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Towards "Good Ecological Status": Analysing the Nitrogen Lock-in in Danish Water Management, from A Transition Theory Perspective

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Abstract

Denmark has reached a stagnant stage of nitrogen reduction in water management, and it probably fail to achieve the goal of “Good Ecological Status” by 2015 required in the EU Water Framework Directive. This research aims to investigate the reasons behind the current stagnation of nitrogen reduction, by exploring both its drivers and barriers for further advancing nitrogen reduction. For an intensive examination, Naestved municipality in Zealand region, Denmark is selected as a single-case study, providing a systematic way for analysing the identified problems. Data from multiple sources in different scale, different level and different domain is collected with a qualitative research strategy. The analysis is conducted from a transition theory perspective in the strive for gaining insights into the current Danish nitrogen reduction issue. After introducing a new concept “nitrogen lock-in” by reframing with transition theory, the study argues that the current Danish nitrogen lock-in is actually the result of the competition between constructive forces and destructive forces. Future breakthrough depends on whether innovative approaches for both water management and economic growth can be harmoniously integrated. Finally, some counter recommendations for Danish water management are provided, and potential improvements for transition theory are proposed for future research.

Key Words: WFD, Water Quality, Eutrophication, Nitrogen Lock-in, Danish Water Management, Transition Theory

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for their endless love and permanent supports.

Table of Contents

Abbreviations

CAS	Complex Adaptive Systems
CIS	Common Implementation Strategy
EEB	The European Environmental Bureau
ENGOs	Environmental Non-governmental Organizations
GAP	Good Agricultural Practices
HABs	Harmful Algal Blooms
ICROFS	The International Centre for Research in Organic Food Systems
N	Nitrogen
NPo	Research Programme on Nitrogen, Phosphorous and Organic matter
P	Phosphorus
PSP	Paralytic shellfish poisoning
R&D	Research and Development
REC	Regional Environmental Centre
WFD	The Water Framework Directive
WWF	World Wildlife Fund

Figures and Tables

1. Introduction

1.1. Background

Water issues have been widely concerned in Europe, different areas are presenting different problems: In southern Europe such as Spain and Greece, water quantity issues like water imbalance and overdraft of water abstraction are prominent (Tsagarakis et al. 2004, Downward and Taylor 2007); while in the agriculture-intensive countries such as the Netherlands and Denmark, water quality issues in terms of diffuse nitrogen pollution are challenging to local water resources management (Oenema and Roest 1998, Grant et al. 2006). Recently, water quality issue has attracted great attention. Figures from 2009 have reported that close to 7 out of 10 of EU citizens considered water quality as a serious problem in their countries (Eurobarometer 2009). To improve and maintain water quality[1] in all water bodies and to deal with complexity and uncertainty in the dynamic situation, the EU Water Framework Directive (WFD) (Directive 2000/60/EC) was adopted in 2000 as a new operational tool for reforming European Water Policy, which has imposed great influences on European water management (EC 2011b). The general goal of the WFD is to achieve "good ecological status" in all water bodies by 2015 (EC 2011a). Despite improvements in some regions in recent years, the situation remains severe. It was estimated that considerable proportions of Europe's freshwaters - 40 % of surface waters and 30 % of the groundwater in Europe - are at risk of not achieving this goal (EEA 2010). Scientific evidence and assessment reports show that the challenge lies in the reduction of diffuse nitrogen losses, which has been observed in the existing policies as being less successful and less effective than the reduction for other pollutants (Artioli et al. 2008). In Europe, by and large, diffuse nitrogen load to water bodies mainly originates from agricultural sector, which is contributing 50 - 80% of the total load (EEA 2005). Therefore, how to reduce diffuse nitrogen losses from agriculture to achieve the goal of the WFD has attracted great attention in European water management.

1.2. The European Water Framework Directive

To protect the water bodies in Europe, the WFD adopts several innovative strategies. First, it integrates several environmental policies[2] which closely relate to water management, acting as an umbrella directive covering various sub-directives (Barreira and Kallis 2004). For example, the Nitrate Directive, which is the former regulation for reducing nitrates from agricultural sources to enter the waterways, has become an integral part of the WFD. Secondly, river basin district is the main water management unit for the implementation of the directive[3], and is considered as an effective operation tool to achieve the goal. Moreover, public participation is emphasized to ensure a coherent and harmonious implementation of this directive (EC 2003). As such,

1 The protection of water quality is the main purpose of the WFD, which also includes the consideration of protecting quantitative status in certain water bodies, such as the groundwater.

2 Programs of measures in the WFD have many overlaps with another 11 directives, they are: Urban Wastewater Treatment Directive, Drinking Water Directive, Bathing Water Directive, Birds Directive, Habitats Directive, IPPC Directive, EIA Directive, SEVESO II Directive, Plant Protection Products Directive, Nitrates Directive, Sewage Sludge Directive (Frederiksen et al. 2007).

3 See Article 3 in the WFD.

European water policy has been undertaking a thorough restructuring process (EC 2011b) imposing profound impact on each Member State.

1.3. Problem Identified

Denmark is one of the member states suffering from water quality issue caused by diffused nitrogen pollution, and nitrogen reduction is a main goal in its water management. Denmark has more than 20 years experiences of managing the issue of diffused nitrogen losses in agriculture, and significant improvement in water quality has been made. However, the current nitrogen level in Danish aquatic environment is still not good enough to achieve the goal of “good ecological status” (see figure 1).

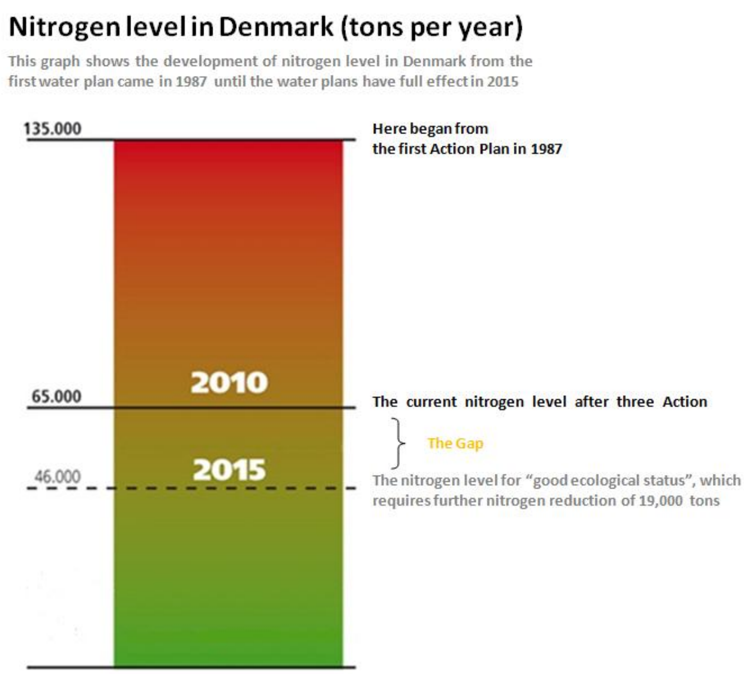

Figure 1. The gap between the current nitrogen level and the level required to achieve “good ecological status” (adapted from MIM 2010a)

There is a series of problems embedded in the current Danish water management, which originated from former two Danish Action Plans[4] for aquatic environment, the problems are: it was actually imposing “real costs on society” (Atkins and Burdon 2006); restriction is expensive (Nørring and Jørgensen 2009) and general regulation is not effective enough (MIM 2009c); the degree of farmers’ participation is relatively low (Wright and Jacobsen 2010) and no major improvement in ecological status is found (Grant et al. 2006). Moreover, the latest Action Plan - Action Plan III adopted in 2004 was reported not having achieved the anticipated result (MIM 2009c), the progress in nitrogen reduction in the recent years was not obvious (see figure 7). It is foreseen that making further progress will become increasingly difficult (only 3% - 4%

[4] Two Danish Action Plans refer to AP I in 1987 and AP II in 1998, please refer to 6.1.2 for detail.

reduction for nitrogen leaching can be made from 2008 to 2015 without further support (Wright and Jacobsen 2010)).

In this situation, many experts and scholars have been calling for a more holistic, integrated, cooperative and target-specific approach (Ærtebjerg et al. 2003, Grant et al. 2006, Kronvang et al. 2008, MIM 2009c). The new water plan under the WFD is believed as a promising approach to make further progress for Danish water management, particularly for nitrogen reduction. However, the challenge is how to bring such a "good will" into reality and to embark on a more radical road to sustainable development, while considering some of the main challenges such as ecological improvement, cost-effectiveness and social harmony in process? In this sense, the problem can be restructured as how to implement Danish water plan under the EU Water Framework Directive in terms of further advancing nitrogen reduction.

In short, this paper aims to explore the status quo of the implementation of the Danish water plan in terms of nitrogen reduction and to explain the rationale behind the problem of nitrogen reduction, with an attempt to gaining insight into the challenges that are needed to move beyond the current situation.

2. Research Objective

2.1. A Complex Problem

In sustainability science, the goal for advancing nitrogen reduction in Danish water management can be understood as a sustainability transition, which has been widely discussed (Kates et al. 2001, Rotmans et al. 2001, Kates and Parris 2003, Rotmans 2005). Complexity is a main feature of a system which is attempting or undergoing sustainability transition, in which it normally presents as a "multiple, compounded problem" (Rotmans 2005). Complexity can be described with different dimensions representing different characteristics: in temporal dimension, it is can be understood as a persistent problem (ibid.) with temporal inertias (Kates et al. 2001); in spatial dimension, it is cross-leveled and scale-dynamic (ibid.) in terms of multi-actor, multi-domain with functional complexity but individual limits, that there is hardly any room for manoeuvre (Rotmans 2005). In addition, the complexity also is represented as a wide range of outlooks for actually achieving the transition, i.e. there is hardly a coherent vision on the long-term future in front of short-term interests (ibid.).

In view of the complexity in sustainability transition, the complex sustainability problems cannot be solved by conventional approaches. Rotmans et al. (2001) believed that complex sustainability problems can be structured by using a transition theory perspective, which was developed in the quest for transitions towards sustainable societal system. Connecting with Danish water management, the three pillars concept of transition theory can be justified. According to my observation, Danish historical approaches to water management represent non-linear changes if framed with (i) "multi-phase" perspective (see section 6.1); activities in different actors and different domains can be considered as the (ii) "multi-change" in (iii) "multi-level" (see section 6.2 and 6.3). Thereby I am convinced that we can reach a deeper understanding of the complexity of Danish water management by applying transition theory.

2.2. Research Question

Based on the identified problem in Danish water management for nitrogen reduction, and my belief in the usefulness of applying transition theory when analysing complex sustainability problems, the following research questions were formulated in order to guide subsequent research activities.

Main Research Question

Why has Denmark reached a stagnant stage concerning the reduction of nitrogen?

Sub-questions

a) How can the tendency towards stagnation of the nitrogen reduction in Denmark be understood?
b) What are the drivers for further advancing nitrogen reduction in Denmark?
c) What are the barriers for further advancing nitrogen reduction in Denmark?

3. Research Methods

The research design and the collection of data in this research are guided by the research questions above (Bryman 2004: 50). This research is conducted in a single-case study design that mainly employs a qualitative research strategy, striving for trustworthiness and authenticity (Bryman 2004: 273) or validity and reliability (Yin 2003: 34). The research process follows the main steps below:

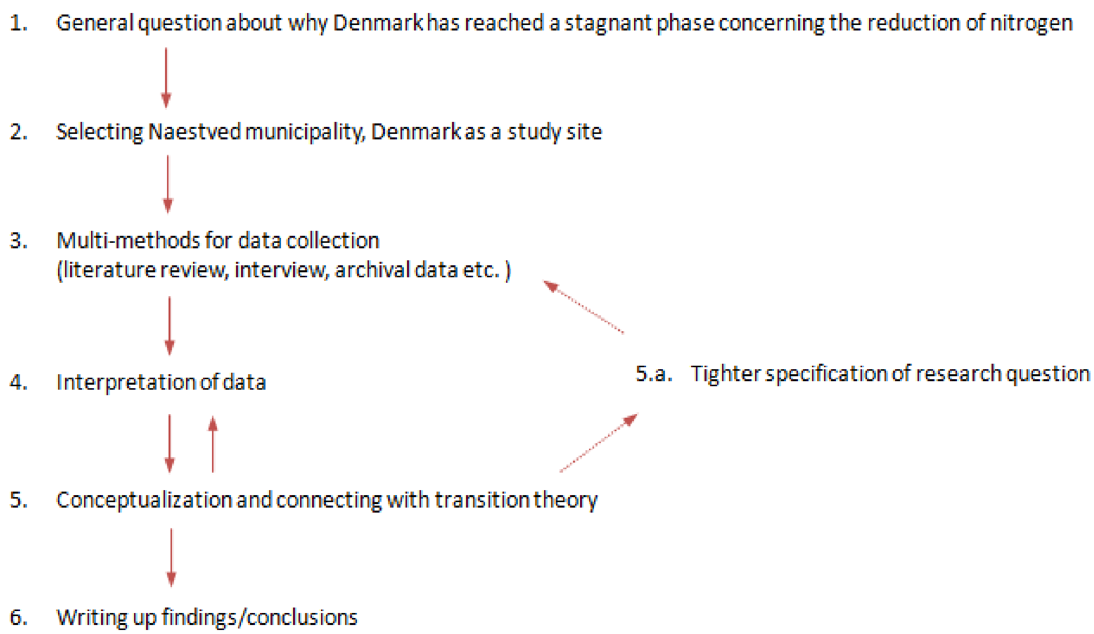

Figure 2. The outline of the main steps in this research (adapted from Bryman 2004: 269).

3.1. Single-case Study

Case study is a preferred strategy when "how" and "why" questions are being posed and when the focus is on a contemporary phenomenon in a real-life context (Yin 2003: 1). A single-case study allows intensive examination ensuring the quality of the theoretical reasoning in analysis (Bryman 2004: 52). Based on these rationales, a single-case study was adopted as a research design for a better focus on demonstrating the challenges of Danish nitrogen reduction. Naestved municipality was selected as a exemplifying case not only because it was the dominant planning authority for parts of the main water catchment Smålandsfarvandet (Waterpraxis 2010), but also it can provide a suitable context for the research (Bryman 2004: 51) in terms of well developed transparency (documents are accessible) and high level of openness (substantial environmental projects experiences). The selection of case area was based on substantial literature reviews and comparisons between potential cases, in an attempt to maximize the access which is needed to collect the case study evidence (Yin 2003: 42), so that ensuring the feasibility for the research.

By employing a single-case study, this thesis does not intend to generalize findings to all other Danish cases, but "relies on analytical generalization" (Yin 2003: 37), in which it is striving to generalize a particular set of results to examine transition theory, "analogous to the way a scientist generalizes from experimental results to theory" (Yin 2003: 38). If the result is acceptable, this would reinforce the hypothesis of transition theory, or the theory needs to be improved.

3.2. A Qualitative Research Strategy

Qualitative research methods are usually employed in case study design because these methods are viewed as particularly helpful in the generation of an intensive, detailed examination of a case (Bryman 2004: 49). Qualitative research focus on the social constructed nature of reality, seeking answers to the questions that stress how social experience is created and given meaning by examining the process of participation (Denzin and Lincoln 2005: 10). In view of the complexity and uncertainty in exploring the issue of Danish nitrogen reduction, it was decided to take a qualitative research strategy for this exploratory study. The research included some kinds of inductive approaches such as in-depth personal communication with key stakeholders and conferences observation, with the purpose of understanding the complex issue, and discovering the rationales behind this issue through the conceptualization of the relevant information with transition theory (see figure 2, step 2 – step 5).

Quantification findings were also employed in this research to help crystallize the generality of the phenomena being described (Silverman 1984, 1985, as cited in Bryman 2002: 445). Some phenomena, for example, the nitrogen surplus tendency and budget trimming, may not be easy to demonstrate by merely using "many", "greatly", "some", this research is thus injected with quantification data in greater precision for an easier demonstration in those sections.

3.3. Data Collection

Multiple sources and methods have been used to collect data for this research, including direct observations, interviews, literature reviews and documents. Using a variety of methods could secure an in-depth understanding of the phenomena in question (Denzin and Lincoln 2005: 6), so as to gain greater confidences for supporting evidence through cross-checking findings deriving from research process (Bryman 2004: 275), and to encourage convergent lines of inquiry (Yin 2003: 36).

3.3.1. Documents

Heterogeneous documents were employed in this research considering authenticity, credibility representativeness and meaning (Bryman 2004: 381). They include official documents, archival information of both the state and Naestved municipality (departmental reports and minutes of meetings) and Danish mass media.

3.3.2. Observations

Direct observations were conducted during my attendance at two water management conferences (see appendix 1:c), with attempts to experience the culture of European water management. By observing behaviors, listening to conversations as well as asking questions (Bryman 2004: 292) during the conferences, the understanding of the WFD was improved and research questions were gradually specified. The visiting period for each conference was 2 days. During these periods, some on-site interviews were conducted with scholars and governmental officials.

3.3.3. Interviews

Semi-structured interviews with certain flexibility were conducted. The main focus is on interviewees' points of views, in an attempt to gain insight into what the interviewees saw as relevant and important (Bryman 2004: 320). Adhering to so-called purposive sampling strategy according to Bryman (2004: 333), people who were relevant to research questions were selected (see appendix 1:a). They were the key actors in Danish water management, including governmental officials at the European level, national level and municipal level; employees in NGOs and scholars in research institutes. Interviews were conducted mainly through in-person interview and phone interview and lasted between 30 and 80 minutes. Each interview was audio-recoded and transcribed within the same day. The way the interviewees said was analysed and transcribed as well for subsequent in-depth analyses. Interviews were conducted in categories based on the needs of research design until achieving theoretical saturation (Bryman 2004: 334), which means that, the relationships among the categories were well established and validated that were enough to answer the research questions (Bryman 2004: 305).

In addition, as shown in figure 2, an iterative approach was adopted from data collection (step 3) to conceptualization (step 5) to cater for the emergence of new findings and new theoretical positions in the course of the research. As a result, the specification of the research question would be tightened in advance, thus continuously spurring the collection of further data to examine transition theory (Bryman 2004: 271) (the loop in dashed). It was especially true for the data sources of interviews and documents, the repetition of data collection were conducted for further specifying research questions.

3.3.4. Field Trip

For gaining more empirical data from the study site, a one day field trip was conducted in Naestved municipality on March 15, 2011, arranged by the Environmental Centre Nykøbing F. In the morning we visited a typical conventional pig farm, in which the farmers use manure to fertilize crop and feed biogas plant (see appendix 1: b). In this course, a fair understanding of farmers' agricultural practices and their concerns on the water plan were obtained. In the afternoon, a short visit was made to the Environmental Centre Nykøbing F to further clarify the understanding of the water plan of main catchment Smålandsfarvandet, and to inquiry the current issue for nitrogen reduction, including historical events and current nitrogen monitoring situation. In the late afternoon, a field visit to a land monitoring site was conducted to gain empirical understanding of the relationship between agricultural practices and water quality monitoring.

4. Study Site

4.1. Municipality Profile and the Catchment

Naestved municipality is selected for a single-case study allowing an intensive examination for the research. Naestved municipality is in the south of region Zealand, Denmark, and situates in the Suså river estuary, approximately 70 km southwest from Copenhagen, with 683 km^2 and a total population of around 80,000 (Næstved 2008b). The Suså river, Zealand's longest river and Denmark's 5th largest water body, is about 85 km long running through Naestved municipality and wandering across the north of the main catchment Smålandsfarvandet (Waterpraxis 2010) (see the green area in figure 3 for the main catchment).

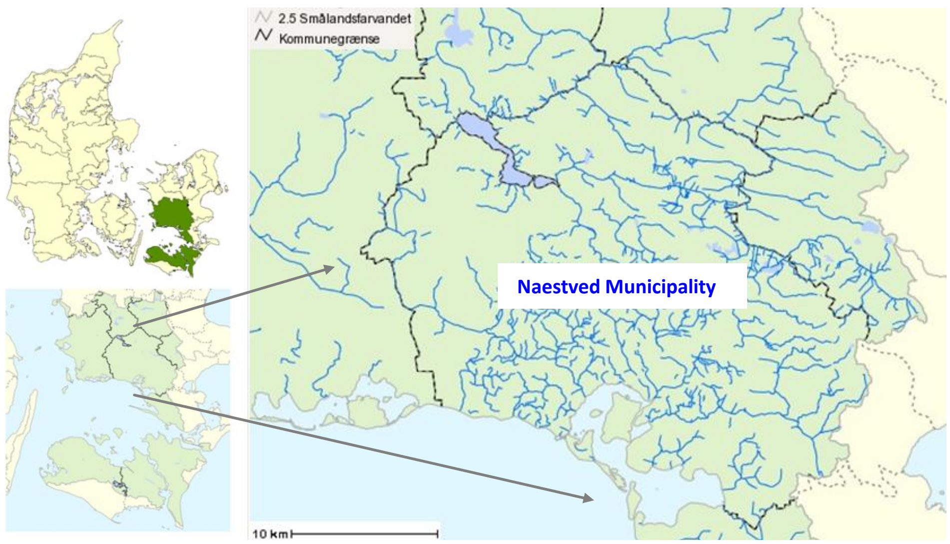

Figure 3. Map of Naestved municipality, Suså river basin and main catchment Smålandsfarvandet (source: miljoegis - Ministry of Environment GIS online).

The main catchment Smålandsfarvandet is one of the 23 main catchments in Denmark, covering the whole Naestved municipality, the whole Suså river basin and most of the region Zealand. Regarding to water management, this main catchment is in the charge of the Regional Environmental Centre Nykøbing F, who is responsible for coordinating the municipalities in this catchment for the implementation of water plan (MIM 2010b). Two thirds of the area of region Zealand is farmland (SJÆLLAND 2008) with about 8000 of the region's 821,000 citizens engaging in agriculture, forestry and fishing (SD 2011a). The types of farms include crops farms, dairy cattle farms, pig farms and poultry farms (SD 2011b). Loamy sand prevails in the Suså basin (86%). The discharge regime in the Suså system is dominated by flood events in winter, in which precipitation is normally much higher than in summer (total 535 mm from July to December compared with 160mm in the rest of the year) (Pedersen et al. 2004). This indicates that potential nitrogen losses from farmland could go through storm water overflowed in winter. According to the baseline analysis, agriculture contributes about 72% of nitrogen load to main catchment Smålandsfarvandet (Næstved 2007), and the current situation is that only 1-4% of the streams in the area has achieved the water quality requirement for good ecological status, while 96-99% would risk not meeting the objectives set in 2015 (ibid.).

5. Concepts and Theory

This part aims at clarifying some basic concepts of the nitrogen cycle and eutrophication, as well as the concepts and rationales in transition theory, so as to pave the way for subsequent analysis and discussion.

5.1. Nitrogen and Sustainability

5.1.1. The Nitrogen Cycle and Agricultural Diffuse Losses

In general, diffuse nitrogen from agriculture to aquatic environment can go through several paths: (i) nitrogen can first be emitted to the atmosphere as NH_3 from commercial and animal fertilizer through ammonia volatilization. Because emitted NH_3 is highly water soluble (Ritter and Bergstrom 2001), it will be washed out by rain and return to the ground or marine environment; or (ii) excessive nitrogen from farmland leaches out to the groundwater and then infiltrate into surface runoff or marine environment; or (iii) in addition to leaching, nitrogen can also reach surface runoff if precipitation exceeds the infiltration capacity of the soil (ibid.) (see figure 4). So the measures taken to reduce nitrogen losses are normally either to reduce nitrogen from sources or to capture nitrogen along its transporting paths.

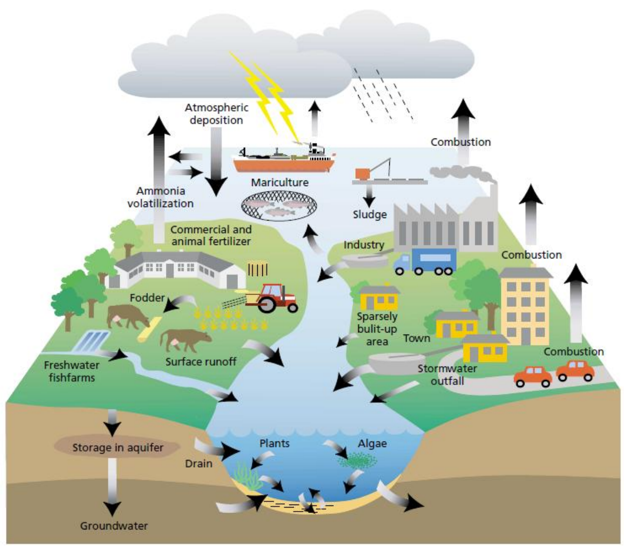

Figure 4. The nitrogen cycle in the aquatic environment (source: Ærtebjerg et al. 2003).

Wetlands and riparian buffer zones can help nitrogen removal because they act as efficient water filters (Comin et al. 1997, Sergi et al. 2003) to capture excessive nitrogen along its transporting paths. Good Agricultural Practices (GAP) can help reduce nitrogen load because nitrogen sources are regulated by optimal management strategy in farmland, such as tuning fertilizer use, considering the timing of fertilization and ploughing, and changing the crop cultivation pattern, so as to improve the efficiency of fertilizer use (Arheimer et al. 2004). This is similar to organic farming[5], in which good agricultural practices are emphasized for better

[5] Organic farming some time is not necessarily equal to less nitrogen losses, it depends on location, farm system and soil type (Hansen et al. 2001).

nitrogen efficiency. In addition, organic farming usually has higher level of biological activity (bacteria, earthworms etc.), which to some extent helps improve nitrogen efficiency as well (Hansen et al. 2001).

5.1.2. Eutrophication and Sustainability

The current anthropogenic interference in the nitrogen cycle has already transgressed its planetary boundaries (Johan et al. 2009). Excessive nitrogen concentration in aquatic environment may lead to eutrophication problems (Nixon 1995). Since the mid-20th century, eutrophication issue has generated increasing attention (Rodhe 1969, Nixon 1995). Eutrophication is usually characterized by algal blooms, dead zone and the decline of fisheries. Nowadays the influences of eutrophication have spread to almost every continent of the world including inland water and marine environments (Duce et al. 2008). Until 2008 there were a total of 405 dead zones worldwide, the representative cases are Gulf of Mexico, Chesapeake Bay in U.S. East Coast as well as Kattegat strait and the Baltic Sea in Europe (Diaz and Rosenberg 2008).

The impacts from eutrophication are profound, imposing adverse influences on ecosystems as well as human sustainability (WHO 2002). Harmful Algal Blooms (HABs) are the well-known characteristics of eutrophication. In the environmental aspect, Paralytic Shellfish Poisoning (PSP) caused by HABs can impose a massive adverse impact on an ecological system. Algal toxins can kill animals directly, or have little effect on them but accumulate in the bodies killing other predators in the relevant food webs (Glibert et al. 2005, Gambi et al. 2009). In the social aspect, HABs would threaten human health. People who have eaten the animal accumulated with algal toxins would suffer from diarrhea, nausea, vomiting and respiratory paralysis (Glibert and Pitcher 2001). In 1974, it was estimated that the worldwide PSP incidence was about 1600 cases with possibly more than 300 deaths per year (WHO 1984). Nevertheless, though it has been observed for more than one century (Conte 1984), there is still no antidote for such marine toxin (Sobel and Painter 2005). In the economic aspect, HABs can bring about significant economic losses in relevant industries. Tourism at beaches usually incurs terrible losses from the discoloration and foam formation of sea water caused by algal blooms or decaying rotting macro algae (Ærtebjerg et al. 2003). A study showed that the potential annual economic losses attributed to eutrophication in recreation use is about 0.37 – 1.16 billion USD in U.S. freshwaters (Dodds et al. 2008); and considerable losses in fisheries and the oyster industry are also reported (Conte 1984).

5.2. Transition Theory

The complexity of sustainability transition determines that transition science cannot be entirely investigated from one scientific discipline (Rotmans 2005). Transition theory derives from Complex Adaptive Systems (CAS) theory, taking complexity and uncertainty as a point of departure. It integrates concepts from governance, evolutionary economics, innovation studies and technological transitions as analytical framework, and develops transition management approaches as steering instruments. It is a non-linear knowledge development science, requiring co-evolutionary social-learning processes (Rotmans 2005, Brugge and Rotmans 2007).

5.2.1. Definition & Typology

In general, the definition of transitions can be summarized as transformation processes from an initial dynamic equilibrium to another, characterized as non-linear, large-scale, spiral, structural changes with long-term, continuous, interacting process (Rotmans et al. 2001, Geels 2002, 2005, Rotmans 2005, DRIFT 2010). Nevertheless, the connotation of the "transition" can be diverse, it can refer to a co-evolutionary, self-organized technological transition similar to the principle of "survival fitness", for example, the technological innovation such as the emergence of steamships (Geels 2002) and the development of ICT (Rotmans 2005); or target-oriented transition, for example, policies or directives such as the nuclear energy provision and national health care system (ibid.). Different connotations of transitions determine different operational strategies. Ambiguous connotation may impede the correct understanding of the complexity of transition system, probably leading to one-for-all approaches which ignore the multiplicity of phenomena. In this sense, it is necessary to distinguish different types of transitions. Based on the initial efforts made by former scholars, Kemp and Rotmans (2004) drew up two main types of transition illustrating them as: (i) the evolutionary transitions and (ii) the targeted-oriented transitions. The former normally is a spontaneous developing process driven by bottom-up forces from individual behavior without too much macro plan, emphasizing fairness and openness for cultivating transition; while the latter usually has a guiding policy with dominant top-down approaches and encouragement of cooperation and participation.

5.2.2. Three Conceptual Pillars

In transition theory, three prominent patterns are recognized as conceptual pillars, they are: multi-phase, multi-level and multi-change (DRIFT 2010). In my understanding, these three conceptual pillars allow me to analyse complex issues from a multi-dimension perspective in terms of spatial and temporal axis. In this paper, these three conceptual pillars are used to reframe the issue of nitrogen reduction, therefore, it is necessary to elaborate these concepts before conducting data analysis.

Multi-phase

In transition theory it is believed that a transition is a result of continuous changes in four phases on a temporal axis (see figure 5), each of them has its own characteristic and meanwhile they are interconnected with each other, these four phases are:

- *A pre-development phase:* innovation emerges in niches in the context of existing regimes and landscape developments (Geels 2005). The changes of socio-environmental conditions impose stress on the regime structure and demand new efforts on policy or regulation domain, but in general, status quo does not visibly change (Brugge and Rotmans 2007).

- *A take-off phase*: the dynamics of the system begins to shift with a process of change (Rotmans et al. 2001). This change is the result of the emergence of innovations and the destabilization of the existing regime, it affects all system domains with different changes, which are normally large-scale, penetrating and inter-connective (Brugge and Rotmans 2007).
- *An acceleration phase*: visible structural changes take place through an accumulation of socio-cultural, economic, ecological and institutional changes that interconnect with each other (Rotmans et al. 2001). In the meantime, power transfers from the traditional regime towards the new regime (Brugge and Rotmans 2007).
- *A stabilization phase:* a new dynamic equilibrium is reached and turns into processes optimization. (Brugge and Rotmans 2007).

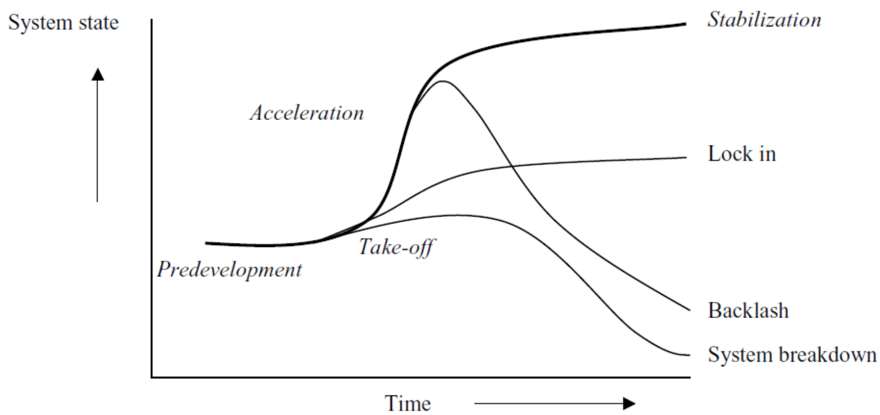

Figure 5. Different phases of a transition and different transition paths (source: Rotmans 2005)

However, according to Rotmans (2005): this S-curve with the four phases above represents an 'ideal' transition, a system lock-in may emerge due to the complexity and path dependency, i.e. choices made in the past exclude new opportunities and reduce the necessary diversity so that a lock-in situation emerges. It was also pointed out that "the only way to clear such a lock-in situation and turn it into a transition is by applying force from outside the system". So the final pathway depends on the competition between the forces from the "new" and "old", leading to different scenarios such as acceleration, or system breakdown, or maintaining the lock-in situation.

Multi-level

Initially developed by Geels and Kemp, the multi-level concept describes a transition in terms of different scale of dynamics, which are interlinked in a spatial dimension (Loorbach and Rotmans 2006). It is not an ontological description of reality, but an analytical and heuristic framework to understand the complexity of reality (Geels 2002). In this framework, the higher the scale level the more aggregated the components and the relationships, and the slower the dynamics are between actors, structures and working practices (Rotmans 2005). The multi-level concept distinguished three levels: the macro level, the meso level and the micro level. They are illustrated as below (see figure 6):

- *The macro level*: also called the landscape, refers to aspects of the wider exogenous environment that are beyond the direct influence of actors and cannot be changed at will (Geels 2005). Changes take place at a relatively slow progress and develop with a high autonomous character (Rotmans 2005). For example, political culture and coalitions, social values, worldviews and paradigms, the macro economy, demography and the natural environment can be classified at this level (Rotmans et al. 2001).
- *The meso level*: refers to regimes, systems of dominant practices, regulations and interests that are shared by groups of actors and guide private action and public policy (Rotmans et al. 2001, Rotmans 2005).
- *The micro level*: or the niche level, relates to individual actors and technologies, and local practices such as companies and environmental movements (Rotmans et al. 2001). At this level short-term changes can follow each other in rapid succession and then disappear again quickly (Rotmans 2005).

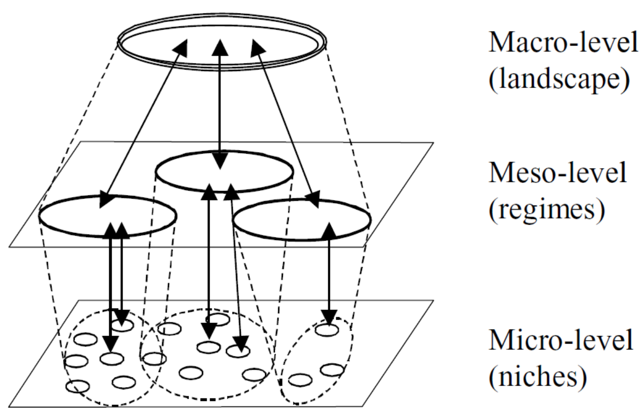

Figure 6. Multi-level concept in transition theory (source: Geels and Kemp 2000)

The ways of interaction among these three levels can be diverse. It can be a bottom-up process in which stress comes from the niches and diffuse to the regimes and the landscape (Geels 2005). It can be a top-down process where interactions begin at the regimes and the landscape in turn stimulate the niches (Rotmans et al. 2001). Or changes can also initially take place within the regimes and from there diverge to the niches and the landscape (Rotmans 2005). It has been acknowledged that interactions between these three levels are important to a transition, a transition only comes out when developments at the three levels move into the same direction and reinforce each other (Geels 2005, Loorbach and Rotmans 2006, Brugge and Rotmans 2007).

Multi-change

The multi-change concept describes the nature of the dynamics of transitions, it offers a regulatory framework for the cyclical process of relative construction and destruction in transitions (Rotmans 2005). That is, it first emphasizes that transition is a spiral development process which may be recursive and fluctuant; meanwhile it also points out that each step in this cyclical process is just the result of the competition between constructive forces and destructive forces, and a transition is the result of continuously reinforcing constructive forces and inhibiting the destructive.

6. Data Analysis

The data analysis can consist of examining, categorizing, tabulating as well as recombining both quantitative and qualitative evidence (Yin 2003: 109). In this research, data collected from multiple sources, that is, the data from observations, interviews, literature reviews and documents is diverse in terms of different scales, different levels and different domains. This information, including both qualitative data like in-depth interview and quantitative data like official statistic data, has been merged into this section to illustrate the nitrogen reduction issue. The following sections are structured through the analytical steps required in a transition theory analysis. The reframing is conducted by pattern matching, explanation building and time-series analysis (ibid.), so that the linkages behind these information are identified.

6.1. Part I: Analysis from A Multi-phase Perspective

Danish water management has progressed several important historical periods, all of which have their own unique characteristic with representative events. Besides analysing historical events, former policies of water management for nitrogen reduction, for example, Danish Action Plan I,II & III for aquatic environment, would offer important references to identify the changes of different periods, so as to come up with an easier understanding of this transition, here I summarized the development of Danish water management into different transition phases from a multi-phase perspective (see table 1).

Transition Phases	Period	Representative Events	Characteristics
Pre-development	Before 1987	Increasing eutrophication worldwide 1985: the NPo Research Programme 1986: the Lobster event in the Kattegat Sea[1].	Increasing global environmental awareness Deteriorating water quality. Growing concerns on Danish nitrogen pollution High fertilizer consumption agriculture Start regulation on agriculture Steep increase of nitrogen surplus in
Take-off	1987 – 1997	1987: Action Plan I	Objective-oriented Evolving programmes of instruments Command and Control regulation General regulation Ban inappropriate farming practices Certain nitrogen reduction
	1998 – 2003	1998: Action Plan II	Objective-oriented Evolving programmes of instruments Regulation enforcement Costly: wetland, N quota of 10% below economic optimum etc. Encourage innovation: Organic farms etc. Great nitrogen reduction
Lock-in?	2004 until now	2004: Action Plan III Water Plan for the Implementation of the WFD	Objective-oriented Integrated programmes of instruments Integrated Water Management River Basin Management Indistinct nitrogen reduction

Table 1. Author's analysis of transition phases based on the data and information from Kronvang et al. (2008), Nørring and Jørgensen (2009) and Holter (1991).

6.1.1. The Pre-development Phase

In view of the deteriorating eutrophication problem worldwide (see section 5.1.2), some countries have made considerable efforts to reduce the impact of this problem. Denmark was one of the first countries that discovered the eutrophication problems caused by nutrient losses (Kronvang et al. 2008). In the 1970's and the early 1980's, there were growing concerns about the effect of nutrient losses from agriculture (ibid.): elevated nitrogen concentrations were observed in groundwater while increasing frequency of situations with serious oxygen depletion were reported by Danish monitoring system (ibid.). The event sparking nationwide concerns was the lobster event, which was a television report in the news of Danish channel 1 on October 8th 1986, showing dead lobsters in Kattegat Sea between Demark and Sweden, this was attributed to anoxia resulting from eutrophication (ibid.). Later in 1984 a report called Research Programme on Nitrogen, Phosphorous and Organic matter (NPo) was prepared synthesizing the nutrients emission issues with primary focus on nitrogen losses from agriculture (Holter 1991). The NPo programme as a result facilitated the adoption of the subsequent action plan - Action Plan I on the Aquatic Environment in 1987 (ibid.). In this phase, social-environmental innovation in terms of increasing environmental awareness to eutrophication and evolving scientific understanding of diffuse nitrogen losses has emerged. However, these innovations seem to be isolated cases, because the NPo programme can merely be considered as a preliminary stage for regime change, while broad-scale regulation to agriculture was still absent (ibid.). But the fact is that these changes had imposed significant stress on regime, leading to a subsequent regime change at large, i.e. the adoption of Action Plan I in the next stage.

The direct result is shown in the curve of nitrogen surplus. In this phase, Denmark maintained high fertilizer consumption, and especially in 1973, it reached the peak of 1,969,900 tons (FVM 2006). In the meantime, due to the absence of relevant approaches to this issue, annual nitrogen surplus from agriculture increased steeply between 1950s and 1980s (see figure 16 in appendix 2). It was observed that both fertilizer consumption and nitrogen surplus from agriculture didn't show any declining tendency in this period. Based on this observation as well as the socio-environmental innovations found in this period, and reframed from a multi-phase perspective in transition theory, this period can be understood as a pre-development phase.

6.1.2. The Take-off Phase

In 1987, the regime of Danish water management started to shift with a process of legislation changes. From 1987 to 2003, Denmark adopted a series of Action Plans for aquatic environment, including Action Plan I & II. Between the main action plans there are several sub action plans in each period for complementation and enforcement. The most striking characteristic is that a clear target was set and programmes of instruments were evolving on scientific basis. In Action Plan I, the target for nitrogen reduction was set to 145,000 tons reduction, i.e. 50% of N-loss (Nørring and Jørgensen 2009). Its regulation was general, i.e. programmes of instruments were mainly relied on common and control regulation to the whole country with a primary objective to control nitrogen input to the field, such as limiting fertilizer use and banning inappropriate farming practices. In this period (1987 – 1998), nitrogen surplus was reduced by 29.9%[6] (didn't

[6] This calculations in this paragraph and subsequent paragraph are based on the data in table 3 of appendix 2. The

achieved the set target of 50%) with annual average reduction by 3%. However, further efforts needed to be made for achieving the set target and for a greater regime change.

In 1998 Action Plan II was adopted for further nitrogen reduction. Based on the previous programmes of measures, some measures were strengthened and new measured were employed, such as tightening limits on nitrogen use to 10% below the economic optimum and establishing wetland (Kronvang et al. 2008). Meanwhile, organic farming was encouraged as an alternative agricultural development pattern. In this phase (1998 - 2003), regime changes actually had touch upon broader system domain, penetrating in different areas and decentralizing the existing regime. For example, establishing wetland requires cooperation between the spatial planning department and the nature protection agency; and the organic farming which is supported by the state-funded research centre - the International Centre for Research in Organic Food Systems (ICROFS), would compete with conventional agriculture in terms of resources and discourses. In this period, the total reduction of nitrogen surplus was 13% with annual average reduction by 2.6%.

These changes and figures above indicate that regime changes in Danish water management had happened in this period and as a result the policy for nitrogen reduction started to take effect; the comparisons between the period of Action Plan I and Action Plan II also imply that this regime change was undergoing and evolving toward greater penetration and interconnectedness in different system domains. In this sense, these two periods can be considered as a take-off phrase from a multi-phase perspective. If accumulations of these changes are sufficient enough, acceleration phase would take place subsequently in theory.

6.1.3. Confronting A "Lock-in"?

For further verifying in what phase the Danish water management is, I believe it would be necessary to utilize different angles to analyse the current situation. To begin with, the figure of nitrogen surplus[7] would be a direct evidence (see figure 7).

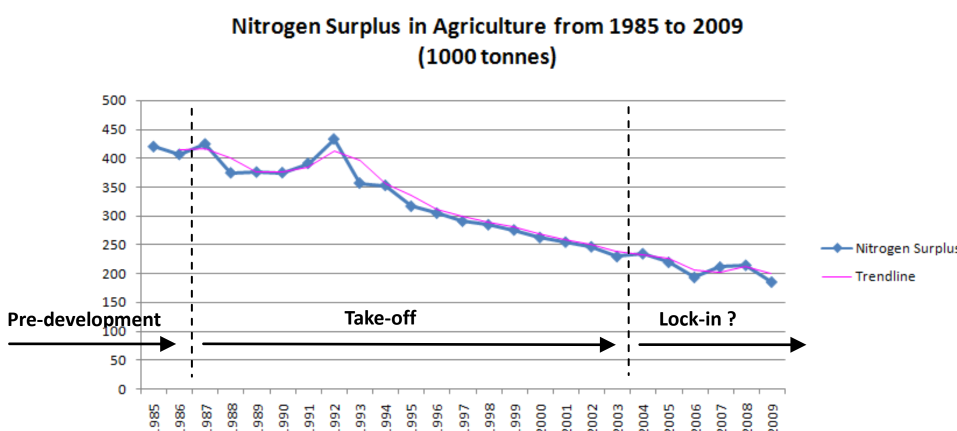

Figure 7. Trend in nitrogen surplus embedded from a multi-phase perspective (generated from data in table 3 in appendix 2), the division of phase is based on policy events.

value in 1987 is set as baseline for the calculation of nitrogen reduction rate and annual nitrogen reduction rate. Annual nitrogen reduction rate = sum of each year reduction rate / number of years.

[7] Nitrogen surplus = nitrogen input – nitrogen out, detailed calculation please refer to table 3 appendix 2

Stagnancy in Nitrogen Reduction

According to figure 7, since 2006 it has been observed that there was no obvious progress. From 2006 to 2009 the total reduction of nitrogen surplus was 1.9% with annual average reduction by 0.6%, which was the lowest among all periods (comparing to the take-off phase). And it is also noted that nitrogen surplus rebounded a little in the years 2007 and 2008. Another measuring approach conducted in catchment level for the whole country also exhibits similar result. The changes for nitrogen surplus for catchment Smålandsfarvandet, where Naestved municipality locates, leveled off since 2003 (see appendix 2:c). This stagnant situation of nitrogen reduction can be explained as "the threshold of cost-effectiveness" of Danish water management, that is, the most cost-effective measures have been adopted and they were relatively easy to be implemented because the they were not that costly to the stakeholders, and to some extent farmers could even economically benefit from the increase of fertilizer efficiency (H.M. Jørgensen, personal communication, March 8, 2011; C.F. Andersen, personal communication, February 23, 2011).

Stagnancy in Institutional Environment: A Political Arena

It is observed that this stagnant stage resides in the take-off phase which I have illustrated in the section above. In view of the complexity of the interaction processes in this phase, I don't pretend to be an omniscient narrator to explain all the reasons. I believe the following findings can help understand the current stagnant situation of nitrogen reduction.

The 2009 Agreement on Green Growth is considered as a key development strategy helping Denmark to meet its obligations under the EU Water Framework Directive (MIM 2009a). However, it is quite debatable and has been regarded as a compromise with conventional agriculture. There are numbers of "brown" components in the Agreement on Green Growth. Firstly, the regulation on the limitation for the maximum number of livestock has been rescinded and the ownership requirements to the farmers was relaxed (MIM 2009a), which means that the admittance requirements to be a farmer have reduced, and farmers would be allowed to keep as many as animals as they wish in their farms. These changes are considered as a stimulation to the development of conventional agriculture, but contradictory to the target for nitrogen removal. Moreover, the plan is also being criticized for lacking ambitions and recycling former action plans. For example, the target of turning 50,000 hectares of agricultural land into uncultivated areas was considered not helpful enough since 83,000 hectares of fallow land has been taken into use again in recent years (Lehmann 2009). So whether it is "Green" enough is being questioned (H.M. Jørgensen, personal communication, March 8, 2011). Therefore, the Agreement on Green Growth is reflecting an inconsistent political culture concerning the issue of nitrogen reduction.

Apart from the problem in development strategy itself, the stagnancy is also represented as the infirm implementation of the strategy. It is reported that the plan for creating buffer zones along watercourses has been postponed to 2012. This change was considered as another agriculture-friendly action at the cost of suspending the goal of the WFD (DR 2010). On the other hand, farmers were quite dissatisfied with the Agreement on Green Growth and have been trying to influence politics ever since the plan was adopted. In March, 2011, nearly 2000 farmers with their 500 tractors marched to Copenhagen, protesting against the Agreement on Green Growth that will weaken the competitiveness of Danish (conventional) agriculture, and as a result sending the Danish agriculture to the grave (NORDJYSKE 2011).

The Phase of Nitrogen Lock-in

The phenomena above are reflecting a stagnant stage of Danish water management for nitrogen reduction, which can be seen in both technical indicator (nitrogen surplus) and ambiguous policy strategy (the Agreement on Green Growth). Meanwhile, it should be noted that this stagnant stage emerged during the take-off phase and probably would continue for a certain time of period. Based on these observations, I argue that a lock-in in Danish water management for nitrogen reduction has emerged. Although there is still no clear definition for the term "lock-in" in transition theory, its connotation has been developed by some researches (Rotmans et al. 2001, Rotmans 2005, Brugge and Rotmans 2007, Avelino and Rotmans 2009). Based on the research above it can be summarised as an ambiguous state of societal changes, which is caused by the incumbencies in the existing system on the way of transition towards an innovative societal system. The lock-in observed in this research, carries a richer connotation than a stagnant phenomenon. Firstly, it is historically dependent and continuous, following a certain trajectory rather than merely a stagnant fragment. The judgment of lock-in in this research is based on the recent evidence combined with those from previous transition phases. Secondly, it is dynamic, consisting of influences from different domains, while stagnancy is relatively static and narrow. As shown above, this identified lock-in consists of multiple stagnancies in different domains. Embedding the nitrogen reduction issue in transition theory, I am hence using the terminology "nitrogen lock-in" to conceptualize the current situation.

After a long take-off phase, when regime attempted a more radical change to accelerate nitrogen reduction, for example, the implementation of the WFD, the phenomenon of nitrogen lock-in emerged. The phase of nitrogen lock-in can be understood as a phase of a competition between the forces from the "new" and the "old", a competition of interests in a political arena for various stakeholders, for example, the hybrid Agreement on Green Growth as illustrated above. In this phase, the "accumulation of socio-cultural, economic, ecological and institutional changes" (Rotmans et al. 2001) is still insufficient to achieve greater interconnectedness, to override the "old" forces, while the "old forces" are still stubborn to changes coming with considerable resistances, for example, the protest of farmers. So without further supports from outside of the system, the nitrogen lock-in may continue.

In this part, I have answered the first sub-question, that is, the current stagnant stage of nitrogen reduction is the manifestation of nitrogen lock-in in the transition of water management towards good ecological status, this lock-in lies between the take-off phase and the acceleration phase. In the next section I will further analyse this nitrogen lock-in situation from the multi-level and the multi-change perspective. Let it start with Henning's words - "the situation it will become more and more difficult because it is more and more costly with increasing conflicts" (H.M. Jørgensen, personal communication, March 8, 2011). So how these conflicts will develop - finally leading to an acceleration, or a breakthrough, or maintaining the current lock-in, or even ending up with system breakdown - depends on the competition between constructive forces and destructive forces. As such, I will provide a snapshot of this lock-in state by analysing drivers and barriers at various scale levels, so as to understand the changes of constructive and destructive forces.

6.2. Part II: Multi-Level Drivers

Drivers can be understood as the increase of constructive forces, alternatively the decrease of destructive forces. For example, it can be a momentum from the take-off phase and remains to impose influences on the current situation, or innovators and innovations emerge in different system domains to reinforce interconnectedness in innovation network and to decompose the incumbent.

6.2.1. Macro-Level

According to the multi-level concepts, change at the macro-level is a relatively slow process in large scale with high autonomous characteristics. Thereby analysis in general is focusing on the global level and the EU-level with longer time axis. These macro changes have become important forces facilitating Danish water management to override the nitrogen lock-in.

Macro-politics: International Legislation regarding Eutrophication

Since mid-20th century the eutrophication issue is increasingly serious and has attracted more and more attention worldwide[8]. In this situation, series of international conventions regarding eutrophication have been developed. The Helsinki Convention (HECOM) with the aim of protecting marine environment of the Baltic Sea entered into force on 17th January, 2000. It prioritizes eutrophication, especially the contribution of agriculture, and specifies certain nitrogen reduction target for the Baltic countries (HELCOM 2004, 2006). Another important international legislation is the 1991 EU Nitrates Directive, which is one of the earliest pieces of EU legislation aiming “to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices” (EC 2010b). Under this directive, all member states are required to establish action programmes to cut nitrate pollution and improve their water quality (ibid.). As an integral part of the WFD, the Nitrates Directive has become the key instrument promoting the protection of waters against agricultural pressures in member states.

Influenced by this international convention and legislation, Denmark, as an European country in the Baltic Sea, has made corresponding efforts on its legislation framework. The HELCOM convention is represented in the 2009 Danish Agreement on Green Growth[9], which contains several overall N and P reduction targets for reducing discharge to the HELCOM areas

[8] See section 5.1.2

[9] See section 6.2.2, the introduction for Agreement on Green Growth in “Regime Innovation in National Level”

(MIM 2010c). The WFD with the spirit of the EU Nitrate Directive, has been transposed to Danish Environmental Objectives Act – Miljømålsloven in 2003 (MIM 2009b)(a national environmental framework for Danish water management). From a multi-level perspective, these changes can be identified as the drivers from the changes of political culture and coalitions at the macro-level.

Social Values on Economic Growth: A Green Growth Tendency

The paradigm about economic growth has been shifting since 1960s. When liberalists were still advocating free trade and globalization for advancing economic growth in the second half of twenty-century, some alien voices about the limits to growth was spoiling such atmosphere (Carson 1962, Brown 1970, Meadows 1972, Gore 1992). The main representatives are Donnella Meadows et al., arguing that the future global development will be constrained by global sustainability issues in terms of world population, industrialization, pollution, food production and resources depletion, that is so called the Limits of Growth (Meadows et al. 2004). In their work they called for changing the attitude about growth so as to reach an ecological-economic equilibrium.

In 2008, UNEP launched a Green Economy Initiative to provide a macroeconomic analysis for policy reforms and investments in green sectors, subsequently triggering more discussions about the transition to a global green economy (UNEP 2011). Several months later, OECD made a declaration on Green growth to facilitate the environmentally and socially sustainable economic growth (OECD 2009). In this circumstance, in 2009 Denmark signed up a Agreement on Green Growth [10] to reach a more appropriate ecological-economic equilibrium. Later, in 2010, the European Commission also launched a new growth strategy - EUROPE 2020 STRATEGY, putting great emphasis on R&D investment in the Green Growth. It proposes that each member state should translate strategy targets into national trajectory (EC 2010a). Based the observation above, it can be summarized that the social values in terms of the understanding of economic growth have changed and have imposed significant influences on the national macro-economic policies.

Political Culture Changes: ENGOs' Facilitation

Generally Environmental Non-governmental Organizations (ENGOs) utilize information dissemination, public mobilization, lobby or complaints to raise public environmental awareness, to influence environmental objective and to facilitate environmental agenda (H.M. Jørgensen, personal communication, March 8, 2011). In European water management, ENGOs have imposed significant influences on the adoption of the WFD and have been taking an increasingly important role in its implementation (Louka 2008: 86, 359-383).

In 2004, the European Environmental Bureau (EEB) and World Wildlife Fund (WWF) were involved in the WFD Common Implementation Strategy process (CIS) - an European level action strategy for providing a guideline of member states. It was believed that this would effectively facilitate public participation in the WFD, to shorten the gap of the understanding of

[10] See section 6.2.2, the introduction for Agreement on Green Growth, in "Regime Innovation in National Level"

the WFD and to ensure compliance with this directive (EEB and WWF 2004). Besides, ENGOs are also actively contributing to the processes of monitoring, evaluation and consultation. The first ENGOs survey in January 2004 carried out by EEB and WWF was to provide an indication of the general progress that had been made on the WFD implementation (EEB and WWF 2005). By utilizing data collected from ENGOs in member states rather than the official data, it was believed as a convincing evaluation approach to assess the public participation progress in reality in each member state.

On the other hand, it is observed that the scale of ENGOs' involvement has increased as well. In England and Wales, ENGOs have been widely participating in the operation of river basin plan embedded in various committees and panels, cooperating with different authorities (Orr et al. 2007, Louka 2008: 242). In Denmark, the increasing scale of involvement is characterized by the increasing surveillance of environmental governance from ENGOs. In 2011, the Danish Society for Nature Conservation (DN) – Danish biggest environmental NGO as well as the partner of EEB, submitted a complaint to the European Commission to steer government's action on the implementation of the WFD, which has been postponed considerably according to EC's agenda (DN 2011). Therefore, environmental NGO has become a significant driver from exogenous environment to steer the development of water governance at the macro level and to facilitate the implementation on the meso.

6.2.2. Meso-Level

At the Meso-level, analysis will be based on the Danish context. As demonstrated above, changes at the macro level in terms of political culture and coalitions, social values and new paradigms have happened in the air. In this section, I will examine relevant findings at the meso level in terms of national level and municipal level, these changes would either directly or indirectly connect with the nitrogen reduction target in Danish water plan under the WFD (see figure 8).

Regime Innovation in National Level

First, the newly adopted Agreement on Green Growth is one of the main primary driving forces for further nitrogen reduction. According to Danish Agreement on Green Growth signed up in June 2009, in order to reach a more appropriate ecological-economic equilibrium and enter into a win-win situation between environment and agriculture, new efforts will be made in a long-term schedule. It includes new investments, new environmental targets and new action strategies. For example, to create such green growth precondition, "a total of DKK 13.5 billion is to be invested in Green Growth until 2015, which is about a 50% increase in investments compared to previous initiatives" (MIM 2009a). It is believed that this will help the implementation of Danish water plan[11] under the WFD because it has also put great focus on improving aquatic environment, including a striking nitrogen removal target of "19,000 tones

[11] the Green Growth Agreement can be considered as the part of the Danish water plan because both of them share the same nitrogen reduction target and has some programs of measures in common, such as wetland and buffer zone.

reduction in nitrogen discharge to the aquatic environment from 2010 to 2015", and "improvement in the physical conditions of selected stretches of watercourses totaling 7,300 km from 2010 to 2015" (ibid.). Meanwhile, it should emphasize that the key component in this agreement is the transition toward green agriculture and food industries, which will be supported by the promotion of green energy, market-based organic sector and new green technologies research.

Moreover, the existing agriculture regime will be decentralized in advance. Based on the development of organic sectors facilitated by early organic farming action I & II (FVM 1999), new target is set in the Agreement on Green Growth to increase the market share of the organic sector to 15% by 2020 compared to 6% in 2007. For archiving this, continuous financial support will be ensured and accessibility of organic food to the public will be increased through regime innovation, that is, it will further simplify the regulation to organic sectors and promote the use of organic raw materials in the catering industries (MIM 2009a). This to some extent will reduce chemical fertilizer use in the fields so as to reduce the risk of nitrogen leaching[12].

Furthermore, in February 2011, a new energy strategy called "Energy Strategy 2050" was announced to achieve independence of fossil fuels by 2050, this strategy aims to significantly increase the share of renewable energy obtained from wind, biomass and biogas (KEMIN 2011). For this initiative, Danish government will introduce a general subsidy of DDK 27/GJ to biogas plant for biogas production from 2012, and additional subsidy of DDK 22.5/GJ to the biogas from livestock manure (ibid.). These approaches are believed to provide greater incentive to livestock manure use so as to reduce the diffuse nitrogen discharge from the fields[13]. Meanwhile, it should be noted that this strategy is echoing the 2009 Agreement on Green Growth, which aims at 50% of livestock manure supplied for green energy by 2020 (MIM 2009a).

Regime Innovation in Local Level

In Naestved Municipality, the approaches associated with manure use and organic farming are embedded in several important municipal strategies and action plans. In the Action Plan of Agenda 21, organic food is one of the focus area and has been prioritized in the 2010 scheme (Næstved 2008a). It aims at raising proportion of organic food in institutions, schools and other social sectors, including a pilot project in 2008 for 80% organic food in meeting catering and a pilot project in 2010 for 30% organic food in 10 institutions and 3 schools (ibid.). Meanwhile, the municipal government is trying to make organic foods be part of the food and meal policy for children and youth, and to influence canteen food and meals to the elderly in an ecological direction (ibid.). In 2010, Naestved municipality moved forward to the external cooperation in organic sectors, as an observer, Naestved municipality participated in "Green Cities" - a municipal collaboration platform among Danish municipalities for the purpose of developing sustainable communities (Næstved 2010). This collaboration strategy announces even ambitious

[12] See section 5.1.1.

[13] This is based on the assumption of economic choices and behaviors, that is, if more values is found from livestock manure, for example, can be used as biogas supply, farmers will "cherish" manure more so that increasing the efficiency of manure use in fields.

target in organic sectors, i.e. to encourage municipal organic farming and to direct local food consumption to 75% organic food proportion (ibid.).

For the energy sector associated with livestock manure, relevant planning has been made regarding biogas in 2009. In Naestved Municipality, it is estimated that around 70,000 tons of cattle manure and 140,000 tons of pig manure are produced per year (Næstved 2009a), it would considerably reduce the risk of nitrogen leaching and nitrogen oxide emission if these manure were fed to biogas plant. As mentioned above, great efforts have been made at the national level, additional efforts at the local level will be done by Naestved government as well. Besides encouraging GAP and promoting biogas use in the area with relatively high price of heat and relatively low efficiency, the Naestved government could facilitate networking for the establishment of new biogas plants, or could invest in the plants directly (Næstved 2009b).

From the above it is observed that not only at the national level but also at the municipal level changes in regime associated with nitrogen reduction have emerged, and inter-connectedness in this innovation network is starting to build up and reinforcing each other, for example, the Agreement on Green Growth is not isolated, it has many connection with other strategies such as Organic Farming Action Plan and Energy Strategy 2050, so that challenging the existing nitrogen-dependent regime like conventional agriculture.

6.2.3. Micro-Level

At the micro-level, driving forces comes from the technical innovation, the changes of individual behaviors, and the individual compliance with the water plan.

Individual Support for Socio-technical Innovation

In Denmark, organic farming as an agricultural innovation has developed significantly due to the increase of individual food preference. From 1990 to 2008, organic market grew greatly from almost zero to more than 6% of market share, especially the period from 2005 to 2008, sale of organic foods in Danish detail stores, supermarkets and department stores grows sharply with the growth of 12%, 18%, 33%, 29% respectively (okologi 2011). This fast growth of organic food can attribute to the growth in both price and quantity during this period, in which the price has a even higher increase rate (126.9% for price increase compared with 51.1% for quantity increase) (SD 2011d). The increase of market share and individual acceptance to the higher price of organic food indicate the changes of individual food preferences, presenting a shift towards an organic-based lifestyle.

In Naestved municipality, organic foods have been close to citizens' life. Rohavegård is an organic farm with 35 hectares in the western part of Naestved municipality. Since its establishment in 1986, Rohavegård has served not only as the organic farm but also as the educational base for promoting organic farming. Each year Rohavegård would organize various activities such as educational courses about organic farming, organic Christmas market and organic cafe, providing great opportunities to the Naestved citizens to experience organic lifestyle (Næstved).

Therefore, the development of organic farming at the niche level is actually providing support to the agricultural regime changes from the root, reinforcing institutional policies at the regime level, for example, the Danish organic farming action plan.

Two Levels of Participation

The WFD considers public participation as one of the significant factors for the success of the directive, it defines three levels of participation: information, consultation and active involvement. Information refers to allowing access to information and background documents; consultation aims at learning from comments, perceptions, experiences and ideas of stakeholders (EC 2003). Such two levels of participation have been fully represented by Danish transparent governance in the implementation of the water plan.

At the information level of participation, relevant information about the water plan from national level to municipal level (Naestved municipality) are easily found on official website; the processes for planning and consultation are transparent. Latest government documents, for example, minutes of meetings for the discussion of water plan, and periodic consultation reports and comments from the public, are accessible in time on official website.

At the consultation level of participation, interactions among different stakeholders and actors were observed. In the hearing stage for the water plan of main water catchment Smålandsfarvandet, stakeholders are widely involved, it includes: Nature Agency; ENGOs such as Danish Society for Nature Conservation, Danish Ornithological Society; various social association such as Danish Forest Association, Outdoor Council, Danish Anglers' Federation, Danish Hunters' Association; and interest group like Forest Growers Association, Fishing Association and Agriculture Association (NS 2011). Christian Fogt Andersen, the coordinator for Water Plan of Main Catchment Smålandsfarvandet in the Environmental Centre Nykøbing F, introduced that besides receiving information from relevant agencies, stakeholders had opportunities to give their comments on the water plan through numerous workshops, information meetings and joint meetings with multi-level actors (personal communication, February 23, 2011). “So far, there is not only the technical hearing, but also a lot of hearing about political issues and economic issues”, Christian said, “after the hearing stage we will check whether the plan is good enough in terms of economic and professional consideration, consequently the plan might need to be revised accordingly” (ibid.).

To summarize, these participative activities at the niche level, to some extent can shorten the gaps between different interests group and increase public understanding of the water plan, so that helping the compliance with the nitrogen reduction target.

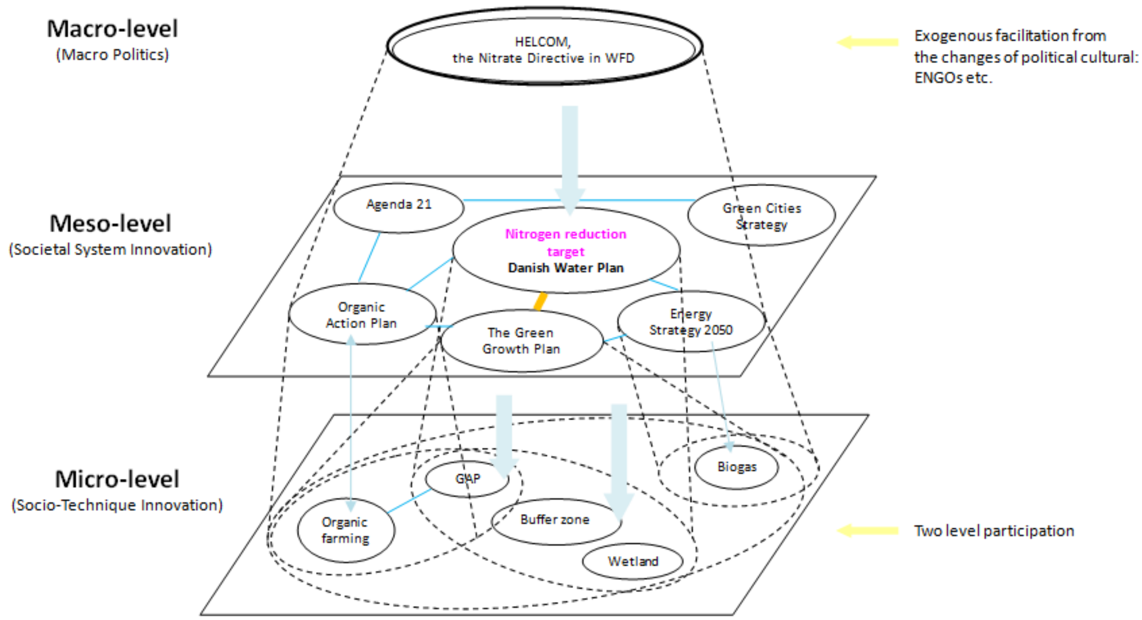

Figure 8. Drivers for the transition towards good ecological status, reframed from a multi-level perspective.

Note:

1. Blue arrow refers to the interactions between different levels, the dominant one-way arrows imply a top-down steering pattern.
2. Bold orange line means strong connection between two factors.
3. Blue line refers to the interconnection between two factors.
4. Yellow arrow refers to indirect influences from external actors.
5. Dashed circle refers to specific domain projected from certain regime, domains may be overlapped with each other, that means one factor in specific domain may belong to another at the same time.

In this part I have demonstrated relevant driving forces observed at three levels which are steering the implementation of the nitrogen reduction target (see figure 8). These forces can be the momentums lasted from the take-off phase such as the encouragement of organic farming and GAP, or new emerging forces such as the promotion of biogas. And it is noted that these forces at the three levels were not isolated, they are interconnected and continuously reinforcing each other. However, this is only one side to explain the current nitrogen lock-in state. Next I will explore how the other side – destructive forces from barriers contribute to this lock-in state.

6.3. Part III: Multi-Level Barriers

Barriers can be described as the decrease of constructive forces, alternatively the increase of destructive forces. It usually derives from the incumbent regime, and resists the emergence of innovations; or roots in other exogenous environments, and demolishes the resources which are for the development of innovation.

6.3.1. Macro-Level

Macro Economy: Global Economic Recession

The current global economic and financial crisis is a one of the main barriers at the macro level. It has been causing severe impacts on European economics and society (eurostat 2010), posing numbers of difficulties for the implementation of EU Sustainable Development Strategy (eurostat 2009). One of the main impacts is the change of EU budget strategy, which tends to tighten the budget for environmental issue in the coming several years. In order to improve the fiscal situation, the European Commission proposed to shave 3.6 billion euro off the EU budget including 820 million euro cuts for the programme under “preservation and management of natural resources” (ENDSEUROPE 2010). It should be noted that the financial sources for the implementation of the WFD in individual member states are mainly from EU funding, the contraction of the EU funding pool would impose profound influences on the project planning and the implementation.

In this circumstances, in 2010, the Danish Government unveiled a plan for saving 24 billion DDK over the next three year in an attempt of repairing its public finances and addressing other short-term social problems, such as unemployment after the great hit from financial crisis (FT 2010, Shilton 2010). Actually the Danish budget trimming emerged early in 2009 - the hardest period of financial crisis. Danish official statistics database shows that the budget allocation for “City development, residence, and environment arrangements” turned down in 2009 and is still maintaining this decline tendency so far (SD 2011c), and it is noted that the average reduction rate accounts for 4.1%[14] during the period 2009 – 2011 (see figure 9 in appendix 2).

The Naestved government also reduces its budget for environmental sector correspondently, and the reduction difference was even bigger than that at the national level. Similar tendencies for environment budget cuts and similar changes in prioritization of budget use are found, of which the average reduction rate for “City development, residence, and environment arrangements” is up to 36.6%[14] during this period (see figure 10 in appendix 2).

However, the influences of current macro economy have not yet retreated. In May 2010, the Naestved government had adopted a budget plan for 2011 to 2020 – “Budget Strategy 2011” including three policy areas: “nature, water and environment”, “waste and rats”, “traffic and green areas”. In this plan, total annual budget reductions for the future three years are 12 million, 18 million and 14 million DDK respectively (Økonomiudvalget 2010a), of which the annual operation budget for “Nature, Water and Environment”, will reduce 2 million (17.6%[15]), 1 million (9.8%), 1 million (9.0%) DDK respectively for the period between 2011 and 2013 (Økonomiudvalget 2010b). Moreover, another proposal for further operation budget reduction has been submitted (Økonomiudvalget 2010a), it indicates that future economy outlook still appears pessimistic. From the transition theory perspective, the current unfavorable macro

[14] Calculation is based on table 4 in appendix 2.
[15] Calculations are based on the budget plan “Specielle bemærkninger til budget 2011-2014 pr. Politikområde” (Økonomiudvalget 2010b).

economy can be considered as a barrier ruining the resources for the development of innovation, and has proven imposing significant impacts on the meso and the micro.

6.3.2. Meso-Level

At the meso level, the great challenge is to apply regime innovation under the existing regime configuration and practices. The WFD as an important water management regime for Member States encounters considerable barriers in its transposition and implementation in Denmark.

Challenges from Institutional Integration

The strategy of integration for water management is highly emphasized in the WFD. It means that first, different pieces of legislation do not contradict with each other in front of different goals of different directives (Frederiksen et al. 2007). Second, integration in the WFD is also characterized by its diverse programmes of measures. The WFD, understood as the directive of directives or “hybrid of EU directive” places strong emphasis on cost-effectiveness and interactivity through integrating various kinds of programs of measures from other directives (P. Frederiksen, personal communication, January 19, 2011). However, this strategy of integration has been widely questioned. The debate focus on the difficulty of introducing such strategy to the existing regime configuration: first, it is not easy to incorporate with different domains such as the social, political, economic and environmental spheres as well as with the planning, administrative and legal systems (White and Howe 2003). Second, how the existing diverse authorities cooperate with each other for water management is still a challenge, especially the role of environmental agency would become ambiguous (Howe and White 2002). Studies on the case UK and Wales (ibid.) and the Netherlands (Beunen et al. 2009) has proven difficult when applying this regime innovation.

In Naestved municipality, applying this strategy of integration is also challenging. The document “Naestved Municipality Environmental Law conception” points out that there are significant areas which are both in the charge of the water plan and the Natura 2000 plan[16] (Næstved 2007). These overlapping areas mean that within a same area, both nitrogen removal and natural conservation need to be considered. For example, the Suså River, an overlapping area between the water plan and the Natura 200 plan, needs to establish wetland for nitrogen removal and free fish passages for conserving the trout, without integration of the water plan target and the Natura 2000 target, there would come up with two separated projects for their own purpose, and the former usually limits the latter.

Hanne Stensen Christiansen, head of Nature and Water Office of Naestved municipality, as well as the project leader in the central coordinating project team, pointed out the difficulties they faced in the wetland projects due to the ignorance of integration of water management in project planning. “We made the wetland project first in 2007 and then will make the fish passages project in 2013”, Hanne said. If taking fish passages into account, the wetland would

[16] Another EU policy aims to assure the long-term survival of Europe's most valuable and threatened species and habitats (EC 2011c).

have designed differently so that both nitrogen removal and the conditions[17] for fish passages are satisfied. “But now the projects are only designed for nitrogen removal, they are not for any other purposes”, Hanne continued and believed that “good project should integrate with other purposes, because it would be too difficult for the new project to make some kinds of cooperation with the existing projects”. Also the cost-effectiveness is concerned according to Hanne, “if projects are done separately, for example, the fish passages project, we have to find another funding to finance the project”, Hanne said (personal communication, March 10, 2011). Without integration, the latter projects are usually limited by the former; also the integrated would be more effective than the separated in terms of cost-effectiveness and functional effectiveness because project planning of the integrated would be more holistic and comprehensive. Such local integration problem in project planning and implementation directly reflects the institutional integration problem when applying regime innovation.

Contradiction between the Top-down Steering and Local Autonomy

The WFD sets ambitious environmental targets for improving water quality that Member States have to achieve at the latest 15 years from the date of entry into force[18] (EC 2000). These targets have been defined as numbers of technical-environmental standards in the annex V in the directive (ibid). In Denmark, these targets are partly transposed into the target for nitrogen reduction in the water plans at the national level, the catchment level and the municipal level. Meanwhile, to ensure the progress of implementation, Denmark is required to submit an interim report within three years after the publication of the water plan[19] (ibid.). Therefore, the WFD can be summarized as a top-down and command-and-control policy framework based on a technocratic governance (Olsson 2003).

On the other hand, Denmark is a traditionally highly decentralized country where local authorities are enjoying an fairly high autonomy comparing with other European countries (Murphy 1995). Before the implementation of the WFD, the responsibility in water management was relatively decentralized. Local water management was usually based on local consensus with high degree of adaptation to the local preferences (H.Ø. Nielsen, personal communication, January 19, 2011). For example, There was no clear-cut nitrogen reduction target for each municipality, nitrogen reduction was voluntary-based (ibid.). The municipalities were responsible for comprehensive municipal planning in an autonomous way, including detailed local planning and permits for construction and changes in land use in rural zones (Bidstrup et al. 2007). As the implementation of the WFD and the structural reform in 2007, administrative structure is changing. The state control associated with water management is reinforced through nationwide statements, directives, and guidance notes (ibid.). The nitrogen reduction target is now clearly defined in each water plan and has become mandatory for each municipality. So Danish water management is undergoing a dynamic period.

[17] Fish passage effectiveness diverse depending on different water velocity levels (Knaepkens et al. 2006), so the designation of wetland should consider the influences on water velocity in river.
[18] Article 4
[19] Article 15

Some contradictions have been observed on the ground in this period. One of the main contradictions is from the transposed nitrogen reduction target, that is, municipalities hardly can reach consensus on the target, questioning the feasibility of the water plan in face of the local situation. For example, many municipalities such as Faxe, Sorø and Naestved in the main catchment Smålandsfarvandet, reflected in their proposals and comments on the water plan that: "it is difficult" (TMU_Sorø 2011) and "unrealistic"(TMU_Faxe 2007) to achieve the goal, because "current instruments are insufficient" (TU 2011b) due to the hardly optimistic situation of local water quality, the pressing schedule of the water plan and the financial uncertainty (TMU_Faxe 2007, TMU_Sorø 2011, TU 2011b). Hanne expressed her concern on the cooperation with the Regional Environmental Centers[20] (REC), hoping that there should be more dialogues with REC so as to strike for more space in water management (personal communication, March 10, 2011). On the other side, REC was just taking different stance. Christian emphasized that "there will not be too much spaces in term of nitrogen reduction because the target has to be met" (personal communication, February 23, 2011). Therefore, the municipality's frustration is quite understandable, because "now the water plan is very centralized" (H.S. Christiansen, personal communication, March 10, 2011) and local autonomy in term of water management is being weakened.

The emergences of these contradictions are quite understandable from a transition theory perspective. It is because if the WFD's top-down steering is seen as an innovation in water management, it most likely encounter resistances from the existing water management regime, that is, the traditional Danish decentralized water management culture, which would like to maintain the status quo. Therefore, this contradiction plays as another barrier in the transition towards nitrogen reduction target.

6.3.3. Micro-Level

At the micro-level, barriers mainly come from the insufficient involvement of stakeholders. Famers, who are the main stakeholders in water management at the micro-level, are playing an important role for the implementation of this regime innovation.

Farmers' Active Involvement: A Great Challenge

The programmes of measures suggested in the water plan are closely related to spatial planning, i.e. the land use in each municipality. In Denmark, more than 62% of the land area is agricultural area (FAO 2010) , and 71 % of the agricultural area is owned by the farmers (eurostat 2008). Therefore gaining farmer's support is crucial to the success of water management, because farmers are usually the main stakeholders in many projects, such as the projects for the restoration of watercourse, wetland project and the projects for maintaining GAP. As illustrated above[21], Denmark has been doing very well at the first two levels of public participation, but to achieve the target of nitrogen reduction these two levels are far from enough. Farmer's support

[20] REC has been considered as the Agents of Ministry of Environment to ensure the adherence to the general nitrogen target, and coordinate inputs to the Water Catchment Plan from relevant municipalities.
[21] see section 6.2.3, "Two Levels of Participation"

in land use is understood as a kind of active involvement, which is considered as the highest level of participation in the WFD (Kranz 2006).

However, active involvement seems to be much tricky and is usually a competition between environmental awareness and economic motivation. In general farmers are sensitive to economic losses. Some programmes of measures in the early Action Plans, for example, the optimization of fertilizer use, would be easier since “it won’t cost farmer anything” (H.M. Jørgensen, personal communication, March 8, 2011), the interest conflict at that time wasn’t magnified. Nevertheless, current implementation of the water plan will, to a certain extent, influence the interest of farmers, so it would become more challenging than before. Christian told a story about this challenge observed in the project for the restoration of watercourse. For the last 100 years, many physical alterations (to rebuild natural water pathway to a “straight line”) have been applied to Danish watercourse preventing water spilling out to the field, so that the farmer would use more land for more yield. However, this physical alteration actually deteriorates nitrogen discharge because nitrogen can go more easily with water run-off, so the restoration of the natural watercourse will be one of the important approaches in Danish water plan, but on the other hand, it would imply economic losses to farmers (personal communication, February 23, 2011).

The conflicts in the wetland project at the niche are also observed in Naestved municipality. “If landowners really don’t want to sell the land, we have to give up the project”, Hanne emphasized the key role of the farmer in their wetland projects (personal communication, March 10, 2011). Land acquisition for wetland establishment can be negotiable and non-negotiable. For the negotiable cases, economic incentive is decisive to gain farmer’s support. Affected farmers are reluctant to involve since they are not satisfied with the economic compensation provided by the projects (C.F. Andersen, personal communication, February 23, 2011; H.S. Christiansen, personal communication, March 10, 2011; TU 2011a). For example, current subsidies for the land growing pasture grass and hay are not attractive to farmers, who require twice as much – should be approximately 3000 DKK/ha for growing pasture grass and 1500 DDK/ha for growing hay (TU 2011a). Nevertheless, such problem in public participation may be controllable since the gap between environmental awareness and economic concern can be filled in through giving more attractive compensation. For the non-negotiable cases, the results are normally discouraging. Some farmers are so ambitious in agriculture but have little environmental awareness, they would not make any compromise to support the projects, regardless of farmland substitution and financial compensation. This has become the biggest risk for the wetland project (H.S. Christiansen, personal communication, March 10, 2011). That would explain why the number of landowners and their attitudes to water management were highly concerned in the feasibility reports for the three wetland projects[22] in Naestved (TU 2010).

On the other hand, active involvement is also essential to maintenance projects like the implementation of GAP. Information for agricultural practices needs to be collected by monitoring system. The WFD requires Member States to establish monitoring programmes for water status in order to present a coherent and comprehensive overview of each river basin

[22] The three wetland projects are the projects for Bjørnebækken, Nedre Saltø Å and Evegrøften.

district[23] (EC 2000). In Denmark, a national integrated monitoring and assessment programme for the aquatic and terrestrial environment named NOVANA is developed to ensure the compliance with GAP associated with the prevention of nitrogen leaching (Friberg et al. 2005, NERI 2011). Generally GAP can ease the burden for monitoring system because investigations for nitrogen leaching issue are usually costly. So the challenges lie in whether farmers can adhere to GAP as suggested by the environmental centers. There would be always a risk that farmers would withdraw their compliance with GAP out of economic consideration (TU 2011a), but meanwhile trust has to be relied on because it might be impossible to control and to monitor all the GAP measures (Wright and Jacobsen 2010) and "a strict enforcement of monitoring would be very expensive" (C.F. Andersen, personal communication, February 23, 2011). Therefore raising environmental awareness and increasing the sense of shared responsibility would help conscious compliance with GAP. However, this would be a persistent challenge if economic incentive is always separated from environmental consideration.

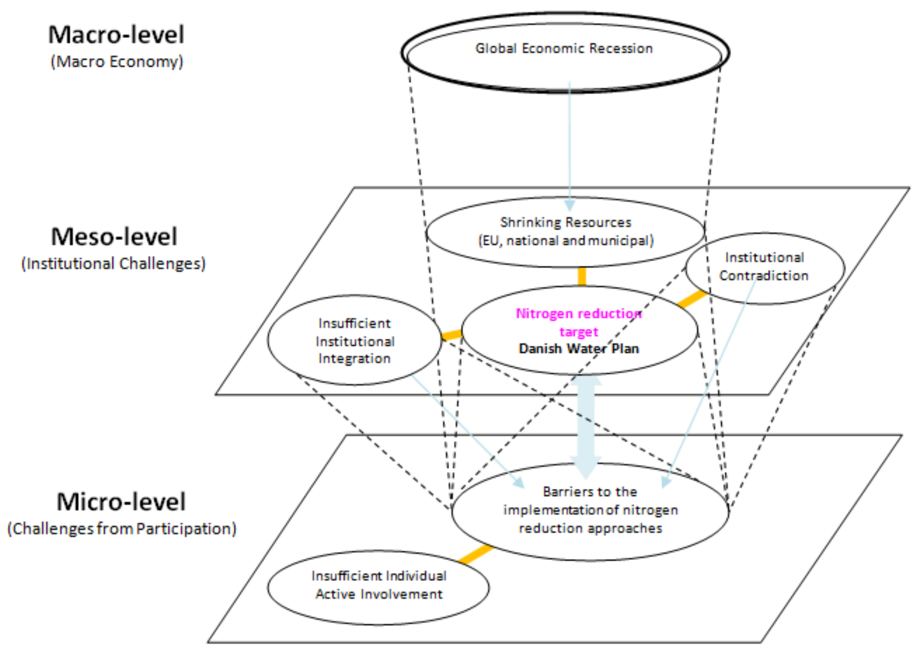

Figure 11. Barriers to the transition towards good ecological status, reframed with a multi-level perspective.

Note:

1. The nitrogen reduction approaches refer to the establishment of wetland and buffer zone, encouragement of GAP etc.
2. Blue arrow refers to the interactions between different levels, the dominant two-way arrows imply a main challenges encountered when putting water plan to the ground, meanwhile, impeding the achieving the nitrogen reduction target.
3. Bold orange line means strong connection between two factors.

In this part I have illustrated the important barriers observed at three levels which have been impeding the implementation of the nitrogen reduction target (see figure 11). To

[23] Referring to Article 8 - Monitoring of surface water status, groundwater status and protected areas; ANNEX V: 1.3. Monitoring of ecological status and chemical status for surface waters.

summarize these barriers are: the economic recession from exogenous environments draining the resources for regime changes; challenges and contradiction in the process of regime changes; and the individual adaption for implementation of regime changes. It should be noted that, similar to the situation of drivers, if interconnections between destructive forces are established, it would intensify the condition of the nitrogen lock-in state so that a breakthrough would become more difficult.

7. Discussion

By now I have answered the main research question through the demonstration of three sub-questions. In short, the current stagnant stage of nitrogen reduction is the manifestation of the nitrogen lock-in in the transition of water management towards good ecological status. The phase of nitrogen lock-in is the result of competition between constructive forces and destructive forces. Thereby, the equilibrium of the nitrogen lock-in might be broken if either side of the forces change, the following reflections are generated to extend this understanding.

7.1. How to Come to A Breakthrough?

The present Danish water management for nitrogen reduction is in a dynamic equilibrium. In the multi-phase analysis, it has been observed that the system has begun to shift with a process of regime changes. For example, the Agreement on Green Growth represents that the interconnectedness at different levels are increasing. However, these changes are still dynamic and hardly reach a stabilized equilibrium. The multi-level and multi-change analyses show that there are still many deviations from the current transition towards the vested target for nitrogen reduction. The transition theory points out that transition only comes out when developments at the three levels move in the same direction and reinforce each other (Geels 2005, Loorbach and Rotmans 2006, Brugge and Rotmans 2007). However, the current situation implies that the barriers are developing at the three levels, thereby reinforcing each other and impeding the transition to designated direction.

As such, whether a breakthrough will come about in current transition processes depends on whether such deviation can be directed to the trajectory designated by the WFD, or say, whether constructive forces can override the destructive. In this research, a prominent conflict was observed between economic concerns and environmental protection initiatives. The Danish green growth strategy is considered as a great potential solution that combines economic growth with environmental protection. The problem is how to empower the “green” components in advance so as to take over the “brown”. This can be considered as a sub-transition, and I believe it would probably be a starting point to a breakthrough for the current nitrogen lock-in.

Based on the analyses of the investigation result, counter measures need to be followed up for improving the current Danish water management. I suggested that the Danish government, as a dominant actor in this transition, should:

- Further engage into global green growth tendency, deepen national green growth strategy by encouraging the development of green industries, such as the organic farming industries and manure use in biogas plant. Meanwhile, the government should cultivate green market and encourage green consumption so as to gain support from the ground.
- Provide sufficient guideline to farmers to increase fertilizer efficiency and encourage GAP concerning different farming systems.

- Increase subsidy to the farmlands where the nitrogen reduction approaches are used, for example, to the farmlands used for growing pasture grass and hay without fertilizer.
- Improve spatial planning strategy, which should be integrated with environmental consideration. To reduce the risk of failing to implement the water management projects due to the weak involvement of farmers, areas which are sensitive to water management, for example, the land with great potential for reducing nitrogen runoff by establishing wetland, should be state-own rather than private-own.
- Increase inter-department cooperation, continuously strengthen the role of REC to steer the cooperation for the implementation of Danish water plan.
- Promote mutual understanding through dialogue and cooperation between REC and the municipalities for a better implementation of Danish water plan.
- Encourage the involvement of ENGOs so as to increase public environmental awareness and public participation.

7.2. Concepts Development

Nitrogen Lock-in

In this research the concept “lock-in” in transition theory is summarized and examined, and one new concept, “nitrogen lock-in” is generated. It should be noted that nitrogen lock-in is different from the techno-economic lock-ins, such as lock-ins in VHS and QWERTY (Liebowitz and Stephen 1995), but is similar to the socio-environmental lock-in, for example the carbon lock-in (Unruh 2000, 2002). The former usually emerge in a techno-economic system under market mechanism, which considers economic efficiency adhering to a “survival fitness” principle; while the latter usually appears in policy-steering societal changes, which may be carried out with less concern on economic efficiency, but is mainly to defend the societal common good. These differences of lock-in are actually determined by the typology of transition, sometime leading to a reverse pattern for lock-in in a transition. So the nitrogen lock-in illustrated in this research is enriching the connotation of lock-in in transition theory.

Constructive Forces and Destructive Forces

At present there is still a lack of a comprehensive approach for lock-in analysis in transition theory. The state of a lock-in was usually illustrated in brief by similar concepts in the early works of transition theory, such as “driving force” (Rotmans et al. 2001, Geels 2002, Loorbach and Rotmans 2006, Brugge and Rotmans 2007) and “driver” (Geels 2005, Rotmans 2005), they are usually used for categorizing different factors in their places of a transition, but are seldom presented in a structured framework for a detailed analysis. In this research, the nitrogen lock-in induced by the deviations is concluded as a competition between constructive forces and destructive forces. I argue that it would allow a more detailed analysis for a lock-in state in transition by further specifying factors into the dimension of constructive forces and destructive forces. And it is found that drivers and barriers are naturally linked with the concepts of constructive forces and destructive forces. Here I summarize them as below:

	Constructive forces	Destructive forces
Drivers	increase	decrease
Barriers	decrease	increase

Table 2. The relationship between drivers/barriers and constructive/destructive forces.

As I exemplified in section 6.2 and 6.3, drivers can be considered as the increase of constructive forces or the decrease of destructive forces, while barriers can be understood as the decrease of constructive forces or the increase of destructive forces. So when analysing a specific factor, for example a driver, it is necessary to split it into both constructive forces to the "new" and destructive forces to the "old" and vice versa. By comparing these two forces, it would be clear whether lock-in will continue or a breakthrough would soon happen. This argument is in line with the power perspective for transition proposed by Avelino et al. (2009), but this power perspective is still a theoretical hypothesis without exemplification, this research in this sense would help further enrich its theoretical basis.

7.3. Potential Improvement for Transition Theory

Transition theory defines that a take-off phase can be understood as a period when regime begins to shift, while an acceleration phase starts with visible structural changes (see section 5.2.2). In this research, it is found that it is not easy to distinguish such boundary that transition theory defines. I argue that if the boundary between the take-off phase and the acceleration phase is judged from the factor of whether the structural changes are visible, but what is so-called "visible"? Once regime begins to shift, there must be always some kinds of visible changes that take places in regime, especially for a target-oriented transition, it's only different from scale and depth. In the meantime, if these two phases are distinguished by the velocity of changes, corresponding to the understanding of "acceleration", what factor should be referenced to represent the velocity? Or actually should the relationship between different factors be referenced? Thereby I think further clarifications for this point in transition theory are required.

Moreover, I am concerned about whether the scale and context in a transition need to be considered as well. An evolutionary transition, for example, the technical innovation, is actually based on the context of liberal market economy; but in a hybrid economic system which combines both liberal economy and planning economy, the question appears to be: ought evolutionary transition still start from the niche? And whether more transition elements should be considered apart from the three pillars concepts? Similar conjecture can be made for a targeted-oriented transition, in which a top-down steering may be easier in a traditionally centralized regime. Therefore, the context of a transition, for example, the political system, may need to be considered as well in the future development of transition theory.

7.4. Research Limitations

Some limitations are found in the research due to practical situation. The result is based on the assumption that all the factors selected in each level are comprehensive and significant enough to support individual rationale in analysis. There is always a risk that some important factors have not been taken into consideration, leading to a weak validity of rationale in some parts of the analytical framework. So for a more comprehensive research, it is necessary to gather more evidence to support the argument. Moreover, to increase reliability and validity, more detailed interrogations of Danish official documents would be needed. During the research process, it was found that the language barrier was always challenging, because most of the official documents were in Danish, some misunderstandings may exist.

8. Conclusion and Further Research

Denmark's more than 20 years history of work on nitrogen reduction is a valuable case for both water management research and transition theory development. This research has not only provided insights into the main research question by using a transition theory perspective, advancing the understanding of the identified problems; but has also provided another opportunity to examine and exercise transition theory, giving new concept and potential improvement for its further development. The main findings in this research can be summarized as below:

- It should be noted that Danish water management for nitrogen reduction is a targeted-oriented transition process mainly steered from EU-level to Denmark's niche under the guide of a dominant policy – the water framework directive, which is quite different from an evolutionary transitions process.
- The current stagnant stage of nitrogen reduction is the manifestation of nitrogen lock-in in the transition of water management towards good ecological status. According to the analysis in this research, this phase is lying between the take-off phase and the acceleration phase.
- The current Danish nitrogen lock-in is actually the result of the competition between constructive forces and destructive forces, the comparison of these two forces will decide whether a breakthrough would come about.
- The current constructive forces for advancing nitrogen reduction at the three levels are interconnected and continuously reinforcing each other. For example, the Water Plan and the Agreement on Green Growth are interconnected for advancing nitrogen reduction; while the Organic Action Plan and the Agreement on Green Growth are interweaved to facilitate the development of organic farming (see section 6.2.2).
- The current destructive forces are still very powerful and are intensifying the condition of nitrogen lock-in. For instance, the insufficient involvement of farmers has posed a great challenge to the wetland project impeding the implementation of the water plan (see section 6.3.3).
- Future breakthrough depends on whether innovative approaches for both water management and economic growth can be harmoniously integrated. The Agreement of Green Growth would probably be a starting point to realize this strategy for a breakthrough to come.
- Counter recommendations are put forward in an attempt to improve the current Danish water management of nitrogen reduction.
- The concept "nitrogen lock-in" has been generated and improved understanding of constructive forces and destructive forces is obtained. Meanwhile, potential improvement for transition theory is proposed. These are believed to be helpful for enriching the theoretical basis of transition theory.

Based on the analysis of this research, which is focusing on the relation between different factors contributing to the nitrogen lock-in, future study can focus on the scenarios analysis by further investigating each factor in detail, to know how the changes of one factor can influence the others as well as the nitrogen lock-in state as a whole. For example, institution integration is emphasized in the WFD and is also important to the success of the Danish water plan, how it changes could influence the interaction between the state and municipality at the regime level, and whether it will help improve public participation at the niche? Likewise to the public participation, how public participation would help institutional integration at the regime level so as to influence the implementation of the water plan? As such, it could be helpful to conduct a scenarios study in advance by specifying the changes of each factor, so that coming up with different possible pathway for future nitrogen reduction.

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Alle aktiviteter på gården er præget af en meget bæredygtig tankegang. Læs mere om aktiviteterne herunder. Rohavegård er åben for at modtage gæster mod foreudgående aftale., Næstved.

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Appendix 1: Data Collection

a. Personal Communication

Name	Title	Methods	Time
EU-level:			
Peter Kristensen	European Environment Agency (EEA) Project manager	Interviews In-Person	January 18, 2011
National-level:			
Christian Fogt Andersen	Coordinator in Environmental Centre Nykøbing F	Interviews via Phone	February 23, 2011
		Interviews In-Person	March 15, 2011
Ole Tyrsted Jørgensen	Project Manager, Environment Centre Odense	Interviews In-Person	March 15, 2011
Hanne Stensen Christiansen	Head of Nature and Water Office in Naestved municipality	Interviews via Phone	March 10, 2011
Other Actors - Scholars, NGOs and Farmers:			
Helle Ørsted Nielsen	Scientist, NERI Department of Policy Analysis	Interviews In-Person	January 19, 2011
Pia Frederiksen	Head of section, NERI, Department of Policy Analysis	Interviews In-Person	January 19, 2011
Henning Mørk Jørgensen	water and environmental policy officer, marine biologist in The Danish Society for Nature Conservation	Interviews In-Person	March 8, 2011
Hans Christian Dahl	Farmer as well as owner of conventional pig farm in the northwest of Naestved municipality	Interviews In-Person	March 15, 2011

b. Field Trip Arrangement

Time	Activities
08.30 – 10.00	Travelled to the south of Zealand
10.00 – 11.00	Visited to a typical conventional pig farm in south of Zealand, the northwest of Naestved municipality.
11.00 – 12.30	Visited to Environmental Centre Nykøbing F and had lunch with the staffs of environmental centre.
12.30 – 15.00	Talked with Ole Tyrsted Jørgensen and Christian Fogt Andersen for clarifying the understanding of the water plan for main catchment Smålandsfarvandet, further inquiry the current issue of nitrogen reduction, including historical event and current nitrogen monitoring situation.
15.00 – 17.30	Field visit to Land Monitoring site in LOOP7 to gain empirical understanding of the relationship between agricultural practices and water quality monitoring.
17.30 – 18.30	Invited to Christian's home

Figure 12. A conventional pig farm in the south of Zealand (picture is taken by the author).

Figure 13. The office building of the Environmental Centre Nykøbing F (picture is taken by the author).

Figure 14 The so-call “green land” and “black land” require different fertilizing patterns (pictures are taken by the author).

Figure 15. A technician in Environmental Centre Nykøbing F Showed their regular work for nitrogen leakage monitoring (picture is taken by the author).

c. Observations

Conferences observations

- **The 2010 World Water Week:** 5-11 September 2010, "Responding to Global Changes: The Water Quality Challenge – Prevention, Wise Use and Abatement". Organised by the Stockholm International Water Institute. Relevant sections include: "From Source to Sea: Baltic Sea Water Award Seminar – Regional Integration, Sustainable Development and Combating Eutrophication in our Common Sea Basin", "Peak phosphorus and eutrophication of surface waters: A symptom of disconnected policies to govern agricultural and sanitation practices". Information available at: http://www.worldwaterweek.org/documents/WWW_PDF/2010/Final_programme_2010_web.pdf
- **Symposium on Climate Change Challenges in River Basin Management:** 17-19 January 2011, Oulu, Finland. Organised by Finnish Environment Institute SYKE and the Thule Institute of the University of Oulu. Relevant sections were included in the 2nd symposium day they are: session 3: River Basin Management and session 5: socio-economical and institutional issues of the WFD. Information available at: http://waterpraxis.net/en/news/147-symposium-on-climate-change-challenges-in-river-basin-management

On-site observations

- Conventional pig farms in the northwest of Naestved municipality, Zealand, Denmark.

- Land Monitoring site in LOOP7 in the northwest of Naestved municipality, Zealand, Denmark.

d. Semi-structured Interview Questions

Questions to the actors in institutional bodies.

1. Why do we come to the WFD, what are the drivers for adopting the WFD?
2. What makes the WFD so different from former water policy?
3. Anything do you think can help further advancing nitrogen reduction in Denmark?
4. What do you think is/are the main reason/reasons for getting slow progress of nitrogen reduction in the past several years in Denmark?
5. Do you think former water action plan (action plan I & II) are good enough to make further nitrogen reduction? why?
6. Do you think the programme of measures suggested in Water Plan (e.g. Vandplan – Hovedvandopland Smålandsfarvandet) are good enough to meet the EU's environmental goals for waters? Why?
7. Apart from the technical and financial problems, what do you think is the main problem for adopting water plan in your municipality? can you give some examples if possible?
8. Is there any challenges for your institute to adapt to the water plan? can you give some examples if possible?
9. Which institute/organization is the coordinator for your work (outside your institute/organization)? Do you think the coordinator is competent to solve the conflicts that your institute/organization meets in water management? can you give some examples if possible?
10. What kinds of stakeholder are included when making water plan?
11. When deciding the measures for water management (for example, measure for reducing nitrogen losses), which aspect would you/your authority be most concerned with? (cost-effectiveness/deadline of target/other stakeholder's interests/others factors?) can you give some examples if possible?
12. From the water plan we can see that, there is only around 10% of water bodies can meet the goal. Do you think it is reasonable to achieve goal of good ecological status by 2015? If not, when do you think should be the appropriate deadline?
13. How the decision is made, for example, the decision for the prioritization of means, how much can the environmental centre influence the decision-making?
14. How does the government handle the conflicts between water management and land use?
15. What 's your suggestion to improve the current situation?

Question to the Farmer and Farmer Representative

1. What is the main influence of water plan on Danish agriculture industry?
2. How would the approaches in water plan, for example, the wetland project, influence Danish agriculture? Who will be influenced most?
3. It is reported that some farmers are not willing to sell the farmland in some wetland projects. Do you know any similar case? if yes, do you know why?
4. What will/did your organization do in front of the influences from the water plan? Do you believe the action taken by your organization would work?

Appendix 2: Data Analysis

a. Historical Trend of Nitrogen Surplus from Danish Agriculture

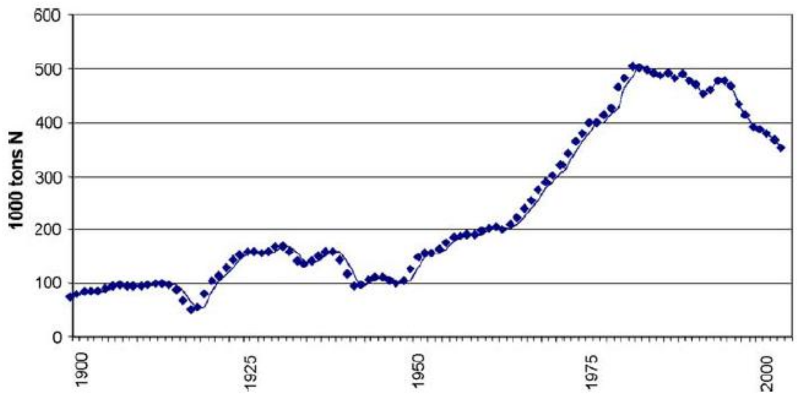

Figure 16. Annual nitrogen surplus from Danish agriculture during the period between 1900 and 2003 (source: Nørring and Jørgensen 2009). According to the nitrogen cycle, certain amount of nitrogen surplus will be removed the denitrification process in the soil before entering into the aquatic environment (ibid.).

b. Recent Trend of Nitrogen Surplus from Danish Agriculture

Nitrogen Surplus from Agriculture between 1985 and 2009

(1000 tonnes)

Items	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Input: Commercial fertilizer	392.1	376.1	375.3	361	371	394	389	365	328	321	311	286	283	278	257	246	229	206	196	202	201	187	190	215	195
Input: Manure	263	261	251	248	247	244	246	245	248	238	231	233	231	233	229	232	235	237	232	230	227	219	237	237	237
Input: Sludge and waste	4	4	4	4	5	5	6	7	10	9	9	9	8	7	7	9	11	11	11	11	11	11	11	11	11
Input: N fixation	43.8	42.6	43.1	43.8	45.3	45	39	41	44	42	40	43	48	46	42	40	37	42	37	35	39	39	40	40	46
Input: Deposition	48.2	47.9	47.6	47.4	52.7	53	53	52	49	46	44	41	40	40	40	40	40	40	40	40	40	38	43	35	35
Total input	751.1	731.6	721	704.2	721	741	733	710	679	656	634	611	610	605	575	567	554	536	516	518	518	494	521	538	524
Output: Harvested	331.2	325.1	296.5	329.5	345	366	342	277	322	303	318	306	319	320	299	304	296	289	286	283	298	300	309	323	338
Surplus (input - output)	419.9	406.5	424.5	374.7	376	375	391	433	357	353	317	305	291	285	276	263	255	247	230	235	220	194	212	215	186
Area (1000 ha)	2834	2819	2800	2787	2774	2788	2770	2756	2739	2691	2726	2716	2688	2672	2644	2647	2676	2666	2761	2767	2777	2746	2730	2706	2694

Table 3. Annual nitrogen surplus from Danish agriculture from 1985 to 2009. (Data is base on: Grant et al. 2003, Grant et al. 2010)

Note:

1. Data from 1985 to 1989 is from Grant et al 2003, data from 1990 to 2009 is from Grant et al 2010.
2. N surplus = N input – N output = $N_{\text{Commercial fertilizer}} + N_{\text{Manure}} + N_{\text{Sludge and waste}} + N_{\text{fixation}} + N_{\text{Deposition}} - N_{\text{Harvested.}}$

c. Model Calculation of Nitrogen Leaching in Denmark

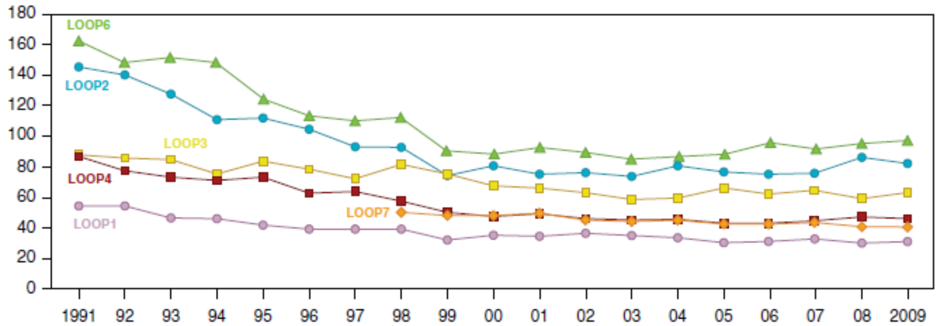

Figure 17. Model calculation of nitrogen leaching in 7 monitoring catchments all over Denmark between 1990/1991 and 2008/2009 (source: Grant et al. 2010). The monitoring site LOOP7 serves for the main catchment Smålandsfarvandet in which Naestved municipality locate.

d. Recent Municipality Budgets in Denmark

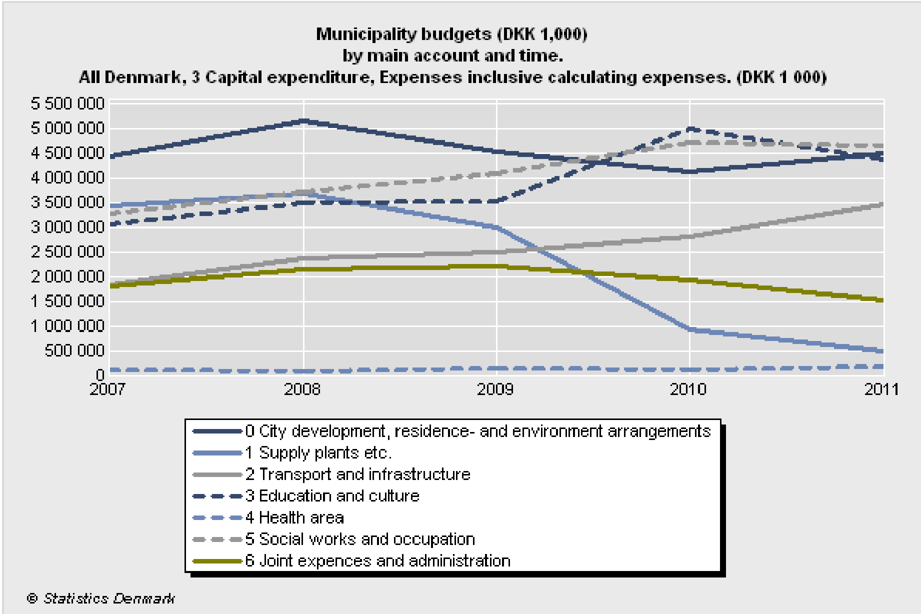

Figure 9. The trends of budgets for all Denmark (source: SD 2011c).

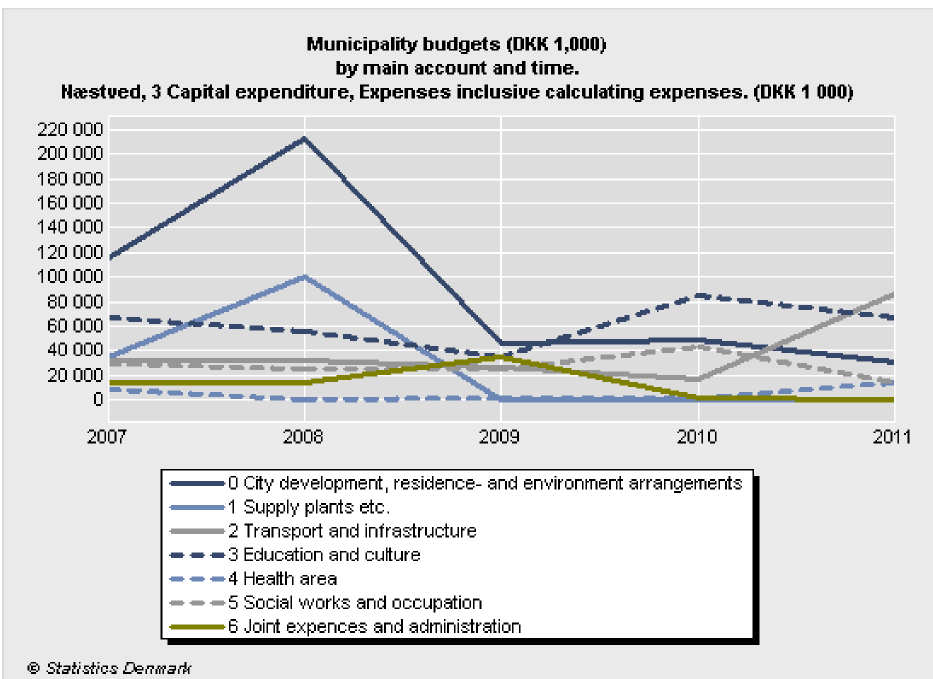

Figure 10. The trends of budgets for Naestved municipality (source: SD 2011c).

Municipality budgets (DKK 1,000) by kind, dranst, municipality, main account and time

	2007	2008	2009	2010	2011
Expenses inclusive calculating expenses					
3 Capital expenditure					
All Denmark					
0 City development, residence- and environment arrangements	4 423 417	5 168 097	4 525 165	4 129 535	4 497 613
1 Supply plants etc.	3 449 991	3 699 327	3 010 280	930 062	489 834
2 Transport and infrastructure	1 839 975	2 359 902	2 498 637	2 795 341	3 450 773
3 Education and culture	3 055 906	3 496 674	3 521 072	4 992 736	4 368 104
4 Health area	135 156	109 174	151 956	110 899	171 889
5 Social works and occupation	3 286 623	3 717 083	4 076 201	4 714 433	4 644 709
6 Joint expences and administration	1 826 709	2 162 785	2 230 877	1 941 294	1 537 803

Municipality budgets (DKK 1,000) by kind, dranst, municipality, main account and time

	2007	2008	2009	2010	2011
Expenses inclusive calculating expenses					
3 Capital expenditure					
Næstved					
0 City development, residence- and environment arrangements	115 805	212 984	46 738	48 997	31 085
1 Supply plants etc.	34 906	100 926	0	0	0
2 Transport and infrastructure	32 100	31 665	26 232	17 565	86 326
3 Education and culture	66 960	55 280	34 384	85 628	66 878
4 Health area	8 231	0	1 537	1 576	14 362
5 Social works and occupation	28 849	24 968	24 972	42 878	14 148
6 Joint expences and administration	14 000	14 151	35 055	1 000	977

Table 4. The budgets data for all Denmark and Naestved municipality (source: SD 2011c). Capital expenditure refers to the new investment in specific sector.