresden: Sonnenbuch. Verfügbar unter: http://www.sonnenbuch.de/windgesichter/start.htm

Pausch, R. (2020, Januar 9). Heldchen der Arbeit Seit an Seit mit der Normalität. Wie FDP-Chef Christian Lindner seine Partei in eine Heimat für Modernisierungszweifler verwandeln will. *Die Zeit*.

Petersen, H. (2003). *Ecopreneurship und Wettbewerbsstrategie: Verbreitung ökologischer Innovationen auf Grundlage von Wettbewerbsvorteilen*. Marburg: Metropolis. Verfügbar unter: http://www.gbv.de/dms/zbw/370245148.pdf

Power to X Allianz. (2019). Power to X Allianz. Verfügbar unter: https://www.ptx-allianz.de/ueber-uns/sprecher-der-power-to-x-allianz/

Rahmstorf, S. (2019). Emissionsbudget Darum schweigt die Bundesregierung zur wichtigsten Zahl beim Klimaschutz. *Spiegel Online*.

Rao, S. B. S. (2017). *Study of Organic Cultivation in Sikkim*. Lucknow. Zugriff am 8.5.2019. Verfügbar unter: http://www.nbsc.in/MediaGallery/Study%20on%20Organic%20cultivation%20in%20Sikkim%20-%20SBR.pdf

Rubik, F. (2002). *Integrierte Produktpolitik* (Ökologie und Wirtschaftsforschung). Marburg: Metropolis-Verl.

Schaltegger, S. (2002). A Framework for Ecopreneurship. Leading Bioneers and Environmental Managers to Ecopreneurship. *Greener Management International*, *2002*(38), 45–58. https://doi.org/10.9774/GLEAF.3062.2002.su.00006

Schaltegger, S. & Petersen, H. (2000). *Ecopreneurship - Konzept und Typologie* (R.I.O.-Management-Forum Analysen). Luzern: R.I.O IMPULS [u.a.].

Schneidewind, U. (2018). *Die große Transition: eine Einführung in die Kunst gesellschaftlichen Wandels* (Fischer) (Originalausgabe.). Frankfurt am Main: Fischer Taschenbuch.

Singh, R., Babu, S., Avasthe, R., Yadav, G. S. & Ngachan, S. V. (2017). *Organic Production Technology for Alternative Cropping Systems in Sikkim*. Gangtok. Zugriff am 8.5.2019. Verfügbar unter: https://www.researchgate.net/publication/316172533_Organic_Production_Technology_for_Alternative_Cropping_Systems_in_Sikkim?_iepl%5BgeneralViewId%5D=BsPijl5zZFJRFr1DHDBJEK095m3Dx3w05h2c&_iepl%5Bcontexts%5D%5B0%5D=searchReact&_iepl%5BviewId%5D=v9ZNfs1ha4JNlc1YQf3hwqEX6krh1PkblD0n&_iepl%5BsearchType%5D=publication&_iepl%5Bdata%5D%5BcountLessEqual20%5D=1&_iepl%5Bdata%5D%5BinteractedWithPosition19%5D=1&_iepl%5Bdata%5D%5BwithEnrichment%5D=1&_iepl%5Bposition%5D=19&_iepl%5BrgKey%5D=PB%3A316172533&_iepl%5BtargetEntityId%5D=PB%3A316172533&_iepl%5BinteractionType%5D=publicationTitle

Singha, K. (2020, Januar 12). Sikkim Organic Mission.

Sköldberg, H. & Rydén, B. (2014). *The heating market in Sweden - an overall view*. Lund und Halmstad. Zugriff am 26.6.2019. Verfügbar unter: http://www.varmemarknad.se/pdf/The_heating_market_in_Sweden_141030.pdf

Statistisches Bundesamt. (2019a, Oktober 9). Bruttostromerzeugung in Deutschland. Zugriff am 14.11.2019. Verfügbar unter: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Erzeugung/Tabellen/bruttostromerzeugung.html

Statistisches Bundesamt. (2019b). *Produzierendes Gewerbe 2017. Fachserie 4 Reihe 6.1*. Wiesbaden. Zugriff am 15.11.2019. Verfügbar unter: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Beschaeftigte-Umsatz-Investitionen/_inhalt.html#sprg236398

Statistisches Landesamt Baden-Württemberg. (2019, Februar 22). Endenergieverbrauch der Haushalte und sonstigen Verbraucher. Zugriff am 14.11.2019. Verfügbar unter: https://www.statistik-bw.de/Energie/Energiebilanz/LRt1005.jsp

Stortinget. (2017). *Innstilling fra transport- og kommunikasjonskomiteen om Nasjonal transportplan 2018–2029*. Oslo. Zugriff am 4.5.2019. Verfügbar unter: https://www.stortinget.no/globalassets/pdf/innstillinger/stortinget/2016-2017/inns-201617-460s.pdf

Swedish Ministry of Environment and Energy. (2019). *Sweden's draft integrated national energy and climate plan*. Stockholm. Zugriff am 27.6.2019. Verfügbar unter: https://ec.europa.eu/energy/sites/ener/files/documents/sweden_draftnecp.pdf

Umweltbundesamt. (2019, September 18). Beschäftigungswirkungen erneuerbarer Energien. Zugriff am 12.11.2019. Verfügbar unter: https://www.umweltbundesamt.de/daten/umwelt-wirtschaft/beschaeftigung-umweltschutz#textpart-3

UN FCCC. (2015). *Adoption of the Paris Agreement*. Paris. Zugriff am 20.6.2016. Verfügbar unter: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy*, *28*, 817–830.

Weiß, R. & Fichter, K. (2013). *Green Economy Gründungsmonitor: Konzeptstudie und Piloterhebung*. Berlin: Borderstep Institut für Innovation und Nachhaltigkeit gemeinnützige GmbH. Verfügbar unter: http://www.borderstep.de/wp-content/uploads/2014/06/Green_Economy_Gruendungsmonitor.pdf

Wenger, E. (2008). *Communities of practice: learning, meaning, and identity* (Learning in doing : social, cognitive, and computational perspectives). Cambridge: Cambridge Univ. Press.

Werner, S. (2017). District heating and cooling in Sweden. *Energy*, *126*, 419–429. https://doi.org/10.1016/j.energy.2017.03.052

Wicke, L., Schellnhuber, H. J. & Klingenfeld, D. (2010). *Nach Kopenhagen. Neue Strategie zur Realisierung des 2 Max Kllimaziels. PIK-Report 116.* Potsdam. Zugriff am 17.11.2019. Verfügbar unter: https://www.pik-potsdam.de/research/publications/pikreports/.files/pr116.pdf

Zu Klampen, R. (2019, November 2). Enercon-Krise: Olaf Lies fordert schnelle Hilfe für Windkraftbranche.