The role of context in the development of radical innovations: The case of Blue Energy in the Netherlands

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Abstract
Research has shown that innovations do not develop in vacuum and that a successful innovation
does not necessarily guarantee success in another setting. The study aims to provide insight into
the role of context in the development of radical innovations and is as thesis subject, part of the
Create Acceptance project at ECN. Literature on technological development has been consulted
to understand what can be considered as context in all phases of development: from research
and development to the final implementation. This knowledge has been applied to a specific
case called Blue Energy. Blue Energy is a renewable energy potential, based on ‘Salinity
Power’ that obtains clean energy from mixing water streams with different salt concentrations.
In the last seven years, two challenging projects have been initiated on this principle in the
Netherlands following a different development. The focus in this research is on situations that
have stimulated or constrained the developments to identify specific contextual factors. This re-
sulted in several crucial elements useful for stakeholders in the Blue Energy development as
well as for managers in similar projects, to broaden their understanding of technological devel-
opment and thus make project management more accountable.
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Summary

Research has shown that innovations do not develop in a vacuum and that a successful innovation does not necessarily guarantee success in another setting. Besides technological factors, also political, socio-economic, geographical and cultural contextual factors influence innovations. Innovations are constantly interacting with their context and therefore context is an important factor in technological development. The role of context however, is underexposed in innovation studies. Various scholars have shown the importance of context, but did not try to make the role of context explicitly clear. The Create Acceptance project is an initiative to understand and influence renewable energy technologies. A considerable amount of renewable energy cases have been analysed and a classification was made of contextual factors influencing the social acceptance of these cases. The ambition of my research is to contribute to the Create Acceptance project by comparing two projects in the Netherlands on a similar renewable energy technology called ‘Blue Energy’. Blue Energy is based on the chemical principle that when two solutions of different salinity join, the concentration will diffuse until the salinity is equal in the total fluid. When a selective membrane is placed between the two solutions, e.g. sweet (river) water and salt (sea) water, the diffusion can be controlled and potential energy gained. The technology is in a very early stage of development and receives little (global) attention. However, recently two projects have been initiated in the Netherlands to develop Blue Energy into a commercial application. Two projects on a similar technique in a similar external context, however with a different outcome; the group that started the first project has now lost their leading role in the development to a newly founded research institute. The main theme of this paper is to understand the different development of the two projects and I compare the projects by discussing the role of context herein. This study can be considered as an explorative research, a pilot investigation or a preliminary study with the intention to shed light on the influence of context on radical innovations.

I formulated the main question guiding my research as follows: What is the role of context in the development of Blue Energy? In order to answer this question, I divided this research question into two sub questions: what is considered as context in literature on innovations? And what factors are discernible in context? I am not only interested in the kind of context to analyse socio-technical developments, but especially in the influence that it has on the development. I therefore elaborate on how technologies develop and on the working of technological development. This resulted in my distinction, based on Geels (2004), between st-systems, actors, rules and a special category of expectations to portray context. To analyse the influence of national and more regional/local context I focused on specific events that stimulated or hindered the development of Blue Energy: occasions, disputes, controversies, problems, decision moments, etc. that changed the direction of development. The most important conclusion from my analysis has been that in the same external context, the role of internal context has been important for the difference between the two projects. Especially the personal network and the actors’ capacity and capability have been crucial for project success. Some participants had been working in the same region or sector for decades and therefore knew each other for a long period. Actors could be approached informally, they trusted and supported each other and convincing them to join the institute has therefore been easy. Some actors also occupied influential positions within their firm and could make financial decisions and had a stronger and more influential network at their disposal, which consisted of actors with capacities and capabilities that have been crucial for further development. But there was also another factor that made a difference: alignment. In order to apply for a government subsidy for example, the project has to fit or match certain criteria. The same can be said about the involvement of stakeholders: they were easily involved when the project suited their strategy and fitted in their line of business; when it created possibilities related to their core business; or when knowledge was already available on this topic.
The alignment of involved actors has been another crucial contextual element and can also be related to the strategy chosen in the project.

Context, however, is not only influencing the development but the development also influences its context. This complexity makes it very difficult to analyse the role of context and it has been particularly difficult to categorise context at a higher level of aggregation. What do we consider as context, or better what element of this context do we point out: the actor, the network, the belief system in the network, the expectation that the actor or network has or the external factor responsible for the expectation… in other words where to look and where to make a division has been my main struggle in the analysis. We therefore rather speak of the interaction between the socio-technological development and its context. In addition, when analysing context, you can go on indeterminably with demonstrating context behind context. Every time you start with demonstrating the influence of an actor or factor, you find that behind each actor and factor that directly influences the innovation another factor or actor is influencing this actor or factor and thus indirectly influences the innovation.

I found that no categorisation of context is easy to make and struggled to get the analysis of context structured. I therefore introduce some facilitating concepts to cope with the complexity of context as an attempt at this structuring. I propose that there are roughly two forms of context: direct context and indirect context. Direct context or first-line context is directly involved in the development. The availability of financial means, the capability of stakeholders, and the organisational setting all have had a direct influence on the development and can be seen as direct context. Indirect context, or second line context, on the other hand influences a first-line contextual element. The societal need for alternative energy sources created expectations about commercial possibilities or business opportunities. These expectations subsequently resulted in the founding of a company, which is the factor that had a direct influence on the Blue Energy development. Furthermore an indirect contextual factor can also influence other direct contextual factors and it is also possible that a direct contextual factor influence another direct factor. This notion of context has consequences for the categorisation of context, because these factors do not fit in a single category. Many scholars use certain categorisations in factors, such as economical, social and infrastructure factors. However, these factors are interrelated and are therefore impossibly placed in specific categories. Furthermore the strategy, the capability of the actors involved, the availability of the network, and the suitability within the organisation can obviously be related to the internal competences, properties or internal context of the project. External context to the project were the formal government support arrangements, government strategies, availability of support programs and any other contextual factor that cannot be influenced directly by the management of the project. Besides the direct and indirect division proposed earlier, I therefore propose an extra division between internal and external context. I have combined these two concepts in a two by two matrix in Table 1 and filled in the elements that have been crucial in the socio-technical development of Blue Energy.

Table S.1 Internal and external versus direct and indirect context

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<th>Indirect</th>
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<td>Internal</td>
<td>Stakeholder involvement, alignment core business, knowledge, financial means available</td>
<td>Alignment expectations and visions, dedication/enthusiasm stakeholders, personal network, capacities and capabilities of actors, knowledge available</td>
</tr>
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<td>External</td>
<td>Government support (financially)</td>
<td>Government attention</td>
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When the two projects are compared using Table 1, the first project only succeeded minimally in the indirect-internal and direct-external categories, whereas the leading project did well in all four quadrants. We can also see that the indirect-external quadrant is at such a great distance...
from the project that this is outside the influence of the project management. The direct-internal quadrant on the other hand has been crucial for the development and can be subscribed to the internal project competence. However, in order to get actors involved and create alignment, actors have to be convinced actively. Expectations have been of great importance in this activity. In each and every situation, expectations were involved. This is also due to the fact that situations depend on actors and actors’ strategies, perception and motivation, which all depend on expectations. Diverse expectations exist around radical technological developments, because network linkages are still weak and future prospects insecure. These expectations are used by actors to convince others and are not always shared within the network around the technological development. These expectations henceforth advice engineers in their search process, mobilise new actors in the network, are used to allocate funding, convince politics or legitimize the project. It is crucial that these expectations become accepted by more actors and taken up in agenda’s. Positive outcomes of developments lead to positive expectations resulting in follow up research programs, related projects and a community or network of involved actors.

What became clear is that context is very complex and that in order to use this method; a very strict outline should be followed focusing on one single aspect of technological development. Generalisation of results has been difficult, but the notion of the direct and indirect context and the influence of internal versus external contextual factors could be a fruitful enhancement for innovation studies. The study also showed the importance of micro sociological studies in the development of technologies. Expectations and network formations are underexposing in for example the Multilevel Perspective and the Systems of Innovation. External landscape (macro) as well as regime factors are often perceived as the most important trigger for technological breakthroughs. Usually, external or landscape factors get the attention and are often treated as fatalistic factors. In the Blue Energy development however, it became clear that network properties and the alignment within the project have been crucial elements for the success of this development. Small-scale research on this technique is only conducted at a few places worldwide and has revived again in the Netherlands. Obviously, the global and national contexts have not been the main concern in this case; the regional and local contexts have also contributed to the development at these specific locations. Therefore attempts to influence this and similar developments into favorable directions should not only focus on subsidiary programs and changing regulations, especially internal properties and the alignment in the project must be taken into account. Furthermore, expectations have been crucial for the allocation of finances, convincing other actors and the enrollment of stakeholders.
1. Introduction

1.1 Introduction

“Salinity power is one of the largest sources of renewable energy that is still not exploited. The exploitable potential worldwide is estimated to be 2000 TWh annually. One of the reasons that this renewable source has not drawn more attention is that it is not readily evident to most people. Another reason is that considerable technological development is necessary to fully utilise this resource.” (UN atlas of the ocean, 2001)

Salinity power is a renewable energy potential that obtains clean energy from mixing water streams with different salt concentrations. Even though energy using salinity gradient power contains a huge worldwide renewable energy potential, its utilisation has been considered to be neither economically feasible nor technically attractive.

*Development of salinity power*

Salinity power is already more than one hundred years old and has received some international attention during the oil crises of the seventies but research only continued at a few locations. Besides the unfamiliarity with the technique and the considerable amount of technological development necessary for its utilisation, the price of membranes has been the main drawback of this technique (Post et al., 2007). However, according to Post et al. the increasing prices of fossil fuels as well as the decreasing prices of membranes\(^1\) will make salinity-gradient power more attractive in the near future. Recently, research on this technique appeared in the Netherlands. The basis for the Dutch project started in the eighties with early attempts to conduct research on an alternative (cheaper) membrane production method. This eventually led, in 2003, to a consortium of several industrial companies that started a feasibility study and system research on a project called Blue Energy.

*Blue Energy*

Blue Energy is a sustainable energy technology, based on the difference in salinity between sweet (river) water and salt (sea) water. When sweet and salt water join, the concentration will diffuse until the salinity is equal in the total fluid (fundamental law). When a selective membrane is placed between sweet and salt water, the diffusion can be controlled and potential energy gained. There are two ways to get energy out of water via membranes: Pressure Retarded Osmosis (PRO) and Reversed Electro Dialysis (RED).\(^2\) It is the second principle, RED, that has gained renewed attention in The Netherlands for the last five years and has received the label Blue Energy.

*Blue energy development in brief*

The development started in the eighties with early attempts to conduct research on an alternative membrane production method. This leaded to a consortium of several industrial companies that started a feasibility study and conducted system research on Blue Energy in 2003. About a year later, a newly founded research institute developed a similar research program and attracted several participants to commercialise the principle. The consortium that first attempted to develop Blue Energy has lost its leading role to the research institute and at this moment only conducts research as a subcontractor. Research has been conducted on the feasibility, membranes

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\(^1\) Membrane technology research has been conducted for other related applications, such as: desalination and water reuse applications, purification, fuel cells, batteries and kidney dialysis.

\(^2\) Both principles are based on salinity gradients and internationally known as salinity power. At the time of writing, the worldwide attention for RED is still marginal and initiatives for an operational power plant have not been reported so far.
and system design for more than four years already. The project elicited a lot of attention and attracted many participants. All stakeholders and also the national government and important spokespersons have high hopes for this technique and the possibilities it creates for the Netherlands. Nevertheless, the development has not always been fluent. Even though the project received positive attention it did not result in meeting the expectations, expressed early in the development.

**Difference between two projects**

As mentioned before, the consortium that started research on Blue Energy already worked on the project for four years when a similar project was started at another research institute. Even though the consortium had the advantage of being a prime mover, their involvement in the project has ended and Blue Energy has been taken over by the other research group. Both developments took place in the Netherlands, which would suggest that the influence of national factors has been equal for both projects. The main theme of this paper is to understand the difference between the two developments (projects) and to analyse the influence of national and more regional/local context.

**1.2 Introducing context**

To understand and investigate the differences between the two developments, I will focus on the role of context herein.

What is context?³

I define context as the environment in which the innovation or technology takes place: that means all the elements that influence the development of the technology. Both factors as well as actors play an important role as context, influencing each other and constraining or stimulating the development. Development does not only involve technological research and technological development. Development also refers to the socio-technological development of the technology: the enrolment of stakeholders, the allocation of financial means and implementing the technology are all part of this process. Let me start by depicting what I define as context by briefly discussing the example of the windmill development; a generally known renewable energy technology.

**Windmill development**

The technological development of windmills started centuries ago when windmills were used to pump water and grind flour. In the last century, this technology has been developed for the application of generating electricity and in the eighties and nineties windmills were seen as a promising technology to overcome energy shortage and environmental problems. Technologically windmills have improved rapidly; nowadays, windmills are utilised that can produce from kW to several MW and generate enough electricity for hundreds of households. Promising as it may seem, windmill projects have been struggling in other areas of development than the technological, such as finding suitable locations. Citizens but also politicians and scientists have often successfully protested against the placement of windmills in the Dutch landscape, and were able to resist local implementation by uttering their formal objections in the (politico-regulatory) licensing process. The most often heard arguments were that windmills pollute the landscape (‘landschapsvervuiling’), that they have a negative effect on birds and that they make an annoying sound. Besides these social and arguably also environmental factors that hindered the implementation of windmills in the Dutch landscape, also economic reasons have been uttered; windmills are not economically viable at the moment, and therefore need a lot of government support.

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³ Linguistically, the concept ‘context’ is usually employed as ‘in context’. For this thesis however, I do not refer to context in the sense of the ‘Context Principle’: that words only have meaning in the context of a sentence (Frege, 1953). I use context as “the surrounding conditions in which something takes place” or “the environment in which the innovation or technology takes place”. This meaning of context is frequently used in technology studies: for example local context, regional context and the national context.
support. Opponents have argued that there are better and cheaper technologies available. Also geographical factors can be mentioned. Windmills have to be placed in windy areas, and preferably not in heavy wind due to technological reasons. Another factor that hindered further employment was of an infrastructural matter. Power generated by windmills fluctuates due to the speed of wind and the resulting energy fluctuation creates problems in the electricity grid. Related is the problem of distributed generation. The Dutch National Grid is not (yet) equipped for large amounts of decentralised electricity production. I have shown in this example that the socio-technological development of windmills does not only depend on technical or scientific aspects, but also economic, infrastructural, social, cultural, and geographical factors have played and still play a role in the development. The realisable potential of a technology will thus most often be far less than the theoretical potential (see Figure 1.1).

![Diagram: Theoretical potential, Technical potential, Realistic potential, Realisable potential](image)

**Figure 1.1 The realisable potential of a technology**

**Importance of context**

Following from the above example of the windmill, one could state that technological development is much more unpredictable than what most technology developers assume, since the development is not logical and does not develop following the optimal, deterministic ‘best technology’ plan. A second briefly discussed example will strengthen this argument: the example of the car. The internal combustion engine is not the most efficient power supply for transportation and air tires produce a lot of friction. So why not drive on electricity? This is because the development of this technology has constantly been in interaction with its context, which predominantly consists of actors (social factor). Hughes has made an interesting remark on this topic:

> ‘Technology should be appropriate for time and place; this does not necessarily mean that it be small and beautiful…There is no best way to paint the virgin; nor is there one best way to build a dynamo.’ (Hughes, 1987: 68)

This makes the prediction or success of a technological development very complex. It is almost like predicting the weather…. On the other hand, it is generally known that the windmill development did do a lot better in Denmark. Can we therefore attribute this difference in development to cultural reasons? I will indeed argue for the remaining of this thesis that understanding contextual factors is crucial in understanding and managing projects. However, this is not always taken into account. Engwall (2003) argues that theories on project management treat projects as islands, assuming the unit of analysis as a lonely phenomenon. According to Engwall: “Current findings suggest that project management success is to a large extent due to context-specific circumstances” and therefore history dependency and organisational-embeddings

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4 This diagram has been copied and adjusted with the permission of Andre Wakker (ECN).
should be acknowledged (ibid.:802,5). Innovations do not develop in a vacuum, but are constantly interacting with their context. Recently, these insights resulted in an initiative to understand and influence renewable energy technologies. The European Create Acceptance project is concerned with the “cultural influences on Renewable Energy Acceptance” and wants to develop “tools for the development of communication strategies to promote acceptance among key actor groups.”

This research is based on the notion that differing visions should be taken into consideration when developing renewable energy technologies. If this is neglected, the implementation might face severe societal resistance. It is also underlined that:

“Societal acceptance of renewable energy is thus obviously a result of the interaction between project and context.” (Create Acceptance, 2006:8)

In this European project a considerable amount of renewable energy cases have been analysed and a classification was made of contextual factors influencing the social acceptance of these cases. The factors are divided in political, socio-economic, geographical and cultural factors and between national and local factors. The ambition of my research will be to contribute to this European project. In the Windmill development the interaction with context was different in each country, whereas the Blue Energy development took place in the same country. This means, my study will focus on the development of a technology in one country that was undertaken at two separate locations by two different actor groups, with different strategies, backgrounds and stakeholders. Thus the influence of local context is at the centre of my study.

1.3 Research question

The main research theme of this paper has been introduced in the beginning of this paper. I am interested in the difference between the two Blue Energy projects that have started in the Netherlands. I have briefly indicated the importance of context in the development of the windmill and explained how this can help me to answer the first question. The question guiding my research can now be formulated as follows:

What is the role of context in the development of Blue Energy?

Context is not a theory. Context is rather a concept used in innovation studies. However, this concept is not always taken into account and there isn’t an approach in the innovation studies that focuses solely on this concept. Consequently, in order to answer my research question I will have to consult literature on technological development in order to come up with an understanding of and a possible definition for context.

To answer my research question, I will therefore elaborate on several sub questions:

- What is considered as context in literature on innovations?
- What factors are discernable in context?
- What is the role of context in the development of Blue Energy?

I will elaborate on the first sub questions in chapter two when I review relevant literature on technological development. The literature that will be discussed approaches this topic from a variety of scientific angles: political, economical, sociological as well as historical approaches will be discussed. The operationalisation of my empirical study and further outline of my approach will be discussed in chapter three.

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5 See: www.createacceptance.net.
1.4 Expected Findings and Relevance

This research is expected to provide insight on the context in which (radical) innovations develop, particularly in the renewable energy sector. The Blue Energy case study and the conceptualisation of context could be relevant both in practical as well as theoretical settings.

**Practical relevance:**
I have conducted my internship and the greater part of this research at ECN. ECN is the Energy research Centre of the Netherlands. My research has been part of the Create Acceptance project for which it is aiming to deliver an interesting addition.

“Most of the previous research on social acceptance and resistance has been conducted in the context of wind and bio energy applications. Less experience has accumulated on (project-level and contextual) factors influencing the acceptance (in concrete applications) of other technologies, such as hydrogen and carbon capture and storage” (Create Acceptance, 2006: 10).

The Create Acceptance project consists of more than 20 case studies on a diverse set of renewable energy developments, and Blue Energy will be the only case on salinity power. Furthermore, the case is interesting as it will demonstrate the contextual difference between two similar projects in one country. Besides delivering another case study, my research is also meant to give insight in the concept of local/regional context.

Another practical outcome that can be expected for the stakeholders in the Blue Energy development as well as for managers in similar projects is that their understanding of technological development becomes broader and thus makes project management more accountable. This also counts for the national government. Their intention to stimulate renewable energy initiatives could be optimised. If we would be able to understand context, policy strategies could be developed to better influence technological development into preferable outcomes on both the local/regional and national level.

“If we knew what kind of activities foster or hamper innovation - thus, how innovation systems function - we would be able to intentionally shape innovation processes” (Hekkert, 2006).

**Theoretical relevance:**
This thesis also has the ambition to contribute to theories on innovation. I hope to give insight in the different perspectives in innovation studies on the conceptualisation of context and make some general conclusions about the influence of context.

1.5 Outline

In order to distil more general assumptions on the role of context I want to examine the Blue Energy project and see what we can learn from this development. What is so special about the context in both projects on Blue Energy? What is context and can we discern certain general factors in the context of technological developments? And if we do, can we use that knowledge in a practical way to understand technological development and make project management more effective and accountable? In my research I will therefore also consult innovation literature on its conceptualisation of context in order to answer the question: “what plays a role as context in the total development of innovations, from R&D and acceptance towards the implementation?”

Chapter 2 investigates context theoretically, Chapter 3 discusses my methodological approach and data collection and the Blue Energy case is introduced and analysed in Chapter 4. I answer
my research questions in Chapter 5, followed by some general conclusions on the role of con-
text.

This study is not intended to argue for or against the desirability of Blue Energy. It is also not
meant to judge the development in any way. My intention is to shed light on the influence of
context on radical innovations. This research can be considered as an explorative research, a pi-
lot investigation or a preliminary study. The focus was on the influence of context on the Blue
Energy development. I am also interested in the question if context could be an interesting per-
spective to analyse radical innovations. This would adhere to the Create Acceptance project.
Chapter 2 has been meant to create a certain sensitivity in order to identify context in techno-
logical development. This would rectify my empirical research, my naive search in innovation
literature, and the doubts, problems and difficulties I have spread in analysing context. After
each problem I have made a decision that I tried to support with an example in order to further
outline the research and also perfectionalise the context perspective.
2. Conceptual framework

The land mill gives you society with the feudal lord;
The steam mill, society with the industrial capitalist.
(Karl Marx)

2.1 Introduction

In this chapter I discuss the theoretical framework and concepts that will guide me to answer my research question. For this purpose, I elaborate on relevant literature on technological development, technological change and innovations. Scholars employ these terms for different purposes and therefore I briefly elaborate on these concepts and definitions (relevant for this thesis) in order to prevent confusion.

Scholars came up with various explanations for technology and have struggled with formulating a clear definition. Not only because the authors are trained in different disciplines and use a different frame of reference, but also because technology in general can be related to tangible objects as well as techniques, processes or skills. Dosi’s definition covers most of the different conceptualisations. He formulates technology as a set of pieces of knowledge (both practical as well as theoretical), know-how, methods, procedures, experience of success and failure, physical devices and equipment (Dosi, 1982: 151,152). For my research I am interested in the development of the technology. The term technological development often covers only the research and development phase of technologies whereas for this thesis all phases are of concern: research and development, deployment and implementation. Therefore, following various authors, I use the concept ‘socio-technological development’ for all phases of development and I refer to technological change as the physical technological development. Another concept that could lead to confusion is ‘innovation’. Innovation can be seen as a phase in technological development and is also used as a broader definition of novelty; technological change, managerial change, scientific novelty, etc.

This thesis is based on the assumption that the environment is influencing the development of a technology, and different than Marx who thought that technologies determine society, follow many authors in the assumption that society and technology are developing together (co-evolve). Dosi (1982) argues that innovation depends on feedback mechanisms between external environments and technical developments provided by institutions, which supports the importance of the external influences. Rothwell (1992) emphasizes the importance of relations for the development of an innovation. He claims that innovation is significantly and increasingly influenced by the formation of networks, collaboration and alliances leading to a variety of external relationships. The external influences or the environment, in which the innovation or technology takes place, is referred to as the context of the technology. Both factors as well as actors play an important role as context, influencing each other and constraining or stimulating the development. Understanding these factors is therefore crucial in understanding and managing projects. Nevertheless, the importance of context is not always taken into account (see Chapter 1: Engwall, 2003; Create Acceptance, 2007).

Is it possible to come up with a list of factors that comprise context? The answer is yes and no. A specific technology can develop fruitfully in one country while it faces many barriers and therefore has a disappointing development in another. The context of a technology is therefore time and location specific. The same holds for the timing of development; over time dominant ways of thinking change and the influence can shift to other regimes. So, what is the point in

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7 Often also the term ‘artefact’ is used for the physical technology.
trying to discern certain contextual factors that influence the development if it doesn’t hold for other technologies? After all, to understand certain developments you always have to take the specific context into account. The ambition in this thesis is therefore to (1) identify general assumptions about the context of technologies; (2) tools that would help to identify factors that comprise context; and (3) propose a way to categorise these factors. Not all possible components and relations between the technology and its context will thereby be specified; such an ambition would certainly be unrealistic.

This chapter is meant to give insight on what constitutes context and which factors are of importance. I will therefore start my search for context in Section 2.2 by consulting theories on (socio-) technological development and position my research in literature. I discuss their conceptualisation of context and elaborate on the relation between context and the perspective on technological development. I will conclude this historical introduction with a conceptualisation of context in 2.3. I then discuss the regime concept and further elaborate on the Multi Level Perspective as proposed by Geels, and introduce his analytic model because it provides me with a framework for categorising context in the development of (radical) innovations and for understanding technological development. The role of expectations around radical novelties is of extra concern and therefore further discussed. I conclude this chapter in Section 2.4.

2.2 Theories on (socio-) technological development

There is abundant literature available on (socio-) technological development and scholars from diverse backgrounds focus on different aspects of development. The explicit question ‘what constitutes the context in which innovations develop?’ is for the greater part avoided and most of the theories inherently presume certain elements that make up context. However, these elements seem to differ among perspectives and theories. Dosi discussed institutional influences whereas Rothwell elaborated on actors and networks. Other scholars focus on inducement mechanisms for technological change and usually categorise certain contextual factors, such as: technological factors, government policy and regulatory framework, cultural and psychological factors, demand factors, production factors, infrastructure and maintenance factors, and undesirable societal and environmental effects of new technologies (Kemp et al., 1998). The conceptualisation of context obviously differs among theories on innovation, mainly because it depends on the unit of analysis, perspective, questions asked, etc. Indirectly the question what constitutes context also encompasses questions about what is meant by technology and innovation. Do we discern among products and processes, incremental or radical innovations, phase or level, etc. The question ‘what constitutes context in the development of a radical innovation?’ is therefore more complex not in the last place because of the dynamic component of technological development.

In trying to understand the differences in the conceptualisation of context, also a practical problem rises on how to discern these perspectives, theories and authors, especially because there are many variations in these diverse fields of research. To my opinion the contemporary research on innovations is still developing into a new discipline and is therefore too dispersed to be able to categorise particular movements. Sociologists, historians, economists as well as political sciences have mingled in the analysis of technological development. I consulted a few textbooks on innovation and technology studies in order to understand the growing literature on this topic and the following meaningful expression says enough:

“Two decades ago, it was still possible for a hard-working student to get a fairly good overview of the scholarly work on innovation by devoting a few years of intensive study to the subject. Not any more. Today, the literature on innovation is so large and diverse that even keeping up-to-date with one specific field of research is very challenging.” (Fagerberg et al., 2005:4)
Elaborating and comparing all research on this topic would be a dissertation on its own resulting in a textbook on innovation studies, which does not belong to the scope of my research. I therefore discuss perspectives and concepts that recognise the notion of context and, to my opinion, are widely acknowledged for their contribution to the research on technological development.

**Early approaches on Technological development**

Economists have dominated research on technological development for centuries, because technological development was considered the motor for economic progress. Technologies were seen as an external influence on the market and technological development followed a deterministic pattern driven by economic competitiveness. According to neo-classical theory the selection environment would be the market; Users need certain technologies and improvements, urging companies to open up the endless box of available technologies and choose the most suitable in a competitive market. In these theories it is all about varying combinations of labour and capital; technology only facilitates. Opposite to this so-called demand-pull perspective is the technology push perspective. Technology leads to production and science was supposed to be the main engine for technological development. Economic factors were hardly taken into account. The example by Marx, cited in the introduction, says enough: the type of technology imposes a particular societal system. Besides these opposite and extreme views on technological development, other scholars aimed at understanding why technologies change and focussed for example on technical bottlenecks, reverse salients, etc. Rosenberg referred to something similar as reverse salients: technical imbalance. He suggests several common external factors (some of which can be explained as context) as an inducement for further innovation: technical imbalance, strikes and availability of supply (Rosenberg, 1976). The inducement mechanism is the prospect of making higher profits, or loosing the ability to do so.

Although these technology-push and market-pull perspectives were suitable for explaining the influence of the market and the deterministic force of technologies, the social dimension is for the greater part avoided. Scholars from various disciplines reacted to these classical models on technological development, pointing out that technologies cannot be seen as exogenous to the environment, are not a priori available to the producers and that the process is more dynamic and the role of firms more complex. I discuss theories that reacted on the technology push and market pull perspectives and to my opinion contributed to the notion of context in technological development. I have grouped these scholars under: the evolutionary economists, social constructivists, the Systems of Innovation and Multi Level Perspectives and discuss their contribution to the conceptualisation of context.

**Evolutionary economists**

Dosi (1982) and Nelson & Winter (1982) elaborated on the variation and selection characteristics of technological development. Similar to the Darwinian perspective on evolution, these evolutionary economists perceive technologies to develop randomly in research labs and the most suitable, preferable designs are selected in the selection environment. Like in evolutionary biology, the fittest or best adapted and suitable creation will survive. However, unlike biological evolution, engineers will develop, imitate and improve successful designs and hereby reduce the variety of technological designs. Dominant designs will therefore prevail over rejected ones, because the knowledge of the selection environment is anticipated for in the design process. The

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8 Although neo-classical theories themselves do not adhere to these evolutionary terms, selection environment is a well-known concept in technology dynamics literature. The selection environment is an analytical term for that factor in the environment that is responsible for selecting specific technologies over others.

9 Reverse salients are components in the system that have fallen behind or are out of phase with others (Hughes, 1988: 73).

10 Another reason for this reaction could be that society has changed and that these conservative views on technological development are no longer valid. Gibbons for example elaborates on the different position of science in society. In the context of application, science, technology and industry are moving closer. Driven by competition and inspired by the need to collaborate (Gibbons, 1994). What he calls Mode2 knowledge production is characterized by a constant flow back and forth, between the fundamental and the applied, between the theoretical and the practical.
in institutional structure provides the system with retention and ‘the mechanism analogous to genetic mutation is innovation’ (Van den Belt & Rip, 1987:137). According to Dosi, shared problem-solving activities of engineers result in patterns of developments, for which he introduced the term: technological trajectories (Dosi, 1982). Dosi refers to this dominant way of thinking as the technological paradigm, analogous to Kuhn’s paradigm. Nelson & Winter (1982) introduced the concept of the technological regime to account for the shared set of beliefs and knowledge. These technological regimes and paradigms have a strong exclusion effect for dissent designs. Engineers and firms are discouraged to design and invest in radically different technologies because they are trained to develop in a specific way and because of market uncertainty. Context is obviously recognised in this evolutionary economist’s perspective and exerts force on the development. Dominant designs, regimes and paradigms are all important notions of context.

Social constructivists
For social scientists the evolutionary economist approach didn't go far enough. They perceive technological artefacts as socially constructed:

‘the development of scientific knowledge and technical systems cannot be understood unless the simultaneous reconstruction of the social contexts of which they form a part is also studied.’ (Callon, 1987: 20).

These ‘micro’ sociological approaches, such as for example Actor Network Theory, assume technological development as a process in which technical and social elements become linked with one another. Actors construct linkages around artefacts (e.g. technologies) and form networks, which stabilise and become dominant and difficult to change. The SCOT approach describes technological artefacts by focusing on the meanings given to them by relevant social groups (Pinch and Bijker, 1987). It is important to understand that the origin of dominant designs can also be found in traditional or historical path-dependencies and that not always the optimal technologies become embedded but that the history of technological developments plays a crucial role. An interesting example is the QWERTY-keyboard. According to David (1985), technical interrelatedness, economies of scale, and quasi-irreversibility of investment constituted the basic ingredients for the QWERTY-keyboard to become ‘locked-in’ as the dominant keyboard arrangement. Even now when mechanical typewriters are almost extinct, this basic line-up, which is not the optimal arrangement, still exists. Another example of a technology that is heavily embedded in society and therefore difficult to change is the internal combustion engine in cars. Alternatives (at this moment more sustainable ones) have been available ever since the first car was born. However, electric or hydrogen cars will have to face the embeddedness of the internal combustion engine in car industry; manufacture and maintenance infrastructure; oil; cultural expectations and habits; and governmental regulations.

‘Technology should be appropriate for time and place; this does not necessarily mean that it be small and beautiful…There is no best way to paint the virgin; nor is there one best way to build a dynamo.’ (Hughes, 1988: 68)

Social constructivist approaches perceive context as mainly social. Dominant designs are explained by the stability of networks and actors or actor-groups create these linkages and give meaning to the technology.

Systems of Innovation
Besides these network and evolutionary approaches, also more ‘meta theories’ emerged as a reaction to classical theories on innovation. The system approaches acknowledge ‘a set of institutional actors that, together, plays the major role in influencing innovative performance’ (Nelson,
System approaches are developed to analyse the contributions of actors and institutions in the innovation process. Technological change is the outcome of a complex process of interactions and systems are generally conceived as control mechanisms at a higher level. Social, political, economical and managerial processes all seem to play a role in technological development. Many scholars have contributed to this approach and different levels of aggregation can be distinguished, being: local, sectoral, technological, regional or the commonly used National Systems of Innovations (Rosenberg, Nelson, Lundvall, Freeman). The focus within these Systems of Innovations (SI) is on institutions and organisations. In the NSI for example, institutional settings are country specific and perceived to influence the management and activities within firms. Systems approaches are interested in finding out how innovations develop and systems are perceived to evolve in accordance with a loosely defined pattern, such as for example: invention, innovation, transfer, consolidation. Innovations develop in a process of co-evolution between the internal innovation process and the innovation system. This implies that context in this view is seen as the institutional arrangements or the system of innovation. Also external factors are distinguished (external to the system and thus also to the technology): oil crisis, economic recession, climate change, etc. These external and internal factors can have a positive or negative influence on the success of the innovation. In Edquist 1997, a more general definition for SI is provided:

‘All important economic, social, political, organisational, institutional and other factors that influence the development, diffusion and use of innovations.’ (Edquist 1997: 3,11-12,14).

This seems like a perfect definition for context. SI approaches however are mainly focusing on ‘macro’ static factors (institutions) that comprise the system and are therefore less suitable for analysing radical innovations. It is an analytic tool to compare different innovation systems on actors, networks and institutions and less on the actions of the individual entrepreneurs. A more dynamic approach would show how interactions between governments and industry develop, how regulations come in place, how events and learning influence the development, in other words how and why processes work. To my opinion the SI approach is mainly concerned with the process of incremental innovation and the different phases of development.

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13 E.g. The Triple Helix model (Etzkowitz & Leydesdorff, 2000) discerns industry, government and science.
14 Within SI there is a lot of confusion about these concepts: institution can mean rules of the game (Lundvall) or different kinds of organizations (Nelson, Rosenberg). In general, organizations are formal structures that are consciously created and have an explicit purpose. Institutions are sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups and organizations (Edquist, 2005: 182).
15 Nelson & Rosenberg (1993: 13) focus on the institutions and mechanisms supporting technological innovation. Besides firms and institutions they acknowledge all factors influencing national technological capabilities, such as (more indirect): schooling, training, and restraining skills of workers, attitude, patterns of labour, (management) degree of mutual commitment of firms and workers, financial institutions, management of firms, but also laws of a nation, existence of a common language, and a shared culture.
16 This is often criticized as institutional determinism (Hekkert et al., 2006).
The Multi Level Perspective

The Multi Level Perspective (MLP)\(^{17}\) is a more dynamic approach that does appreciate radical novelties. The MLP is an offspring of the sectoral systems of innovation.\(^{18}\) Based on Dosi, who emphasizes the role of institutional factors in the construction of technological paradigms and Nelson & Winter’s regime concept, the MLP is build around these engineering beliefs, cognitive factors, rules and expectations. Actor groups are guided by shared and linked rules and perceptions called regimes. The model tries to understand long-term and large-scale technological developments by focusing on particular patterns and mechanisms in transition processes (Geels, 2002). To understand the complex dynamics of socio-technical development this model discerns three analytical levels: micro, meso and macro. The regime level (meso) explains how best practices, expectations and rules can steer technological development in certain development-paths or trajectories. Incremental innovations usually take place at this level. The landscape or macro level refers to the more external, not directly related influences, such as oil-prices or environmental problems. Radical innovations take place at the niche level (micro), protected from the selection criteria of the regime level.

Technological development can be seen as the outcome of the interplay between actor groups and regimes structuring these groups. Five regimes are distinguished: technology, science, users and markets, industry and policy regime (Geels, 2004). This so-called ‘meta-technological regime’ broadens the notion of a technological regime in relation to different actor-groups. The regimes co-evolve and influence the actor-groups as well as each other. More meta-regimes can exist around one development. In the case of electricity producing lighthouses for example, both the electricity regime as well as the agricultural regime could be expected to be present. I believe that in this perspective, the niche, regimes and landscape function as context. The regime level accounts for contextual factors that have a direct influence on both incremental as well as radical innovations and can also be influenced or changed by the development. The landscape level comprises general developments on which a single innovation does not have much influence. Niches function as incubation rooms (Geels, 2004) for radical technologies; a specific context in which the development is ‘protected’ from regime and landscape influences.

To summarise

It became evident that most of the perspectives recognise the role of dominant designs, actors and some sort of shared norms and values. Table 2.1 categorises the important contextual concepts and perspectives.

Table 2.1  Contextual factors in various perspectives on technological development

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Dominant Design</th>
<th>Radical</th>
<th>Actor</th>
<th>Network</th>
<th>Rules</th>
<th>Int/ext Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolutionary economist</td>
<td>+</td>
<td>-</td>
<td>+/-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Social constructivist</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>Systems of innovation</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Multilevel perspective</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

I have mentioned earlier that not only the purely technical challenge or market prospect hinders the development and implementation of technologies. Reactions on classical theories often focus on dominant designs in the engineering process. Basic or dominant designs are important notions in innovation studies and most theories on technological development emphasize the constraining role of dominant ways of thinking, such as values, problem definitions and search

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\(^{17}\) This contemporary model receives a lot of attention in Dutch transition research.

\(^{18}\) A sector would be the group of firms (system) active in developing and utilising products and technologies that comprise the sector.
heuristics. Dominant designs are embedded in society and therefore innovations usually develop in line with the existing technologies. Most theories explain certain path dependencies and trajectories using this concept. For the purpose of my research especially the exclusion effect of these dominant designs is important for understanding the effect on radical novelties. Not every approach, however, discusses the complexity of radical novelties in technological development. The above-discussed perspectives on technological development have mostly been aimed at understanding technological development; how technological development is connected to scientific developments and how technologies follow certain dominant trajectories. Others are interested in why technologies change. Early concerns were for example on ‘reverse salients’. These reverse salients lead to (conservative) or incremental innovations within the same trajectory. Sometimes critical problems are solved by radical innovations leading to the creation of new systems. The types of technologies discussed in these approaches are mainly incremental innovations and radical novelties are only perceived to create new systems (in SI for example).

The notion of dominant designs is also related to norms and values. Not every perspective appreciates the social dimension of context in technological development evenly. Evolutionary economists take certain shared social values, search heuristics and rules (cognitive and regulatory) into account and constructivists also stress the actors’ influence and perception on the development. Most of the perspectives on technological development use the concept of rules, when referring to theses shared values and norms. Routines, roles, norms, protocols, and values guide actors’ behaviour, therefore carry history and are maintained by actors. Another important notion of context that becomes evident in these previous theories is the division between internal and external influences. External influences such as oil prices or environmental problems are usually seen as exogenous but influential to the development.

I have summarised some of the salient factors of context as discussed in perspectives on technological development. I asked myself in the introduction, if the role of context depends on how one perceives technological development? Variation and selection mechanisms, regimes, rules, actors groups and their construction of networks and institutions are important concepts for understanding technological development and are obviously also part of context. Not every approach uses all of these concepts, because their focus or unit of analysis is on another factor, level or phase of technological development. We can therefore say that there is a strong relation between the perception of technological development and the role of context. Taking this relation into account, I elaborate on my theoretical framework in the next section. This framework makes it possible to further elaborate on and possibly categorise the factors that I found to be of great importance in context.

2.3 Towards a conceptualisation of context

In the previous section I have summarised some of the salient similarities and differences among the theories. It became evident that there is a strong link between the way one perceives technological development and the role of context herein. Even though many scholars have a different focus on technological development, some contextual factors are addressed by many of them. The notion of dominant designs, rules, actors and their network activities have become evident as contextual factors. In this section I discuss the framework for categorising these contextual factors and, as discussed in the previous, an important aspect for my thesis is that the theory recognises the complex role of radical novelties in comparison to the more incremental ones. Another important element is that the approach I am looking for is concerned with the social dimension of technological development in all of its phases. Systems of innovation approaches for example, mainly discuss the research and development phase of novelties; production, and the creation of knowledge and innovation. Markets are assumed to be out there. How-

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19 Path-dependencies, trajectories (Dosi, 1982), innovation avenues (Sahal, 1985), momentum (Hughes, 1988), and the technological regime (Nelson & Winter, 1982) all embody this feature.

20 Others, such as often in constructivist approaches, do not make a clear distinction between radical and incremental innovations.
ever, many radical innovations fail during acceptance and implementation. On the other hand, market-pull perspectives only focus on the influence of user preferences and forget the internal technological dynamics (treated as a black box).  A combination of push and pull insights is therefore crucial in understanding the development of novelties in all of its phases; research and development, employment and implementation. It is important to find a balance between social and technical shaping. Transition theories do focus on radical novelty and recognise all phases of development. Kemp et al. (1998) developed a way to analyse how technologies with a more desirable outcome could be stimulated. They argue that new favourable regimes have to be formed and that this process has to be accomplished by a transition (regime shift) in which both the technology and the system change. In light of the need for a transition towards more sustainable technologies, theories are developed that take these notions of regime shift and transition management into account. The regime concept is recognised by many scholars and is obviously an important factor in context. I elaborate further on the usefulness of this concept to categorise and understand context.

Regimes

Technological regimes have a strong exclusion effect for dissent designs, which makes the regime concept an important constraining factor in the context of radical and incremental technological development. As mentioned earlier, engineers take the selection environment into account, and the design process becomes a shared process, which results in routines, shared search heuristics and dominant way of thinking. Dominant perceptions form a technological framework and result in a shared outlook and can be summarised under the existing technological paradigm. According to Kemp et al. (1998), not only cognitive aspects of problem-solving activities influence technological change, also the interplay with other social and economic factors plays a role. External pressure from the selection environment influences the innovator and the research agenda, however this selection environment is also influenced by the R&D company and a host of other actors involved in the technology (ibid.: 181). Therefore they enhance the concept of a technological regime by Nelson & Winter. Besides the dominant paradigm it also contains the selection environment:

“A technological regime is thus the technology-specific context of a technology which pre-structures the kind of problem-solving activities that engineers are likely to do; a structure that both enables and constrains certain changes.” (ibid.: 182)

This so called structure contains many interrelated and reinforcing factors, impeding the development and creating inertia and specific patterns. Kemp et al. discuss and categorise certain factors in this context affecting technological development (ibid.; 117-181): technological factors, government policy and regulatory framework, cultural and psychological factors, demand factors, production factors, infrastructure and maintenance factors, and undesirable societal and environmental effects of new technologies. We can conclude that Kemp et al. consider the technological regime as the context in which technological development occurs. The regime concept refers to commands and requirements but also practices and roles, which are made up of interrelated factors that feed back on one another. Regimes can be seen as a constraining influence on radical novelties innovations because they favour the incumbent technology and create economic, technological, cognitive, cultural and social barriers for radical new technologies. The concept of regimes is therefore an interesting concept to categorise factors that stimulate and constrain the technological development.

21 Similar critique has been expressed by many scholars on innovation studies. The Multi Level Perspective and especially Strategic Niche Management approaches can be seen as a reaction to these deficiencies.
22 A similar point is made by Geels (2004).
23 The definition as it is introduced by Rip & Kemp reveals that regimes consist of rules that are embedded in engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems all of which are embedded in institutions and infrastructures. Regimes stand for the interrelatedness of these rules.
Various scholars have focused on many aspects of these regimes and actor groups and various categories are available. Geels (2004) distinguished five, however also listings of seven or nine are developed. Geels distinguishes different regimes whereas Kemp et al. focus on different factors within the regimes. To use the regime concept for categorising context, I believe a division on different factors (Kemp et al.) or on actor-groups (Geels) would demarcate my findings too much. Furthermore, actors’ individual behaviour, system builders and outsiders (van der Poel, 2000) will be left out of such a categorisation.

Geels (2004) refines the notion of regimes by making clear how all elements in technological development are linked. He distinguishes three analytic dimensions: ST-systems, actors and rules (ibid.:902). The so-called socio-technical systems are the material aspects and resources (products, money, tools). Actors are also social-groups, and are guided by rules.

What is important is that the interactions between these dimensions explain their constraining influence on one another and therefore the dynamic element of technological development. Actors are influenced by elements in the ST-system (material nature) and are vice versa also reproducing the same elements (1,4). Rules constrain and enable actions and the same actors carry and reproduce the rules (2,3). Rules are embedded in artefacts and technologies have a certain hardness that shapes (5,6). This division makes the technology and the environment perfectly clear:

‘The advantage of looking explicitly at socio-technical systems is that the co-evolution of technology and society, of form and function becomes the focus of attention. Dynamics in ST-systems involve a dynamic process of mutual adaptations and feedbacks between technology and user environment.’ (Geels, 2004:902).

If we take the actors around the technological development as the main focus, this analytic division would make two types of context visible of which the importance was already made clear in the previous section: the influence of technological properties and the notion of rules. ST-systems can be seen as material context and rules as in-material. In-material doesn’t mean that rules are only cognitive and invisible. The difference with material structure means that it is the material configuration that structures and that in the case of rules, the in-material value, norms, and conceptions do so. However, this analysis of context would make it difficult to categorise network advantages and entrepreneurial action, in other words also actors are part of context. I therefore use the three analytic dimensions, mentioned by Geels, as the context around the socio-technological development. To explain the constraining elements of these dimensions,
Geels uses the notion of stability. Stability is what constrains radical novelty in that it creates path-dependencies and lock-in for existing technologies. Rules and regimes guide perceptions and actions, actors and social groups are part of networks and depend on one another, and systems embody hardness (Geels, 2004:910,911). Therefore I want to propose the following framework for categorising context, based on this analytic dimension by Geels (2004), see fig 2.2. All three elements are interrelated and comprise context as a whole not as individual factors.

![Diagram of context framework]

Figure 2.2 *Three interrelated contextual elements around a socio-technical development*

Many scholars have elaborated on specific rules: formal rules, such as administrative procedures, subsidy applications, and product standards; as well as the informal ones, such as routines, paradigms, symbolic meanings, and user preferences. I believe the distinction by Geels(2004), based on Scott (1995), covers almost all. He distinguishes three dimensions: regulative, normative, and cognitive rules (see Table 2.2).

| Table 2.2  Varying emphasis three kinds of rules/institutions |
|-----------------|-----------------|-----------------|
| **Regulative**  | **Normative**    | **Cognitive**   |
| **Examples**    | Formal rules, laws, sanctions, incentive structures, reward and cost structures, governance systems, power systems, protocols, standards, procedures | Values, norms, role expectations, authority systems, duty, codes of conduct | Priorities, problem agendas, beliefs, bodies of knowledge (paradigms), models of reality, categories, classifications, jargon/language, search heuristics |
| **Basis of compliance** | **Expedience** | **Social obligation** | **Mimetic, learning, imitation** |
| **Mechanisms**  | Coercive (force, punishments) | Normative pressure (social sanctions such as ‘shaming’) | |
| **Logic**       | Instrumentality (creating stability, ‘rules of the game’) | Appropriateness, becoming part of the group (‘how we do things’) | Orthodoxy (shared ideas, concepts) |
| **Basis of legitimacy** | Legally sanctioned | Morally governed | Culturally supported, conceptually correct |


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See also appendix A. Geels summarised various common examples of rules by different scholars.
Rules are important contextual factors for both radical as well as incremental innovations. One specific type of cognitive rules, expectations, is especially crucial for radical novelties. When new technologies emerge they carry many disadvantages: low performance, high costs, uncertainty of form and function, no stable network and therefore have many difficulties competing with existing technological regimes (Geels & Raven, 2006). Therefore, around every socio-technological development, expectation statements are expressed (e.g. concerning societal options or technical specifications). Many scholars also acknowledged these expectations and visions. They often discuss the institutionalised expectations. However, around radical technological developments, with its weak network linkages and insecure future prospects, diverse expectations exist. These expectations are used by actors to convince others and are not always shared within the network around the technological development. I therefore further elaborate on some general insights of expectations to understand their contextual influence on especially radical innovations.

Expectations:
Expectations give direction to search and development activities and have the dynamic of self-fulfilling prophecies. These expectations henceforth advice engineers in their search process, mobilise new actors in the network, are used to allocate funding, convince politics or legitimise the project (e.g. Moore’s law). According to Van Lente (1993), promises create agenda’s interlocking activities and demanding action. He argues that this is based on the notion that expectation statements contain implicit or explicit messages (scripts) and are therefore actants creating and recreating linkages, allocating roles and demanding action in order to reach specifications. When the general manager of an energy company foresees offshore wind energy to be the source of the future, this is not just an idea of what might happen. It also entails roles for other actors, those who are responsible for funding the research and for those who will investigate the possibilities. Van Lente recognised this process of the conversion of a promise to a requirement:

‘…an option or new possibility is presented as a promising new route, it becomes accepted as such, thereby invoking new interactions, leading to new task divisions and specifications to be met.’ (ibid.: 195)

The crucial step in the conversion from promises to requirements is that the expectations become accepted by more actors and taken up in agenda’s. This notion of implicit or explicit messages also counts for actions. When governments spend money on offshore wind research, this can be read as ‘offshore wind will become important.’

An expectation as a factor of context does not exist on its own. The moment, the place, the person who makes the statement and the public to whom it is addressed matters; in other words the context (or background, van Lente 1993) in which the expectation statement is made. A different background means different roles and interlocks different activities.

‘Basic idea behind background is that a single expectation statement or a single readable action itself does not automatically lead to action. It has to be read in such a way that action is demanded.’ (ibid.: 195).

Expectations also create and maintain protected spaces.

“A protected space in R&D activities, created on the basis of expectations, enabled engineers to focus on the development of a technology that was potentially a radical innovation, but had no contemporary market value.” (Raven, 2005: 30)

The acceptance of promises helps to protect ongoing activities and their behaviour resembles that of structures.

25 Note that I am referring to another context than the main concern of this thesis.
“Relatively independent of the work to keep it in existence, a space has a life on its own. Spaces are constructed, but they may continue to exist and exert power (e.g. protecting search processes) without continuous work being done explicitly to keep them in existence.” (Van Lente, 1993: 204)

These niches in a sense created a special context for the technological development. It is also important to understand that radical technologies have to anticipate on future markets, for which expectations are of great importance. In cases of risk, expectations on specific values of variables can be gathered to allow for decision-making. When there is a lack of insight in the nature of variables (will BE play a role?) expectations expressed at conferences or in journals might reduce the uncertainty. However, when the future depends on what others will decide it is no longer about getting information but about collaboration and coordination; a strategic game has to be played (Van Lente, 1993: 190). This also means that actors (spokespersons) and the network configuration play an important role in the propagation of expectations.

Obviously expectations exert force on the development and are therefore crucial elements for understanding the context of socio-technological developments. Expectations are not only used (passive) but also do something (active). Radically new innovations need expectations to legitimise their development and attract actors by reducing uncertainty. Expectations are contextual factors. However, these early expectations, used to reduce uncertainty around radical novelties, are not generally shared yet. I therefore appreciate these not yet shared expectations as a separate contextual factor.

2.4 Concluding remarks

Context has become more and more important in explaining socio-technological development. In this chapter I have discussed theories that appreciate the role of context and positioned my thesis in literature. In order to understand why alternative radical energy technologies have so much difficulty to develop in society, we need to focus on theories that stress this position of radical innovations, appreciate all levels and phases of development and especially the social dimension of technological development. I discussed useful concepts and theories that (1) could categorise these factors, (2) could be part of context, and (3) could reveal factors in context. I therefore discussed the conceptualisation of context in various perspectives on socio-technological development. What could be learned from the historical review is that the way one perceives technological development changes the role of context. Another point is that the discussion on the role of context has changed. Context was previously seen as irrelevant for technological change in the earlier technology push perspectives and underexposed in market pull approaches. Contemporary theories place most of the weight on the interaction of the technology and its environment. The determinants of innovations vary over time and space, between systems, categories of innovations, process and product, incremental and radical. Both variation as well as selection takes place in context, and the choices made in the development depend on a wide range of conditions: factors (personal, organisational, political, and economic, etc.), contingencies (historical, local) and actors (competing strategies and perceptions) all play a role in the development (Jamison & Rohracher, 2002: 7). In contemporary literature, technologies are no longer perceived as an autonomous, deterministic element of society. Technologies do not develop in isolation but are part of a larger system or network. Technological change is therefore frequently perceived as the co-evolution of technological and social developments and many scholars refer to this topic as socio-technological developments, social shaping of technology and the co-evolution of technology and society. Furthermore, technological development is more and more understood to be a network activity.

I have discussed several difficulties in defining the role of context. First of all a wide range of scholars from different perspectives (sociology, history, economics, science & technology stud-
ies) has mingled in the research on technological development. I therefore found it very difficult to categorise these scholars into distinct approaches and my historical introduction can merely be seen as an exploration on this topic. This relates to the second problem of defining the role of context: the focus of attention. Some scholars elaborate on the R&D phase of technologies and argue that engineers already search in distinct directions because of previous knowledge and education (design heuristics). Others focus on the inherent hardness of technological artefacts and argue that new technologies have to integrate into a certain infrastructure. Again others perceive technological development as the co-evolution of technological and social elements. I have shown that discussing the role of context depends on the focus of study and the way one perceives technological development. It became clear however, that even though the concepts and metaphors originate in various disciplines they intersect in many ways. To my opinion Geels (2004) managed to develop the Multi Level Perspective into a consistent analytic framework that covers many aspects of technological development. He explains radical novelties, all phases of development, the social dimension, and has found a way to incorporate many of the existing knowledge and concepts on socio-technological development. I have used his distinction into three analytic dimensions: systems, actors and rules as my analytical framework in order to understand and categorise certain factors comprising the context of radical innovations. However, what is underexposed in this distinction is the notion of expectations. Uninstitutionalised expectations are especially important contextual factors around radical novelties in that they mobilise and advice actors, allocate funding etc. This will therefore be an important focus in this thesis.

I want to make clear that it is too ambitious to make a list of contextual factors that are present in any development. Context changes and is embedded in extended parts of social life. If we want to explain the influencing factors we should take a momentary shot. A certain technology would follow a different development say ten years earlier and possibly also one week earlier. A similar remark could be made about the location; could the same development have taken place in a different country, region, sector or company? So what is the point of quantifying or qualifying context? The importance of this paper is to show the influence of context. That means we cannot pretend that technologies develop in a vacuum: it is important to appreciate and recognise context.

In the next chapter, I discuss the operationalisation of my research design. Therefore I further elaborate on concepts and theories that I used to uncover certain factor that comprise context.
3. Methodology

3.1 Introduction

In this chapter I explain and justify my data collection approach for gaining insight on factors comprising context. As became clear in Chapter 2, in order to generalise certain key-factors of context, one should ask questions about the level (micro/meso/macro or national/regional/sectoral/local) and the phase (invention/innovation/diffusion) in which the development takes place. In the previous chapter I also elaborated on the usefulness of analytical elements as perceived by Geels for understanding technological development and categorising context. I also discussed some of these factors that could be part of context, such as rules and more explicit expectations. In this chapter I outline my research in order to identify context in the Blue Energy development and I take some normative decisions on where I put my focus. In Section 3.2 I briefly introduce the Blue Energy development and discuss the difficulty of using the project concept, followed by the further outline of my research in Section 3.3. In the final Section 3.4 I elaborate on the difficulties of gathering empirical data on the case and also discuss what I experienced during the research.

3.2 The project Blue Energy

I concluded that technological development is an outcome of the interplay between the project and its context. In this research I hope to shed more light on these issues by examining the Blue Energy case. However, what is Blue Energy? A case, concept, project… Defining Blue Energy as a project implies that there is a certain project goal, project manager, that the project contains well-defined participants and that Blue Energy is the name of the project. However, in this case the use of the concept project is slightly problematic. In this section I briefly introduce the principle and the development in the Netherlands followed by the further outline of my research. A thorough description of the technology and the development is discussed in Chapter 4.

Intro Blue Energy
As mentioned in Chapter 1, there are two ways to obtain energy from water with different salinity using membranes: Pressure Retarded Osmosis (PRO) and Reversed Electro Dialysis (RED). PRO uses water permeable membranes and is based on osmosis. RED uses ion permeable membranes and is based on reversed electrolysis. It is the second principle, RED, that has gained renewed attention in The Netherlands for the last seven years and has received the label Blue Energy by its followers. The basic principle of RED is already known for more than a century and received renewed attention in the fifties and during the first oil crisis. Ever since, several small scale programs seem to exist worldwide that are only retraceable via a few (scientific) publications. The history of the Dutch involvement in RED and the subsequent network is very interesting.26 Several actors have developed an interest for RED separately and most of them work together in the resulting research programs. At this moment there are three Dutch institutions working on Blue Energy and a short introduction of their involvement will suffice.

The development in the Netherlands
Kema was the first Dutch company to apply for research funding linked to RED. Together with several participants they started a renewable energy project called Blue Energy based on an alternative membrane production method. Although they won the ID-price for best innovation, the research and consultancy company did not manage to develop a long-term energy project. At

26 I did a research on the historical development of Blue Energy and specifically on the Dutch involvement, see ‘De Blauwe Energie Transiteit, Toekomst of Fictie?’ by Willemse (2005).
this moment they still carry on with a small-scale research on the alternative production method. The first actor that started a serious long-term project on Blue Energy is Wetsus, a recently founded research institute for sustainable water technology. The core research within Wetsus is focused on sustainable technologies for treatment and production of water (Wetsus, 2005). This research is centred on five themes and Blue Energy comes under ‘energy out of water’. At present, their main contribution to Blue Energy is scientific and technological research, but they also serve an important network function. “Wetsus main characteristic is cooperation” and the “commercial parties involved in Wetsus define and guide the research program to ensure commercial relevance of the developments.” (Wetsus, 2005). In 2006, several participants in Wetsus founded a spin-off company, under the name of Redstack, to commercialise the results of the fundamental research. Several engineering companies are shareholder in Redstack (and Wetsus) and they aim to develop the RED technology into a market product. Redstack allocated funding for research and recently contracted Kema for developing the alternative membrane technology.

The project Blue Energy

Blue Energy is a concept on its own, based on a chemical principle and therefore more of a notion of a certain technology, namely: a technique to gain energy out of water using membranes. There is no such thing as THE project Blue Energy. To my opinion there are two options for outlining the scope of my research: defining the development in terms of a general definition of a project, or evading this clear definition and taking Blue Energy as the development of a concept. The first approach would result in a case description with a clear project goal, project manager and participants. I could take Wetsus, or better, Redstack as the project manager and position the development around their goal and activities. However, Blue Energy consists of different research and business projects and the establishment of Redstack changed the project status. First Kema and later also Wetsus were conducting research on the Blue Energy principle. Redstack transformed the research into a commercial project aiming at the implementation of the principle. The problem of defining the Blue Energy development as a project is that a heterogeneous set of actors has been involved. Focussing on the contemporary development would exclude the pioneering developments of Kema. Especially these early stage developments can identify interesting insights on how projects might fail or become adopted in context. The approach of defining one project is thus not applicable to my research. In the following, I therefore rather refer to the stages of this socio-technological development, covering all phases of development: Research & Development, deployment and implementation. As will become evident in the next chapter, I have divided the development into two projects with its own management and group of actors: the project on Blue Energy that was started by the consortium around Kema and the development at Wetsus and Redstack. The case is situated within the Dutch national borders and I therefore restrict my search to the Dutch involvement.

3.3 Method & Indicators

My interest is not purely technological, on how membranes change form or the optimisation of the technology. I take the socio-technological development as the main point of interest and its entire context as the unit of analysis. The question is how I can identify factors that comprise context and the role they play on the development of Blue Energy?

Situational factors hinder and steer the development

Contextual factors enable or constrain the development and therefore influence the development positively or negatively. Influence on the socio-technical development becomes apparent when certain developments change, take another direction, stop, attract new actors, problems occur, etc. I therefore focus on specific occasions, disputes, controversies, problems, decision moments, etc. that changed the direction of development (either by stimulating or hindering the development). To my opinion, context can be seen as those factors influenced by or influencing the development. I am therefore concerned with why a certain development (or the development as a whole) was hindered or stimulated, which identifies factors that comprise context.
Role of expectations
In the previous chapter I have discussed how especially expectations are relevant contextual factors for radical innovations. Expectations reduce uncertainty and are therefore necessary for radical novelty to advice engineers in their search process, mobilise new actors in the network, and used to allocate funding, convince politics or legitimise the project. Expectations therefore exert force on the development. Expectations allocate roles for actors and create agenda’s interlocking activities and demanding action in order to reach specifications. Expectations also constrain or stimulate the development. “If we accept that shared cognitive rules and expectations create stable trajectories, then a change in direction, i.e. non-linearity, depends on a change in the content of cognitive rules and expectations.” (Geels & Raven, 2006: 376). Geels and Raven discuss how the non-linearity and change in direction of developments are related to a change in the content of expectations, especially new visions on functionality. They give the example of how the Biogas development was first used in the discussion on energy savings (during the oil-crisis), later switched to manure processing (to reduce the manure surplus) and was eventually deployed to cut down on methane emissions. Geels & Raven refer to positive or negative developments in the project as ‘upswings’ and ‘downswings’. Positive outcomes of developments lead to positive expectations resulting in follow up research programs, related projects and a community or network of involved actors. These upswings in the developments can be explained by expectations, when they link technology to a functional application and get support from social networks. ‘Downswings’ can evolve from learning processes that produce outcomes that do not meet the expectations, which leads to a backlash in expectations. When beliefs turn sour, networks fall apart and resources become reduced (Geels & Raven, 2006). Barriers, stimuli, events and expectations belong to the scope of my research and are, to my opinion, of importance to explain the role of context in the development. As discussed in the previous chapter my focus is on the three dimensions as discussed by Geels (2004): rules, st-systems and actor-network factors27 as well as more explicitly expectations.

Data collection
Due to the relatively short development of Blue Energy in the Netherlands, the innovation system around the social-technical development is at a very pre-mature stage and little documented material can be expected, such as: scientific publications, project folders and other written documentation. Therefore mainly interviews were conducted to identify the network and the role of context on the development. I also consulted my previous work on the initial activities around Blue Energy, two years ago. Ever since, new actors got involved such as government agencies, municipalities and NGO’s. At the start of this research I did not know enough about their role in the case and believed their direct influence had been marginal in the beginning but may play an important role in present and future developments.

What does the research look like and how did I identify the role of context through interviews?
To my opinion the following information could be gathered by conducting interviews:
• The network and actors around the development (only the last two years of the development are underexposed so far).
• Events that influenced the development, identifying constraining and stimulating factors.
• Expectation about the future of the project (on implementation, final outcome etc.).
• Expectations with hindsight (when the actors became involved).

Unravelling the network is important for understanding the development and therefore inherent to this research. It is impossible to use certain predefined social networks, because the precise configuration of social groups differs between sectors and cases; in modern day society roles are not fixed to specific actors anymore. Actors from diverse fields of research occupying different societal roles are involved: government agencies, industry, universities, users, and societal

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27 I also use these elements for categorising contextual factors.
groups. I used the snowball method to discover the crucial actors and their linkages in the network. That means, through every interview new actors became visible (direct or indirect) and were approached. I therefore conducted primary interviews at Wetsus and Redstack, with key researcher and project managers. The focus on specific situations or events identifies the past development of the Blue Energy case and could explain crucial decisions, whereas uncovering expectations could give insight in future barriers or developments. Expectations explain the actors’ perceptions on the development and what contextual factors could be met in the future. Diverging expectations can identify misconceptions that could lead to future failure of the Blue Energy development. Also ‘initial expectations’ are of importance. Expectations that enrolled stakeholders to the project for example, can identify factors in context when expectations are not met or have developed differently.

By focussing on barriers, stimuli and expectations, the interviews delivered up circumstantial examples of context, which could be identified as rules, systems, actors and network factors and by doing so I also found new actors. In the next section I discuss the difficulties I encountered when gathering this data.

### 3.4 Experiences

In the previous section I discussed the method I used for gathering my empirical data on the Blue Energy development. The case study is mainly based on interviews with key actors, however, these actors usually occupy different positions and are therefore also involved in more than one actor-group. Furthermore some actors can be involved in the early days of development whereas others are only involved recently. An actor participating in Wetsus can explain more on the underlying strategy of the company, whereas policy actors are not directly involved and can give insight in specific regulation or application difficulties. Therefore I used semi-structured interviews in which not all actors were confronted with the same questions; this depends on their role in the development. Therefore I have made a list of points that guided me in these semi-structured interviews (see appendix B). Let me discuss this guide briefly.

**Interview Guide**

I started the interviews by identifying who the actor is, for which audience he or she speaks and when and how he or she became involved in the case. Most of the actors however, occupy more than one role in the development (active in Wetsus, Redstack and the participating company for example). When the actor occupies different functions, I discussed these points separately. After understanding the position of the actor in the network I focussed on their initial involvement with Blue Energy: what were the expectations and external influences at that time to become involved in the development. I called this ‘initial expectations’, because the actor should focus on the knowledge available at that moment. When these early visions and expectations are compared to the present status of the case, inconsistencies can become apparent. These inconsistencies identify constraining or stimulating factors that comprise context. Also the discussion on certain occasions identifies factors. When these points do not become apparent, distinct events such as stakeholder meetings and patent or subsidy applications are discussed to discover the influence on the further development of Blue Energy. For this purpose, I have used insights from previous interviews and other written documentation. By confronting the interviewee with explicit happenings, such as disputes, problems, changes, and decisions, more information can be gathered. Specific occasions that influenced the development are discussed at great length: why, where, who else was involved (to also discover new actors for interviews and to verify the information). After the detour to find contextual factors, I did ask more explicitly what and who was experienced as constraining or stimulating to the development of Blue Energy.

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28 The Kema contribution is believed to be small at this moment; Wetsus and Redstack are primarily involved.
29 For my research most of the stakeholders and their network configuration is already known, due to previous work on this case done by the same author.
Guiding concepts

A list of general factors was useful to guide the interviews: e.g. (Kemp et al., 1998): “technological factors, government policy and regulatory framework, cultural and psychological factors, demand factors, production factors, infrastructure and maintenance factors, and undesirable societal and environmental effects of new technologies”. I have added economic factors to cover subsidy applications and competition, and infrastructural factors also contain geographical properties. I have used the notion of regimes (categories) for guiding my research (note: not for the analysis of the data) to search for actors in the network and to confront interviewees with possible actors. Based on Geels (2004) I used scientific and technological, industrial (partners, competitors), political (local, provincial, national, European, worldwide), users and markets (also NGO/Lobby/media) actors. Also specific actors that became apparent through this research were explicitly used, such as ‘Rijkswaterstaat’ (Dutch agency for water protection) and ‘SenterNovem’ (government agency that carries out financial support programs).

![Figure 3.1 The social technical regime](source: Geels, 2004)

After mapping the past and present the second half of the interview was oriented towards the future. What are the expectations at this moment, such as when can we expect the first commercial application, for what purpose, who will be involved, etc. To make it more explicit, the interviewee is asked what he or she expects to be constraining or stimulating to the development: certain rules, competition, actors, external factors, etc. In the remaining part of this section I further elaborate on the experiences and difficulties that I encountered during the data collection.

Verifying information

These interviews generated insights on the position and visions of the actors and identified factors in context (or events that could make this apparent). These interviews also gave insight in the network configuration for successive interviews (snowball method). Actors did indeed provide names and numbers of other relevant actors, involved in the Blue Energy development. Relevant criteria for my selection of actors were: direct involvement in the development, influential or perceived to be influential by involved actors, and actors that could confirm or clear up certain developments. I also used as many written sources as possible to reduce bias and make my research more replicable. Information on Wetsus for example has been documented in various newsletters available online. Redstack and Kema however did not deliver much publicly available documentation for which I have relied on newspapers, journals, external brochures and archives. Governmental interest in the development can be obtained from various publications (reports on subsidy arrangements, Rijkswaterstaat etc.). Some information was kept back, because a lot of interests are involved in the development. Therefore information is not always publicly available and certain events or developments are sensitive material to a lot of actors involved. I believe this is a common phenomenon around innovative projects that contain information that is not patented yet, or relies on external support. When external support depends on the possibilities of the innovation, negative expectations are not favouring subsidy applications and the popularity of the project.

Due to the variety in answers of respondents, it was eventually difficult to create an unambiguous picture of activities. Some actors therefore might not recognise themselves in certain explanations or developments. This is a general difficulty in trying to reconstruct a story based on in-
Interviews. What should be taken into account is that case studies try to retell a story and wish to identify the logic behind the case. This story is recovered through interviews with actors that themselves have constructed their story. “What the analyst can and must do is to reconstruct what actors have constructed before.” (Van Lente, 1993: 180,181). It is not the same story as of the actors involved, because the position of the researcher and the audience is different. Case studies are therefore reconstructions of prior constructions.

What questions to ask?
I experienced the difficulty of gathering actors’ expectations and information on constraining and stimulating events. You cannot just ask for this information because interviewees might not experience certain events as stimulating or constraining to the development. Actors tend to explain situations that they recall as important, however I was also interested in their experiences in other situations. Therefore I have tried to find starting-points such as certain general phenomena, events and problems; for example subsidy applications, enrolment of stakeholders and experiences with internal management. I also introduced several topics in advance so that interviewees could think more thoroughly about these developments. Another prominent objection with formulating distinct indicators is the risk of a tunnel vision. Many aspects that could also contribute to this research might be overlooked. For this reason I did not only ask directly for specific indicators, but also questions were asked in which the actor’s own interpretation could come to the fore. Because of the diverging visions, a variety of aspects of one topic or event turned up. The point I wished to make is that we as social science researchers should take a symmetric approach, in which it is not assumed a priori what factors explain the context of these socio-technical developments.

Problem of causality and the unit of analysis
With a background in constructivists theories, this research is strongly influenced by social science research on technologies and in this thesis I wish to stress the importance of the social element in technological development. Not only the technologies are constructed in the development, also its context; routines, search strategies, firms, social worlds, expectations, etc. The question is what will be my object of analysis? It is not only the technology that is being shaped but also the social elements around it. Van Lente argues: “What is constructed, then, and by what, is not easy to say.” (Van Lente, 1993: 178). Van Lente argues that we are concerned with the yield of research on technological development. Therefore, in order to not go in the direction of general sociology, we (researchers) have to balance the yield of our studies between: general understanding of social dynamics against understanding technology dynamics (ibid.: 178/9). In the previous chapter I have elaborated on rules, actors, st-systems and expectations. These rules and expectations guide actors’ behaviour and are therefore an important factor in context. However, the system is more complex: rules and expectations influence actors and are also constructed, maintained and influenced by the activities of these same actors. In reaction to new technologies, policy makers may develop new rules to regulate it and user’ preferences may change. This complicates the task of defining context. I therefore took the socio-technological development of Blue Energy in the Netherlands as the starting point. Every factors or element that influenced this development is than seen as context, be they technological, social economical, etc.

Deductive versus inductive approach
Due to the complexity of technological development, I constantly worked back and forth on theory and data. Consulting literature while holding interviews and analysing the data: starting from the deductive approach of consulting perspectives on technological development towards a more inductive analysis of the data. I simultaneously consulted and searched for insights in theories, to position this empirical case on Blue Energy in literature but also to create certain sensitivity and identify influential factors in the context of development. Insights from literature and interviews are used in follow up interviews.
In the next chapter I introduce the Blue Energy case based on the results of my interviews. The case is analysed using the analytic distinction between actors, rules, st-systems, and expectations and linked to some general concepts in innovation studies as discussed in chapter two. I also elaborate on difficulties I encountered when analysing the results, which relate to some of the problems I discussed in this chapter concerning data gathering.
4. The Blue Energy Case: empirical description and analysis

4.1 Introduction

Technologies do not develop in a linear order from research and development stages to market introduction. I have shown in chapter two that technological developments are inherently social and therefore complex and unpredictable. Changes can be attributed to technological factors, but often also to political, social, cultural and institutional circumstances and considerations. Especially in early stages of development the project and technology can shift to different directions, sectors, publics etc. due to the interaction of the technology and its context. Radical novelties are vulnerable to failure and can eventually become rejected. In this chapter I introduce Blue Energy, a renewable energy innovation that serves as an interesting case to identify contextual factors influencing early socio-technical developments. Salinity power based on membranes has been known for more than a hundred years; however, this case study mainly addresses the Blue Energy socio-technical development in the Netherlands, which predominantly involves the research and development phase of this principle. The development started in the eighties with early attempts to conduct research on an alternative (cheap) membrane technology. This led to a consortium of several industrial companies that conducted a feasibility study and system research on Blue Energy in 2003. About a year later, a newly founded research institute developed a similar research program and attracted several participants to commercialise the principle. The consortium that first attempted to develop Blue Energy has lost their leading role to the research institute and at this moment only conducts research as a subcontractor. This case study aims to understand how the particular context factors have influenced the Dutch Blue Energy developments.

I will start with an introduction to the Blue Energy technological principle in section 4.2. After that the Dutch Blue Energy development is elaborately discussed and briefly analysed in sections 4.3 to 4.5. In Paragraph 4.6 the case is analysed using the insights on context from scholars on technological development. The chapter concludes in section 4.7 with some issues that I think should be taken into account by all parties involved in further developing the Blue Energy technology.

This chapter is meant to identify the contextual factors that influenced the Blue Energy development by focussing on constraining or stimulating events. A variety of stakeholders are involved in the Blue Energy development and appendix C gives an overview of the complex network configuration. In chapter 5 I draw more general conclusions on contextual factors and actors influencing new energy technologies.

4.2 What is ‘Blue Energy’?

The principle

Blue Energy is a renewable energy technology that is based on the difference in salinity between two solutions of different salinity, e.g. sweet (river) water and salt (sea) water. When sweet and salt water join, the concentration will diffuse until the salinity is equal in the total fluid (fundamental law). When a selective membrane is placed between sweet and salt water, the diffusion can be controlled and potential energy gained. This implies that energy can be ob-
tained at all places where rivers meet the sea. In theory 1 m$^3$ of sweet water combined with 1 m$^3$ of salt water contains 1.7 MJ (practically 1MJ). Knowing that in the Netherlands 3000 m$^3$ of sweet water runs into the sea every second, this could generate more than 3000MW. This is almost one third of the total Dutch annual energy consumption (Ross & Krijgsman, 2004).

**PRO - RED**

There are two ways to get energy out of water using membranes: Pressure Retarded Osmosis (PRO) and Reversed Electro Dialysis (RED). PRO uses water permeable membranes and is based on osmosis.

![Figure 4.1 Osmotic principle](image)

Membranes are placed between two streams of water with different salinity: a concentrated salt solution and a diluted salt solution. Water will flow from the sweat to the saltier side and build up a pressure or water column that contains potential energy. (Ross & Krijgsman, 2004)

RED uses ion permeable membranes, is based on reversed electro dialysis and resembles the battery principle.

![Figure 4.2 Reversed Electro Dialysis principle](image)

In this case two streams of water with different salinity flow through compartments that are placed in an alternating pattern. Cation and anion exchange membranes are placed between the compartments, which allow for positive ions to displace in one direction and negatives ones in the opposite. A cathode and an anode are placed in the system to connect the potential difference resulting from the salinity gradient to the grid. (Post et al., 2007).

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31 Figures 4.1 and 4.2 have been placed with permission of Kema from the brochure Blue Energy, “Energie op het grensvlak van zoet en zout” (KEMA, Noordelijke Hogeschool Leeuwarden en VolkerWessels, 2005).

32 Theoretically, the pressure can amount to 25bar or 300 meter water column, assuming the use of sea and river water.

33 In case of seawater and river water the potential over each membrane is 80mV. When more membranes and compartments are placed in line (stacked), the potential difference is the sum of the potential over each membrane.
Both methods rely on specific membranes: water permeable membranes in the case of PRO and ion-permeable membranes for RED and can be applied for electricity production. However, RED uses direct energy conversion whereas PRO generates pressure or a water column that can be converted into electricity using a generator. Operation of both installations implies an enormous displacement of water and therefore these techniques are also considered as an alternative pumping method. This can be utilised as an alternative spouting possibility e.g. at dikes and sluices. Each technique is considered to have its own field of application. Theoretically, pressure-retarded osmosis seems to be more attractive for power generation using concentrated saline brines and reverse electro dialysis seems to be more attractive for power generation using seawater and river water (Post et al., 2007). Practically, PRO is interesting as a spouting alternative for which electricity production is an additional benefit. RED on the other produces power and also displaces water (Regeling, 2007).

4.3 The historical Blue Energy development.

4.3.1 The History of Blue Energy

The basic principle of Blue Energy is already known for more than a century. In the late 19th century, the Dutch Nobel-Price winner van ’t Hoff proved that thermodynamic laws not only apply to gasses but also to liquids and in 1885 he published his formula for osmotic pressure. Manecke experimented with electricity storage using membranes in the fifties of the last century (Weinstein, 1976: 557). The first notion of reversed electro dialysis (RED) for electricity production started with Pattle, who managed to produce a constant power in the laboratory (Pattle, 1954). It took another twenty years before this topic received renewed attention during the first oil crisis. Norman argued that the US could produce $10^{10}$ Watt, using all the sweet water running to the see (Norman, 1974: 351). Norman was surprised that salinity power was never employed as a possible alternative energy source, because: ‘the reversal of any desalination process should, in theory, release energy’ (Norman, 1974: 350). He based this on the osmotic pressure that could be employed by reversing the osmotic desalination process at salt production industries. The calculated price of 0.20$ kWh could be reduced by more research on membranes. According to Loeb, the amount of energy could be twenty times higher using saltier water concentrations instead of seawater (Loeb, 1975: 654-655). Weinstein & Leitz resumed the pioneering work of Pattle reversing the conventional electro dialysis desalination process (Weinstein & Leitz, 1976: 557). Jagur-Grodzinski & Kramer conducted an extensive study on RED instead of the more indirect electricity conversion (PRO). They discovered the electrode influence on the process and produced a constant current (Jagur-Grodzinski & Kramer, 1986). Ever since, several small scale programs seem to exist worldwide that are only retraceable via a few (scientific) publications and to the best of my knowledge, there are no reasonable installations operational at this moment based on either PRO or RED. According to the UN atlas of the ocean (2001), no installations were operational in 2001; only small scale projects were conducted in Japan, Israel and the US. Experiments on PRO are still running at the Ben Gurion university in Israel (succession of Loeb’s research), and at Statkraft FS in Norway. Statkraft is a large Norwegian energy production company, involved in large-scale hydropower projects. There are also indications of an operational installation at a Russian Marine base in Vladivostok (Noorderlicht Nieuws, 5 juni 2004 ; Jones & Finley, 2003: 2286).

4.3.2 Analysing the History of Blue Energy

There's not a lot of information on this preliminary stage of development, nor on contemporary global development, but I would like to point out several contextual factors that have become evident in the short introduction. In this preliminary stage of development on salinity power, the reason for most of the research was the expectation of a possible alternative renewable energy

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34 The international term for obtaining the potential energy out of water, utilising the difference in salinity.
source (or in Maneckes case to store electricity). What stands out is that the development was picked up in situations when the world was searching for alternative energy sources. Especially during the first and second oil crisis in the Seventies, many research topics related to alternative energy sources were picked up again. The oil crisis can therefore be seen as being the most important contextual factor that stimulated the preliminary development. The pioneering activities have been cancelled because of high membrane costs and discussions on the feasibility of this technology. Furthermore, during the Eighties and Nineties when oil prices had decreased again, the need for an alternative was less important and therefore probably also the lack of societal interest can be pointed out as a negative contextual factor. Most of the scholars involved, were amazed by the little attention this technology received. They all stress the huge potential of salinity power for the world energy need. The question remains why research has continued in Japan, Israel, and in the US? An answer could be that Japan has always been involved in desalination techniques (reversal of salinity power based on membranes) and research in Israel and the US is conducted at specific locations where extreme salt concentrations are available: The Dead Sea and Salt Lake City. Concentrated salt streams result in higher yields, which could make the technology economically viable. Obviously, the global context has not been the only concern in these cases; the national and even regional/local context have also contributed to the development at these specific locations.

4.4 Renewed interest for RED

4.4.1 The Kema project.
RED involvement has been marginal for the last decade until it revived again in the Netherlands around 2000 where it received the label Blue Energy by its followers. An important aspect for this revival can be traced back to the eighties, when Kema had coincidentally discovered an alternative technique for the production of ion-permeable membranes during research on the degradation of power cables (Ross, 2005). Kema is a Dutch research and consultancy company that is mainly concerned with certification and testing. The research group that made the discovery had high expectations about this technique because it would reduce membrane production costs significantly. Further research however, did not belong to their core business because Kema needed a commercial order or other external financial support to proceed. Kema tried to get governmental support several times without success. In 1994 for example, an application linked to fuel cell utilisation was rejected because membrane research concerning hydrogen fuel cells was already conducted at another Dutch institute (ECN). Kema did not have the financial means available to support this project. Several employees however, put much of their spare time in the promotion and attraction of participants. They believed this project could be a breakthrough because contemporary membranes were very expensive and the raw material for their production technique was ordinary cheap plastic. The symbolic meaning of gaining energy out of water also drove most of the respondents. In 2000, internal contacts brought these employees to VolkerWessels, a reasonably large Dutch civil construction company. They had heard about an alternative way of spouting using membranes called osmosis. VolkerWessels is often involved in water projects concerning dikes, sluices and spouting pump. They were aware of the concerns for sea level rise expressed by the Dutch agency for water protection (Rijkswaterstaat): The afsluitdijk for example, where it is expected that in the future insufficient water can be released into the ocean from the lake IJssel due to climate changes. Eventually more spouting facilities are therefore necessary (Kema et al., 2005). Blue Energy would perfectly fit this project, offering a spouting alternative with additional electricity production. Together Kema and Volker-

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35 Blue Energy is a concept on its own, based on a chemical principle and therefore more of a notion of a certain technology, namely: a technique to gain energy out of water using membranes... I do not know the exact origin of the term Blue Energy and therefore it is problematic to note what exactly comes under this label. To my opinion the concept is first used to denote RED by Kema and is eventually incorporated by the Wetsus research institute. However, the concept is also used by a tidal wave company for their technology (www.blueenergy.com).

36 This dike in the northwest of the Netherlands closes the ‘IJsselmeer’ (lake IJssel).
Wessels evaluated the possibilities and started a project on the RED principle, called Blue Energy. VolkerWessels was supposed to invest start-up capital, however the management appeared difficult to convince of the possibilities. They were not impressed by the first prototype that drove an electrical motor. With a background in mechanical constructions, electrons did not mean a lot to them. They only got convinced after the second prototype pumped the water back into the reservoir; “water could run up the mountain” (Oudakker, 2005).

In their search for more financial support and participants Kema and VolkerWessels laid contacts with Statkraft. This Norwegian electricity producer developed the osmotic variant of salinity power. They had been working on the PRO principle since 1997 and claimed to be world leader in this area (Statkraft, 2003). Statkraft was not interested to join the Dutch companies because it believed in the osmotic variant and did not need/want to bet on two horses. The osmotic variant is also more suitable to integrate in hydropower plants which Statkraft exploits (Oudakker, 2005). However, in order to finance the project and apply for government subsidy, Kema and VolkerWessels needed a third party and eventually Velsen Flexoplast was attracted. This Foil Production Company produces plastic bags and the new production method (discovered by Kema) could be installed at their production facilities. One of the largest Dutch energy production companies (Nuon) was also attracted and provided their expertise. They did not participate in the consortium but helped with calculations and were present at meetings and functioned as a benchmark to generate publicity. They were expected to eventually exploit the power plant in the future.

Initial visions on Blue Energy in the Netherlands started with this consortium that wanted to apply the alternative membrane production technique for the production of cheaper membranes that could be used in a Blue Energy system. According to the pioneers: the only thing that needs to be done is bring down the membrane costs (Global Contact, 2006). Feasibility studies were conducted in order to receive financial aid and attract new partners. The availability of sweet and salt water made river deltas the most suitable locations for Blue Energy. Calculations were made based on the amount of water running to the sea and the efficiency of the available membranes, stating that the Blue Energy technology could produce 3000MW in The Netherlands. The optimal location would be the afsluitdijk, which the consortium entitled ‘the inexhaustible battery’, capable of producing 200MW (Ross & Krijgsman, 2004).

The consortium experienced much disbelief (from governmental organisations, industry but also science), due to the unfamiliarity of the Blue Energy principle. They needed the vision of an actual application in Dutch waters to attract and convince stakeholders. Stakeholders present at government innovation meetings, ran off with this principle as the perfect Dutch energy alternative for the future. The Dutch government had committed itself to the realisation of a 10% share of sustainable energy in the total energy production by 2020 and assigned SenterNovem, the government agency part of the Ministry of Economic Affairs (EZ), to carry out the policy and support innovative initiatives. SenterNovem offers advice, networks, information and subsidies. Organisations, research institutes and local governments can apply for several programs to gain subsidy for energy efficient measures, environmental care and risky technologies. SenterNovem runs the program Energy Research Subsidy (EOS) that aims to support the energy-efficiency and sustainable energy developments. EOS consists of four programs covering all phases of development, from innovative idea to market introduction. EOS-LT (Long Term) is developed to support research for several years. EOS-ES (energy and cooperation) supports non-commercial research and development of innovative energy techniques and EOS-Demo is issued for the first serious pilot tests. EOS-NEO (New Energy Research) addresses to the first phase of development: work out new ideas. Under this subprogram unconventional research is stimulated with

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37 Kema had discovered an alternative production method for ion-permeable membranes, suitable for the RED technique. PRO on the other hand, needs water permeable membranes.

38 In 2005 Nuon introduced the Blue Energy power plant at the afsluitdijk to its ‘green’ consumers in their newsletter (Nuon, 2005).

funding for feasibility, research and development projects: projects that could have potential to develop into a new energy research domain.\textsuperscript{40}

The consortium applied for the EOS financial support program, which they expected to get because of all the positive attention. Blue Energy seemed to fit perfectly in these financial programs and the consortium had complied with an important condition: the collaboration of three industrial partners. Nevertheless, the applications were rejected several times. The unfamiliarity with the principle (it just cannot work) and also incorrect and incomplete application requests were mentioned as the main reasons (Roest-Krijgsman, 2005). Eventually the consortium received NEO (new energy research) start-up support in 2003. However, despite positive reactions from government and industry on this feasibility study and even though they won the ID-NL\textsuperscript{41} price for best innovation, the project did not continue in the follow-up program of EOS. The Blue Energy simulator was present at many workshops and seminars of the Innovationplatform and project folders mentioned Blue Energy as one of the examples of an interesting Long Term research program (SenterNovem, 2006). However, the EOS-NEO program had been adjusted. In 2003 the Dutch cabinet founded the ‘Innovationplatform’ to get The Netherlands to the European top in education, research and innovation. The platform consists of key players in the knowledge economy with experts from politics, business, science and education.\textsuperscript{42} The prime minister is the chairman of the platform and many Dutch companies such as Shell and Philips participate. In this platform transition routes towards a more sustainable future are negotiated which influences the subsidy programs such as EOS. Specific themes were chosen and the categories for energy research were wind, tidal, and solar energy. Blue Energy did not fit in any of these categories (Ross, 2005). This problem was also noted by the Innovationplatform and the Ministry of Economic Affairs (EZ) who are responsible for the content of these programs. However, projects are rejected formally when not fitting the specific spear points/themes and in principle these themes are chosen on purpose to strengthen specific developments that were selected as promising for the Dutch innovative industry. This can lead to limitations and Blue Energy was one of those projects that was rejected. Evaluation rounds between SenterNovem and EZ take place yearly to overcome these problems. (Sijens, 2007).

After these evaluation rounds between EZ and SenterNovem, the category ‘remaining’ was taken up in which Blue Energy could be accommodated (Hack, 2007). However, the committees installed by SenterNovem to evaluate and grant the subsidies for innovative projects have been reluctant to support the development. The application was rejected again because they felt the idea of gaining energy out of water using membranes was not technologically and economically viable. Another comment for the rejection has been that research on one type of membrane was considered limiting and too vulnerable for the further progress of the Blue Energy development. Besides the EOS program also other governmental activities have attributed to the furthering of the Blue Energy development. One of the initiatives resulting from the Innovation platform was to found a Technological Top Institute for Water technology (The TTIW-program). The government and water sector work together in the Innovationplatform ‘Water Technology’ because the Dutch water technology sector has a strong position in the Netherlands but economic export is lagging behind the world growth. The Innovationplatform has pointed out the water sector as one of the key sectors in the Dutch economy. The water sector has presented their vision arguing that the water sector should cooperate in a new manner and focus on promising clusters. Even though The Dutch already work on unique technologies, they should keep their strong position and even strengthen it. For this purpose, more research and development is necessary. Therefore they proposed the Technological Top Institute Water technology, in which public and private organisations participate. They also proposed to install two other instruments: Innowator and a guarantee fund. Innowator is a subsidy instrument to support excellent knowledge devel-

\textsuperscript{40} For more information see also: http://www.senternovem.nl/eos/.

\textsuperscript{41} The prestigious price is yearly issued at the Netherlands Innovative Event (Nederland Innovatief Event) for best Dutch innovation (www.nederlandinnovatief.nl). In November 2004 Blue Energy received the ID-NL price in the category: Energy and Environmental technique.

\textsuperscript{42} http://www.innovatieplatform.nl/.
opment into market products, necessary because mainly middle-range organisations are involved in innovations and cannot cover the risky product developments without government support. The guarantee fund should cover the costs that are made when projects do not satisfy the expectations. Tenders for Innovator have started in 2006. The cooperation between industries, institutions and the national government has the ambition to bundle the technological expertise in the Dutch water sector and an important aspect of the technologies must be sustainability (Stuurgroep Watertechnologie/a/b, 2006). The development of the TTIW program also serves as a good example of how the national government wishes to stimulate the Dutch innovative development.

At this moment, the consortium around Kema that started the initial project is no longer active in the Blue Energy development because they could not secure finance for the project anymore. Kema is only involved as a subcontractor for research and development of membranes and lost control over their Blue Energy project. Moreover, the same research within Kema is also part of a larger European programme on membranes for CO₂ capture. VolkerWessels is not involved anymore since, in civil construction projects, companies that have done explorative research can be excluded for acquiring the follow-up project. Therefore, if Blue Energy would be integrated, VolkerWessels could not be the constructor (Oudakker, 2005). For several years after this, the Kema research group worked in their own spare time and students upheld further research.

4.4.2 Analysing the Kema project.

What does this first stage of the case tell us about context? First of all, context played an important role to motivate actors. The contextual factor of expensive membranes created expectations about a cheap alternative membrane production method that could create opportunities for Kema. Context in this example can be seen as an economic factor that created expectations, which motivated actors to get involved in this research. Kema’s organisational structure (infrastructural factor) however, did not allow for further research, because it needed an external order to proceed. It was the company’s core business not to invest in a technique that was still in very early stage of development, unproven and therefore a very risky undertaking. This type of industrial or business context hindered the further development of the project. In this situation, lacking financial means (also context) and the expectation of a promising technology influenced actors’ strategies. External finances were sought and in order to enrol other actors the technology was strategically linked to an application that might receive more attention: fuel cell developments. In the context of this popular new application, Kema applied for government funding. In this case the rising popularity of fuel cells influenced the actors’ strategy to adapt their research plan. Fuel cells were so popular because of environmental concerns and as such this different socio-technical context indirectly positively influenced the further development of Blue Energy.

This first analysis shows three types of interactions between the socio-technological development and its context: 1) context influencing motives, 2) actor strategies as part of context, and 3) organisational, more formal, factors that directly hindered the development. These examples can be traced back in many situations during the development of Blue Energy. Many contextual factors that stimulated or influenced expectations can be found at moments when actors got involved in the project. VolkerWessels was enrolled because of the expectation that this technique could generate new business opportunities. In the context of sea level rise concerns, alternative spouting pumps were expected to be installed in future civil construction projects. Also Flexoplast expected new business opportunities and joined the consortium. Context also created expectations that unmotivated actors’ behaviour. The management at VolkerWessels was unfamiliar with the principle and in their belief system (context of engineering practices), ‘water could not run up the mountain’. This resulted in their expectation that this could never work.

http://www.senternovem.nl/Watertechnologie/.

Kema is only allowed to act on behalf of Redstack (van den Ende, 2007), which will be explained later.
Eventually they approved the project, but in a later stage withdrew again (due to a formal institutional/regulatory contextual factor). The same happened when committee members from established electricity companies did not believe Blue Energy could work. Their expertise and belief system did not comply with this extraordinary innovation. Formal rules concerning construction projects would exclude VolkerWessels to take part as a contractor. The expectation of exclusion motivated the management to resign from the project.

The second role of context that I pointed out was the influence on actors’ strategies, e.g. Kema altered their research proposal several times. First the project was linked to fuel cells, then to Blue Energy and eventually they are also working on CO₂ capture and storage. Strategies were altered in many other cases due to context: the lack of financial means urged Kema to enrol more stakeholders; the unfamiliarity of the principle resulted in a demo installation; disbelief and an unconvincing strategy necessitated feasibility studies that were aligned with societal needs; and to convince the management at VolkerWessels the strategy of demonstrating the functionality of the principle did not prove to be convincing, because it did not appeal to them. The installation was therefore adapted to fit their line of work and interest. Strategies of actors on the other hand are also part of context. The application for research on fuel cells for example was rejected due to the fact that research on fuel cells was already conducted at another research institute. In this case the government strategy can be pointed out as context.

The third category comprises the more formal institutionalised contextual factors. The organisational structure at Kema did not allow for a further research project. Similar types of contextual factors also influenced the application requests. Incomplete and incorrect application forms were rejected. Another request was formally rejected because the project could not be fit in the programme, despite positive reactions and support from the government agency responsible for this grant. In some occasions formal, contextual, factors stimulated the development. The availability of the government support programme for example, can also be seen as context. If there had not been a government programme for sustainable energy research, there would not have been possibilities for financial support. Another factor can be found in the decision to work on the RED principle. Due to the fact that Kema had discovered an alternative production method for ion-permeable membranes, they started on a salinity power project based on RED, which can be pointed out as a technological contextual factor. A final point I wish to make is that not only strategies of actors are context, but also their position is part of context and influences a development. For example, the researchers at Kema, as well as the employees that were contacted at VolkerWessels did not have the capabilities to decide on entering the project.

The contextual factors that have been discussed in this section have been of a more organisational, technological and economical nature. The specific context created possibilities for further development, got actors involved and on the other hand hindered the development and excluded actors. What also became clear is that context is very complex: contextual factors in different dimensions (economic, political, technological etcetera) and on a global, national and more local/regional level interact. In several examples more contextual factors were present which directly or indirectly influenced the situation, which made it extremely difficult to point out each and every specific contextual factor and the causal lines leading to failure or success. The motivation for VolkerWessels for example was based on the context of the concern for a sea level rise (global and national level). However, this concern (context) created expectations on more future construction projects (regional/national level). The alternative spouting possibility (context) created expectations that fitted other expectations about the application in future projects. This example shows the complexity of a variety of contextual factors and expectations, which are also contextual factors, influencing a single situation or decision.

45 In this way every factor is a result of some actor’s strategy. The difference with the example of VolkerWessels is that these strategies are formalized and more stable/hard (not easily changed). For my analysis, I categorise these formalized factors under institutionalised factors.
Context obviously has its effect on actors (motives and strategy) as well as that it creates opportunities or on the contrary, hinders activities in that it does not contain the necessary elements for further development. Important contextual factors in the first stage of development have been expectations, formal rules and the capabilities of the actors involved on different levels. These examples all show how context influenced the socio-technological development. However, the technological development has also influenced its context. Actors around the project got convinced about the possibilities, it attracted a lot of attention and the government changed its strategy and included an extra entry so that Blue Energy could get subsidy.

4.5 A new player in the field

4.5.1 The Wetsus project

The economy of the Northern provinces Groningen, Friesland and Drenthe had fallen behind national economic development. These provinces had bundled their political forces since 1992 in the cooperative formation SNN.\textsuperscript{46} SNN negotiates with the national cabinet to strengthen the economic structure of the Northern provinces. The Northern provinces cater a lot of water management and technology companies and one of the results of the SNN negotiations with EZ, the Leeuwarden municipality, the Province of Friesland, local education institutes and water industries was the founding of Wetsus in 2003.\textsuperscript{47} This research institute joined the forces of universities and industrial partners on the development of treatment technologies for sustainable water. Financed by industrial participants and lump sum governmental support, Ph.D. students conduct the research in collaboration with three Dutch universities: Delft, Twente and Wageningen. The province Friesland, where Wetsus is located and its capital Leeuwarden have high expectations of Wetsus for the attention it attracts and the jobs it offers.

Wetsus was interested in the Blue Energy development at Kema because this radical water technology fitted their strategy of starting projects on highly radical innovative water technologies. Both Kema as well as Wetsus applied for financial support and searched for influential participants from that moment on. Wetsus had secured its research with governmental lump sum finances and industrial capital. They did not need to further cooperate with Kema and started a project on their own, to the dissatisfaction of Kema. Kema was supposed to follow the Wetsus formula. Kema however, could not contribute the 50.000 Euro yearly participant fees. From that moment onwards the Blue Energy development in the Netherlands shifted towards Wetsus. Wetsus conducts research on five themes involving water technologies (and in several cases also membranes); Blue Energy falls under their theme ‘energy out of water’ (Wetsus, 2005). Scientific and technological research is focused on the Blue Energy system design, membrane design and fouling of membranes.

Wetsus has received a lot of attention ever since it was founded in 2003. Water was and is seen as ‘hot’ and the amount and size of the organisations involved grew rapidly, leading to more publicity. The location is situated in the same building as the engineering school of Leeuwarden and several research institutes. The founders of Wetsus also possess a large network of industrial and scientific organisations and as mentioned earlier local, regional, national and European authorities are involved in the development. Furthermore, the management and many of the participants in Wetsus already knew each other from their previous collaboration in the water sector, and more specific, most of them had worked for the same company called Paques B.V. This water and gas purification company had changed its strategy, which didn’t suit the innovative style of many involved and resulted in employees moving to (starting) Wetsus. Also previous employees of Paques and other ‘friends in the business’ now participate. Both scientific as well

\textsuperscript{46} Samenwerkingsverband Noord-Nederland (http://www.snonline.nl/).

\textsuperscript{47} “This project is co-financed by the European Union European fund for regional development and Samenwerkingsverband Noord-Nederland, EZ/Kompas and Provincie Fryslân” (http://www.wetsus.nl/).
as industrial partners from a wide range of disciplines have been attracted because of personal relations. Besides this network advantage, the actors involved also occupy highly influential positions in their organisation. Participants in Wetsus have to come up with substantial financial means. Financing a highly radical innovation with unpredictable and risky outcomes usually needs time and strenuous negotiation. Wetsus did not need a lot of effort to convince parties to join. The advantage of personal relations with influential actors resulted in good cooperation and made decision-making fast and easy. Because these actors knew each other for a long period they trusted and supported each other (Hack, 2007).

Wetsus frequently organises open access congresses and private participant meetings to discuss outcomes. “Wetsus’ main characteristic is cooperation” and the “commercial parties involved in Wetsus define and guide the research program to ensure commercial relevance of the developments.” (Wetsus, 2005). A monthly newsletter and frequent articles in newspapers, journals and more specialised papers also inform those who are interested. Furthermore, the management, PhD students and the involved stakeholders are frequently found at workshops, congresses and Innovationplatform meetings to increase publicity and get more parties involved. Publicity is also enlarged by attracting famous or highly influential actors to visit and present at Wetsus in Leeuwarden, such as The Dutch Queen, Prince (also involved in water management), Prime-Minister, members of the National and European parliament, Commissioners of the Queen, the mayor, etc. Especially national governmental spokespersons and the Innovationplatform have high hopes for Wetsus and Blue Energy. Blue Energy in particular is often presented at meetings, congresses and other promotional activities as an example of an interesting Dutch innovation.

Wetsus also wants to stimulate industrial participants to start a spin off company. In 2006, several participants in Wetsus who expected to develop the technique into a business opportunity founded Redstack. The shareholders in Redstack, Harlingen Holding Industries B.V. (Landustrie en Hubert Stavoren BV) and Magneto Special Anodes B.V. expected to develop a commercially interesting sustainable energy alternative for which these engineering companies will deliver the materials and knowledge (Hack, 2007). Similar to the enrolment of actors in Wetsus, the shareholders new each other from previous jobs for a long time and occupied highly influential positions within their company. The mutual trust and possibilities were crucial for the smooth founding of Redstack. These shareholders do not have the financial possibilities to commercialise the principle on their own and therefore their next step is to prove the principle by means of a pilot installation of several kW and attract investors. Nuon was attracted in the hope that they would finance and exploit the eventual power plant, but is at the time of writing only involved as a partner and not financially. They are reluctant to get involved in another highly risk-bearing project, because of their experience on a tidal wave project that had failed recently. Another partner is Frysia Zout B.V. who is also involved as a participant in Wetsus. At this salt production company located in Harlingen (province Friesland) all kinds of salt concentrates are available which makes it an interesting site for the Blue Energy trials. Pure salt and sweat water do not foul the membranes, and many mechanical facilities and technical expertise is present. Frysia can also use the positive publicity around the sustainable project. They have received much critique in the past by environmental organisations and farmers because of soil settlement due to salt mining. Furthermore, a substantial part of their production costs is energy: almost 50%. Green and cheap energy that could be produced on site would therefore be an interesting technique that can contribute to more positive communication (Mulder & Weewer, 2007).

Redstack applied for government funding and applied for the similar NEO support for which the consortium around Kema had been rejected several times. Kema who had a lot of experience

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48 Nuon again reported on Blue Energy to their customers in 2007 (Nuon, 2007).
49 Nuon was involved in a tidal wave project called The Archimedes Wave Swing. This project was abandoned after the installation sunk at the Portugal coastline during initial trials.
with these requests, assisted with the application. Eventually Redstack received the EOS-NEO for membrane research and production in 2006 and secured their project for at least one year. Three research institutes will conduct research on three different approaches of membrane design: Kema, EMI in Twente and the Ben Gurion University in Israel. Redstack also applied for the new Innowator subsidy arrangement related to innovative water techniques. Innowator supports early pilot installations. Redstack applied for this grant to finance the pilot tests at Fry sia (or any other location). Again, Blue Energy was mentioned in the programme brochure (Stuurgroep Watertechnologie, 2006a/b) and received a lot of attention. Prime Minister Balkenende even mentioned this technique as promising (Euverink, 2007). However, their application was rejected because the assessment comity did not believe this RED principle might work. The same disbelief and unfamiliarity that had hindered Kema’s subsidy applications for EOS support, slows down the further development of Blue Energy again, this time for Redstack. Besides the unsuccessful attempts to receive additional government funding for trial and pilot-plant activities, industrial applications and accompanying finance are being negotiated. The tests at Fry sia were expected to start in 2005 and have been delayed for more than a year already. There are proposals for trials at Frysia, however, an actual start-up date, at the time of writing, was yet to be announced (Mulder, 2007). No further action has been taken, because of this financial drawback. Another reason for the delay of the trials at Frysia is technical: the difficulty of building an operational installation has been underestimated. Redstack, however, is also working on other locations for preliminary tests. Industries where salt residues are available benefit from extra energy income and these forms of implementation become economically viable within several years (Hack, 2007). Rijkswaterstaat, responsible for the Afsluitdijk, has high hopes for Blue Energy. Through various routes they came in contact with Wetsus and Redstack. They also conducted their own research on necessities and possibilities for the Afsluitdijk in which Blue Energy was discussed at great length (Witteveen+Bos, 2006). However, according to Rijkswaterstaat, they keep all options open: that is PRO, RED or any other technology (Regeling, 2007).

The developments at Wetsus have been prosperous. The ambition to become the European Centre of Excellence for sustainable water treatment has come a serious step closer. Recently The Dutch water technology industries have brought up 17,5 million Euro and EZ has reserved 35 million for TTIW. TTIW will be accommodated at Wetsus and according to Wetsus they will eventually merge. The extra attention and financial means create more opportunities for research at the institute and in the field of research in general. At the time of writing, Wetsus is so popular that many organisations contact ‘them’, whereas the management actively had to approach stakeholders in the start-up phase of Wetsus three years earlier. Established (conservative in the eyes of Wetsus) companies in water technology and management that have dominated the sector for more than a hundred years were rather sceptical about Wetsus and Blue Energy (Boonstra, 2007). The situation at Wetsus concerning the content of scientific research on Blue Energy is unclear. Recently the first scientific article was published in a specialised membrane journal, making a comparison between RED and PRO. This article was meant to justify the RED strategy and has been positively accepted in the membrane society. Technical development, however, has not been reported so far. There have not been any tests that proved the principle significantly for the suitability of electricity production. Wetsus’ early expectations were about a 200MW power plant at the afsluitdijk. However, the use of natural water incorporates many disadvantages (e.g. fouling, algae’s) and therefore initial applications are perceived to appear at salt producing industries and industrial locations where uncontaminated sweet and salt-water remnants are produced. Locations at river deltas (and especially the afsluitdijk) are mainly used for promotional purposes and perceived as far future possibilities. At the time of writing, no power plant, pilot installation or demonstration project has started in the Netherlands yet.

This was their ambition from the start (Wetsus, 2005 ; (http://www.wetsus.nl/).
4.5.2 Analysing the Wetsus project

Similar interactions between Blue Energy and its context, as found in the first stage of this socio-technical development mainly involving Kema and its consortium, can be identified in the second development stage of Blue Energy in the Netherlands involving also the newcomer Wetsus. Context often influenced expectations that motivated actors to get involved in the development. The availability of water management and treatment technologies in the Northern region influenced the expectation that this could be a boost for the regional economy. This eventually led to the founding of Wetsus. The resulting expertise in Wetsus created expectations about the possibilities for and with Blue Energy. In the context of their research for interesting projects that could be an example for the Dutch innovativeness, the Innovationplatform created expectations on the possibilities for the Netherlands. Fryisia was enrolled in the Blue Energy project because they expected this would reduce their electricity costs (economic factor) and build up their image. These expectations were created in the context of high electricity costs and critique on their business. Context also influenced strategies. The rejections for a government allowance inspired the stakeholders to work on three different membrane approaches. This also encouraged them to look for other financial opportunities, and they shifted to allowances for water technologies. Available knowledge at Wetsus and the fact that research was already conducted on PRO gave reasons for this research institute to focus on RED. Technical problems later shifted their strategy from natural water to industrial clean water streams. The third point was that context directly influenced situations or actions (mainly institutional). Network properties and personal capabilities created possibilities for starting Wetsus, attracting finances and involving stakeholders and also the availability of funding programmes that suited their research can be seen as institutional factors within context.

Another point that was made in the previous analysis was that actors and particularly their position are part of context as well. In the second stage of the development, this element has become very clear. The stakeholders that were attracted occupy highly influential positions at middle-range companies, which provided them with a sort of ‘carte blanche’. Either they are the general manager of the company involved, or are highly placed and have a long history in their company and good understanding with their management. This makes decision making fast, simple and less bureaucratic and these actors can therefore be seen as an important contextual factor (actors capabilities) generating possibilities for the project. They are in a way ‘champions’ for this radical technology. The actor’s position also comprised another form of context. The actors that started Wetsus had an enormous personal network containing influential and capable actors to their disposal. In this context, stakeholders and therefore also financial means and support were easily attracted. The stakeholders already knew each other from previous jobs and projects, which had created trust and support. This actors’ capacity has been an important contextual factor for the start up of both Wetsus and Redstack. The final point concerning actors is their motivation. In both cases, the personal motivation of stakeholders in the project has been crucial. Efforts to get the project off the ground, to convince and involve stakeholders, and to acquire external finances, would probably have been weakened after all the disappointments. Kema as well as Wetsus/Redstack underwent difficulties to get governmental support. And especially at Kema, employees have been working on the project in their spare time. But also actors involved in Wetsus and Redstack have invested a lot of their spare time in the project. This factor has been difficult to point out in the case description and is based on my personal feeling about their involvement. In many interviews I found that the ideas of getting energy out of water, and the fact that the world is obviously unfamiliar with this technique, have contributed to their enthusiasm. This once-in-a-lifetime opportunity and in particular at Wetsus and Redstack the fact that they were working together with a group that they trusted and saw opportunities with, encouraged them to proceed with the project.
4.6 Comparing the projects

Blue Energy is a renewable energy technology that received renewed attention several years ago in the Netherlands. Kema was the first Dutch company to get involved in this renewable energy technology. Together with two other stakeholders, a consortium around Kema started a project on the development of an alternative membrane production method to apply for Blue Energy. The consortium struggled for attention, support and financial means ever since. At first, the project did not receive a lot of support and the consortium invested a lot of effort to get the project financed and attract more stakeholders. They eventually received a one-year government subsidy in 2003. However, after a successful year, they did not receive any follow-up allowances. From that moment onwards the consortium has been inactive and only at Kema several actors have been trying to keep the project running in their spare time. Recently Kema has been contracted to develop the alternative membranes for Blue Energy and other applications. Meanwhile, the overall development of Blue energy in the Netherlands continued at another research Institute. Wetsus had started research on Blue Energy in 2004, together with several industrial and academic partners. At the moment, Wetsus has three researchers working full-time on the project, a spin-off company has been founded to commercialise the outcomes, and the project has been picked up and is championed by many (semi-) governmental organisations and spokespersons.

The question is why Kema was rather unsuccessful in its attempts to further commercialise Blue Energy, compared to Wetsus and Redstack who attracted a lot more attention, stakeholders and financial means? When Wetsus entered the scene, Kema already worked on the project for four years and had the advantage of being a prime mover. Furthermore, both developments took place in the Netherlands, which would imply that the influence of national factors has been equal for both projects. So, what has been the reason for the difference between the two projects? Looking at the overall development, and especially at moments when the project at Kema was hindered, one could conclude that the Kema project suffered especially from government subsidy programmes. However, whilst Kema struggled for financial government support ever since it tried to develop the alternative membrane technology, Wetsus got its research secured for at least four years through a direct lump sum government allowance.

In this chapter I try to show that the development was more complicated than merely a financial issue. The strategy, structure and involvement in both projects have been different, and therefore I focused on the context around the socio-technological development at both projects to analyse situations that hindered or stimulated the development in more detail. By pointing out situations that spurred or moulded the development, I have identified contextual factors that have been influential. In the previous chapter I have elaborated on the type and influence of these factors and compared these with insights from innovation studies. In this section I will compare the contextual factors of the two projects, which I will refer to as the Kema project and the Wetsus project. Crucial moments in both developments have been centred on convincing other actors, the enrolment of stakeholders and securing the project financially. I will elaborate on these three situations or activities and point out the crucial contextual factors herein.

**Attracting attention, stakeholders and financial means**

One of the most important activities in the Blue Energy development has been and still is: convincing other actors. This is always a crucial activity when radical novelties are being developed: either within the firm, when different management layers have to be convinced, or outside the firm, when the technology is placed on the market, or when other stakeholders must be enrolled to further employ the technology. Both Blue Energy projects, however, were started in a fairly new setting. The initial project was not started within a company that has experience in working out radical innovations as a strategic activity. Kema started a consortium in which they were responsible for the scientific research and together the three parties took care of the project management: taking strategically decisions but also securing financial needs, enrolling stakeholders, familiarise and convince others. At Wetsus the project was managed in a more organ-
ised structure, in which PhD students conduct research and a separate management takes care of the social and financial business. However, in this case, the institute had just started and the projects success was heavily based on external inputs, stakeholders, and financial means. What becomes clear is that both projects were heavily dependent on convincing other actors, enrolling stakeholders, and attracting financial means. It is also important to understand that these three activities are interrelated. Kema had the disadvantage of the unfamiliarity with the technique during the first years and has done most of the preliminary work in trying to convince more actors for the possibility to gain energy out of water. The unfamiliarity of the RED technology led to rather critical reactions from scientific, governmental and industrial organisations. However, in 2004, when both parties were working on the project, attended workshops and congresses, and when both had built a demonstration installation, Wetsus managed to do better. This can be related to two important contextual factors: the availability of a personal network and the capacities and capabilities of the actors involved.

**Network properties, actor’s capabilities and capacities**

Kema underwent many difficulties in enrolling partners. They eventually attracted two companies from very different sectors. The management within VolkerWessels was not fully convinced from the beginning, and the resulting consortium was not very stable. After several setbacks, and especially when they did not receive follow-up governmental finances for Blue Energy despite positive reactions, Kema had to continue the project on their own. Wetsus on the other hand had secured their research with lump sum grants and industrial capital. The management and many of the participants in Wetsus already knew each other from their previous collaboration in the water sector, and more specific, most of them had worked for Paques B.V. Also previous employees of Paques and other ‘friends in the business’ now participate. Most of the industrial partners have been working in the same region and sector (water management and techniques) for decades and because these actors knew each other for a long period they trusted and supported each other. Most of the actors could therefore be approached informally and convincing them to join the institute has been easy. This is also valid for relations with the scientific community. Actors within the management of Wetsus also occupy positions at involved universities, where relations with other scientists brought them into contact with a larger network. The scientists as well as the industrialists also worked with governmental organisations for years and as mentioned, political actors at all levels have been active in the founding of Wetsus. Besides these network advantages, the actors involved also occupy important positions in their organisation, which provided them with a sort of ‘carte blanche’ in decision-making. They occupy highly influential positions at middle-range companies, either are the general manager, or are highly placed and have a long history in their company and good understanding with their management. These actors’ capabilities made decision making fast, simple and less bureaucratic, and also their capacities have been an influential factor: the personal network they have had at their disposal, the position in their company which provided them with a ‘carte blanche’, as well as the financial capacities of these organisations. To participate in Wetsus and Redstack means investing large amounts of money in a radical project for which pay back is very uncertain. Kema for example did not have the financial means to join the research institute. The founding of and participation in Wetsus and Redstack did not need a lot of bureaucratic and formal arrangements but could be initiated by actors that trusted each other and were enthusiastic to start a project together.51

In this analysis, I focused on the micro level of development, but of course the fact that Wetsus had received a lot of attention and government funding (which takes place at the meso level of development) has been crucial for the enrolment of other actors. Blue Energy gained momentum when Wetsus got involved, actors had to participate or otherwise miss an important opportunity

51 I would like to point out that the personal relations can also have a negative influence on the project. One of the committee members for example was also involved in an organisation that competed with Wetsus for the accommodation of TTIW, which could have had an influence on the rejection of subsidy application. Many respondents from within the Blue Energy development therefore mentioned these personal relations between actors and organisations both as hindering as well as stimulating.
and local and regional governments had invested a lot of money, time and effort in Wetsus. Therefore Wetsus, and all the attention it attracted, has been the most important factor for the difference, between the Blue Energy project at Kema and Wetsus. However, as became clear in the case description, the Blue Energy stakeholders at Wetsus had a stronger and more influential network at their disposal, which consisted of actors with capacities and capabilities that have been crucial for further development. The difference cannot be explained by the personal dedication of the actors; in both projects, most of the stakeholders have spent their spare time in the project and fulfilled important network functions as a ‘spokesperson or champion’.

**Strategy**

Another important factor explaining the difference has been the strategy followed in both projects. Wetsus and Redstack developed in the context of attention for energy, membranes and water, whereas Kema only exploited the attention for energy. Kema has been working in the energy sector for decades, and has a separate department for sustainable energy research. Volker-Wessels and Flexoplast on the other hand, come from different sectors, and did not have any connection with energy. Wetsus however, received a lot of attention from industrial partners, in the context of water management and techniques and, energy has always been an interesting supplement. Moreover, both organisations also worked on the membrane aspect for which they had the knowledge available.52

**Alignment**

In all the situations and activities that I have described above, another important aspect of context has become clear: the alignment with its context. In order to apply for a government subsidy, the project has to fit or match certain criteria. The same can be said about the involvement of stakeholders: they were easily involved when the project suited their strategy and fitted in their line of business; when it created possibilities related to their core business; or when knowledge was already available on this topic. Kema, VolkerWessels and Flexoplast did not have a lot in common. Their company structure, size and strategy was different, their expertise and available knowledge did not correspond, and they operated in different sectors. Whereas the stakeholders involved in Wetsus mostly came from the same sector and industry, the stakeholders that had started Redstack were all middle range companies, and their knowledge that will contribute to the development shows overlap. Probably the most important aspect of alignment in this early stage of development has also been the alignment of their visions and expectations.

**Alignment of their visions and expectations**

Kema expected to provide their specialised research for proving the principle and assist in developing the first power plant. Revenues would result from selling patents and taking care of future research, quality control, advice and the inspection of constructions. VolkerWessels joined the consortium because they could use this technique as an alternative spouting possibility and they expected to construct the installation. Velsen Flexoplast, producer of plastic bags, was only attracted for the mechanical facilities (instead of contemporary manual production) to produce large quantities of polyethylene (main ingredient for the alternative membrane) and eventually this would imply new business opportunities for them. From this view, each company had an input that was complementary. However, they were not interested in the same functionality of Blue Energy. VolkerWessels was not interested in electricity, but in an alternative (cheaper and innovative) method for the displacement of water. For them, it did not matter whether the installation was based on osmosis or reversed electrolysis. Kema on the other hand had acquired patents for the alternative ion-permeable membrane (suitable for RED) and foresaw possibilities to develop knowledge on an interesting new field of research. Knowledge and expertise is their main product for consultancy purposes and this project could extend their expertise and provide more work. The technique discovered by Kema to electrically modify plastics is also suitable for desalination purposes, fuel cells and super conductors (Kema, 2005).

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52 It should be mentioned that there is also a department working on bio fouling within Kema.
Velsen Flexoplast could only facilitate the production of membranes and did not have any connection with a Blue Energy installation. The alignment of expectations within the consortium was not optimal and their interrelatedness not stable.

The stakeholders involved in Wetsus on the other hand, got involved in a research project on a radical innovation, which could possibly become an interesting technology for them. Wetsus, placed most of their time on the development of the installation, that means on the operation of a power plant based on Blue Energy. They did not focus on one specific membrane, but used contemporary (expensive) industrial membranes to build an installation and prove the functionality. The stakeholders that eventually saw possibilities for their business, as a constructor or a deliverer of parts, started Redstack to commercialise this technique. Wetsus conducts further research on the installation, and external institutes will eventually deliver cheaper membranes. Besides the different strategy, the project was constantly aligned with the interests and expectations of the stakeholders and had many starting points to connect to. If another application of this technique would have been more suitable, they would probably have altered their strategy.

The vision by Kema was that they could produce economically interesting plastic membranes that could be used for Blue Energy. Wetsus and later Redstack focus on the system design and expect to deliver an economically viable power plant for which Wetsus conducts the research and the companies participating in Redstack will deliver specialised parts. The consortium around Kema did not make clear that their strategy was based on RED, and for the application of a power plant or spouting alternative. PRO is interesting as a spouting alternative for which electricity production is an additional benefit. RED on the other hand is meant as a power plant and because of the necessary water management also displaces water. Osmosis and RED need different types of membranes. Kema worked on RED whereas VolkerWessels has patents for the osmotic spouting alternative. Participants in Wetsus and Redstack on the other hand share similar and clearer visions. They all contribute to the vision of a RED power plant for which they deliver their expertise and crucial parts for this installation.

What can be learned from these early experiences in the Dutch Blue Energy development is that there is a big difference between the initial project started by the consortium around Kema and the latter development at Wetsus and Redstack; The alignment of visions and expectations and also network possibilities have been crucial in this development. The main conclusions have been summarised in Table 4.1. In the next chapter I will elaborate on the outcome of the case for the notion of context, and the role context could play in the analysis of radical innovation projects. The remaining section of this chapter discusses some issues related to the case that deserve more attention.

<table>
<thead>
<tr>
<th>Table 4.1 Alignment and network properties in both projects on Blue Energy</th>
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<tbody>
<tr>
<td><strong>Kema</strong></td>
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<tr>
<td>Personal network</td>
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<tr>
<td>Stakeholder involvement</td>
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<tr>
<td>Capacities and capabilities of actors</td>
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<tr>
<td>Knowledge available</td>
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<tr>
<td>Dedication and enthusiasm stakeholders</td>
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<td>Government attention</td>
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<tr>
<td>Alignment</td>
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<tr>
<td>Alignment expectations and visions</td>
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<td>Alignment core business</td>
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<td>Alignment of knowledge</td>
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<tr>
<td>Government attention</td>
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<tr>
<td>Government support (financially)</td>
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</table>
4.7 Food for future thoughts

This empirical case has given insight in the complexity of financial support programs and can serve as a good example of how expectations become requirements. In this section, I conclude with some issues that I think should be taken into account by the parties involved in further developing the Blue Energy technology.

Financial support

The complex and opaque public financial support system was of great influence in the development of Blue Energy. After the struggle in stage one to familiarise the Dutch innovative system with Blue Energy, the project became popular and was frequently put forward as a promising development for The Netherlands. SenterNovem, the Innovationplatform, governmental spokespersons and many highly influential actors have supported the vision of a promising renewable energy alternative. However, both Kema as well as Redstack have struggled to get public financial support. In the beginning Blue Energy did not fall under the strategically chosen paths in subsidy programs to stimulate sustainable electricity projects. Later, when also water related subsidiary support programs were available, the project got rejected again. In both cases, the responsible organisations were in favour of the project and Blue Energy appeared in official governmental publications concerning strategically projects. Kema, Redstack and Wetsus have all been present at meetings and have been cited in publications. The comities that should approve the projects, however, rejected the project because the principle could never work, or could not become economically viable in the future. According to several actors involved in the development, these comities consist of actor from established institutes and organisations. These actors are usually pensioners or respected actors from within the field and more conservative and related to established organisations. One of the committee members for example was also involved in an organisation that competed with Wetsus for the accommodation of TTIW. This relates to an earlier point of personal relationships. According to SenterNovem, EZ is aware of this problem. However, the project got rejected for NEO support because committee members from the energy sector were not familiar with the principle and did not believe in its possibilities. The same happened when Redstack applied for a water related subsidy. This time the committee members existed of respected and established members from the water sector. The project is delayed again, which will require a lot of effort from the stakeholders to convince this community. If the national government has the ambition to support radical innovations, they better take lessons from developments such as Blue Energy. Many respondents have uttered their disbelief on the development with government support programs and had experienced similar situations before. Most of the respondents were therefore reluctant to invest in local innovations because they could not rely on government support. Another reason was that programmes change to often and that it is too difficult and strenuous for corporations to stay up-to-date with the latest requirements. Furthermore, applications usually take several months to get approved or not. When companies decide to invest in a project, they get the rejection for government allowance much later, and are faced with high investments that cannot be retraced. A final point that has been made about investing in projects is the main bottleneck experienced by many respondents, which seems to lie at the implementation phase. Governments support research on radical innovations, but companies especially need external finances to employ the project for which substantial investments are necessary. Kemp et al. also acknowledged this point of high barriers for newcomers (Kemp, 1998: 180). Without government funding for marketing, small companies do not prevail. The government used to finance these projects a decade ago but has only recently been active in trying to get a similar support programme off the ground. It is obviously very difficulty to install a satisfying system.

Promises become requirements

The Blue Energy development is a good case to show how expectations turn into requirements (Van Lente, 1993: promise-requirement cycle). The initial expectation of the 200 MW power plant at the afsluitdijk has travelled from Kema, to Wetsus and eventually Redstack. It convinced and enrolled many (industrial as well as governmental) actors, and set requirements for
the future installation. Wetsus attracted enormous amounts of funding for scientific research completely based on expectations (Wetsus as a whole, not only for Blue Energy). Besides a scientific article, and three patents they haven’t produced energy yet. Kema and Redstack have had more struggles to get public finance for actual specific installations, but eventually did. The prospect of an alternative energy technology, the reduction of CO₂ emissions, the availability of (weather independent) supply, low cost spouting possibilities and the symbolic meaning of gaining energy out of water have led to the expectation of a power plant running on river and sea water. This requires cheaper membranes and the afsluitdijk functioned as the flag on the horizon, to which every participant and researcher lives up to. The requirements therefore became: develop efficient cheap membranes (for less than one euro/mm²), a 200MW power plant on the afsluitdijk, and electricity production for 0.05 cents per kWh (to compete with fossil fuels). Wetsus is expected to conduct the research and develop the pilot installations together with Redstack who will lead the project and deliver the parts.

**Popularity**

Another point I wish to make is about the popularity of Blue Energy. According to many respondents, politicians were searching for a project to dwell around with. The attention Blue Energy received in the second phase of the development can be attributed to the ‘hype’ around Wetsus. Wetsus is hot and opens doors for funding, participants, etc. (van Riet, 2007). Factors, such as the national interest for innovation, the underdevelopment of Friesland, the attention for water and membranes have all contributed to the successful start-up of Wetsus. Wetsus attracted more stakeholders and increased the expectations about the research institute. However, if results fail and nothing is proven within several years, this dream might fall into peaces and might even be a serious threat to Wetsus as a whole. It is important to understand that the developments at Wetsus and the attention it attracts do not only involve the Blue Energy development. Many stakeholders and media attention is directed towards other themes at Wetsus. However, Blue Energy has been one of the main attractors for Wetsus, because Blue Energy is one of the first projects and Redstack the first spin-off.⁵³

**Made in Holland**

The development of Blue Energy could have been much further if Kema and Wetsus would have worked together from the start. I did not mention why the parties did not work together from the start because it was difficult to make the situation clear. Respondents have been reluctant to discuss the situation, although several diverse reasons have been mentioned. The main reason is that the relation and trust between Wetsus and Kema has been very bad from the start. This relation was worsened, during negotiations to attract an important stakeholder. At this moment Kema is working together with Redstack but is not involved in the research at Wetsus and could not share their knowledge on the project. Respondents have mentioned that this probably has delayed the project and had its effect on the reluctance from government support programs. I also noticed from the references in official government brochures, that it was not always clear to them who were working on the project and especially in the beginning both Kema as well as Wetsus could be found at workshops and meetings. According to some of the insiders, it is a missed chance for an interesting project that could be an excellent example of a typical Dutch innovation: ‘made in Holland’.

**RED versus PRO**

The research on salinity power has been divided into two groups: those conducting research on the indirect electricity conversion method PRO, and those who expected more from RED: direct electricity conversion. In both processes, membrane costs were seen as an important barrier for this technology to evolve in competition with conventional electricity production methods. The ten times lower price for osmotic membranes, could have been the reason why this technique has received more attention. Recently, scholars have compared both methods and concluded that each technique has its own field of application. ‘Pressure-retarded osmosis seems to be more

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⁵³ Probably also because of the symbolic meaning: gaining energy out of water.
attractive for power generation using concentrated saline brines …. reverse electro dialysis seems to be more attractive for power generation using seawater and river water’ (Post et al., 2007). This means that Wetsus and Redstack eventually have to work on natural water, or otherwise lose the race on salinity power in the future against the osmotic variant.
5. Answering my research questions and conclusions on the role of context

5.1 Introduction

Chapter two has shown that technologies do not develop linear from research and development to market introduction. Demonstration phases for example are often negotiated during periods of research, when outcomes of the technology are not evident. This makes socio-technological development complex and unpredictable. Especially in early stages of development the project and technology can shift to different directions, sectors, public etc. However, when technologies become more and more embedded, they are hard to change or alter in more preferable directions. Scholars in technology dynamics have referred to this as Lock-In or the “technology gained momentum” and “continues its own trajectory”. In this phase the technology seems to follow a deterministic development, almost as if the technology developed logically into the best option. However, a technology is not developing autonomously but is linked to its context and therefore complex and inherently unpredictable, which means that technology should be appropriate for time and place. The context surrounding technological developments consists of heterogeneous actors and factors maintaining a network. Technological, scientific, economic, political and cultural circumstances and considerations form a seamless web. Technological development is a social process and the technology is in constant interaction with its context. In chapter two this complexity and unpredictability of socio-technological developments has been discussed. To identify contextual factors in the development is a difficult task, mainly because stages in the development do not follow each other in a logical order and therefore seeds for all stages are already presents in early developments. In chapter three, I therefore elaborated on the problem of how to identify context and concluded that focussing on specific events that stimulated or hindered the development can best identify contextual factors. In the former chapter, I have answered one of my research questions addressed in the introduction: how and why did Blue Energy develop more successful at Wetsus than at Kema. I introduced a methodology based on the notion of context to investigate and understand the different development of the same technology in two different project groups. In the introduction I formulated my question guiding my research as follows: What is the role of context in the development of Blue Energy? In order to answer this question, I divided the main research question into two sub questions: what is considered as context in literature on innovations? And what factors are discernible in context? In the following sections I will elaborate on these questions in order to draw some general conclusions. Section 5.2 discusses the role of context on radical innovations. In 5.3 I elaborate on the problems that I encountered when trying to analyse and categorise the role of context and in 5.4 I introduce new concepts in order to understand the role of context. This chapter will conclude with discussing several issues related to studying the role of context.

5.2 The role of context in the development of radical innovations

In Chapter 2 I elaborated on the role of context in different approaches on technological development. The ambition was to (1) identify general assumptions about the context of technologies; (2) find tools that would help to identify factors that comprise context; and (3) propose a way to categorise these factors. In the analysis of the Blue Energy case, I have already discussed several concepts that are often used in innovation studies. The kind of context for example, such as an economical (high membrane price), government policy (support specific technologies), infrastructural (core business at Kema but also the availability of government support programs), regulatory (formal rejection of application), technological (membrane specifications lead to distinct technology), can be related to the factors that Kemp et al. (1998) refer to. In this perspec-
tive, the actors’ influence is understood as cultural and psychological factors: motivation, strategy, dominant way of thinking, belief system or paradigm. The multilevel perspective on the other hand, makes a distinction in micro, meso and macro levels of context. Climate change is an external macro (landscape) factor, formal rejection of application is a meso (regime) factor and actor and network capabilities are seen as micro (niche) level factors. However, I was not only interested in the kind of context to analyse socio-technical developments, but especially in the influence that it has on the development. I therefore elaborated on how technologies develop and on the working of technological development. I found the distinction by Geels (2004) in st-systems, actors and rules suitable for this purpose and subsequently accepted this analytic distinction in order to categorise contextual factors and explain how it influenced the development.

In early stage radical developments however, expectations are often involved that cannot be categorised as rules yet. These expectations differ between actors, but have a strong influence on their motivation. I have included this as a separate factor to categorise context. This categorisation is shown in Table 5.1 founded by an example of the property and influence of each factor.

<table>
<thead>
<tr>
<th>Context</th>
<th>Example</th>
<th>Property</th>
<th>Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectations</td>
<td>Business opportunity, alternative spouting possibility</td>
<td>Psychological element</td>
<td>Motivate actors to get involved in the project</td>
</tr>
<tr>
<td>Rules</td>
<td>Specific categories in subsidy program</td>
<td>Socially accepted or institutionalised elements</td>
<td>Hinders or stimulates actions</td>
</tr>
<tr>
<td>Actors</td>
<td>Stakeholders in Wetsus: network, influential position,</td>
<td>Elements that contain agency, motivation, and possess capabilities and capacities</td>
<td>Make decisions, attract other elements</td>
</tr>
<tr>
<td>ST systems</td>
<td>Availability of salt streams, alternative membranes or finances</td>
<td>Technological, infrastructural, geographical elements in the development</td>
<td>Make the development possible</td>
</tr>
</tbody>
</table>

Not yet formalised expectations are psychological elements that motivate actors to get involved in the project. The expectation of a business opportunity or enhancement of their image, for example, got actors involved in the Blue Energy development. Rules on the other hand are socially accepted or institutionalised elements that directly hinder or stimulate the development. The formality of specific categories in subsidy programs, resulted in the rejection of the Blue Energy application, even though the agency, responsible for these programs, was in favour of the development. Actors are elements that contain agency and do something. Actors make decisions to join the project, reject the application or to enrol another actor. Their motivation, capability and capacity are therefore an important element of this contextual factor. The last category is st-systems, which comprises all the more material, technological, infrastructural and geographical elements that are present in the context of the development: for example the availability of salt streams, alternative membranes or finances. Unfortunately, the influence of context is more complicated than this. The case also shows the influence of context on strategies. Often, expectations have had their influence on the strategies of actors and expectations are always built up around another contextual factor. Also formal rules (the rejection of applications), st-systems (availability of a specific membrane) and other actors have strongly influenced actors’ strategies. The same can be said about expectations, which are also influenced by actors, st-systems, formal rules and other expectations. Context is therefore more complex to describe than in the above categories provided by Geels and most of the literature on technological development. I further elaborate on this point in the next section.
5.3 Problems when analysing the role of context

In chapter four, the role and influence of context has been discussed. The Blue Energy development served as an interesting case to identify contextual factors influencing radical innovations. During this analysis on context in the Blue Energy socio-technical development, I ran into several important difficulties. The main problem was the complexity of context and the difficulty of generalising, categorising or drawing conclusions on context. This complexity is related to several aspects that I discuss in the sections below.

Interaction context and socio-technical development.
Context obviously has an influence on a socio-technical development. However, when context has an influence on a situation or action, this situation in turn also influences its context: context and innovation therefore co-evolve. The deficiency of financial means for example, influenced actors to enrol new stakeholders and attract government funding. Moreover, it also created the need for a re-evaluation of the subsidy program and strategic themes (EOS). Subsequently, financial means became available and the actors’ strategies changed again. The notion of time is therefore crucial in understanding context and it also makes clear that it is difficult to argue that context influences the development or that the development influences context. This is rather a matter of the interaction between context and the socio-technical development. Context and the socio-technological development are constantly in interaction and this is therefore often referred to as co-evolvement in which both elements are in constant flux.

I have mentioned several times already that the complexity of the interaction between the socio-technological development and its context has made it very difficult to analyse the role of context. It was particularly difficult to categorise context at a higher level of aggregation. What do we consider as context, or better what element of this context do we point out: the actor, the network, the belief system in the network, the expectation that the actor or network has or the external factor responsible for the expectation… in other words where to look and where to make a division has been my main struggle in the analysis. I have therefore decided to mainly focus on the influence of context on the innovation, taking context to be more static for a period of time, and to a lesser extent focused on the co-evolution of context and innovation. In addition, when analysing context, you can go on indeterminably with demonstrating context behind context. Every time you start with demonstrating the influence of an actor or factor, you find that behind each actor and factor that directly influences the innovation another factor or actor is influencing this actor or factor and thus indirectly influences the innovation.

Causality: The context of what?
Related to the last problem is another element I encountered during the analysis of the case: the problem of causality and the unit of analysis. When I look at the Blue Energy development, Wetsus has been an important contextual factor: Wetsus created attention, attracted stakeholders and capital, attributed to the scientific and technical development, etc. However, when I look at Wetsus, Blue Energy has been an important contextual factor: it created expectations resulting in attention and stakeholder involvement, convince people, functioned as a benchmark for Wetsus, resulted in the first spin off, etc. It is therefore important to outline the research. What I have been interested in was the interaction between the socio-technological development of Blue Energy and its context.

I found out that no categorisation of context is easy to make. The conclusion of chapter four can be understood as my struggle to get the analysis of context structured. Below is an attempt at this structuring in which I introduce some facilitating concepts to cope with the complexity of context.
5.4 Towards categorising context

Direct and indirect context.
I would first propose that there are roughly two forms of context: direct context and indirect context. Direct context or first-line context is directly involved in the development. The availability of financial means, the capability of stakeholders, and the organisational setting all have had a direct influence on the development and can be seen as context. Indirect context, or second line context, on the other hand influences a first-line contextual element. Water is hot (lots of money available for water technologies) and the societal need for alternative energy sources created expectations about commercial possibilities or business opportunities. These expectations subsequently resulted in the founding of a spin-off company, which is the factor that had a direct influence on the Blue Energy development. As mentioned earlier, the same indirect contextual factor can also influence other direct contextual factors. The initial factor (water is hot, societal needs) also encouraged governments’ strategies resulting in the development of new/suitable financial programmes. It is also possible that a direct contextual factor influence another direct factor. The expectations about commercial possibilities or business opportunities also enrolled new actors.

Figure 5.1 The influence of direct and indirect contextual factors on socio-technical developments

Figure 5.1 illustrates the relations between the socio-technological development and direct or indirect contextual factors. This notion of context has consequences for any categorisation of context, because these factors do not fit in a single category. As mentioned earlier, many scholars use certain categorisations in factors; such as economical, social and infrastructure factors. However, these factors are interrelated and are therefore difficult to be placed in specific categories. The same counts for theories that use the notion of levels, such as the Multi Level Perspective. At the niche level radical innovations take place in a specific context protected from the
dominant regime factors (meso level). Depending on the unit of analysis factors and actors are placed in certain levels and possess certain properties. However, these actors as well as factors are interrelated and can be active in both levels. These elements interact and usually exist in more than one level and cannot be taken separate. Let me give a more elaborative example on the notion of direct and indirect contextual factors (also see Table 5.2).

Table 5.2  *An example to illustrate the complexity of categorising context*

<table>
<thead>
<tr>
<th>Context</th>
<th>Action</th>
<th>Factors</th>
<th>Levels</th>
<th>Category</th>
<th>(in) direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expensive membranes</td>
<td>Expectation of a business opportunity</td>
<td>Economical</td>
<td>Macro</td>
<td>St system</td>
<td>Indirect</td>
</tr>
<tr>
<td>The expectations of a business opportunity</td>
<td>Motivate actor to get involved</td>
<td>Psychological</td>
<td>Micro</td>
<td>Expectations</td>
<td>Direct/indirect</td>
</tr>
<tr>
<td>Involved actor</td>
<td>Applied for a funding</td>
<td>Social</td>
<td>Micro</td>
<td>Actor</td>
<td>Direct</td>
</tr>
<tr>
<td>Organisational structure Kema</td>
<td>No further project, unless external order</td>
<td>Infrastructural/regulatory</td>
<td>Meso</td>
<td>ST system/ (actor capacity)</td>
<td>Direct</td>
</tr>
<tr>
<td>Kema organisation/no financial means</td>
<td>Alter strategy</td>
<td>Economical</td>
<td>Micro</td>
<td>ST system/ (actor capacity)</td>
<td>Direct/indirect</td>
</tr>
</tbody>
</table>

In the context of expensive membranes actors develop expectations on business opportunities. This is an obvious economic contextual factor, which can also be seen as a macro level factor in the Multi Level Perspective and as an st-system element in the categorisation I used in chapter four to analyse the case. However, these expectations did not change anything in the socio-technical development of Blue Energy. It was the motivation of actors to get involved in the project that can be seen as a change in the development, influenced by the expectations. Therefore the economical context factor of expensive membranes can rather be seen as an indirect factor, influencing a direct factor. To make it more complicated the actor that became involved also functioned as an indirect factor on another factor namely the application for government funding. These factors cannot be linked to certain levels because they interact on all levels with a varying influence on the development.

Another important aspect of context became clear after the analysis of the Blue Energy case. Especially the personal network and the actors’ capacity and capability have been crucial in the difference between the two projects. But there was also another factor that made the difference: alignment. The alignment of involved actors has made a crucial difference between the two projects and can also be related to the strategy chosen in the project. Again the problem of causality is evident. Was it the strategy, the capability of the actors involved, the availability of the network, or the suitability within the organisation that created alignment? Obviously, these factors can be related to the internal competences, properties or internal context of the project. External context to the project were the formal government support arrangements, government strategies, availability of support programs and any other contextual factor that cannot be influenced directly by the management of the project. Besides the direct and indirect division proposed earlier, I therefore propose an extra division between internal and external context. I have combined these two concepts in a two by two matrix in Table 5.3 and filled in the elements that have been crucial in the socio-technical development.
Table 5.3  
Internal and external versus direct and indirect context

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal</td>
<td>Stakeholder involvement, alignment core</td>
</tr>
<tr>
<td></td>
<td>business, knowledge, financial means available</td>
</tr>
<tr>
<td></td>
<td>Alignment expectations and visions,</td>
</tr>
<tr>
<td></td>
<td>dedication/enthusiasm stakeholders,</td>
</tr>
<tr>
<td></td>
<td>personal network, capacities and capabilities of actors, knowledge available</td>
</tr>
<tr>
<td>External</td>
<td>Government support (financially)</td>
</tr>
<tr>
<td></td>
<td>Government attention</td>
</tr>
</tbody>
</table>

5.5 To conclude

Two projects on a similar technique have developed in the Netherlands, however with a different outcome. An important conclusion from this analysis has been that in the same external context, the role of internal context has been crucial for the success of the project. When the two projects are compared using Table 5.3, Wetsus did well in all four quadrants, whereas Kema only succeeded minimally in the indirect-internal and direct-external categories. We can also see that the indirect-external quadrant is at such a great distance from the project that this is outside the influence of the project management. The direct-internal quadrant on the other hand has been crucial for the development and can be subscribed to the internal project competence. However, in order to get actors involved and create alignment, actors have to be convinced actively. Expectations have been of great importance in this activity. In each and every situation, expectations were involved. This is also due to the fact that situations depend on actors and actors’ strategies, perception and motivation, which all depend on expectations. What became clear was that diverse expectations exist around radical technological developments, because network linkages are still weak and future prospects insecure. These expectations are used by actors to convince others and are not always shared within the network around the technological development. Van Lente (1993) has shown that these expectations henceforth advice engineers in their search process, mobilise new actors in the network, are used to allocate funding, convince politics or legitimise the project. It is crucial that these expectations become accepted by more actors and taken up in agenda’s and that it depends on the context around the expectation (actor, influence) on the public that can be reached. Positive outcomes of developments lead to positive expectations resulting in follow up research programs, related projects and a community or network of involved actors. Geels & Raven refer to positive or negative developments in the project as ‘upswings’ and ‘downswings’. These upswings in the developments can be explained by expectations, when they link technology to a functional application and get support from social networks. However, when technological outcomes do not meet the expectations, this factor might also form a serious threat to the development. ‘Downswings’ can evolve from outcomes that do not meet the expectations, which leads to a backlash in expectations. When beliefs turn sour, networks fall apart and resources become reduced (Geels & Raven, 2006). In order to enhance collaboration and coordination, strategic games are being played to reduce uncertainty in the socio-technological development of (radical) novelties. Actors, networks and especially expectations are crucial in this aspect.

This research has shown that context is an important factor in technological development and that this aspect is underexposed in innovation studies. Various scholars have mentioned context and have shown the importance of context, but did not try to make the role of context explicitly clear. The determinants of technological development vary over time and space, between systems, categories of innovations, process and product, incremental and radical. Both variation as well as selection takes place in context, and the choices made in the development depend on a wide range of conditions: factors (personal, organisational, political, and economic, etc.), contingencies (historical, local) and actors (competing strategies and perceptions) all play a role in the development (Jamison & Rohracher, 2002: 7). An underexposed factor in this distinction is the notion of expectations. Not (yet) institutionalised expectations are especially important contextual factors around radical novelties because they mobilise and steer actors, allocate funding.
etc. This resulted in my distinction between st-systems, actors, rules and a special category of expectations to portray context. However, I have shown that context does not allow for categorisation in levels or factors, because these factors are interrelated which makes the notion of context far more complex. Context is not only influencing the development but also vice versa and we can therefore rather speak of the interaction between the socio-technological development and its context. Another important conclusion is that each contextual factor has both positive as well as negative influences on the development. The strong network between committee members and established firms for example, had a negative effect on the Blue Energy development.

My analysis on the role of context in technological developments could be a fruitful approach to understand the success or failure of projects. However, what became clear is that context is very complex and that in order to use this method; a very strict outline should be followed focusing on one single aspect of technological development. Generalisations of results have been difficult, but the notion of the direct and indirect context and the influence of internal versus external contextual factors could be a fruitful enhancement for innovation studies. The study also showed the importance of micro sociological studies in the development of technologies. Expectations and network formations are underexposing in for example the Multilevel Perspective and the Systems of Innovation. External landscape (macro) as well as regime factors are often perceived as the most important trigger for technological breakthroughs. Usually, external or landscape factors get the attention and are often treated as fatalistic factors. In the Blue Energy development however, it became clear that network properties and the alignment within the project have been crucial elements for the success of this development. Small-scale research on this technique is only conducted at a few places worldwide and has revived again in the Netherlands. Obviously, the global and national contexts have not been the main concern in this case; the regional and local contexts have also contributed to the development at these specific locations. Therefore attempts to influence this and similar developments into favourable directions should not only focus on subsidiary programs and changing regulations, especially internal properties and the alignment in the project must be taken into account. Furthermore, expectations have been crucial for the allocation of finances, convincing other actors and enrolling stakeholders.

In this thesis I wanted to make clear that context plays an important role in the development of radical innovations. However, context changes and is embedded in extended parts of social life. A certain technology would follow a different development say ten years earlier and possibly also one week earlier. A similar remark could be made about the location; could the same development have taken place in a different country, region, sector or company? So what is the point of quantifying or qualifying context? The importance of this paper is to show the influence of context. That means we cannot pretend that technologies develop in a vacuum: it is important to appreciate and recognise its context.
References

Internet
Nederland innovatief (2005): ID-NL jaarprijs info: www.nederlandinnovatief.nl
UN atlas of the ocean (2001): Salinity Energy: http://www.oceansatlas.org/servlet/CDSServlet?status=ND0zMDY0JmN0b19pbmZvX3ZpZXdfe2l6ZT1jdG5faW5mb192aWV3X2Z1bGwmNj1biYzZ0qjM3PWtv~ (accessed on 2 may 2005).

Interviews, Symposia and workshops
Almost all stakeholders have been enthusiastic about this research and cooperated. Only SenterNovem and EZ were reluctant and did not fully cooperate. For this case study various stakeholders have been approached for the last three years through interviews, (telephone) conversations and by attending workshops and seminars. The following actors cooperated and have been interviewed:

Fryisia: Mulder (2007); Weewer (2007)
Nuon: Riet, M. van (2007)
EZ: Damme, L. van (2007)
Boonstra, J. (17-01-2007), Telephonic Interview, Wetsus.
Ende, K. van den (16-02-2007), Telephonic Interview, Kema
Nymeijer, K. (1-3-2007), Telephonic Interview. University of Twente, Faculty of Science and Technology, Membrane Technology Group.
Oudakker, G. (16 juni 2005), In interview with author at Schiphol, VolkerWessels/Wetsus/Tetradon
Regeling, E. (16-02-2007) Telephonic Interview, Rijkswaterstaat
Roest- Krijgsman, J. (26-05-2005), In interview with author at KEMA Arnhem.
Sijens, L. (14-03-2007), In interview with author at SenterNovem in Utrecht, SenterNovem Suburban Ark
23 juni 2005. BLUE ENERGY, ENERGIE UIT OSMOSIS. Workshop Rotterdam.
Wetsus congres (participantendag) 9 juni 2005.

Newspaper articles, brochures, government reports, etc.:
Natuur Wetenschap & Techniek
Statkraft (2003): Focus on sustainability, Statkraft brochure 2003


**Scientific literature:**


Appendix A  Examples of rules in different regimes (Geels, 2004: 906)

<table>
<thead>
<tr>
<th></th>
<th>Formal/regulative</th>
<th>Normative</th>
<th>Cognitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological and product regimes (research, development production)</td>
<td>Technical standards, product specifications (e.g. emissions, weight), functional requirements (articulated by customers or marketing departments), accounting rules to establish profitability for R&amp;D projects (Christensen, 1997), expected capital return rate for investments, R&amp;D subsidies.</td>
<td>Companies own sense of itself (what company are we? what business are we in?), authority structures in technical communities or firms, testing procedures.</td>
<td>Search heuristics, routines, exemplars (Dosi, 1982; Nelson and Winter, 1982), guiding principles (Elzen et al., 1990), expectations (Van Lente, 1993; Van Lente and Rip, 1998), technological guideposts (Salah, 1985), technical problem agendas, presumptive anomalies (Constant, 1990), problem solving strategies, technical recipes, ‘user representations’ (Akrich, 1995), interpretative flexibility and technological frame (Bijker, 1995), classifications (Bovens and Star, 2000).</td>
</tr>
<tr>
<td>Science regimes</td>
<td>Formal research programmes (in research groups, governments), professional boundaries, rules for government subsidies.</td>
<td>Review procedures for publication, norms for citation, academic values and norms (Merton, 1973).</td>
<td>Paradigms (Kuhn, 1962), exemplars, criteria and methods of knowledge production.</td>
</tr>
<tr>
<td>Policy regimes</td>
<td>Administrative regulations and procedures which structure the legislative process, formal regulations of technology (e.g. safety standards, emission norms), subsidy programs, procurement programs.</td>
<td>Policy goals, interaction patterns between industry and government (e.g. corporatism), institutional commitment to existing systems (Walker, 2000), role perceptions of government.</td>
<td>Ideas about the effectiveness of instruments, guiding principles (e.g. liberalisation), problem- agendas.</td>
</tr>
<tr>
<td>Socio-cultural regimes</td>
<td>Rules which structure the spread of information production of cultural symbols (e.g. media laws).</td>
<td>Cultural values in society or sectors, ways in which users interact with firms (Lundvall, 1988).</td>
<td>Symbolic meanings of technologies, ideas about impacts, cultural categories.</td>
</tr>
<tr>
<td>(societal groups, media)</td>
<td>Users, markets and distribution networks</td>
<td>Interlocking role relationships between users and firms, mutual perceptions and expectations (White, 1981, 1988; Swedberg, 1994).</td>
<td>User practices, user preferences, user competencies, interpretation of functionalities of technologies, beliefs about the efficiency of (free)markets, perceptions of what ‘the market’ wants (i.e. selection criteria, user preferences).</td>
</tr>
</tbody>
</table>
Appendix B  Interview guide

PAST - PRESENT

Interviewee:
- WHO
- WHEN and HOW involved in the case (Kema, Wetsus, Redstack)

Expectations (initial):
- WHY involved in Blue Energy (reason/goal/strategy)
- WHAT were the expectations of the case
- WHICH advantageous for this actor(group)
- WHICH external influences present (e.g. oil, water, Paques, environmental problems or opportunities, costs,
- WHAT was the outcome of the expectations

Occasions:
- WHICH occasions were experienced as constraining or stimulating to the development? (problems, controversies, disputes, changes, decisions. E.g.: project, founding of Wetsus/Redstack, stakeholder meetings, patent or subsidy application, demonstration project Harlingen, involvement innovation platform, afsluitdijk)
- WHY (reason, cause)
- WHERE were these decisions taken
- WHO was important in the decision and who else was involved?

Constraining or stimulating factors (general):
- WHAT was experienced as constraining or stimulating to the development?
- WHO was experienced as constraining or stimulating to the development?

PRESENT - FUTURE

Expectations:
- WHAT is your expectation of the Blue Energy development (and your role in it) (application, size, location, etc.)
- WHEN do you expect the first commercial application (implementation)
- WHO will be involved (when do they become involved)
- WHAT does the market look like (external factors, problems)

Constraining or stimulating factors (general):
- WHAT constraining or stimulating factors to the development of Blue Energy do you expect? (competition, subsidies, investors, external factors, oilprice, environmental problems,
- WHAT are the factors in general for (radical) alternative energy developments

Remarks/Questions
Appendix C  Network configuration of stakeholders in the Blue Energy development