The capability of existing wastewater treatment plants to be energy self-sufficient and comply with the strict emissions regulation in The Netherlands.

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ABSTRACT

The aim of this research is to study if existing Wastewater treatment plants (WWTPs) in the Netherlands are capable of being energy self-sufficient and at the same time comply with the strict emission-regulations. Furthermore to study the circumstances and factors that influence the decision-makers to actually implement options towards energy self-sufficiency.

In order to reach the research goals, data are collected and analyzed. Both secondary and primary data are used. The secondary data are derived from WWTPs documents, energy management documents, documents from national governance networks and documents in the field of emissions policies and regulations. The primary data of this research are derived by conducting in-depth interviews with decision makers of three water boards.

To analyze circumstances and factors that influence decision-makers in a structured manner, a theoretical framework is used. The Contextual Interaction Theory offers a scheme that orders circumstances and factors in layers of context surrounding the decision-arena in which actors based on their cognitions (what actors know), motivations (what to reach out for, and when) and resources (what they are able of) interact and take decisions. This analysis supports conclusions and recommendations.

The result of this research shows that being energy self-sufficient for existing WWTPs (or water boards) in the Netherlands is possible and it within reach for the short or long term, depending on different factors that influence the decision-makers. These factors are the scale, the cost, the national government pressure and the uncertainty with the future discharge regulations.

Keywords: Wastewater treatment plants, Energy self-sufficient, Decision Makers

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Chapter 1: INTRODUCTION

1.1. Background

Water is essential for the existing of life on earth. In the early history of mankind, treatment of wastewater was done naturally through natural processes, like evaporation, rainfall, bio-chemical absorption and adsorption by soil particles. This system remained in equilibrium for a long time, but not anymore. By time, the population of the humans increased and the life style of the humans changed due to the fact that technical development enabled mankind to expand production and consumption. These were the two main reasons for the humans to use more water and pollute the water more. The natural purification capacity is not enough anymore, which is why we need wastewater treatment technology and plants so the wastewater from the polluting processes can be treated before we send it back into to the nature.

As the population of the humans increased, especially in the last century, humans need of resources increased, and that led to a lot of problems, such as water scarcity, ecosystem degradation and climate change. At that time, some humans started to think that they cannot continue with their behavior of living, and that what the club of Rome mention in their book, “If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continues unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years”, (Meadows et al., 1972). The understanding of the problems increased continuously and led to the conclusion that the best solution for this problem is to be more sustainable in the handling and use of the resources, mankind needs to change its thinking about the way of living, the need to reduce the use of raw materials and reduce the green gas emissions by reducing the use of fossil fuel to generate energy, the need to change the old industry by new more sustainable industry, “The sustainability revolution is nothing less than a rethinking and remaking of our role in the natural world”, (Edwards, 2005).

Being sustainable does not have a fixed target or final state. It requires an ongoing process of getting aware of developments and risks and changing practices and developing new processes and new technology.

Now mankind, under the influence of climate changes awareness, start to focus on renewable energy and raising the energy efficiency. The focus upon wastewater treatment plants also changed. The perspective of a method of water treatment and water reuse is still relevant and urgent, improvements in this field are still needed, however water treatment as a source of energy generation and nutrient recycling is now added to the agenda of core sustainability issues. The agenda is to make the wastewater treatment plant energy self-sufficient on the long run and still raise the effectiveness and efficiency of water treatment.

The energy self-sufficient wastewater treatment plant is not a new concept. It's been a topic for some researchers in the last decade, and the preliminary outcomes are already implemented in some wastewater treatment plants over the world. Examples are the Strass Wastewater treatment plants in Austria and the Hokubu sludge treatment plant in Japan. However, as I mentioned before, the WWTP should not be only energy self-sufficient but also should comply with emission's regulation. A study on the art life cycle assessment to an energy self-sufficient WWTP in Strass (Austria) shows that applying DEMON on the digesters rejects water leads to a considerable saving of natural resources and increasing electricity production. However, its N2O emission represents a large share of the plants' damaging effect on human health, this through climate change, (Schaubroeck et al., 2015). So that applying this technology in The Netherlands may need to be restrained through an extra treatment.

1.2. Problem statement

Since excellent water treatment comes with steeply increasing costs, and also the price of energy is not believed to decrease, and the world has to handle climate change and, in Europe, the conventions of Paris is valued highly, energy is a topic in wastewater treatment plants and especially among its managers.

I think it’s important to make the wastewater treatment plant energy self-sufficient, that because it will reduce the total energy consumption of within the territory of the municipality. Being energy self-sufficient for the water treatment plant in The Netherlands is not only about finding a technology for that but also to find a technology that met the strict emissions regulations that water treatment plants have to meet.

1.3. Research objective

The aim of this paper is to assess the capability of existing wastewater treatment plants to be energy self-sufficient and comply with the strict emissions regulation in The Netherlands.

Chapter 2: LITERATURE REVIEW

2.1. Energy management in WWTP

The first step toward energy self-sufficient waste water treatment plant (WWTP) is to know how much energy is consumed and what the trend over time is, so we have a good understanding of the facts and the efforts already undertaken or planned. Afterwards we can discuss the potential of reducing the use of energy and assessing how much energy it can generate from the different sources and processes. By this we can check the potential of improvement and elaborate whether the WWTP can be energy self-sufficient. Maybe it's not a problem to reach this balance state, "It is a known fact that the potential energy available in the raw wastewater influent exceeds the Electricity requirements of the treatment process significantly", (Wett et al., 2007). But the problem is, as I mention before, to reach the balance state and comply with the strict regulations in the same time.

2.1.1. Energy generation

The main strategy of being energy self-sufficient strategy is to increase the energy generation, and that covers all kinds of energy generation that can enhance the sustainability. Of course generation of energy from fossil fuel is excluded, the focus will be on the type that do both; reduce the use of new fossil resources and reduce the CO2 emissions, like heat and power recovery from combustion or digestion gas, the potential of sludge incineration and its potential for green energy. Let us discuss some of the most frequently used technologies in existing waste water treatment plants.

2.1.1.1. Combined heat and power

"Combined heat and power (CHP) is an efficient, clean, and reliable approach to generating power and thermal energy from a single fuel source, such as natural gas, biomass, biogas, coal, or oil", (Spellman, 2013). CHP is clear as Spellman wrote it's the generation of both power and heat from a single fuel source, for the case of a WWTP this relates to anaerobic digestion, therein generation of Methane gas as byproduct occurs, and (I will discuss that in 2.2. Energy recovery technology in WWTP). The typical CHP unit is a power plant attached to the WWTP, consisting of a Boiler, a Turbine, an electrical generator and a heat recovery system to recover the heat from the exhausted gases, the recovered heat can be used to cover the heat needed for the digester unit and also for the heating of the buildings. See figure 1.

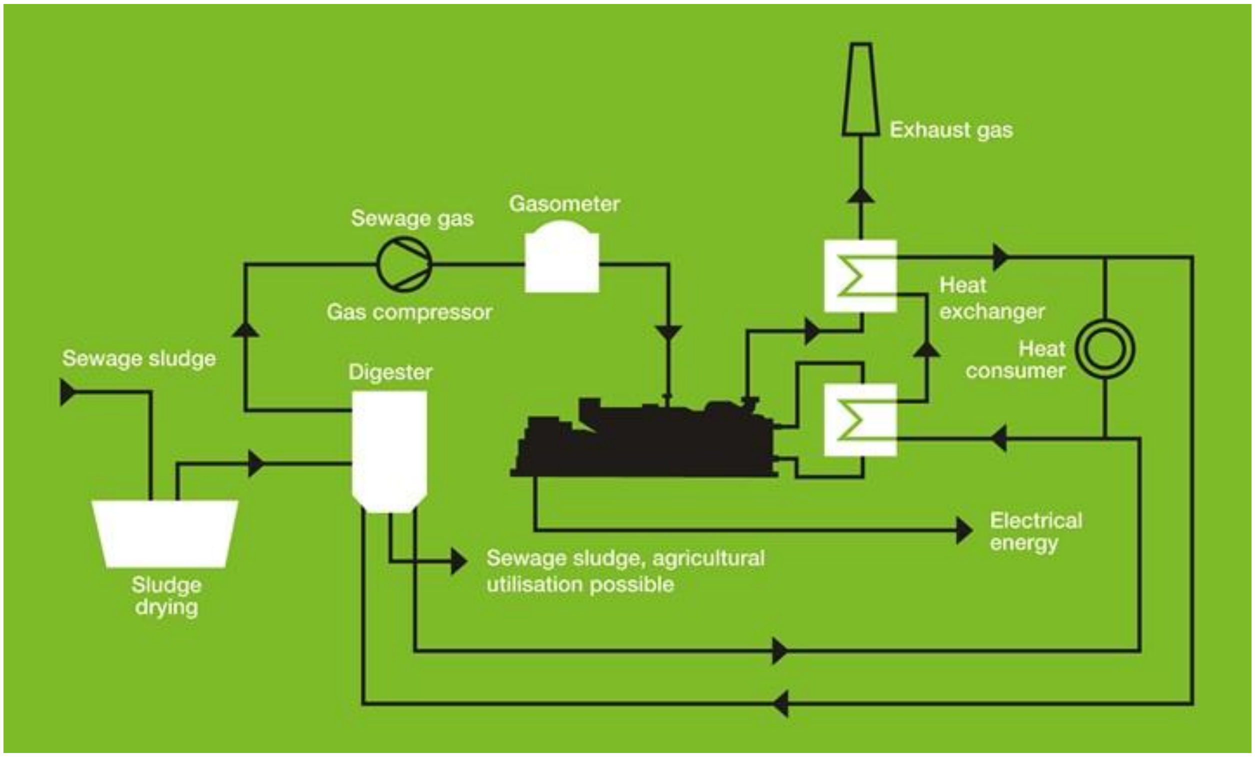


Figure 1: Combined heat and power in WWTP (Clarke Energy, 2017).

Generating electricity from Digestion gas by CHP has some benefits:-

1- It has economic benefits, generate electricity by using CHP in the WWTP can give electricity with low cost. As the EPA mention in their report, in USA, the cost of generate electricity by CHP in WWTP range from (1.1 – 8.3) cents per kWh, while the current electricity cost range from (3.9 – 21) cents per kWh. (U.S. Environmental Protection Agency, 2011).

2- It reduces the GHG emissions. It prevents any Methane gas emissions to the atmosphere which is the result from the treatment of the wastewater. In the same time, generating power will reduce the electricity needed from the grid, and that will reduce the CO2 emissions due to electricity transfer by the grid," CO2 emission's reductions. Therefore, arise from displaced grid electricity only" (U.S. Environmental Protection Agency, 2011).

2.1.1.2. Sludge incineration

The final step of any wastewater treatment plant is the treatment and disposal of the sludge, there are several ways for the disposal of the sludge, "the most widely available options in the EU are the agriculture utilization, the waste-disposal sites, the land reclamation and restoration, the incineration and other novel uses" (Fytili and Zabaniotou, 2006). Although there are all these options, the method used for each country is different depending on the regulations they have. In The Netherlands, it's almost impossible to use sludge as agriculture utilization, "The Dutch Decree of November 20, 1991 established limit values so strict that the use of sludge in agriculture is only possible for a very limited share of the national production of sewage sludge (approximately 4% of urban sludge)" (European Commission, 2001). Actually the only method of sludge disposal that can be used in The Netherlands is the sludge incineration, "Because of existing regulatory restrictions on land filling, the only viable option remaining for sludge appears to be incineration" (European Commission, 2001).

Although the fact that sludge incineration needs high capital investment, potentially high operations costs and expansive end of pipe air pollution treatment, due to the strict regulations for the incineration plant, a lot of countries (especially The Netherlands) prefer to use it because the incineration is the most efficient way to reduce the size of the sludge,"Biosolids incineration has the advantage of achieving maximum solids reduction with energy recovery, in addition to producing a stable waste material as ash and requiring small amounts of land", (Stillwell et al., 2010). A report issued by the Committed to the Environment Delft, shows a result of an environmental analysis research of two cases of sludge treatment, landfilling in the UK and incineration at Twence's AEC plant in The Netherlands, the report shows that the incineration is more environmental friendly than the landfilling (CE Delft, 2012). Besides all the advantages I mention before, the energy recovery from the incineration of the sludge makes it very attractive method for sludge treatment.

2.1.1.3. Other types of renewable energy

There are many types of renewable energy, but I will only focus on the one that we can use it in the WWTP, like solar panel, wind turbine and geothermal. Although renewable energy needs big investment, it has economic and environmental benefits, and the Dutch government might support this kind of investment because it's helped to accomplish their 2020 renewable energy goal, which is to raise the share of energy consumption produced from renewable resources to 14%, (Government of The Netherlands).

2.1.2 Energy consumption

In order to accomplish energy self-sufficiency in WWTP (as I mention before), we don't only need to increase the energy generation, but also need to reduce the energy consumption. WWTP and drinking water are the largest energy consumers of municipal governments, "as a percent of operating costs for drinking water systems, energy can represent as much as 40% of those costs and is expected to increase 20% over the next 15 years due to population growth and tightening drinking water regulations" (Spellman, 2013). Energy demand is increasing every day, and that is due to the increase of the population. This will lead to increase of the GHG emissions, which is why it is very important to try to reduce the energy consumption in WWTP and make it more energy efficient.

To check the capability of WWTP to be more energy efficient, there are some factors we need to put in our considerations; which are the age of the WWTP and the equipment, the size of the WWTP and the technologies they use.

2.1.2.1 The age of the WWTP and the Equipment

It is significant to know the age of the WWTP because most of them were built many years ago. At that time, energy efficiency was not important and energy prices were not that high. "Most facilities were designed and built when energy costs were not a major concern, with large pumps, drives, motors, and other equipment operating 24 hours a day" (Spellman, 2013). Of course, all the WWTP had some maintenance and changes of their equipment through the years, so that it is also important to know the age of the equipment.

Some of the WWTP's equipment is manufactured to last for many years, but the problem is that the efficiency of this equipment (such as the motors) will gradually decrease by time. "Most electric motors are designed to run at 50 to 100% of rated load. Maximum efficiency is usually near 75% of rated load. The efficiency of a motor tends to decrease dramatically by time until it become below about 50% of the load" (Spellman, 2013). So that knowing the age of the WWTP is important to know if it needs to change or maintain it equipment.

2.1.2.2 The size of the WWTP and the Equipment

The amount of energy that a WWTP consumes per one M^3 depends on the size of the WWTP. Studies showed that the larger the WWTP, the less energy it consumed per one M^3. "It is advisable to design WWTPs to be as large as possible, attempting to concentrate effluent from several urban areas such that the energy consumption is 1/3rd that of small WWTPs" (Albaladejo et al., 2014). However, that don't necessarily mean making one big central WWTP is more energy efficient than making many small. We need to put in our consideration the energy consumption of the pumps that will be used to pump the wastewater through the sewage system to the central WWTP.

Not only is the size of the WWTP affecting the plant energy consumption, but also the size of the equipment such as the motors. According to (Spellman, 2013), sometimes motors are oversized such as when a pumping system must satisfy occasionally high demands, in this case a better solution should apply, such as two-speed motors, adjustable speed drives, load management strategies that maintain loads within an acceptable range and other alternatives, that helps in reduce the energy consumptions.

2.1.2.3 The technologies used in the WWTP

The energy consumption of the WWTP is also depend on the technology that the WWTP is equipped with, some technologies are used less energy for the treatment of the sewage, for example, according to (Royal Haskoning DHV, 2017), the energy consumption of the sewage treatment by using the Nereda© technology is 50% of the energy consumption by using the activated sludge technologies, and that show us how much the type of technology can affect the energy consumption.

Not only the type of the technology used in the treatment affects the energy consumption but also the technologies of the equipment that used in the WWTP in general. The equipment that manufactured nowadays is more energy-efficient than those which manufactured 10 years ago, (for example), the new LED lights are far more efficient than the old light bulbs, besides that there are many types of LED light. Some of them are more efficient than others. The European Commission issued a costumer's guide to advise the people which light is more energy efficient, and that show us how different kind of manufacturers and technologies can use a different amount of energy.

2.2. Treatment technologies in WWTP

Wastewater treatment plants in The Netherlands started more than 100 years ago. Technologies of wastewater purification continue to be developed. The Integral wastewater treatment in the Netherlands started since 1970. From that time, wastewater treatment technology became a sector of industry. In the past, the aim of a WWTP is to clean the water streams from the pollutant that generate by the humans activities, but the new technologies, as I mention before, made the WWTP not only a plant for wastewater treatment but also for energy generation. Due to the increasing of climate change issue and the raising of the energy prices, researchers and companies are continuously developing new technologies for the treatment of wastewater that can increase the generation of the Methane gas, reduce the energy consumption and also reduce the effect of the WWTP on the environment.

Most of the WWTP in The Netherlands consist of at least two stages of treatment; primary treatment, which includes purification processes of physical nature such as screening, filtration, centrifugal separation, sedimentation and gravity separation. And secondary treatment, which includes biological treatment and removal of nutrients and pollutants by microbes such as Aerobic and Anaerobic digestions (Lulofs and Bressers, 2017). Nowadays and for stricter regulations in the future, in some of the WWTP and special sector pollution focused treatment plants, tertiary is considered, which includes an extra treatment as the water result from the secondary stage by removing bacterial and viral agents and to get high-quality water by using distillation, evaporation, adsorption and reverse osmosis (Fig 2).

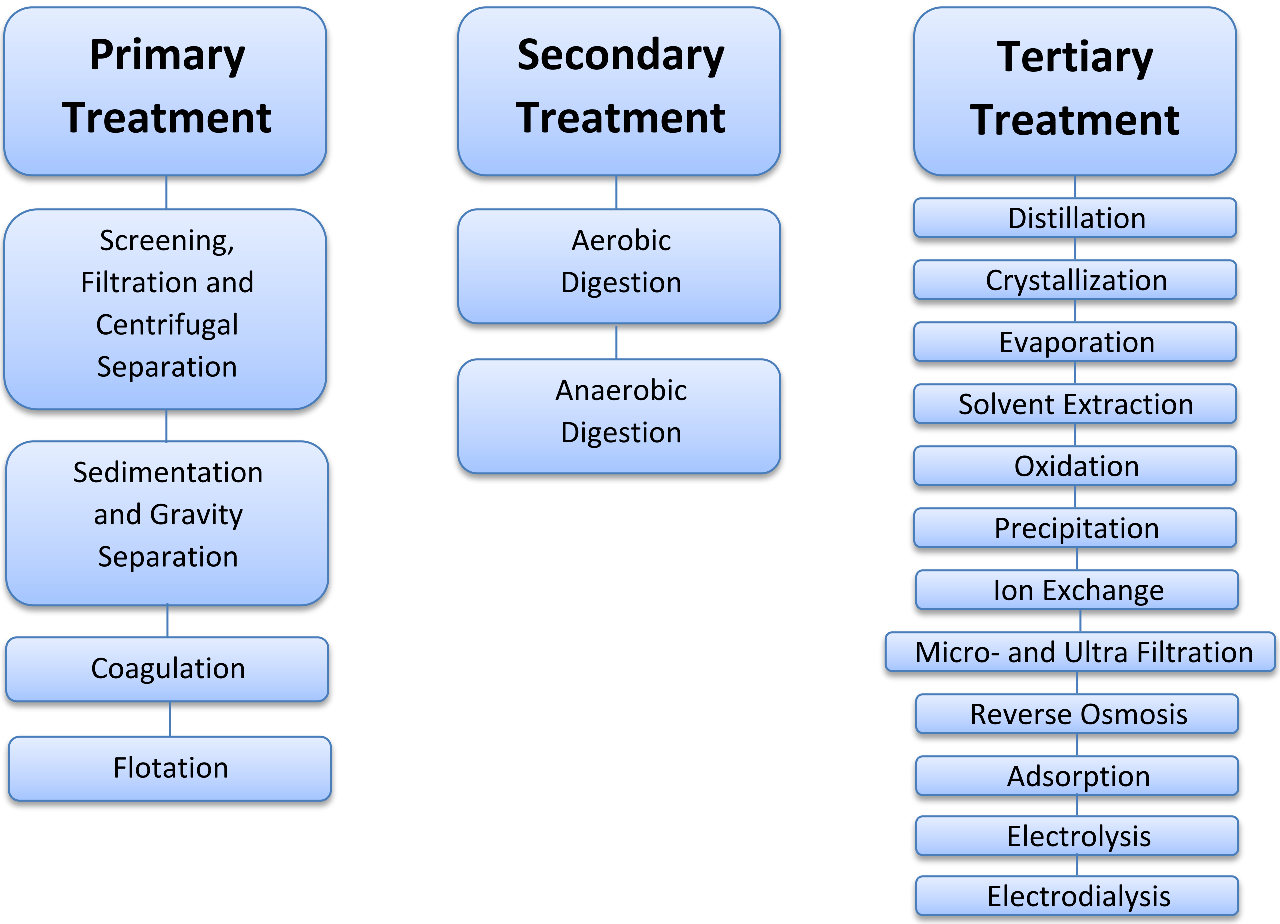


Figure 2: Wastewater Treatment stages (Gupta et al., 2012).

For this paper, the focus will be on the technologies of the secondary treatment which related to the energy recovery from the sewage water.

2.2.1. Aerobic digestion

The process of the aerobic digestion of the organic compound in the WWTP is similar to the process that occurs naturally, but this one is taking place in the big tank, and it's easy to control. The digestion occurs by especial type of microorganisms, it's called the decomposers, which is responsible for the biochemical oxidation of the organic compound into inorganic compound, new microorganisms' cells and some heat. The biochemical oxidation is also converting the organic bound like nitrogen, sulfur and phosphorus into mineralized forms (i.e., NH3, NH4, NO3, SO4, and PO4). The problem with the aerobic digestion is that the microorganisms consume the oxygen dissolved out of the water so that it needs to balance the oxygen dissolved concentration in the water before it released into the environment. If the rate of re-aeration is not equal to the rate of consumption, the dissolved oxygen concentration will fall below the level needed to sustain a viable aquatic system (Buchanan and Seabloom, 2004).

2.2.2. Anaerobic digestion

The process of the anaerobic digestion is much similar to that in the aerobic digestion, but it uses different type of microorganisms, in which microorganisms break down biodegradable material in the absence of oxygen. After the primary stage, the sludge is transferred into the anaerobic digestion reactor; the process is usually taken place in temperature between (35-39 Co) (Bachmann, 2015). In the anaerobic digestion, the microorganisms are treated the organic compound and produce biogas which consisted mainly of Methane, CO2 and small amount of other gases.

The biogas produced from the anaerobic digestion is not ready for combustion, it needs to dry and remove unwanted substances and gases. So that the biogas can burn more efficiently and also to avoid corrosion and damage to the combustion equipment, so that the result gas will be bio-methane. After that the bio-methane is taken to the CHP to generate electricity and heat.

2.2.3. Nereda©

The Nereda© technology was invented by the University of Delft in 1993, the difference between this technology and the traditional digestion is that the Nereda© technology's bacteria grow in granules while the traditional purification's bacteria grow in flocs. The granulate includes two layers; the outer aerobic layer takes care of biological oxidation and oxidation of ammonium to nitrate, while the inner anoxic/anaerobic layer reduces nitrate to nitrate gas and takes care of the phosphate removal. This technology shows that the processes of nitrification, de-nitrification and removal of phosphate are done in one tank while the traditional treatment needs multi-tanks. That is the main reason why using the Nereda© technology can save about 70% on required space (Lulofs and Bressers, 2017). The Nereda© technology has more advantages. It has a faster settlement process than that of the traditional treatment, and that what made the operation to have lower price. It can also reduce the energy consumption by 50% (Royal Haskoning DHV, 2017), and the recovery of nitrates and phosphates is relatively easy without using many chemicals (Lulofs and Bressers, 2017).

2.2.4. DEMON®

The DEMON® is a treatment system of removal of nitrogen during the purification of the sewage water in the WWTP. There is a different between DEMON® treatment technology and the biological nitrification process. The biological nitrification process is oxidized the ammonia and convert it into nitrite and nitrate by aerobic autotrophic bacteria. The final product of the nitrification, which is nitrate, is converted into nitrogen gas through the de-nitrification process under anoxic condition and removed from the sewage, (Kutty et al., 2011). The DEMON system uses two steps mechanisms. The first step is to convert half the loaded ammonia to nitrite by using ammonia-oxidizing bacteria (AOB). The second step is to convert the combination of nitrite generated from the first step and remaining ammonia directly into nitrogen gas by using the anaerobic biological process uses Anammox bacteria (World Water Works, 2017).

According to (World Water Works, 2017), The DEMON® system reduces energy requirements by 60 percent compared to biological nitrification process, that eliminates the need for all chemicals and produces 90 percent less sludge. The system also has a low carbon footprint – the anaerobic process actually consumes carbon dioxide.

2.3. Water management in The Netherlands

The Government in The Netherlands is consisting of three tiers; National, Province and Municipal. Each one is responsible on a wide range of duties in specific geographic area and has its own legislative assemblies and executive organizations. Besides these governments, there are regional water boards. "These regional water authorities are among the oldest forms of local government in the Netherlands, some of them having been founded in the 13th century" (Lulofs and Bressers, 2017). The water boards are responsible for the management of dikes, water quantity and (since 1970) water quality. The members of the boards of water authorities are elected. The regional water authority is a decentralized government body. They are financially independent and can therefore adopt regulations and make certain rules that are binding for the citizens, but they are supervised by the provincial government (Fig 3).

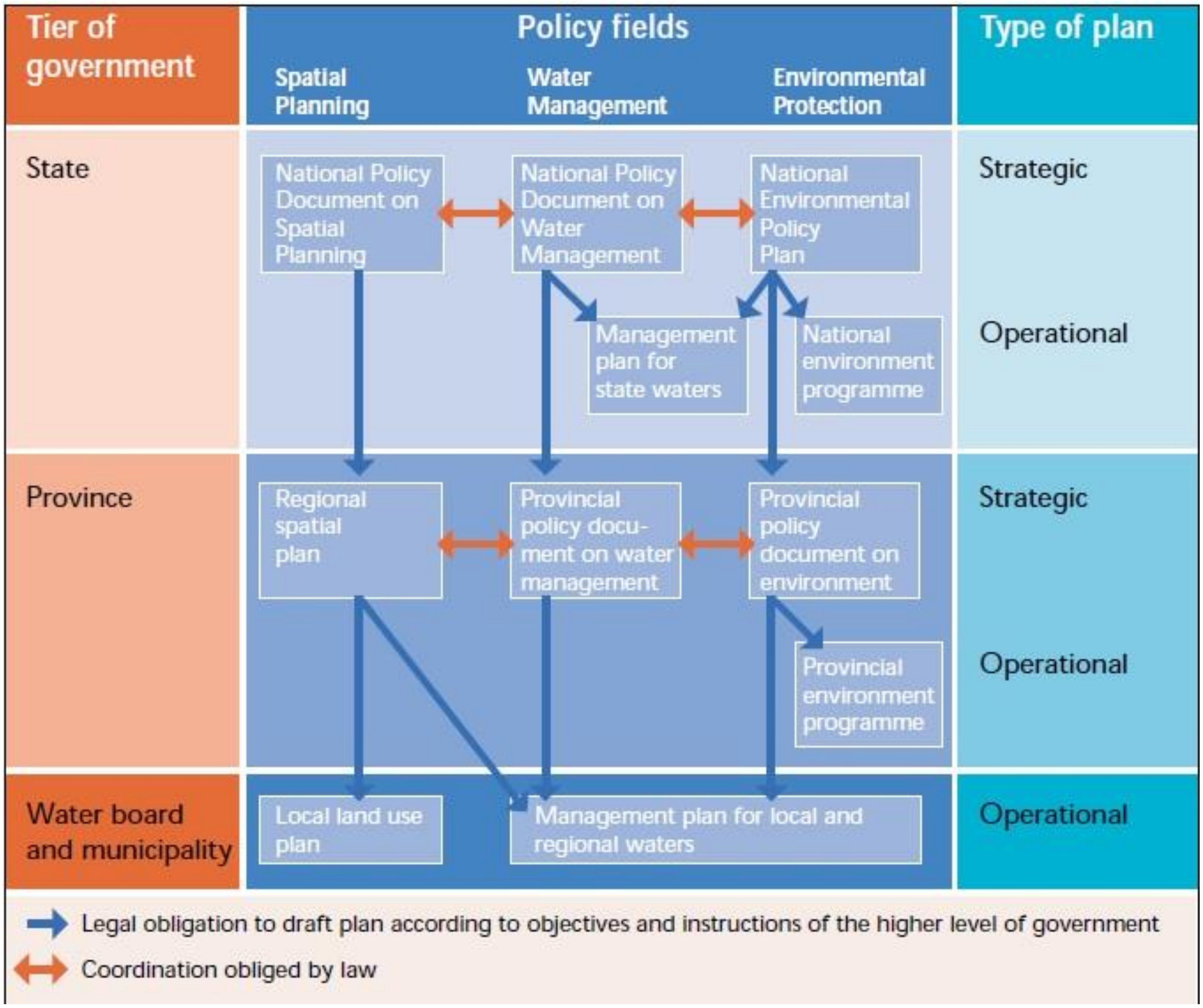


Figure 3: Government policy Planning structure (Henk Warmer & Ronald van Dokkum, 2002).

WWTP has to have a permit for operation based on the Omgevingswet, this has to do with emissions to air, noise, smell, measures to avoid soil and water contamination, requirements to processes and storage, etc. Also additional requirements can be set in terms of research on better alternatives or goals to improve. Besides, the discharge purified water need to meet specific requirements before it release to the surface water. So that if the existing WWTP wants to be energy self-sufficient by using different technology or added an extra source of energy, it is very important to know what is the regulation that binding the operations.

Chapter 3: RESEARCH DESIGN

3.1 RESEARCH FRAMEWORK

Research framework, based on Vershuren and Doorewaard (2010), means a schematic presentation of the research objective. It includes step by step activities to achieve research objective. Research framework consists of seven steps can be seen as follow:

Step 1: Characterizing briefly the objective of the research project

The aim of this paper is to find out the capability of the wastewater treatment plants to be energy self-sufficient and comply with the strict emission's regulation in the Netherlands, and what is the influential circumstances and factor of the decision-makers to achieve that.

Step 2: Determining the research object

The research object in this research is three different water boards in The Netherlands.

Step 3: Establishing the nature of research perspective

The research will study three water boards in the Netherlands and collect data regarding the existing situation of the water boards, including the area covered, the capacity, treatment technologies used, the latest maintenance and the percentage of energy self-sufficiency of each water board. To give a recommendation for the water boards, the research will use the Contextual Interaction Theory to the analysis of the decision makers' motivations for the previous and future maintenance and renovation. The research will also use Contextual Interaction Theory to the analysis of the decision makers' future plans to increase the energy efficiency, which will require knowledge of the National governance context, which will be analysis by applying the Governance assessment Tool (GAT). Giving a recommendation will also require knowledge about the emission's regulation in the Netherlands.

Step 4: Determining the sources of the research perspective

The research uses scientific literatures to develop a conceptual model. Theories to be used in this research are:

Key concepts	**Theories and documentation**
Energy self-sufficient	Document on existing situation of WWTPs.
Capability	Theory on decision maker.
Decision maker	Theory on future energy self-sufficiency.
Emission-regulations	Theory on the National governance context.
	Preliminary Research.

Table 1: Sources of the Research Perspective

Contextual Interaction Theory (CIT)

The Contextual Interaction Theory will be used in this research as analytical framework to analyze the decision makers' motivations for the previous maintenance and renovation and also the decision makers' future plans to increase the energy efficiency. By using the three characteristics of The Contextual Interaction Theory; cognitions (what actors know or think they know and what is within their world and what they consider outside their perspectives), motivations (goals, what to reach out for, including when and in which tempo) and resources (what they are able of). We can't use the contextual interaction theory unless we use the all three characteristics, "These three characteristics are influencing each other, but cannot be restricted to two or one without losing much insight" (Bressers, 2007). This interaction is illustrated in Figure 4.

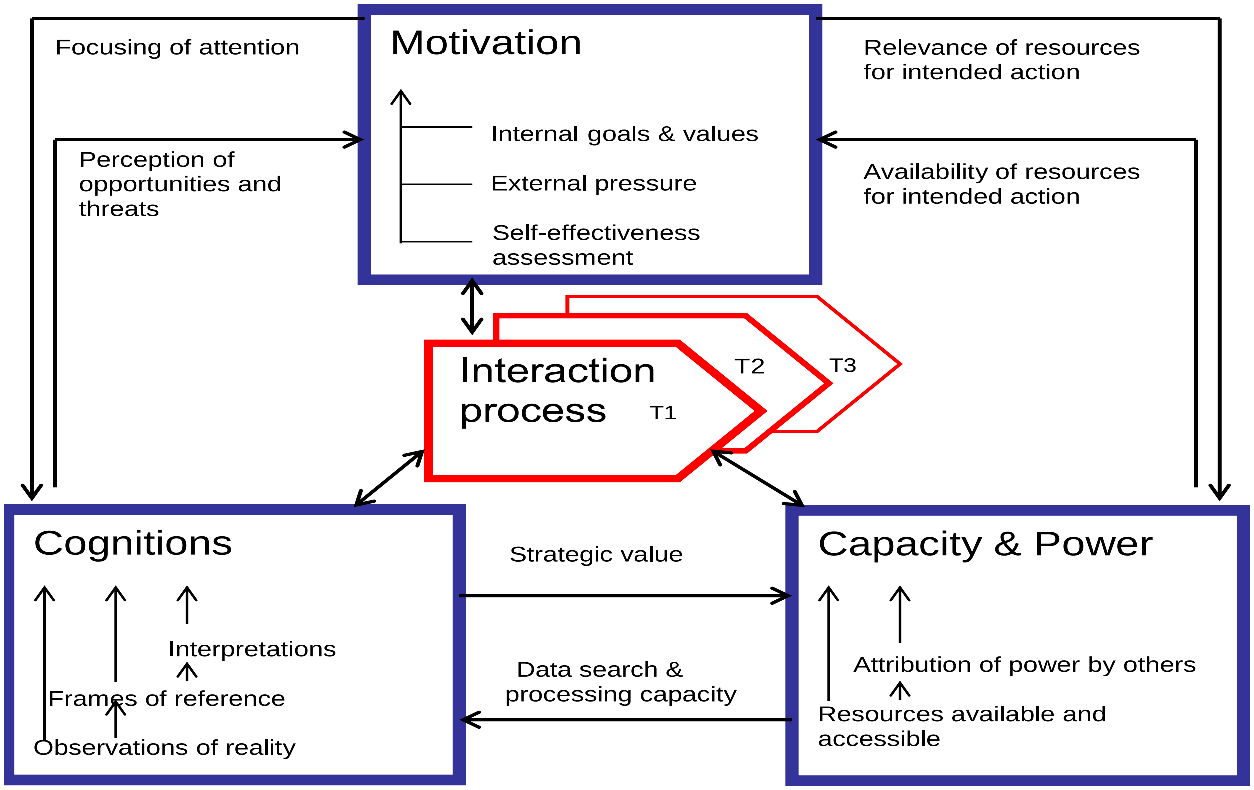


Figure 4: Dynamic interaction between the key actor characteristics that drive social interaction processes and in turn are reshaped by the process (Bressers, 2009).

Governance Assessment Tool (GAT)

The thesis will apply the Governance Assessment Tool (GAT) to assess the interaction of actors concerned with the national governance, within the governance context. The governance context has five dimensions; levels and scales, actors and networks, problem perspectives and goal ambitions, strategies and instruments, and responsibilities and resources (Bressers & de Boer, 2013). These dimensions when they related in a matrix against the four governance quality elements of extent, coherence, flexibility and intensity, result in the matrix questions of the Governance Assessment Tool (GAT). The matrix of this tool is showed in Table 2 (Bressers and de Boer, 2013).

Table 2: The governance assessment tool matrix with its main evaluative questions.

Governance dimension	Quality of the governance context			
	Extent	**Coherence**	**Flexibility**	**Intensity**
Level and scale	How many levels are involved in managing the wetland?	Do these levels work together?	Is it possible to move up and down levels (up scaling and downscaling)	Is there a strong impact from a certain level towards behavioural change or management reform?
Actors and networks	Are all relevant stakeholders involved? Who are excluded?	What is the strength of interactions between stakeholders?	Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this?	Is there a strong pressure from an actor or actor coalition towards behavioural change or management reform?
Problem perspectives and goal ambitions	To what extent are the various problem perspectives taken into account?	To what extent do the various perspectives and goals support each other, or are they in competition or conflict?	Are there opportunities to re-assess goals?	How different are the goal ambitions from the status quo or business as usual?
Strategies and instruments	What types of instruments are included in the wetland's policy strategy?	To what extent is the incentive system based on synergy?	Are there opportunities to combine or make use of different types of instruments? Is there a choice?	What is the implied behavioural deviation from current practice and how strongly do the instruments require and enforce this?
Responsibilities and resources	Are all responsibilities clearly assigned and facilitated with resources?	To what extent do the assigned responsibilities create competence struggles or cooperation within or across wetland's management staffs?	To what extent is it possible to pool the assigned responsibilities and resources as long as accountability and transparency are not compromised?	Is the amount of allocated resources sufficient to implement the measures needed for the intended change?

Step 5: Making a schematic presentation of the research framework

The research framework is described through the following flow charts (figure 5):

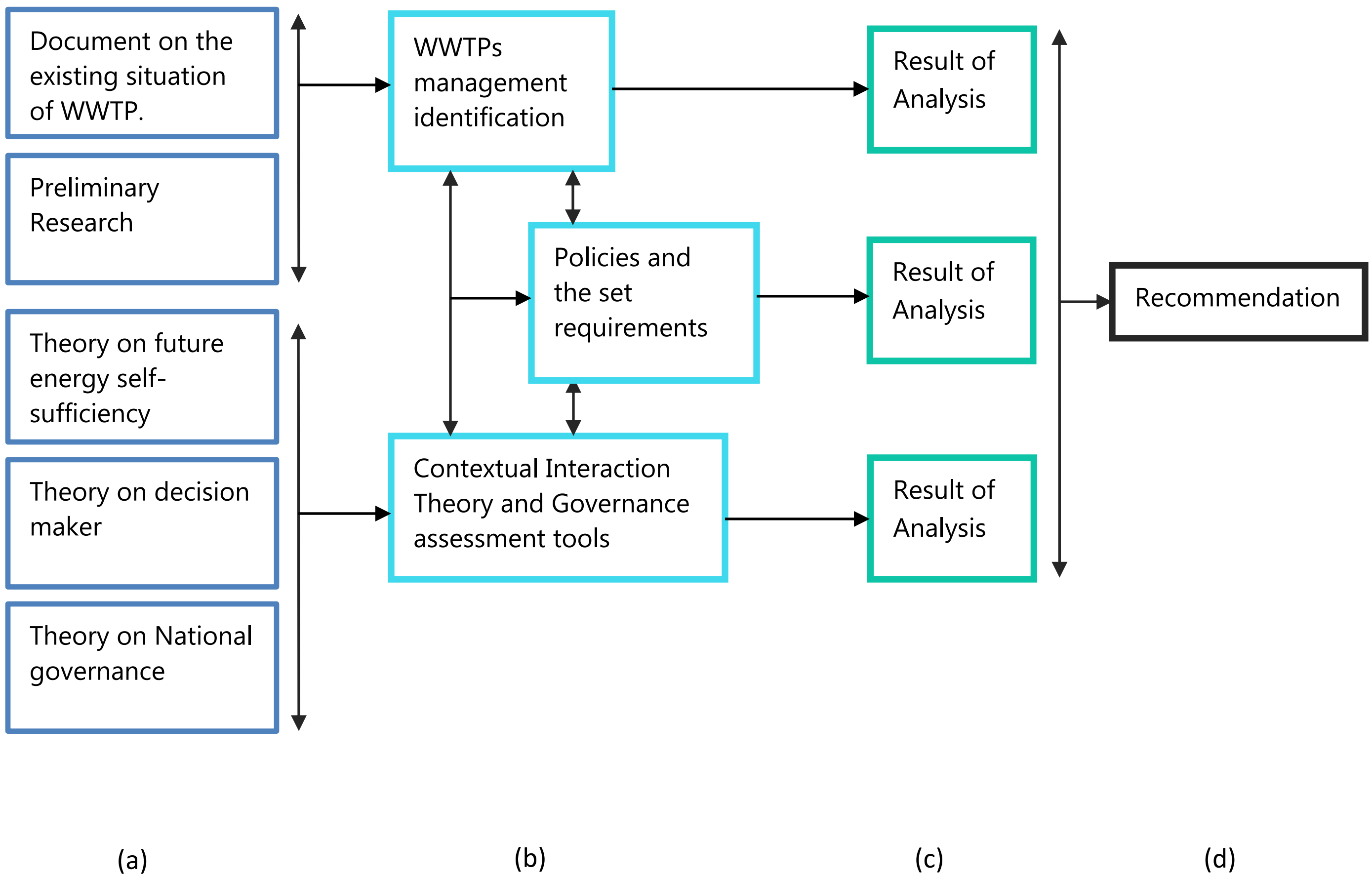


Figure 5: A Schematic Presentation of Research Framework

Step 6: Formulating the research framework in the form of arguments which are elaborated

(a) An analysis of the data from WWTPs, theories of increasing energy efficiency and preliminary research on the WWTP.
(b) By means of which the research object will be identified
(c) Confronting the result of the analysis as the basis for recommendation
(d) Recommendation with regard to solve the problem

3.2. RESEARCH QUESTION

The main Research Question:

Can existing WWTPs be energy self-sufficient and at the same time comply with the strict emission- regulations and to the extent that this is within reach, what will be the influential circumstances and factor in decision-making on WWTPs in the Netherlands?

Sub-Research Question:

1. What is the the current situation of the WWTPs?
2. How did decision makers plan maintenance and renovation in the past?
3. How do decision makers think about the idea of energy self-sufficient WWTP? And what are their future plans to increase the energy self-sufficiency?
4. What are the current policies and the set requirements for the WWTP?
5. What is the current national governance context?

The research main question and sub-questions will be answered in chapter 7.

3.3. DEFINING CONCEPT

For the purpose of this research, the following key concepts are defined:

Energy self-sufficient: the ability of WWTP to operate without the need of an external source of energy.

Capability: Capabilities of both as incorporating technical options and aspects as well as socio-economic perspectives of decision-makers

Emission's regulations: the limitation of the amount of pollutants that can be released into the environment.

Decision maker: the person or groups of people who decide wither to do some improvements and maintenance for the WWTP.

3.4. RESEARCH STRATEGY

The research uses the multi case study approach as its strategy. The research will focus on three cases. An in-depth study is applied by using various methods for generating data.

3.4.1. Research Unit

The research unit of this research is three different water boards in the Netherlands. The research will focus on the energy management, the decision maker motivation governance context and the emission's regulation in The Netherlands.

3.4.2. Selection of Research Unit

Selection of the informant and respondent in the Park is based on the following criteria:

- The manager and decision maker of three water boards.
- Available data on the energy management from the WWTPs. That's including data on the energy self-sufficiency.
- Available data on the latest maintenance and renovation of the WWTPs.
- Three water boards will be chosen for this research.

3.4.3. Research Boundary

Research boundary is used to determine the limitation of study and its consistency. Thus, the goal of study can be achieved within the specific time.

The following boundary is used in this research:

- In the process of choose the water boards. The research will not consider the location of the water boards.
- The numbers of water boards chosen are as mentioned in 3.4.2.

3.5. RESEARCH MATERIAL AND ACCESSING METHOD

Research material means "Defining and operationalizing the key concept of the research objective and of the set of research question" (Verschuren and Doorewaard, 2010: 203). Data and information required to answer the RQs will be collected via several methods including documents and in depth interviews.

The documents analysis will be conducted with energy management of the WWTPs, maintenance and renovation and emissions police, the in depth interviews will hold with the decision makers of the three water boards to identify the motivation behind the previous and the future plane of the maintenance and renovation and the influential circumstances and factor in decision-making, and the existing national governance and it affect to encourage the renewable energy in the WWTPs.

The data and information required and its accessing method in this research are identified through the set of sub-research question, as displayed in the following Table 3.

Table 3: Data and Information Required for the Research and Accessing Method

Research Question	**Data/Information Required to Answer the Question**	**Sources of Data**	**Accessing Data**
What is the current situation of the WWTPs?	The area covered, capacity, technologies used, energy self-sufficiency and the latest maintenance and renovation in the WWTPs	<u>Secondary Data</u> Documents	Content Analysis
How the decision makers planned for maintenance and renovation in the past?	Cognitions: what the actors know	<u>Primary Data</u> Managers or decision makers	Questioning: Face to face individual interview
	Motivations: what to reach out for and when		
	Resources: what the actors are able of		
How the decision makers think about the idea of energy self-sufficient WWTP and what are their future plans to increase the energy self-sufficiency?	Cognitions: what the actors know	<u>Primary Data</u> Managers or decision makers	Questioning: Face to face individual interview
	Motivations: what to reach out for and when		
	Resources: what the actors are able of		
What are the current policies and the set requirement for the WWTP?	The limitation of the pollutant release by the WWTP	<u>Secondary Data</u> Documents	Content Analysis
What is the current national governance management?	The policy instrument that encourage the renewable energy projects	<u>Primary Data</u> Documents	Content Analysis

3.6. DATA ANALYSIS

Data analysis means data evaluation process through logical and analytical framework as presented in the following:

3.6.1. Method of Data Analysis

This research will use only qualitative. The analysis methods will is as showing in the following table:

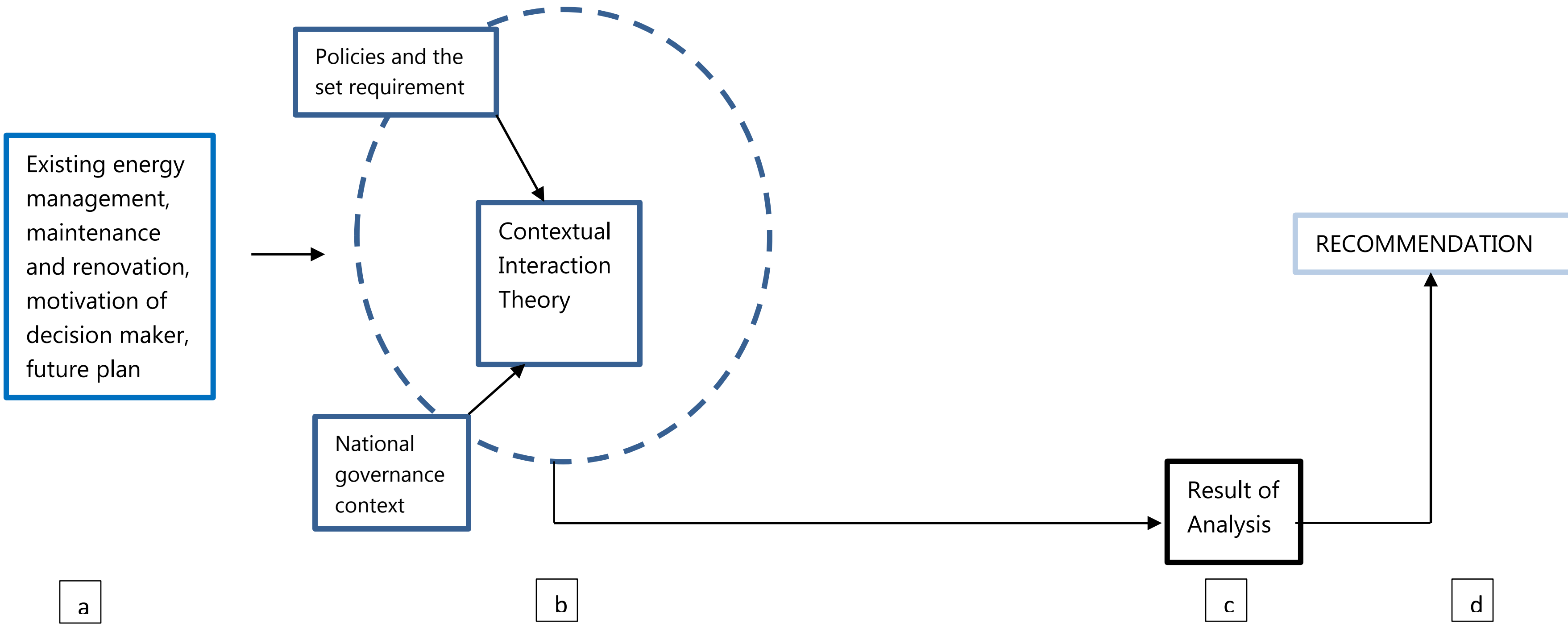
Table 4: Data and Method of Data Analysis

Data/Information Required to Answer the Question	**Method of Analysis**
The existing WWTPs	Qualitative: analyzing the existing situation of the WWTPs.
Theory on decision makers' previous maintenance and renovation.	Qualitative: analysis of the previous and future maintenance and renovation and the motivation of the decision maker using Contextual Interaction Theory.
Theory on decision makers' future plan to increase the energy self-sufficiency.	Qualitative: analysis of the future plane for increasing the energy efficiency and the motivation of the decision maker behind it using Contextual Interaction Theory.
Policies and the set requirement for the WWTP	Qualitative: analysis of the limitation of the pollutant allowed to release by the WWTPs
Theory on the National governance context.	Qualitative: analysis of current policy instruments that encourage on produce renewable energy by the use of the Governance Assessment Tool.

3.6.2. Analytical Framework

The schematic presentation of analytical framework is shown in Figure 6:

Figure 6: A Schematic Presentation of Analytical Framework



The data analysis will be conducted with the following sequences:

a. The first step is the analysis of the existing situation of the WWTPs, which includes information collected from question one and two. The information is about the plant age, size, the last maintenance, treatment technologies, energy generation and energy consumption.
b. The second step is the analysis of the national governance context by the using of the Governance assessment tool.

c. The third step is the analysis of the decision makers' motivation of previous maintenance and renovation using Contextual Interaction theory.

d. The fourth step is analysis of the future plans for increasing the energy self-sufficiency and the decision makers' motivation behind it using Contextual Interaction Theory.

e. The fifth step is bringing out the results of the analysis of each case.

f. The final step will answer the research central question and sub-questions, and will give a solution for the energy problems in the WWTP.

3.7. RESEARCH PLANNING

3.7.1. Activity Planning and Time Schedule

Planning is the designing and the stimulating tool that helps on one hand in building a research design and on the other, in carrying out the research project in an efficient way (Verschuren and Doorewaard, 2010). The research has two parallel processes; data collecting and writing activities.

3.7.2. Table of Contents

The construction of table of content during the research design process will help the researcher to visualize the final result of research writing as well as building a joint research that can be understood by others (Verschuren & Doorewaard, 2010).

Chapter 4: CURRENT POLICIES AND THE SET REQUIREMENT FOR THE WWTP IN THE NETHERLANDS

In this chapter I will discuss the regulations and rules for the establishment and work of the WWTPs in the Netherlands. That will cover the permits required and discharging limitations for the purified water to the surface water. This chapter will answer sub-question 5, regarding the current policies and the set requirement for the WWTP.

4.1. Permits Required

According to the Dutch Ministry of Infrastructure and the Environment, WWTPs don't need any water permit. The 2014 amendment Activities Decision made some desired changes under the concept of politically neutrally. This decision stated that the discharge of purification works under the general rules of Chapter 3 of the Activities Decision is exempts from the permit requirement of Article 6.2, first and second paragraphs of the Water Act, in particular for the discharge of substances into surface water from purification works, (SKN, 2014). The decree also states that if a WWTP purifies purely urban waste water, which is supplied via the municipal sewage system, no environmental permit is required. But for some activities, an environmental permit is still required. Below is the list of the cases where environmental permit is required, (Ministerie van Infrastructuur en Milieu, 2017a):

1. Create, modify or expand of WWTP; these activities are falling under section 7.2 of the Environmental Management Act as "Activities which may have serious adverse effects on the environment", (Environmental Management Act, 2004). For these activities, an environmental impact statement must be drawn up.
2. Disposal of the sludge; Environmental permit is required for all kind of disposal of the sludge except of the mechanical dewatering of sewage sludge. According to (Environmental Decree, 2010, Annex I, Part C, Category 28.10, point 3^{o}), the waste of mechanical dewatering of sewage sludge is considered as a non-hazardous waste.
3. Disposal of non-hazardous waste; According to the European Directive 2010/75/EU of industrial pollution, Environmental permit is required for the following cases;

a. Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving one or more of the following activities;
   I. biological treatment.
   II. physico-chemical treatment.
   III. pre-treatment of waste for incineration or co-incineration.
   IV. treatment of slags and ashes.
   V. treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.

b. Recovery or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tons per day involving one or more of the following activities.
   I. biological treatment.
   II. pre-treatment of waste for incineration or co-incineration.
   III. treatment of slags and ashes.
   IV. treatment in shredders of metal waste, including waste electrical and electronic equipment and end-of-life vehicles and their components.

c. When the only waste treatment activity carried out is anaerobic digestion, the capacity threshold for this activity shall be 100 tons per day.

4. Storage iron / aluminum chloride; Environmental permit is required only if the storage was above the ground and the capacity was more than 10 M^3, (Environmental Decree, 2010, Annex I, Part C, Category 4.4, C).
5. Storage of methanol in tanks; Environmental permit is always required for the storage of the methanol, there is no different if it was under or above the ground, (Environmental Decree, 2010, Annex I, Part C, Category 4.4, D).
6. Processing of streams other than wastewater in the waterline; Environmental permit is required if they want to transport other liquids using the waterline.

4.2. Discharging Regulation and Limitations

Although WWTPs don't need water permit for the discharge of the purified water into surface water, it should meet a certain specification before it is released. Since the Netherlands should complies with the European Commission Directive (91/271/EEC) and the improved version (98/15/EC) (Ministerie van Infrastructuur en Milieu, 2017b), there are specific regulations and limitations for the disposal of the purified water in to surface water.

Discharge from urban wastewater treatment plants

Every WWTP should have the following procedures to insure that it is eligible to work in the Netherlands;

1. Waste water treatment plants shall be designed so that representative samples of the raw wastewater and purified water can be obtained before they are discharged. The minimum annual number of samples per year is variable according to the size of the WWTP, as shown in table 5.

Table 5: Annual sampling for WWTPs (EC, 91/271/EEC)

Size of the WWTP	Number of samples per year
2000 – 9,999 p.e.	12 samples in the first year and four samples in the following years. Note: if one of the four samples fails, 12 samples should be taken the next year.
10,000 – 49,999 p.e.	12 samples
50,000 and more	24 samples

2. The quality of the purified water discharges from urban wastewater treatment plants should meet specific requirements. These requirements have been change through the years. Table 6 shows these requirements that the Netherlands follow now, the previous requirements, and the European Union directive 91/271/EEC requirements.

Table 6: Requirements for discharges from waste water treatment plants, (EC, 91/271/EEC) & (SKN, 2007 & 2014).

Paramenter	Concentration EU regulation	Concentration Netherlands Regulation 2007	Concentration Netherlands Regulation 2014
Biochemical oxygen demand	25 mg/l O2	20 mg/l O2	20 mg/l O2
Chemical oxygen demand (COD)	125 mg/l O2	100 mg/l O2	125 mg/l O2
Total suspended solids	35 mg/l (More than 10,000 p. e.) 60 mg/l (2,000 - 10,000 p. e.)	30 mg/l	30 mg/l
Total phosphorus	2 mg/l (10 000 - 100 000 p. e.) 1 mg/l (More than 100 000 p. e.)	3 mg/l	2 mg/l (2 000 - 100 000 p. e.) 1 mg/l (More than 100 000 p. e.)
Total nitrogen	15 mg/l (10 000 - 100 000 p. e.) 10 mg/l (More than 100 000 P. e.)	30 mg/l	15 mg/l (2 000 - 20 000 p. e.) 10 mg/l (More than 20 000 P. e.)

3. More stringent requirements than those shown in Table 5 and/or Table 6 shall be applied where required to ensure that the discharging waters satisfy all other relevant Directives.
4. The points of discharge of urban waste water shall be chosen, as far as possible, so as to minimize the effects on discharging waters.

Special requirement for the industrial wastewater

Industrial wastewater entering collecting systems and urban waste water treatment plants shall be subject to such pre-treatment as is required in order to:

1. Protect the health of staff working in the collecting systems and the treatment plants.
2. Ensure that collecting systems, the treatment plants and associated equipment are not damaged.
3. Ensure that the operation of the wastewater treatment plant and the treatment of sludge are not impeded.
4. Ensure that discharges from the treatment plants do not adversely affect the environment, or prevent receiving water from complying with other Community Directives.
5. Ensure that sludge can be disposed safely in an environmentally acceptable manner.

Chapter 5: GOVERNANCE CONTEXT

The 2020 European Union goal is binding the Netherlands to increase their share of renewable energy by 14% of the total mix of energy in 2020. This percentage should be increased to 27% of the total mix of energy in 2030, (Government of The Netherlands, 2017). So that the Netherlands government issued number of policy instrument to support the development of the renewable energy.

In this chapter, I will make an evaluation for the National government context by applying the Governance Assessment Tool (GAT). Table 8 shows the governance assessment tool matrix, which gives a quick evaluation about the Netherlands governance context.

The following is comprehensive discussion regarding the National governance context, which evaluate the found situation by the core governance qualities extent, coherence, flexibility and intensity:

Levels and scales

Extent is high

The policies of the Dutch governments involve various relevant levels and scales, in order to achieve its renewable energy goal through different policy instruments; The Energy Agreement for Sustainable Growth, which is signed by different central governments, decentral governments and non-governmental representatives gives an example (SER, 2013). The so called Green Deal Approach is a strategy to establish cooperation and agreements between central government and other parties such as decentral governments, companies, stakeholders and interest-groups, in order to work on green growth and social issues (Green Deal Approach, 2017). The Local Climate Agenda is another example, boosted by a joint group of seven 'climate ambassadors' (directors from municipalities and water boards), including representatives of both decentral governments and the national government, (Ministry of Infrastructure and the Environment, 2011).

The policy also involve the private investor through The Green Funds instrument, The Green Funds is a tax incentive funds that pushes private investors to invest in green projects that benefit the nature and the environment, (NL Agency, 2010).

Coherence is high

Representatives of companies, decentral government and invited parties, who were involved in the Energy Agreement for Sustainable Growth, are playing a crucial role, in close cooperation with the government, in achieving national and European goals in the area of climate and sustainability in a balanced and cost effected way (SER, 2013). The government also pushes balanced cooperation through a group of climate ambassadors, The Green Deal and the Energy Agreement.

Furthermore, the cooperation under the Energy Agreement has contributed to new links between organizations, which led to mutual understanding, a sense of shared responsibility and mutual accountability. As a result, the commitment to parties has increased. Parties did not get lost and jointly seek solutions, (KWINK group, 2016).

However, the green deal has been functioned with regard to cooperation between governments, the task force and the co-operation program heat / cold storage are referred to explicitly in an evaluation study (KplusV, 2012).

Flexibility is high

An organization that takes an initiative (for instant a regional water board) can ask for support from different governmental levels regarding different issues, as stated in the Energy Agreement for Sustainable Growth. Government and other parties also agreed to conduct further consultations on the removal of non-financial barriers, which limit the scaling up of renewable energy. These barriers are solving organizational bottlenecks, adequate laws and regulations and fiscal measures, (SER, 2013).

In the Green Deal, the government is trying to remove bottlenecks in practical sustainable plans. The government helps in several ways (Rijksoverheid, 2017):

i. Make efforts to adapt legislation and regulations. In this way, the government can reduce administrative burdens for businesses.
ii. Sometimes the government acts as a mediator. For example, bringing together organizations or making negotiations easy.
iii. The government can help companies exploit new markets for sustainable technology. For example, by helping companies to enter foreign markets ("Green Trade Missions").

The local Climate Agenda also stated that the national government will support the local government by providing solution regarding bottlenecks and by providing practical tools, (Ministry of Infrastructure and the Environment, 2011).

Intensity is Medium

Although the Netherlands government policy is based on negotiated agreements and it doesn't involve a strong pressure toward behavior change, these agreements had an impact on regional water board behavior. The water boards used to invest mainly in reducing the cost of the treatment and they only make the investment if it has good business case, but that change under the pressure of the national government, as Sybren Gerbens stated, "We did the biogas reactor to fulfill with the general water board energy ambition".

Actors and networks

Extent is high

The policies of the Dutch government policies involved other actors in the establishments of some of its instruments.

The Energy Agreement for Sustainable Growth was signed by more than 40 organizations, including government, employers, trade unions, nature and environmental organizations, civil society organizations and financial institutions (SER, 2013).

The Green Deal Approach was established as a joint venture by the Dutch Ministries of Economic Affairs, Infrastructure and the Environment and Internal Affairs and the Kingdom Relations. The green deal is a way for cooperation between central government and other parties, decentralized governments, companies, stakeholders and interesting groups, to work on green growth and social issues (Green Deal Approach, 2017).

Coherence is high

Representative organizations of companies, government and invited parties, who involved in the Energy Agreement for Sustainable Growth, are making a framework for company-specific agreements aimed to improve the energy efficiency and competitiveness of the involved companies. They are convinced that the power of a targeted approach to energy-saving measures largely consists of the degree of coherence between individual measures and actions, (SER, 2013).

According to the Local Climate Agenda, sustainability does not stop at the municipal boundary, but it usually refers to a region or an area. This requires intensive cooperation between city and region, between municipality, province and water board. Sustainable water management, for example, requires a good interaction between water boards, municipalities and provinces. Starting a biogas project or building a wind farm is impossible without proper cooperation between companies and the various governments, (Ministry of Infrastructure and the Environment, 2011).

Flexibility is high

The policy instruments in the Netherlands built on high flexibility with regard to the actors involved in them. Furthermore, during the implementation of the instruments, it is possible to include new actors. As stated in (KWINK group, 2016), "When implementing the Energy Agreement, parties from outside the Energy Agreement will also be involved".

Intensity is Low

There isn't a strong pressure or impact from a certain actor toward behavior change. According to, (KWINK group, 2016), the intensity of cooperation is a focus. The cooperation within the Energy Agreement requires a certain effort from parties in terms of time spent on preparing. This effort is for larger parties and parties where the issue of energy is their core business should be easier than for small parties or parties where this is not the case. However, involvement of these parties can be of great importance, because they can sometimes bring innovative perspectives.

Problem perspectives and goal ambitions

Extent is medium

The policies took into account different problem perspectives

a- Financial problems

The policy-makers understood that the price of the renewable energy is usually higher than the market price, so that the production of renewable energy is not always economically viable. Such projects might need a capital investment or another financial arrangement. But the policy-makers gave less attention to big projects (For example, a biogas reactor), which require big capital investment with a payback period up to 15 years. The existing GO (Enterprise Finance Guarantee) scheme, which is part of the Energy Agreement, can already be used for investment in energy efficiency in the industry with a payback period of up to eight years, (SER, 2013), that makes it very difficult to be used in case of big investments with long payback periods.

b- Organizational bottlenecks

The policy-makers put into account the following issues regarding the organizational bottlenecks in the establishment of the policy, (SER, 2013);

i- Local energy initiatives strong need for support in the form of information, knowledge and knowledge exchange, whether they are in the preliminary phase or planning phase.

ii- The supply side (sustainable energy sector) need to establish a quality and certification system within one year, aimed at sustainable decentralized energy providers in compliance with the Competition Act. This helps consumers to make a good choice from the wide range.

iii- Municipalities and provinces make spatial policy for decentralized renewable energy. This relates to wind farms of less than 100 MW and the use of bio-energy.

c- Adequate laws and regulations

According to, (SER, 2013), in order to realize the energy transition, legislation must be framework and consistent to provide long-term security to investors. The legislation must also facilitate innovation. This means that legislation must provide sufficient space to allow for desired new developments, especially when it comes to local production of renewable energy.

The legislations issued are;

i- An adjustment in tariff structure for the transport rates and makes it the same for all regions. In this way customers in a region with a lot of decentralized renewable energy will not experience a disadvantage.

ii- There is an analysis of the need for network administrators to expand the network to those areas where a structural vision is provided for sustainable energy generation, with the expectation that total social costs will decrease.

iii- Network administrators make information anonymous available for transition, such as for energy saving services, as well as the availability of consumption data at postcode level (Energy in Image).

iv- Licensing for decentralized renewable energy projects, under the Environmental Act, becomes simple in such a way that it require the license application relates exclusively to the renewable energy plant and not for the whole company.

For the organizational bottlenecks and legislations issues, the policy-makers give less attention to project with regards to biogas project, and focused more on Solar PV and Wind turbine projects.

Coherence is medium

Although each actor has its own goals and ambitions, they are all going toward the same direction, sustainability. The government and other parties, who joined the Energy Agreement for Sustainable Growth, agreed on energy saving, clean technology and climate policy. Implementation of the agreements should result in affordable and clean energy supply, employment and opportunities for the Netherlands in clean technology markets.

The agreement intend to, (SER, 2013):

a- A saving of final energy consumption on average 1.5 percent per year.
b- 100 PJ to save in the final energy consumption of The Netherlands by 2020.
c- An increase in the share of renewable energy generation to 14 percent by 2020.
d- A further increase of this share to 16 percent 2023.
e- At least 15,000 jobs will be created in next years in the investments in energy from renewable sources and energy conservation.

The Netherlands government goal is to enhance the sustainable and economic growth in the same time, which may be difficult to achieve together.

Flexibility is high

The goals can be easily changed or modified since there is no any legal binding. Some water boards already achieved the 40% energy self-sufficient and they have more ambition goals. Furthermore, the current Netherlands 2020 renewable energy target, 14%, is less ambition than the previous one, 20%, (Statistics Netherlands, 2010).

Optimizing multiple goals into a package deal is possible. The different goals of different actors are combined into one package through the Energy Agreement for Sustainable Growth.

Strategies and Instruments

Extent is medium

The national policy consisted of different instruments;

a. *Financial Instruments*

There is a variety of financial instruments that the national governments implemented in order to encourage the renewable energy projects. These instruments are:

The Green Funds, which is a tax incentive funds that allow private investors to invest in green projects that benefit the nature and the environment. The fund is eligible for a variety of projects that fall under one of the following categories; Nature and forest, Agriculture, Energy and sustainability, (NL Agency, 2010).

SDE+ (*Stimulering Duurzame Energieproductie*/Encouraging Sustainable Energy Production), which is a subsidy regime established by the ministry of economic Affairs to encourage the renewable energy projects in The Netherlands. The target groups for this grant are companies, institutions and non-profit organizations (Netherlands Enterprise Agency, 2017).

Topsector energy provides funding for projects and research to strength a number of topics in the energy sector. Topics, that the national government thinks, have a shortage of (technically) skilled staff, at both, college and university level. These topics are Energy-saving built environment, Energy-saving industry, Gas, Smart grids, Wind at Sea, Solar Energy and Bioenergy, (Rijksoverheid, 2012).

b- Energy Agreement for Sustainable Growth

It is an agreement established by the Social and Economic Council of the Netherlands with cooperation of more than 40 organizations. The agreement contains provisions on energy conservation, boosting energy from renewable sources and job creation, (SER, 2013).

c- The Green Deal Approach

The green deal is a way for cooperation between central government and other parties, decentral governments, companies, stakeholders and interest groups, to work on green growth and social issues (Green Deal Approach, 2017). In the Green Deal, the government is trying to remove bottlenecks in sustainable plans (Rijksoverheid, 2017).

d- Local Climate Agenda

The Climate Agenda is part of a more comprehensive strategy, the Sustainability Agenda. The Climate Agenda is coordinated by the Ministry of Infrastructure and the Environment. It aims for a sustainable climate and a healthy living environment for humans and nature, but also wants to boost the local economy and employment. The Climate Agenda wants to scale up successful projects through a wide network of municipalities, water boards and provinces.

Although a variety of policy instruments applied, there is absence of regulatory and enforcement.

Coherence is Low

The incentive instruments are not always balanced. As I mention before, they focus less on the big projects. For instant the 'Green Deal' scheme required showing rapid results within three years, (The Green Deal, 2015), and that makes it very difficult to be used for large investments. Furthermore, The SDE+ subsidy can be up to 15 years for Water, Wind and geothermal projects and 12 years for biomass projects, except for the incineration of the biomass, which is 8 years (Rijksdienst voor ondernemend Nederland, 2017).

Flexibility is medium

It is possible to make use of different types of instruments. For example, an initiative can use SDE+ financial instruments and in the same time make use of Energy Agreement or the Green Deal regarding find a solution for the bottlenecks or legislation problems. But it is not possible to use two different financial instruments since each instrument support different type of investments, and according to (Warbroek, 2014), "the application of policy instruments typically mutually exclude one another".

Intensity is medium

The variety of instruments did influence behavior but not strongly. For example, the Green Deal seems to be a good move, but insufficient to ensure integrated and wide commitment from decentralized authorities (KplusV, 2012). Furthermore, As a result of the Energy Agreement, intensive cooperation has been developed between the government and civil society on the topic of sustainable growth and energy. This has led to increase the support for civil society, (KWINK group, 2016).

Responsibilities and resources

Extent is medium

Responsibilities of actors are clearly assigned. For example, the water boards are responsible to produce at least 40% (4 PJ) of their own energy consumption by 2020. Member States must ensure that by 2020 all new buildings are almost energy-neutral. The association of municipalities' cooperation with building installation sector is responsible to jointly build the market for sustainable construction, sustainable renovation and decentralized power generation. The municipalities are responsible to facilitate an integrated approach, such as local heating networks, heat / cold storage and decentralized energy production. In addition, the municipalities will work together with the water boards, for example in the field of energy recovery from sewage and waste water treatment, (SER, 2013).

Although the responsibilities of every actor are clearly assigned, less clarity is there with regard to the resources needed and who should contribute what.

Coherence is high

The responsibilities assigned to each actor created cooperation between many decentral governments, national governments and private organizations aiming at achieving the renewable energy goals. Cooperation under the Energy Agreement has contributed to new links between organizations, mutual understanding, a sense of shared responsibility and mutual accountability. As a result, the commitment to parties has increased; parties did not get lost and jointly seek solutions, also at times when the tension increased. This creates more realization power. As a result, it has been possible to book results that previously did not seem to be within reach and gradually gaining broad support for measures that were still unacceptable at the start of the agreement for some parties (KWINK group, 2016).

Intensity is Low

Some policy instruments don't have any financial resources to support it or it's not clear about the resources so that there are no enough financial resources to cover the high costs of the installing of the renewable energy. For example, SDE+ only provide subsidy but no funds for the installing of the renewable energy.

Table 8: The governance assessment tool matrix with its main evaluation.

Governance Quality **Governance Dimension**	***Extent***	***Coherence***	***Flexibility***	***Intensity***
Levels and scales	High	High	High	Medium
Actors and networks	High	High	High	Low
Problem perspectives and goal ambitions	Medium	Medium	High	/
Strategies and instruments	Medium	Low	Medium	Medium
Responsibilities and resources	Medium	High	/	Low

Chapter 6: PRACTICES OF DUTCH REGIONAL WATER AUTHORITIES: THREE CASE STUDIES

Now we are informed about the governance context in which energy initiatives are taken by various actors. We now, in this section, present our case studies on three water boards, energy self-sufficiency, decision-making and influential factors.

6.1. Wetterskip Fryslân

Wetterskip Fryslan is a water board in the province of Friesland and the western part of Groningen with area of (346.000 hectare). Wetterskip Fryslan is in charge of 29 WWTPs, with total capacity of (1.031.000 p. e.).

6.1.1. What they did until now and what are their future plans.

History

The majority of the WWTPs that they have are using the Carrousel Treatment System as a treatment technology for the wastewater. This treatment is based on the principle of oxidation ditch where primary settlement, the activated sludge process, secondary settlement and sludge mineralization can take place simultaneously. This technic digests only 30% of the sludge. The resulted sludge transferred to the Dewatering plant in Heerenveen.

In 2010, the Friesland Water board started thinking about the capability of establishing an anaerobic digester to produce biogas. The idea and knowledge about the possibility of the anaerobic digester came to the decision-makers from other water boards through their participation in the Energy Factory Network Club. This club involves different water boards in the Netherlands to discuss the energy issues and new technology in the water sector in the Netherlands. In the same year, a business case to check if this investment is economically valuable was performed. Although the result of this business case shows that it is cheaper to pay for the end of pipe treatment, in 2011, the Friesland water board decided to go with biogas plant to fulfill with the water board ambition, which is to get 40% energy self-sufficient of total Netherlands water board in 2020, said Sybren Gerbens.

Current Situation

In 2016, Leeuwarden wastewater treatment plant had 100% sludge digestion and more than 1 million m^3 of biogas per year was produced The biogas was used to operate the digester, the plant building heating, Greunshiem Care Center, an eldery house and Wetsus building heating. The biogas production of the plant increased significantly last year. The current biogas production of Leeuwarden wastewater treatment plant is 4 million m^3 per year. Although Leeuwarden wastewater treatment plant produces biogas more than it needs to operate the plant, we can't consider it as energy self-sufficient because it does not only digest its sludge but also sludge from other wastewater treatment plants in Friesland. As Sybren Gerbens stated, they have four anaerobic digesters in four different cities in Friesland; Leeuwarden, Draghten, Franeker and Burgum. That makes their percentage of energy self-sufficiency 9% in 2015, (Arcadis, 2016). However, the digester in Burgum will be closed next year, and they will depend only on the other three digesters.

Future plan

In the future, the plan of the decision-makers is to increase the biogas production to fulfill the water board ambition of 40% energy self-sufficient but most importantly to reduce the cost of the sludge treatment. They have planned to install a Thermal Hydrolysis process in the plant next year. The Thermal Hydrolysis process is basically a procedure whereby bio-solids are pressure-cooked at high temperature to improve the digestibility of the bio-solids, usually before anaerobic digestion (Greg Knight, 2017). The process uses a steam to heat the sludge to about 165 C^o for 20 to 30 minutes. The benefits of this process mainly are to reduce the sludge size to about half and produce more biogas.

Wetterskip Fryslân future plan is to be 40% energy self-sufficient in 2020, and 100% energy self-sufficient in 2030. To do that Wetterskip Fryslân will not only investing in increasing the biogas production but also produce other type of renewable energy. Wetterskip Fryslân is committed to the installation of solar panels in its own areas and buildings. Particularly in the field of its wastewater treatment, there is room for the installation of approximately 40,000 solar panels (Wetterskip Fryslân, 2017).

In the end Sybren Gerbens has also mentioned that "the biggest challenge they are facing toward more energy self-sufficient is the lack of knowledge with the new technologies and having the right people in the board".

6.1.2. Dynamic interaction between the key actor-characteristics

Motivation

The motivation of Wetterskip Fryslan for the previous investment was mainly to reduce the treatment cost. Even when they start the biogas reactor in Leeuwarden WWTP, the first plan was to check if the project can make a good business case but then they do it anyway although the business case was not good. That happened under the pressure of the general water board, as Sybren Gerbens stated, "we did the biogas reactor to fulfill with the general water board energy ambition".

Their motivation for the future plan didn't change much. Although they have the ambition to be 40% energy self-sufficient and they have plans for increase their energy production, the Wetterskip Fryslan still concern more about the cost. Sybren Gerbens made it clear when he said that, "I need to show the board that this investment should be paid back in 15 years, so it will be approved".

Cognition

Wetterskip Fryslan has a good knowledge about the idea of reducing the energy consumption and being energy self-sufficient and how this can enhance The Netherlands renewable energy 2020 goal. This knowledge is mainly through the general water board pressure by sitting its own goal of 40% energy self-sufficient in 2020.

Wetterskip Fryslan learned about the implementation of renewable energy investments from other water boards through the participation in the Energy Factory Network. That allowed them to have an insight on the expected problems and learn from other water board's mistakes

Although Wetterskip Fryslan has also good knowledge regarding the technology available, mainly through their own interest and the cooperating with institutions and research centers, especially Wetsus, Wetterskip Fryslan does not have the knowledge and the experiences to operate these technologies.

Capacity and Power

Although investing in renewable energy projects require big financial resources, Wetterskip Fryslan never consider it as a problem as long as the project has a good business case and can be paid back within 15 years, and sometimes even if the business case is not good. Because finding a financial support for such a project is easy through different type of grant available.

All of the projects they did in the past and the projects they plan to do in the future are within their WWTPs's area, for the biogas production projects, and buildings, for the solar PV projects. So that the space need for these projects is available.

The problem that they had in their previous projects is finding the market for their biogas products but that one has been solved. But they are expecting to face the same problem when their biogas production increased.

The shortage of power they have is the lake of experience regarding the operation of some projects they are planning to do, for instant the operation of the Thermal Hydrolysis.

6.1.3. Conclusion on Wetterskip Fryslan

Wetterskip Fryslan is more concern on reducing the treatment cost of the WWTPs. They have a good idea and knowledge about the concept of energy self-sufficient, but they lack of a clear goal or ambition regarding energy self-sufficient, that due to the lack of intensity with the national governance regime. Wetterskip Fryslan is just following the general water board goal. Even when they started the biogas reactor in Leeuwarden, they only did it under the pressure of the general water board.

Although Wetterskip Fryslan's decision-makers have the ambition and the knowledge to be energy self-sufficient, the final decision is by the hand of the members of the boards. That why the decision-makers need to show a good business case for the Thermal Hydrolysis project in Leeuwarden WWTP, and it should be paid back in 15 years. And that what Sybren Gerbens said about the biggest challenge they are facing toward more energy self-sufficient, "We need the right people in the board".

Wetterskip Fryslan starts to release that to fulfill with the water board goal, they don't only need to increase their biogas production but also they need to produce more renewable energy from other sources, that due to the flexibility of renewable energy policy and the availability of the financial instruments. That why they planned to install solar PV on top of their building. The solar PV is also another way of reducing the cost.

6.2. Waterschap Vallei en Veluwe

Valley and Veluwe is a water board in the provinces of Gelderland and Utrecht, with area of (244.833 hectare). The water board is in charge of 16 wastewater treatment plants, half of them have a biogas reactor. The total capacity of Valley and Veluwe water board's WWTPs is (1.464.000 p. e.).

6.2.1 What they did until now and what are their future plans

History

The biggest two WWTPs are the one in Amersfoort and in Apeldoorn. Both plants have been built in the early 1970's. But they have constantly been improved and enlarged. The majority of the WWTPs are using the Carrousel Treatment System as a treatment technology for the wastewater, expect of the WWTP in Epe, which uses Nereda Technology, the first full scale plant that use Nereda Technology. Beside the activated sludge technology, Apeldoorn wastewater treatment plant uses a DEMON reactor for nitrogen removal. In addition, they have a Struvite reactor for Phosphorous removal in Amersfoort and Apeldoorn.

The Valley and Veluwe's decision makers are very interesting in the new technology and applying them in their WWTPs and keep themselves updated and collect all the needed information through three directions; first through STOWA, The Foundation for Applied Water Management, which is the knowledge center of regional water managers in the Netherlands. Secondly through their own scanning by participating in international conferences. For example, in August, 2017, the decision makers are going to New York for a conference on the resource recovery. Thirdly through their participation in the Energy Factory Network.

The last investment that the Valley and Veluwe water board did was in Amersfoort wastewater treatment plant. They rebuilt and changed most of the existing parts of plant to reduce energy consumption of the plant. They also installed the Energy and Raw Materials Factory. The motivation behind this investment was to be more sustainable and to fulfill the water board ambition of 40% energy self-sufficient in 2020. For this, they have invested 11 million Euro, which, as they expect, will be returned in 7 years.

Current Situation

On 17 June 2016, the Valley and Veluwe water board opened its new Energy and Raw Materials Factory in Amersfoort WWTP, and they are still working on optimizing it. The Amersfoort WWTP digests sludge of 4 WWTPs in Amersfoort, Brummen, Soest and Nijkerk. The sludge which comes to the plant is equal to (500,000 p. e.) First, they recover Phosphorous from the sludge through the Struvite reactor. Then they use Thermal hydrolysis to break up the bacteria and produce more biogas. The produced biogas goes to the power plant, which consists of three CHP power plants with total production of (1.5 MW). Valley and Veluwe water board was 71% energy self-sufficient in 2015, (Arcadis, 2016).

Future plan

The Valley and Veluwe water board has its own goal regarding the energy self-sufficient, which is to be fully self-sufficient in 2025. To achieve this, the Valley and Veluwe water board is planning to increase its production of biogas by opening a biomass digester for animal manure and other types of biomass. They will have a joint-venture project with a manure delivery company. The study that they have made shows that with this project, the water board can produce 120% of the energy needed for the WWTPs. Henry Van Veldhuizen, a decision maker at Valley and Veluwe water board stated that, "all the resources that we need are available, financially and the arrangement for permit to build the plant, but we need to make sure that the biomass delivery company can deliver the biomass and it should be at least 50% manure". He also stated that "being energy self-sufficient is not a challenge any more; it's a matter of time. Our next challenge is to be 100% self-sufficient from Solar and Wind energy. And the biogas we produce will be used as replacement for the petroleum products for transportation".

6.2.2 Dynamic interaction between the key actor-characteristics

Motivation

Previously, the motivation of Valley and Veluwe water board in investing in energy self-sufficient projects was to both reduce the treatment price and to fulfill with general water board energy ambition. But this motivation has been changed recently. Since they already accomplish more than 40% energy self-sufficient and they are expected to get 80% by the beginning of next year.

The motivation now is to be more sustainable in general. The first part is to be 100% energy self-sufficient by 2025. And the second part is the recovery of raw material. "As a government body, we feel that we are responsible to the community to work on sustainable projects", said Henry Van Veldhuizen.

Cognition

Valley and Veluwe water board has a very good knowledge regarding the idea of energy self-sufficient and its effect, first to The Netherlands renewable energy goal, secondly to make the board work sustainably and thirdly to reduce the wastewater treatment cost for the citizen.

Valley and Veluwe water board has a good cooperating with STOWA, who has a connection with the markets and research institutions to provide them with the information they need for the available technologies and projects. Beside that the decision makers are also attend many of the international conferences regarding new technologies.

Henry Van Veldhuizen, a decision maker in Valley and Veluwe water board, is the co-founder of the Energy Factory Network so that they can transfer and get experience and knowledge from other water boards.

Capacity and Power

For the previous investment, Valley and Veluwe water board needed (11 million euro) but that was not a problem. As the business case showed, the investment can be paid back in 7 years, which made it very easy to get fund for this project from different types of grants available. While for their future plan, building the digester for animal manure, they will need a huge investment. They already applied to get the SDE+ subsidy, , which offer (15 million euro) over 10 years.

Valley and Veluwe water board is just like Wetterskip Fryslan, they didn’t have problems regarding the place for their investment. All of their projects are built or will build in the area of their WWTPs. That was one of the reason they agreed on the joint venture project, they already have the place inside WWTP within an industrial area where they are allowed to build a biomass digester.

The shortage they have is the lake of experiences of working within a joint venture project with a privet company. And they are uncertain about the capability of the other company to deliver the biomass on time with a suitable amount of animal manure in it.

The other shortage is to find the market for their biogas. As Henry Van Veldhuizen stated ”we want to use the biogas as replacement of the petroleum products, we want to use it as fuel for the transportation of the cars and ships”.

6.2.3 Conclusion with regard to Valley and Veluwe

Valley and Veluwe water board had already achieved the general water board energy self-sufficient goal, but they continue to invest in increasing the energy and biogas production. That is because the decision-makers and the board member have the ambition of being more sustainable, especially when these investments will reduce the treatment cost for the long term. This ambition was the reason for the previous investments and will play an important rule for their future plans.

Valley and Veluwe water board wants to boost its biogas production by investing in another type of biomass, animal manure. This project is far from the main work of the water board but we can consider it as another type of renewable energy. This type of projects is possible for the water board due to the high flexibility of the governance regime, which does not strict an initiative with a specific type of renewable energy. The other thing that supports this type of projects is the availability of the financial instruments with the governance. For example, the Valley and Veluwe water board applied for SDE+ regarding to this project.

Valley and Veluwe water board future ambition is to be 100% self-sufficient from Solar and Wind energy. That mean they want to take this path, investing in solar and wind energy. They didn't do it yet but I think they will do in the near future. And as I mention before, the flexibility with governance regime will make it possible.

6.3. Waterschap Rijn en IJssel

Rijn and Ijssel is a water board, which manage the water in eastern Gelderland province and the southern part of Overijssel province with area of (195.000 hectare). The board has 13 wastewater treatment plants, 4 of them have anaerobic digester for biogas production. The total capacity of Rijn and Ijssel water board's WWTPs is (894.000 p. e.).

6.3.1. What they did until now and what are their future plans.

History

The last investment they made regarding energy efficiency was in 2013. The work mainly cover two part; firstly a maintenance on some part of the plant to reduce the energy consumption, and secondly the installing of thermal hydrolysis to increase the biogas production. There were two main motivation for this investment said Dr. Rudi Gerard, "Economically, to reduce the cost of the treatment and environmentally, to reduce our carbon foot print. But more economically than environmentally". Dr. Gerard also stated that the plans for any new investment are done through a team of specialist, who is in contact with markets, engineers and universities about the new possibilities and keep self-updated about the technology available and the possibility of increasing their energy self-sufficient percentage, and made business cases to check if these investments have economically benefits. The only problem with this investment was to find a market for the biogas. But this issue had been solved.

Current Situation

Rijn and Ijssel water board has 4 anaerobic mesophilic digesters in 4 WWTPs in Duiven, Etten, Oldburgen and Holten. These plants digest the sludge from the other 9 WWTPs to produce biogas equal to 27% of the total energy the water board need, (Arcadis, 2016). The water board doesn't have a power plant to generate electricity but instead it sells the biogas to other companies near the plants.

Future plan

The future goal of Rijn and Ijssel water board is to be energy self-sufficient in 2025. To achieve this, the water board has planned not only to increase their biogas production but also to look for the right mixture of sustainable energy sources, such as biogas, hydropower, solar and wind energy. For wind energy, the possibilities have been invented of four potential locations on or about our wastewater treatment plant. But the legislation and procedure for building a wind turbine can take around three years. And for the solar energy, the board is looking for the possibility of installing solar PV on the roofs of the WWTPs. These plans are also derived by two main motivations; economically and environmentally. But the priorities have been changed, said Dr. Gerard, "Before we used to do the investments with more economically and less environmentally motivation, but now it has changed to be more environmentally and less economically".

Dr. Gerard has also stated that, "The challenge that will face to achieve their energy self-sufficient goal is the public opinion, everyone wants to use more renewable energy but nobody wants to see the wind turbine from his back yard".

6.3.2. Dynamic interaction between the key actor-characteristics

Motivation

Rijn and Ijssel water board motivation for the previous investments was mainly to reduce the treatment cost and secondly to comply with general board energy goal. But their motivation has been changed. Now they have their own energy goal, which is to be 100% energy self-sufficient in 2025, and their motivation is to reach this goal and to reduce their carbon print. Dr. Rudi Gerard stated that "now, our motivation is more environmentally and less economically, and our board thinks that it is fine to spend money of the environment projects, even when it is not economically valuable".

Cognition

Rijn and Ijssel water board has a very good knowledge about the idea of energy self-sufficient and they are planning to reach 100% in 2025. The knowledge was in the beginning through the pressure of the general water board energy goal, and later it become theirs own ambition.

Rijn and Ijssel water board has a team of specialists, who have a contact with institutions, markets and expertise, to keep the board up to date with the technologies available and possible projects.

Capacity and Power

Rijn and Ijssel water board is just like the other water board, the financial support for any projects is not a problem.

All the previous projects were either as maintenances for the existing plants or to build a digester inside one of the plants, but for the future project, they will need to find place for it. Because some time it is not possible to install the wind turbine inside the plant. The first plan is to install 4 wind turbines. They already specify the place of them, which are in or around the plants.

Another issue is the permitting to the built the wind turbine. As Dr. Gerard stated, "it takes up to 3 years to get the approval to build a wind turbine".

The final thing is the public opinions, a lot of people don't want to see the wind turbine near their houses and Rijn and Ijssel water board will have to solve this issue.

6.3.3. Conclusion with regard to Rijn and IJssel

Until 2013, Rijn and Ijssel water board was more concern about reducing the treatment cost, and that was the main motivation for the investment they made. The motivations of the decision-makers and the board member have been change. Now they want to be more sustainable in general and want to be 100% energy self-sufficient in 2025.

Rijn and Ijssel water board 100% energy self-sufficient goal is seems difficult, since they are only 27% energy self-sufficient right now. That why, I think, they start to invest in other types of renewable energy (wind turbines and on roof solar PV). They already planned and nominate four potential locations to install wind turbines, two of which already got approval. They want to boost the energy production, and not depend only on the biogas production. As I mention before, these investments are possible due to the flexibility of the governance regime.

6.4. Case Comparison

In order to make an overall conclusion and answer the research question and sub-questions in chapter 7 and thus to achieve the aim of this research, it's important to make comparisons between the three cases with regard to the elements that have been studied in the previous chapter. Table 9 shows an overview of the comparative elements for the three cases.

Current Status of the Water Board

Valley and Veluwe water board achieved the highest level of energy self-sufficiency compared to the other two cases. And that is a result of different influential factors.

The first four elements, shows that the three cases have different area covered, capacity and number of WWTPs. For example, Valley and Veluwe has less area, more population, smaller number of WWTPs and larger number of biogas reactor, comparing to Wetterskip Fryslan.

The fifth element is discussing the technologies applied by each water board. Wetterskip Fryslan, used the Carrousel Treatment System for the purification of the sewage, the resulted sludge is then sent to one of the four anaerobic digesters to digest the sludge and produce biogas. Rijn and Ijssel water board like Wetterskip Fryslan uses anaerobic digesters, though they also installed Thermal Hydrolysis technology in one of the four anaerobic digesters, in order to increase the biogas production. And Valley and Veluwe water board also uses the Carrousel Treatment System for the wastewater in most WWTPs, except the WWTP in Epe, which uses Nereda Technology. Beside the activated sludge technology, the Apeldoorn wastewater treatment plant uses a DEMON reactor for nitrogen removal. They also have a Struvite reactor for Phosphorous removal in Amersfoort and Apeldoorn. That shows that Valley and Veluwe uses more technologies in its WWTPs than the other two.

Although the future plans of the three water boards are not that different, they all share the same goal. All of the three water boards want to invest in produce other type of renewable energy, not only biogas from sludge. Valley and Veluwe future plan is to produce biogas from animal manure. Rijn and Ijssel future plan is to install wind turbines and solar PV, While Fryslan wants to install solar PV beside the Thermal Hydrolysis in Leeuwarden WWTP.

Interaction process for the previous maintenance and renovation

The motivation of the decision-makers of all three water boards was the same, to reduce the treatment cost and to fulfill energy self-sufficient ambitions.

The cognition of the decision-makers regarding the possibility of WWTPs energy self-sufficiency was not the same. Although they all got the idea of energy self-sufficient under the pressure of the general water board of achieving 40% energy self-sufficient, they got knowledge regarding the technologies available in the markets and the possibility of applying them from different sources; Wetterskip Fryslan got the knowledge from the participation in the Energy Factory Network, Rijn and Ijssel has a team of specialists, who are responsible for that, while Valley and Veluwe has a good cooperation with STOWA, and their participation in the Energy Factory Network was more on sharing information and knowledge of their previous experience with similar investments.

Regarding the capacity and power for the previous maintenance and renovation, the three cases have similarities and differences. They all had enough space inside the WWTP for the investments, they all had problems in finding the market for their biogas, but the main difference was the financial factor. For example, Wetterskip Fryslan previous investment encountered problem in providing a good business case with maximum of 15 years payback period in order to get financial support, while Valley and Veluwe previous investment had a very good business case with 7 years payback period, and that made it easy to find financial support.

Interaction process for the future maintenance and renovation

The motivation of the three water boards for the future is different from each other. The motivation of Wetterskip Fryslan didn’t change a lot; they planned to invest in more energy self-sufficiency projects, to fulfill with the general water board goal, but they tend to focus more on reducing the cost. The motivation of Valley and Veluwe water board changed, they want to be more sustainable in general, not only to be 100% energy self-sufficient in 2025, but they also want to recover raw materials. Rijn and Ijssel water board motivation is also changed, on top of the goal to fulfill the requirements of the general water board, they set their own goal of being 100% energy self-sufficient in 2025.

The cognition of the decision-makers for the three water boards didn't change from the cognition of the previous maintenance and renovation.

The capacity and power of the three cases for future plans also have some differences. Wetterskip Fryslan still encountered problems to provide a good business case and find a financial support to their investment, besides that, Wetterskip Fryslan's shortage of power is the lack of experience regarding the operation of the Thermal Hydrolysis. On the other hand, Valley and Veluwe has better business cases for their future investment, which make it easier to find financial support, but they lake of experience regard working with a joint-venture project with other company. While Rijn and Ijssel's future plans will need good communications with people and communities, who stand against the built of the wind turbines.

Table 9: Comparison of the three cases.

Comparison Elements	Water Boards		
	Wetterskip Fryslan	*Valley and Veluwe*	*Rijn and Ijssel*
Current Status of the Water Board			
Area (Hectare)	346.000	244.833	195.000
Capacity (p. e.)	1.031.000	1.464.000	894.000
Number of WWTPs	29	16	13
Number of WWTPs that have a biogas reactor	4	8	4
Technologies use	Carrousel	Carrousel, Thermal Hydrolysis, Nereda, DEMON & Struvite	Carrousel & Thermal Hydrolysis
Percentage of energy self-sufficient in 2015	9%	71%	27%
Future plans	Thermal Hydrolysis Solar PV	Biogas from animal manure	Wind turbines Solar PV
Interaction process for the previous maintenance and renovation			
The Motivation	Reduce the cost fulfill with Board goal	Reduce the cost fulfill with Board goal	Reduce the cost fulfill with Board goal
The Cognation	General board pressure Energy Factory Network	General board pressure STOWA	General board pressure Team of specialists
The Capacity & Power	Similar	Similar	Similar Financial problems
Interaction process for the future maintenance and renovation			
The Motivation	Reduce the cost fulfill with Board goal	100% Energy in 2025 Sustainability	fulfill with Board goal 100% Energy in 2025
The Cognation	Energy Factory Network	STOWA	Team of specialists
The Capacity & Power	Similar lack of experiences	Similar	Similar public opinions

Chapter 7: CONCLUSIONS

Summarizing, the final answers to the research main question and sub-questions

Research Sub-Questions:

1. What is the the current situation of the WWTPs?

The three cases that I chose for this research are different in terms of area covered, capacity, number of WWTPs and the technologies used. Wetterskip Fryslan covers area of (346.000 Hectare) with (1.031.000 p. e.) and has 29 WWTPs, which 4 of them have biogas reactor. That allowed it to be 9% energy self-sufficient in 2015. Wetterskip Fryslan uses the Carrousel Treatment System as treatment technology. Valley and Veluwe water board covers area of (244.833 Hectare) with (1.464.000 p. e.) and has 16 WWTPs, which 8 of them have biogas reactor. That allowed it to be 71% energy self-sufficient in 2015. Valley and Veluwe water board uses different types of technologies for the treatment of the sewage; Carrousel Treatment System, Thermal Hydrolysis, Nereda, DEMON & Struvite. While Rijn and Ijssel water board covers area of (195.000 Hectare) with (894.000 p. e.) and has 13 WWTPs, which 4 of them have biogas reactor. That allowed it to be 27% energy self-sufficient in 2015. Rijn and Ijssel uses Carrousel Treatment System and Thermal Hydrolysis to treat the sewage.

If we compare Valley and Veluwe Waterschap with Wetterskip Fryslan, Valley and Veluwe has less area, more population and smaller number of WWTPs. That made the average size and capacity of the WWTPs of Valley and Veluwe larger than the average size and capacity of Fryslan. And that is a difference Albaladejo argued about when he wrote “It is advisable to design WWTPs to be as large as possible, attempting to concentrate effluent from several urban areas such that the energy consumption is 1/3rd that of small WWTPs” (Albaladejo et al., 2014).

Scale effects matter, and these, as I argue, lead to positive expectancies for developing a good business case, once they raised their ambitions and wanted to apply new technologies. This seems a logic explaining factor why Valley and Veluwe invested more in energy self-sufficiency, though they were as concerned about reducing costs. In Fryslan the business cases was not good enough to support large investments. That is the main reason besides average size of the

WWTP why Valley and Veluwe water board scores higher with regard to the energy self-sufficiency percentage compared to the others.

The comparison also shows that Valley and Veluwe uses more technologies in its WWTPs than the other two. Valley and Veluwe nowadays has double the number of biogas digesters compares to Fryslan, and that explains the difference regarding energy generation between the two. That is the main reason besides average size of the WWTP why Valley and Veluwe water board scores higher with regard to the energy self-sufficiency percentage compared to the others. Obviously the data gathered and analyzed for three water boards cannot be generalized for all water boards

2. *How did decision-makers plan maintenance and renovation in the past?*

For the three cases, the decision-makers motivation behind the previous maintenance and renovation was the same, which is reducing the treatment cost. Reducing the cost of the treatment can be done in different ways; establish a biogas reactor and produce energy, reduce the energy consumption, or through using a cheaper technology for the end of pipe treatment. This research shows that, in the past, each water board used different method to reduce the treatment cost; Wetterskip Fryslan found that it is cheaper to pay for end of pipe treatment, and establishing a biogas reactor is not financially beneficial, while Valley and Veluwe water board found that investing in the production of the biogas and increasing the energy efficiency projects have good business cases. And that, as I argue, is the reason why Valley and Veluwe water board started to invest in energy self-sufficiency before the other two and that also why it scores higher with regard to the energy self-sufficiency percentage compared to the others.

The motivations have been changed in the resent years, the national government renewable energy policy put pressure on the water boards, binding them to be 40% energy self-sufficient in 2020. And this, as I argue, is the main reason why some regional water boards start to invest in more energy self-sufficient even though the business case shows that it not financially beneficial, Wetterskip Fryslan case.

3. *How do decision makers think about the idea of energy self-sufficient WWTP? And what are their future plans to increase the energy self-sufficiency?*

All the three cases believe that achieving energy self-sufficient for the regional water board is possible. Each one has its own goal of achieving that beside the water board goal of 40% energy self-sufficient in 2020; Wetterskip Fryslan goal is to be 100% energy self-sufficient by 2030, Valley and Veluwe water board goal is to be 100% energy self-sufficient by 2025 and Rijn and Ijssel water board goal is to be 100% energy self-sufficient by 2025.

Although each case has different plan to increase its energy self-sufficiency, they all planned on investing in other types of renewable energy, not only the production of biogas. Valley and Veluwe future plan is to produce biogas from animal manure. Rijn and Ijssel future plan is to install wind turbines and solar PV, While Fryslan wants to install solar PV beside the Thermal Hydrolysis in Leeuwarden WWTP.

Investing in increasing energy production from other sources of renewable energy is a good way to boost the energy production of the water board and achieve energy self-sufficient, especially for the water board that investing in the production of the biogas is not financially beneficial. But we can't conceder it as energy self-sufficient for WWTPs, since they cross-boundary with other sectors, which are not related to the WWTPs.

4. *What are the current policies and the set requirements for the WWTP?*

According to the 2014 amendment Activities Decision, WWTPs don't need any water permit any more for the discharge of the purified water into surface water (SKN, 2014). Regulations are covered in general rules for all treatment plants. The Activities Decision also stated that if a WWTP purifies purely urban waste water, which is supplied via the municipal sewage system, no environmental permit is required. But for some activities, an environmental permit is still required (Ministerie van Infrastructuur en Milieu, 2017a), as shown in chapter 4, (page 32&33).

Although there is no permit needed for the discharge of purified water into surface water, it should meet specific requirements. The European Commission Directive (91/271/EEC) and the improved version (98/15/EC) put guidelines for the European countries regarding the requirements to discharge the purified water. Until 2014, the Netherlands was not complying with the EU directive. As shown in table 6, (page 35), the 2007 general rules for establishments stated that the Netherlands government used more strict limitations with regard to the concentration of Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) and Total suspended solids (TSS), while less strict limitations has been used with regard to the concentration of Total phosphorus and Total nitrogen.

In 2014, the Netherlands government has new regulations with regard to the discharge of the purified water into the surface water. As shown in table 6, (page 35), the new regulations have more strict limitations than the previous one in terms of the concentration of Total phosphorus and Total nitrogen, and less strict limitations in term of the COD, while the BOD and TSS stay the same. Currently, the Netherlands government complies with the EU directive. They use the same limitations in terms of the concentration of COD, Total phosphorus and Total nitrogen, and more strict limitations in terms of BOD and TSS.

These changes with discharge limitations shows uncertainty about the future regulations, and that, as I argue, can affect the water board's energy self-sufficiency goal negatively if the Netherlands governments applied more strict regulations in the future.

5. What is the current national governance context?

The national governance context shows coverage of different level and scales, with participation of representative actors from government, employers, trade unions, nature and environmental organizations, civil society organizations and financial institutions, and if needed a new actors. Policies and instruments are based on negotiated agreements which pushed coherence between actors from different levels.

The national governance context is also based on high flexibility in terms of the goals and the use of the instruments. That allows the initiatives to choose their own goal and the method to contribute to the national renewable energy goal.

The national governance context was evaluated medium in terms of identifying the problems and instruments needed for some types of renewable energy. The national goverment gives less attention to project with regards to biogas project, and focused more on Solar PV and Wind turbine projects, and although a variety of policy instruments applied, there is an absence of regulatory and enforcement.

The national governance context shows low intensity in term of the resources available. Some policy instruments don't have any financial resources to support it or it's not clear about the resources so that there are no enough financial resources to cover the high initial costs of big projects, for instant, biogas projects.

The research main question:

Can existing WWTPs be energy self-sufficient and at the same time comply with the strict emission-regulations and to the extent that this is within reach, what will be the influential circumstances and factor in decision-making on WWTPs in the Netherlands?

The answers of the sub-questions indicate that being energy self-sufficient for existing WWTPs (or water boards) in the Netherlands is possible and it within reach for the short or long term, depending on different factors that influence the decision-makers. The first factor is the scale of the WWTP, and that, as argued, can lead to positive expectancies for developing a good business and make it easier to invest in energy self-sufficient projects. The second factor refers to costs. As argued, there are not enough financial resources available, in the national policy, to cover the high initial costs of big projects, and that makes it difficult, especially for the small scale WWTP, to invest in energy self-sufficient projects. The third factor is the pressure of the national government. The 40% energy self-sufficient agreement forces the water board to invest in energy self-sufficient projects and that, as argued, is the main reason why some regional water boards start to invest in more energy self-sufficient even though the business case shows that it not financially beneficial. The fourth factor is the uncertainty with the future discharge regulations, which, as argued, can affect the water board's energy self-sufficiency goal negatively if the Netherlands governments applied more strict limitations in the future.

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