Possibilities of Open Data and Digital Twins in the Swedish Water Sector

AG1815

Group 1

Group members

Andreas Grunde
agrunde@kth.se

Anna Bogacova
bogacova@kth.se

Larisa Cof
larisac@kth.se

Sara Moazez Gharebagh
saramg@kth.se

Sebastian Lihammer
lihammer@kth.se

Supervisors

Eva Stattin (supervisor at IVL)
eva.stattin@ivl.se

Fredrik Hallgren (supervisor at IVL)
fredrik.hallgren@ivl.se

Mattias Höjer (supervisor at KTH)
mattias.hojer@abe.kth.se

Abstract

The intention with this study was to investigate how open data and digital twin technology are applicable in the Swedish water sector. A core part of this project was to incorporate how digital twins and open data in the water treatment sector could aid Sweden in fulfilling the United Nations Sustainable Development Goals 6 and 9.

An extensive literature study was conducted which covered the areas of the digital twin technology, open data, and the Swedish water sector. Following the literature study, two interviews were held with Björn Hagström (expert on open data) and Glen Nivert (Recycling and Water Gothenburg) in order to gain further information on open data in Sweden. In the final stage of the project, suggestions on innovative implementations of open data and the digital twin technology were formulated. These were based on the findings regarding innovations in open data as well as through group-brainstorming.

Upon evaluating the possible risks with implementing the digital twin technology, the benefits gained stayed being of true value. By enabling accurate, real-time based measurements and simulations, the technology is widely applicable across sectors, such as infrastructural management of entire countries. Regarding open data, there is a clear initiative and devotion on an EU level to incorporate the openness and sharing of data on a broader level. The benefits are clear: improved public services and forecasted cost savings of up to 1,705 billion euros among the national governments of the EU28+ in 2020.

Table of contents

1. Introduction with background and problem formulation

1.1 Background

1.1.1 Digital Twins

A Digital Twin is a digital copy of a physical system. It can be a copy of a jet motor, wind farms, a building or even whole cities. It is designed to receive data, for instance from sensors, from the physical system which allows the digital twin to simulate the physical system in real time. A digital twin can also be used as a prototype to provide feedback before the physical system is built. (TWI, n.d.)

1.1.2 Open Data

Open data is data which can be accessed, studied, used and modified either completely without restrictions or with restrictions that ensure that this continues to apply to the data in the future. (Murray-Rust, 2008)

The general way of thinking within the scientific community is that once data or a set of findings are published, it belongs to the scientific community at large. In contrast to this idea, many publishers of scientific material claim copyright on data, block articles behind paywalls and refuse researchers the ability to re-use published data without explicit permission. (Murray-Rust, 2008)

1.1.3 The Swedish Water Sector

As early as in 1930, sewage treatment plants were introduced in Sweden. As a result of the early investments in water and wastewater treatment technologies, a wide range of innovative solutions have been developed and implemented in many countries around the world. (Swedish Cleantech, n.d.)

The Swedish water and wastewater management facilities in use today were built during the 50's, 60's and the 70's. Swedish municipalities are managing their drinking water as well as their wastewater. The need for maintenance, renewance and upgrade of the facilities is crucial for the continuance of service delivery. Increasing population, renewed regulations and climate change are the driving factors for new investments regarding urban construction, nonetheless in the larger cities and growth regions of Sweden. (Svenskt Vatten, 2020b)

1.1.4 United Nations Sustainable Development Goals

In 2015 all countries in the United Nations signed the 17 Sustainable Development Goals (SDGs). These goals are intended to be reached by 2030. They can be seen as a definition of sustainable development and are connected to each other, together covering social, economic and environmental sustainability. (Finnveden, 2021)

SDG 6 ("clean water and sanitation") mostly relates to access to clean water and sanitation, a social, rather than environmental, problem (United Nations, 2020a). According to the government-funded website Smart City Sweden, access to clean water and sanitation is not a problem in Sweden and the goal is already largely fulfilled (Smart City Sweden, 2019a). SDG 6 also relates to sustainable management of water (United Nations, 2020a), and the biggest challenges listed at Smart City Sweden relating to this goal is that the groundwater (freshwater present beneath the surface) is threatened by pollution and that the available amount could decrease, threatening the water supply (Smart City Sweden, 2019a).

SDG 9 ("industry, innovation and infrastructure") contains a wide range of individual targets, relating to the development of reliable and sustainable infrastructure, enhancing scientific research, and upgrading technological capabilities of the sectors in each country. In addition, it is encouraging further innovation and increasing access to IT technology. (United Nations, 2020b)

Compared to many other countries, the infrastructure in Sweden is relatively good. A series of bills passed from 2016 onwards have served to bring the country closer to fulfilling the goal through making decisions on how to improve existing and future infrastructure deciding that technologies such as automation and digitalisation are to be increasingly used. (Smart City Sweden, 2019b)

1.2 Problem Formulation

The ongoing project *Open Waters,* which is run by IVL Swedish Environmental Research Institute, is currently investigating how open data and digital twin technology for water treatment plants (WTPs) are enabling new innovative products and services for efficient and sustainable water purification (IVL Swedish Environmental Research Institute, 2020).

The intention of this project is to investigate how open data and digital twin technology is applicable in Swedish water treatment plants. It is also intended to investigate if there are any best practice examples of uses of open data and digital twin technology in other countries that the Swedish WTPs could be inspired by and learn from. Of interest to this topic is also how these implementations could aid Sweden in reaching the SDGs 6 and 9.

2. Purpose and goals

2.1 Purpose

The purpose of this assignment is to investigate 1) if there are any best practice examples on how to use open data and digital twin technology in other countries that the Swedish WTPs could be inspired by and learn from, 2) in what ways working with open data could be valuable to the WTPs (i.e. what the incentive is for the companies that work with water treatment), 3) how WTPs in Sweden could benefit from incorporating digital twin technology and 4) how open data and open source software would stimulate new innovations and increase the collaboration between different stakeholders within the water sector and help bring Sweden closer to fulfilling SDGs 6 and 9.

2.2 Goal

The goal of this project is to promote the use of open data and open source in the water sector (in Sweden) by investigating the benefits and disadvantages, especially with regard to the SDGs 6 and 9. Another goal is to gain a better understanding of the use of the digital twin technology and how the exchange of data between different stakeholders could be used as a basis for innovation and smart sustainable solutions.

3. Project design

The information needed for the project was collected through conducting interviews with relevant people within information technology, open data specifically, and within the water treatment sector. A literature study was conducted as well. The material used in the literature study was found through internet tools, such as Google Scholar, and through recommendations received from supervisors and interviewees. The literature study covered open data in Sweden and other countries, benefits and risks of open data, how digital twin technology has been used in Sweden and elsewhere, as well as stated benefits of digital twins. The interviewees were recommended by the supervisors at IVL. The interview questions were open-ended with the intention of acquiring elaborate and informative answers. Interviews were conducted by two people where one asked questions whilst the other one took notes. Adjustments, including changes and added content, were also made continuously as feedback was received from our supervisors during supervision meetings and from other students at project seminars. Based on the results obtained through the literature study and the interviews, connections that could be made to SDGs 6 and 9, as well as suggestions for innovative ways to use open data were suggested.

4. Results

4.1 Open Data: Sweden

According to the Global Open Data Index (GODI), the annual global benchmark for publication of open government data, Sweden's rank is 21 (2017) with a ranking score adding up to a total of 53 %. Out of the Nordic countries, Sweden is ranked the lowest (excluding Iceland). (Open Knowledge, 2015)

One of the datasets taken into account was the water quality. Sweden's score on how open the data is for this dataset was 0 %. Stated in the specification was that the data regarding the water quality was: not openly licensed, not publicly available, not in an open and machine-readable format, not available free of charge, not downloadable at once, and not up-to-date. (Open Knowledge, 2017)

The European Data Portal (EDP) conducts yearly studies of the EU country's Open Data Maturity (a benchmark in order to gain insights into the development achieved regarding open data in Europe). The EDP assesses the level of maturity against four dimensions: policy, portal, impact, and quality. The study clusters countries into four different groups: Trend-setters, Fast-trackers, Followers, and Beginners, from the most mature to the least. In 2019, Sweden was ranked at number 23. For 2020, the ranking was 16 (European Data Portal, 2020a), meaning that Sweden went from being classified as a Follower in 2019 to a Fast-tracker in 2020.

During the interview with Björn Hagström (expert on Open Data and part of the Open Waters project group) he stated that the Swedish principle of public access to information (offentlighetsprincipen) to some extent is limiting the use of open data in Sweden. In addition, Glen Nivert from Recycling and Water Gothenburg (Göteborg Kretslopp och vatten) also mentioned the strong impact of the principle of public access. He stated that the current national-level monitoring in Sweden is quite weak in terms of requirements on how to present data. Furthermore, he added that it is beneficial with clearer national requirements and guidelines with the purpose of achieving more standardized methodics regarding sharing our data. Nivert mentioned Denmark and Germany as examples of implementing better standardization.

4.2 Denmark

4.2.1 Open Data

According to the GODI, Denmark was ranked at 11 with a total score of 65% in 2016. Denmark scored 30% on open data for water quality and unlike Sweden, the data regarding the water quality is publicly available free of charge (Open Knowledge, 2016a). In Denmark, data on water quality is collected by the Geological Survey of Denmark (GEUS), which also supplies the data for free on their website, both in the form of detailed reports and in the form of annotated maps (Geological Survey of Denmark and Greenland, n.d.).

4.2.2 Digital Twins

The Danish Hydraulic Institute (DHI) offers a Cloud based Digital Twin called TwinPlant for wastewater treatment operations. TwinPlant offers the possibility to access the plant remotely and to monitor and control the plant online, allowing adjustments to be made immediately. It also has a built-in function that automatically reports from environmental and process monitoring, power consumption and chemical use. With TwinPlant it is possible to receive real-time data and to run simultaneous simulations, test complex control strategies and run advanced experiments which enables operators to optimise the treatment process. (DHI, n.d)

4.3 Germany

4.3.1 Open Data

Germany is ranked at 24 in the GODI. Germany's score was 51% in 2016. Open data for water quality in that period of time was 0% which was similar to Sweden (Open Knowledge, 2016a). However, in July 2017, the German Open Data Law came into effect. "The Law mandates all federal authorities to release their data in open and machine-readable formats, free of charge, and with associated metadata on the federal metadata portal GovData.de." "The Organisation for Economic Co-operation and Development (OECD) is an international organisation that works on establishing international standards and finding solutions to a range of social, economic and environmental challenges." (OECD, 2019)

After the Open Data Law was launched, Germany's open data has been improved and became more accessible. Germany is still below the OECD average, because few attempts were made to contact stakeholders to inform about an open data policy. From a data

accessibility perspective it was a burst for Germany from 2017 to 2019, as it overcame the average OECD of other countries. As for government support for data reuse, Germany remains below the average of OECD and was lower in 2019 compared to 2017, due to not organising events that could help to promote the reuse of open data among business and civil society. (OECD OGD, 2019)

4.3.2 Digital Twins

One example of implementing digital twins technology in Germany is used by Siemens as the first wastewater digital twin. The Technical University of Berlin studies innovative concepts in a realistic environment using a digital twin of a pump station. As one of the professors working on this project mentioned that research's main idea is to improve water plant and system operation in the water industry in Germany, Berlin in particular. That can be reached by helping existing systems to operate more flexibly and more efficiently. Digitalization provides safe treatment of wastewater, reliable supply of fresh water and approaches to data analysis in operation and maintenance. (Siemens, 2020)

4.4 Security Risks of Open Data

When sharing data, it is important to take into account the security risks that could follow. The more detailed, multi-dimensional and raw the data is, the greater is the benefit (since it increases the usability), but also the risk (since the risk that sensitive information is included is greater) (Green et al., 2017). The water sector faces various potential risks and threats that range in severity from employees unknowingly making errors, to politically motivated terrorism and vandalism. These risks are compounded by many organizations lacking data security policies that take things like the SCADA system into account (Myndigheten för samhällsskydd och beredskap, 2011). The threats are real: in 2018, Russian government cyber actors targeted facilities in the United States and gathered information, for instance through open source information, from the water sectors (among others) (Germano, 2019).

In our interview with Björn Hagström, he stated that sharing your data brings with it various potential security concerns, even within the water sector. For example, demands for open and accessible data can not take priority over national security and the Swedish water supply must not be jeopardized. Some information will need to be kept confidential.

In our interview with Glen Nivert, he pointed out that there are also security concerns with data which does not affect national security, stating that many may be afraid to share

their data out of fear of it being misused and misinterpreted, leading to the data potentially being used incorrectly to make wrong decisions. Nivert believed that the risks of not sharing data, and in turn not having access to the information shared by others, could be greater than any potential risks of sharing your own data.

4.5 Stated Benefits with Open Data

Previous work has concluded that there are many benefits of open data, pertaining both to governments and businesses, and to individual citizens. Among the most widely cited benefits are various improvements to public services, such as increased transparency, efficiency and quality, as well as economical benefits. An example of an efficiency improvement is that if data is easily accessible, civil servants will have to address less inquiries from the general public and it will facilitate the handling of the inquiries that are received since they will know where the relevant information can be found (European Data Portal, 2020b). Economical benefits come in the form of cost savings - if real property data, geographical data, business register extractions etc. are freely available, there is no need to spend money and energy at gathering the same data again (European Data Portal, 2015). The EU had saved an estimated 1.7 billion euros by 2020 due to open data initiatives (European Data Portal, 2020b).

In our interview with Nivert, he said that the more accessible information is, the more it can be used: if the information is easily accessible, different types of organizations and businesses can use it. He also pointed out that if an organization finds that the data they require is already published there is no need to conduct an expensive study of their own. According to Glen, the largest problem to overcome is convincing organizations of what is "in it for them" to share their data - many corporations use the data obtained by others while not sharing their own. Glen thought that this is a question of solidarity, but that economical incentives can be found in that sharing your data can act as a way of granting yourself exposure and generating interest in your business. Even if negative aspects (such as sustainability issues) become apparent through examining your data, Glen believed this to be good for the future development of your business.

According to Hagström, data is worthless unless it is used for something and the value of information first comes at the time it is used. Corporations may not use all the data they produce, which in turn becomes an incentive to share it. Hagström also believes publicly

financed institutions should share their data since the taxpayers that fund them should get the maximum amount of value out of their tax money.

4.6 Open Data Innovations

Data on water, such as measurements of precipitation, river flows, lake and groundwater levels, and water quality, are used by many different organizations. Making this data open would provide researchers with information that would help to track and observe water across scales and timeframes, making it possible to reconstruct and understand environmental processes such as changes in rainfall patterns or surface water temperatures. Satellites give data about groundwater levels that makes it possible for researchers to identify potential challenges for people and ecosystems. (Hering, 2014)

One more innovative way of using open data can be seen in the WaterWatchers program developed by IBM and used in the City of Tshwane, South Africa. This project enables citizens to help capture, share and analyze information about the water distribution system in South Africa. (Wilber, 2017)

Open water data can also provide essential government transparency, and empowers citizens to hold government officials accountable. For instance, Dan Telvock, a journalist of the Investigative Post, used open data to expose higher than reported levels of lead in the drinking water of Buffalo, New York City. Cross-referencing open records from the Erie County Health Department with open water testing data showed that the city rarely tested drinking water for lead in homes where a child had been diagnosed with a high blood-lead level." (Wilber, 2017)

4.7 National Digital Twin Programme

Launched by HM Treasury in July 2018 was the Nation Digital Twin programme (NDTp). This program is run by the Centre for Digital Built Britain which is a partnership between the University of Cambridge and the Department for Business, Energy and Industrial Strategy. The NDTp was established with the purpose to deliver key recommendations of the *Data for the Public Good Report* written by the National Infrastructure Commision. (University of Cambridge, 2019)

Stated in the *Data for the Public Good Report* is a timeframe of 10-30 years. In the report, a roadmap was set out towards a national digital twin. It is further declared that the digital twin will serve as a digital model of Britain's national infrastructure, enabling

monitoring of infrastructure in real-time as well as simulations of the impacts of possible events (for example a natural disaster). In addition, the digital twin is said to enable further aid and management of the nation's infrastructure in a more efficient way which is said to only be made possible through secure sharing of high quality, standardised data across infrastructure. (National Infrastructure Commission, 2017, p. 3)

Objectives for the NDTp focus on the following:

- Enable a National Digital Twin - an ecosystem of connected digital twins to foster better outcomes from the built environment;
- Deliver an Information Management Framework - to ensure secure resilient data sharing and effective information management;
- Align a Digital Force Task Group - to provide coordination and alignment among key players.

Furthermore, there are several benefits stated on the project website concerning the society, economy, business, and environment. In regard to the society, it is claimed that the customer satisfaction and experience gets improved through higher-performing infrastructure. Regarding the economical benefitients, higher-performing and resilient infrastructure operating as a system is said to increase national productivity. In addition, it is claimed that information security and cyber security is enhanced. A higher-performing infrastructure is also claimed to improve business efficiency. Environmental benefits regarding the NDT are claimed to be less disruption and waste. It enables more reuse and greater resource efficiency. In the built environment, this is said to be a key enabler of the circular economy. (University of Cambridge, 2019)

4.8 Digital Twin Technology: Ongoing Projects in Sweden

There are great areas of opportunity for improvement through increased automation and through digitization of the water and wastewater systems. To develop and implement digital twin technology within the water treatment sector in Sweden, there needs to be an innovative and radical readjustment in how the treatment plants are operated and controlled (RISE Research Institutes of Sweden, 2020a). The digitalization and increased focus on technical water treatment innovation has led to a situation where it today is easier to both test and design new kinds of custom solutions (Svenskt Vatten, 2020a).

This section will describe implementations and ongoing projects in Sweden regarding digital twin technology.

4.8.1 Digital Twin Cities Centre (DTCC)

The Digital Twin Cities project involves 31 Swedish and international stakeholders and the centre is led by the Chalmers Department of Architecture and Civil Engineering and Area of Advance, Information and Communication Technology. In order to incorporate all aspects that are needed to develop large-scale digital twins, eight different research areas (RAs) have been defined. (Digital Twin Cities Centre, 2021a)

In the defined project mission, it is intended to make Sweden a leading European country in the implementation and utilisation of digital twin cities as well as to make strong and lasting contributions to fulfilling the SDGs at different levels. In addition, it is also intended to become recognised as an international leader and a strong contributor to the global research and dissemination of knowledge and practices for digital twin cities. Lastly, stated in the project's mission is to help to enable all Swedish built environment actors to utilise digital twins as a main tool for sustainable and inclusive planning, execution and management as well as support the full integration of the digital twin concept in all parts of the planning process for the Built Environment (Digital Twin Cities Centre, 2021a). It is also stated that the Digital Twin Platform (RA 0) shall be developed as an open-source project, and be based on open data (Digital Twin Cities Centre, 2021b).

4.8.2 Digital Twin WWTP

The Digital Twin WWTP (wastewater treatment plant) project commenced in september 2020 and its expected duration is three years. This project is funded by Formas Smart Built Environment, Nordvästra Skånes Vatten och Avlopp AB (NSVA) and Svenskt Vatten Utveckling. (RISE Research Institutes of Sweden, 2020a)

It is stated that the implementation of digital twins within the wastewater treatment facilitates a substantially increased overview over the resources that are handled through the use of different types of models as well as data quality control. In addition, the digital twins make it possible to operate the plant in a better way, supposedly contributing to optimal design of new plants. (RISE Research Institutes of Sweden, 2020a)

The project will create a method for developing digital twins as WWTPs as well as real time process simulation and data validation. The method will be verified by implementation of a digital twin for the WWTP Öresundsverket in Helsingborg, Sweden. Here, the results are said to be evaluated and benefits to be quantified. (RISE Research Institutes of Sweden, 2020a)

The method being developed is stated to be generic; meaning there is great potential to reuse the knowledge for other process industries with the need to treat water. This project contributes to the SDGs number **6**, 7, **9**, 11, 13, and 14. (RISE Research Institutes of Sweden, 2020a)

4.8.3 Virtuella Göteborg

"Virtuella Göteborg" (Virtual Gothenburg) is the digital twin of the entire city of Gothenburg. The digital twin is intended to be finalised during 2021, as the city celebrates 400 years of existence. This project is led by the City Planning Authority (CPA) of Gothenburg. (City of Gothenburg, 2019)

Eric Jeansson, the geodata strategist at the CPA, explained the development of the digital twin as follows: "*We realise that the challenges faced by the city are constantly increasing with climate change, segregation and the overall complexity of society and we need better methods of describing, understanding, planning and governing the city – which is where the digital twin comes into the picture*". (City of Gothenburg, 2019)

4.8.3.1 Skyfallssäkra Göteborg

The problem with too large amounts of rainwater during a short period of time is that the wastewater system is not able to handle the water amount. Since the unhandled rainwater will proceed to take its own paths, it could lead to detrimental damages caused by flooding. The digital twin of Gothenburg, Virtuella Göteborg, is going to provide aid to all city planners involved in finding solutions on how to handle the consequences followed by skyfall's. Göteborg Kretslopp och Vatten (Recycling and Water Gothenburg) is the responsible party for coordinating the work. (City of Gothenburg, 2021)

4.9 Stated Benefits with the Digital Twin Technology

As mentioned in section 1.1.1, digital twins are always up to date with the physical system using real-time data which provides the opportunity to always keep track of the system's current performance. This means that weaknesses and issues with the system can be identified and handled quickly. This data can also be used for multiple analyses that can contribute with beneficial insights which can help in decision making, planning of future projects and optimising water treatment plants. (Williams, n.d)

Digital twins bring the ability to test different scenarios, such as population growth or exposing the system to extreme cases, in a virtual environment. This can help with

identifying deficiencies and strengths in the system and to prepare for eventual events in the future. It is also possible to test different strategies, examine the system's reaction and then analyse the strategies effectiveness without having to implement changes in the physical system, thus not having to risk damaging or wasting the equipment or negatively affecting public health. At the same time it reduces costs and enables more efficient development of the system. These possibilities could also result in more creative thinking of new, innovative and better solutions. (M. Curl et al., 2019)

Digital twin technology can enable more efficient systems where resources are better dealt with; where water and air emissions are lowered and where costs are minimized. (RISE Research Institutes of Sweden, 2020b)

5. Discussion and Conclusions

5.1 Discussion

5.1.1 Innovative Ways to Use Open Data in Sweden

One innovative way to improve open data, already employed in, for instance, Germany (see section 4.3) would be to not only encourage or mandate that data be released, but also regulate format and mandate the data to be machine-readable. As mentioned under 4.1, data in Sweden is not required to be machine-readable at the moment and current laws are weak in terms of requirements on how the data should be released and presented. Non machine-readable data is more difficult to use, meaning that Sweden would undoubtedly benefit from "stronger" national guidelines and a mandated standardized format and structure, including a requirement for it to be machine readable, for open data.

The Global Open Data Index lists various problems with open data specifically related to water (see section 4.1). Most of the issues - that the data on water quality is not publicly available, not available for free, not downloadable at once and not up-to-date, would not be difficult to solve. As mentioned in section 4.2, the same data in Denmark is publicly available for free. Sweden's counterpart to the Danish GEUS, Sveriges geologiska undersökning (SGU) has a corresponding website with open data, but only supplies data relating to groundwater, rather than water in general (Sveriges geologiska undersökning, n.d.). Solving these issues could be a matter of standardizing the data and expanding what can be accessed through the SGU website.

By enabling easier access to data, innovations regarding sharing and compilation of data could be easier to develop. For instance, offering a digital solution, such as an app, regarding water treatment could make it easier to involve end-users. Being able to follow up on the water quality levels in your area or perhaps track your household's water usage could make it easier to raise awareness and facilitate a more sustainable water usage among end users.

As digital copies of physical systems, digital twins need large amounts of data for their creation. Creating digital twins is thus made easier if this data is already available. Open data in digital twins makes it possible for stakeholders to access data, study it and adapt parts of an existing solution to their system and also brings the opportunity for stakeholders to contribute with knowledge, facts, different perspectives and research experiences, leading to new, or improved, digital twins, which in turn can lead to new innovative solutions that

contribute to improved and more sustainable water treatment plants. One possibility with digital twin technology is to use machine learning in order to interpret, learn and predict future events from historical data, making it possible to act preventively. If this data is open, other actors can use it to also develop preventive solutions for their systems. It also enables digital twins to access data from several different sources and with machine learning learn from a wide range of information.

5.1.2 Connection to the sustainability goals

As mentioned under 4.5, one of the noted benefits of making data publicly available is that if the information is easily accessible, it can be used by several different organizations and businesses without the need of conducting their own expensive studies. As stated under 1.1.4, SDG 9 relates to enhancing scientific research, encouraging further innovation, and upgrading technological capabilities, all things made easier and cheaper if the data is already available and does not need to be collected several times. Virtually all the major benefits associated with digital twin technology, discussed in section 4.9, including identifying and handling weaknesses and issues in systems, the ability to test extreme cases, and gaining additional insight, also work towards SDG 9. As mentioned under 4.9, digital twin technology has explicitly been identified as helpful in creating new and innovative solutions.

As mentioned under 1.1.4, the main issue that remains related to SDG 6 in Sweden is that the groundwater is threatened by pollution and that the water supply can be threatened due to low amounts of groundwater. As mentioned under 4.5, sharing your data can reveal negative environmental impacts. If data was available from every water treatment plant it would be very easy to identify where the most work has to be done to counter pollution. The possibility to optimise water treatment plants and run tests digitally rather than physically, brought up as benefits of digital twins in section 4.9, also mean that more sustainable solutions could be worked on more quickly and efficiently.

Two of the ongoing Swedish digital twin projects (as described under 4.8) are focused on wastewater treatment. The Digital Twin WWTP project is supposed to, among other things, lead to more optimal water treatment plant designs in the future, which, as a type of fostering of innovation and creation of more resilient infrastructure, is a clear connection to SDG 9. Additionally, sustainably managing wastewater, such as large amounts of rainwater, is important, as excess water could lead to flooding and because excess water is water that is not being used to work towards more sustainability or towards solving water scarcity, one of the bigger issues tackled by SDG 6.

Together, digital twins and open data combine the beneficial sustainability impacts listed above. By sharing your data, and having access to the data of others, creating digital twins (or using those of others) will be made easier. In effect, open data, alongside its own sustainability benefits, can work towards accelerating progress on digital twins and thus enhances the sustainability benefits already associated with the technology.

5.1.3 Promotion of Digital Twins and Open Data in Sweden

In section 4.1 it is mentioned that data regarding water quality is not in an open machine-readable format, is charged and not accessible to the public. In the interview, Björn Hagström brought up that many already believe that Sweden is open and that electronic machine-readable data is a simple way to provide more information that can affect people's attitude towards open data in Sweden, making it more positive. One possible way to promote open data is to introduce a law that can standardise it. For instance, as has been said in section 4.3.1, Germany's government introduced a law of using and sharing open data, as well as making data machine-readable. This makes it possible to access up-to-date data and use it for different purposes, instead of spending time and money on organisation's own research. Also as it has been mentioned above in connections to the sustainability goals section, this promotion of open data workstowards SDG 9.

As Nivert mentioned, the biggest obstacles of sharing information in the water sector are safety issues. The solution could be promotion of standardised plans and requirements for data that can be shared among organisations and businesses. People want access to others' information, but never share their own, this can be improved by organising events advertising each other's businesses. In that way you will create interest in your business and other organisations will be willing to exchange data and collaborate, as Nivert thinks it will be better for their own development in the long run.

One more way to promote open data and digital twins is to educate organisations by showing examples of using these technologies in other countries. In sections 4.2 and 4.3 are possible solutions how digital twins can be implemented in Denmark and Germany. In section 4.6, innovative solutions for open data usage in different countries can be found. Spreading knowledge of digital twins and open data to Swedish organisations may affect their attitude towards using these technologies. This can be done by organising seminars for organisation managers or other workers that are connected to data analysis and research.

5.2 Conclusion

By investigating and analyzing international implementations of digital twins, several suggestions were pointed out regarding how Sweden could incorporate open data and digital twins more extensively in the water treatment sector. As stated in section 4.8.1, Sweden strives towards becoming recognized as an international leader and a strong contributor to the global research and dissemination of knowledge and practices for digital twin cities. The suggested solutions regarding a more standardized way of collecting and compiling data on a national level could result in easier access to data as well as several economical benefits. Both of these factors are important to consider in order for Sweden to fulfill the United Nations Sustainable Development Goals. When implemented together, open data and digital twins are applicable in multiple different sectors and enable management, simulations and estimations in a way that has never been done before. The infrastructural empowerment from gaining more control over cities and nations through digital twins, enables innovation to thrive and develop. This in turn, can aid us in maintaining a more sustainable way of living on our planet Earth. Digital twins are just the tip of the iceberg on our journey towards a sustainable planet, although it is a starting point full of potential.

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