BLUE ENERGY

Barriers of up-scaling Salinity Gradient Power

Master Thesis

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Master Thesis
Partial Fulfillment of the Requirements for
Master of Science 'Water and Coastal Management'
and
Master of Science 'Environmental and Infrastructure Planning'

Supervised by: Dr. Margo van den Brink, University of Groningen, the Netherlands
Dr. Thomas Klenke, University of Oldenburg, Germany

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ABSTRACT

Blue Energy, a new and renewable energy innovation uses salinity gradient differences to gain energy by applying the method reverse electrodialysis (RED). The technology generates power from mixing waters with different salinity. The Dutch energy transition requires new and innovative technologies to reach renewable energy targets in the future. Different barriers and challenges could delay an up-scaling of Blue Energy. This research aims to develop a classification of such barriers. Developed barriers are based on transition theory, integrated energy landscapes, and institutional barriers. This classification is translated into the conceptual framework for this research. The framework is used as a tool to identify context specific barriers of up-scaling Blue Energy in the Netherlands. The six main categories of barriers are (1) technological barriers, (2) sense of urgency and timing, (3) spatial barriers, (4) awareness as a barrier, (5) finical barriers, and (6) environmental barriers. The approach could also be used elsewhere for renewable technologies that are currently still insignificant in terms of energy production. Identified stakeholders contribute knowledge and ideas via interviews as qualitative research. The current technology is not yet mature enough for a large-scale implementation, although the overall potential to produce energy is enormous.

Keywords: Blue Energy, salinity gradient power, energy transition, up-scaling technological innovations

ZUSAMMENFASSUNG

Blue Energy ist eine erneuerbare Energien Innovation, die den veränderten Salzgehaltgradienten im Wasser nutzt, um Energie zu erzeugen. Dabei wird die Methode reverse electrodialysis (RED) genutzt. Die Technologie erzeugt Energie, indem Wasser mit verschiedenem Salzgehalt vermischt wird. Die Niederländische Energiewende benötigt neue und innovative Technologien um zukünftig die Nutzung von erneuerbaren Energien zu erhöhen. Verschiedene Barrieren und Herausforderungen könnten ein Weiterentwickeln der Technologie hinauszögern. Diese Forschung hat das Ziel, eine Klassifikation dieser Barrieren zu entwickeln. Diese basieren auf 'transition theory', 'integrated energy landscapes' und 'institutional barriers'. Die Klassifikation ist in einen Konzeptionellen Rahmen übersetzt. Dieser Rahmen wird als ein Werkzeug genutzt, um kontextspezifische Barrieren einer weiteren Entwicklung von Blue Energy in den Niederlanden zu identifizieren. Die sechs Hauptkategorien sind, (1) technische Barrieren, (2) Gefühl für Zeitpunkt und Dringlichkeit, (3) räumliche Barrieren, (4) Sensibilität und Bewusstsein als Barrieren, (5) Finanzierung als Barriere, und (6) umweltbedingte Barrieren. Die Vorgehensweise könnte auf andere erneuerbare Technologien bezogen werden, die aktuell noch nicht signifikant in Bezug der Energieproduktion sind. Identifizierte Akteure steuern Wissen und Ideen mit Hilfe von Interviews bei, durch die Nutzung qualitativen Untersuchungen. Gegenwärtig kann die Technologie als noch nicht ausgereift genug beschrieben werden, um für einen Großeinsatz genutzt zu werden. Jedoch ist das generelle Potenzial, um Energie zu produzieren sehr hoch.

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LIST OF ABBREVIATIONS

AEM	Anion exchange membranes
CEM	Ion exchange membranes
Cl-	Chloride
CO_2	Carbon dioxide
EU	European Union
GHG	Greenhouse gas emission
kW	Kilowatt
kW/h	Kilowatt hour
MJ	Megajoule
MW	Megawatt
Na+	Sodium
NaCl	Sodium chloride
PRO	Pressure retarted osmoses
RED	Reverse electrodialysis
SDE	Dutch subsidy program
SGP	Salinity gradient power
TW	Terawatt
W/m^3	Volume power density

1. INTRODUCTION

During recent years, renewable energies got increased attention and a rising importance in society is notable. In 2009, the EU Renewable Energy Directive stated that by the year 2020, 14 percent (16 percent in 2023) of the Dutch energy consumption must be derived from renewable sources. This agreement is based on a joint decision by the governments of the European countries and the European Parliament (Ministry of Economic Affairs, Agriculture and Innovation, 2011). Currently, as specified in the Renewable Energy Report of the Netherlands (2010) only 3.7 percent of renewable energy consumption is realized (Statistics Netherlands, 2010). Therefore, sustainability and sustainable development are considered as top Dutch priorities (Statistics Netherlands, 2010).

The Netherlands, such as many other European countries has set various goals and objectives to achieve a more sustainable usage of energy, which can be summarized as an ongoing 'energy transition'. The Netherlands needs innovation to lower the impacts of climate change and to eventually aim towards an energy transition by using more renewable resources. Consequently, the country will face strict standards, such as a change in energy consumption in the near future. Subsequently, different national boards and administrations like the Ministry of Infrastructure and Environment, or the Ministry of Economic Affairs are looking for opportunities to reach the defined national targets (Ministry of Economic Affairs, Agriculture and Innovation, 2011; Overloop et al., 2010), as the world's energy consumption is still accelerating rapidly (BP, 2014).

An innovative approach towards new development in the renewable energy sector is called 'Blue Energy'. Blue Energy is considered to be a Dutch innovation (Willemse, 2007) and a promising approach to gain electricity. Blue Energy (referring to salinity gradient power) is a sustainable energy source, based on salinity differences in sweet (river) water and salt (sea) water. When sea and salt water intermix, the water will defuse until the salinity gradient is equal. Blue Energy uses membranes, placed between both kinds of water. The diffusion can be controlled and energy can be gained. Furthermore, salinity gradient energy can be stored and used, due to a controlled water outflow (Vermaas et al. 2010). This will particularly contribute to the energy production when there is a low production of wind or sun energy, which cannot be controlled.

According to the director of a Dutch Blue Energy pilot plant, latest calculations are expecting a worldwide theoretical potential of up to 2.6 TW. Translated to a smaller scale, each cubic meter of river water, mixed with the same amount of seawater (assuming 30‰ salinity) can generate 1.4 MJ of energy (Post et al., 2008). This would even exceed the total global energy demand (Acuna Mora & de Rijck, 2014). The current development of Blue Energy in the Netherlands is entirely based on the principle of reverse electrodialysis (RED) (Helsen, 2015). The first RED power plant has recently been opened on the Afsluitdijk in the Netherlands and is operated by the company REDstack. The pilot plant produces up to 50 kW/h of Blue Energy and aims to demonstrate the technical feasibility under real life conditions. It will use fresh water from the IJsselmeer and salt water from the Wadden Sea (REDstack, in Dutch Water Sector, 2014). REDstack is the first company worldwide generating Blue Energy based on RED in a power plant.

The Netherlands as a low-lying country with no mountainous areas had always a limited potential to generate energy from water flows (Overloop et al., 2010). Hence, present development of a technology that is independent of flow velocity is not surprising. Nevertheless, hydropower - on a worldwide scale – is an important source of energy. Approximately 20% of the world´s electricity generation derives from hydropower sources (International Hydropower Association, 2010). Overloop et al. (2010) demonstrate that hydropower is usually associated with reservoirs and large dams in mountain areas. Lowland areas, which can be found in river deltas in countries as the Netherlands or Belgium, are in general not suitable for this type of energy production (Overloop et al., 2010). New developments and advancements within hydropower innovations are therefore required.

Different renewable energy options are already available and well-known, such as solar energy, wind energy or geothermal solutions. However, Blue Energy is yet not sufficient enough even though the technology seems to be very promising and could contribute to the wider transformation in energy supply. Therefore, the long-term process and complexity of an energy transition (de Boer & Zuidema, 2013) will demonstrate that a development and finally an up-scaling of Blue Energy could be a promising shift in the future.

1.1 PROBLEM STATEMENT AND RESEARCH QUESTION

Blue Energy and the technology of RED is a rather new approach with limited focus on planning practice, its environment or management yet. So far, most attention has been given to technical issues with numerous literature on the technology itself (e.g. Post et al., 2010, Vermaas et al., 2012). However a lack of implementation in planning practice is notable. Blue Energy can be considered as not mature enough for large-scale implementation due to its lack of attention to non-technical and planning related issues. Therefore this thesis aims to identify and develop a classification of challenges and barriers towards an up-scaling of the technology and to recognize the importance of the energy transition, the (local-) context, institutions and further 'non-technical' concerns.

Relating Blue Energy to transition theory and the Dutch energy transition, it has not yet developed into a well-recognized source of energy (Overloop et al., 2010), which could lead towards an up-scaling of the technology. However, as an expert and project manager of Wetsus explains, the Netherlands wants to be a frontrunner in the field of Blue Energy. Barriers therefore need to be identified to categorize current and future challenges of Blue Energy. Based and derived from this knowledge, the research question is formulated as:

> *Which barriers of Blue Energy can be identified, (using reverse electrodialysis) – to be able to up-scale the technology towards a well-established part of the current renewable energy transition in the Netherlands?*

Therefore, this thesis aims to:

1. Develop an assessment tool within the conceptual framework by reviewing different bodies of literature to eventually develop a classification of barriers.
2. Identify barriers that are facing a large-scale implementation of Blue Energy in the Netherlands.
3. Discuss and evaluate the identified barriers to place Blue Energy within the Dutch energy transition.

1.2 RESEARCH STRATEGY

Different academic theories will be used and conceptualized for this research. First of all, the energy transition will be specified to highlight the importance of present transformations in the energy system, followed by transition theories specifically the multiphase and the multilevel concept to set the base for changes in the energy system. Furthermore, the notion of integrated energy landscapes will be introduced to emphasize the importance of the integrated local context and conclusively, institutional barriers will finalize the theoretical framework. All theories have the communality to give concepts and ideas of barriers. The developed conceptual framework will eventually be used as a set of criteria to identify context specific barriers of Blue Energy. The conceptual framework will illustrate the linkage of different barriers and the importance and integration (de Boer & Zuidema, 2013) of different lessons learned in the theoretical framework.

1.3 RESEARCH DESIGN

The technology of Blue Energy has been explored and analyzed to frame this research. In general two main analytical steps have been conducted. Foremost, the broader debate about Blue Energy in the Netherlands will be discussed and analyzed. A description of the technology and an in-detail analysis of important stakeholders, followed by the overall Blue Energy discussion on European level are important, before introducing the case at the Afsluitdijk power plant at the IJsselmeer. The second step will be to apply the conceptual framework of this research to identify context specific barriers of Blue Energy. Finally, these barriers will be discussed.

It is necessary to define the use of the term Blue Energy for this research. On European level (EU Commission, 2014) Blue Energy refers to all kind of water related energy production. However, Blue Energy in the Netherlands refers to the technology of salinity gradient power, as explained by an policy studies expert at a Dutch energy research institute. Thus, this research will henceforth use the term Blue Energy by defining it as salinity gradient power, using the method RED.

1.4 IMPORTANCE & RELEVANCE

Climate Change is a global problem that each country has to face. Important issues are the decreasing snow cover in the northern hemisphere, as well as global average sea level changes (IPCC, 2013). However, climate change itself is an uncertainty and almost impossible to predict. One approach is a transition towards a more renewable and sustainable future, as an option to cope with uncertainty of current energy sources. Today, fossil fuels are a major contributor to climate change, as they are not renewable and moreover even limited.

This thesis is focusing on the method titled RED (Vermaas et al., 2012). RED is considered to be one of the latest technologies and got increased attention recently. Research and literature is limited, nevertheless more knowledge and research is highly important in this field of science to be able to contribute to a renewable and sustainable future.

RED could potentially develop to a much bigger scale in the future. According to Overloop et al. (2010) in his publication on water and energy objectives in lowland areas from 2010, that they are not going to discuss "(…) hydropower from a salinity gradient (…) as this technique currently not mature enough for practical implementation" (Overloop et al., 2010 p. 1888). This statement highlights that salinity gradient power has not been of significance regarding energy objectives in 2010, but its importance is increasing.

This research aims to contribute to the current Dutch renewable energy debate. Relevance can therefore be seen from a *scientific* point of view with attention on renewable energies, energy and energy transition, energy landscapes but also barriers in the sense of institutional debates. A shift from energy dependency towards a local energy security (Hauff et al., 2014) is aspired and can be recognized.

Furthermore, the importance of *societal* significance can be identified. Additionally to the governmental energy goals, according to a local energy coordinator, an increasing number of Dutch citizens are interested in renewable energy solutions and innovations. A tool to assess and identify a list of barriers of Blue Energy could potentially be transferred and translated to other renewable energy innovations in the future. Thus, if Blue Energy could overcome the identified barriers and contribute to the overall energy mix of the Netherlands and likewise promote future energy targets, it could be used as an example or model for forthcoming innovations.

1.4 OUTLINE OF THE RESEARCH

This thesis will start by giving an insight and clear explanations about the different concepts that are important for the theoretical background of this research. This will include a conceptualization of the energy transition, transition theory, integrated energy landscapes, as well as institutional barriers.

The third chapter contains the research methods and strategy used for this research, including a detailed description of interviews, as well as a conference on the current international Blue Energy debate. Two different analytical chapters will frame this research. On the one hand, Blue Energy will be set in its context to analyze the broader debate and to introduce stakeholders and the technology from literature and policy review as well as elaborated interviews. On the other hand context specific barriers of Blue Energy will be identified.

The discussion of identified barriers and a conclusion with recommendations for further research will finalize this thesis.

2. THEORETICAL FRAMEWORK

The following theoretical chapter is discussing different academic concepts, referring to the idea and technology of Blue Energy. The overall aim is to develop a classification of barriers. Therefore different bodies of literature will be reviewed to identify concepts and main barriers that are significant to develop a tool to classify context specific barriers of Blue Energy. According to the reviewed literature all lessons will be highlighted and assembled to finally have one assessment tool. Therefore, most important outcomes and theories will be presented and relationships will be illustrated. First, the energy transition will be conceptualized to understand the importance and central ideas of moving towards renewable energy resources and the significance of barriers themselves. Additionally, transition theories and related concepts, such as the multiphase and multilevel transition models will be introduced to elaborate which barriers are important according to significant authors (e.g. Loorbach; van der Brugge; Rotmans) of transition literature. Subsequently, integrated energy landscapes will be analyzed, to highlight what according to them (e.g. de Boer; Zuidema) can be perceived as barriers towards and up-scaling of a technology. Followed, institutions will add valuable notions of barriers.

Eventually, this theoretical background will lead to the conceptual framework of this research by translating lessons and ideas of barriers from theory to an applied framework to finally identify barriers towards an up-scaling of Blue Energy.

2.1 ENERGY TRANSITION

The overall context of this research is the ongoing energy transition in the Netherlands. The energy transition is a promising and apparently obvious solution to move towards a 'post-oil-era', an era of renewable energy solutions and therefore an era of less disadvantages from energies (Rojey, 2009). Many energy concerns have risen lately and problems facing our today's energy sector are considered to be serious (Rojey, 2009; Weaver et al., 2000). According to Rojey (2009), particularly alarming is the peak oil production; tensions over oil supply with an increasing demand and therefore price instability. Furthermore, the impacts of fossil fuel energy production on the environment on a local and on large scale and the danger of global warming initiated by CO_2 emission are immense (Rojey, 2009).

The motivation and reason for an energy transition has been summarized in Morris & Pehnt (2014). They divide the motives into following groups: (1) fighting climate change, (2) reducing energy imports, (3) stimulating technology innovation and green economy, (4) reducing and eliminating the risk of nuclear power, (5) energy security, (6) strengthening local economies and providing social justice. The authors argue that in this regard, technology and innovation is a key issue. According to Hauff et al. (2014) the security of energy supply and therefore the decrease of dependency on other countries as well as to expand the supply to meet future energy needs can be considered as most important (Hauff et al., 2014). Moreover, many countries see the rising environmental awareness and the loss of public acceptance of 'non renewable energies' as an important factor (Hauff et al., 2014).

Opponents of nuclear power initially used the term energy transition. Their attempt was to clarify that also alternative energy supplies are possible (Morris & Pehnt, 2014). The idea of an energy transition already popped up in the early 1980s. However groundbreaking publications only started to rise in the late 1990s (Morris & Pehnt, 2014). Publications before then, such as the Club of Rome´s report Limits to Growth (1972) (Meadows et al., 1972), were lacking specific solutions and mainly consisted of warnings. The energy transition concept however "(…) was one of the first attempts to propose a holistic solution, and it consisted of renewable energy and energy efficiency" (Morris & Pehnt, 2014 p. 52).

The shift towards renewable energies can be considered as a difficult challenge. Renewable energies can play an important role within this transition. The recent transition towards renewable energies, which is still ongoing involves many different important factors. Cheaper renewable technologies are developing, civil awareness is rising and even different user and consumption patterns arise (Loorbach et al., 2008). The concept of an energy transition is a transition moving from one stable use of energy towards another new energy resource. Different authors (Hauff et al., 2014; Loorbach et al., 2008; Morris & Pehnt, 2014; Rotmans, 2001) have adapted the concept in recent literature. Different definitions are available but are most comprehensively specified in the energy dictionary (2006), where the energy transition is defined as:

"(...) a change in the primary form of energy consumption of a given society; e.g., the historic transition from wood to coal and then to oil and gas in industrial Europe; the current shift from biomass fuels to commercial energy in some areas of the developing world" *(Dictionary of Energy, 2006)*

To summarize this in other words for the context of this research: the current energy transition describes the change of energy supply from fossil fuels and nuclear power towards renewable energies and in the words of Smil (2004) "(...) a period of passing from one configuration of prime movers and dominant fuels to a new setup" (Smil, 2004 p. 549). Regenerative sources are wind- and hydropower, solar energy, geothermal energy and also Blue Energy. Energy supply and demand are quantifying and qualifying a given state of an energy system (Grubler, 2006 in Dictionary of Energy, 2006). Thus, also Blue Energy can be considered as a part of the broader ongoing Dutch energy transition. Different important energy transitions already occurred and will occur in the future (Grubler, 2006 in Dictionary of Energy, 2006).

To give an example, the Netherlands from the historical context used to rely on coal for energy production. Eventually they moved towards oil and natural gas, which are most important nowadays. Rotmans et al. (2001) analyzed the dynamic mechanism behind this energy transition with focus on the role of the government. The authors concluded, that speed seems to be the most striking aspect of this particular energy transition in the Netherlands, as the entire transition seemed to be happening in just six years. However, Rotmans et al. (2001) identified that the energy transition started approximately after the Second World War. Rising awareness of gas as a cleaner source was one of the starting points. Dutch coal mines became unprofitable due to rising competition from other countries (Rotmans et al., 2001).

Smil (2010) highlights and demonstrates that a transition from a fossil fuel dominated energy supply to a non-fossil fuel relying world by harnessing renewable energy is desirable and furthermore even inevitable (Smil, 2010). However, renewable energies are depended on regional and local limits, such as geographical and environmental factors. Different renewable resources have already been developed and evolved as valuable energy source (Smil, 2010). Yet, well-known renewable sources proof to be not sufficient enough. For instance, Verbong & Geels (2007) investigated the ongoing energy transition with attention to, amongst others, wind energy. They describe that the rise of wind energy started with a bottom-up approach of the Danes, starting with small-size turbines (Verbong & Geels, 2007). A gradual up-scaling followed later. However, nowadays the image of wind energy is weakened, due to doubts from environmental groups and local residents, who consider wind turbines as 'noisy, ugly objects' (Verborg & Geels, 2007).

Blue Energy is not very well-known yet but could be a necessary system innovation. It is a practice a shift from fossil fuels towards a more sustainable future in the Netherlands. Rojey (2009) exemplifies that a move to a sustainable energy system involves radically changing our habits, energy production as well as consumption structures. One example to change the current energy production system is the development of Blue Energy. Therefore a classification of barriers is necessary to assess Blue Energy as a new innovation in the Dutch energy transition.

Different authors have adapted the idea of barriers especially connected to adaptation (Biesbroek et al., 2011) during the recent years. According to Biesbroek et al. (2011) Barriers are defined as "(…) those conditions and factors that actors experience as impending, diverting, or blocking the process of developing and implementing (…)" (Biesbroek et al., 2011 p. 182). Biesbroek et al. (2011) argue that especially social barriers are difficult to research, as they cannot be observed or measured like technical barriers (Biesbroek et al., 2011). People facing such barriers in their daily life can only report them. Therefore qualitative research is of particular importance. Actors need to be able to manage barriers in order to be able to develop further (Biesbroek et al., 2011). Various examples of barriers are uncertainty, cost of adaptation measures, unawareness or the lack of attention (Biesbroek et al., 2011).

Different forms of renewable energies are already well-known. However, Blue Energy is not yet part of the Dutch energy system, as an up-scaling is difficult due to barriers. It is not an easy task to get a transition going. The review of following literature will show, which lessons can be learned to finally translate them into barriers of a development and transition. These barriers will finally be discussed in the classification of barriers in the conceptual framework.

2.2 TRANSITION THEORY

According to transition theory, different barriers of a development to up-scale a technology can be identified. First of all, transition theory will be studied to emphasize important barriers according to recent transition theory literature. Therefore it will be highlighted what transitions are, how they work and finally what recent authors (e.g. Loorbach, 2007; Rotmans et al., 2001; van der Brugge et al., 2005) define as barriers in transitions.

A transition occurs when a dominant structure in society is under pressure by an external change in society or endogenous innovation (Loorbach, 2010). The transition concept originates in biology science and population dynamics (Rotmans et al., 2001). Rotmans et al. (2001) define a transition as "(…) as a set of connected changes, which reinforce each other but take place in several different areas, such as technology, the economy, institutions, behavior, culture, ecology and belief system" (Rotmans et al., 2001 p.16). Loorbach (2010) adds, that transitions can be considered as processes of "(…) structural change in societal (sub-) systems such as energy supply, housing, mobility (…)" (Loorbach, 2010 p. 166). It is a structural change of how a system operates (van der Brugge et al., 2005).

Transitions come about when external changes, or innovations in society put pressure on dominant structures in society (the so called regimes) (Loorbach, 2010). Transitions are multi-dimensional and several developments at different dynamic layers must occur simultaneously (Rotmans et al., 2001). Transitions are a result of slow social change, as well as the outcome of short-term events or fluctuations (van der Brugge et al., 2005). The process is considered to be long-term (25-50 years) (van der Brugge et al., 2005), where different developments and events positively reinforce each other (Rotmans et al., 2000).

For the theoretical background it is important to understand how transitions come about and how they are able to manage barriers. Two main concepts are therefore important, namely (1) the multiphase concept, which composes a pre-development stage, a take-off-, acceleration- and stabilization phase and (2) the multilevel concept, which describes innovation in niches, a dominant regime and an external landscape. A change in energy supply could be an example of a multiphase model. First of all, the multiphase concept will be analyzed before moving to the conceptualization of the multilevel concept.

2.2.1 THE MULTIPHASE CONCEPT

A multiphase transition follows different stages. In total, four different phases, which are a simplification of a transition but however, can be identified. They are usually displayed in an S-curved profile (figure 1) (Loorbach, 2007; Rotmans et al., 2001; Rotmans & Kemp, 2009a; Van Buuren & Loorbach, 2009; van der Brugge, 2004).

1. *Pre-development phase*

   A stage of a dynamic equilibrium with no visible change of the status quo. Experimentation is key at this phase with pilot-projects, which could help to gain social acceptance, learning towards solutions.
2. *Take-off phase*

   The process of change gets under way because the state of the system itself begins to shift. The status quo is changing and the speed is increasing
3. *Acceleration (breakthrough) phase*

   A change is now happening and gets visible in different societal domains with additional reaction to each other.
4. *Stabilization phase*

   The speed of change is now decreasing again. A new equilibrium has developed.

Subsequently, Rotmans et al. (2001) specifies that different social processes happen during the various phases. Speed and acceleration are relative with slow as well as fast development (Rotmans et al., 2001; van der Brugge et al., 2005). The transition usually lasts for at least 25 years.

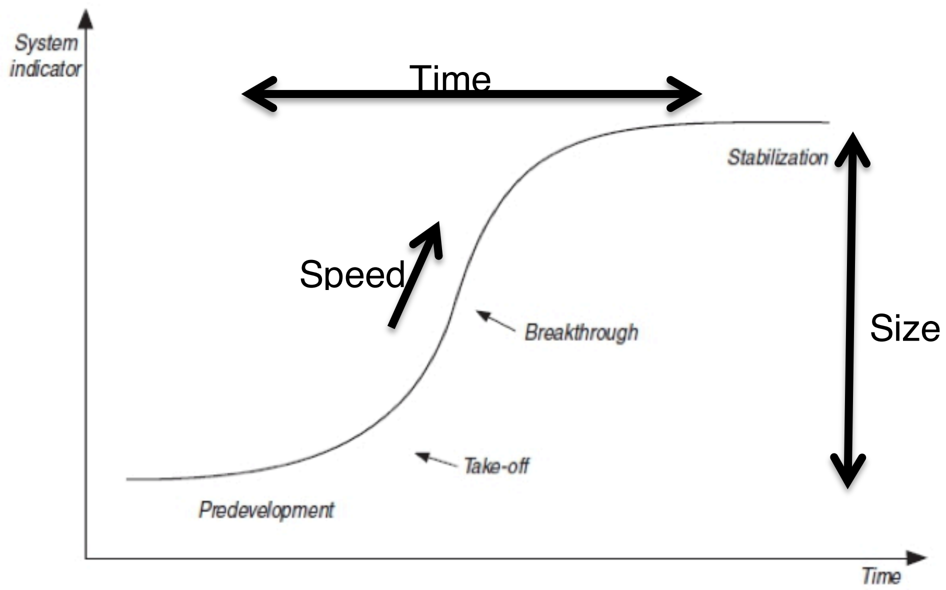

Fig. 1 The multiphase concept - S-curved model (based on Loorbach, 2010 and Rotmans et al., 2001)

The new reached equilibrium is dynamic with no status quo. The change is non-linear with a total of three dimensions (Rotmans et al., 2001): the speed of change; size of change; and time period of change (fig. 1).

2.2.2 THE MULTILEVEL CONCEPT

While analyzing societal systems it is necessary to take the whole system, its environment and the dominant structure of the system into account. The second transition concept, the multilevel concept (Geels & Kemp, 2000; Loorbach, 2007; Markard & Truffer, 2008; Rip & Kemp, 1998; van der Brugge et al., 2005) is therefore used. The concept has been developed by Geels (2000) who makes a distinction between niches, regimes and landscapes (micro, meso, macro level). As demonstrated by van der Brugge et al. (2005) the concept indicates the division between the different levels at which transitions take place (van der Brugge et al., 2005) and the interplay of processes at all levels (Markard & Truffer, 2008).

The *macro*-level, the societal landscape is determined by changes in economy, politics, population dynamics, natural environment on a macro scale. This level responds relatively slow (van der Brugge et al., 2005).

The *meso*-level (regimes) contains institutions as well as rules and norms and interests that underlie strategies set by companies, organizations and institutions in order to preserve the status quo. This level is more about optimization and protecting investments rather than system innovations (van der Brugge et al., 2005).

The micro-level or niche-level involves individual actors, alternative technologies as well as local practices. New ideas and innovations lead to deviations from the status quo (Kemp et al., 1998; van der Brugge et al., 2005) (fig. 2).

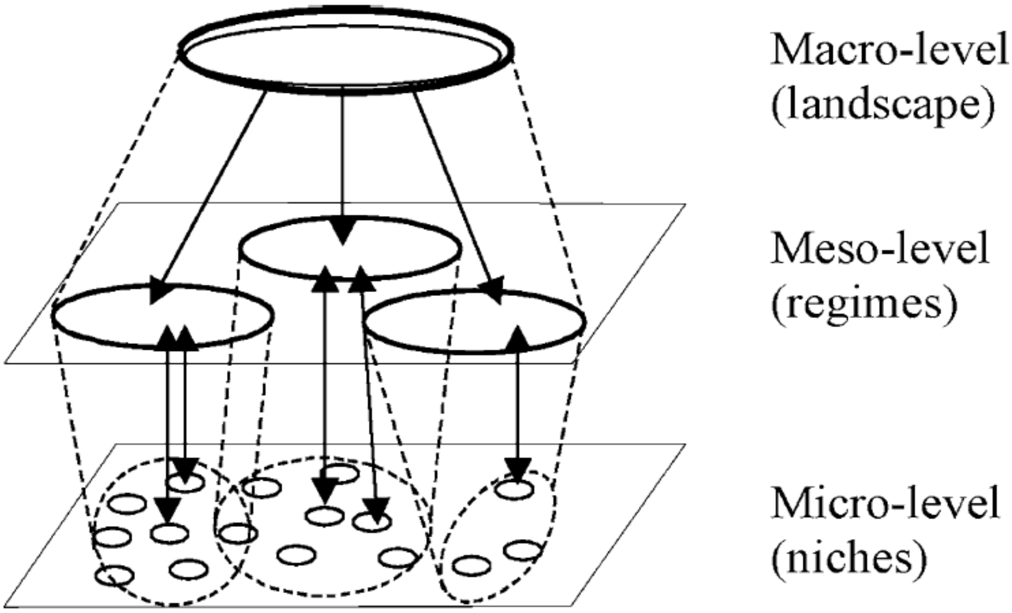

Fig. 2 Multi-level concept (Geels and Kemp, 2000 in van der Brugge et al., 2005)

Transitions often appear to be bottom-up through experiments on the niche (micro) level. Other levels consequently have to create room for experiments. If so, experiments can eventually broaden and move to larger scales (Kemp, et al., 1998; Loorbach, 2007; Rotmans et al., 2001).

2.2.3 LINKING CONCEPTS

Both concepts need to be linked to finally elaborate existing barriers according to transition theories. Highlighting those is important to be able to detect challenges of up-scaling an innovation.

Bridging the multi-phase- and multi-level concept, van der Brugge et al. (2005) describes the pre-development phase of a transition (regime) as an inhibiting factor because it seeks to maintain the social norms and tries to improve current technologies. Maintaining the status-quo is a major barrier for new innovations. It can therefore be learned that strategies, rules and norms set by amongst others (van der Brugge et al., 2005) are hindering new innovations. Therefore institutions that are restraining a new innovation can be seen as an example. Blue Energy, which itself has not developed into a well established or well-recognized source of renewable energy yet, can therefore also be considered as a new innovation. Context specific barriers therefore need to be identified.

The take-off phase of a transition is linked to the micro and macro level of the multilevel concept. On both levels, modulation of development takes place. More precisely, innovations on the micro-level like certain technologies, as Blue Energy, are reinforced by changes in the macro-level. This can work either way (van der Brugge et al., 2005).

In the acceleration phase, the application of large amounts of money, technology and knowledge shows also the enabling role of the regime. The regime changes as a result of bottom-up pressure from the micro-level as well as top-down pressure from the macro-level. The regime level can therefore be considered as flexible.

In the final phase of stabilization, the speed slows down due to a new regime that has been build. A new equilibrium has been developed (van der Brugge et al., 2005).

Different aspects are important to get a transition started. Development in different domains (economic, ecological, social-cultural, institutional, technological) have to interact to be able to positively reinforce each other (van der Brugge et al., 2005). Transitions are a result of social change, which is considered to be slow and non-linear. Next to the regime, as an inhibiting factor, further barriers of transitions can be identified and will be elaborated in the following sections. „A transition process is full of obstacles, barriers and surprises. None of the transition trajectories (...) went smoothly (...)“ (Loorbach & Rotmans, 2009 p. 244). According to Loorbach (2007) following main barriers are important.

The timing of an intervention is crucial. Innovations need space to build up alternative regimes (Loorbach, 2007). Transitions are complex (Loorbach, 2007; Rotmans et al., 2001; van der Brugge et al., 2005), adaptive societal systems (Loorbach, 2007). Meaning that transition objectives have to be flexible and adjustable (Loorbach, 2007), which is not easy, having the idea of long-term thinking in mind. Hence, interaction between stakeholders is necessary. Otherwise no support for developing policies can be gained (Loorbach, 2007). Thus, no stakeholder interaction is a major barrier within transition theory.

CONCLUSION

To underline, following barriers can be identified according to transition theory. First of all, not a single actor can steer a transition (Romans et al., 2001). Stakeholder interaction and integration is important. Furthermore barriers on meso level can be identified, which inhibit new innovation from developing and the macro level where political awareness becomes important (van der Brugge et al., 2005). Finally timing is considered to be crucial (Loorbach, 2007).

A transition is a necessary process (Loorbach, 2010; Romans et al., 2001). Long-term thinking as well as moving towards a more sustainable future could make the promising idea of Blue Energy very valuable. The overall goal of a more sustainable future can therefore be seen as starting point of a transition – to be able to move from one dynamic stage to another. As described by the European Commission (2014) Blue Energy is still in an early (or infant) stage (European Commission, 2014). It is therefore nothing near a fast acceleration stage, or even a take-off phase within a transition towards a well-established energy source. To get a transition started and to identify barriers of a large-scale implementation of Blue Energy, this research will focus on all levels of the multi-level transition concept. For this research, all levels can be described as particularly important, as they deal with innovations and new technologies that lead to deviations (Kemp et al., 1998; van der Brugge et al., 2005), as well as regimes and the overall landscape. Blue Energy can certainly be described as a innovation and even local practices. On the one hand the method of RED is only applied in the Netherlands and on the other hand, the scale is even smaller with just one local power plant located at the Afsluitdijk. Therefore one can assume that Blue Energy is not even in a take-off phase of a transition yet.

As already highlighted, transition theory showed us that not a single actor can steer a transition (Rotmans et al., 2001) but multiple actors at different levels working together. This refers to the meso level again, where institutions become central. The micro level showed that niches are important, even though new technologies are still insignificant, but could develop in the future. The macro level highlights the importance of the large landscape scale of for example politics.

Verbong & Geels (2007) argue that new technologies have a difficult time to break through the existing regime (Verbong & Geels, 2007). We can learn from transition theory, when linked to new innovations, that different dilemmas and barriers still exist.

2.3 INTEGRATED ENERGY LANDSCAPES

Integrated Energy landscapes will be reviewed to identify further barriers of up-scaling an innovation and to highlight the importance of the local context of energy innovations.

The shift towards the use of renewable energies and more local resources is usually not easy to accommodate (de Boer & Zuidema, 2013). Energy systems are a complex web of networks and interrelated actors, in a economic, physical, social as well as institutional sense (de Boer & Zuidema, 2013). Geels (2011) claims that understanding how innovations emerge and contribute to the energy systems can be seen as an analytical puzzle (Geels, 2011).

De Boer & Zuidema (2013), as well as Noorman & de Roo (2011) are therefore recommending that planners and policy makers need to develop new approaches. The authors are consequently proposing the concept of an integrated energy landscape. It is defined as "(…) a multifunctional physical and socio-economic landscape of which energy initiatives and systems are an integrated part" (de Boer & Zuidema, 2013 p. 4). Energy systems become integrated through linkages, especially interaction, relationships and movements (de Boer & Zuidema, 2013). In other words, the authors are demonstrating that an area-based approach has potential to foster an energy transition. According to Heeres et al. (2012), an area-oriented approach is considered to be particularly integrated. It can therefore be described as an approach that is also focusing on the surrounding and local context.

Transition thinking is an important part of integrated energy landscapes, as it provides a framework to understand the complexity and complex web of interrelated actors. The earlier described multi-level perspective (Geels & Kemp, 2000; Loorbach, 2007; Markard & Truffer, 2008; Rip & Kemp, 1998; van der Brugge et al., 2005) helps to understand the dynamics in a transition, such as the energy transition (de Boer & Zuidema, 2013) and the micro level supports the idea of local practices of integrated energy landscapes.

It is argued that an integration can smoothen the development and implementation of renewable energies initiatives (de Boer & Zuidema, 2013). Furthermore, it is stated that an increased supply of renewables goes hand-in-hand with the interest of alternative societal interests and development (de Boer & Zuidema, 2013). Cameron et al. (2004) see the necessity to create space for new innovation towards sustainable development. De Boer & Zuidema (2013) go further, by supporting the 'local importance' by explaining that projects seem easier to develop and implement if they use local potentials, which are available and also well matched with local land use functions. Renewable energies are still often highly visible within the landscape and are also demanding space.

Secondly, energy initiatives, which are based on complimentary interests, are also less vulnerable to societal resistance and economical changes (de Boer & Zuidema, 2013). Lastly, if linking energy initiatives, such as renewable energies within the context of socio-economy and physical background it is important to create societal support (de Boer & Zuidema, 2013). To work towards the goals of an area-based approach, including the importance of the local context, combined complementary interests and creating social support, existing barriers need to be identified to moving towards sustainable energy systems in an area-based and spatial approach. Gaining renewables is not equally possible at all locations (Smil, 2008). Moreover, renewables are often considered to have a high visibility in the landscape (de Boer & Zuidema, 2013). This could cause an NIMBY phenomena (Olsen, 2010; Wolf, 1987). Most important, local and small-scale renewables are not yet an integrated part of the landscape (de Boer & Zuidema, 2013).

De Boer and Zuidema (2013) emphasis on a major difficulty of isolated energy initiatives (de Boer & Zuidema, 2013). They are highlighting again that it is important "(…) to see initiatives in their context" (de Boer & Zuidema, 2013 p. 12) and not as isolated parts.

Linking the idea of integrated energy landscapes and Blue Energy could be an interesting approach and consequently connecting Blue Energy to its local environment. So far, Blue Energy is a very isolated renewable energy source with little public attention. However, one has to be careful when linking Blue Energy to integrated energy landscape concept because some challenges that are connected with a shift towards renewable energies in context of planning do not apply for Blue Energy (described in de Boer & Zuidema, 2013; Smil, 2010). The authors are describing the high visibility effect of many renewable energy sources (de Boer & Zuidema, 2013) usually connected to wind energy farms or solar power panels. Furthermore, so described, renewables are typically demanding more space for the production of energy compared to fossil sources (Smil, 2010). This relates only very limited to the approach of Blue Energy. According to a scientific expert, Blue Energy plants are almost invisible because they are located under the surface. Additionally, the required space does not involve land mass but a water body. Having water as a resource and spatial factor leads to further challenges that are often connected to nature protection and environmental problems. These issues will be described later on.

Yet, other described challenges however do also apply for the Blue Energy technology. Blue Energy is not an integrated part of the energy network yet. Moreover, experts stress that no societal involvement or local interest has been recognized so far.

CONCLUSION

De Boer & Zuidema (2013) highlight the importance of the local context, the spatial importance, stakeholder interaction, and integration. However, they also emphasize the lack of sensitivity of interaction between local and national level. The previous highlighted barriers are adding important information towards an overall classification of barriers towards an up-scaling of a new innovation, such as Blue Energy.

2.4 INSTITUTIONAL BARRIERS

Previous discussion of literature, such as transition theory and integrated energy landscapes showed the importance of institutions. A conceptualization of institutions and their barriers is therefore reasonable. Institutions will be introduced first before institutional barriers will be classified, as they are especially important for Blue Energy development. Loorbach (2007), Rotmans et al. (2011) and van der Brugge et al. (2005) already mentioned barriers connected with institutions. However, Tan et al. (2014) but also Clifford et al. (2005) are adding significant institutional barriers. These can be summarized as financial, political and technological (Clifford et al., 2005; Tan et al., 2014).

According to North (1986), Institutions can be defined as,

"First, institutions are regularities in repetitive interactions among individuals. They provide a framework within which people have some confidence as to how outcomes will be determined. Institutions are not persons, they are customs and rules that provide a set of incentives and disincentives for individuals. They entail enforcement either of the self-enforcing variety, through codes of behavior, or by third party policing and monitoring"
(North, 1986, p.231).

North continues by describing that institutions only evolve or arise due to interaction of individuals (North, 1986). In 1990 he specifies by saying that "Institutions are the humanly devised constraints that structure political, economic and social interaction" (North, 1990, p. 97).

In general, institutions have been designed to create order and, after all, to reduce uncertainty in exchange (North, 1990, Biesbroek et al., 2011). According to Alexander (2005), only one way will lead to significant and social change: changing the people who build up society (Alexander, 2005).

Rietveld & Stough (2009) are relating institutions and technological change. The overall potential of technological change towards more sustainability (in their context: transportation systems) is considered being high. A large investment is necessary to bring such a change (Rietveld & Stough, 2009). Furthermore, institutions have an impact on the direction of the development and technology also affects the structure and form of institutions (Rietveld & Stough, 2009).

This leads to institutional barriers that could further hinder the development and up-scaling of a new technology. Tan et al. (2014) gives an insight into institutional barriers, in regard to transit development. However, institutional barriers can be connected and transferred to many cases, such as energy (Blumstein et al., 1980). Institutional barriers are defined to be context-specific (Tan et al., 2014). The authors are proposing a conceptual model, which illustrates the interaction and relations of barriers. The context specificity makes the concept of institutional barriers very interesting, as niche technologies are usually 'one of a kind' and local practices (Kemp et al., 1998; van der Brugge et al., 2005).

Tan et al. (2014) are identifying the involvement of actors and stakeholders as most important and necessary to identify barriers (Tan et al., 2014). This is a concerted action with ideas developed in the integrated energy landscape concept. Barriers to sustainable development are abstracted into different sub-structures, whereat financial, political and technological are most significant for this research (Clifford et al., 2005; Tan et al., 2014). Tan et al. (2014) is adding that institutional barriers are the most crucial to overcome.

CONCLUSION

Barriers are impending, diverting, or even blocking the process of developing and implementing new technology (Biesbroek et al., 2011). Institutions however, create order and reduce uncertainty (North, 1990), which is very valuable for innovations and new technology. Institutions form and impact the development of technology and vise versa (Rietveld & Stough, 2009). Blue Energy is still in its infancy and context specificity of institutional barriers towards sustainable development is very promising. Institutions are adding valuable concepts and ideas to the former two concepts by emphasizing the importance of the context and the need to involve different levels of actors (Tan et al., 2014). Furthermore, in regard to work towards an up-scaling of a niche technology, barriers and especially institutional barriers, such as financial, political or even technological barriers underlined crucial barriers to overcome before further development is possible.

2.5 CONCEPTUAL FRAMEWORK

Transition theory, integrated energy landscapes and institutional barriers have shown interesting notions of difficulties and challenges towards a new transition in current Dutch energy systems. Different linkages between the theories have been highlighted and need to be integrated and conceptualized within one framework with emphasis on Blue Energy and its infancy technology (European Commission, 2014).

To summarize, all barriers developed from previous conceptualized literature are the following: Transition theory showed that stakeholder interaction is necessary; as well as the political awareness, and also timing. Furthermore, we learned from integrated energy landscapes that the local context, as well as the local awareness matters. Moreover, institutional barriers emphasize that finances, politics and the technology itself are major barriers. Finally urgency is necessary to act.

Additionally, an environmental barrier has been added. Based on the literature review about Blue Energy, environmental questions and challenge often have been a part of current discussion and are therefore important (Irena, 2014).

This conceptual framework therefore aims to give a tool, which can also be seen as a list of criteria or classification of barriers, to categorize current challenges, which face a so called large scale implementation of this new kind of renewable energy towards an up-scaling of Blue Energy.

The transition towards an increased use of renewable energies and especially Blue Energy can be considered as the overall objective of the aspired transition. Reaching a new equilibrium (up-scaling from niche level) and therefore establish Blue Energy as a well-known and promising technology and to get to a pre-development or even further phase (Rietveld & Stough, 2009), while integrated energy landscapes defined the multifunctional physical and socio-economic landscape. Within this landscape, energy systems are an integrated part (de Boer & Zuidema, 2013).

Figure 3 clarifies the developed tool to identify barriers for an up-scaling of Blue Energy to move towards an pre-development or even acceleration phase of a transition. Focus is on all levels of a transition, as well as barriers to eventually evolve into an integrated part of the energy system.

The current Blue Energy debate is referring to ‘technical’ and ‘non-technical’ barriers (fig. 3), which are also used for this framework. Technical barriers combine technical issues, which is mostly the responsibility of the research level. However, these barriers are also important as they are considered to be a major obstacle towards up-scaling. Former research mostly focused on technical issues, while non-technical barriers have mostly been neglected. Non-technical barriers are associated with all other kinds of barriers, mainly referring to social, political, institutional and spatial issues.

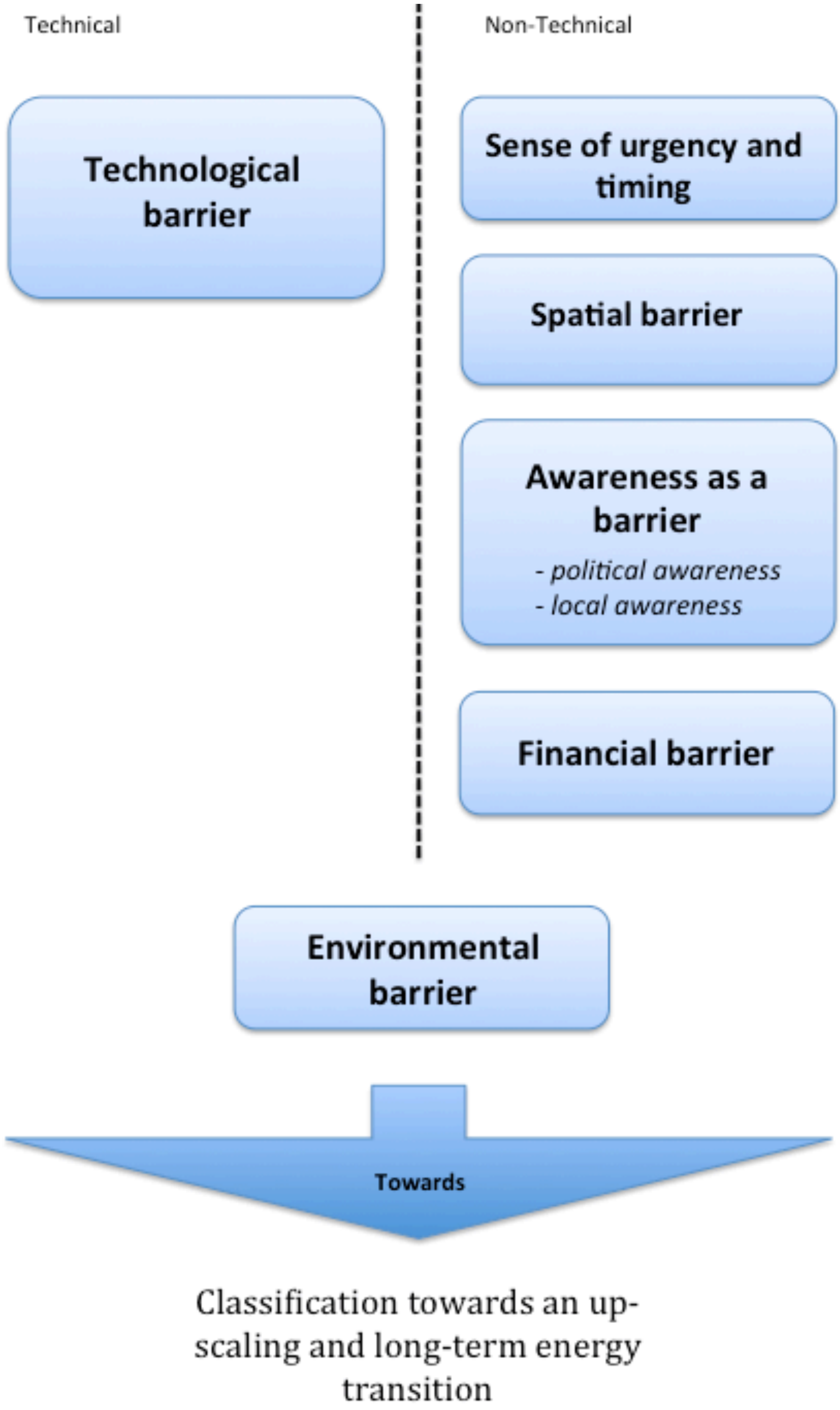

Fig. 3 Conceptual framework of the research

The developed categories are based on the previous reflected and conceptualized literature. The in-detail description of the particular category of barriers will clarify the origin of the criterion. Every lesson learned from the previous theories will be translated into a specific and context related barrier.

2.5.1 TECHNICAL BARRIERS

Tab. 1 Description of individual barriers

TECHNOLOGICAL BARRIERS	Technological barriers, referring to Blue Energy, are considered to be limitations related to technical obstacles, which could challenge an up-scaling of the technology. Some barriers may be considered to be 'general technical issues' or 'case specific issues', due to the context specificity and special circumstances of the Afsluitdijk, as a dike line with a key function to protect land from the sea. Technological barriers (discussed in Clifford et al., 2005; Tan et al., 2014) will therefore be categorized in this classification.

2.5.2 NON-TECHNICAL BARRIERS

SENSE OF URGNCY AND TIMING	Timing is one of the crucial elements (Loorbach, 2007) that needs to be taken into account towards an up-scaling and a long-term energy transition. Finding a potential window of opportunity is essential to further develop and enable Blue Energy to up-scale. According to Biesbroek et al. (2011) it is necessary to have a certain pressure to act today even though effects will only be visible in the future.
SPATIAL BARRIER	Spatial requirements are important in regard to the future development and challenges related to identifying suitable locations for Blue Energy. Spatial barriers concerning locations have been discussed within integrated energy landscape literature (Smil, 2008; de Boer & Zuidema, 2013). Subsequently, limiting spatial factors, such as suitable locations, which could hinder an up-scaling of the current plant or further new development need to be discussed.
AWARENESS	Awareness is a central barrier and has been reflected on in all

	theories. Awareness, integration and Communication are necessary to be able to develop and adapt (Biesbroek et al., 2011). Awareness can be subdivided into two major parts, which are both considered to be equally important (Biesbroek et al., 2011):
	Political awareness as a barrier is based on transition- and institutional literature (Clifford et al., 2005; Loorbach, 2007). Loorbach (2007) highlights the importance of stakeholder involvement and integration (Loorbach, 2007) on all levels, such as governmental, market and research. Different governmental levels play important roles within the Dutch renewable energy sector. The fragmentation, the lack of coordination and connection of different levels (Biesbroek et al., 2011) is important to study. Furthermore, the awareness of politicians concerning Blue Energy needs to be addressed and analyzed.
	Local awareness (de Boer & Zuidema, 2013) is a barrier considering social aspects and local context. Local barriers will therefore analyze the extent, to which local residents and initiatives are aware of the technology.
FIANCIAL BARRIER	Financial resources are an important part of institutional barriers (Tan et al., 2014) and a general challenge (Biesbroek et al., 2011). Hence, the availability of funding will be questioned to identify if it is sufficient enough towards a further up-scaling and future development.
ENVIRONMENTAL BARRIERS	Environmental challenges are related to both, technical and non-technical barriers. On the one hand it can be considered as technical barrier, because technical failure could cause environmental harm. On the other hand building and operating a power plant could also cause environmental damage and therefore social and political attention. Which environmental issues can be recognized, what is still uncertain?

This framework will help and be used as a tool to identify, which barriers and challenges apply within the Blue Energy concept to finally be able to understand what still needs to be overcome before an energy transition of Blue Energy is possible.

2.6 CONCLUSION

The current Dutch energy debate illustrates the importance of an ongoing transition towards renewable energies (Smil, 2010). Different goals have been set by the Dutch government to increase the use of renewable energies to move towards a post oil era (Rojey, 2009). Transition theory literature illustrates that not a single actor can steer such a transition (Rotmans et al., 2001) and therefore demonstrates the importance of two different transition concepts. The multi-phase model highlights the significance of the four different transition stages, while the multi-level perspective is particularly crucial on two different levels, when it comes to new innovations. The micro-level contains niche innovation and technology, whereas the meso-level comprises regimes (van der Brugge et al., 2005). The regime can be seen as an inhibiting factor or major barrier towards an up-scaling of a technology due to its interest to preserve the status quo (van der Brugge et al., 2005).

Integrated energy landscapes are highlighting the importance of the local context, where transition thinking is an essential part (de Boer & Zuidema, 2013). Small-scale innovations like Blue Energy are not yet an integrated part of the energy system (de Boer & Zuidema, 2013). Furthermore, the lack of sensitivity of national policies towards the regional and local interests could also harm a development of Blue Energy. Integrated energy landscapes are also paying major attention to the niche and regime level of transitions by defining barriers as spatial importance, significance of local context and the integration and interrelation issues of stakeholders and policies.

Transition theory and integrated energy landscape are very well aware of the importance of institutions. Institutions are emphasizing the need of funding (Rietveld & Stough, 2009; Tan et al., 2014), politics and the use of technology (Tan et al., 2014).

To sum up, all theories discussed in the theoretical framework are adding to the current debate about Blue Energy and lead to the conceptual framework. The framework will be used as a tool or list of criteria to identify context specific barriers of Blue Energy towards further development within the energy transition.

3. METHODS

Within this chapter the used methodology to collect the data will be discussed. This research is based on qualitative nature to give an insight into the technology of Blue Energy, as well as to identify barriers and challenges towards a large-scale implementation. Furthermore, the research strategy aims to study Blue Energy to give an insight into the current state of the art.

Literature on transition theory, integrated energy landscapes, institutional barriers and the general idea of barriers are providing the basis for the conceptual framework. This chapter is going to explain the research strategy and methodology for the following chapters in detail.

3.1 METHODOLOGY

For this research, a qualitative approach has been chosen. Qualitative research has been selected, as information about Blue Energy are limited and mostly not published yet. Qualitative research uses text as empirical material and not numbers (Flick, 2008) and is interested in the perspective of participants, social construction of realities to allow an understanding of the issue, process or relation (Flick, 2008).

Existing literature and documents were collected and analyzed to gather data. Furthermore, in-person, as well as telephone interviews with relevant actors were conducted. Additionally, a participatory observation at a conference in Brussels has been made to collect data, learn about the current state of the art, network and to conduct interviews.

3.2 EMPIRICAL RESEARCH

Data for qualitative research was gained by performing semi-structured interviews. Gaining knowledge and information from interviews has been chosen to seek information, as literature is limited and attention to the technology has just recently been accelerating. Interviews were therefore necessary to get information ranging from basic information about the technology to in detail discussions of possible barriers and challenges. Moreover, this research is reflecting upon different governmental levels of stakeholders, which many have never been asked about Blue Energy (fig. 4).

Semi-structured interviews are described as interviews, which involve predetermined questions, as well as the possibility for deviation to go beyond answers to initial questions (Berg, 2004). The set of pre-determined interview questions can be found in the appendix. The detailed interview process and structure is described later.

A stakeholder analysis has been carried out to identify most important stakeholders of the Blue Energy sector. Roughly, stakeholders have been categorized into three different levels. The levels resemble a 'governmental level', 'research level' and 'other stakeholders'. Based on the stakeholder analysis, experts have been selected for interviews.

Tab. 2 List of interviewees

File no.	**Organization**	**Name of Interviewee**	**Date**	**Category**	**Type**
1	University of Groningen	Alexandros Daniilidis	21.05.2015	Research	Face-to-face
PhD researcher at the University of Groningen, with research on Blue Energy					
2	Wetsus, Leeuwarden	Dr. Michel Saakes	29.05.2015	Research	Face-to-face
Scientific project manager and researcher on Blue Energy at Wetsus in Leeuwarden					
3	REDstack	Rik Siebers	16.06.2015	Operation	Face-to-face
Director of REDstack					
4	Energy Research Institute NL (ECN)	Paul Lako	13.07.2015	Research	Telephone
Expert on policy studies at the Energy Research Institute					
5	Municipality of Leeuwarden	Bouwe de Boer	15.07.2015	Government	Telephone
Energy coordinator in Leeuwarden and former energy coordinator of the Province of Friesland					
6	Wetsus, Leeuwarden	Dr. Jan Post	14.08.2015	Research	Telephone
Program manager and researcher at Wetsus in Leeuwarden					
7	Rijkswaterstaat	Joyce de Leeuw	14.08.2015	Government	Telephone
Employee at Rijkswaterstaat					
8	Ministry of Infrastructure and Environment	Olga Clevering	18.08.2015	Government	Telephone
Policy maker at the Ministry of Infrastructure and Environment					
Salinity gradient power conference in Brussels, Belgium:					
9	Institute for Infrastructure, Environment and Innovation	Frank Neumann	16.06.2015	Private non-profit	
10	European Commission	Petra Sarapatkova	16.06.2015	Government	
11	VITO	Joost Helsen	16.06.2015	Research	
12	GIST South Korea	Prof. Joon Ha Kim	16.06.2015	Research	
13	WIP	Michael Papapetrou	16.06.2015	Research	
14	MENA II: Middle East	Boris Liebermann	16.06.2015	Research	

3.3 RESEARCH STRATEGY

The first step (fig. 4) of this thesis is the selection of an appropriate case as a basis for the research. However, selecting cases is connected to several difficulties. Blue Energy is, as described, a new approach and the method of reverse electrodialysis is so far only applied in the Netherlands. Furthermore, only one pilot plant is operated. This research will therefore focus on Blue Energy with emphasis on the Netherlands and the European context. However, general barriers and challenges will affect most future cases of implementation also on a worldwide scale.

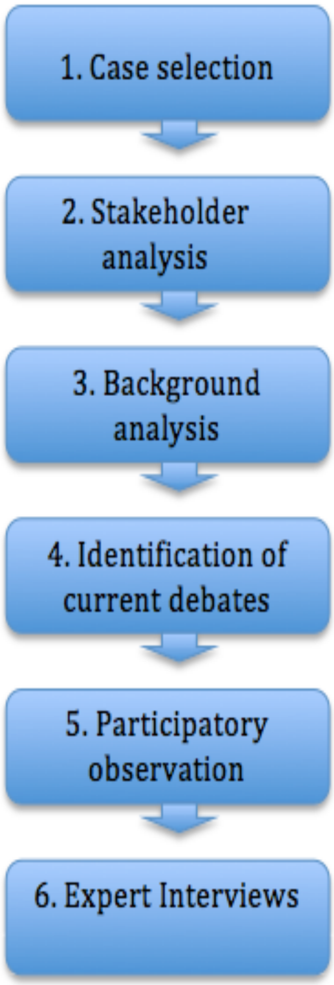

Fig. 4 Research strategy

Subsequently, the second step includes the identification of stakeholders. Stakeholders were identified by literature review, networking during the conference in Brussels and through recommendations of actors.

In step three and four, first background analyses were undertaken to identify and provide insights into current policy plans, the current state of the technology, environmental and governmental debates and possibilities of implementation.

Participatory observation was made at a conference in Brussels, Belgium "Energy from Water/Water from Energy: Salinity Gradient Power Update: Latest developments and updates in Europe and Asia" on the 16th of June. The conference offered different presentations on Blue Energy as well as the possibility to network with stakeholders and to conduct interviews.

The final step of the research strategy comprises expert interviews. Interviewees were contacted based on the stakeholder analysis of this research. However, at first, many challenges arose mainly on the governmental level. First of all, some ministries are not willing to give interviews or information to university students. Secondly a language barrier was obvious, as the interviews requests, as well as the interviews themselves used the English language and not Dutch. This discouraged many possible experts. A more detailed description of the interview process can be found below.

3.4 INTERVIEW PROCESS AND STRUCTURE

In most cases, relevant experts were contacted personally via email, however sometimes an organization was contacted in order to come in touch with relevant experts. In each case, the intention of the interview, as well as the background of the research has been clarified. After positive feedback, a list of interview questions was provided a couple of days before the interview to introduce the interview candidates to the case and purpose of the research. The interview guide (in appendix) has been altered for each individual interview, as some experts declared during previous email contact that they have no knowledge in certain domains or it was obvious that specific questions are not relevant for some stakeholders. Therefore an adapted and individual version of the guide has been send to the interviewees.

Face-to-face interviews were conducted three times, while most of the later interviews were conducted by telephone, as it was suggested by the candidates or due to large spatial separation. All interviews have been conducted in the English language. Each interview has been transcribed and can be found in the appendix. However, one transcript (annotation in the appendix) has not been transcribed but ideas and notions have been written down. Each question that has been answered and further relevant information have been precisely transcribed. Yet, small-talk and off-topic information have not been transcribed, due to their lack of importance for this research. Information that have not been transcribed include introduction of myself, the study program or detailed information about my research. Moreover, topics that are not relevant for renewable energies, Blue Energy or the general energy debate have also been left out. However, this applies only for minor parts and some of the interviews.

The interviews have been analyzed via manual coding. Coding is necessary to organize and sort the data. To exemplify, each pre-defined category of barriers has been labeled with a different color. Colors have been used as a code for the analysis. Interview transcripts have been analyzed and revisited several times to label each relevant information with the color code. Thus, it was possible to assign information and data to each barrier or other relevant analytical parts without missing any important data.

Furthermore, the conference about salinity gradient power in Brussels was an all day conference and organized by IMIEU (The Institute for Infrastructure, Environment and Innovation) and experts from different countries worldwide were invited to contribute knowledge and updates on SGP. During the conference, presentations were given and some short interviews were possible. All presentations have been recorded and detailed notes have been taken. Presentations have not been transcribed but could be made available as audio.

CONCLUSION

Both, the participation at the conference as well as all interviews were key information for this study. Policy documents and non-technical literature is almost nonexistent. This resulted in a division of this research. The first analytical step is the broader debate and also context of Blue Energy, including the stakeholder analysis. Followed by the second analytical step, which includes the identification and discussion of barriers.

4. BLUE ENERGY

The following chapter is the first analytical step of this research. For that reason, key information result from interview data, as well as document analysis. First of all, the stakeholder analysis will be visualized by identifying all important stakeholders within Blue Energy. Moreover, the current state of the art will be presented, while also introducing the technology, possible implementation, environmental criteria and the European discussions. Furthermore, the pilot power plant at the Afsluitdijk will be introduced.

4.1 STAKEHOLDER ANALYSIS

First of all, a detailed stakeholder analysis is necessary to identify the most important stakeholders within the Dutch Blue Energy development. Based on the different background of stakeholders, they could be divided into three different groups, namely: 'government level', 'research level', and 'other stakeholders' (fig. 5).

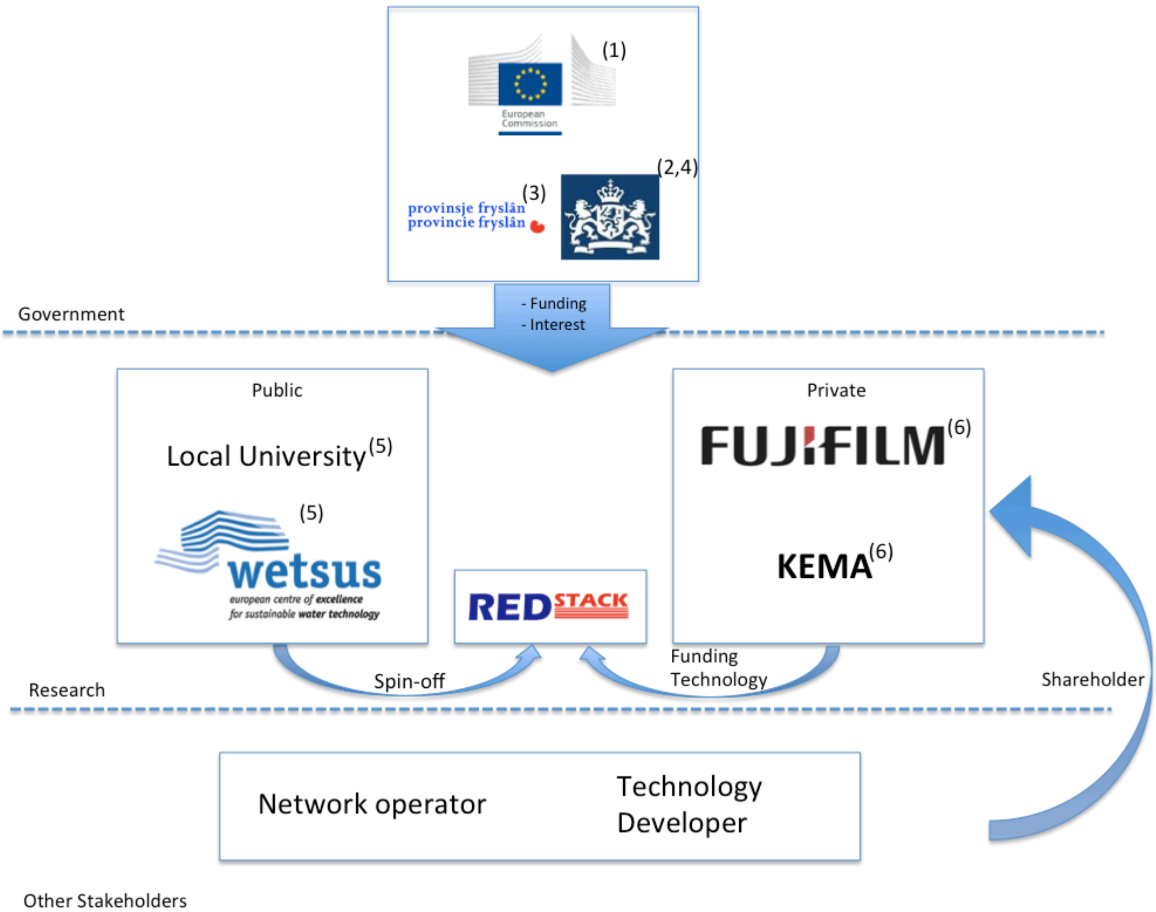

Fig. 5 Overview and interaction of stakeholders within the Blue Energy sector in the Netherlands

The first cluster can be described as the governmental level. Hereby, four different governmental levels can be considered as important.

(1) The European Commission. According to an expert of the European Commission, they have an overall interest in blue growth. The overarching goal is to create new employment opportunities. Furthermore, the European Commission describes ocean energy as particularly important because of (1) climate change mitigation, (2) worldwide energy needs (3) creating jobs and (4) coastal protection (double use). Moreover, the European Commission is one of the main funding sources for research in the Blue Energy sector. The different funds, like the European structural and investment fund, the Horizon 2020 project, the European Fund for Strategic Investment and the so called Juncker Fund are providing resources and opportunities for market partners and research organizations, described by a European policy officer.

(2) The Dutch National Government as well as the *Province of Friesland (3)* itself are also major funding sources for Blue Energy development (Willemse, 2007) This has also been described by an environmental and infrastructure coordinator working on Blue Energy, as well as a manager on operational level of SGP. Therefore, the government has a strong interest in new opportunities and innovations in renewable energies to eventually reach the Dutch renewable energy targets (Willemse, 2007).

(4) Rijkswaterstaat. According to an employee of he Rijkswaterstaat, they formulated an ambition to involve more renewable energies in their projects. Most water related locations are managed by the Rijkswaterstaat and they are facilitating Blue Energy on their ground. She additionally mentioned that contracts have been signed with public and private stakeholders to provide the room for renewable innovations (this case: Afsluitdijk).

The second cluster can be described as a research level and must further be divided into different sub groups. One the one hand private research is a major stakeholder and on the other hand public research is essential.

(5) Public research. One of the most important stakeholders within research and Blue Energy is Wetsus, the European Center of Excellence for Sustainable Water Technology.

Wetsus coordinates strategic cooperation and an environment for development of sustainable as well as profitable technology for state of the art water treatment (Wetsus, 2015). Collaboration between companies and research institutes are one of the main duties to develop innovations that significantly contribute to solve worldwide water problems. “Innovation, partnership, joy, cooperation and reliability are the values around which all Wetsus’ activities are organized and performed” (Wetsus, 2015). Wetsus describes itself as a technological top institute for water technology (Wetsus, 2015). Wetsus has the leading role in Blue Energy development (Willemse, 2007). It is located in Leeuwarden, the Netherlands and was founded in 2003 (Willemse, 2007). Universities and the private and public water sector support the research program. The national government, northern provinces, the European Union and the city of Leeuwarden inter alia are funding Wetsus (Wetsus, 2015).

(6) Private Research, on the other hand is adding important contributions to the Blue Energy development. Noteworthy are especially Fujifilm and KEMA. Private companies play an important role. According to a project manager at Wetsus, different companies provide money for research, because they see the potential and believe in and are also conducting own research. Fujifilm is contributing research on the membranes, which are also currently used in the pilot power plant at the Afsluitdijk. KEMA has been one of the first companies doing research on membranes for the technology. Both companies are partners of REDstack, a spin off company of Wetsus, operating the Afsluitdijk pilot plant (Willemse, 2007). REDstack staff confirmed that REDstack recently opened the pilot plant at the Afsluitdijk in November 2014. REDstack is funded with public and private money and is currently employing 12 employees.

Further Stakeholders, resembling network operators or technology developer in the Netherlands, are also acting as shareholders for REDstack and are contributing infrastructure and knowledge.

4.2. BLUE ENERGY IN EUROPE

The participatory observation in Brussels reveled the importance of the European level for Dutch Blue Energy development. Therefore, this chapter is focusing on the current debate within the Blue Energy sector on the governmental level, as a development in the Netherlands would not be possible without support on a higher governmental level (e.g. in research or funding). The European Commission sees Blue Energy as a combination and integration of all marine renewable energies, including amongst others, salinity gradient power.

Marine renewable energies in general have a huge potential to become a major source of clean energy in the future (European Commission, 2014). Marine renewable energies are presenting the EU with an opportunity to create jobs, enhance the security of future energy supply and advance competiveness through technological innovation (European Commission, 2014). A variety of different technologies, including: wave energy converters, tidal stream technology, tidal range technologies, ocean thermal energy and finally salinity gradient power are currently under development (European Commission, 2014). An impact assessment conducted by the European Commission (2014) on ocean energy in general concluded that:

(1) Ocean energy resources that are available will exceed the worlds current and future energy needs. According to the study, the highest potential in the EU is on the Atlantic seaboard, as well as Mediterranean and Baltic basins. Exploiting this resources would help to mitigate our current dependency on fossil fuels and could contribute towards energy security.

(2) Ocean energy can become an important pillar of blue economy. Blue economy in general is a principal to protect the Earth and the environment while at the same time economic growth and creation of jobs are the goal (Pauli, 2010).

(3) European industries are currently well represented in the global ocean energy market. This is shown by the fact that most developers are based in Europe. However, growing competition from China or other industrialized nations is expected. Further innovations could allow the EU to export, both technology and expertise.

(4) Ocean energy can create many high quality jobs. These could be in operation or manufacturing. The impact assessment of the European Commission (2014) showed

that 10,500 – 26,500 permanent jobs and almost as much temporary jobs could be created in the field of ocean energy by 2035.

(5) The opportunity of up scaling ocean technology will contribute to the EUs decarbonization goals and could eventually reduce greenhouse gas emission by 80-95% by 2050.

(6) Ocean energy is especially valuable because it could help to balance the energy output from other renewable resources like wind energy or solar energy. This could guaranty a steady supply of renewable energies to the grid system

(7) Ocean energy has comparatively low visual impacts. This could lead to a higher acceptance among locals compared to other on-land renewable energy sources.

The European commission (2014) describes that "ocean energy currently is an infant industry, within which wave and tidal stream technologies are relatively more developed than other technologies" (European Commission, 2014 p. 8). Different support structures on European, as well as national level are already existing. These structures include, capital grants, research funding and revenue support schemes (European Commission, 2014).

The overall goal and policy objective is to enable the ocean energy sector to be able to make a significant contribution to European targets, which are an increase in employment, innovation, and climate and environmental objectives (European Commission, 2014).

Ocean energy is currently at a critical state. It is moving from prototypes towards commercialization. This is an important but also difficult step (European Commission, 2014).

4.3 SALINITY GRADIENT POWER

Salinity gradient power and the principal of reverse electrodialysis will be explained here in more detail to discuss the potential, clarify the function of the technology and to highlight possible applications.

In 2005, Wetsus started the project and named it 'Blue Energy', focusing on RED (Post et al., 2010). Before 2005 only limited publications on SGP were available (Post et al., 2010). However, scientific papers on reverse electrodialysis increased rapidly since 2007/2008 (Helse, 2015). Furthermore, the performance of reverse electrodialysis has increased enormously over the past years.

In general, reverse electrodialysis (RED) can be described as a technology generating power from mixing waters with different salinity (Vermaas et al., 2012). The two water solutions are for example sea water and river water.

The idea of mixing fresh water and sea water to gain energy has already been developed in the 1950s with experiments on 'hydroelectric pile' (Pattle, 1954). The overall potential to generate energy is huge. The theoretical capacity when mixing sea water with the global river water runoff would meet the present electricity demand for the entire world (Post, 2009; Vermaas, 2013).

RED is just one approach out of two to generate electricity from salinity gradient power. The other technology is called pressure retarded osmosis (PRO) (Vermaas, 2013). However, this chapter will be focused on RED, because "(..) research, development and pilot plants of salinity gradient power in the Netherlands are completely based on RED" (Acuna Mora & de Rijck, 2015 p. 1). The recent increased attention for salinity gradient power is mostly related to the increasing price of fossil fuels. Emerging discussions on pollution showed the increasing demand for new sources of renewable energies (Vermaas, 2013).

It was visible that more common forms of renewable energy sources like wind energy or solar energy have developed much faster lately. They are already well established in the Dutch and worldwide energy mix (Vermaas, 2013). They have an even larger potential (theoretical capacity) than salinity gradient power, however, they have unpredictable fluctuations in power production. Furthermore they also depend on local circumstances like sunshine and the availability of wind. This is leading to increased problems (Vermaas, 2013).

Salinity gradient power is predictable. It is even possible (e.g. in case of freshwater lake as a source) to regulate to compensate fluctuations in production of energy from other renewable energy sources (Vermaas, 2013). The described technical possibilities are the main reasons to up-scale the production of salinity gradient power.

4.3.1 THE PRINCIPLE OF RED

This section will go into more detail by summarizing the basic principle of reverse electrodialysis to provide a better understanding of the technology itself.

Capturing energy by mixing salt water and fresh water is done by using ion exchange membranes (CEMs) as well as anion exchange membranes (AEMs) (fig. 6). Both membranes are separated by spacers to guaranty a flow compartment for the feed waters (Vermaas, 2013).

A voltage is created over each ion selective membrane, when salt water is on the one side of the membrane and fresh water on the other side. This is explainable by the Donnan potentials at the membrane-water interfaces (Vermaas, 2013). CEMs and AEMs are stacked alternately. Hereby, voltage over each membrane accumulates, when salt water and fresh water is supplied between each of the membranes (Vermaas, 2013). Because of the salinity gradient between the different compartments, ions will pass selectively through the membranes themselves and are ultimately generating an ionic flux (Daniilidis et al., 2012).

The produced voltage can be used to power for example an electronic device. However a further reaction (e.g. redox reaction) is necessary to convert the ionic current into an electrical current (Vermaas, 2013). Figure 6 shows the basic principle of RED in more detail.

This process is indeed renewable. River water (fresh water) is discharged into the sea. The energy that was necessary to separate salt water and fresh water can eventually be converted into electrical energy (Vermaas, 2013).

There are two different key performance indicators (Daniilidis et al., 2014) for the production of electricity using RED. First of all, the power per membrane area (power density in W/m^2) and secondly the actual fraction of retrieved energy compared to the theoretically available amount (Daniilidis et al., 2014). Recently, on-going and significant improvements have been made regarding power density output, by optimizing, among others, the stack design (Vermaas et al., 2012). However, the cost of the technology is still a major key parameter (Daniilidis, 2014).

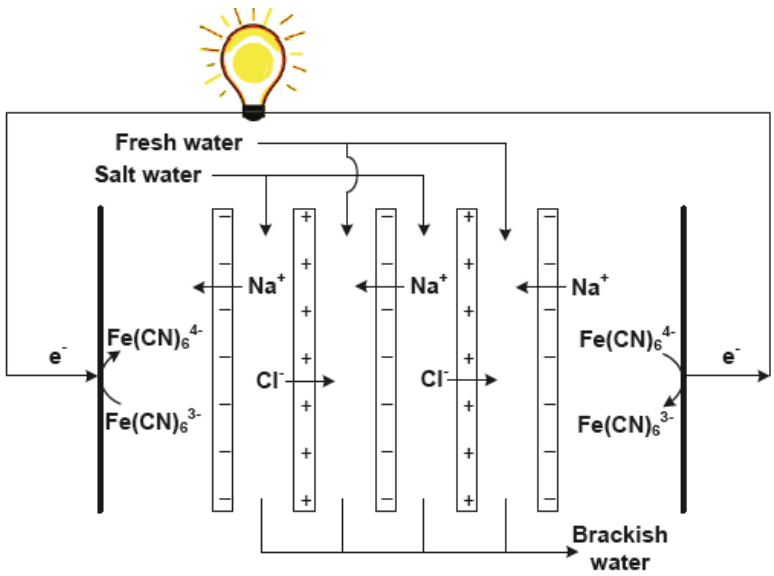

Fig. 6 Basic principle of RED (Vermaas et al., 2012)

4.3.2 POSSIBLE APPLICATIONS OF RED

In general, different applications of RED are possible, as long as there is a salinity gradient. This chapter will briefly discuss possible applications using i) sea water and river water, ii) using brine and sea water or river water iii) using a close system.

i) Sea water and river water

Mixing 1m^3 sea water (30g of NaCl per liter) and 1 m^3 river water (1g of NaCl per liter) can obtain energy of about 1.39 MJ, which equals 0.386 kWh (Post et al., 2008).

Comparable, the energy density of fossil fuels is typically 32000 MJ per m^3 (Wicket et al., 1978), which is significantly higher. However, RED compared to other technologies (e.g. tidal wave energy) gaining energy from water, has a high energy density.

Furthermore, the volume of sea water is pretty much infinite (Vermaas, 2013). Vermaas (2013) listed several rivers to show their potential for generating power from mixing both solutions. His results are mainly displaying that large rivers like the Amazon have an enormous theoretical potential, however the practical potential is significantly smaller due to the diffuse salinity gradient that is present in estuaries (Kuleszo et al., 2010 in Vermaas, 2013). Other rivers in more densely populated areas like the Rhine; Mississippi or the Yangtze River in Asia have also large potential and benefit from the availability of infrastructure. Furthermore, these areas are also showing an increasing demand for renewable energies. Vermaas (2013) assesses them to have the best potential for future locations for salinity gradient power plants.

ii) Brine and seawater or river water

An even higher energy density can be gained by using brine, or just more saline feed water streams. Up to 17 MJ can be obtained, when mixing $1m^3$ saturated NaCl brine and 1 m^3 river water. Furthermore, the salinity difference between sea water and brine can also be used to generate energy (Vermaas, 2013). In practice, this potential could theoretical be found for example in the Dead Sea or the Great Salt Lake (Loeb, 1998).

iii) Closed loop systems

The last option is to re-use the feed water in RED. It is possible to re-generate the salinity difference in a so called closed loop system (Vermaas, 2013). Evaporated salt water as brine and evaporated water as condensate can be used for RED, as explained earlier (Vermaas, 2013). Numerous further options are possible in closed loop systems like using waste heat. However the technical potential is still limited.

All of the systems described above are still in an early stage and not optimized yet. Further research will likely lead to higher power densities in the future (Vermaas, 2013).

4.4 AFSLUITDIJK POWER PLANT

The first and only Blue Energy power plant is located at the Afsluitdijk in the northern part of the Netherlands. The plant is a pilot plant operated by REDstack. The design process started in 2012 followed by starting building the plant in June 2013. According to a manager at REDstack, public funding started in 2011 and was followed by private funding.

According to him, the overall theoretical potential for the location at the Afsluitdijk is up to 200 MW of energy production. The pilot is the world's first real world implementation of Blue Energy and opened in 2014. Total costs add up to a total of about 14.48€ million. 6.000 hours of operation pumped a total water amount of 1.000.000m^3. Currently a maximum of 50 kW is installed for research purpose, using 2.500m^2 of membranes in 23 stacks.

4.4.1 ENVIRONMENTAL CRITERIA

To further describe the current state of the art of Blue Energy, different environmental and ecological factors and influences need to be considered. These are necessary to present before context specific barriers can be identified and discusses.

Calculating the greenhouse gas (GHG) emission from a SGP plant is important, to be able to access the environmental criteria's for Blue Energy. Current calculations are demonstrating GHGs emissions of less than 10 g Co_2-e/kWh (tab. 3) for a SGP power plant (Acuna Mora & de Rijck, 2014).

The power plant at the Afsluitdijk is unique due to the dike line separating IJsselmeer and Wadden Sea. In a common and natural estuary with an open connection between river water and sea, construction of a dam or dike line would be necessary to distinct between fresh water and sea water. This could have different effects on the landscape, ecological system or water management rules (Acuna Mora & de Rijck, 2014).

Implementing a SGP plant will likely have, compared to wind energy farms, less impacts on the environment (landscape, noise, required land etc.), while producing the same amount of energy (Post, 2009). Nevertheless, chemicals could be used as electrode rinse solution. In this case precautions are necessary to prevent leakage into the environment (Daniilidis et al., 2014). Still, using chemicals would not be sustainable in a up scaled reverse electrodialysis plant, as "(...)as only one electrode pair per several hundreds or thousands of cells would be needed and the chemicals are recycled through recirculation" (Daniilidis et al., 2014 p. 263). Furthermore, the usage of non toxic chemicals has been tested in the lab and minimized or even eliminated possible environmental impacts (Daniilidis et al., 2014). According to a manager at the pilot plant, the current Afsluitdijk plant is not using any chemicals.

Yet, most ecological impacts are still largely unknown. First studies will start in 2015 to examine the consequences of large scale Blue Energy plants (Didde, 2014). However, it is known that ecologist are concerned about the effects of filtering the water (Didde, 2014). Environmental barriers, which could challenge an up-scaling of the technology will be discussed in chapter five in more detail.

Tab. 3 Comparison of SGP with other energy sources (based on Acuna Mora & de Rijck, 2014)

	GhGs emission	**Price of generated electricity**	**Availability of renewable energy sources**	**Efficiency of energy conversion**
Units	G CO2 – e/kWh	$/kWh	-	%
Photovoltaic	90	0.24	Dependent	4 – 22
Wind	25	0.07	Dependent	24 – 22
Hydro	41	0.05	Always avail.	>90
Geothermal	170	0.07	Dependent	10 – 20
Coal	1004	0.042	Non-renewable	32 – 45
Gas	543	0.048	Non-renewable	45 – 53
SGP (RED)	<10	0.10	Always avail.*	50 - 70

*in coastal countries

4.5 CONCLUSION

The stakeholder analysis was the first important step towards the aim of this research, which is to identify and discuss barriers of up-scaling Blue Energy. The identified stakeholders will be the most important source for data in the next chapter. The background information about the current state of the art and the technology are necessary information to understand the relation and content of the following barriers.

5. BARRIERS OF BLUE ENERGY

According to the conceptual framework of this research, six main categories of barriers have been developed. This chapter is going to present and discuss the data gained for each classification of barriers. Each barrier is an obstacle that could hinter an up-scaling of the Blue Energy technology.

First of all, 'technological barriers' of Blue Energy will be demonstrated, followed by 'sense of urgency and timing', 'spatial barriers', 'political- and local awareness', 'financial barriers' and finally 'environmental barriers', which could hinder a development towards and up-scaling of Blue Energy.

5.1 TECHNOLOGICAL BARRIERS

According to the conceptual framework, technological barriers are defined as limitations related to technical obstacles of Blue Energy. Technological barriers are often affecting the research level of a new technology, as researchers are the ones who are potentially able to solve technical issues. Most technical barriers can be described as general technical issues of Blue Energy development, however some may be case specific issues, especially relevant for the Afsluitdijk power plant in the northern part of the Netherlands.

To summarize, four main technical barriers can be identified, namely the up-scaling itself, the fouling of membranes, the membrane price, and from lab to real life. The four main technical barriers are described by experts in research at Wetsus and at the University of Groningen, as well as the directors of REDstack and a European Infrastructure and Environmental Institute. Following each technical barrier will be discussed in more detail.

The general question is, if Blue Energy can actually compete with other (renewable) forms of energy. Technical barriers are comparable easy to identify, as many experts have technical knowledge.

1. 'Up-scaling of the technology'

According to a program manager at Wetsus, one barrier is "first of all, the up-scaling itself". He is arguing that this barrier is not obvious, because most people forget that this is still a challenge. He explains, "you have to engineer the up-scaling". This up-scaling is a goal itself and which cannot be considered as a small task.

2. 'Bio-fouling'

One of the major challenges mentioned is the bio-fouling issue. The IJsselmeer as well as the Wadden Sea are full of organisms, sediments and other things that can affect the membranes. As highlighted by a researcher at Wetsus, "fouling is (..) a big issue". Another researcher from the University of Groningen is adding that, "in real life you have a lot of different things in the water like sediments and that all affects the membranes". Also, the director of the pilot plant at the Afsluitdijk admits that fouling is a big issue at the Afsluitdijk. A researcher illustrates that "(…) in winter time I believe it is easy because we have low bio activity and in summer time it is the opposite". "Therefore it is necessary to find an operational mode, which can satisfy both conditions", says the researcher at Wetsus. "You cannot speed it up (…) lab is not the real world".

3. 'From lab to real life'

All experts agree on the obvious that 'lab is not real life', and also approved that further research is necessary. Therefore one of the researchers at Wetsus claims that one barrier is "(…) to bring it to a product". Furthermore, he explains, "you cannot scale it up by just copying from the lab". He exemplifies by describing the possibility to measure everything in the laboratory, where a lot of equipment is available. However, in real life it is necessary to have "(…) a technically sound, engineered product". He emphasizes that it is necessary that it is, "something simple, robust, easy to manufacture, easy to construct, easy to replace if something is broken". The director of an international Environmental and Infrastructure institute is adding that membrane quality, efficiency and durability need to be improved. "Theoretical numbers are theoretical and it is difficult to rely on them", said a researcher from Groningen. He and the director of REDstack are confirming that the up-scaling is still an issue and needs to be done, even at the pilot plant at the Afsluitdijk

4. 'Membrane price'

A researcher from the University of Groningen identifies, an up-scaling "(…) heavily depends on the membrane price". He describes the membrane price as "(…) the biggest contributor". Similarly, an expert on policy studies at the energy research institute underlines, "(…) the life time of membranes is shorter compared to laboratory conditions and that is a big issues". Furthermore he highlights that reinvestment is membranes will be necessary and therefore the costs will increase. According to him, "this is the holy grail of salinity gradient power". It is necessary "(…) to develop the technology to such a level that this issue will be mastered in such a way that it will be affordable"

Conclusion

Most technical barriers are solvable in the future. A project manager at Wetsus concluded that the pilot plant already faced many other issues in the past and most of them have already been solved. However, according to him, "one important information is that no mistakes can happen". That means that if anything would happen, like environmental or ecological impacts or failures, the entire project would be over.

This research identified no major dissension between people in research and operation of Blue Energy. There is consensus that technical barriers exists and that they need to be solved. However, during interviews a certain pressure to solve those issues was recognizable. Many years of research have already gone into development and exploration of Blue Energy and many people are keen to eventually up-scale the power plant. A policy maker at the Ministry of Infrastructure and Environment reported "(…) of course it is the question if it will be a good source of energy and where will you use it?" She is challenging the idea of Blue Energy by questioning if it will be able to compete with other forms of energy like wind energy or biomass. She states, "I think there are still a lot of technical problems that need to be solved".

5.2 SENSE OF URGENCY AND TIMING

Sense of urgency and timing can be considered as a crucial element towards an up-scaling of Blue Energy. Recognizing the perfect window of opportunity is essential and a certain pressure to act 'today' even though effects will only be visible in the future. Following, three different barriers limiting a possible development of Blue Energy were identified. First of all, according to a program manager at Wetsus, private companies must see the opportunity and potential of the technology. However, the second barrier is that past years were even better to develop the technology. The last barrier is that there appears to be a need that according to the energy coordinator at the province of Friesland, technology becomes part of the Dutch energy program.

1. 'Recognizing the opportunity and potential'

A discordance between different stakeholders has been identified. One the one hand, all stakeholders agree that the Afsluitdijk is a good location and that is has to be renewed anyway. Though, some seem not to be sure if Blue Energy will develop in one country like the Netherlands but rather in different countries. This is exemplified by an expert on policy studies at an energy research center. According to him "SGP has more the potential to develop in a more international framework". That would militate against the idea of Blue Energy to become a 'Dutch thing'. A Dutch innovation, which has been developed and established in the Netherlands.

A researcher at Wetsus has the opinion that technical companies need to see the opportunity of the technology, otherwise it will not develop that much, "(…) if they see the opportunity they will even develop more than you ask them for. If technical companies see the opportunity they will put efforts in it as their own initiative".

2. 'Window of opportunity'

If today is the perfect window of opportunity to develop Blue Energy can be argued in different ways. On the one hand "oil prices were increasing daily", states a program manager at Wetsus. He adds, "today we have low oil prices, we have a financial crises". He also claims that in the past, between "(…) 2005 and 2009 I was more optimistic to get money." Nevertheless, "(…) today there is a sense of urgency to reach targets". He also highlights that the year 2020 is coming close, though the government is not even close to reach 20 percent renewable energy targets. Furthermore, he points out that the window, "is becoming perfect again". The program manager concludes that, "in the past at conferences they never heart about the technology. Nowadays, people from all over the world are citing us".

On the one hand, a policy maker at the Ministry of Infrastructure and Environment and also a local energy coordinator from Friesland are demonstrating that 'today' could be perfect, as economics are better now. The energy coordinator mentioned, "the circumstances are not really bad for pushing renewable energies". However, according to him, "(…) wind and solar is now". He adds, "(..) for municipalities it is not the time to be involved (...) that is a question for the next five, six or seven years".

A project manager at Wetsus emphasizes that the Afsluitdijk has to be renewed anyway due to its age and the rising hazard of climate change in the future and changes in sea level. In the past, "(…) it happened that technologies developed in a small country" said the expert on policy studies. Denmark for example became world market leader in wind energy during the last 30 or 40 years. According to him, "(..) it depends also on surrounding countries if they pick up the technology sooner or later. "Maybe this technology will not only be developed in one particular country but maybe in different countries simultaneously", identifies the energy research institute expert, as one has to be aware of different routes to go. Similarly he claims that, "SGP has the potential to develop more in an international framework. If you look at the technology it could develop in a more international technology". He is adding, "we do not know which countries have the best position in this area. I am not convinced that the Netherlands may become a world market leader. I am not convinced because the potential of the Netherlands is rather small (…)". In general the specialist on policy studies is saying, "but maybe they can more or less try to master a very crucial part of the technology and then try to maintain their leadership in that specific part of the technology and then be satisfied with that position (…)". "(…) becoming a world market leader in this complete technology is maybe a bit too ambitious", according to him. Furthermore, he is adding, "they should try to focus on crucial parts and try to collect companies and partners from other EU countries or outside the EU (…)".

The statement of a policy maker at the Ministry of Infrastructure and Environment shows that there is still too much attention on other forms of renewable energies. Argued by her, "the economics are a little bit better now. The energy sector is very much in favor of other forms of energy and not that one. They are in favor of for example wind energy or biomass".

3. 'Lack in the Dutch energy program'

Agreed Dutch renewable energy targets are coming closer and so far, the national government tis not even close to reach them. "Blue Energy is not in the energy program and that is a pity", says the local energy coordinator. The policy studies expert claims that, "it is not reasonable that SGP is part of the 2023 agreement. Now, the technology is not yet relevant".

Conclusion

A leadership in the technology could be crucial to be able to compete with other forms of renewable energies. If further development would be transferred or assigned to other countries, the Netherlands would give away a high potential form of renewable energy that actually could contribute to the Dutch energy transition. Having in mind existing Dutch resources and infrastructure to develop and study innovations like research institutes and well known experts, the Netherlands are able to manage further development of Blue Energy.

It will be confirmed at one point that there will be a higher need of renewable energies in the future, because now it is the time of solar energy and wind energy to develop and establish. But agreed Dutch national renewable energy target are coming closer and Blue Energy will be a promising innovation to reach those.

5.3 SPATIAL BARRIER

Spatial requirements are important in regard to future developments and identification of suitable locations for Blue Energy. The Afsluitdijk is considered to be, "(…) a rather 'easy' location (…)" for a Blue Energy plant, says a policy studies expert at an energy research center. However, spatial barriers towards an up-scaling still exists. Three main barriers can be identified. First of all, water systems also contain other infrastructure like marine traffic, which is also important. Furthermore, specific spatial requirements are necessary to accommodate a Blue Energy plant. These can be summarized as: availability of fresh and salt water and a system to discharge the brackish water, and preferable an engineered estuary with a sharp distinction between fresh and salt water.

1. 'Interference with marine functions'

The first barrier is about interference between energy production on the one hand and marine functions on the other hand. An employee from the Rijkswaterstaat emphasizes that they are not responsible to initiate projects like Blue Energy. However, according to her, "we only facilitate them on our infrastructure, on our ground. What we do is try to think along with them to optimize the installation and how to make room because the dike secures the Netherlands from water". Furthermore she is adding, "there are always limitations in that sense on how much they can up-scale".

A policy maker of the Ministry of Infrastructure and Environment states, "(..) you cannot put a large Blue Energy installation in a water system because there is traffic and ships have to move". The spatial barrier is misprize.

2. 'Need of availability of fresh water and a system to discharge'

A program manager at Wetsus has an innovative idea to possibly build a Blue Energy plant not directly at the coast. Yet, this shows advantages as well as disadvantages. "Of course you need fresh and salt water and something to discharge the brackish water. Actually you need a sharp distinction between fresh and salt water. It is not that obvious to see where you can do it". Furthermore he is stating that, "most people would say you have to do it near the coast. (...) I am not that convinced (…). I would say you have to build it a bit more inland and supply it with salt water(…)." This would consequently mean that water has to be transported a few kilometers. Additionally, the expert is saying, "the people there are not always that positive because they do not envision the Blue Energy plant as a big plant".

Moreover, the stakeholder at Wetsus is envisioning, "(…) you can build a plant and discharge the brackish water into the harbor of Rotterdam. That is something no-one ever considered. People think you have to build it near the sea (…)". He however suggests, "(…) you can better use a harbor for the discharge that is open to the sea".

3. 'Availability of an engineered estuary'

Moreover, the program manager at Wetsus reports, "most rivers in Europe have engineered estuaries. Always use the engineered rivers and not for example the Amazon river that is very natural. But engineered river systems are perfect". Finally he concludes, “the main spatial obstacle is that it is never obvious and it is always different”.

Conclusion

A scientist at Wetsus verified that the Afsluitdijk has to be renewed and reconstructed anyway due to the age of the dike and rising hazards of future climate change. Spatial barriers show that in some cases you can solve some issues but also create others at the same time, such as the example of channeling the influx waters. Moreover, the spatial barrier is especially a major challenge for countries with a limited excess to fresh and salt water. Even an expert on policy studies argues that some countries are maybe even more suitable for Blue Energy production in spatial terms. The necessity of channeling the sea water could affect the landscape, environment and would further artificially change the water body. However, a location not next to the sea would have the benefit to have a large selection of possible locations and could solve the challenge to combine energy production and sea defense measure on a dike.

If the Netherlands, as a country closely connected to the sea with a lot of fresh water discharge, is not perfectly suitable for Blue Energy production, then hardly any other country worldwide will be able to do so on a large scale.

5.4. AWARENESS

As demonstrated in the conceptual framework, awareness and communication can be considered as a major barrier of up-scaling a technology. A scientist at Wetsus highlights that creating awareness of a new form of renewable energy is most important. First of all, barriers of political awareness will be displayed before highlighting the local perspective and their awareness of Blue Energy.

5.4.1 POLITICAL AWARENESS

Political barriers can be summarized as the lack of involvement of regional government, the circumstance that Blue Energy is not mentioned in the Dutch energy program yet, the current missing relevance, missing connectedness of the sector to other (-worldwide) countries, and also the missing political trust in the technology.

1. 'Lack of involvement of regional government'

A local energy coordinator of Leeuwarden confirms that, "renewable energies is a big topic (..)", and that a lot of money is going to renewables. However, he is also adding that on a small governmental scale "(…) the relation between the projects on the Afsluitdijk and the municipality is not very big. I am not really involved in the development of Blue Energy on the Afsluitdijk. Because the municipality is not directly in the area". He exemplifies that "municipalities are only partly involved in this stage". In general, the expert says, "so far, there is no involvement of municipalities, only the province and national level, who invest money.

2. 'Lack in the Dutch energy program'

Once again, the Dutch energy program becomes a barrier. Though, it connected to awareness on this level. According to the energy coordinator of Leeuwarden, the ministry is currently working on a new energy future document. "(…) everybody is curious what will be in it. It will show how the government is dealing with the new situation to speed up to 25 percent" of renewable energies in the Netherlands. As described earlier, according to him, "Blue Energy is not in the energy program and that is a pity". However, a scientist at Wetsus reported, that politicians are very interested and that they like it. This is also shown by the detail that the Dutch King opened the pilot plant at the Afsluitdijk.

3. 'Missing relevance'

A missing relevance is notable and explainable due to the fact that the national government establishes an energy program. It seems that the national level is only aware of technologies mentioned in the agreement. Everything that is not stated in the program is not on their agenda.

An expert of Wetsus clarifies, "we have the province supporting us and the city of Leeuwarden supporting us. I think they are all proud of it but also have high expectations". He thinks, "most Dutch parties know about it and also rise questions about it”. Additionally, “I am happy with their enthusiasm but I am also happy they do not consider it for the short term”.

On the other hand, a policy studies expert states, “it is hardly possible for them to give an opinion about this technology because it is not part for instance of the national energy agreement, because the technology is still in its infancy”. Moreover, he claims, “it is not reasonable that SGP is part of the 2023 agreement. The technology is not yet relevant. There is no minister with a clear view of SGP (…). It is far from a commercial technology”. Furthermore, he is arguing, “people rather invest in offshore wind because it was cheaper (…)”. Additionally he emphasizes “an update of the energy agreement in the future, also considering SGP would be interesting”, proposed the expert from the energy research institute. Also he says, “if bigger demonstration plants of e.g. 10 MW would be build then probably the awareness of politicians will increase (…)”.

4. ‘Missing connectedness of the sector’

A major lack of connectedness and communication between different governmental levels, as well as between government, research and especially operation was notable.

An expert on policy studies from the energy research institute highlights, “(..) the sector is also not too well connected to other European countries”. This means that politicians may have difficulty to get a clear view on the potential of the technology, the economic potential or even global potential.

The expert from the Ministry of Infrastructure and Environment says that they have a lot of contact to Wetsus and, “(…) we support Wetsus since a few years to develop Blue Energy”. Furthermore “we try to stimulate different forms of ocean energy”. The ministry “(..) likes to stimulate energy out of water because our role at the subsector water(…)”. According her, “we give companies the possibility to develop new forms of energy but to make it bigger you need the Ministry of Economic Affairs because they are the one subsidizing it”.

5. ‘Missing political trust’

The policy maker from the Ministry of Infrastructure and Environment underlines, “I do not expect large scale. Maybe there will be one plant or maybe two at the most I think it is more of interest for export. To have a technique and to export it". She also points out that, "(..) it cannot compete with wind mills".

Conclusion

Many stakeholders are reporting about governmental awareness, political interest in the technology and also quite some enthusiasm. Nonetheless, due to a lack of communication the political knowledge is limited. It also quickly turned out that the governmental interest is focusing on other forms of renewable energies like wind or solar energy. A more comprehensive overview of all existing technologies, which are in development or already established, is necessary.

5.4.2 LOCAL AWARENESS

Local awareness on the one hand is about local initiatives, interested in local renewable energies, as well as local residents of renewable energy projects. Overall, two main local barriers can be identified. The first barrier is described as missing local education, the second one as lack of transparency for locals.

1. 'Missing local education'

According to a program manager at Wetsus, many local residents seem very interested in the Blue Energy technology. Additionally the number of people who want to be part of an energy transition and want to use renewable energy is also accelerating. However it seems that quite some people know Blue Energy, though they only know that there is something called Blue Energy but they do not know what it is exactly or how it even works. The local interest shows that people are curious and that there is a need to inform and educate them even more.

"This development stage is maybe to difficult to get all local initiatives involved", explains a program manager at Wetsus. According to him, it might be interesting in the future to involve local initiatives. Furthermore, he is claiming that, "local awareness will come but not yet". On the other hand, the researcher thinks that, "(…) most people here know about it". He exemplifies by stating, "we give once a year a winter school by our local newspaper with lectures for people because hundreds want to come. It was amazing. They were interested, they had heard about it and had questions". He also explained that people are proud of it and that they also want to know about. Nevertheless, "(…) people were also asking critical questions like environmental impacts".

"Some people want to get their energy for example from wind or solar etc. and this is growing quite fast", clarified a local energy coordinator. He confirms, "(..) there is a growing number of people who choose to use local energy (…)". However, he further recognizes that, "a lot of Dutch people are mad of the government to speed up and get a new goal of 25 percent by 2020 and went to court".

2. 'Lack of transparency'

One approach to solve lacking education and knowledge about Blue Energy is to show interested residents and also energy initiatives the current power plant to increase transparency and to give them the possibility to raise questions. According to an expert on policy studies, locals favor one specific kind of energy. They do know which drawbacks most technologies have. Blue Energy could be an interesting alternative for people who are not in favor of for example wind energy due to its noise pollution or visibility in the landscape.

According to the energy coordinator, "50 percent of the people know" about Blue Energy. Nevertheless, "(..) they do not know in which stage it currently is". Furthermore, Blue Energy is currently not considered to be "(…) talk of the town everyday but I think it could be very good to inform the people and make a possibility to show them the building at the Afsluitdijk and then it will be part of the talk in the town (…)", said energy representative of Leeuwarden. Again, "creating awareness of a new form of renewable energy is most important", highlights a Wetsus scientist.

An energy research scientist and policy studies expert points out, "(…) local people favor one specific renewable energy technology". Likewise, "most renewable energies have some kind of drawback, like visibility issues, or environmental harm". Furthermore, according to him, "(…) residents of boring landscapes are much more willing to accommodate renewable energies, like wind farms, compared to regions with beautiful landscapes and nice old towns and villages". He argues, that on a larger national scale, “there is only one demonstration plant, then maybe less than one percent of the population of the Netherlands should be aware of it. Less than one out of 10.000 are aware of the technology in the Netherlands, I think”. However, “for some renewables the awareness is higher, even though it is also not developed yet, like Fusion Energy, which is also in its infancy” said the expert. He continues by stating, “but there are a lot of publications and there are a lot of impressive funds available”. Finally, if bigger Blue Energy plants would be build, “then probably the awareness of public will increase” according to the expert on energy research.

Conclusion

An up-scaling of Blue Energy would draw more attention on the technology and more people would be informed. According to experts, more attention and awareness of locals would also bring more private money, which is essential to the project. Transparency and local involvement is therefore necessary to up-scale. Eventually, local awareness will lead to a national awareness of Dutch residents, which will increase the demand for renewable energies and will therefore speed up the development of Blue Energy.

5.5 FINANCIAL BARRIERS

The most obvious barrier appears to be the uncertainty of costs related to Blue Energy development. Development and innovation is always connected to investments of large amount of money. Secondly, the lack of funding displays another major barrier, followed by the difficulty to compete with other forms of renewable energies.

1. ‘Uncertainty of costs’

Most stakeholders agree that there is quite an amount of public money available for renewable energy production in general. However, only technologies that are developed and that have proved itself are entitled for the Dutch SDE subsidy program. New technologies have difficulties to raise public money due to the uncertainty of costs connected to the production of energy.

“Also private companies need some kind of insurance that they do not support energy development that is too expensive”, says a policy maker from the Ministry of Infrastructure and Environment. An energy expert from Leeuwarden claims, “a lot of money is going to renewable energies" and "if you want local energy you need to invest (…)". He says, "so far, there is no involvement of municipalities, only the province and national level, who invest money".

An employee of the Rijkswaterstaat continues by exemplifying, "the Rijkswaterstaat and the Ministry of Infrastructure and Environment have a special program in which these projects can apply for financing. If they apply, we give them money if the regional government is also putting money in it". This financing can be considered as a fifty / fifty investment, 50 percent from the state and 50 percent from the region.

2. 'Lack of funding'

Investments and therefore the lack of funding are a major issue for Blue Energy. "That is the holy grail of SGP. To develop the technology to such a level that this issue will be mastered in such a way that it will be affordable", explains an energy expert from an energy research institute. He claims, "having the leading role in an innovation you have to be careful and consider pros and cons and the cost involved. If you want to become world market leader you have to have a clear strategy and clear vision. Continuously he explains, "(…) you have to be willing to invest a sustainable amount of money". A director of REDstack also mentions that cost reduction is necessary in the future.

The funding seems not to be sufficient enough. "It is obvious that the technology needs to be pushed further and it needs to be pushed further, then there needs to be a larger demonstration in the future" identifies an energy expert. Though according to him, "future costs are mostly still unknown". Therefore, "(…) you need the Ministry of Economics Affairs because they are the once subsidizing it", highlights a policy maker from the ministry. The Ministry of Infrastructure and Environment gives "(…) the opportunity to develop but if it gets to big the Ministry of Economic Affairs will subsidize it". A Wetsus researcher is adding. That there is "(…) a lack of financing (…). There is private money and public money and also European money". "If you do not have enough resources it forces you to practical solutions. The first installation you build will always need improvement in the next years because of new knowledge", declares the scientist. Besides concluded by him, "(…) finances are needed all the time and mostly done by private investors and it is supported by public grants".

3. 'Competition with other renewable energies'

Blue Energy is not the only innovative source of renewable energy on the Dutch market. "Every year there is three to five billion euros to subsidize renewable energy programs. Every year there is an amount of euros to produce renewable energies", says an energy coordinator from Leeuwarden. He adds, "(…) but technologies like Blue Energy are not on the list (…). If the energy is great then you can get money from the SDE as a subsidy. It is always hart, also in Holland to get money for new techniques".

A Wetsus project manager confirms that private companies, which have a lot of trust and see the potential of the technology, mostly fund Blue Energy. Also, according to him, the Province of Friesland and the national government is funding. However, an expert on policy studies thinks, people seem to, "rather invest in offshore wind because it was cheaper (…)".

Furthermore, an expert from the Ministry of Infrastructure and Environment highlights that Blue Energy, "cannot compete with wind mills. Who is paying for the extra costs for Blue Energy?". An employee from the Rijkswaterstaat emphasizes, "(..) that governmental organizations put a lot of subsidies into e.g. wind and solar energy. Blue Energy is so new that they actually get less money, which is challenging for Blue Energy".

Conclusion

Blue Energy also shows a lack of public funding. The major challenge of Blue Energy is to be to compete with well-established renewable energy sources. So far, other renewable energies are cheaper. Cost reduction is therefore necessary to be able to compete on the world market.

According to the stakeholders, Blue Energy needs to be pushed further and larger demonstration plants are required. The lack of money and current involved costs to produce energy also makes the national governmental level skeptical about the technology. Blue Energy therefore needs to demonstrate that a cost reduction is possible to produce renewable energies. A cost reduction in production, maintenance and operation will lead to new investments, which are necessary for an up-scaling of the technology.

5.6 ENVIRONMENTAL BARRIERS

Roughly, stakeholders have identified three possible environmental impacts of a Blue Energy power plant. First of all, fish or smaller organisms could get trapped in the membranes. Secondly channeling and streaming water influx or discharge could cause environmental harm, the salinity of the salt water will change. Additionally one further barrier can be added, namely a general uncertainty about environmental impacts.

To operate RED a pretreatment of the water is necessary. The Wadden Sea is an UNESCO World Heritage side. One has to have a close look at possible ecological and environmental impacts.

1. 'Trapping of fish or smaller organisms'

A Wetsus scientific project manager highlights that for example eggs of mussels could get trapped in the filter and that filtering is important due to the clay in the water that should not get into the power plant itself. A program manager from Wetsus says, "one concern I have myself is the trapping of fish. It is no issue for big fish, because you can engineer it the way that there will be no entrapping". According to him, "(…) small fish and organisms they will enter and go through the system and what happen to them is a matter of study". Furthermore the project manager is emphasizing again, "(…) no mistakes can happen. If anything happens, like environmental or ecological impacts the project would be over". According to policy maker from the Ministry, "I think there are a few environmental issues". Also a policy studies expert is stressing, "most renewable energies have drawbacks. Like (…) environmental harm".

2. 'Channeling of water'

An expert from an energy research institute states that he is, "(..) not aware of any environmental problems related to SGP". Moreover, he identifies the issue as complex. It is maybe necessary, "(...) to collect water and more or less create one power station where all the sweet water is channeled". According to him, "that will create some streams on the sweat water side and on the salt water side. That will have impacts on nature perhaps. You cannot just create large streams in the Wadden Sea area". A researcher from Groningen stresses, "in this sense you do disturb the environment. As far as I know there is no paper looking into the effects of ecosystem disturbances in specific”.

3. ‘Change of salinity in water’

Change of salinity is an impact that is already certain. A Wetsus scientist argues, “the salinity of the Wadden Sea will change and that you will not have the big fresh water bubbles anymore, which will be much, much better for the Wadden Sea I think. Not everyone is agreeing on it”. “In the Wadden Sea you deal with the ecological value of the Wadden Sea and in Rotterdam there is navigation on rivers”, said the scientist from Wetsus. Furthermore, he is also emphasizing positive effects “(…) even if you do not make any energy out of it, the mixing itself is interesting enough”. Also, “if you mix them, you are just producing brackish water with no environmental harm”, highlights the researcher from Groningen.

4. ‘Uncertainty about environmental impacts’

The uncertainty about possible environmental challenges of a Blue Energy power plant is immense. Uncertainty about environmental harm has been identified for both, the current small scale plant as well as for future large scale ones. Furthermore, the current plant is located at a very sensitive location at the Wadden Sea, which is an Unesco world heritage side and therefore protected by law. Interference in such as system needs strong monitoring. “I do not know which environmental issues are related to such a plant”, says an expert on policy studies. A local energy coordinator, related to environmental harm and involvement of NGOs pointed out that, “no, I am not sure. I do not think that they are involved. I never heart them talking about Blue Energy. He claims, “maybe there are a few NGOs that are aware of the technology. It would be strange of not but probably they have the same difficulty as the politicians and general public to get a very clear view (…)”.

Conclusion

Uncertainty is still a major barrier. Some environmental changes are certain, like the change of the salinity gradient where water is discharged. However, consequences are unclear. According to a researcher at in Groningen, positive, neutral as well as negative effects are possible. Therefore a need of strong monitoring and future research is necessary to prevent failures. Much the same for entrapping of fish, which is likely easy to prevent.

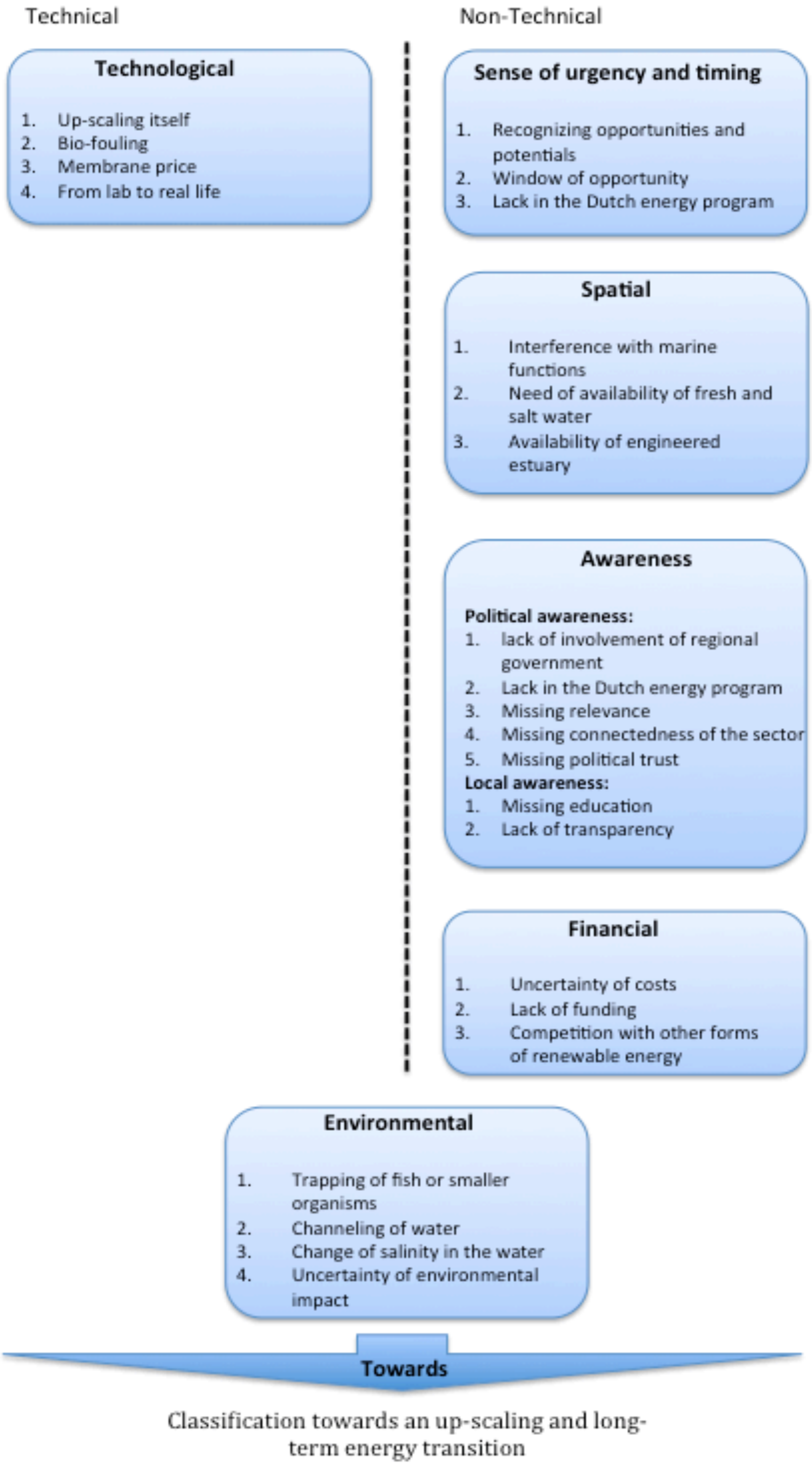

Fig. 7 Overview of identified barriers using the conceptual framework

6. CONCLUSION

Today, most renewable energy sources are well established and contribute to the present energy mix. According to Vermaas (2013), wind energy or solar energy sources have an even larger theoretical potential capacity to produce energy compared to salinity gradient power. Though, they depend on unpredictable circumstances like sunshine or wind and therefore become an increasing problem (Vermaas, 2013). This highlights the significance of new technologies like Blue Energy for the future.

The first aim of the research is to develop an assessment tool by reviewing different bodies of literature. This has been done by developing a classification of barriers for up-scaling Blue Energy. Theoretical literature proved to be useful, as the energy transition can be seen as the overall objective of Blue Energy development. Transition theory therefore helped to understand essential concepts of innovation development. Integrated energy landscape and institutional barriers highlighted the importance of context and contributed major ideas to the conceptual framework. The development of this classification was a necessary step, as the knowledge about Blue Energy is limited with a lack of non-technical publications.

The classification of barriers was used as a tool for further research to identify context specific barriers of Blue Energy that are facing a large scale implementation of Blue Energy in the Netherlands. The tool evidenced to be a success, even though identifying barriers was still a challenge due to the lack of data. Therefore quantitative research was chosen to identify barriers by conducting interviews, based on a stakeholder analysis. Three major groups of stakeholders have been identified. The groups are namely a governmental level, a research level and further stakeholders. The data showed that all groups seem to be equally important and that interaction between stakeholders is important.

Identified barriers have been discussed to illustrate the current development of Blue Energy within the energy transition. To summarize, it can be said that Blue Energy has not yet developed into a well-established source of energy. Barriers can be summarized as 'technological barriers', which consists of four major challenges. First of all the up-scaling itself, followed by fouling of membranes, the membrane price, as well as the challenge to bring the technology from lab to real life.

Secondly, ‘sense of urgency and timing’ as a barrier composes the recognition of opportunities and potentials, recognition of the perfect window of opportunity, and finally the lack in the Dutch renewable energy program.

‘Spatial barriers’ are composed of three challenges. First of all, interference with marine functions, followed by the need of availability of fresh water and lastly, the availability of an engineered estuary.

‘Awareness’ as a barrier is sub-divided into ‘political awareness’ and ‘local awareness’. According to ‘political awareness’, the lack of involvement of the regional government, the lack in the Dutch renewable energy program, missing relevance, the missing connectedness of the sector, as well as the missing political trust are defined as barriers. ‘Local awareness’ highlights missing education and the lack of transparency as major challenges.

‘Financial barriers’ identified further three challenges of up-scaling Blue Energy. Uncertainty of costs, the lack of funding and the competition with other renewable energies are most striking.

The last challenges are ‘environmental barriers’. These consist of the issue of trapping fish or smaller organisms, a problem with channeling the water, the change of salinity in the water and finally, the overall uncertainty of possible environmental impacts.

All identified barriers are substantial. Some may be easy to overcome, others are more challenging. The amount of identified barriers shows the remaining challenges to eventually be able to up-scale the technology towards a well-established part of the current energy transition. Most barriers are strongly interrelated. A weighting or valuing each barrier is not possible, as every classification is different and difficult to compare. Each barrier can be considered as a construction site itself. The research showed that other forms of renewable energy get much more public and political attention than Blue Energy. Awareness seems to be the crucial point.

The energy transition emphasizes that a transition from fossil fuels towards a more sustainable use of energy is necessary. Different European countries already developed further than the Netherlands, as it was stated at the beginning of this research. The Dutch government should try to focus on different forms of renewable energy rather then focus on one or two of them. As they are already moving further by making room for the river, the Dutch government should consider making also room for energy innovation. Currently, Blue Energy seems to be insignificant, however, this research shows that the theoretical potential is significantly higher.

The need and demand for more renewable energy solutions is high. According to a scientist working on Blue Energy, local Dutch residents, knowing about the technology, are already feeling proud. Involvement of such people and local initiates is therefore necessary. A researcher is even stating that, "(…) Dutch people are not that proud of their own achievements". They used to be with the dike development for example but nowadays "(…) we are skeptical and many people do not believe in the government anymore. This can be the one to help us and to become proud again".

The qualitative origin of this research also raised methodological challenges. It turned out to be difficult to do research in a country without being native to it. However, this challenge was just a handicap at the beginning of the research, when stakeholders were identified and interview requests have been send. Later on, most stakeholders were willing to conduct interviews in the English language. The participatory observation at the conference in Brussels turned out to be very valuable, as many up to date information have been discussed. However, cooperation with some companies, ministries and organizations could have been better, as some were not willing to participate in the research or were not willing to give information. A reason could have been the earlier described language barrier. An approach to solve this issue could have been to select a research case located in Germany. However, most stakeholders were more than willing to participate and put a lot of time and effort into sharing their knowledge and were therefore extremely helpful. I would therefore recommend not to be undeterred by setbacks and continue to work.

This leads to further suggestions for this research. The categorization of barriers could be further elaborated or even altered to apply it as a tool in another country.

Furthermore, it is now necessary to work on each individual barrier to eventually be able to solve all challenges. I suppose that the framework can also be applied for other new and innovative forms of renewable energies. However, each case is context specific. Adjustments are therefore highly recommended.

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9. Appendix

LIST OF INTERVIEW CANDIDATES

File no.	Organization	Name of Interviewee	Date	Category	Type
1	University of Groningen	Alexandros Daniilidis	21.05.2015	Research	Face-to-face
PhD researcher at the University of Groningen, with research on Blue Energy					
2	Wetsus, Leeuwarden	Dr. Michel Saakes	29.05.2015	Research	Face-to-face
Scientific project manager and researcher on Blue Energy at Wetsus in Leeuwarden					
3	REDstack	Riek Siebers	16.06.2015	Operation	Face-to-face
Director of REDstack					
4	Energy Research Institute NL (ECN)	Paul Lako	13.07.2015	Research	telephone
Expert on policy studies at the Energy Research Institute					
5	Municipality of Leeuwarden	Bouwe de Boer	15.07.2015	Government	telephone
Energy coordinator in Leeuwarden and former energy coordinator of the Province of Friesland					
6	Wetsus, Leeuwarden	Dr. Jan Post	14.08.2015	Research	telephone
Program manager and researcher at Wetsus in Leeuwarden					
7	Rijkswaterstaat	Joyce de Leeuw	14.08.2015	Government	telephone
Employee at Rijkswaterstaat					
8	Ministry of Infrastructure and Environment	Olga Clevering	18.08.2015	Government	telephone
Policy maker at the Ministry of Infrastructure and Environment					

Salinity gradient power conference in Brussels, Belgium:

9	Institute for Infrastructure, Environment and Innovation	Frank Neumann	16.06.2015	Private non-profit
10	European Commission	Petra Sarapatkova	16.06.2015	Government
11	VITO	Joost Helsen	16.06.2015	Research
12	GIST South Korea	Prof. Joon Ha Kim	16.06.2015	Research
13	WIP	Michael Papapetrou	16.06.2015	Research
14	MENA II: Middle East	Boris Liebermann	16.06.2015	Research

The aim of my research is to identify barriers and challenges of Blue Energy (Salinity gradient power (SGP), using RED) towards an up-scaling of the technology in the Netherlands. I am therefore looking at the broader debate about SGP in the Netherlands, the EU and also the pilot plant at the Afsluitdijk. I am also trying to place the technology within the Dutch energy transition to detect how far the technology has already been developed.
I want to understand which barriers need to be overcome before an up-scaling is possible and to eventually become a part of the Dutch renewable energy mix.

Questions:

Introduction

1. Can you tell me about the *COMPANY/GOVERNMENTAL BODY* and which function it has concerning renewable energies and innovative technologies within the Netherlands?

2. Can you also introduce yourself and describe your position at *COMPANY/GOVERNMENTAL BODY*?

Main

3. Who is involved in the "SGP sector" in the Netherlands?
4. Who is responsible for renewable energies and especially SGP on the private / governmental level?

Barriers:

Technology

5. Which technological obstacles does the technology (RED) still face until it can be up-scaled?

Territorial / Location

6. On the one hand, which location requirements are necessary for larger scale power plants and does *COUNTRY* or even *REGION* meet this demands?
7. On the other hand, are there any territorial challenges, like conflicts between different organizations/governments or even within organizations and their view and opinion about SGP?

Financial

8. Who is financing the research, the pilot and also future development?
9. Is the financing sufficient enough?

Local awareness

10. Is there a local awareness about the technology? Do local residents know about the technology?
11. What is their opinion? (e.g. strong local involvement with wind energy projects)

Political

12. Is there a political awareness? Do *POLITICIANS / GOVERNMENT* even know about this new technology?
13. Do they think it is promising / what is their opinion about SGP? How does the government supports it?

Pilot plant

14. Is the pilot plant at the Afsluitdijk facing even more challenges due to its unique location?

Timing

13. Why is SGP developing now? Can "today" be considered as the perfect window of opportunity?

Environmental

15. Which environmental issues can be identified?
16. Is there already any resistance from environmental NGOs? Are there still uncertainties?

Concluding questions

17. Can you identify further barriers of up-scaling Blue Energy?

18. Is there any resistance from environmental NGOs? Are there still uncertainties?

19. How far would you consider SGP within the Dutch energy transition?

20. Would you consider it as an integrated part of the Dutch Energy landscape yet?

21. What is your personal opinion? Will the technology be able to upscale soon or are there to many challenges left?

22. Can you recommend further literature / interview partner for my research?

THANK YOU!

Interview Alexandros Daniilidis– RUG

Interview file no: 1	Date: 21.05.2015
Time: 11.10 am – 11.35 am	Duration: 25 minutes
Name of interviewee: Alexandros Daniilidis (A.D.)	Conducted by: Malena Ripken (M.R.)
Organization: University of Groningen	
Type of Interview: in person	

A.D.: Can you tell me what the whole idea of your thesis is?

M.R.: My background is water related. I have a bachelor degree with a major in Hydrology and I am a double degree student from Germany also studying water and coastal management. I was looking for a topic that is combining planning + water management + my background in hydrology. I also had some lectures about renewable energies and energy landscape.

A.D.: With Christian Zuidema?

M.R.: Yes, and I have heart about the possibility of gaining energy out of the salinity gradient difference in water but never had a deeper look at it. So I made some research and I did not find a lot of information about planning but there was a lot of physical or engineering things but not about implementation or what kind of barriers there are. My overall goal is to look at the future potential, why it has not been implemented yet, how could it be implemented, where could it be implemented, maybe just here or also worldwide? Are there already power plants. This is kind of my major idea.

A.D.: ok, I can also tell you a bit about where I was involved in. I did the energy and environmental science master in Groningen at this faculty and we started with the idea to somehow produce energy from salt. We were looking for ways how this could be done and pretty soon we found out about this RED or salinity gradient power, this is the overarching term and then we have different things. There is pressure retarted osmosis and RED. They both operate on the same principal that you have water with different salt concentrations. The first method you have a membrane that allows water to pass through and you create a difference in pressure. In RED you have a membrane that separates the water and only allows the ions to pass through. We went with RED and we found some contacts with Wetsus and David Vermaas, he was a student there, he is now finished. This was already 3 years ago. So we found a contact there and we agreed to work on this. This was for my master thesis and for the research master. In my training thesis I did some experiments and for the master thesis I did new experiments, different types plus some modeling and the whole idea behind this, and I am not too much up to date because I stopped working on this but that there are a lot of technical things and that time they had the idea to use the Afsluitdijk as a location. As far as I am aware there is this hydro plant in construction.

M.R.: Yes, I read that they started building it in 2012 but that was the latest update I found.
A.D.: I think there was already something like cutting the ribbon. Last year I think, but it is still a pilot plant. There was a small installation of reverse electrodyaliys in Haarlington, Esco. The principal is the higher the content of salt is the higher the energy potential is. My master thesis was to compare with the current technology , how is the energy output in terms of power and efficiently with different accomulations of Salt. Based on those results then modeled and calculated the price of the membrane that you need to have per square meter in order to get to a point where you have a payback time within 20 years. That is the maximum we need to say that this can be proceeded. It is a technical approach but at that times this was very relevant to establish the price because you cannot because the membranes used so far are mostly used for electrodialysis, which is the opposite process. So they are need especially made for this because there is nor real demand yet. As this is growing it might be the case and there are a lot of people working in the membranes themself in general what I have seen in energy potential studies that you have three levels. Theoretical potential, the amount of energy in theory, with the physical formula what you can get, then you have the technical potential what is feasible with the technology you have today because you always have some losses. So it's always theoretical (he is drawing) and then down to technical and then you can get further down to economical. This always gives you a lower potential.

M.R.: of course and the energy potential that I read was quite high and even higher than the potential of wind energy or solar power but do you know how high the economical potential actually is?

A.D.: So in general what I've seen in energy potential studies is that you have three levels we have the theoretical potential energy from the physical formula, then you have the technical potential. What is feasible because you always have losses. So you go from theoretical to technical to economical. This always gives you a lower potential.

M.R.: An the theoretical – what I read so far – was quite high, even higher than the potential of wind energy or solar energy. Do you know how high the economical potential is?

A.D.: Well from what I concluded from my research at that time was that it is heavily dependent on the membrane price. The membrane price is the biggest contributor. Most research is done with artificial work that means that you have pure water and add salt to it. But in real live you have a lot of different things in the water like sediments and that all affects the membranes. That is called fouling. So we do all this real nice things in the lab but how does it look in real live? Davis Vermaas has published something on this, he was my colleague. So then the question is how this translates in real life. Because the conditions are slightly different. Theoretical numbers are theoretical and it's difficult to rely on them. The added benefit on RED is that in principle you can operate it on a high capacity factor. So for wind its 30 percent and for this its higher, like 90 percent or more. That is quite high. Now regarding the planning part, the idea is that you want to do it were a river flows into the sea, because the mixing part is already happening there. If you mix them, you are just producing brackish water with no environmental harm. However, you do need to channel those streams. It this sense you do disturb the environment. As far as I know there is no paper looking into the effects of ecosystem disturbances in specific.

I know that they are also looking at this technology in Israel around the death sea. However most publications are coming from the Netherlands. They are one of the major developer. There is also Fuji who are looking at the membrane process. For the planning part I do not know if there is anything published. Therefore your research will be very in interesting but also challenging.

Interview Dr. Michel Saakes - Wetsus

Interview file no: 2	Date: 29.05.2015
Time: 12.00 am – 13.30 am	Duration: 90 minutes
Name of interviewee: Michel Saakes (M.S.)	Conducted by: Malena Ripken (M.R.)
Organization: Wetsus, Leeuwarden	
Type of Interview: in person (not a transcript)	

Questions

1. Could you give me a brief overview about Blue Energy and the method of reversed electrodialysis?
    a. Do you think this technology will help to reach the RE energy target of the Netherlands?

    The current pilot plant at the Afsluitdijk is producing 50kwh but has a potential of 200 MW due to the discharge of the Issellake to the North Sea. This equals about 40 modern windmills.

2. Where is it already implemented and where could it be implemented in the future? Are there other places (maybe even worldwide) where plants could or will be build soon?
    a. Why did you decide to build the plant at the dike?

        The Afsluitdijk had to be renewed and reconstructed anyway due to the age of the dike and the rising hazard of future changes in climate and sea level. 300m3/s freshwater are discharged into the sea at Afsluitdijk. This will be up to 5 times higher (up to 1500m3/s in the future due to more water coming down the Isselriver.

        RedStack is operating the power plant at the Afsluitdijk and built it for 7,5 mio. €. 220 m3 of seawater and 220m3 of river water an hour are pumped through the membranes. This is not full scale yet. Up to 400m3/s near Rotterdam could be possible. The potential is even 6 times higher in Rotterdam.

        Thesis Jan Post has a worldwide calculation of potential.

3. What are barriers, which an implementation could face? (e.g. technology, laws and regulations, environmental concerns etc.)
    - *With wind and solar energy an overload of produced energy already happened several times especially in countries like Germany. They had to get rid of the energy as soon as possible and the Netherlands had to turn everything on to use the energy and actually even got it for free. To store energy somewhere is necessary. The Dutch's are making room for the river. Why do not they make room or space for energy. This is so far not on the political agenda.*
    - *Wind and solar energy moved away to Germany and Denmark because the Dutch missed their opportunity and companies moved away. RED is something new and it is Dutch and could also be exported in the future. Politicians are very interested and they like it. Even the King opened the power plant.*
    - *One important information is, that no mistake can happen. If anything happens, like environmental or ecological impacts the project would be over!*
    - *Many smaller issues are already solved. But from lab to real life is always difficult due to many environmental factors (e.g. water temperature that has been used in the lab etc.)*
4. Are there any environmental impacts?

    To operate RED a pretreatment of the water is necessary. The area of the Wadden Sea is a national park. One has to have a close look at possible ecological and environmental impacts. For example the eggs of mussels could get stuck in filter. But there are possible solutions like using sand filters. However filtering is important due to the clay that is in the water and should not get into the power plant itself.
5. Are there any social impacts?

    Not any known of. Dutch people do not like to sea a disturbance in their landscape. That's why the also do not like wind energy that much. The advantage of a RED power plant is that there is no reason that it has to be above ground. It can be invisible under the ground. So far no one said that they do not like it.
6. How are the current projects funded?

    It is mostly funded by private companies, which have a lot of trust and see the potential of blue energy. The province of Friesland and the national government is funding it.
7. How is the energy stored and is it already fed into the Dutch grid system?

No not yet.

8. Who are the most important stakeholders (e.g. government, research) and who is currently working on RED?

   The companies that are in the blue energy team are the stakeholders. More or less 3 big companies that believe in the it and are therefore willing to pay for it.

9. Do you have further literature and interview or other recommendations?

   A possible or even necessary solution is that every house should have a storage (large battery) for energy. This has been not invented yet on a sufficient and working scale.

Creating awareness of a new form of renewable energy most

Interview Paul Lako - ECN

Interview file no: 4	Date: 13.07.2015
Time: 10.00 am – 11.31 am	Duration: 91 minutes
Name of interviewee: Paul Lako (P.L.)	Conducted by: Malena Ripken (M.R.)
Organization: Energy Research Institute of The Netherlands (ECN)	
Type of Interview: Telephone	

M.R.: Can you shortly introduce the ECN and yourself, and describe your current position at the ECN

P.L.: It is a research institute. The English name is: energy research institute of the Netherlands. It is party public because it is party financed by the Ministry of economic affairs and a lot of research is in EU programs and they are co-financed by the institute of economic affairs. We use the subsidy for co-financed projects. But there are also project financed 100 percent by the EU. Some many is also coming from licenses or private money.

ECN is involved in a number of renewable energy technologies, as well as other sustainable energy technologies, among energy efficiency and CO2 capture. These renewable energy technologies are solar, wind energy (onshore and particular offshore), and biomass and biofuels.

ECN consist of five different technical unites, i.e. solar energy, wind energy, biomass and energy efficiency, energy and environmental engineering, and policy studies. I work together with 65 colleagues at ECN policy studies. My main interest is renewable and sustainable energy technologies, but I have also analyzed nuclear energy, mainly for integrated energy studies.

M.R.: Who is involved in the SGP sector in the Netherlands?

P.L.: I think the ECN did not yet contribute to anything related to SGP. We have a portfolio that is very sound and we focus on three or four renewable energies that we really want to push in the Netherlands, which is solar, wind and biomass. A number of parties is already involved in SGP research and development, among which Wetsus, Redstack, Twente Technical University, Hogeschool Leeuwarden, and Fujifilm.

M.R.: Do you think that will change in the future, if Blue Energy will up-scale at one point?
P.L.: probably not in the short term. We already try to stick with current priorities because all of the different segments of energy research appeared not only to be valuable but also needed for the renewable energy targets of the Dutch government. It might be that the technology develops in the next five years. There could be a moment in time then it could be considered as valuable to have ECN on board. Because we still have some knowledge that might give some advantages. Abut this is also still speculative. It would probably not be before 2020. There is already one research company on board, Wetsus and private companies already have commercial interests. Also the involvement of energy companies seems also valuable. The current consortium that is try to develop Blue Energy seems to be appropriate for me.

M.R.: as you have seen, I tried to develop different categories or groups of barriers. Do you think there is anything I need to add to this group? I already involved: technological barriers, as well as territorial/location, financial, political and local awareness, environmental barriers etc.
P.L.: I think that is already quite rational. It includes everything that matters at the moment.

M.R.: My first question would address the technology itself. I think one of the main issues is the development of membranes and the fouling.
P.L.: Yes, these two issues are interrelated more or less. Of course they try to develop membranes that function but then of course this is just the laboratory but not real life. If the membranes are not functioning well in practice then also the life time of membranes is shorter compared to laboratory condition and that is a big issue. Reinvestment in membranes is then necessary and the costs will increase. That is the holy grail of SGP. To developed the technology to such a level that this issue will be mastered in such a way that it will be affordable. Also for maintenance.

M.R.: Concerning the location of future power plants. Currently there is only one pilot plant at the Afsluitsdijk. Do you think that SGP will continue to be a Dutch think/innovation?

P.L.: Sometimes it happens that technologies developed in a small country. If you look for example at wind energy in Denmark, it is amazing that they became leading in wind energy in the last 30 or 40 years even though it's a rather small country. So it depends also on surrounding countries if they pick up the technology sooner or later. Having the leading role in a innovation you have to be careful and consider pros and cons and the costs involved. If you want to become the world market leader you have to have a clear strategy and clear vision and you have to willing to invest a sustainable amount of money. Maybe this technology will not only be developed in one particularly country but maybe in different countries simultaneously. You have to aware that there a different routes to go.

M.R.: for me it was very difficult to get information for the governmental on level of ministry to get information about their opinion of salinity gradient power.

P.L.: Yes, it is sometimes difficult to get information to get information about new technologies compared to existing technologies. It is hardly possible for them to give a opinion about this technology because it is not part of for instant of the national energy agreement, because the technology its still in its infancy. It is not reasonable that SGP is part of the of the 2023 agreement. Maybe in 5 or more years from know to build bigger plants. Now, the technology it's not yet relevant. There is no minister with a clear view of SGP because the technology still has to prove itself. It's far from a commercial technology. It's in the R&D stage. That is not bad.

M.R.: Yes, so it is promising but far from implementation in real life and actually contributing anything to the renewable energy mix of the Netherlands.

P.L.: Technologies that are more or less comparable in terms of development are for instants wave energy. If you look how much wave energy is contributing to the energy mix, it's insignificant. But it's a little bit further down the road than SGP. People rather invested in offshore wind because it was cheaper than wave energy.

M.R.: About the financial issues, it's partly founded by private and public money. Do you think it's sufficient enough?

P.L.: No, I do not think it's sufficient enough. It is obvious if the technology needs to be pushed further and it needs to be pushed further, then there needs to be a larger demonstration in the future. Like 2020 or 2023. But that is not related to the national Dutch energy agreement. The reason it is not included is that the technology is not far enough yet. But an update of the energy agreement in the future also to considered SGP would be interesting. Some renewable technologies had their drawbacks.

M.R.: Do you think it makes sense to up-scale the current power plant or to build new plants for demonstration.
P.L.: I think the current plant is reasonable and necessary in the development stage. Probably in a period from 5 to 10 years from now it is maybe necessary to build a larger demonstration plant, which more or less demonstrates the economical feasibility. That also needs to be proved. Future costs are mostly still unknown.

M.R.: As another barrier I consider the local awareness. Do you think the local awareness will rise In the future
P.L.: I know that some local people favor one specific renewable energy technology. Most renewable energies have some kind of drawbacks. Like visible issues, or environmental harm. It happens that residents of "boring landscapes" are much more willing to accommodate renewable energies, like wind farms, compared to regions with beautiful landscapes with nice old town and villages.

M.R.: is it true that also the political awareness is very low?
P.L.: Yes, because it is in the R&D stage and pre-commercial state. If bigger demonstration plants of e.g. 10 MW would be build then probably the awareness of politicians will increase and also the public awareness. But that will follow the take-off stage of this technology. There is still only one demonstration plant, then maybe less than 1 percent of the population of the Netherlands should be aware of it. Less than one out of 10.000 people are aware of the technology in the Netherlands, I think. Awareness of the local population is neglect able. This is not a rule. For some renewables the awareness is higher, even though it is also not developed yet like fusion energy, which is also in its infancy. There is one pilot plant in the southern part of France. But you can find it in a lot of publications and there a lot of impressive funds available. The invest is very solid there. However outcomes are not clear yet.

SGP is not a technology you can ignore. But how to bring it to the next stage? It still has its cons and pros of course.

M.R.: My last barrier concerns environmental issues. I talked to Rik Siebers already, the manager of the current pilot plant. He told me that there was no environmental impact assessment so far. Are you aware of any environmental problems?

P.L.: No, I am not aware of any environmental problems related to SGP. But of course you can imagine that the issue is more or less complex. The amount of sweet water needed is a limiting factor. The advantage of the technology is that you use sweat water, the runoff of the river. That water will escape to the sea anyhow. But then of course you maybe need to collect water and more or less create one power station where all the sweat water is channeled. It is mixed with the salt water in the power plant. That will create some streams on the sweat water side and on the salt water side. That will have impacts on nature perhaps. The Wadden Sea is a protected area. You cannot just create large streams on the Wadden Sea area.

I do not know which environmental issues are related to such a plant. If there is a dike like the Afsluitdijk it is reasonable to use such. But there are also channels used for sea transport etc. Afsluitdijk is a rather easy location because of the dike.

If it is possible to identify further areas for SGP the government could be more aware of the technology. Maybe other areas in the world are more prospective in terms of SGP potential, I do not know. I am not aware of other countries but maybe even more suitable.

SGP has the potential to develop more in a international framework. If I look at the technology it could develop in a more international technology.

It is always a question of timing. We do not know which countries have the best position in this area. I am not convinced that the Netherlands may become a world market leader. I am not convinced because the potential of the Netherlands is rather small to become a world market leader for the whole technology but maybe they can more or less try to master a very crucial part of the technology and then try to maintain their leadership in that specific part of the technology and then be satisfied with that position in the technology. That would maybe be the best compromise. Because trying to become the world market leader in this complete technology is maybe a bit too ambitious. It does not sound good to try to master the whole technology. They should try to focus on the crucial part and try to collect companies and partners from other EU countries or outside the Eu to compliment the crucial main technology.

Maybe there are a few NGOs that are aware of the technology. It would be strange if not but probably they have the same difficulty as the politicians and the general public to get a very clear view on the potential of the technology and the global potential and also the economic potential or even difficulties. Maybe the sector is also not too well connected to other European countries.

Interview Bouwe de Boer – Municipality of Leeuwarden

Interview file no: 5	Date: 15.07.2015
Time: 8:30 am – 9:07 am	Duration: 37 minutes
Name of interviewee: Bouwe de Boer (B.B.)	Conducted by: Malena Ripken (M.R.)
Organization: Municipality of Leeuwarden	
Type of Interview: Telephone	

M.R.: Can you introduce yourself shortly and tell me about the geemente Leeuwarden?

B.B.: Leeuwarden is one of the 23 municipalities in Friesland. We have 100.000 inhabitants and we are the capital of Friesland. My position is the energy coordinator and I am doing this for more than 20 years already and also I worked for 6 years for the province also as the energy coordinator. I worked fifty / fifty for both. Since 2010 I work 100 percent for the municipality again.

We have a energy program together with the province. Every for years we make a program for the coming four years. The goal of the municipality is to become independent from fossil fuels by the year 2030 and the province has a new goal of 20 percent renewable energies by 2020 and I think 50 percent by 2035. Renewable energies is a big topic here. A lot of money is going to renewable energies. 6 years ago the province sold her energy company and they got one billion euros for it. That is a lot of money for new things like renewable energies. The circumstances are not really bad for pushing renewable energies. And when we talk about Blue Energy and the relation between the project on the Afsluitsdijk and the municipality is not very big. I am not really involved in the development of Blue Energy on the Afsluitdijk. Because the municipality is not directly in the area. We do not have it in the energy agenda of our municipality. So if we want to achieve our goals of being fossil free by 2030 then we have a lot of opportunities like geothermic energy, like solar, like wind, like biogas etc. and on this list is no Blue Energy.

M.R.: So this means the scale of Blue Energy is currently to small for you?

B.B.: Well, it´s not in our region. Leeuwarden is not at the sea. For that reason its not on the list to solve our energy problem. You could say that's a little bit strange but we think producing Blue Energy on a big scale could last for 10 years but wind and solar is now. I know its there and it will be one of the future solutions but in the development and the current stage its more a problem of the province and national level. The municipalities are only party involved in this stage. But it could be a huge producer, I could imagine that it will become a provincial part in the development. Because we have like in Groningen a lot of energy problems. Some people want to get their energy for example from wind or solar etc. and this is growing quite fast. SO there is a need to produce more local renewable energies for people who want to buy local energy. And in the future we try to grow the costumers. For example the NLD (North local renewable) it's a company owned by all the energy cooperation's, the local initiatives cooperation's from Drenthe, Groningen and Friesland. So there is a growing number of people who choose to use local energy and now since one year we have almost three thousand people who choose this company and we want to have until 2018 15 thousand customers. If you want local energy you need to invest, like in solar, wind and Blue Energy. SO far there is no involvement of municipalities, only the province and national level, who invested money. I am very interested in Blue Energy and read every month what is going on. I think that the province is investing more money so it's quite interesting. But for municipalities it's not the time to be involved. But in the future, when it is a serious technique there could be the need and possibility of investment when there is the need of more renewable energies. But that is a question for the next 5, 6 or seven years. So the involvement now is quite low.

M.R.: Do you know about the national level and their opinion about Blue Energy?
B.B.: I do not know. We have the ministry of economics and they are responsible for the energy future. They have a goal for 13 percent by 2020 and that's quite low. A lot of Dutch people are mad of the government because they do it so slow. They event want the national government to speed up and get a new goal of 25 percent by 2020 and went to court. Currently the minister of energy is working on a new energy future document. I read about it one time and everybody is curios what will be in it. It will show how the government is dealing with the new situation to speed up to 25 percent. Every year there is three to five billion euros to subsidies renewable energy programs. Every year there is an amount of euros to produce renewable energies. But techniques like Blue Energy are not on the list because it's in the pilot plants. If the energy is great then you can get money from the SDE as a subsidy. It's always hard, also in Holland, to get money for new techniques. I am quite curious. The pilot got 10 mio euros. I have never been in the building and I am not sure how far they actually are. There has never been a contract

between the municipality and the Blue Energy pilot plant. So they never asked for money or anything. Leeuwarden is interested but not involved in Blue Energy.

M.R.: Do you know about local awareness people? Do people in Leeuwarden know about the technology and are they interested?
B.B.: Yes, I think when you are walking in the streets in Leeuwarden and ask people about Blue Energy I think 50 percent of the people know. And that's quite high. They know about Sea Water, they know about sweet water and the possibility to produce energy. But they do not know in which stage it currently is. A lot of people are aware of a change and you can see that in the fact that we had years ago two local energy cooperation's in our province and then we started a new projects "our cooperation" and it's a mother cooperation for all local initiatives and I started this with a group of friends of mine and now, three years later we have 60 local energy cooperation's. Its growing very fast and people are connected. And they want people in the villages to safe energy in their houses to buy clean energy and the awareness is growing. And by 2018 we want 100 villages with their own energy cooperation. And we want 15000 people who made the choice of local renewable energy. And that group of people in our province is very interested and in the future they will be proud to see also Blue Energy. But it is not the talk of the town every day but I think it could be very good to inform the people and make a possibility to show them the building at the Afsluitdijk and the it will be part of the talk in the town and then there is more ability of politicians to give money and finance the next step. I´m very curious how it goes. Even I am not sure in which stadium the project of Blue Energy currently is. I have in my mind to call the people and have a look myself. Because I have a lot of connections in the energy world. At some point I will call them and make an appointment to see how the municipality could be involved.

M.R.: Do you know anything about environmental issues or any environmental NGOs who are involved.
B.B.: No, I´m not sure. I do not think that they are involved. But I think they are interested. I never heard them talking about Blue Energy. Everybody feels that we have to wait for at least another 5 years. I you see a presentation of the province then they explain to the people: in the coming years we will do this and this and this, wind, solar, biogas etc. and in the far future we have wave technologies, Blue Energy. So it's always on the picture but far away. So people think we just have to wait.

Blue Energy is not in the energy program and that is a pity. And there is also a lot of money for energy in general

Interview Dr. Jan Post – Wetsus

Interview file no: 6	Date: 14.08.2015
Time: 13:30 am – 14:32 am	Duration: 62 minutes
Name of interviewee: Dr. Jan Post (J.P.)	Conducted by: Malena Ripken (M.R.)
Organization: Wetsus	
Type of Interview: Telephone	

M.R.: Can you introduce yourself shortly and describe your current position at Wetsus?

J.P.: My current position at Wetsus is program Manager. At Wetsus we do a scientific program together with companies and universities and amongst others on Blue Energy. I am in the scientific management team that means we coordinate all those research teams that we have. Well actually I am not responsible for Blue Energy anymore but in the past I used to work as a PhD student on Blue Energy. I think I was recognized in the Netherlands and also Europe and worldwide as an expert. I know a lot about the technology and I know what is going on. But I am not involved much in research anymore. I took some distance from the research because I also started my own company, which is closely related to what is going on in Blue energy, but I did not want to interfere with current research. Actually that will change in the future again because I think we can strengthen each other.

M.R.: Can you tell we who is involved in the Blue Energy sector in the Netherlands?

J.P.: Yes, if we look to the parties in the Blue Energy sector.

IN research it mainly Wetsus, with University of Drenthe and the Wageningen University. We still have research going on with this universities. Research is happening at Wetsus but it's supervised by these universities. Meanwhile we work together with other universities as well. We work also together with for example the university of Palermo. We want to work with universities and also worldwide like United States or South Korea and Singapore. But our policy is to work together with European Universities.

Operational level: The companies collected to our research. Like Fujifilm, Redstack, etc. Actually most of them components developers or suppliers. In the past Starkraft in Norway was also involved in SGP but they skipped the activity a few years ago.

If the technical companies do not see the opportunity it will not develop that much, but if they see the opportunity they will even develop more than you ask them for. Fujifilm is a nice example. They want to develop membranes and they see the market so they decided them self to develop the membranes and not some one ask them. It was their own initiative. If they see the opportunity the put the efforts in it.

Governmental level: I can just speak for the Netherlands. There is a strong push from the northern region stimulating the development. Rijkswaterstaat is always supporting and also some support from the national government. In Europe it is a bit harder because Blue Energy was not on their agenda. But Starkraft did some efforts when they were still active.

M.R.: Do you know if there is any local support? Like local initiatives?

J.P.: I think it has never been considered. It might be interesting in the future. The development stage is maybe to difficult to get all the local initiatives involved. But that would be interesting in the future.

I am developing a Blue Battery for households. You use the same technology without a sea or a river. It's a small scale. It is an interesting move, because the pilot plant at the Aflsuitdijk is running. If the Afsluitdijk succeeds then you have to find another spot to do the Blue Energy experiment. Each spot will be different with different challenges. Local awareness will come but not yet.

M.R.: I am trying to develop barriers, which harm an up-scaling of the technology. One is the technological barrier. Maybe you can summarize the main technological barriers of Blue Energy towards an up-scaling.

J.P.: Yes, alright. I think there are three major issues.

First of all, the up-scaling itself. It is not that obvious. It's something people mostly forget. Small scale unit, all the efficiency will change. You have to engineer the up-scaling. Just up-scaling is a goal itself. It is giving us headaches. It is not a small task.

Second issue, we are gaining more knowledge everyday in practical situations. At the Afsluitdijk we have the Wadden Sea, we have seasonal effects. SO in winter time I believe it's easy because we have low bio activity and in summer time it's the opposite. We therefore have to find an operational mode, which satisfies both circumstances. Every effort that you take, you have to invest. You can not speed it up. Lab is not the real world. Fouling is therefore a big issue.

Third one is bring it to a product. You cannot scale it up by just coping from the lab. In the lab we have a lot of equipment to measure everything etc. But for real life we need a technically sound, engineered product. Something simple, robust, easy to manufacture, easy to construct, easy to replace if something is broken. That is something that is not science but it is still important. That is something that still has to be done, even at the Afsluitsdijk. It is still a pilot and an experiment. But if you want to build a demonstration, that still has to be done.
That are the three main challenges and will hopefully be solved in the next years. What I have heard that by 2020 they want to have a demonstration. And meanwhile with my company I want to scale it down to make it easier to access.

M.R.: Which location / spatial requirements are necessary to up-scale Blue Energy? Is it even possible in the Netherlands?
J.P.: Of course you need fresh and salt water and something to discharge the brackish water. Actually you need a sharp distinction between fresh and salt water. It is not that obvious to see where you can to it. Most people would say you have to do it near the coast. But I am not that convinced about it. I would say you have to build it a bit more inland and supply it with salt water with a channel for example. So you have to transport it a few kilometers. AT the Afsluitdijk that is not the case because it's the perfect situation. The people there are not always that positive because the don't envision the Blue Energy plant as a big plant.
The salinity of the Wadden Sea will change and you will not have the big fresh water bubbles anymore, which will be much much better for the Wadden Sea I think. Not everyone is agreeing on it. Most of the freshwater in the Netherlands is going to Rotterdam. You can cider ether to do something with Blue Energy you have to use the channels that are available. Then you need knowledge about the infrastructure there. There you can build a plant and discharge the brackish water in the harbor of Rotterdam. That is something no-one ever considered. People think you have to build it near the sea but you can better use a harbor for the discharge that is open to the sea. Most rivers in Europe have engineered estuary. Always use the engineered rivers and not for example the amazon river that is very natural. But engineered river system are perfect. The main spatial obstacle is that it never obvious and it is always different.

M.R.: Do you see any territorial challenges, like conflicts between different organizations or the government or even within organizations and their view and opinion about Blue Energy?
J.P.: In the Wadden Sea you deal with the ecological value of the Wadden Sean and in Rotterdam there is navigation on rivers. Two totally different situations.

M.R.: Do you think the financing is sufficient enough?
J.P.: There is always a lack of financing and it is not always easy to find out. There is private money and public money and also European money. If you ask a researcher and developer will never say yes. If you don´t have enough resources it forces you to practical solutions. The first installation you build will always be improved in the next years because of new knowledge. Finances are needed all the time and is mostly done by private investors and is supported by public grants.

M.R.: We already talked a little bit about local awareness. Is there anything you would like to add?
J.P.: Lets look to our own region in the northern part of the Netherlands. I think most people here know about it. For example we give once a year a winter school by our local newspaper with lectures for the people. When I gave the lecture about Blue Energy, we had to limit the amount of people because hundreds wanted to come. It was amazing. They were interested, they had heard about it and had questions. How it compared to wind energy. They are also proud about it to live in a city were it has been developed. We have the province supporting us and the city of Leeuwarden supporting us. I think they are all proud of it but also have high expectations. There is a lot of local awareness. But people where also asking critical questions like environmental impacts.

M.R.: How about the political awareness?
J.P.: I think most Dutch parties know about it and also rise questions about it. They are following us at Wetsus. I am happy with their enthusiasm but I'm also happy that they do not consider it for the short term.

M.R.: Do you think that today can be considered as the perfect window of opportunity to develop Blue Energy?

J.P.: I think in the period when I was working on it in 2005 to 2009 it was even better. Oil prices were increasing daily. Today we have low oil prices we have a financial crises. There were a lot of investors ready to jump in but then the finical crises came. During my PhD thesis I was much more optimistic to get money but nowadays there is a sense of urgency to reach targets. And 2020 is coming close but we are not close to 20 percent renewables. I think it is becoming perfect again. Also the rest of the world is following us here. In the past at conferences never heart about the technology. Nowadays people from all over the world are citing us. Maybe in the end, the Dutch people will become proud of it. Because I think we, the Dutch people are not that proud of our own achievement. We were with the dikes but nowadays we are skeptical and many people do not believe in the government anymore. This can be on to help us to become proud again.

M.R.: Which environmental issues can be identified?
J.P.: The pilot is so small it will not have any environmental impacts. Well, at least not something to mention. The positive one, even if you do not make any energy out of it, the mixing itself is interesting enough. Blue Energy is better than sluices because the output is brackish and not salty once and then again fresh water.
One concern that I have myself is the trapping of fish. It is no issue for big fish, because you can engineer it the way that there will be no entrapping. For small fish and organisms they will enter and go through the system and what happen to them is a matter of study. That is something that will be done in the pilot.

M.R.: What is your personal opinion about Blue Energy. Will it be able to upscale soon?
J.P.: Well if we do not go on, they will go on. That is what we do not want. It forces us and gives us motivation.

Interview Joyce de Leeuw - Rijkswaterstaat

Interview file no: 7	Date: 14.08.2015
Time: 14:35 am – 14:57 am	Duration: 22 minutes
Name of interviewee: Joyce de Leeuw (J.L.)	Conducted by: Malena Ripken (M.R.)
Organization: Rijkswaterstaat	
Type of Interview: Telephone	

M.R.: Can you briefly introduce yourself and also your current position at the Rijkswaterstaat?

J.L.: Yes, I am working the project Afsluitdijk and I am especially working on renewable energy projects and the synergies between the projects that are already at the Afsluitsdijk and how we can involve these projects to the rebuilding of the Afsluitsdijk. We want to take into account that these projects are also there and we want to give them space to up-scale.

M.R.: Ok, that means you already have these projects in mind and you more or less reserve the space that it is able to upscale in the future.

J.L. Yes there is this ambitions to have the governmental parties of the regional governments, like the provinces and the ministry of infrastructure and environment and we as the Rijkswaterstaat. Together we formulated an ambition to also involve renewable energies at the projects.

We as Rijkswaterstaat are not responsible to initiate projects like Blue Energy. We only facilitate them on our infrastructure, on our ground. What we do is try to think along with them to optimize the installation and how to make room for up-scaling. But on the other hand it is difficult to give enough room because the dike secures the Netherlands from water. There are always limitations in that sense on how much they can up-scale.

M.R.: Do you know anything about barriers or challenges towards up-scaling Blue Energy? Or do you know how promising the technology is?

J.L.: Yes, I think of course we see a lot of potential and especially the fact that it is very innovative. We also see that governmental organizations but a lot of subsidies into e.g. wind and solar energy. Blue Energy is so new that they actually get less money, which is challenging for Blue Energy.

M.R.: Is the Rijkswaterstaat putting money into Blue Energy?

J.L.: The Rijkswaterstaat and the ministry of infrastructure and environment we have a special grogram in which these projects can apply for financing. If they apply, we only give them the money if the regional government is also putting money in it. It is a fifty / fifty investment. Fifty from the state and fifty from the regional government.

M.R.: Do you know anything about the spatial issues, for example further locations to build Blue Energy power plants?

J.L.: I think the whole Afsluitsdijk could be a potential location for Blue Energy.

M.R.: So even if it would develop to a very large scale it could still be located at the Afsluitdijk?

J.L.: Yeah, I think it could be a very large Blue Energy installation. But it is difficult to say now. That is something that is still far away. But I think there is a large potential towards up-scaling.

We are trying to give them as much space as possible, but we cannot predict the future.

M.R.: You talked about the up-scaling at the Afsluitdijk. Will there be any special issue due to its sea defense measure?

J.L.: That is not sure yet. That is up to RedStack to prove if they can make pipelines through the dike. They first have to check if it possible and if they do not endanger the function of the dike. They need to apply at the Rijkswaterstaat to get permission to place pipelines.

Interview Olga Clevering – Ministry of Infrastructure and Environment

Interview file no: 8	Date: 18.08.2015
Time: 10:01 am – 10:26 am	Duration: 25 minutes
Name of interviewee: Olga Clevering (O.C.)	Conducted by: Malena Ripken (M.R.)
Organization: Ministry of Infrastructure and Environment	
Type of Interview: Telephone	

M.R.: Can you introduce yourself and also describe your current position at the ministry?

O.C.: I am a policy maker and I am working in the sub sector water. We are working with business and knowledge institutes and it is all about enterprises and party have a say what is needed and what universities and applied research should do. My department is on water safety. We stimulate new forms of energies and dikes, for example Blue Energy or tidal energy. We are working together with the ministry of economic affairs. They are about energy and we are about water. For the rest of the time I am involved in knowledge in general and how universities works and all the polices about that and I am working on the connections with European programs.

M.R.: What do you or the ministry actually know about Blue Energy? Is it on your agenda?

O.C.: Yes, because we have a lot of contact with Wetsus and we support Wetsus since a few years to develop Blue Energy. The Afsluitsdijk is one of our main projects and one of the goals is to develop sustainable energy on the dike. We try to stimulate different forms of ocean energy. And I am a biologist and so I know the principle of Blue Energy and how it works.

M.R.: Do you think Blue Energy is important and promising for the future?

O.C.: I think there a two different ways to look at it. We like to stimulate energy out of water because of our role at the subsector water and because we want to have to own infrastructure energy neutral. Because there is lot of sluices and locks and we want to be energy neutral. We give companies the possibility to develop new forms of energy but to

make it bigger you need the ministry of economic affairs because they are the once subsidizing it.
We finance the development of new forms and if it gets very big and it has to compete with coal or wind energy you need subsidies these forms and responsible for that is the ministry of economic affairs. We give them the opportunity to develop but if it gets to big the ministry of economic affairs will subsidize it. Because it is not our role to subsidize it.

M.R.: I am looking into barriers of Blue Energy. Can you see any barriers before and up-scaling of the technology is possible?
O.C.: I think there are a few environmental issues. I think the water has to be quite clean to pass the membranes. I am not sure if the problem will be solved and the other problem is of course the mix of fresh and salt water and that could be a problem. It is of course it is the question if it will be a good source of energy and where will you use it. And if I read the current papers I think it can compete with other forms of water energy but can it compete with wind or solar energy? Or other forms of energy like from biomass and I am not quite sure about it. I think there a still a lot of technical problems that need to be solved. And you cannot put a large Blue Energy installation in a water system becase there is traffic and ships have to move.

M.R.: Do you also work together with RedStack or mostly with research like Wetsus?
O.C.: The Afsluitdijk is quite difficult because we give the province of Friesland and north Holland money to develop sustainable energy. AT the Afsluitdijk the projects have to come from these two provinces. To subsidize a party directly is quite difficult in Holland. We give RedStack and other parties place on the Afsluitdijk to develop.

M.R.: DO you think Blue Energy will be part of the Dutch energy transition in the future?
O.C.: I do not expect large scale. Maybe they will have one plant or maybe two at the most. I think it is more of interest for export. To have a technique and to export it.

M.R.: Do you think that the politics and the Dutch ministries are aware of the technology or should there be more people working on it?
O.C.: I think they know enough. The question we have at the ministry is about subsidizing Blue Energy and Ocean Energy. Because it cannot compete with wind mills. Who is paying for the extra costs for Blue Energy. As long as Blue Energy is very

expensive it will be difficult to up-scale. Other technologies like wind, solar or biomass are more promising and especially cheaper. Also private companies need some kind of insurance that they do not support energy development that is too expensive.

I hope all the issue will be solved. The economic are a little bit better now. The energy sector is very much in favor of other forms of energy and not that one. They are in favor of for example wind energy or biomass