

Worth its salt?

Critical analysis of desalination for drinking water supply on
Gotland (Sweden)

Sophia Speckhahn

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A thesis submitted in partial fulfillment of the requirements of Lund University
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Supervisor: Ellinor Isgren, LUCSUS, Lund University

Abstract

Water is an essential resource for humans as well as the environment and water resources globally are under increasing pressure resulting in local conditions of water scarcity. The tension between increasing water demands and the natural limit to freshwater supply challenges authorities to find solutions that fulfil societal demands and economic purposes without compromising environmental integrity. Water production, flow and distribution is shaped by a complex set of political, social, historic, environmental and economic parameters that need to be coordinated in order to facilitate long-term sustainable water supply that acknowledges various interests. As one way to counteract water deficits, desalination of seawater has evolved as an attractive solution over the last decades and became an option to supply additional amounts of freshwater to human societies. The use of this technology is contested and associated with a variety of social, environmental and economic consequences; yet its application increases continuously around the globe. Drawing on political ecology, and using the case of the Swedish island Gotland where Sweden's first bigger desalination plant has been inaugurated in 2016 as an entry point, the benefits and drawbacks of the technology as well as the decision-making process were examined. By qualitatively analysing public documents and conducting interviews with different stakeholders, information about the application of desalination on Gotland could be obtained in order to provide knowledge about the challenges and potential trade-offs connected to the technology as well as the underlying mechanisms in decision-making. The findings indicate a number of benefits that are in line with broader development goals and therefore receive a high level of attention while drawbacks are considered to be manageable or externalised. Using technology to extend natural limits in order to serve human interests is prioritised over deeper restructuring of societal and economic patterns that would be required to align development to natural water supplies. This is accompanied by a process of depoliticisation facilitated through technocratic tendencies, naturalisation of root-causes and a sense of urgency resulting in a normalisation of desalination as an acceptable solution over time. Consequently, the decision's legitimacy can be challenged and conflicting interests are obscured. In order to invoke a transformation towards long-term sustainability of Gotland's water supply, decision-makers should seek to diversify their knowledge input and envision alternative futures that acknowledge various water needs and limits. Moreover, political debate should be encouraged and conflicting interests embraced in order to revive democratic processes.

Keywords: natural limits, water scarcity, sustainable development, political ecology, technocracy, depoliticisation

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If not stated otherwise, translations from Swedish statements and documents were made by the author.

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1 Introduction

Access to a sufficient amount of clean water is a prerequisite for the well-being of human societies and a variety of global and local phenomena increasingly put pressure on available water resources (World Water Assessment Programme, 2012), while the freshwater-supply globally is limited and therefore constitutes one of the Planetary Boundaries (Steffen et al., 2015). Simultaneously, context-specific factors construct and shape water conditions that reflect the location's social, political, ecological and economic present and past (Swyngedouw, 2009), calling for contextualised solutions while also following principles of justice and sustainability. Water management hence exemplifies an area of complex interactions and often conflicting interests and water uses. These tensions stress the need for reasonable and foresighted action and decision-making in water management that takes into account the manifold interests of water users and produces adequate solutions to give justice to both humankind and environment.

Sweden is normally associated with an abundance of water. Yet, local water shortages occur; threatening the water-supply for people and environment and demanding authorities to provide solutions that guarantee future water security. On the island of Gotland in south-eastern Sweden, water scarcity recently caused problems for the local freshwater supply, stimulating discussions about how to safeguard water resources in the future. As a result, a desalination plant converting saltwater from the Baltic Sea into drinkable tap-water has been opened in Herrvik on the island's east coast in summer 2016 to complement the municipal water supply (Region Gotland, n.d.-c).

The Geological Survey of Sweden suggests that the amount of water reaching the island is per se enough to fulfil its water needs, but keeping sufficient water on the island and make it accessible for human consumption is problematic due to lacking storage capacities (Dahlqvist et al., 2017). In light of this knowledge, it is natural to wonder why it is considered necessary to technologically increase water supply with seawater instead of improving accessibility of naturally available water resources or reducing water consumption.

Desalination is controversial because of negative environmental consequences like high energy consumption and impacts on marine ecosystems but also potential influences on the region's water use and development (Meerganz von Medeazza, 2005). The strategy to solve water scarcity problems by increasing water supply is contested as for instance Gleick (2003) points out that the goal should not be to provide ever more water but instead to improve the benefits per unit of water used and to reconsider the purposes of water. It is also argued that increased supply potentially leads to the

postponing of necessary measures to reduce water demand or eventually even an increase in water demand, adding pressure on local water systems (Kallis, 2008; Meerganz von Medeazza, 2005).

1.1 Aim and Research Questions

The aim of this thesis is to contribute knowledge about the challenges and potential trade-offs of integrating new technologies for resource extraction while advancing sustainable development. This could be relevant in decision-making as well as in academic debates. I therefore want to investigate the intersection of technology, environment and society and portray different perspectives on the use of technology and its subsequent influences through the case of desalination on Gotland.

My research is guided by the overarching question

Why did Gotland's authorities decide to complement the island's water supply with desalination despite its known controversies?

To approach this question, three sub-questions shall be answered:

RQ1: What does Gotland's society gain from implementing desalination?

This first sub-question shall capture the benefits of desalination. This helps to illustrate the expectations connected to its use and the motivations for its implementation.

RQ2: What problems does desalination on Gotland (potentially) cause or leave unaddressed?

This second sub-question sheds light on the shortcomings of desalination on Gotland. These include not only problems directly or indirectly caused by the implementation of desalination but also depict the limitations of the technology to address prevailing challenges. As in this early stage a final assessment of all effects is impossible, this question also deals with concerns that might or might not prove to be true.

RQ3: Which mechanisms made desalination a favourable solution for Gotland?

This third sub-question takes a more analytical stand and draws from insights from RQ1 and RQ2 in order to examine the decision-making and highlight relevant processes that shaped the problem understanding and hence the outcome of decision-making in this particular case.

1.2 Contribution to Sustainability Science

Water availability and use on Gotland is shaped by global phenomena, including changes of climatic conditions, use of energy, changes in land-use, modern lifestyles and economic interests but also produces effects beyond the island's boundaries, thus exemplifying an area of global-local interactions. The environment, providing water in the first place, and society, arranging its distribution and use, interact and can thus restrain or enable one another. Both forms of interaction are common topics in Sustainability Science (Jerneck et al., 2011).

In this thesis I intend to address the challenges of adequate resource use and distribution and the social, natural and economic dynamics involved. Kates (2011) formulates seven questions for Sustainability Science research of which I want to contribute to the fourth, addressing the "trade-offs between human well-being and the environment" (p. 19450) and the sixth, asking for ways to "effectively guide or manage human environment systems towards a sustainability transition" (p. 19450). The underlying tension between ecologic integrity and human dependency on environmental resources expressed in these questions builds the core of sustainable development (Kates et al., 2001) which therefore also plays a key-role in this context. By highlighting the problematic aspects of using desalination on Gotland, while simultaneously acknowledging the high importance of water for Gotland's inhabitants, conflicting interests can be understood and potentially inform future decisions. An alternative understanding of water scarcity could therefore be seen as an opportunity to develop along a more sustainable pathway.

My research has hence both critical and problem-solving components even though the focus is on a critical examination of current decisions and developing more sustainable solutions would require further research. However, as stated by Jerneck et al. (2011), questioning unsustainable circumstances and their explanations can clear the way for problem resolution.

1.3 Thesis Structure

In the following, I will first present the context of this work by providing information on the study-site. Next, the debate on desalination and sustainability will be portrayed which is followed by a clarification on the theoretical approach to this thesis and an explanation of the applied methodology. In the findings section I will then answer my research questions and afterwards discuss their implications. Finally, the conclusion will summarize the main points of this thesis.

2 The Case of Gotland

With an area of 3,140 km² and located about 90 km off the country's east-coast, Gotland is Sweden's biggest island and the second-biggest island in the Baltic (**Figure 1**). The population size is 57,391 (2015) of which ca. 24,000 people live in the capital Visby (Region Gotland, 2016). The regional development plan aims for a population increase to 65,000 residents by 2025 (Gotlands Kommun, 2008). Especially during summer however, tourism increases the number of water users drastically. In 2015 for instance, 931,000 night guests visited the popular holiday destination (Region Gotland, 2016, p. 24).

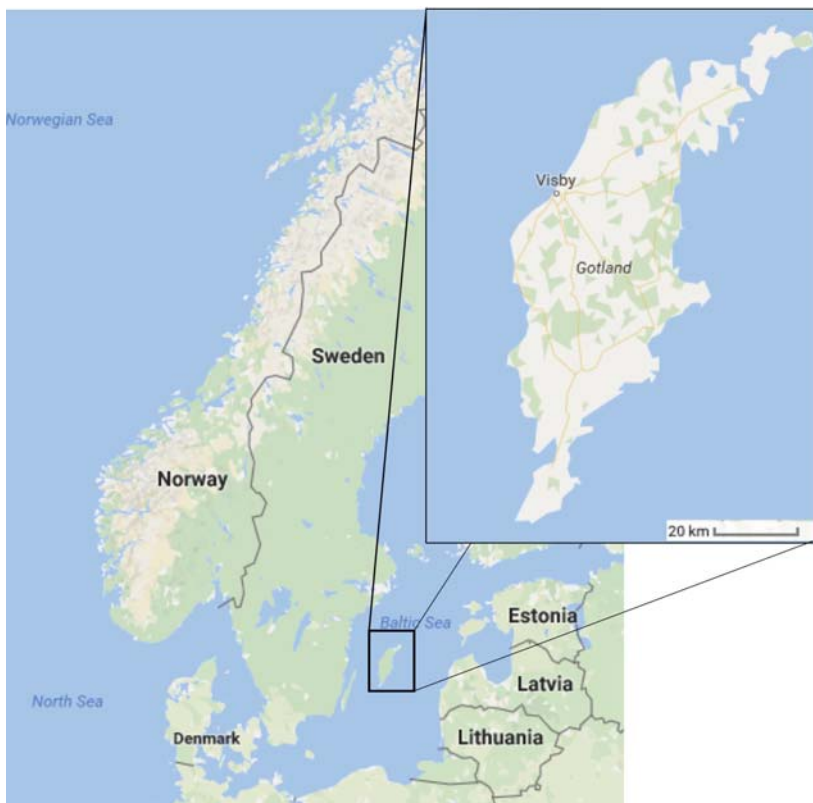


Figure 1. Location of Gotland. Own illustration based on Google Maps.

Groundwater levels in south-eastern Sweden are decreasing and reached historically low values in March 2016 (Geological Survey of Sweden, 2016). In 2017, Gotland starts the summer season again with a water deficit and groundwater levels below normal (Länsstyrelsen Gotlands län, 2017). As groundwater is a substantial input to drinking water, Gotland faces difficulties to ensure water security which is why a desalination strategy was recently adopted.

2.1 Gotland's Water Use

Figure 2 illustrates different water sources and purposes on Gotland and their relative contribution to the overall water-use. As the numbers are referring to different years and not using the same categories the figures are not directly comparable. However, the data depicts main water users and

sources. Nearly two-thirds of water is retrieved from groundwater and the agricultural sector is the biggest water user, followed by households including water used by tourists. Both agriculture and tourism are highly important economic activities on the island.

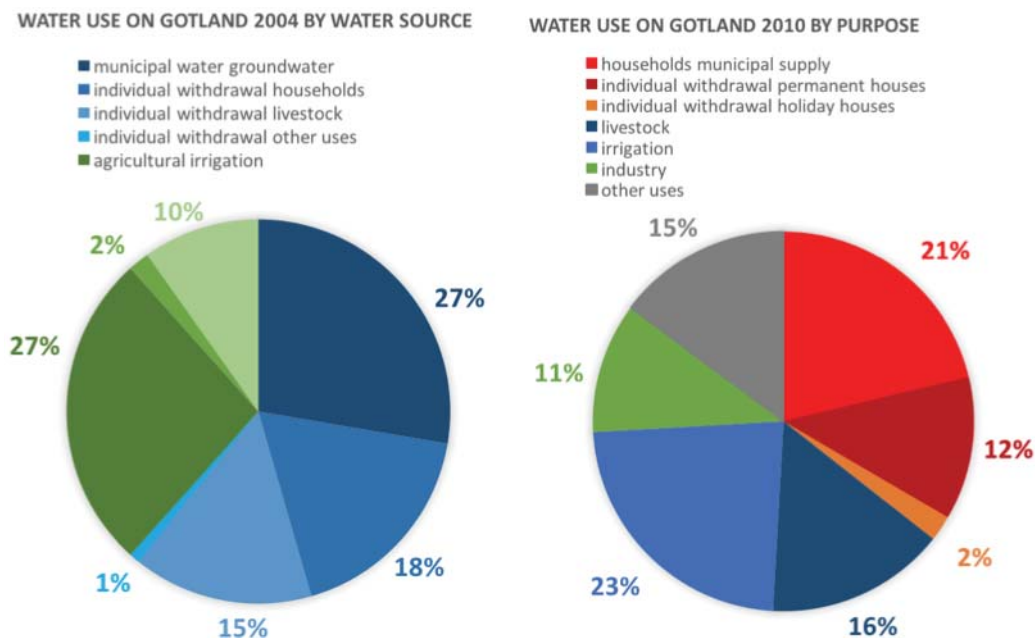


Figure 2. Water use on Gotland 2004 (left) by water source, where groundwater is depicted in blue and surface water in green, and water use 2010 distinguished by purpose (right). Own illustration based on Gotlands Kommun (2005) and Statistics Sweden (2012).

Only 63 % of Gotland's population is connected to the municipal water and sewage grid; 37 % thus rely on individual water withdrawals (Region Gotland, 2014, p. 7). Municipal water supply has been quite stable within the last decade despite an increase of subscribers from less than 10,000 to nearly 13,000 (Region Gotland Teknikförvaltningen, 2016a, p. 4). The per-person water-consumption thus decreased. This however only accounts for the municipal supply and neglects seasonal variations and spatial distribution. Information on temporal development of water use by individual water withdrawals is not available.

2.2 Role of Agriculture and Tourism

Two main economic sectors for Gotland, agriculture and tourism, are highly dependent on water in sufficient amounts and right quality to fulfil their purposes. In agriculture, water is used for irrigation but also to sustain animals. Both uses require different water-qualities and normally come from different sources as shown in section 2.1. In 2010, 34.9 % of Gotland's land was used for agriculture (Statistics Sweden, 2013, p. 41) which together with forestry and fishing accounted for 12.4 % of the jobs in 2007 (Gotlands Kommun, 2010, p. 65). Tourism on Gotland is essential to provide jobs for the local population as it is directly related to accommodation, restaurants, shopping and other activities

(Gotlands Kommun, 2010). Considering the accommodation revenue per capita, measuring the economic significance of tourism, Gotland was ranked highest in Sweden (Swedish Agency for Economic and Regional Growth, 2011, p. 39). The high importance of tourism is not coincidental. In reaction to a lack of employment in consequence of agricultural mechanisation, purposeful local and national policies were implemented since the 1960's to counteract population decrease, including strengthening of the tourism industry (Zucchetto & Jansson, 1985).

2.3 Hydraulic and Climatic Conditions

Gotland's future water supply needs to be aligned to climate change impacts. Asp et al. (2015) predict a temperature increase of 3-5 °C for Gotland until the end of the century, coming along with an extended vegetation period by two to four months. On the other hand, an increase in precipitation of 20-30 % compared to 1961-1990 is expected, including heavy rain events and an increase of maximum daily precipitation by up to 25 % (Asp et al., 2015). While temperature rise and prolonged vegetation period could signal a higher water need, the expected increase of precipitation augments water input which could be taken advantage of.

Geologic conditions are also crucial for water supply. Gotland's geology is characterized by fractured limestone bedrock covered by only thin layers of soil and without major water-bearing strata (Region Gotland, n.d.-b). As stated by Dahlqvist et al. (2017) water storing capacity is limited due to little soil thicknesses and there is a need for other storage reservoirs in order to provide water when it is requested. Water is usually transported in small cracks and surface water can reach groundwater within minutes or hours while it also gets transported long distances in short time (Region Gotland, n.d.-b). Both factors make Gotland's groundwater highly vulnerable and sensitive to contamination.

2.4 Drainage of Wetlands

Gotland's landscape was considerably altered in the past. In the late 18th and early 19th century, extensive drainage and ditching activities exploited 70 % of Gotland's wetlands in order to increase agricultural land (Martinsson, 1997). Consequently, high amounts of surface water run off with the spring flood and many rivers dry out over summer which also impacts many organisms (Martinsson, 1997). The drainage caused a decline of the water table and thus locally made water a limiting factor (Zucchetto & Jansson, 1985). As mires also have a hydrologic utility to store water, Zucchetto and Jansson (1985) see a direct connection of the draining activities to a decline of groundwater recharge and water storage capacity as well as a higher runoff. The vast loss of wetland area on the island within that time is illustrated in **Figure 3**.

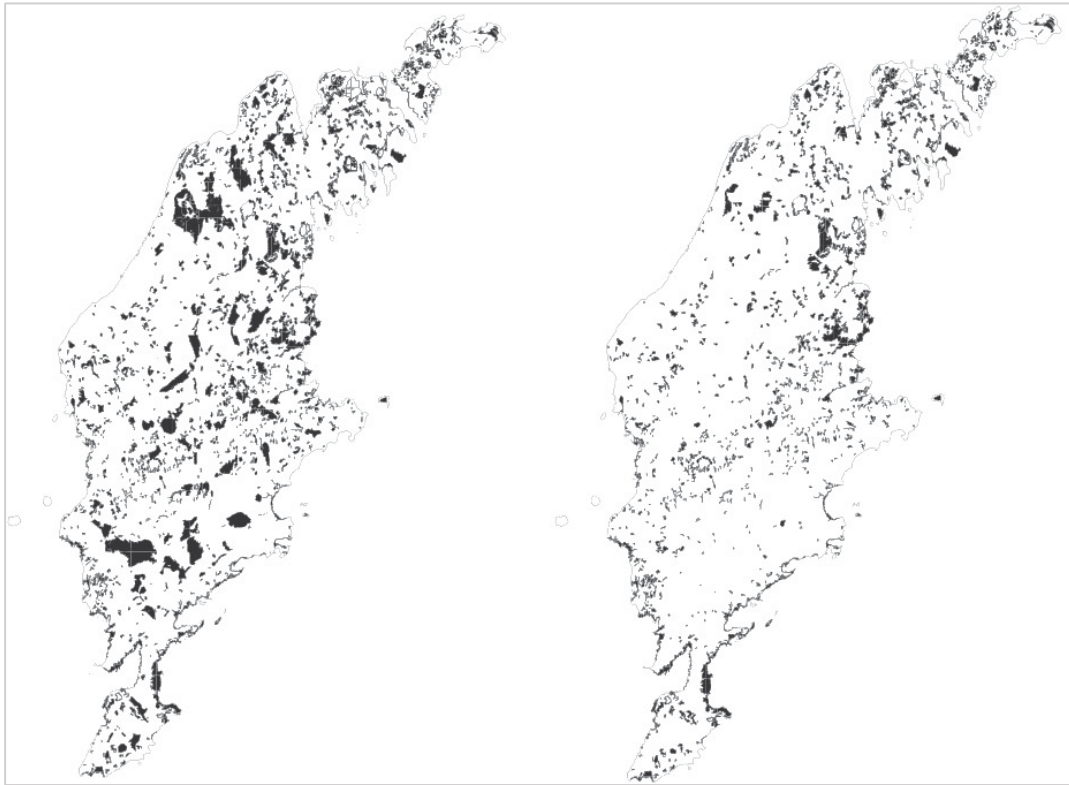


Figure 3. Wetlands on Gotland in 1700 (left) and in 1996 (right) retrieved from Martinsson (1997, pp. 22-23).

The wetland drainage had an immense influence on Gotland's water system with two important implications for the discussions around water scarcity nowadays. First, current water problems are to some extent man-made. Second, already 30 years ago potential water problems had been recognized and the consequences were hence predictable and could have been addressed earlier.

2.5 Desalination on Gotland

Sweden's first bigger desalination plant for municipal supply was inaugurated in Herrvik (**Figure 4**), east Gotland, in summer 2016 (Region Gotland, n.d.-c). The plant uses reverse osmosis to convert up to 20 m³ seawater per hour into drinkable water that is then distributed to the surrounding communities (Region Gotland, n.d.-c).



Figure 4. Desalination plant in Herrvik from the outside (left) and the membrane filter inside (right). Own photographs.

A second plant will be built in Kvarnåkershamn, located approximately 50 km south of Visby on Gotland's west coast. This second facility will have a maximum production capacity of 5,000 m³ per day, about ten times larger than the first one, and will supply drinking water for the southern parts of the island and potentially parts of Visby (Region Gotland, n.d.-a). Desalination is meant to be used as a complement to existing water resources in order to match the island's water demand and to avoid the overuse of groundwater (Region Gotland, 2014) and thereby potentially irrevocable damage of aquifers.

3 Desalination and Sustainability

As the vast majority of global water resources consist of seawater, the idea to use it for human consumption is nothing new. First efforts to transform it into freshwater were already made in the 17th century to ensure water supply on ships (Greenlee, Lawler, Freeman, Marrot, & Moulin, 2009). Today, a variety of desalination-technologies are widely applied, especially in the Middle East (Greenlee et al., 2009) and its use expands massively on a global scale due to increasing water demands and cost reductions (Ghaffour, Missimer, & Amy, 2013). For 2013, a production capacity of 80 million m³/day delivering water to about 300 million people in 150 countries was reported (March, 2015, p. 233). The preferred technology nowadays is reversed osmosis desalination; creating pressures higher than the osmotic pressure of the salt-solution in order to force the liquid through a membrane filtering out salt ions (Miller, 2003).

Compared to conventional water supply measures, desalination has several advantages which make its application seem favourable in many cases. The infinity of the ocean's water supply and its independency from precipitation (Ghaffour et al., 2013) are two features of desalination that conventional measures are unable to deliver and that make the supply controllable. Moreover, the water is seen to be free and not subject to property rights or cultural meaning (Swyngedouw, 2013). Another benefit is that groundwater extraction could be reduced when water is instead taken from the sea which would consequently relieve groundwater resources (March, 2015).

Despite those benefits, using desalination is controversial. A number of direct and indirect effects of desalination plants are illustrated in the literature. First, the process of desalination is very energy intensive (March, 2015) and will therefore increase overall energy consumption. The actual energy need for a specific plant depends on various factors like temperature, salinity or the applied technology (Swyngedouw & Williams, 2016) and is impossible to generalize. Lior (2017) states an energy demand of 3-4 kWh per m³ desalinated seawater using reverse osmosis which corresponds to the emission of 1.4-1.8 kgCO₂/m³ water (p. 102). For the desalination of brackish water however, energy requirements can drop to 0.5 - 2.5 kWh/m³ (March, 2015, p. 233). High energy needs are problematic in a time when energy consumption and greenhouse gas emissions should be reduced to mitigate climate change (Anderson et al., 2008). As Knights, MacGill, and Passey (2007) point out, even offsetting these emissions by using renewable energy is problematic considering that long-term goals to prevent dangerous climate change require an overall reduction of energy consumption. In this context, March (2015) also highlights the paradox of potentially exacerbating climate change through greenhouse gas emissions while simultaneously depicting desalination as an adaptation strategy; yet, he acknowledges reductions in energy demands throughout the last four decades.

Second, desalination can cause harm to the water bodies in use. Open water intake can impact aquatic organisms (March, 2015) and the discharge of brine, a waste product of desalination, can affect marine ecosystems in the plant's surroundings (March, 2015; Meerganz von Medeazza, 2005). In addition, land use, noise production and chemical pollution are mentioned as potential environmental impacts (Pereira, Cordery, & Iacovides, 2009).

Economic and social implications are also described. A common concern associated with the use of desalination is the high costs of water production. The actual costs for desalinated water are extremely variable and depend on multiple factors (Miller, 2003). For the use of reverse osmosis of seawater, Pereira et al. (2009) report a range of 0.45-0.71 €/m³ (p. 214). This consequently raises questions about the affordability and accessibility of desalinated water and the effect of producing "relative scarcities" (March, 2015, p. 238). This could not only exclude certain groups or countries from using desalination, but also encourage additional groundwater pumping, even illegally (Swyngedouw & Williams, 2016). Moreover, future cost development is insecure: costs could either decline due to advances in energy efficiency or rise with regard to potential internalisation of ecological costs (March, 2015).

Further critique is expressed about the general approach of solving water scarcity by increasing the supply. Meerganz von Medeazza (2005) indicates potential indirect consequences on water consumption and stresses that the increase of water supply risks to further increase demand as well — a trend that would intensify the overall pressure on local water systems. Moreover, the removal of an environmental constraint (limited water supply) can also trigger further development, potentially accompanied by additional consequences for the region's sustainability and leading to a use of water that rather serves economic or individual purposes than actual needs (Meerganz von Medeazza, 2005). Kallis (2008) expresses a similar concern but also emphasises that small-scale plants that only are in use temporarily, can have a securing influence and not necessarily produce these effects. The potential to foster demand is thus context dependent and requires special attention. Dickie (2007) argues that a new perspective about water, appreciating the resource and the environment more, is needed instead of a new water source and that desalination undermines the obligation to use water thoughtfully.

A major benefit of desalination is its independence from climatic conditions (Knights et al., 2007) leading to a more secure water output (Kallis, 2008). However, instead of depending on precipitation water supply becomes dependent on energy prices and variabilities (Kallis, 2008; Swyngedouw & Williams, 2016). It can therefore also be seen as shifting problems from one scarce factor (freshwater) to another (energy) (Swyngedouw & Williams, 2016) or postponing problem-solving into the future. Both effects indicate unsustainable dynamics.

Political aspects related to the adoption of desalination are also subject of discussions. Using the example of Spain, Swyngedouw and Williams (2016) claim that the increasing use of desalination reflects a process of depoliticisation by eliminating conflict and thus the opportunity for political debates. They argue that desalination often is portrayed as a counter strategy to large-scale infrastructure albeit it rather offers technocratic solutions to sustain economic growth; thereby advancing development. Kallis (2008) warns that the feature of 'urgency' in water crises can take away awareness from drivers of water scarcity and produce solutions that rather reinforce them. In this context, Knights et al. (2007) also mention the risk of 'option foreclosing', meaning that alternatives, such as demand-management or reusing storm- or wastewater, are outpaced by desalination's perceived benefits of scalability and efficiency. This also obscures additional merits of those options including potential synergies of social, economic and environmental aspects (Knights et al., 2007).

Due to these problematic aspects, the WWF (Dickie, 2007) as well as the World Bank (Schiffler, 2004) see desalination as the 'last option' that should only be applied if water saving strategies, effective resource management and efficiency increasing measures have shown to be insufficient to meet water needs. Yet, considering the growing use of desalination globally, it is questionable if it really is applied as the 'last option'. As outlined above, desalination can have various implications for all three pillars of sustainability, while the environmental realm and cost issues are often prioritized in assessments (Lior, 2017). Koontz and Hatfield (2016) emphasise that careful evaluation of desalination in comparison to other measures is necessary and stress the importance of socio-environmental context in such assessments.

Gotland recently decided to supplement its water supply with desalination facilities to guarantee water security. The presented discussions around the use of desalination and the conditions making its application legitimate in terms of sustainability highlight the importance of investigating new desalination projects carefully and questioning their role in a specific context. Considering these drawbacks and the calls to only use desalination as a 'last option', this decision needs to be analysed critically. The following two chapters portray how I designed and conducted such an analysis for the case of Gotland.

4 Theoretical Approach

My theoretical understanding, forming the basis of this thesis, is situated in the field of political ecology as a lens for analysis and my research takes a critical realist perspective as a philosophy of science. The following sections briefly explain how ideas of political ecology are applied throughout this thesis and how I perceive my role and contribution as a researcher with a critical realist understanding.

4.1 Political Ecology

Political ecology investigates politics involved in environmental challenges and questions common understandings and perceptions of problem solving strategies (Gezon & Paulson, 2005). It is based on the understanding that resource uses are shaped by social processes that can put pressure on the environment and acknowledges multiple valid conceptualisations of environmental goods (Gezon & Paulson, 2005). Resource allocation and related challenges are central themes within political ecology, often investigated in the Global South (Forsyth, 2003). Yet, conflicting resource uses and questions of social justice also play a role in the Global North and deserve attention.

As pointed out by Robbins (2012), findings in political ecology provide knowledge in relation to an established, 'apolitical' explanation for the studied phenomena. However, as political components are inherent in all explanations, the merit of political ecology rather lies in making those political aspects explicit and hence more tangible (Robbins, 2012). Special attention will therefore be devoted to the reasoning behind and the explanation for the necessity to install desalination on Gotland. I thereby follow Robbins' (2012) understanding that there is room for improvement of current practices and that research within this field should be guided by "finding causes rather than symptoms of problems" (Robbins, 2012, p. 20).

Talking about the 'hydro-social-cycle', Swyngedouw (2009) emphasises that physical and social components of water and its flows are equally relevant and that the interplay of both is what constructs the 'hydraulic environment'. Thus, it is not enough to examine physical characteristics of water and its material flows to understand conflicts and discussions on water use; instead one must look beyond and investigate the social and political settings determining these flows.

These ideas lead to the recognition that the decision to complement water supply with desalination is not only a result of insufficient physical availability of water but also involves social and political ideas of how water is used and produced. These social and political aspects of water (scarcity) and their consideration in decision-making processes are the starting point of my investigation.

More specifically, political ecology is used to investigate correlations among resource-use and resource understanding, especially when technologic solutions intervene and open up new opportunities. It further helps to identify conflicting interests in relation to resource-use and how those are solved. This includes investigating varying opinions and understanding their underlying rationales and values. Finally, political ecology also serves to examine the actual decision-making process in water management which reflects how varying views are weighed and incorporated. To achieve this, it is necessary to compare and challenge different explanations for particular phenomena and causalities and to bring contentious aspects to the surface in order to de-neutralise decision-outcomes.

4.2 Critical Realism

I see several reasons to use critical realism for studying water scarcity and Gotland's decision for desalination. First, critical realists' understanding of reality presumes the existence of a reality independent from our understanding and conceptualization of it (Benton & Craib, 2010). The presence of water in its materialistic, biophysical sense at a particular place in a particular time or the lack thereof is a condition that I see as something real and existing regardless of how we understand it.

Second, critical realism sees knowledge as an instrument to change reality and thus improve existing conditions (Benton & Craib, 2010). This is in line with the normative approach of Sustainability Science and my aim to understand challenges and trade-offs regarding technology for water supply. As water flow, access and distribution are shaped by human interaction with the material 'water' and therefore are subject to numerous social processes, knowledge about these processes can clear the way for change.

Third, this thesis seeks to critically investigate the explanations and decisions leading to the implementation of desalination on Gotland. This involves contesting commonly accepted descriptions of causality. As pointed out by Sayer (2000), critical realism can help doing this by acknowledging the validity of causal explanations despite the necessary presence of interpretation. This is also recognized by Forsyth (2001) who argues that it can be beneficial to apply critical realism to study resource management and environmental degradation to illustrate potentially obscured agendas in the scientific representation of particular processes. Moreover, critical realism provides an alternative to reductionist views of causalities and accepts the feature of emergence, meaning that the combination of different factors can produce effects beyond the single components (Sayer, 2000). Both aspects are crucial as I believe that decision-making processes are complex and require multiple perspectives, and that interactions among different stakeholders shape the outcome.

A crucial characteristic of critical realism is a 'stratified ontology' that distinguishes between the *real*, the *actual* and the *empirical* domain (Sayer, 2000). While the *real* domain includes all existing objects, be they social or natural, as well as their internal structures and powers, the *actual* domain depicts the effects that happen through the stimulation of those powers (Sayer, 2000). The *empirical* domain then is built up by experiences and can help to approach both other domains.

Figure 5 portrays the application of these domains in my thesis. Diverse experiences are manifested in interviews and documents that form the raw data for this work and give access to the other domains. RQ1 and RQ2 address the *actual* domain and are rather descriptive to capture the positive and negative effects of desalination on Gotland. The *real* domain is then approached through the more analytical RQ3 but also contains the place-specific social, ecological and historical factors including the material water flows they produce which is also tied to cultural and traditional aspects.

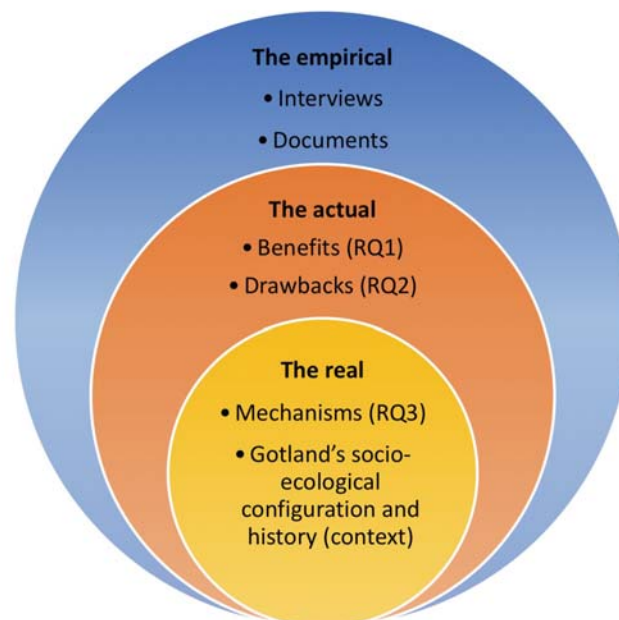


Figure 5. Application of the three domains of critical realism to this thesis. Own illustration.

While reality is in fact knowable, it does not mean that all developed knowledge about it, acquired through 'cognitive work', is a correct and final depiction of it (Benton & Craib, 2010). Contributions might be temporary and can be refined later on. My work certainly reflects to some extent my values and priorities as a sustainability scientist and I do not believe in complete objectivity. However, by applying established methods and ensuring transparency about my research process I aim to minimize potential bias and increase the credibility of this thesis.

5 Methodology

5.1 Research Design

This study takes a qualitative approach as it aims to identify challenges and trade-offs connected to technological solutions to resource scarcity, requiring an investigation of arguments and dynamics rather than quantitative measurements. The research design is a single case-study design allowing the in-depth analysis of a particular phenomenon in a specific location (Bryman, 2012). Gotland, due to its geographic location, needs to organize its water supply independently from other parts of the country and therefore allows me to investigate dynamics that might prevail in many contexts at a smaller scale.

The desalination plant in Herrvik is comparably small and only produces a minor fraction of Gotland's publicly supplied water resources. Yet, the case is used as a critical case as it is the first bigger plant of its kind in Sweden and can be a door-opener for this technology in other Swedish locations suffering water scarcity. A considerably larger second plant in Kvarnåkershamn in the south of the island is already in progress (Region Gotland, n.d.-a) and another one is to follow on the neighbouring island Öland (Borgholms Kommun, 2016, pp. 7-12). Moreover, a third plant on Gotland to supply its capital Visby is in discussion (Region Gotland Teknikförvaltningen, 2016b) although a final decision about its implementation is not yet made. I thus follow Flyvbjerg (2006) who describes a critical case to have "strategic importance in relation to the general problem" (p. 229). I therefore want to present findings from Gotland that might be useful in the planning and decision-making process for similar facilities elsewhere. In this context however, it needs to be kept in mind that the water planning and management on Gotland are currently subject to numerous discussions and that the process is ongoing. The full spectrum of potential consequences and complementing measures might not be visible yet and this thesis needs to be seen as a preliminary investigation of one particular component.

I assume that relevant information is manifested in a variety of documents but also becomes tangible in personal interaction with locals and by looking at current practices. For these reasons and for the purpose of triangulation (Yin, 2009), I will draw on multiple sources of information, including documents and interviews.

5.2 Empirical Material

First, I analysed case-specific documents using a mix of content analysis and thematic analysis (Bowen, 2009), described below in more detail. There is little publicly available information on the case and the decision to construct the desalination plant in Herrvik; complementing the information with interviews was therefore necessary. Moreover, the complementation with interviews minimizes potential

limitations due to language barriers as my imperfect Swedish skills potentially reduce the depth of the document analysis. Interviews were thus also used to verify information withdrawn from documents and thereby increase reliability.

Six documents were used for the document analysis (**Table 1**). All chosen documents are published by Gotland's authorities¹ and give insights on Gotland's development and the water situation on the island. Verifying information with a larger sample of documents would have been beneficial; however, there are only few accessible documents about the Herrvik plant specifically. As it is a plant of low capacity, only a regular permit [Swedish: 'anmälan'] from the County Administrative Board was necessary but no licence [Swedish: 'tillstånd'] issued by the Environmental Court as it is the case for Kvarnåkershamn. This means that no assessment of for example environmental consequences was required, and therefore no documents of this kind are available for analysis. Some analysed documents were written several years before the implementation of desalination on the island, when it was still only an idea for the future. Even though those texts do not necessarily connect certain problems and arguments to desalination, the way particular statements are framed and how causal relationships are presented can provide interesting insights into how the option of desalination became more relevant. This material can further help to understand how opinions and perceptions changed over time.

Table 1. Documents used for document analysis.

Document	Reference	Justification
Water plan Gotlands municipality	(Gotlands Kommun, 2005)	The water plan portrays the overall water situation and planning for the island while also illustrating current problems.
Vision Gotland 2025	Gotlands Kommun (2008)	This document illustrates Gotland's regional development programme until 2025.
Bygg Gotland, overview plan for Gotlands municipality; chapter 8 on water and wastewater	(Gotlands Kommun, 2010)	This report presents a detailed overview of Gotland's different sectors and activities. The chapter about water and wastewater highlights current problems and how they are perceived.
Long-term water and wastewater plan Gotland 2014-2022 and its revision of 2016	(Region Gotland, 2014) (Region Gotland Teknikförvaltningen, 2016b)	This document outlines measures in the municipal water and wastewater system for the coming years and is agreed on by the local parliament, thus showing the directions of water planning for the future.

¹ 'Gotlands Kommun' was renamed to 'Region Gotland' in 2011 but refers to the same administrative entity. The technical administration [Swedish: 'Teknikförvaltningen'] is part of Region Gotland.

Document	Reference	Justification
Pre-study for Visby's future water supply	(Region Gotland Teknikförvaltningen, 2016a) ²	This study investigated needs and options for the future water supply of Visby; the arguments in it can however also be taken for other parts of the island. The document gives insights into the assessment criteria and the discussed options.
Fact-sheets for desalination plants Herrvik and Kvarnåkershamn	Region Gotland (n.d.-a, n.d.-c)	These two short fact sheets for both desalination plants are published online to inform about the plants. They provide information on how the plans are communicated to the public and how the decision for those plants is justified.

Additionally, information regarding the decision-making and construction process of the Herrvik desalination plant were retrieved from protocols from Gotland's technical committee from 2013 to 2016. The committee was in charge of planning and constructing the plant and Gotland's water and sewage activities. Information were found in 16 protocols which I then summarized (see Appendix A) and analysed.

The second pillar of evidence comes from seven qualitative, semi-structured, face-to-face interviews with representatives of different stakeholders in Gotland's water discussion. Semi-structured interviews allow flexibility and give participants the opportunity to highlight particularly relevant thoughts while still ensuring a guided interview process with predefined questions (Bryman, 2012) enhancing comparability. The interviews complement the document analysis and fill in potential gaps. Again, language barriers need to be considered as not all interviewees felt equally confident to speak English, potentially limiting their abilities to express their thoughts. This influenced the level of depth reached in the conversations which might affect how well insights could be incorporated into this research. Interviewees were selected using purposive sampling (Bryman, 2012), informed by background research on the decision-making process and current discussions. Valuable insights were expected from planning, administrating and decision-making entities, the biggest water using sectors (agriculture and tourism) and local organisations concerned with water-questions. By covering a variety of actors, I want to understand different opinions about desalination and, more importantly, the underlying reasoning. Even though actor groups might not be homogeneous, the selected interviewees may not represent the view of all individuals within their group, and the small number might not give justice to the complexity of the case, the diversity of interviewees increases the likelihood of covering the most relevant arguments.

² This document is not publicly available but was provided by one of my contacts from Region Gotland.

I met the following key informants (**Table 2**) for interviews lasting between 46 min and 1h44min and taking place on Gotland from 2nd to 14th of March 2017. The interview guide used to steer the conversations can be found in Appendix B.

Table 2. Key informants for semi-structured interviews and their position.

	Acronym	Organisation	Justification
Public sector	Politician MP	Member of Regionfullmäktige (local parliament) Region Gotland and chair of environmental and health board, Miljöparti [Environmental party] Gotland	The local parliament decides on the water strategies for Gotland's water management and thus is an important stakeholder in the discussions on measures for Gotland's water provision.
	County Administrative Board	Responsible for drinking and groundwater questions at Länsstyrelsen Gotland [County Administrative Board]	The County Administrative Board is the regional representation of Sweden's government and in duty of inspecting water activities. My interviewee is the project leader of developing a water-supply-plan for the whole island.
Private sector	Representative LRF	Vice president of Lantbrukarnas Riksförbund [Farmers Association] Gotland	Agriculture plays an important role for Gotland's economy while also being one of the biggest water users. Farmers' perspectives hence need to be included in the discussions on water management.
	Representative GFB	Managing Director of Gotlands Förenade Besöksnäring [Gotlands united tourism industry]	The tourism sector considerably shapes life and activities on Gotland. Planning of water infrastructure needs to be in line with tourism development, which is why their insights are beneficial.
Other initiatives	Vattenråd ÖG	Chief of Östra Gotlands Vattenråd [water council East Gotland]	Local water councils were established in Sweden following the EU Water Framework Directive to incorporate local knowledge into decision-making.
	Aquabrava project	Ek. för. Jordgumman, Aquabrava initiative of wetland restoration	This private initiative started a wetland restoration project 14 years ago, increasing their water access considerably. Insights on this alternative to desalination were provided. More information on the project are found in Appendix C.
	Representative NF	Secretary of Naturskyddsföreningen [Society for Nature Conservation] Gotland	Groundwater is not only crucial for humans but also local ecosystems. To understand the ecological consequences, Naturskyddsföreningen is included in the investigation.

A discussion meeting with a group of engineers from Region Gotland's technical committee, working with construction and maintenance of the water and sewage system, was also carried out. This conversation did not follow the interview guide to encourage an open discussion along specific questions matching the engineer's expertise.

Additionally, site visits to Visby waterworks, the desalination plant in Herrvik and the wetland restoration project 'Aquabrava' initiated by the association 'Jordgumman' further provided impressions on how different measures function in practice.

Engaging with people during research requires considering ethical aspects and reflecting on how to ensure fair treatment and representation of interviewees. I therefore followed the principles set out by Bryman (2012, p. 135) to not cause harm, ensure informed consent, respect their privacy and not deceive them. I informed them about the context of my research, encouraged clarification and follow up questions if needed, offered anonymity and asked for consent to record the conversations.

5.3 Data Analysis

The technique for data analysis was coding and a combined content and thematic analysis (Bowen, 2009). The documents were collected and analysed by allocating statements and information into different categories, formed based on the research questions. Relevant text passages were first highlighted in different colours (coding) and then put into different categories in a spreadsheet according to their content (extracting). The codes help to assimilate data retrieved from different sources (Bowen, 2009) and thereby allow the identification of common patterns and recurring arguments.

The interviews were analysed similarly. First, interview-recordings were transcribed word-by-word while omitting off-topic talk and language clarification parts. The engineers did not want to be recorded but notes were taken that allow me to use the provided information. Based on the interview transcripts, statements could be categorised as described for the document-analysis. Throughout the analysis-process, pre-defined categories have been complemented with additional themes that emerged from conversations in the field.

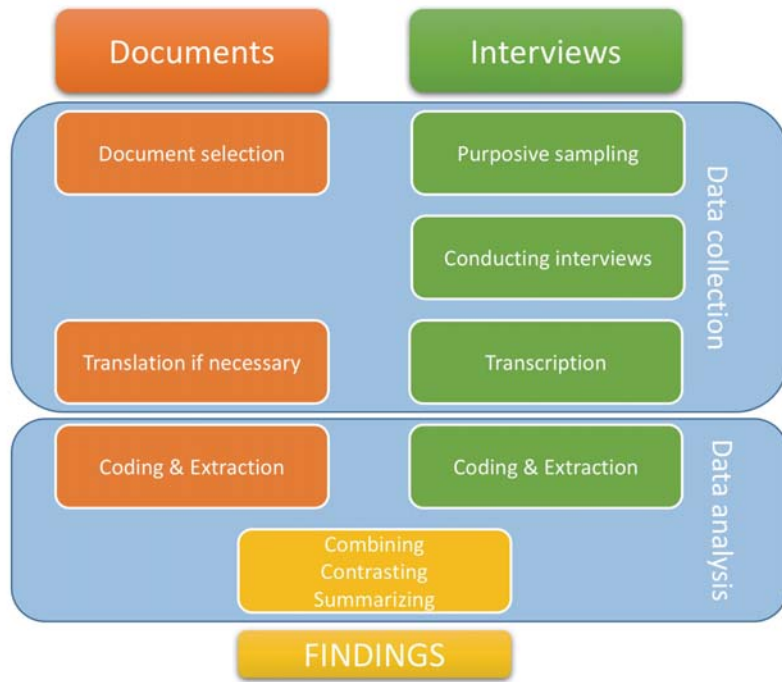


Figure 6. From empirical material to findings. Own illustration of the research process.

By summarizing, contrasting and combining insights from interviews and documents, findings could be formulated. The research process is illustrated in **Figure 6**, showing the pathway from empirical data to findings, which will be presented in the following chapter.

6 Findings

While I initially expected to find conflict and scepticism among the locals about the strategies to combat water scarcity, going into the field and talking to different people showed how little desalination is questioned despite a rather unconventional decision-making process. Most people are primarily relieved that their water concerns are solved to some extent even though there is a high level of awareness that desalination alone is not enough. Aiming to look beyond the promises of 'unlimited water supply' of desalination however, I realised some drawbacks with this strategy that might not affect a majority of the population now, but could become problematic in the future. The findings are presented in the following sections, structured according to the research questions: first, I present the benefits of desalination on Gotland, second I outline problems of this strategy and third I highlight identified mechanisms that encouraged the decision for desalination.

6.1 RQ1: Gains for Gotland

With the first research question, I seek to identify the benefits Gotland's society receives through the implementation of desalination. These are important to consider as they form the base for justification and show which problems desalination is able to address.

6.1.1 *Quick and safe access to an infinite resource*

The purpose of desalination is of course to supply additional water to consumers. Water supply has to be designed for the highest consumption rates because of lacking storage capacities (Region Gotland Teknikförvaltningen, 2016a) and desalination is thus a good complement, especially for summertime when tourism increases the number of water users (representative LRF). As pointed out by the representative of GFB, water access is one of the most important prerequisites for a tourist destination.

The Baltic Sea provides additional water in sufficient quantity (Region Gotland Teknikförvaltningen, 2016a). The representatives of NF and GFB emphasised the unlimited potential supply of seawater. As pointed out by the representative of NF "All the other water sources can fail and dry [out] but not the Baltic, that will [always] have water". Ultimately, desalination thus solves the problem of a water-deficit not least for the tourism industry.

Many involved actors perceive a lack of precipitation as one of the major causes for the severe water problems in the last years. The engineers state that dependence on rain is a general hazard for water supply and Region Gotland (2014) also highlights the weather independency and operational reliability

of desalination plants as major advantages. Solving the dependency on climatic conditions is thus seen to be advantageous and allows a higher stability of water supply.

The conversation with the politician MP revealed an additional argument: Urgency for action was emphasised as the rapid deterioration of water access within recent years required quick decision-making. This is particularly interesting as all interviewees except for the representative of GFB considered the water problems to have been predictable; yet decisions were taken under time pressure.

6.1.2 Protection of groundwater resources and production of clean water

Gotland's major primary source for freshwater is groundwater. Both the politician MP as well as the engineers highlight desalination's positive indirect effect of protecting groundwater by preventing its overuse. The engineers claim that the purpose of desalination also is to protect groundwater resources and prevent saltwater intrusions which could destroy whole aquifers. Desalination should hence also reduce groundwater withdrawal in order to achieve sustainable drinking water supply while reducing the risk of groundwater overuse (Region Gotland, 2014, n.d.-a). While this certainly is an important ambition, it relies on the assumption that groundwater takings are directly replaced by desalinated water while the overall consumption remains stable. Whether or not this is accurate will be seen in the future but as mentioned by the Aquabrava project, residents with access to both private groundwater wells and municipal desalinated water still use groundwater for certain purposes as it is, unlike tap-water, free of charge.

Not only water quantity, but also the quality of groundwater has caused supply problems in the past. The possibility to produce very clean water by desalination (Region Gotland Teknikförvaltningen, 2016a) is a prerequisite to use it for human consumption and does also have potential additional benefits of adjusting water hardness, which allows reducing the amount of detergents and can also decrease the copper content of sludge (Region Gotland Teknikförvaltningen, 2016a). This addresses the pollution of natural water sources by inadequate water treatment and ultimately benefits their integrity.

6.1.3 Water for development

The implementation of desalination also addresses the lack of water as an obstacle for future development. The engineers report that the increase of tourism and industry requires new solutions for the 'normal people' and that Gotland's development plans have put them under pressure to deliver solutions which clear the way for the anticipated future. They feel that water management is not

considered early enough in decision-making and planning processes and that it is difficult to implement what has been decided on in the political sphere. It seems as if water supply is subordinated to broader development strategies and gives the engineers little time to react. This is particularly relevant considering that Gotland's water struggles are seen to have been predictable and that urgency can produce inadequate solutions.

The representative of LRF also sees benefits for the bigger water users and expects that tourism and agriculture will profit from a more secure water supply on the island. The Vattenråd ÖG adds that the possibility to connect to the municipal system, which in some cases is directly related to additional water supply by desalination, will raise the value of properties, thus benefitting individual land and property owners in those areas. Lack of water is hence not only perceived problematic in relation to residents' own needs but expands to a concern about water for economic purposes and future development.

6.1.4 Additional benefits

The engineers presented a number of additional justifications for desalination including the ability to scale supply according to needs, the lack of feasible alternatives and having additional reason to invest in pipe replacements as desalinated water requires modern pipes. The conversation with the engineers also showed the high pressure they were feeling to provide a solution for municipal water supply. This was for example expressed as the problem of only being able to prevent emergencies in terms of water supply and not adequately engaging in planning and maintenance work.

Additionally, mentioned by the representatives of NF and LRF, desalination avoids conflicts over land-use, especially as opposed to the restoration of wetlands. In this context, it also takes away the burden of decision-makers to position themselves concerning priorities and legitimacies of different water and land-uses and neutralises such debates.

An important consideration, made explicit by the engineers and the representatives of LRF and NF as well as the County Administrative Board and the politician MP, is that despite the expressed benefits, desalination is seen to only be a complement to other solutions. This means to acknowledge the shortcomings of desalination which are introduced in the next section.

6.2 RQ 2: Drawbacks and Limitations of Desalination

A number of problematic aspects of desalination in general are already outlined in chapter 3. For the case of Gotland specifically, some concerns have been expressed by the interviewees or been evident in the analysed documents.

6.2.1 Trade-offs

Desalination comes with a number of trade-offs embedded in the technology. These include the higher costs compared to conventional water supply measures, the energy intensity, and the discharge of brine into the Baltic Sea. Those concerns have also been raised in the case of Gotland. Higher costs are expected due to increasing energy costs and the purchase of membrane filters (Region Gotland, 2014; Region Gotland Teknikförvaltningen, 2016a). The construction, maintenance and water supply from the municipal provider is financed by fees paid by the subscribers. Consequently, increasing costs for water production will lead to higher prices for consumers and an incentive to increase the number of subscribers to distribute the higher fix costs among more individuals. Vattenråd ÖG sees the costs especially problematic in comparison to the use of groundwater: "It's not cost effective to have a plant running if you can have natural water [re]stored down in the ground." Creating high pressures for the reverse osmosis process requires high energy input (Region Gotland, 2014, n.d.-c; Region Gotland Teknikförvaltningen, 2016a), representing another drawback of the technology. The discharge of brine was only commented on in the interviews by the politician MP and the Aquabrava project who expressed concerns about potential damages to natural ecosystems primarily in a long-term perspective. While all these effects are mentioned as shortcomings, their impacts are not further discussed except for reducing the energy need by using solar panels.

Another problematic aspect about desalination on Gotland is health concerns raised by a number of different people. When desalination on Gotland was first discussed, the desalinated water should be mixed with groundwater in order to provide recipients with minerals (politician MP). However, there is no groundwater for mixing available in Herrvik which means that the delivered water basically contains no minerals (politician MP, Vattenråd ÖG). This led to insecurities among the water consumers. On the one hand, the desalinated water reacted with the pipe material, leading to discoloured, malodorous water in the beginning (politician MP, engineers); on the other hand, the lack of minerals gave some people the impression of getting water of lower quality compared to groundwater. While the engineers argue that the water fulfils the regulations of WHO and the National Food Agency [Swedish: Livsmedelsverket] and that their responsibility is to deliver water and not a pharmaceutical that provides minerals, opponents question the appropriateness of current legislations

as those only consider maximum values of drinking water components and do not request minimum concentrations of beneficial substances (Vattenråd ÖG, politician MP). Indeed, Rosborg (2015) describes potential negative health impacts from demineralised water and argues that legislations should be adapted to the technology. Authorities are criticized for not taking these concerns seriously enough and not taking water samples from the consumers in order to conduct analyses of the components (Aquabrava project).

Other trade-offs relate more to social consequences of the implementation of desalination. Those were not discussed in the reviewed documents but expressed by some of the interviewees. The representative of LRF sees a problem in desalination if it is misinterpreted as the ultimate solution and thus leads to not taking enough care of the water resources on the island. Another reason for not presenting desalination as the answer to all water problems is in their opinion that this could be accompanied by an increase in water consumption. This concern is shared by other interviewees. The engineers expect an increase in water demand resulting from the implementation of desalination but assume that this will stabilise when the most attractive tourist areas are developed. They hence see a correlation between the desalination plants and the tourism expansion. The Vattenråd ÖG however anticipates that even the per-person consumption will increase as water access improves. The representative of NF sees a drawback in desalination of losing an argument to fight the local mining industry, thus allow business as usual or even expansion of potentially water damaging businesses. Even though this argument was specifically expressed in relation to the limestone mining on the island, it is also valid for other water-intense activities, which through the implementation of desalination might not need to prove the legitimacy of their water use.

6.2.2 Remaining problems

Shortcomings of desalination are not only apparent in the direct or indirect consequences of the implementation of desalination but also by looking at water related problems desalination is unable to solve. This is particularly relevant as it reveals implicit priorities.

While desalinated water can provide people with tap-water, it does not interact with the environment and cannot address the lack of water in nature. This was mentioned by several interviewees. The politician MP perceives a risk to forget about ecosystem services if desalination is presented as the ultimate solution. The Aquabrava project and Vattenråd ÖG expressed concerns about the wildlife and also water needs of agriculture. The Vattenråd ÖG even says:

I think the biggest issue is not the drinking water. [...] The big problem is the nature, the forests, the fields, the crops, the wildlife, birds [...] and if we solve that then the drinking water problem will not be a problem.

This statement exemplifies the narrow, human-centric approach of desalination.

Another major concern is the high percentage of Gotland's population that is not connected to the municipal water supply and also will not be in the future. The documents clearly state that there is no obligation for the authorities to connect all properties to the municipal grid and also no motivation to do so in the future, not least for economic reasons (Gotlands Kommun, 2005, 2010; Region Gotland, 2014). While the municipal grid is expanding, individual water takings also expand continuously due to the scattered settlements outside the grid-expansion areas (Region Gotland, 2014). As the additional water received from the Baltic Sea is fed into the municipal system, the unconnected 37 % of Gotland's population still rely on access to groundwater through individual wells. Among those are also most farmers and livestock owners. (Gotlands Kommun, 2010). Many individual water sources on Gotland suffer problems in terms of water quantity and quality and affected water users occasionally need to use public supply-points and transport water elsewhere (Gotlands Kommun, 2005, 2008, 2010). This deficit is also acknowledged by the politician MP, the County Administrative Board, the Aquabrava project and the representative NF and is presented as an explanation for why desalination can only be a complement and other measures directed to increase groundwater availability are needed.

This raises questions about the responsibility for water supply to the disconnected part of Gotland's society. While subscribers of the municipal grid can rely on the public water supply, knowing that the municipality is accountable to fulfil their water needs (Region Gotland, n.d.-b), thus counteracting scarcity and reallocating water from one place to another if necessary, the private-well owner's claims for water are futile as it is unclear who to address. Even though the municipality officially has an obligation to secure their supply too (Gotlands Kommun, 2010), the interviewee from the Aquabrava project reports that none of six administration entities contacted wanted to confirm their responsibility for groundwater and groundwater recharge.

Additional problems outside the scope of desalination are high runoff of rainwater into the sea and persisting water quality problems. Gotlands Kommun (2010) report that private water sources are not adequately protected to guarantee future water supply. Many sources are affected by bacterial contamination or pesticides (Gotlands Kommun, 2010; Region Gotland, 2014). Gotlands Kommun (2008) confirms that individual sewage facilities often not meet the requirements and the representative of NF refers to contamination of water sources by inadequate sewage treatment as a

common problem. Those problems are especially pressing in the summer months due to lacking groundwater recharge (Gotlands Kommun, 2005).

The implementation of desalination neither solves nor exacerbates these problems. Yet, while searching solutions to combat water scarcity on Gotland, it might have been beneficial to incorporate these perspectives into the decision-making in order to find out if there are feasible options that not only address the lack of water for people but also address water quality problems and the water needs of ecosystems.

6.3 RQ 3: Mechanisms in the Decision-making Process

This thesis should not only highlight problematic aspects about desalination on Gotland but also provide information for improvements. Therefore, it is important to understand how the decision came about and which mechanisms enforced desalination to be seen as an attractive solution.

6.3.1 *Understanding of water scarcity*

How a problem is understood shapes the solution; how water scarcity is conceptualised and problematized is hence crucial to understand the requirements for an adequate solution.

There is no universal definition of water scarcity on Gotland. While the term is regularly used by different groups to discuss current water problems, its meaning is rather unclear. Some people see water scarcity primarily as a mismatch between human water demands and accessible capacity; others conceptualise it rather as a problem of inadequate water treatment. These two ideas need not be contradicting and were sometimes even expressed by the same individual.

A common answer to what water scarcity means was that there is an insufficient amount of water to fulfil the demands of society and businesses. As the politician MP pointed out "If we can't use water for our companies, our businesses, whatever, we won't be able to live in Gotland, because just drinking water is not sufficient for a livelihood." This emphasises that water is necessary for more than direct human consumption and that the interest to use water for economic purposes is perceived to be valid. Furthermore, it exemplifies the high dependency of Gotland's main economic activities on water input. However, it also illustrates that water is first and foremost seen in relation to its benefit for humans.

The perceived reasons for water scarcity also vary. The documents mention a number of factors contributing to the water deficit: hydraulic and climatic conditions, lack of precipitation, increase of water demand over summer and its spacial distribution as well as an overall increase in demand following population growth, climate change and tourism development. In contrast, some

interviewees (Politician MP, Vattenråd ÖG, Representatives LRF and NF) and documents (Gotlands Kommun, 2005, 2010) report that there is no lack of water per se but that most water is currently inaccessible for human consumption. As described in section 2.3, Gotland's water is running off quickly and the capacity to keep water on land is limited. The conclusions from this are different. The Vattenråd ÖG thinks that this reflects bad water management and a lack of water engineering and suggests to hold more water on the island. Several other interviewees however see geologic and climatic factors as major reasons for water scarcity which supports a view of causes outside the scope of human influence. Additional water must thus be provided from an external source.

Additionally, the politician MP sees a general problem of not appreciating water enough and argues that a new attitude towards water and water use is required that for instance recognizes the value of storm- or wastewater and acknowledges ecosystem services. Further reasons for water scarcity mentioned in the interviews were historic drainage, wasting water, high water needs of agriculture, tourism and limestone mining and increasing water quality problems in some of the used water sources which forced authorities to stop their exploitation.

6.3.2 Need for more water

Water has many different purposes; the main uses on Gotland are illustrated in section 2.1 and the importance of agriculture tourism in this context was already explained in section 2.2. The dominant argument for why additional water is required on Gotland is the need to develop.

There is a high pressure in many regions of the island for construction of new housing (Region Gotland, 2014), for permanent residents as well as for tourists (Region Gotland, n.d.-c). Region Gotland Teknikförvaltningen (2016a) states that due to construction pressure and already accepted water connections exceeding current production capacities, an additional water need of at least 1.5 million m³/year is estimated. This is about 37.5 % of what is currently supplied in the municipal water grid and thus represents a considerable increase in water supply.

Several interviewees (politician MP, County Administrative Board, representatives of NF and GFB, the engineers) as well as numerous documents (Gotlands Kommun, 2008, 2010; Region Gotland, 2014, n.d.-c; Region Gotland Teknikförvaltningen, 2016a) acknowledge the dependency of Gotland's development on secure water supply in a long-term perspective. A new water supply is thus seen to enable the planned development for Gotland and even perceived as a premise to maintain Gotland as a tourist destination. They agree that water should not be a limiting factor for Gotland's plans to expand tourism and increase residential development. This is expected to go hand in hand with an

expansion of the municipal water grid which should provide both connection of existing properties as well as delivering the capacity for new construction. The expansion of the public water and sewage system has in the past already allowed new construction development and is seen as a crucial factor for new housing (Region Gotland, 2014).

As a consequence, the engineers state that they expect an increase in water demand within the municipal system. That the search for additional suitable groundwater sources in the past has not been successful and that groundwater levels are decreasing despite a fairly stable outtake further explains the perceived need for additional water input. Acknowledging the high water dependency clearly enforces the attractiveness of desalination as its 'unlimited' water supply from the Baltic can be in line with a potentially unlimited growth scenario.

Water is of course not only needed for development but also to maintain living standards for current residents. Yet, the predicted increase in tourism and population as well as planned construction define the scope and partly the spatial distribution of water supplies. Even if a need for additional water can be established without development, the measures to fulfil it might look different.

6.3.3 Normalisation of desalination over time

How desalination is presented in the documents changed over time. Desalination as a potential component of future water supply on Gotland was already suggested in Gotland's water plan from 2005 even though the document simultaneously states that the amount of groundwater recharge is sufficient to fulfil the population's needs (Gotlands Kommun, 2005). In the Bygg Gotland document from 2010, desalination is discussed as a small-scale option for individual supply and only as the third and last choice if neither municipal supply nor private wells are feasible (Gotlands Kommun, 2010). Moreover, if desalination is used, an assessment needs to show that the water need cannot be fulfilled with groundwater while nevertheless access to a minimum of 150 l groundwater per household and day is required to guarantee water supply if problems with a desalination facility occur (Gotlands Kommun, 2010). Another change can be seen in the long-term water and wastewater plan where Region Gotland (2014) states that the access to suitable raw water is limited and suggests to investigate the conditions to completely or partly base future water supply on desalination. Having desalination as a component of the municipal water supply in order to combat future water scarcities in summer is presented as inevitable and several facilities are suggested in the plan. This is in line with the introduction of the desalination plant in Kvarnåkershamn where its construction is called an "absolute must to solve the future water supply" (Region Gotland, n.d.-a, p. 1). Hence, the perception of desalination changed from a vague idea and small-scale option to a necessary pillar of water supply.

6.3.4 Assessment criteria

The pre-study for Visby's future water supply (Region Gotland Teknikförvaltningen, 2016a) presents assessment criteria for water supply options (**Table 3**). Although this document specifically refers to the water supply of Visby and not Gotland as a whole, the rationale for decision-making can be assessed and is supposed to be likewise valid for Gotland's water management in general.

Table 3. Assessment criteria for water supply options in Region Gotland Teknikförvaltningen (2016a).

Factor	Criterion
Time	Provision of the stated amount within three years.
Weather dependence	Independence of precipitation and evaporation.
Economy	Production cost per unit in relation to conventional water production and predictable factors which may significantly affect the investment costs in relation to other options.
Technic	Security of operation and security of supply.
Amount	Provides the additional amount of 15,000 m ³ per day to Visby. ³
Quality	Supply of clean drinking water according to water quality legislations.
Environment	Environmentally acceptable.

There is no further information on how precisely these criteria are assessed or weighed. Yet, this selection in itself prioritizes technical solutions. The time restriction, technical security, pre-defined amount and especially weather independency favours constructed water supply systems. Moreover, environmental protection is only considered by a vague criterion that does not explicitly identify desalination's impacts. Consequently, desalination is seen to be a suitable option meeting all requirements except for the costs (Region Gotland Teknikförvaltningen, 2016a). Additional advantages of desalination presented in the documents are that seawater is not requested by any other party (Gotlands Kommun, 2005) and that desalination plants do not require much space which avoids conflicts over land resources (Region Gotland Teknikförvaltningen, 2016a).

³ The amount here is specified for an investigation of water supply for Visby and would be different for other locations on the island or even the whole island.

6.3.5 Engineers as decision-makers

The decision-making for desalination in Herrvik was dominated by the engineers. As the politician MP highlighted: "It's been engineers that have been trying to solve a very difficult situation with a lack of time and this is the solution that they came up with." Indeed, the procedure was rather unconventional and has been subject to discussions. Initially, the area around Herrvik was not planned to be expanded in the near future and the initiative to develop the municipal gird there came from a group of locals (Herrviksområdets Reningsanläggningar ekonomisk förening) who formed an organisation to solve their water and sewage problems. The technical committee saw this as an opportunity to collaborate and secure the supply for neighbouring Katthammarsvik which was already in their operational area while simultaneously expanding the supply to Herrvik. Over time, the project grew considerably which required more financial input from the technical committee and thus reallocation of money from other projects. The protocols of the technical committee (Appendix A) give insights about different steps in this process. An interesting aspect is that local participation was not considered necessary. While there might be justifications to do so in the case of Herrvik as it only is a small plant with little direct impact, this procedure neglects the door-opener function of this decision in a larger context. As stated in Gotland's Vision 2025,

citizens should feel involved, have the opportunity to influence the development of society and to take responsibility for this. This requires natural meeting places and meeting procedures. Open discussions and conversations are important for democracy and also for the people's basic trust in the democratic system. (Gotlands Kommun, 2008, p. 16)

This premise does not seem to be followed in this context. The long-term water and wastewater plan even states that

the consequences of a possible future water supply based on desalination of the Baltic must be preceded by thorough investigations with regard to quality issues, implementation issues and the economy. The technical and economic consequences should be discussed and considered in close cooperation between civil servants and politicians. (Region Gotland, 2014, p. 17)

It seems that by implementing desalination on a small scale first, the political debate about it was to some extent sidestepped, even though this did not necessarily happen intentionally but rather as a result of pressure and urgency felt by the engineers. Discontent about this was also expressed by some interviewees. As the politician MP complains: "From a democratic perspective, this hasn't been processed correctly because what they decided in 'tekniska nämnden' [the technical committee]

should have been brought up to the 'fullmäktiget', the local parliament." Even the local water council was not informed in the process and perceives a general lack of interest in their work from local authorities (Vattenråd ÖG). This reflects a bigger problem concerning insufficient communication and cooperation among different institutions, highlighted by several respondents (engineers, representative GFB, Aquabrava project).

The engineers of Region Gotland played a key role in the decision for desalination in Herrvik and their responsibility continues as additional facilities are in progress. Power was shifted to experts instead of elected officials and their field of expertise shaped the outcome of the decision.

7 Discussion

The starting point for the implementation of desalination is the tension between growing human water demands and the natural limits of groundwater supply. This tension can in various ways be seen in discussions within sustainable development, in particular regarding the role of technology to extend natural limits. The first section of this discussion will thus engage in this debate. A rather unexpected outcome of my work has been the identification of depoliticising tendencies which, especially from a political ecology perspective, are an interesting finding in itself and will here be looked at in the bigger picture. In that context, internal contradictions in the case of Gotland are also presented which could provoke further discussions and thereby contribute to a repoliticisation of the issue.

7.1 Sustainable Development

Considering intra- and intergenerational justice as an important premise of sustainable development, organizing the spatial and temporal distribution of natural resources forms an important realm for discussion. The use of desalination fits into Dryzek's (2013) description of ecological modernisation where nature is mainly conceptualized as a source of resources (or absorbent of waste) for humans. Capitalism and economic growth are therein taken for granted and supposed to be aligned with environmental protection. More precisely, desalination represents a form of 'weak' ecological modernisation which includes technocratic forms of decision-making as well as a prominent role of technology to align human interests and environmental limits (Dryzek, 2013).

In order to maintain the earth in a secure, liveable status, there are limits for human action which for example have been described and quantified in the Planetary Boundaries framework (Steffen et al., 2015). Freshwater resources are therein recognized as one of nine crucial limits on a global scale. Regional conditions naturally vary but accepting that there are limits remains an important consideration. Desalination extends those limits technologically which, as described in this thesis, has both positive and negative consequences.

However, there are alternative approaches to address the gap between freshwater needs and the limited capacity, and develop within limits. For instance, the idea of 'backcasting' water use and management strategies according to negotiated sustainability goals is described by Gleeson et al. (2012) and in line with what Gleick (2003) calls 'soft-path' solutions. This approach involves a shift from 'fixed-goals' targeting supply or demand management to 'process-based' attitudes that embrace the additional feature of 'social learning' (Bagheri & Hjorth, 2007). Instead of ecological balance, joint efforts directed to social processes and structural change determine what sustainable development

means (Bagheri & Hjorth, 2007). This striving for structural change might be what prevents the implementation of such approaches and in turn fosters the attractiveness of technologies. Structural change would greatly differ from dominant post-1970 eco-political discourses that are rather driven by the idea of adjusting and thereby preserving current structures based on economic growth (Kenis & Lievens, 2014).

In the context of defining desirable targets, Lautze, De Silva, Giordano, and Sanford (2011) emphasise the importance of water governance; seen as the negotiating process of setting goals but often confounded with water management criteria that rather address the decision's outcome such as efficiency or sustainability. Technology extending naturally given limits of resources is thus not inevitable which should be recognized in decision-making and in the public representation of such problems. Using technology can still be the outcome of discussions but should be based on a more comprehensive understanding of underlying dynamics and potential trade-offs. Instead, a strategy to advance sustainable water use within natural limits could also be to improve water governance and facilitate the application of backcasting approaches. Good water governance however becomes even more challenging when social choices are undermined by processes of depoliticisation which is discussed next.

7.2 Depoliticisation

The potential of desalination to depoliticise decisions on water resources has for instance been highlighted by Swyngedouw and Williams (2016) and is a crucial aspect from a political ecologist perspective that rather argues to (re)politicise prevailing tensions. The mechanisms found in Gotland contribute to such dynamics and are below discussed in more detail.

7.2.1 Technocracy

As shown in the findings, the engineer's perspective gained a prominent role in the decision-making on Gotland. This reflects a technocratic tendency which directs "ever more influence in political decision-making to those with particular forms of scientific and/or technological expertise" (Machin & Smith, 2014, p. 50). As argued by Pielke Jr (2004), while science engaging in *policy* illustrates the range of available options and their potential consequences, science engaging in *politics* minimizes the choice among different options by fostering one particular solution. This is ultimately what happened on Gotland where the narrow assessment criteria for water supply solutions already prioritized technical solutions and thus shaped the assessment's outcome beforehand. Second, technocratic governance is blamed to be anti-democratic by prioritizing expert knowledge not only over other forms of knowledge

but also over the debate of elected representatives (Machin & Smith, 2014). Power is thus shifted to a particular group that represents certain values and priorities and has not gained legitimacy through the votes of the public. The technocratic character of desalination thus serves to eliminate conflict (Swyngedouw & Williams, 2016).

7.2.2 *Naturalising root-causes*

My findings indicate that the problem of water scarcity is partly understood as a consequence of natural configurations like rainfall or geology which is used to justify the desalination approach. This argumentation is built on the assumption that nature and society can be regarded as two separable influences. However, considering the interdependencies of nature and society and the vast extent to which human societies have shaped water conditions in order to make use of resources, as also seen in Gotland's history, this view can be challenged (Boelens, Hoogesteger, Vos, Wester, & Swyngedouw, 2016; Swyngedouw, 2011). Humans and nature interact in various ways and the concept of 'nature' is fluid and depicts what people ascribe to it; thus it does not represent an independent force itself (Swyngedouw, 2011). Naturalisation then becomes part of a depoliticising trend because it omits political accountability for problem causes and for decisions that this naturalisation puts forward (Kallis, 2008). It does also mean to shift attention away from problem causes to solutions. As the origin of a problem (nature) cannot be addressed, only reactions to its consequences are within the scope of human influence. As stated by Kenis and Lievens (2014), externalising natural elements from the social sphere and political debates obscures powerful human influences on those dynamics and neutralises taken decisions. They see this as one potential reason for environmental concerns to be particularly prone to depoliticisation.

7.2.3 *Urgency and predictability*

The feature of urgency was found to be a powerful justification for the implementation of desalination, referring to its capacity to quickly supply additional water. Urgency is however a dangerous attribute in decision-making as it hinders time-consuming yet important reflections and assessments which are blamed to delay consensus and cooperation (Kenis & Lievens, 2014). Political debate is thus sacrificed in favour of a quick solution that supposedly needs to be based on agreement. Moreover, it can be used to direct awareness from problem drivers to solutions which potentially exacerbate underlying causal structures (Kallis, 2008).

Acknowledging predictability of water shortages however challenges the urgency-argument and shifts attention to historic failure; pointing out institutional and managerial weaknesses rather than lacking

supply capacities. It therefore might be a useful entry point to foster political discussions again and remind authorities of their responsibilities.

7.2.4 Normalisation

The interplay of the above-discussed effects contributed to a normalisation of desalination in the case of Gotland, but there are additional plausible explanations for why the concerns about desalination diminished throughout the years. One aspect is that the costs of desalination dropped significantly over the last decades (Ghaffour et al., 2013); a financial hindrance for its implementation thus got minimised. This is even more influential as simultaneously access to groundwater got worse and therefore costs for its withdrawal or emergency measures increased, reducing the cost-gap further. Moreover, the application of desalination globally increased extraordinarily (Ghaffour et al., 2013) leaving the impression of a reliable, successful and unproblematic technology as a solution to water scarcity. While this as a justification represents a reductionist view that neglects contextualised factors, it likely increases the acceptance among stakeholders.

This effect of normalisation fosters consensus which ultimately epitomizes a form of depoliticisation. The rejection of disagreement obscures the benefits of vibrant political discussion and the potential for alternative visions to be shared (Swyngedouw, 2011). Depoliticisation, according to Swyngedouw and Williams (2016), serves to preserve water-intense development and through the dominance of ecological modernisation, Kenis and Lievens (2014) argue, criticism against technocracy tends to be set aside.

To overcome depoliticisation, Machin and Smith (2014) encourage embracing disagreement as an inherent part of democracy and to engage with opponent's arguments instead of trying to achieve consensus. Disagreement can be a powerful way to advance decision-making by exchanging arguments and understanding competing points of view. Another entry point to repoliticise can be to uncover and address inconsistencies (Swyngedouw & Williams, 2016); some examples for the case of Gotland will therefore be presented next.

7.3 Problematic Internal Contradictions

The following sections describe three inconsistencies in the rationale of justifying desalination. They exemplify why benefits might not unfold as anticipated and point to potential unwanted dynamics caused by desalination. Those contradictions and their subsequent effects can function as entry points for new debates and repoliticisation.

7.3.1 Need for water vs. protection of groundwater

Two justifications for the application of desalination are an additional need for water on the one hand and the protection of groundwater on the other hand. The latter is built on the assumption that groundwater takings are directly replaced by water from desalination plants. While this is a reasonable assumption in a simplistic, closed system with a defined overall amount of water it becomes problematic when the anticipated overall increase of water in the system is acknowledged. One of the main purposes of desalination is enabling further development and expanding the municipal grid; it is hence unlikely that the groundwater withdrawal will stop once desalination is established. Moreover, as also found by Swyngedouw and Williams (2016), the exploitation of groundwater from private wells might continue, even illegally, in order to avoid the purchase of desalinated water. Groundwater protection thus risks to become a fallacy that rather serves political legitimisation of desalination.

7.3.2 Need for change vs. reinforcement of current systems

The limitations of desalination are acknowledged by many of the stakeholders and the need for additional measures is emphasised. For many respondents this includes rethinking the purpose of water uses, the potential of using water resources with lower qualities for non-drinking water consumption and to reuse water. While these ideas require restructuring of current systems, the implementation of desalination rather reinforces these very same systems: Desalination is part of a water supply strategy that includes investments in physical infrastructure that fit to today's needs but is likely not in line with future needs. Additionally, by allowing business-as-usual, it also reinforces current structures of water-use and the reliance on water-intense sectors. Desalination thereby exacerbates an infrastructural lock-in and creates dependencies on the additional water supply.

7.3.3 Systematic rise of water consumption and costs

Water supply and development are closely connected in the case of Gotland and two dynamics are of particular interest. On the one hand, the taken-for-granted need to develop in a certain way fosters the expansion of the grid and the implementation of desalination. On the other hand, these same activities rely on increasing water demands to be financed. The water price per unit gets cheaper the more people are connected and the more water is consumed. There is hence a structural incentive to increase water consumption.

Water costs rise in a similar way: a discussed alternative to address the water problems has been to reduce water consumption by increasing costs, which was found to be problematic as it might create prohibited surplus (Region Gotland Teknikförvaltningen, 2016a). However, it is somehow a paradox

that instead a costly measure as desalination is put forward. This also illustrates the inadequacy of the applied assessment criteria which fail to recognize such dynamics.

8 Conclusions

This research was directed to discover trade-offs and challenges of using technology for resource exploitation, in particular seawater desalination on Gotland. The production and distribution of water intrinsically ties political decisions and priorities to their materialistic and biophysical outcomes of water flows, serving particular needs and interests. Yet, technocratic tendencies, naturalisation of root-causes as well as urgency risk to depoliticise such decisions. Outcomes are then depicted as rational and inevitable solutions instead of the choice they truly mirror. This does not mean that the outcomes necessarily reflect bad strategies; yet their legitimacy can be challenged.

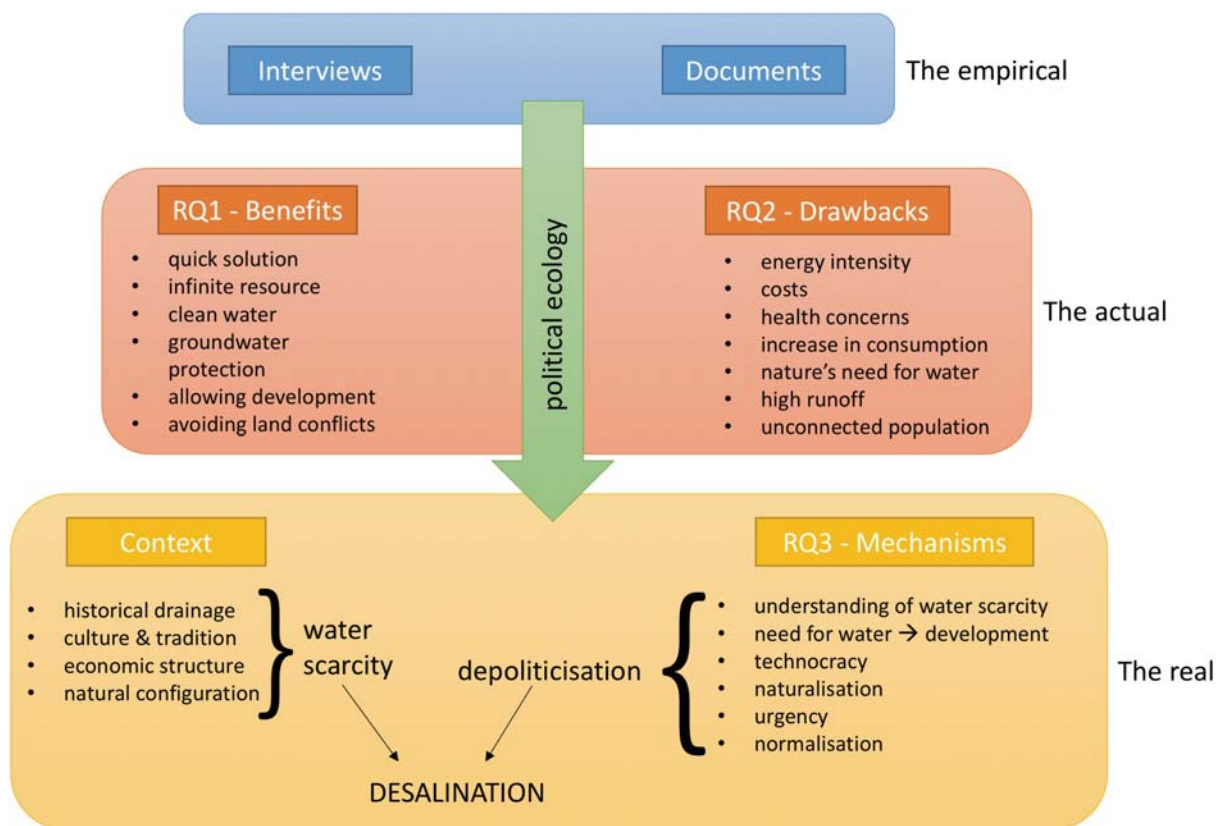


Figure 7. Synopsis of the research, illustrating connections among used empirical material, findings and discussion points which combined serve to explain Gotland's decision for desalination. The boxes refer to the three domains of reality in critical realism. The empirical domain includes the raw data of documents and interviews; the descriptive RQ1 and RQ2 are situated in the actual domain and the mechanisms presented in RQ3 led in combination with the site-specific context and its resulting biophysical reality of water scarcity to the implementation of desalination which in turn became a new physical reality. Own illustration.

Figure 7 illustrates my research process and its outcome and depicts how the interplay of benefits, drawbacks and underlying mechanisms of depoliticisation shaped Gotland's decision for desalination.

Revisiting my overarching research question of *why Gotland's authorities decided to complement the island's water supply with desalination despite its known controversies*, there are three aspects to highlight:

First, the anticipated benefits of desalination are in line with a broader development agenda that relies on water-intensive sectors and thus can be continued through the implementation of desalination.

Second, the drawbacks are either considered to be acceptable in relation to the received benefits or externalised, meaning that remaining problems are supposed to be addressed by additional measures. Yet, a comprehensive plan how to do this is still in progress.

Third, the controversies have, due to depoliticising mechanisms, not been acknowledged sufficiently and critical voices did not gain a prominent role.

Engaging with locals during fieldwork, I was surprised by how little the decision for desalination was questioned. I realised that most interviewees see Gotland's society as a whole benefiting from the desalination plants and the development they allow to continue. Only during the process of data analysis and reflection on my work, I realised that this support might not reflect an unproblematic decision but rather is the outcome of the here described depoliticising trend within decision-making and a taken-for-granted development trajectory.

The following recommendations are based on my findings and could be of use for authorities on Gotland and potentially beyond.

- Political aspects of decisions about water production, use and allocation should be highlighted in decision-making. Conflicts of interest and priorities should be negotiated in a democratic process. Benefits for certain groups should be made explicit and legitimized through political debate. Likewise, drawbacks should be acknowledged and affected people compensated if applicable.
- Decision-making should be informed not only by experts but also by other forms of knowledge, including experiences from within the population. Input from locals with knowledge about the place-specific characteristics can constitute valuable input.
- The assessment criteria for options to improve the island's water security should be refined. This should be carried out in an inclusive manner and involve an investigation of what values locals consider important and worth protecting. The new criteria would then need to be weighed accordingly in order to incorporate these preferences in decision-making.

- Current legislations should be reviewed concerning their ability to address the challenges posed by new technologies and adjusted if proved to be insufficient.
- In order to ensure long-term sustainability, alternative development opportunities for Gotland should be investigated. This potentially means to accept natural limits of water supply and plan water use within these boundaries ('backcasting') which likely includes considerable restructuring of societal and economic configurations.

This research presents a single-case study and findings should not be uncritically generalized. However, by adopting a critical realist approach and looking at underlying mechanisms which are likely to similarly exist in different settings, the discovered dynamics can be relevant beyond. Yet, it is the interplay of those mechanisms with contextual elements that will shape how effects will unfold. This could be an entry point for further research.

Moreover, this study was investigating an ongoing process where not all consequences are visible yet; decisions can change as time passes on and anticipated dynamics can prove to be wrong. It would therefore be interesting to re-investigate the case in the future and to for example examine how water-consumption patterns responded to the implementation of bigger scale desalination and what subsequent effects this had on sustainability. Another aspect could be to investigate the efforts for implementing water reuse and -recycling systems and how they can be aligned with the desalination strategy. Both aspects indicate additional areas for further research.

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10 Appendices

10.1 Appendix A: Summary of TN Protocols

The protocols were retrieved from the website of the technical committee (Region Gotland Tekniska Nämnden, 2017). In those from 2013 to 2016 the term 'Herrvik' was searched. All those with relevant information on the desalination plant in Herrvik have been collected and their content is summarized in the table below.

Table 4. Summary of statements to Herrvik desalination plant in TN's protocols from 2013 to 2016.

Date	Content
<p>28/02/2013 TN §38</p>	<ul style="list-style-type: none"> - the water situation in Katthammarsvik has been difficult, and the future looks worse. - None of the two water sources are owned by RG. The raw water is of poor quality and difficult to clean. RG has for many years sought a better water source without success. - The situation has been discussed with TKF who compiled their comments in a letter, date 2013-01-22. - It turns out that there may be an opportunity to cooperate with Herrviksområdets Reningsanläggningar ek för to provide Katthammarsvik with good drinking water. - The association wants to construct a desalination plant in Herrvik. - The distance from the association's pipe to the existing pipe of the aquifer "prästgården" is about 2.5 km. From there to the water plant in Katthammarsvik is a 1 km long PEM 63 that is somewhat weak but likely enough the next few years. - Perhaps, some form of pressure rise is required. - RG investment volume in the water plant is estimated 2-3 million. - Technical Board decides to give the administration a mandate to begin discussions with Herrviksområdets Reningsanläggningar ek för to investigate the possibility of a solution concerning the water supply in Katthammarsvik that satisfies both parties.
<p>27/06/2013 TN §140</p>	<ul style="list-style-type: none"> - operation to supply Katthammarsvik has become more expensive - VA-operation got additional 20-30 million --> suggestion to use 1 million for this project in 2013 - additional finances have been approved so that in 2014 5 million and in 2015 5 million could be used for this project - This means that the region is investing a large part of its surplus in this instead of other important projects previously thought about. - The administration sees this as a very good opportunity to solve the water issue of Katthammarsvik and, by extension to other areas, while it also contributes to the solution of the question on an expansion of the VA-area in Herrvik.

Date	Content
	<p>- Moreover, the current solution for Katthammarsvik is very expensive with an operating cost of about 950 000: - / year.</p> <p>- Unfortunately the contract for the two water sources used today end at the end of 2015. How we could the water supply is otherwise unclear</p> <p>- Technical Board decides to approve the proposal to build a water treatment plant in Herrvik (desalination) to provide Katthammarsvik and surroundings with drinking water.</p> <p>- The working committee asks questions about the quality of the Baltic Sea water, about which pollutants may still may remain. Risk analysis is requested, how does the technology work in case of seawater contamination.</p> <p>- When asked how many households may be affected by the water plant, he answered that today there are about 60 households and a further 90 can be connected.</p> <p>- The administration will return to the Board with accounting. ____</p> <p>Working Committee draft technical committee</p> <p>- The matter is referred to the technical committee</p> <p>Draftsman at Board; Jonas Aaw and Sten Reutervik.</p> <p>- Technical Committee decides to authorize the proposal to install a water-work in Herrvik (desalination) for providing Katthammarsvik and surroundings with drinking water.</p> <p>Appendices:</p> <p>(1) Katthammarsvik: 110 subscribers; Herrvik: 60 + 20 later, capacity for an extra 70; New capacity estimated to be needed in 4-5 years; No need for inclusion of locals is seen as the difference in risk is negligible compared to other Waterworks.</p> <p>'Assessed'/mentioned risks are medicin in water and emissions/contamination risks.</p> <p>(2) Report on pre study in Visby 2011; explanation of how the technique works but no discussion of for instance cost/energy questions</p>
21/05/2014 TN §121	<p>- Building permit is ready</p> <p>- Exemptions for beach protection is done</p> <p>- Application for environmental activities (miljöverksamhet) is ready</p> <p>- There is a risk of delays due to delayed planning and that the land transfer in Katthammarsvik is not finished</p>
19/11/2014 TN §249	Plant will be ready in summer 2015
18/12/2014 TN §288	Plant will be ready in summer 2015
28/01/2015 TN §23	desalination plants in Herrvik will be completed by summer 2016. The project got reworked so that it gets a new scope, schedule and cost estimate.

Date	Content
<p>03/03/2015 TN §29</p>	<ul style="list-style-type: none"> - TN reallocated 16619 tkr from other projects to the project 'water supply Östergarnsland' - Because of the new, higher standards of including the plants protection against sabotage and a desire to operate more than a few years, the container solution is replaced by a built water-work. - The design is made for a production of 10 cubic meters of water per hour, with an option to double it in the future. In order to achieve a better functioning of the intake duct an intake pump station has to come. - Mountain shafts of the transmission line through the sensitive environment of Herrvik and Katthammarvik has proved cumbersome and expensive. - A connection possibility for community facility in Sandviken is included. - The plant is expected to be completed in 2016. - Table with cost allocation, total costs are 19,8 million kr - Means, to increase the financing from the available 3.2 million to an estimated 19.8 million, proposed to be reallocated from the project Burgsvik-Klintehamn sewerage, which due to understaffing in the administration will not need all the funds allocated in 2015. - In 2015, 4.0 million are included in the investment budget for the project in Herrvik - Östergarn. Capital expenditure in 2014 amounted to 0.8 million, which will be charged against 2015 as the investment budget was missing. A total of 3.2 million transferred in 2015.
<p>25/03/2015 TN §56</p>	<p>Desalination plant in Herrvik will be completed by summer 2016. Procurement will be April-May 2015. There are several requests for membership. Funding is not ready. New budget is decided 19.8 million.</p>
<p>29/04/2015 TN §109</p>	<ul style="list-style-type: none"> - Herrvik is not part of VA-operational area - Herrviksområdets Reningsanläggningar ek för has taken the decision to independently build a sewage network in the area. About 50% of properties in the area chose to join their networks. - The association believes that Region Gotland should connect the harbour to the network, and has initiated a dialogue. In 2014, this has been discussed and negotiated between the parties and 2015-02-15 Region Gotland received an offer of affiliation. - In Herrviks harbour, there are three devices that could be considered for connection to the society-VA networks: the harbour's service building consisting of 3 toilets and 2 showers "LOVA" pumps which disposes wastewater from boats The region plans to build a new water plant in the harbour area and its connection to VA network handled separately in the project

Date	Content
	<ul style="list-style-type: none"> - The service building is now connected to a recharge facility that was renovated as recently as 2006. Wastewater from "LOVA" is managed via a closed tank that is emptied along with 3-chamber pit 1-2 / year with a lorry. Port Department thus has an approved and well-VA system that has about 15 years of life left. - The port's service functions must have access to quality assured water. Today the port is supplied with water from their own wells that do not meet this requirement. - If the decision is made to connect to the association's sewer system, it also means to obtain water from the region's new waterworks. - If decided not to connect to the VA network, availability of high quality water must still be ensured. - In this context, there are two options for technology management to assess: The region connects to the association's sewer system or retain existing infiltration and connect only to the region's new water - Region Gotland, both politicians and officials, have been positive to the association's water and sanitation projects. - In the short term, considering the economic perspective is heavy, it is most beneficial for the region to use existing infiltration and connect only to the region's new waterworks. - The administration believes that this VA-project can not only be judged in the short term and by hard parameters such as the economy. - Instead, a long-term perspective should be the starting point where both environmental aspects as prerequisites for growth and development are taken into account. - Technology management makes, on the basis of the above, an overall assessment, from a long term overall perspective, a sewage connection advocated primarily to create conditions for growth and development of the Herrvik port. - Financial resources to finance the connection costs, 950 000, should be allocated from the technical committee's capital. - It should be noted that a decision for the VA connection in Herrviks port could be considered as leading for the region's future positions on accession to private VA solutions.
<p>27/05/2015 TN §127</p>	<ul style="list-style-type: none"> - Östergarn country's desalination plant in Herrvik planned to be ready by summer 2016. Procurement will be in June 2015. There are several requests for membership. Funding is not ready. New budget is decided 19.8 million. Uncertainty exists regarding the budget.

Date	Content
24/06/2015 TN §160	<ul style="list-style-type: none"> -Technical Committee rearranges 2015 budget with 2 500 thousand from project 12452 "Water regional network" and 3500 thousand from project 12454 "Gotland's water supply." -Rearrangement goes with 6000 thousand to the "Östergarnland water supply." - A cost estimate for the construction of waterworks in Herrvik established winter 2014/2015 which involved capital expenditure totaling 19.8 million. The estimate was drawn from the experience of the ongoing project with Fårösunds new waterworks. - The table shows the initial estimate for the construction of Herrviks water plant (plant producing 10 m³ / h). - Interest in the municipal water supply of Östergarn country's property has now increased. The planned water plant with a capacity of 10 m³ / h will not be enough. This means that the plant needs to be upgraded to a production of 20 m³/h. - A connection possibility for a community facility in Sandviken, among others, are now included in the project. - The table below shows the calculation for the construction of Herrviks waterworks upgraded plant producing 20 m³/h. - The plant is expected to be completed in 2016. - Funds to increase the financing from the available 19.8 million to an estimated 25.8 million kr proposed by reallocation of project 12452 "Water regional network" and "Gotland's water supply" which as a result of understaffing in the administration will not need all the allocated investment funds 2015.
26/08/2015 TN §179 and §197	<ul style="list-style-type: none"> - desalination plants in Herrvik planned completed by summer 2016. The contract is finished. - Will water from Herrvik be mixed with well water, so that everyone gets the same water? <p>Answer: No</p>
23/09/2015 TN §201	Desalination plants in Herrvik planned to be completed by the summer in 2016.
27/04/2016 TN §86	<ul style="list-style-type: none"> - TN reallocates 6000 tkr from 'Gotlands water supply' and 'water regional network' to the 'water supply Östergarnsland' - Interest in the municipal water supply of Östergarn country's property has now increased. - The planned water plant with a capacity of 10 m³/h will not be enough. This means that the plant needs to be upgraded to a production of 20 m³/h. - A connection possibility for community facility Sandviken is now available in the project. - The table below shows the calculation for the construction of Herrviks waterworks upgraded plant producing 20 m³/h. Total costs are 25,8 million kr.

Date	Content
	<ul style="list-style-type: none"> - Facility is expected to be ready in 2016 - Funds to increase the financing from the available 19.8 million to an estimated 25.8 million proposed reallocation of project 12452 "Water regional network" and "Gotland's water supply" as a result of understaffing in the administration will not need all the allocated investment funds 2015. - Rearrangement of funds proposed with 2500 from 12452 "Water regional network", with 3 500 thousand from 12454 "Gotland water", a total of 6 000 thousand. - TN approves this suggestion
29/06/2016 TN §137	- The annual budget for 2016 allocated 16.6 million to Gotland's water supply. A total of 6.0 million has been reallocated to Herrviks desalination plants.
24/08/2016 TN §156	-project as planned, opening desalination in Herrvik on August 31

10.2 Appendix B: Interview Guide

Interview Guide

This interview guide serves as a general guidance for conducting the interviews in the field and provides a 'pool' of interview questions. The interview guide for each specific interview is adjusted to the interviewee and his/her role and expertise. Moreover, it is expected that additional questions or discussion points might evolve during the conversation.

Questions to interviewees involved in planning and decision-making

Questions to interviewees affected by desalination or water scarcity or differently involved in water discussions on Gotland

Questions to all interviewees

Before the interview

- Introduce myself and briefly explain my thesis-project
- Ask for consent to record the interview
- State that interviewees can be anonymous if they wish so
- Provide my contact details in case anyone wants to get in touch with me again later
- write down name, time, location, context
- Emphasise that there are no right or wrong answers and that I am interested in their particular insights and expertise, that they don't have to answer all questions if they feel uncomfortable and that they can interrupt me or ask questions at any time
- remember interviewees to speak clearly in order to allow good quality audio record

turn on recorder

- give short overview of the themes that will be covered during the interview and expected timeframe

Conducting the interview

Interviewees background, involvement and expertise

1. What is your background and your working experience?
Vad är din bakgrund och din arbetserfarenhet?
2. For how long are you **involved/interested** in Gotlands water management?
Hur länge har du varit involverad i /intresserad av Gotlands vatten hantering?
3. Can you describe your role within Gotlands water management?
Kan du beskriva din roll i Gotlands vatten hantering?

Understanding of water and water scarcity

1. How do you define water scarcity?
Hur definiera du 'vattenbrist'?
2. What should Gotlands water be used for?
Vad borde Gotlands vatten används för?

3. What should Gotlands water NOT be used for?
Vad borde Gotlands vatten inte används för?
4. How do you prioritize different water uses in times of scarcity? Which water uses are considered more important than others and why?
*Hur prioritera du olika sorters vattenanvändning i vattenbrist-situationer?
Vilka sorters är uppfattas viktigare och varför?*
5. From your understanding: What are the reasons for water scarcity on Gotland?
Vad tycker du är orsakerna för Gotlands vattenbrist?
6. What have been the measures to prevent water scarcity in the past (last 2-3 decades)
Vad har varit åtgärder för att förhindra vattenbrist förut?
7. Was Gotlands water scarcity foreseeable? If so, why has it not been addressed earlier?
Var Gotlands vattenbrist förutsebar? Om ja, varför åtgärdades det inte tidigare?
8. What do you personally/in your business (or your organisation) do to improve the water conditions on Gotland?
Vad gör du individuellt/i ditt företag (eller din organisation) för att förbättra vattensituation på Gotland?

Perspectives on desalination

1. What is your opinion about the implementation of desalination plants on Gotland?
Vad är din åsikt om installation av avsaltningsverket på Gotland?
2. Do you think desalination is the best solution for Gotlands water scarcity?
Tycker du att avsaltning är bäst lösning för Gotlands vattenbrist?
3. Which alternative solutions have been discussed? Why have those not been implemented?
Vilka alternativa lösningar diskuterades? Varför installerades de inte?
4. Who do you think benefits most from the desalination plants? Why?
Vem tycker du tjänar mest på avsaltningsverket? Varför?
5. Does the implementation of desalination influence you or your work? If so, how?
Påverkar installation av avsaltningsverket ditt arbete? Hur?
6. Do you think that there would have been a better alternative to address the water scarcity on Gotland?
Tycker du att det finns bättre alternativ för att lösa vattenbrist på Gotland?

Motivations for implementation of desalination

1. What scenarios of water use is the implementation of desalination based on?
Vilken vattenförbruknings scenario är planering av avsaltningsverket baserad på?
2. Who was involved in the decision-making process?
Vem var involverad i beslutsprocessen?
3. How is the construction, operation and maintenance of the desalination plants financed?
Hur är byggnad, drift och underhåll av avsaltningsanläggningar finansierad?
4. (How) was the local community consulted in the planning process?
(Hur) var lokal samhället involverat i planeringsprocessen?
5. Do you expect changes in water consumption following the implementation of desalination and grid expansion?
Förvänta du förändringar i vattenkonsumtion efter installation av avsaltningsanläggningar och VA-utbyggnad?

6. What is the role of desalination in a broader water management strategy?
Vad är avsaltnings roll i er övergripande vattenstrategi?
7. Do you see a limit to Gotlands water supply in the future (considering that desalination opens up a theoretically infinite supply)?
Se du en gräns för vattenförsörjning i framtiden (trots att avsaltning teoretiskt tillåter en obegränsat försörjning)?
8. 'Development' is often mentioned throughout the documents as a motivation for expanding the water-grid and implementing new supply options: How do you understand 'development' in this context and how is it connected to the water supply?
'Utveckling' anges ofta i dokumenter som motivation för att utbygga VA-nätet och installera nya försörjningsanläggningar: Hur uppfattar du 'utveckling' i det här sammanhanget?

Problematic aspects of desalination

1. Do you think there are trade-offs in using desalination? If so, which?
Tycker du att det finns nackdelar med att använda avsaltning?
2. Has there been opposition to the plans of implementing desalination plants?
Fanns det motsånd mot planeringer av installera avsaltningsanläggningar?
3. Do you think that social and environmental effects of desalination have been adequately considered? If so, how? If not, why?
Tycker du att sociala effekte och miljöeffekter av avsaltning beaktades tillräckligt? Om ja, hur? Om nej, varför?
4. Which water related problems can desalination not address?
Vilka problem som hänger ihop med vatten kan avsaltning inte lösa?
5. How do you approach these problems?
Hur löser du den här problemen?

Perceived limitations of own action

1. What barriers (e.g. lack of financial resources, practical knowledge, permits, etc.) do you experience in **your work** / **personal commitment** in the water management? What makes good water management challenging?
Vilka hinder (till exempel bristanda finansiella resurser, praktisk kuskaper, tillstånd, osv.) uppfattar du i ditt arbete / personliga insats i vatten hantering? Vad gör bra vatten hantering så svart?
2. What legal obligations and principles guide your work? (e.g. CBA, EIA, Building Code, etc.)
Vilka rättsliga skyldigheter och principer styr ditt arbete?
3. Do you feel supported in your actions by Gotlands authorities?
Känner du att du får stöd för dina insatser från Gotlands myndigheter?

Possible solutions and alternatives (to desalination)

1. If you alone were to decide on Gotlands water management: What would be the ideal solution to Gotlands water problems? Why?
Om det vore upp till dig att besluta om Gotlands vatten hantering: Vad skulle vara en idealisk lösning för Gotlands vatten problem? Varför?
2. What are the barriers to this solution?
Vad är hinder för den här lösningen?

3. *Only if not already suggested by interviewee:* What do you think about using wetland restoration in order to increase the capacity of keeping water on the island? Why is that not integrated into the water management strategy?

Vad tycker du om att nytta återskapande våtmarker för att öka öns kapacitet att hålla vatten? Varför är det inte integrerat i vatten hanterings strategien?

4. Do you think that the implementation of desalination reduces incentives to further promote these alternative measures?

Tycker du att installation av avsaltningsanläggningar minskar incitament för att ytterligare främja den här alternativa lösningarna?

Ways to overcome the problems and initiate change

1. What do you think would need to change in order to improve Gotlands water management?

Vad tycker du måste ändras för att förbättra Gotlands vatten hantering?

2. Who is responsible/able to initiate these changes?

Vem är ansvarig/kapabel till inleda den här förändringar?

Ending the interview

- Thank you very much for taking time to discuss these questions with me and to share your knowledge. I have learned a lot from you and am sure it will help me with my thesis.
- Is there any additional aspect I did not cover but you feel is important to talk about with me?

switch off recorder

- making sure again that the interviewee has my contact details and I have theirs
- encourage to send follow-up questions or comments that might come up a few days later
- offer interviewees to check their input in my thesis before submission

10.3 Appendix C: Information Sheet Aquabrava

This information sheet is retrieved from the European Network for Rural Development (2016).



Water preservation project 'AQUABRAVA'

EAFRD-funded projects

This LEADER-funded project created several small wetlands and helped raise awareness of and interest in water protection among landowners. It also contributed to increasing the amount of available water in the island of Gotland.

SWEDEN

Implementing Local Development Strategies

Location

Gotland, Sweden

Programming period

2007 - 2013

Axis / Priority

Axis 4 – LEADER

Measure

M412 – 412 Environment / land management

Funding (EUR)

Total budget: 154 554
EAFRD: 88 096

Project duration

2011 – 2013

Project promoter

Economic Association
Jordgumman

Contact

Eva Frölander
eva@gammelgarn.se
Tel. +46 498 52 333

Additional information

www.lantbruk.com/lantbruk/knot-ihop-vatmarker-pa-gotland-fick-mer-vatten
www.youtube.com/watch?v=9MtMexmqUYg&feature=youtu.be

Summary

Since the 1990's, access to ground water has been declining in the island of Gotland, Sweden. Private dug wells have been drying out, which is problematic especially for livestock farmers who have been obliged to tap water from a municipal water catchment. Drilling new wells had not brought a solution since the newly drilled wells produced either brackish or gassy water, or often there was high drilling cost for no water found.



In 2003, a study on the water system circle started to investigate the factors that had a crucial effect on the water access in the area and would increase the water resource for their wells. At first, three ponds and wetlands were created to test the effectiveness of the method which proved to be far better than expected. The 'Aquabrava' project supported the creation of an additional eight wetlands and ponds with a total area of 10 ha.

The project further set up a monitoring system, including metrics, methods and templates, and applied it in the year following the construction of the wetlands to document changes. Finally, a series of lectures and meetings were conducted to raise awareness and promote the construction or restoration of wetlands among landowners.

Results

The efficiency of the wetland system was proven when the autumn rain filled all wetlands and increased water levels in wells closest to the system within a week. A subsequent measurement showed increased water levels in wells located further away from the wetland system. The creation of wetlands and ponds noticeably increased access to water in the area even during periods of droughts.

The method has proved to be cost-efficient as the costs are limited to construction and maintenance.

Another advantage of the wetland system is that it is largely located on pasture land, thus providing the cattle with constant access to water: a highly valued asset by the farmers in the area. The system has also reduced the amount of water provided by other parts of the Gotland island.

Additionally, the wetland system provides a buffer zone reducing the eutrophication of the Baltic Sea as wetlands have now become stable ecosystems with high biodiversity in the watershed area. Species include different types of water plants and insects.

Finally, the wetland system provides social benefits – it has become a recreational area for strolls in the summer time and for ice-skating in the winter.

Lessons & Recommendations

- ☐ It is be advisable to monitor the wetland system and water level increases beyond the duration of the project in order to obtain better and more scientifically valid results.

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