THE ROAD TOWARDS A NORDIC CLIMATE NEUTRAL WATER SECTOR

DANVA FIWA Norsk Vann Svenskt Vatten

The Road Towards a Nordic Climate Neutral Water Sector

Working document – still in progress

Version 2 - September 2022

A Cooperation of the Nordic water associations:

- DANVA – Danish Water and Wastewater Association
- FIWA – Finnish Water Utilities Association
- Norsk Vann - Norwegian Water
- Svenskt Vatten - Swedish Water and Wastewater Association
  and
- EnviDan A/S (Technical assistance)

Front page photo by Jani Wihinen, Jyväskylä Region WWTP Plant Ltd, Finland

Introduction

By Carl-Emil Larsen, DANVA, Osmo Seppälä, FIWA, Thomas Breen, Norwegian Water and Pär Dalhielm, Swedish Water, CEOs of the Nordic water and wastewater associations

Finding the road towards a Nordic climate water sector

We are looking towards an uncertain future. All over the world, countries, cities, and people are facing severe risks related to climate change.

From the Nordic water sector, we are ready to take up this challenge and do our part to reduce CO_2-emissions from our activities and work together towards a climate neutral water sector.

It varies across our four countries, when we will be able to meet this goal, but we share the aim to set ambitious goals for the water sector and we will work together to encourage similar ambitious goals from the European and global water sector at this time where the development and the agenda on climate change is moving very fast.

The recent IPCC report (AR6) presents the facts clearly. Developing countries are less resilient and will be greatly affected, but also in our region we will see changes that will be challenging to cope with for water utilities and for our societies.

The European drought this summer of 2022 has demonstrated that climate change also poses risks to people and environment in highly developed countries, and the Nordic countries will not be spared.

Even if we succeed in meeting the 1.5-degree target set by the Paris agreement, most Nordic regions will be troubled by the rising sea levels. The temperature rise in the arctic region is expected to be 3-4 times higher than in the rest of the world. And all our countries will experience increasing precipitation and more frequent and serious extreme events. The IPCC report, however, also states that it is not too late to act on climate change and reduce emissions of all greenhouse gasses.

The outcome of the COP26 in Glasgow demonstrated that acting on climate change cannot be left to UN and politicians alone, and the water sector needs to follow a two-string approach where we are building resilience to cope with the inevitable at the same time as we are reducing our CO2-emissions.

The European Union has a goal of 55% reduction of CO2-emissions in 2030 and of becoming Net Zero EU in 2050. Achieving this will be a challenge for all countries and all sectors in our part of the world and achieving a climate neutral water sector will also be challenging for us.

Ambitious EU goals correspond to the ambitions of the Nordic water sector. We encourage the EU to promote climate neutrality in the water sector well ahead of the 2050, and we encourage our members to work towards climate neutrality in our different countries.

We need to look carefully into technologies and processes, and we need to monitor our emissions and keep track of our progress. We can neither neglect nor negotiate about our main tasks when it comes to water quality and treatment to protect our health and environment. We need to secure a balance between our various targets:

- Energy neutrality
- Climate neutrality
- Costs and price
- Quality and treatment efficiency

We need to work for low cost, high quality, and low carbon footprint. Experience from the Nordic water sector is that this is possible, but not easy and will indeed challenge the ways we are working today. There will be situations, in which we need to phase out technologies that have proven to have a high carbon impact. We need to take a holistic look at our resources and assets and cooperate with other sectors to achieve our goals.

This report presents common principles for working towards a climate neutral water sector that can be useful as a guidance all over the world, even if all countries must find their specific road towards climate neutrality.

With this report we further demonstrate that it is possible to set ambitious targets, measure emissions and monitor progress.

With data from 12-16 utilities from four Nordic countries we present their recording of emissions within key elements of their activities such as energy consumption, transport, energy recovery, sludge disposal, drinking water treatment. It is possible to follow emissions within wastewater, water works and sewers and monitor closely, where main emissions are, where to focus measures and when to become climate neutral in the utilities, individually and for the sector.

Finally, to reach our common goal, we need to share experiences and learn from each other on technologies, methods, reporting, benchmarking systems and other ways to move towards a climate neutral water sector. This report presenting our common principles and selected cases from utilities working towards a climate neutrality is an important step in this direction.

We look forward to sharing our experience and working together jointly in EU and other international fora to move the European and global water sector towards ambitious climate targets.

Carl-Emil Larsen	Osmo Seppälä	Thomas Breen	Pär Dalhielm
DANVA	FIWA	Norwegian Water	Swedish Water
DANVA	FIWA	Norsk Vann	SvensktVatten

Background and method

The overall objective of this report is to reach a common understanding of national climate accounting models and to create common principles for making climate accounting models for the water sector in the Nordic countries.

The overall aim is not to create one common Nordic model since all countries are already working on their respective national models, but to reach a common understanding of national CO_2 models and to propose common principles for making climate accounting models for the water sector in the Nordic countries. The principles are also highly relevant for the global water sector if they aim to become climate neutral.

Thus, the Nordic Water and Wastewater Associations asked EnviDan to assist with this project on climate mitigation in the Nordic water sector. The water sector is defined as both water supply (water works), transportation of wastewater (sewage system) and wastewater treatment (wastewater treatment plants).

The four Nordic Water and Wastewater Associations: DANVA - Danish Water and Wastewater Association, FIWA - Finnish Water Utilities Association, Norsk Vann - Norwegian Water and Svenskt Vatten – Swedish Water and Wastewater Association are national associations representing the four countries' water and wastewater utilities. We act on behalf of our members, mainly municipal water and wastewater utilities and water utilities in public ownership.

Our members supply drinking water, manage, and treat wastewater and discharge this into recipients and are responsible for stormwater management and climate change adaptation in cooperation with other actors in the water sector. Some are multi-utilities, who are also responsible for solid waste, district heating and cooling or other supply related tasks. The four water sector associations represent more than 11,1 million households and more than 1,9 billion m^3 sold water.

The focus in the project is on the operational phase, which was chosen due to simplicity. The supply chain and the construction and demolition phases have significant emissions, and these phases could be included at a later stage.

In general, all the included parameters in reporting tools include both emissions and avoided emissions. Avoided emissions are defined as emissions that are avoided due to substitution of a product/process, that would otherwise have been emitting emissions (e.g., substitution of electricity from the national electricity grid by generating electricity from biogas).

Greenhouse gas emissions are commonly categorized into three Scopes:

Scope 1: covers direct emissions from a company's activities (e.g., CH_4 and N_2O emissions)

Scope 2: covers indirect emissions from the generation of purchased electricity, steam, heating/cooling consumed by the company

Scope 3: includes all other indirect emissions that occur in a company's value chain.

This report covers all three scopes but does not take everything into account. Full overview of all GHG-emission on all three scopes can be a task for future joint activities.

One of the focus points in this report is to ensure that as much as possible is included in the reporting, but at the same time keeping the models simple and easy to operate. The overall purpose in this context is to mitigate CO_2 emissions. To do that, it is necessary to make reliable reports on the CO_2 emissions and monitor activities. When this report refers to CO_2 emissions from the sector, we are in most cases referring to all emissions from the sector, meaning that CH_4 and N_2O emissions are included and calculated into CO_2 equivalents to do so.

EnviDan has facilitated interviews with the water sector associations in the four biggest Nordic countries, namely DANVA, Svenskt Vatten, Norsk Vann and FIWA. The first interviews were conducted in June 2021 with follow-up talks in August 2021. A common meeting with all stakeholders was held on 26th August to discuss relevant questions. Based on the interviews and the common meeting, the initial report was prepared.

DANVA organized a workshop during the NORDIWA – Nordic Wastewater Conference in the end of September 2021 on climate neutrality in the water sector. The work that is described in this document was presented and 3 groups were discussing the content. The outcome from these discussions is also incorporated into this document.

Following this workshop and based on input from the four Nordic directors it has in the spring of 2022 been decided to supplement Part I of the report with a Part II that describes the Nordic climate accounting models in further detail and presents an overview of the different countries' climate accounting models.

Then the accounting models have been tested in 12-16 utilities in the four countries to verify if it is possible to use the models for accounting and presenting an overview of the climate emissions and of tracking progress towards reducing emissions. This is presented in part 2 of this report.

The climate accounting models are under development in all countries but are at this stage ready to be presented for a discussion on how to use, disseminate and improve the models at the World Water Congress & Exhibition in Copenhagen and in other relevant global and European water sector events within the next year.

Based on these discussions we will continue working together to improve the methods and share knowledge on climate accounting in the Nordic countries and how our experience and lessons can benefit the global water sector.

The 12-16 participating utilities are all existing utilities from the Nordic countries, not theoretic cases, but have chosen to be anonymous while the models are under development. From the Nordic water sector associations, we look forward to next step in our cooperation, where we will be finalizing the models and presenting the public data in a non-anonymous form.

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Part I Nordic principles for a climate neutral water sector

1. Greenhouse gas emissions in the Nordic water sector

Globally, the Kyoto protocol and Paris agreement are examples of international agreements in mitigating Greenhouse gas (GHG) emissions of which Denmark, Sweden, Norway, and Finland are participants. Based on these initiatives, the yearly GHG emissions are reported as part of the GHG monitoring process. For example, the Kyoto protocol obliges participating countries to establish a national system for monitoring GHG emissions. The Inter-Governmental Panel on Climate Change (IPCC) also developed guidelines for countries to estimate their GHGs.

Following the overview below, a short status on GHG emission reporting in the Nordic water sector (Denmark, Sweden, Norway, and Finland) is presented in the following sub-chapters.

Water sector emission estimates

The emissions from the water sector have been estimated in more detail in all countries. The estimates are presented in Table 1. The estimated emissions are quite similar in Denmark and Norway, lower in Sweden and significantly higher in Finland (per inhabitant). The reason for the high number in Finland, is likely because the Finnish estimate is made approximately 10 years earlier than the Danish and Norwegian.

Table 1. Overview of GHG emissions estimates for the four Nordic countries for the entire water sector.

Parameter	**Denmark**	**Sweden**	**Norway**	**Finland**
Estimated for year:	**2017**	**2019**	**2019**	**2007**
Total emission estimates	218.000 t CO_2	*228.000 t CO_2	**185.000 t CO_2	310-400.000 t CO_2
Inhabitants	5,8 mio. inh.	10,1 mio. inh.	5,4 mio. inh.	5,5 mio. inh.
Inhabitants connected to municipal and/or public water & wastewater systems	5,6 mio. inh. (water) 5,2 mio. inh. (wastewater)	9 mio inh.	4,8 mio. inh. (water) 4,7 mio.inh. (wastewater)	4,8 mio inh. (water) 4,5 mio inh. (waste water)
Emission estimate/inhabitant	38 kg CO_2/inh.	23 kg CO_2/inh.	34 kg CO_2/inh.	56-73 kg CO_2/inh.
Total national emissions***	61 mio. t CO_2/år (2020)	51 mio. t CO_2/år (2019)	49 mio. t CO_2/år (2020)	48 mio. t CO_2/år (2020)
Total national emissions, 1990	77 mio. t CO_2/år	71 mio. t CO_2/år	41 mio. t CO_2/år	71 mio. t CO_2/år
Contribution from water sector of national emission	0,4 %	0,4 %	0,4 %	0,6-0,8 %

*Covers only sludge handling and wastewater treatment
**Calculated based on a 2019 estimate of 740.000 t CO_2, which included buildings and infrastructure (estimated at 75 % of total emissions).
**(Energistyrelsen, 2021a) / (Naturvårdsverket, 2019) / (Energi og Klima, 2020) / (Tilastokeskus, 2020)

Denmark

In the 80's and 90's the primary focus of the wastewater sector in Denmark was reduction of nutrient discharge to rivers, lakes, and the ocean. In the 00's and 10's the focus shifted to energy efficiency, but it was only the biggest and most ambitious utilities that were working dedicated to becoming energy neutral. Marselisborg WWTP in Aarhus, Denmark already reported energy neutrality in 2012. During the 10's the new trend became carbon efficiency and the importance of becoming CO_2 neutral now seemed to be more important than being energy neutral. This has put a very large focus, also politically, on climate mitigation, not only in the wastewater sector, but in the entire water sector, and knowledge on especially direct emissions of nitrous oxide and methane is very much in demand.

Denmark has reported GHG emissions from all sectors since 1990 in the yearly published "National Inventory Report". The report contains detailed information about Denmark's inventories for all years from 1990 to 2019. The structure of the report is in accordance with the IPCC reporting guidelines. It is, however, not possible to extract total emissions from the water sector since it is incorporated in several different sectors.

In Denmark, DANVA prepared a guidance for "CO_2-accounting for utilities" in 2012. This report came with recommendations and guidelines but no direct model and therefore each company could create their own model. Some companies made their own climate reports, but they are very different.

In 2018 DANVA started a working group with the primary goal to create a 2-level model for CO_2-accounting for water companies with an overall simple model to be useful for all companies and a more detailed for the more ambitious companies. The aim is to have this model included in the Danish national performance benchmark system so that water companies can use this for reporting for the ministries, the municipalities, and the public. The Danish performance benchmarking system has been compulsory for all water utilities since 2010.

In December 2019, a broad majority in the Danish Parliament reached an agreement on a new climate law for Denmark, which will replace the existing one from 2014. The new climate law includes binding sub-goals every five years towards a goal of climate neutrality by 2050. In June 2020, the law was implemented. On the short run, Denmark must reduce the emissions of GHG by 70 % by 2030 (from the level in 1990).

In 2019, the Danish Government invited Danish businesses to participate in 13 climate partnerships in different industries. The businesses should come up with suggestions on how to reduce GHG emissions and thus live up to the Governmental goals, and thereby become a pioneer for the rest of the world's green transition

In June 2020, a new climate plan (Climate plan for a green waste sector and circular economy), was implemented. In the water sector, a so-called Paris model was established by the Danish Environmental Protection Agency (EPA) (Miljøstyrelsen, 2020a). In the model, the water and wastewater utilities subject to the Danish Water Sector Act (Vandsektorloven and 330 companies in 2019) were urged to report their ambitions in relation to energy consumption, energy production and CO_2 emissions for the next 15 years to the Danish EPA. The "result" of the Paris model was a very ambitious goal for the water sector of being climate neutral in 2030.

The climate plan introduced a new limit value for N_2O emissions from WWTPs larger than 30.000 PE that must be implemented before 2025. The goal might be followed by N_2O taxes in a not-too-distant future. The overall goal is to decrease the total direct N_2O emissions by 50 %. Based on a new report about emissions from biogas plants, which shows that the methane emissions are 5 times higher than expected, the Ministry of Energy has announced, that they want to introduce some kind of regulation to lower the emissions in the coming years.

The Paris model is a good starting point for a GHG-emission model for Denmark. But it probably needs to be elaborated during the next years. The model will be slightly modified in the coming years concerning energy accounting and we need somehow to include emissions from sludge disposal. Furthermore, we need to find a way to handle the future carbon capture solutions.

The Paris model includes the parameters that are shown with green dots (●) in Table 2. Red dots (●) are parameters that are not included.

Sweden

In 2017, Sweden adopted a climate policy framework. The framework consists of a climate law, climate goals and a climate policy. The long-term goal is that Sweden will have no net emissions of greenhouse gases by 2045. Interim targets for 2030 and 2040 is to lower the emissions by 63 percent respectively 75 percent compared to the level in 1990.

Sweden has reported greenhouse gas (GHG) emissions from all sectors since 1990 in the yearly published "National Inventory Report". The calculations of GHG emissions are carried out in accordance with the IPCC's reporting guidelines. The national inventory report shows that emissions from solid waste and wastewater treatment corresponds to approximately 2 percent of Sweden's total greenhouse gas emissions. Emissions included in the national reporting are:

- CH_4 from landfills
- N_2O and CH_4 from wastewater treatment and sludge
- N_2O and CH_4 from biological treatment of solid waste
- CO_2, N_2O and CH_4 from the incineration of hazardous waste (for destruction)

Emissions from wastewater and sludge treatment alone were 228,000 tons CO_{2e} in 2019, which accounts for 21 percent of the total emissions within the waste treatment sector. In 1990 reported emissions from wastewater and sludge treatment were 263,000 tons of CO_{2e} and the amount has since then continuously decreased. *(Note: The reported emissions of 228,00 tons of CO_{2e} are only including emissions from WWTPs that have 2000 or more people equivalents (PE) connected. This means that emissions from the smaller WWTPs and water works are not included in the national statistics)* (Naturvårdsverket, 2021).

On a national level, there are currently no specified targets set for the water sector. However, several organizations/utilities have already set their own targets and it is especially the larger utilities that are leading the way. The Swedish water sector has worked with energy efficiency projects and less carbon emissions for many years, but the sector is still a little behind compared to the general development of carbon neutrality in Denmark.

Svenskt Vatten recently (2021) made a board decision on a goal for climate neutrality in 2030 for the operation phase of the Swedish water sector. In addition to this, a project aiming at developing a common methodology for reporting and monitoring the sector's climate emissions started in autumn 2020. The aim of the work is to ease the climate effect calculation work for Svenskt Vatten's members as well as to facilitate comparison, cooperation, and benchmark.

Svenskt Vatten's research branch (Svenskt Vatten Utveckling (SVU)) has previously supported the development a model for reporting of GHG emissions in WWTPs (Excel spreadsheet, Svenskt Vatten Utveckling, 2014 and 2021). The model is academic and detailed and Svenskt Vatten's ambition is to make the new model simpler and to also include GHG emissions from water works.

Svenskt Vatten has a statistical benchmarking system for reporting data and calculating key indicators, called VASS (VASS, 2016). In VASS both mandatory and voluntary data are reported in many different fields. Consumption of energy and chemicals and production of energy (biogas) is currently included in VASS. GHG emissions are not included in VASS now, but this could be a possibility for the future. Every WWTP in Sweden yearly also sends in an environmental report to the Swedish Environmental Protection Agency including data on consumption of energy, chemicals, and other resources. GHG emissions are however not included in the environmental reporting either.

Parameters included in the previously developed SVU-model is presented in Table 2.Included parameters are shown with green dots (●) Red dots (●) are parameters that are not included.

Since the new Svenskt Vatten model for climate accounting is currently in preparation, it has not been included in the table.

Norway

Norway has committed to reducing greenhouse gas emissions by 50-55% by 2030, as compared to 1990.

In 2019, Norway´s total emissions were 49,3 mill tonnes CO_2-equivalents. 0,11 % of this came from sewage and wastewater treatment, and 0,08% from composting and biogas production.

Some utilities studied GHG emissions in the late 1990´s, with a focus on N_2O-emissions from nitrogen removal. Since 2014, water utility HIAS has reported GHG emissions.

In 2017, the General Assembly of Norsk Vann approved a Sustainability Strategy, stating that the water industry must take its share of the responsibility by helping to reach the national GHG goal. Following this strategy, a guideline, and a reporting tool in Excel-format for reporting GHG emissions from the Norwegian water sector was presented and tested in 2019. The reporting tool includes both direct and indirect emissions (scope 1,2 and 3), and covers water treatment, transport systems and treatment of wastewater.

Data from the Sustainability Strategy is reported and integrated into Norsk Vann´s benchmarking system called BedreVANN, working as tools for participating municipalities and the companies' work to reduce emissions. The measurements are also important for following up the implementation of the sectors' overall action plan. BedreVANN has performed annual benchmarking of municipal water utilities since 2003. Participation is optional.

The reporting tool is quite detailed, and it includes all the parameters that are shown with green dots (●) in Table 2. Red dots (●) are parameters that are not included.

The model is currently used by many of the largest municipalities and utilities in Norway.

The Norwegian reporting tool is the only one that includes emissions related to construction and production of materials (scope 3). A revised Sustainability Strategy will be established in 2022, and the GHG reporting tool will be evaluated and possibly revised.

Finland

From the 70's the primary focus in the wastewater sector in Finland has been reduction of phosphorus and BOD discharge to lakes, rivers, and the Baltic Sea. Since the mid-90's attention has also been paid to nitrogen removal.

The Finnish Climate Change Act from 2015, stated that: "The goal of the planning system for climate change policy is to ensure that the total anthropogenic emissions of greenhouse gases into the atmosphere are reduced in Finland by at least 80 per cent by 2050 compared to 1990 levels" (Climate Change Act, 2015).

The Ministry of the Environment has 2nd July 2021 sent a proposal for a new climate law for a round of opinions. The aim of the reform is to ensure that Finland achieves carbon neutrality in 2035 in accordance with Sanna Marin's government program (Valtioneuvosto, 2021).

The plans in the Climate Act guide Finland's national climate policy. The plans will help ensure that national climate change mitigation and adaptation targets are met.

Based on the proposal, the target of Finland being carbon neutral in 2035 would be added to the law. This target also takes into account emission sinks. The law would also include emission reduction targets in line with the climate panel recommendations: a 60% emission reduction target for 2030 and an 80% emission reduction target for 2040, compared to 1990 levels. The 2050 target contained in the current climate law would be updated to 90% of 1990 levels but aiming at 95%.

The reform of the Climate Act guarantees that Finland will act decisively to stop the climate crisis and play its part in achieving the goals of the Paris Agreement. The carbon neutrality target 2035 is enshrined in law and thus confirmed as the target for Finland as a whole. The law's emission reduction targets have been set in accordance with the recommendations of the Finnish Climate Panel. The goal is to reduce emissions by 60 percent by 2030. New climate change Act entered into force on 1 July 2022.

The land use sector plays an important role both in causing and controlling emissions. A key reform of the planning system would be to include the land use sector in the climate law. The plan for the land use sector would become a new plan in accordance with the Climate Act.

Based on the Kyoto Protocol and the IPCC guidelines, Finland established its own national Greenhouse Gas Inventory System in 2005. Apart from this no initiatives have been implemented specifically for the water sector on a national scale.

On a regional scale, the Finnish Ministry of the Environment implemented the "Municipal Climate Change Solutions Programme (2018–2023)" to boost GHG mitigation in municipalities. The Ministry of the Environment emphasized the importance of municipalities as key players in facilitating and improving regional climate work. Thus, the collective monitoring and quantification of GHG emissions in municipalities are important for the country to meet its national GHG mitigation targets.

The Towards Carbon Neutral Municipalities (Hinku) network brings together municipalities, businesses, citizens, and experts to create and carry out solutions to reduce greenhouse gas emissions. The municipalities involved are committed to reduce greenhouse gas emissions more extensively and rapidly than EU targets require. The network aims at creating solutions that have economic and social benefits as well as environmental advantages. Some Finnish regions are also involved in the Hinku network. The network is coordinated by the Finnish Environment Institute (SYKE). The municipalities in the network are committed to an 80% reduction in greenhouse gas emissions from 2007 levels by 2030.

Now, there are 80 Hinku municipalities and five Hinku regions in the network, all committed to the same emission reduction target. Since water utilities are either part of municipal organization or owned by municipalities, reduction activities by Hinku network concern utilities as well. A large group of Hinku companies and experts are also involved as partners (Hinku, 2021).

A regional calculation model known as "ALas" was developed to calculate the emissions from municipalities and regions in Finland. This model is in accordance with the IPCC (2006) guidelines, of which Finnish GHG reporting is based on. The results of the calculation based on the ALas model showed an average GHG decrease of 15% for municipalities in 2018 compared to 2005.

In 2009 FIWA ordered a master's thesis aiming to find out the magnitude of the greenhouse gas emissions resulting from the functions of Finnish water and wastewater utilities and to find ways to reduce those emissions. The focus was on three greenhouse gases considered the most essential ones evolving from the activities of water and wastewater facilities – fossil CO_2, CH_4 and N_2O. Both the emissions resulting from energy use as well as the fugitive emissions from wastewater and sludge treatment were considered. Elements requiring life cycle assessment, e.g., the energy demand of chemicals production, were left outside the scope of the work.

FIWA has a recent new strategy, that aims at Finland having "the world's best functioning water services" by 2030. The first step is to create a "roadmap for emissionless water sector" (2021-2023) and then to have a carbon neutral water sector (2028-2030).

There are no models for reporting the GHG emissions in the Finnish water sector. However, some utilities have started to make CO_2 balances. A LCA study was carried out at the biggest WWTP in Finland and here N_2O were also measured.

Finland has a KPI-system, called Venla. The KPI-system administered by FIWA is connected to the national water information system called Veeti, administered by the Ministry of Agriculture and Forestry of Finland and operated by the Finnish Environment Institute. This connection allows some of the data to be transferred directly from the latter into FIWA's KPI system. Therefore, the basic data included in both systems will only be entered to Veeti and then automatically transferred into FIWA's system. Venla has two different levels: broader (subject to charge) and a narrower one, which FIWA offers as a member service (free of charge).

FIWA is considering a new reporting tool for CO_2 in the water sector.

2. Similarities and differences in greenhouse gas emission reporting

All Nordic countries have a national benchmarking system, which includes a lot of valuable data. However, for climate accounting a lot of important information is still lacking, which means that none of the Nordic countries have a full overview of the total GHG emissions from the water sector.
To secure reduction of GHG emissions we need to know current status and be able to follow progress. All the Nordic countries are working thoroughly on systems that can report GHG emissions from the water sector. Some systems are already implemented, others are not yet. There are some variations in what will be included and, as important, what is not included. A common goal for the Nordic countries, is however, to create functional and relatively simple models, that can easily be applied by the water utilities and can be included in benchmark systems for the water sector.

An overview of the parameters that are included in the Nordic countries' models (or principles) is presented in Table 2. There are many similarities, especially in relation to consumption of energy and emissions of N_2O from the biological processes and in the effluent. But there are also quite a few differences in the different models. The overview in Table 2 is based on different initiatives in the four Nordic countries. Sweden and Finland are working on a setup for new models, so they are not included in the table.

An elaboration is provided in Section 1 with description of the status in each country and a short version is stated here:

Denmark: The Danish overview is based on the Paris model for the water sector (from the Danish EPA), where all water utilities are urged to report GHG emissions and ambitions on mitigation (Excel reporting tool).

Sweden: Sweden has initiated work on a national model, but the elements are not ready to be shared yet. Svenskt Vatten Utveckling (SVU) supported the development of an Excel GHG emission model in 2014. This model has been included for comparison (Svenskt Vatten Utveckling, 2014).

Norway: The Norwegian overview is based on a guideline and a reporting tool (Excel format) that was developed by Norsk Vann.

Finland: Finland has initiated work on a national model, but the elements are not ready to be shared yet.

Table 2. Overview of the parameters that are included in the Nordic countries' water sectors' climate models or future climate models. Red marked parameters indicate emissions, Green marked parameters indicate avoided emissions. Green dots (🟢) = included; Red dots (🔴) = not included.

	Parameter	**DK**	**SE (SVU) *****	**N**	**FI**
WW	Consumption of electricity and heat	🟢	🔴	🟢	*National work has not been initiated yet*
	Consumption of chemicals	🔴	🔴	🟢	
	Handling of residues	🔴	🔴	🔴	
	Transportation	🔴	🔴	🟢	
	Afforestation (to protect groundwater)	🟢	🔴	🔴	
	Other CO_2 reducing activities*	🟢	🔴	🔴	

Sewers	Consumption of electricity and heat	🟢	🔴	🟢	
	Production of pipes	🔴	🔴	🟢	
	Construction	🔴	🔴	🟢	
	Handling of filter materials	🔴	🔴	🟢	
WWTP	Consumption of electricity and heat	🟢	🟢	🟢	
	Consumption of fuel (diesel)	🔴	🟢	🔴	
	Sold energy (electricity, heat, biogas)	🟢	🟢	🟢	
	Consumption of chemicals	🔴	🟢	🟢	
	Consumption of filter materials	🔴	🔴	🟢	
	Sludge handling	🔴	🟢	🔴	
	Transportation	🔴	🟢	🟢	
	CH_4 emissions (biogas)	🟢	🟢	🔴	
	N_2O emissions (process)	🟢	🟢	🟢	
	N_2O emissions avoided**	🟢	🔴	🔴	
	CH_4 from septic tanks	🟢	🔴	🟢	
	P recycling (subs. of virgin P)	🔴	🟢	🔴	
	N_2O emissions, effluent	🟢	🟢	🟢	
	Emissions, use of sludge	🔴	🟢	🔴	
	Avoided emissions, use of sludge	🔴	🟢	🔴	
	CH_4 emissions, effluent	🔴	🟢	🔴	
	Carbon binding	🔴	🟢	🔴	

*: e.g. further new reduction measures in relation to N_2O emissions from WWTP, wetlands in connection with tariff-financed climate adjustment, technologies for carbon storage, collaboration with external partners on installation of heat pumps.
**: this is a theoretical calculation on the emission that is avoided by having the WWTP.
***: New simplified model under development

3. Inclusion of the most important parameters in climate accounting models

When assessing GHG emissions from the water sector there are a quite a few parameters to assess. It might not be possible to include all parameters in a climate accounting model, due to very time-consuming data gathering for some parameters. Therefore, it might be relevant to look at the most important parameters.

When looking at the entire water sector, most of the GHG emissions stems from wastewater treatment (WWTP). The sewer systems almost only contribute with electricity consumption for pumping of water and the contributions from treatment of water (WW) is also only minor.

In climate accounting models, it is important to find a balance between including as many parameters as possible, but at the same time keeping it as simple as possible.

To find this balance, a few different criteria has been assessed for each of the emissions and avoided emissions. The criteria are:

1) <u>Data availability</u>:

Is data easily available, e.g., already a part of the benchmarking system in the specific country? Or is it necessary to use standard emission factors (EFs) to estimate the contribution.

2) <u>Importance (contribution)</u>:

How much does the parameter (typically) contribute to the total GHG emission from the water sector? This criterion might differ depending on regional or local conditions, e.g., the choice of electricity mix (country specific, Nordic, European) effects the EF of electricity production.

All emissions and avoided emissions that were presented in Table 2 are shown in Table 3 together with an evaluation of the two abovementioned criteria. Based on the criteria, a suggested "result" is shown also. The result indicates whether a parameter:

- Should be included in climate accounting models
- Should be excluded in climate accounting models
- Is uncertain, and should be discussed further

These indications are only suggestions, and should be discussed further between EnviDan, DANVA, Svenskt Vatten, Norsk Vann and FIWA.

Table 3 also includes a few "new" parameters, which has not been introduced in Table 2. These are parameters that are not included in any of the initiatives from DANVA, Svenskt Vatten, Norsk Vann and FIWA, but where recent research has shown that they may have a significant contribution and/or where new reporting methods are developed. These parameters are for instance methane from sewer systems and wastewater and chemicals in sewer systems. These could be interesting to include in an improved future model for GHG reporting.

When considering future GHG-reporting, it would be beneficial to have 2 levels of ambition, so 1 basic level, that would suit all utilities and 1 optional level for the more ambitious utilities.

Table 3. Assessment of data availability and importance for all contributions to GHG emissions. The "Result" is the suggested parameters for inclusions in a future common GHG emissions model for the Nordic water sector. Green dot (🟢) = included (importance ≥ medium), Red dot (🔴) = not included, yellow dot (🟡) = uncertain. WW: water works; WWTP: wastewater treatment plants.

	Parameter	Data availability	Importance	Comments	Suggested result
WW	Consumption of electricity and heat	Good	Medium	Typically, low consumption, easy to evaluate	🟢
	Consumption of chemicals	Good	Low / Medium	Typically, low consumption, easy to evaluate	🟢
	Handling of residues	Good	Low	Typically, low production, easy to evaluate	🔴
	Transportation	Good	Low	Typically, low contribution, easy to evaluate	🔴
	Afforestation	Medium	Medium	Not a typical parameter for the water sector, but might be relevant	🟡
	Other CO_2 reducing activities	Variable	Medium / High	New reduction measures in relation to N_2O emissions from WWTP. Important to reach climate neutrality	🟢
Sewers	Consumption of electricity and heat	Good	Medium	Typically, relatively low consumption, easy to evaluate	🟢
	Production of pipes	Not relevant, since the focus is on the operation phase			
	Construction	Not relevant, since the focus is on the operation phase			
	Handling of filter materials	Good	Low	Typically, low consumption, easy to evaluate	🔴
WWTP	Consumption of electricity and heat	Good	Medium / High	High consumption, but varying EF for production, e.g., high in Denmark, low in Sweden.	🟢
	Consumption of fuel	Good	Low	Typically, low consumption, easy to evaluate	🔴
	Sold energy	Good	High	Typically, high amount, easy to evaluate	🟢
	Consumption of chemicals	Good	Medium / High	Variable amounts, e.g., low chemical consumption in Denmark, high in Sweden. Easy to assess.	🟢
	Consumption of filter materials	Good	Low	Typically, low consumption, easy to evaluate	🔴
	Sludge handling	Medium	Medium / High	Typically, low contribution, relatively easy to evaluate	🟢
	Transportation	Medium	Low	Typically, low contribution, but might be tricky to evaluate transportation distances (e.g., for sludge disposal)	🔴
	CH_4 emissions (biogas)	Low*	High	High contribution, typically. Bad data availability unless the emissions are measured at the specific WWTP	🟢
	N_2O emissions (process)	Low*	High	High contribution, typically. Bad data availability unless the emissions are measured at the specific WWTP	🟢
	N_2O emissions avoided	Not relevant, since the focus is on the operation phase			
	CH_4 from septic tanks	Medium	Medium	Significant contribution, but variable importance due to variations in number of septic tanks in different areas	🟡
	P recycling (subs. of virgin P)	Medium	Low	Typically, small amounts of recovered P	🟡
	N_2O emissions, effluent	Low	Medium	Not a lot of specific data, but might be significant	🟡
	Emissions, use of sludge	Variable	Variable	Large variations depending on the use (use on land, incineration, pyrolysis etc.). Significant contribution	🟡
	Avoided emissions, use of sludge	Variable	Variable	Large variations depending on the use (use on land, incineration, pyrolysis etc.). Significant contribution	🟡
	CH_4 emissions, effluent	Medium	Medium	Not a lot of specific data, but might be significant	🟡
	Carbon binding	Medium	Medium	Not a lot of specific data, but might be significant	🟡
New	CH_4 from sewer systems	Low	Low / Medium	Not a lot of specific data, but might be significant	🟡
	CH_4 from WW	Low	Low / Medium	Not a lot of specific data, but might be significant	🟡
	Chemicals, sewer	Good	Low	Typically, low consumption, relatively easy to evaluate	🔴

Examples of variation in emission factors

Some of the most important and very varying parameters regarding climate accounting models are N_2O emissions from the biological treatment in the process tanks at WWTP (including reject water treatment) and CH_4 emissions from the biogas and sludge systems.

Only few WWTPs are measuring specific emissions and even when this is the case, there are still some issues with the different measuring technologies and estimation of emissions. So, in many cases standard EFs are used when reporting N_2O and CH_4 from WWTPs.

Table 4 shows some EFs that are used in the Nordic countries. As an example, the Danish EF for direct N_2O emissions have until recently been 0,32 % N_2O of the total N input to the WWTP. This factor has been reported in the National GHG inventory for Denmark in many years. The EF is an average value of two measuring studies, performed in the US and Germany. Both studies are published in 1995 and is not considered very representative of emissions at Danish WWTPs. In 2020 a measuring study was performed in Denmark at 9 WWTPs and a new EF of 0,84 % was established (Miljøstyrelsen, 2020b). The EF still has a very high standard deviation, so the variations in emissions are quite substantial. Thus, actual measurements of N_2O at WWTPs are still highly recommended.

Table 4. Examples of EFs used in the Nordic countries and the IPCC EF for comparison.

Parameter	IPCC, 2019	Denmark	Sweden (SVU)	Norway	Finland
Direct N_2O emissions	1,60 % of TN_{in}	0,32 % (0,84 %*) of TN_{in} 0,84 % = ~0,96 % of N(DN)	0,0157 kg N_2O/kg N(DN) 1,57 % of N(DN)	0,031 kg N_2O/kg N(DN) 3,1 % of N(DN)	0,0181 kg N2O/kg N(in)***
CH_4 emissions (biogas)		1,3 % (7,5 % / 7,7 %**)	2,1 %	0 %	

*A new EF of 0,84 % is available, but not yet official in the Paris model.

**Scheutz and Fredenslund (2019) measured total CH_4 emissions from biogas plants at WWTPs and here the emissions were estimated at 7,5 % of the total production (this number however includes all fugitive emissions from the process, sludge storage, gas system etc.). A recent published study of more than >50 % of the WWTPs in Denmark with biogas production, showed similar emissions of 7,7 % (Energistyrelsen, 2021b).

***Viikinmäki WWTP year 2020

In Finland Viikinmäki WWTP in Helsinki is situated in the rock and all air emissions are collected to the pipe where N_2O emissions have been measured 2007 and 2009. Based on these measurements an EF of 0,0162 kg N_2O/kg removed N was widely used also in other WWTPs plants in EPTR-reporting. Nowadays Viikinmäki WWTP has a Gasmet FT-IR-meter in the exhaust pipe and thus it can report reliable results. During years 2018 and 2020 measured EF has been 1,82 and 1,92 % kg N2O/kg N, respectively. There can be different practices in WWTPs, e.e. Turku has used an EF of 0,001013 kg N_2O/m^3 but also calculated emissions with 0,01223 kg N_2O-N/kg N (HSY factor) and 0,016 kg N_2O-N/kg N (IPCC). Study by Kosonen published in 2016 reported 1.9% N_2O-N/ TN influent. Measurements were conducted in four WWTPs (Mikola et al., 2014)

The EF in the Swedish SVU model is derived from Australian studies from scientific papers published in 2008 and 2010, also not the most representable for Swedish conditions.

The EF in the Norwegian model is based on the IPCC values. When comparing the EFs from the different countries, it is evident that the variation is large. The EF for N_2O emissions in Norway is almost 10 times higher than the old EF in Denmark and 3 times higher than the new one. This has a significant impact on the total emission calculation. The official IPCC EF is shown in the table for comparison. In the same way, there are a lot of variations when assessing the CH_4 emissions from WWTPs.

Another example of variations in EFs is in relation to electricity consumption and production. The EFs reflects the national energy system and thus various according to the level of fossil-free energy in the energy grid. As an example, Denmark has an EF of around 130 t CO_2/GWh in 2020, with a predicted EF of <50 t CO_2/GWh in 2030. In Sweden, the electricity mix gives an EF of only 10 t CO_2/GWh. That, of course gives completely different contributions to the total GHG emissions in Denmark and Sweden.

This also means that electricity (and heat for that matter) is getting less and less important in relation to GHG emission reporting. In the near future the GHG emissions from electricity are predicted to be close to zero when only considering the operation phase.

4. Common principles for national climate accounting for the water sector

Based on our discussions, including at the NORDIWA – Nordic Wastewater Conference 2021, and the outcomes of this project, we have established set of principles to guide nations, associations and/or utilities working towards climate neutrality in the water sector. With these common principles, the Nordic countries will stand stronger when presenting the work for the rest of the EU.

The principles are:

- Cooperate and learn from each other. This is both the case for utilities and for the water industry associations in the Nordic countries. A lot of the same questions are being discussed in many places and sharing of experience between Nordic and European countries will speed up the transformation of the water sector towards climate neutrality.
- Include both water supply (water works), transportation of wastewater (sewage system) and wastewater treatment (wastewater treatment plants) to sum up emissions from the entire water sector.
- Consider including both emissions and avoided emissions (avoided emissions are defined as emissions that are avoided due to substitution of a product/process, that would otherwise have been emitting emissions.
- Consider to only include the operations level in the first phase, to make the model simpler. Emissions from construction and demolition phase are more difficult to handle but may be included in a later phase
- Start by measuring GHG emissions and establish the baseline of emissions to start reporting from.
- Develop a system for reporting emissions.
- <u>Keep the model and reporting as simple as possible while still including the most important contributions</u>. It is better to get all utilities to report GHG-emissions at a relatively low level of detail than to get very detailed data from only a few utilities.
- <u>Start with a selection of the parameters where data availability is high, and importance is medium or high (See Table 3). The exact parameters vary from country to country.</u>
- Consider dividing the model in 2 levels. 1 basic level for all utilities, and 1 more comprehensive level for the more ambitious utilities.
- The climate accounting models can be expanded over time and get more and more detailed, as more and more utilities start to report.
- Emission Factors should be defined based on latest scientific results. We need clear information on the units and how emissions are calculated,
- The reporting may be voluntary depending on national traditions, but a mandatory reporting will be stronger and give more consolidated results.
- If there is a national benchmarking system, then consider incorporating climate and energy reporting into this. In general, developing a robust benchmarking system will enable setting of common targets for the sector and tracking progress.

It is not expected that the Nordic countries will create a common Nordic climate accounting model for the water sector given the variations between countries, but the national climate accounting models can be built up using these presented common principles and based on common experience.

As an example, due to expected national targets, Denmark is quite far regarding measuring of N_2O and estimation of N_2O emissions from WWTPs. Thus, it is a good opportunity for the other Nordic countries to look at the experiences in Denmark. Information from Finnish and Swedish research projects can also be utilized and measuring experiences can be exchanged over borders. We need to build on to the already existing experiences and knowledge from all the Nordic countries.

5. Perspectives for national climate accounting models for the water sector

The aim of EU and for the whole world is to reduce the overall emissions of GHG.

The European Union is working towards a general EU goal stating that EU must:

- Reduce emissions by 55% in 2030 and
- Be carbon neutral in 2050

Examples of recent EU legislation to support this goal is the EU Taxonomy and the proposal for revision of the Urban Wastewater Treatment Directive ((UWWTD):

- The Taxonomy of the EU and the water & wastewater sector
- The delegated act of climate mitigation in the EU Taxonomy regulation (2020/852) was agreed and published on the 9h December 2021 and will be in force already from 1st January 2022. To be defined as a green investment the water & wastewater must fulfil certain requirements regarding net energy use and methane leakage, please see chapters 5.1-5.4 and 5.6 in https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2021:442:FULL&from=EN The existing UWWTD was evaluated 2018-2019 and several policy options regarding energy use and climate mitigation was presented by the European Commission in October 2021. Among them were Policy options A and B for the revised UWWTD:

Policy option A, Member States must ensure that:

iii) treatment plants >1mln p.e. improve energy efficiency including regular energy audits for their treatment plants and public networks.

iv) that levels of GHG emissions of treatment plants are monitored and reported to the Commission; mandate to fix a GHG target at the by 2030.

Policy option B. Member States must ensure that:

iii) Treatment plants >10 000 p.e. must improve energy efficiency including regular energy audits for their plants and public networks.

iii) GHG emissions of treatment plants reach climate neutrality by 2035 for treatment plants >100 000 p.e. and by 2040 for the sector.

A final proposal regarding the UWWTD will be officially presented by the European commission in October 2022.

The principles and nationally developed models represent the commitment of the water sector to do our part, to be responsible for a de-carbonized economy. The whole economy must develop in such a way that GHG emissions are minimized and that we have, eventually, a net zero economy. This will be achieved by implementing several policies and policy instruments. Examples are carbon trading systems, carbon tax etc. Still, there is a long way to go, and new policies and possible instruments might occur that we do not know of yet.

Therefore - how, when, and to what extent this will influence the different parts of the economy, including indirect emissions from e.g. energy, chemicals, concrete, other construction material, is not clear. Emissions and emission factors from biological processes is still a topic discussed among scientists and practitioners.

A possible effect of increased focus on reducing GHG emissions may be a shift towards treatment processes with less GHG emissions.

Water utilities need to consider simultaneously various goals. As stated by the directors of the Nordic water and wastewater associations there is a trade-off between different environmental targets, costs, and quality. GHG emissions are not the only problem related to environment. It is one indicator of environmental performance, and it is recommended to also assess other parameters. Some of the GHG emissions are inevitable, since we need, from a legislative and environmental point of view, to treat the wastewater. We cannot at this stage avoid e.g. consumption of energy and chemicals completely.

We may also face situations where technologies that were promising a few years ago, are now found to have too high GHG footprints and will have to be replaced by others, and we need to develop technologies and processes that are efficient on more challenges simultaneously.

When a model is established, it is very important to remember why we are doing this. The overall aim is to mitigate GHG emissions, and this can be done in a range of ways – both by decreasing emissions and increasing avoided emissions. Some of the emissions can already be decreased now, since we already have some knowledge on the large emitters. Reduction of other emissions depend on technology development, which is happening fast these years.

Here are examples of decreasing and avoiding emissions that may be relevant to consider and start with, as technologies and measurement methods are available.

Decreasing emissions:

- Lowering the energy consumption by e.g., advanced online control of aeration
- Lowering chemical consumption by e.g., enhancing bio-P activity or advanced online control of precipitation of P
- Lowering the CH_4 loss from biogas production by e.g. implementing closed sludge tank and identifying leaks in gas system
- Lowering the direct N_2O emissions from the process tanks by e.g., advanced online control of the aeration
- Considering alternatives for dedicated reject water treatment (sidestream treatment has high direct N_2O emissions).
- Investigate industrial symbiosis with nearby companies. Symbiosis in relation to electricity, heat, cooling, clean water, chemicals etc. could be of interest

Avoiding emissions:

- Implementation of heat recovery from treated effluent
- Increased biogas production by e.g., increasing the carbon harvest (this might, however, lead to increased N_2O emissions, due to lack of carbon in the process tanks)
- Make the best possible use of the produced biogas, e.g., producing upgraded biogas for vehicles instead of electricity and heat
- Make the best possible use of the sludge to substitute use of other raw materials, e.g. production of fertilizer, biochar or fuel
- Implement carbon storage technologies

6. Where to go from here

In Part I of this report, we have presented our experiences and ambitions, our common goals alongside principles and perspectives for working towards a climate neutral water sector in the Nordic countries and in Europe. This work resulted in the development of common principles and parameters that needs to be included in the development of models for a climate neutral water sector. This served at a platform for the next phase in our common project, Part II.

In Part II, we are going to test the principles and validity of the parameters, and on the recommendation of the Nordic directors, to verify if we have the data and are able to monitor emissions and track progress. This will be based on data from utilities in the four Nordic countries.

The findings in Part I have been discussed at NORDIWA - the Nordic Wastewater Conference in September 2021 and we will continue international discussions to promote progress and will be discussed again at the next Nordic Wastewater Conference in September 2023, but before that we will, together with other partners in the sector, organize a workshop during the International Water Association World Water Congress and Exhibition that will take place September 11-15, 2022, in Copenhagen.

We will also continue the discussion amongst ourselves and with European partners, in particular in EurEau and EurEau-members on securing progress towards a European climate and energy neutral water sector. In parallel we will continue to engage politicians on national and international level to support their work towards climate neutrality.

Based on our work, we highly recommend establishing robust measurements, monitoring and benchmark systems as a vehicle to move towards climate neutrality. In these years, for instance we are learning that N_20 and CH_4 are strong elements in the emissions from our sector and that they are even more critical greenhouse gasses than expected. Therefore, measuring N_20 and CH_4 is important as a first step to reduce these emissions and we will share knowledge on technologies and monitoring tools that are valuable.

We will also, jointly, within our organizations, and with our members look deeper into practical elements of reducing emissions. We will also discuss and develop the principles in this report further and discuss the different parameters and how we can work with them.

Another discussion that most likely will gain momentum in the coming years is the broader model. In this report we have, for practical reasons, limited ourselves to operations within the sector, but what about the emissions from transport, construction, and demolition? The international climate agenda is changing fast, and Scope 3 emissions and climate neutrality in the whole water cycle may well be the next step on the road to climate and energy neutrality in the water sector.

We have challenging, but also interesting tasks ahead of us and we will continue sharing experience amongst our organizations and our members, in particular on some of the more challenging areas of our activities.

We welcome all partners in the European and global water sector to contact us and take part in the discussions in Copenhagen and beyond.

Part II – Overview of Nordic climate models and examples of results from Nordic utilities

Photo: Marselisborg WWTP, Aarhus

1. Introduction

This is Part II of the report "Nordic principles for a climate neutral water sector", a collaboration between EnviDan and the four Nordic Water and Wastewater Associations: DANVA - Danish Water and Wastewater Association, FIWA - Finnish Water Utilities Association, Norsk Vann - Norwegian Water and Svenskt Vatten – Swedish Water and Wastewater Association. Part II consist of an overview of Nordic climate models and examples of results. Part II is work in progress, since not all data has been 100 % verified and the results must thus be considered to be preliminary. However, the results give a very good insight in the use of climate models and a comparison between climate accounting at utility and country level. The content of Part II of the report will be elaborated and finished after the IWA congress in Denmark in September 2022.

Part I describes the background of the project and presents the common principles for national climate accounting for the water sector, which were agreed upon in the working group. It also sums up all the relevant parameters for inclusion in climate accounting models, which is gathered in one large table in the Part I report (see Table 3).

Based on Table 3, the project group has identified the most relevant parameters to include in climate accounting models (see Table 5, Table 6, and Table 7). Part II is based on these parameters and their role in each of the climate accounting models in the four Nordic countries.
It is important to emphasize that the focus of the project is the operational phase, so no emissions related to the construction and demolition phase are included. The included parameters include both emissions and avoided emissions. Avoided emissions are defined as emissions that are avoided due to substitution of a product/process, that would otherwise have been emitting emissions (e.g. substitution of electricity from the national electricity grid by generating electricity from biogas).

The parameters that are included in the report are divided in 3 categories: 1) Water works / drinking, 2) Transportation / sewer system, and 3) Wastewater Treatment Plants.

One of the focus points in this report is to ensure that as much as possible is included in the reporting, but at the same time keeping the models simple and easy to operate. The overall purpose in this context is to mitigate CO_2 emissions. To do that, it is necessary to make reliable reports on the CO_2 emissions and monitor activities. When this report refers to CO_2 emissions from the sector, we are in most cases referring to all emissions from the sector, meaning that CH_4 and N_2O emissions are included and calculated into CO_2 equivalents to do so.

The overall aim of this Part II of the report, is to compare the differences in the climate accounting models from each country. The aim is not to make a common model, but to show real data as basis for fruitful discussions on how to become even better at reporting, and hence implementing reduction initiatives in the future.

In the following sections, an overview of the content and the differences in the climate models from the four Nordic countries are presented:

- Short description of the models from each country
- Overview of the content of each model
- Detail comparison of which data is included, and which emission factors are used in each country

2. Short description of the models from each country

Each of the four Nordic Water and Wastewater Associations has been asked to describe the actual national models of climate accounting or alternatively the status of the work in the specific country.

Sweden

The Swedish climate accounting model is constructed in a way that water utilities in an easy way can calculate the climate impact from the operational phase of drinking water production plants, wastewater treatment plants and their respective sewer systems. The model is constructed in Excel and based on life cycle assessment calculations and include both direct and indirect emissions. Example of indirect emissions are emissions connected to the production and transportation of chemicals used in the processes and emissions connected to handling of wastes and by-products from the processes.

Currently, only emissions related to the direct operation of the processes are included but the model will be extended to also include the building phase of the processes. The model is based on the Greenhouse gas protocol structure but does not follow the structure fully to 100%, since parts not related to the operations of the processes such as business trips and investments are not included. The results of the model are presented in two separate tables, one presenting the generated emissions and one presenting the avoided emissions.

Links to relevant reports from Sweden:

- About the climate neutrality ambition: https://www.svensktvatten.se/medlemsservice/klimat-neutral-va/
- About the climate accounting model: https://www.svensktvatten.se/medlemsservice/klimatneu-tral-va/klimatberakningsverktyg/

Norway

The Norwegian climate accounting model was developed as a result of The Sustainability Strategy for the Water Sector, that was adopted by the Annual Meeting of Norsk Vann in 2017. The strategy included a goal stating that by 2020, as many utilities as possible, shall provide climate change accounts. All data from the Strategy are reported and integrated into the benchmarking system bedreVANN (better water). The climate accounting model is developed in Excel, and was first tested on 2019 data in eleven utilities. From 2020, the model has been further developed, and the updated tool were used by the utilities for reporting. The model includes both scope 1, 2 and 3 from the IPPC protocol.

The model consists of two main parts, one simple and one advanced. The simple model is based on the mandatory economic data each municipality or utility must report to the national authorities. GHG emissions are then calculated based on these data. For the advanced model, the utilities must provide detailed information on both investments and the operational phase of drinking water production plants, wastewater treatment plants and the sewer systems. This includes e.g., use of energy and chemicals, transportation, and pipes for the network.

Finland

There are no national models for reporting the GHG emissions in the Finnish water sector yet. GHG emission calculations from Finland in this document are provided as two case studies that cover water and sanitation services of regional utilities: Helsinki Region Environmental Services Authority (HSY, referred to as **a**) and Hämeenlinnan Seudun Vesi Oy (HS-Vesi Oy, referred to as **b**). Both companies account for water and wastewater treatment and networks.

The calculation of case HS-Vesi is based on FCG Finnish Consulting Group Oy (FCG) carbon footprint analysis on HS-Vesi Oy and carbon footprint assessment of the Paroinen WWTP in Hämeenlinna. Calculation of case HSY is based on HSY's annual data on their carbon footprint assessment and life-cycle assessment on the Viikinmäki WWTP. Because those are based on calculation procedures of different parties, also many emission factors differ from each other.

Calculations for HSY are based on 2021 data and for HS-Vesi 2019 data.

Denmark

In Denmark, DANVA prepared a guidance for "CO_2-accounting for utilities" in 2012. This report came with recommendations and guidelines but no direct model and therefore each company could create their own model. Some companies have made their own climate reports, but they are very different.

In December 2019, a broad majority in the Danish Parliament reached an agreement on a new climate law for Denmark. Derived from that a new climate plan was introduced in June 2020, with the ambition that the Danish water sector shall be energy- and climate neutral. The year was subsequently chosen as 2030 and is based on a so-called "Paris model", which was established by the Danish Environmental Protection Agency (EPA) (Miljøstyrelsen, 2020a). In the model, the water and wastewater utilities were urged to report their ambitions in relation to energy consumption, energy production and CO_2 emissions for the next 15 years to the Danish EPA.

The Paris model is a good starting point for a GHG-emission model for Denmark. But it probably needs to be elaborated during the next years. The model will be slightly modified in the coming years concerning energy accounting and we need somehow to include emissions from sludge disposal. Furthermore, we need to find a way to handle the future carbon capture solutions.

The comparison in the tables below is based on the Paris model from 2020 in the areas that we have chosen to compare with the other Nordic countries' models.

Links to relevant reports in from Denmark:

- *Guidelines for reporting with Paris Model for climate- and energy-neutral Water Sector:*

https://mst.dk/service/publikationer/publikationsarkiv/2021/apr/guidelines-for-reporting-with-paris-model-for-climate-and-energy-neutral-water-sector/

- *"Paris model" reporting for the water sector in Denmark:*

https://mst.dk/media/221807/reporting-for-a-climate-and-energy-neutral-water-sector-in-denmark.pdf

    - DANVA's guidance for "CO_2-accounting for utilities" from 2012 (only in Danish):

https://www.danva.dk/publikationer/vejledninger-og-rapporter/vejledning-88-co2-regnskab-for-forsyninger-en-guide-2012/

3. Overview of the content of each model

In Part II, selected parameters from Table 3 were chosen based on data availability and relative importance in climate accounting. The parameters are divided in 3 categories: 1) Water works / drinking water, 2) Transportation / sewer system, and 3) Wastewater Treatment Plants and they are presented in Table 5, Table 6, and Table 7, respectively. Emissions that are not included are also shown in the bottom of each table.

The parameters are taken from national models in the cases of Sweden, Norway, and Denmark and from two selected utility companies in the case of Finland.

Table 5. Overview of parameters included for climate accounting in relation to Water works / drinking water

Selected sum-emissions:	**Scope**	**Sweden**	**Norway**	**Finland**	**Denmark**
1. Consumption of electricity (Purchased)	2	Yes	Yes	Yes	Yes
2. Consumption of heat/energy (purchased)	2	Yes	Yes	Yes	Yes
3. Consumption of chemicals	3	Yes	Yes	Yes	No
4. CO_2 reducing activities – substitution of products, production of electricity/heat or Carbon Capture	3	Yes	Yes	Yes	Yes
5. List of emissions not included					*

*CH_4 in groundwater (Scope 1)

Table 6. Overview of parameters included for climate accounting in relation to Transportation / sewer system

Selected sum-emissions:	**Scope**	**Sweden**	**Norway**	**Finland**	**Denmark**
1. Consumption of electricity (Purchased)	2	Yes	Yes	Yes	Yes
2. Consumption of heat/energy (purchased)	2	Yes	Yes	No	Yes
3. List of emissions not included					*

*Avoided N_2O to nature based on the removed nitrogen at WWTP

Table 7. Overview of parameters included for climate accounting in relation to Wastewater Treatment Plants

Selected sum-emissions:	**Scope**	**Sweden**	**Norway**	**Finland**	**Denmark**
1. Consumption of electricity (pur-chased)	2	Yes	Yes	Yes	Yes
2. Consumption of heat/energy (pur-chased)	2	Yes	Yes	Yes	Yes
3. Sold Electricity	2	Yes	Yes	Yes	Yes
4. Sold heat/energy	2	Yes	Yes	Yes	Yes
5. Consumption of fuel for cars/vans/trucks	3	Yes	Yes	Yes	No
6. Consumption of chemicals	3	Yes	Yes	Yes	No
7. CH_4 - emissions – biogas plants	1	Yes	Yes	Yes	Yes
8. CH_4 - emissions - from aerations tanks/processes	1	Yes	No	Yes	(Yes)
9. N_2O - emissions - processes	1	Yes	Yes	Yes	Yes
10. N_2O - emission in effluent from WWTP	1	Yes	Yes	Yes	Yes
11. Emissions from sludge	?	Yes	No	Yes	no
12. CO_2 reducing activities - substitu-tion of products	?	No	No	Yes	Yes
13. CO_2 - carbon capture	?	No	No	No	No
14. List of emissions not included	3				

4. Detailed comparison of data from the four countries

The four Nordic Water and Wastewater Associations was asked to fill in all relevant parameters and emission factors for each of the three tables, Table 6 and Table 7). The outcome is presented in Table 8, Table 9, and Table 10.

The emission factors are national values in the cases of Sweden, Norway, and Denmark and from two selected utility companies in the case of Finland.
There are several similarities in the reported numbers, but also quite a few differences. The main differences of interests are:

- The Danish model includes afforestation since this is an important parameter in terms of groundwater protection in Denmark. This is not included in any of the other models.
- The Danish model does not include chemicals in the water works / drinking water category, since the water in Denmark is not chemically treated.
- The emission factors for consumption of electricity and heat used in the different countries differs a lot. It is crucial whether national or local emission factors are applied in the calculations.
- Sludge treatment has a large contribution to the climate accounting and thus it is important that it is included, however the Danish model does not include it so far.
- The emission factor for N_2O emissions from wastewater treatment plants (and CH_4 emissions from biogas plants) differ quite a bit too.

It is quite important how Guarantees of Origin for electricity and biogas as well as sale of CO2 credits is handled. This has not been discussed in detail in the working group, but it is something that could be interesting to emphasize in the coming work with climate accounting models in the Nordic countries.

Table 8. Overview of parameters included, and emissions factors used, for climate accounting in relation to Water works / drinking water in the four Nordic countries.

Sweden	Norway	Finland (two cases, a and b)	Denmark
1. Consumption of Electricity (purchased)			
Reporting data: • Electricity used for operation of plant – kWh/year • Type of electricity purchased • Emission factor if differs from the default emission factors	Reporting data: • Electricity used for operation of plant – kWh/year • Type of electricity purchased • Emission factor if differs from the default emission factors	Reporting data: • Purchased electricity – MWh/a	Reporting data: • Electricity purchased – kWh
Used emission factors: • EF Nordic electricity mix: 0,365 kg CO2e/kWh • EF hydro power: 0,007 kg CO2e/kWh • EF wind power: 0,015 kg CO2e/kWh • EF solar power: 0,067 kg CO2e/kWh EF biogas: 0 kg CO2e/kWh	Used emissions factors: • Norwegian_electricity mix: 0,0361 kg CO2e/kWh	Used emissions factors: a) 0 MWh/a (local emission factor, renewable electricity) b) 259 MWh/a (local emission factor)	Used emissions factors: • EF(Electricity): 0,111 kg CO2e/kWh (National average emissions factor 2020-Paris model)
Comments:	Comments:	Comments:	Comments: EF(Electricity) is expected to be 0,012 kg CO2e/kWh in 2030

<table>
<tr><th colspan="4">2. Consumption of heat/energy(purchased)</th></tr>
<tr>
<td>Reporting data:

• Oil heating kWh/year
• Natural gas heating kWh/year
• Internally produced biogas heating kWh/year
• District heating kWh/year + emission factor
• District cooling kWh/year + emission factor
• Other types of heating + emission factor</td>
<td>Reporting data:

• District heating kWh/year r
• Oil heating kWh/year
• Natural gas heating kWh/year
• Pellet heating kWh/year</td>
<td>Reporting data:

• Purchased heat - MWh/a</td>
<td>Reporting data:

• Heat purchased (total sum) – converted to kWh
• District heating purchased - kWh
• Emission factor for local district heating company - kg CO2e/kWh:
• Natural gas purchased – converted to kWh
• Oil purchased - converted to kWh</td>
</tr>
<tr>
<td>Used emissions factors:

• EF Oil heating indirect emissions: 0,054 kg CO2e/kWh
• EF Oil heating direct emissions: 0,279 kg CO2e/kWh
• EF Natural gas indirect emissions: 0,026 kg CO2e/kWh
• EF natural gas direct emissions: 0,205 kg CO2e/kWh
• EF biogas heating direct indirect emissions: 0 kg CO2e/kWh
• EF biogas direct emissions: 0 kg CO2e/kWh</td>
<td>Used emissions factors:

• District heating 0,182 kg CO2e/kWh
• Oil heating 0,347 kg CO2e/kWh
• Natural gas heating 0,273 kg CO2e/kWh
• Propane heating 0,313 kg CO2e/kWh
• Pellet heating 0,248 kg CO2e/kWh</td>
<td>Used emissions factors:

a) 197 kg CO2e/MWh (local emission factor)

b) 125 kg CO2e/MWh (local emission factor)</td>
<td>Used emissions factors:

• EF (District heating):
• Local emissions factor - if accessible
• 0,059 kg CO2e/kWh (national average emissions factor – if local is missing)</td>
</tr>
<tr>
<td>Comments:</td>
<td>Comments:</td>
<td>Comments:</td>
<td>Comments:</td>
</tr>
</table>

3. Consumption of chemicals			
<u>Reporting data:</u> • Type pf precipitation chemical (tons/year) + type of transport • Type of polymer (tons/year) + type of transport • Type of carbon source (tons/year) + type of transport Other chemicals used + type of transport	<u>Reporting data:</u> • Type pf precipitation chemical (tons/year) + type of transport • Type of polymer (tons/year) + type of transport • Type of carbon source (tons/year) + type of transport Other chemicals used + type of transport	<u>Reporting data:</u> Type of chemical tn/a + type of transport km/a or tkm/a	Not included
<u>Used emissions factors:</u> See Swedish model manual.	<u>Used emissions factors:</u> See Norwegian model manual	<u>Used emission factors:</u> Check “climate model Finland”	
<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u> Drinking water is based on groundwa-ter and the main part of waterwork does not use chemicals. Waterworks who reduce hardness used chemicals but so far it only few WW,

<table>
<tr><th colspan="4">4. CO_2 reducing activities – substitution of products, production of electricity/heat or Carbon Capture</th></tr>
<tr>
<td><u>Reporting data:</u>

• Electricity sold kWh/year</td>
<td><u>Reporting data:</u>

• Electricity sold kWh/year
• Produced heat for district heating kWh/year</td>
<td><u>Reporting data:</u>

• Produced electricity - MWh/a
• Produced heat - MWh/a</td>
<td><u>Reporting data:</u>

• Electricity sold – kWh
• Heat sold to District heating – kWh
• Local emissions factor – if accessible
• Afforestation for groundwaterprotection – hectare</td>
</tr>
<tr>
<td><u>Used emissions factors:</u>

• EF Electricity: 0,365 kg CO2e/kWh</td>
<td><u>Used emissions factors:</u>

• Norwegian_electricity mix: 0,0361 kg CO2e/kWh
• District heating 0,182 kg CO2e/kWh</td>
<td><u>Used emissions factors:</u>

<u>a)</u> electricity 89 kg CO2e/MWh (national average emission factor)

heat 177 kg CO2e/MWh (national average emission factor)</td>
<td><u>Used emissions factors:</u>

• EF(Electricity): 0,111 kg CO2e/kWh
• EF(district heating):
• Local emissions factor – if accessible
• 0,059 kg CO2/kWh (national average)

Afforestation:

• Carbone footprint: 5,8 tonnes CO2e is capture by each hectare for the first 10 years.
• Se further description in guidelines for a climate and energy-neutral water sector.</td>
</tr>
<tr>
<td><u>Comments:</u></td>
<td><u>Comments:</u></td>
<td><u>Comments:</u></td>
<td><u>Comments:</u>

Solar power and heat pumps used in waterworks</td>
</tr>
</table>

5. List of emissions not included in the comparison			
• Fuel for transportation for drinking water model			Methane: Some waterworks have a high me-thane content in the groundwater wish is released when aerated.

Table 9. Overview of parameters included, and emissions factors used, for climate accounting in relation to Transportation / sewer systems in the four Nordic countries.

<table>
<tr><th>Sweden</th><th>Norway</th><th>Finland (two cases, a and b)</th><th>Denmark</th></tr>
<tr><td colspan="4">1. Consumption of Electricity (purchased)</td></tr>
<tr><td>Reporting data:

• Electricity used for sewer system – kWh/year
• Type of electricity purchased
• Emission factor if differs from the default emission factors</td><td>Reporting data:

• Electricity purchased – kWh
• Emissions factor if differs from the national average emissions factor</td><td>Reporting data: Purchased electricity – MWh/a</td><td>Reporting data:

• Electricity purchased – kWh</td></tr>
<tr><td>Used emission factors:

• EF Nordic electricity mix: 0,365 kg CO2e/kWh
• EF hydro power: 0,007 kg CO2e/kWh
• EF wind power: 0,015 kg CO2e/kWh
• EF solar power: 0,067 kg CO2e/kWh
• EF biogas: 0 kg CO2e/kWh</td><td>• Norwegian electricity mix: 0,0361 kg CO2e/kWh</td><td>Used emissions factors:

a) 0 kg CO2e/MWh (local emission factor, renewable electricity)

b) 259 kg CO2e/MWh (local emission factor)</td><td>Used emissions factors:

• EF(Electricity): 0,111 kg CO2e/kWh

(National average emissions factor 2020-Paris model)</td></tr>
<tr><td>Comments:</td><td>Comments:

From the reporting year 2022 energy consumption

data for the transportation / sewer system will not

be included in the model</td><td>Comments:</td><td>Comments:

EF(Electricity) is expected to be 0,012 kg CO2e/kWh in 2030</td></tr>
</table>

2. Consumption of heat/energy(purchased)			
Reporting data: • Oil heating kWh/year • Natural gas heating kWh/year • Internally produced biogas heating kWh/year • District heating kWh/year + emission factor • District cooling kWh/year + emission factor • Other types of heating + emission factor		Reporting data:	Reporting data: • Heat purchased (total sum) – converted to kWh • District heating purchased - kWh • Emission factor for local district heating company - kg CO2e/kWh: • Natural gas purchased – converted to kWh • Oil purchased - converted to kWh
Used emissions factors: • EF Oil heating indirect emissions: 0,054 kg CO2e/kWh • EF Oil heating direct emissions: 0,279 kg CO2e/kWh • EF Natural gas indirect emissions: 0,026 kg CO2e/kWh • EF natural gas direct emissions: 0,205 kg CO2e/kWh • EF biogas heating direct indirect emissions: 0 kg CO2e/kWh • EF biogas direct emissions: 0 kg CO2e/kWh		Used emissions factors:	Used emissions factors: • EF (District heating): • Local emissions factor - if accessible • 0,059 kg CO2e/kWh (national average emissions factor – if local is missing)
Comments:		Comments:	Comments:

Table 10. Overview of parameters included, and emissions factors used, for climate accounting in relation to Wastewater Treatment Plants in the four Nordic countries.

Sweden	Norway	Finland (two cases, a and b)	Denmark
1. Consumption of Electricity (purchased)			
<u>Reporting data:</u> • Electricity used for sewer system – kWh/year • Electricity used for operation of plant – kWh/year • Type of electricity purchased • Emission factor if differs from the default emission factors	<u>Reporting data:</u> • Electricity purchased – kWh • Emissions factor if differs from the national average emissions factor	<u>Reporting data:</u> • Electricity purchased – MWh/a	<u>Reporting data:</u> • Electricity purchased – kWh
<u>Used emission factors:</u> • EF Nordic electricity mix: 0,365 kg CO2e/kWh • EF hydro power: 0,007 kg CO2e/kWh • EF wind power: 0,015 kg CO2e/kWh • EF solar power: 0,067 kg CO2e/kWh • EF biogas: 0 kg CO2e/kWh	• Norwegian_electricity mix: 0,0361 kg CO2e/kWh	<u>Used emission factors:</u> a) 0 kg CO2e/MWh (local emission factor, renewable electricity) b) 259 kg CO2e/MWh (local emission factor)	<u>Used emissions factors:</u> • EF(Electricity): 0,111 kg CO2e/kWh (National average emissions factor 2020-Paris model)
<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u> EF(Electricity) is expected to be 0,012 kg CO2e/kWh in 2030 How to handle “Guarantees of origin for electricity”?

<table>
<tr><td colspan="4">2. Consumption of heat/energy (purchased)</td></tr>
<tr>
<td>Reporting data:

• Oil heating kWh/year
• Natural gas heating kWh/year
• Internally produced biogas heating kWh/year
• District heating kWh/year + emission factor
• District cooling kWh/year + emission factor
• Other types of heating + emission factor</td>
<td>Reporting data:

• District heating kWh and emission factor
• Natural gass kWh and emission factor
• Propane heating kWh and emission factor
• Oil heating kWh and emission factor
• Pellets heating kWh and emission factor</td>
<td>Reporting data:

• Heat purchased (total sum) MWh/a
• Natural gas heating (only for a) NWh/year
• Oil heating (only for a) NWh
• Oil purchased (only for b) dm3/a</td>
<td>Reporting data:

• Heat purchased (total sum) – converted to kWh
• District heating purchased - kWh
• Emission factor for local district heating company - kg CO2e/kWh:
• Natural gas purchased – converted to kWh
• Oil purchased - converted to kWh</td>
</tr>
<tr>
<td>Used emission factors:

• EF Oil heating indirect emissions: 0,054 kg CO2e/kWh
• EF Oil heating direct emissions: 0,279 kg CO2e/kWh
• EF Natural gas indirect emissions: 0,026 kg CO2e/kWh
• EF natural gas direct emissions: 0,205 kg CO2e/kWh
• EF biogas heating direct indirect emissions: 0 kg CO2e/kWh
• EF biogas direct emissions: 0 kg CO2e/kWh</td>
<td>Standard national emission factors:

• District heating 0,182 kg CO2 ekv/kWh
• Natural gas 0,273
• Propane heating 0,313
• Oil heating 0,347
• Pellets heating 0,248</td>
<td>Used emission factors:

a) District heating 197 kg CO2e/MWh (local emission factor)

Natural gas 199 kg CO2e/MWh

Oil 774 kg CO2e/MWh

b) District heating 125 kg CO2e/MWh (local emission factor, district heat)

Oil 2,63 kg CO2e/dm3</td>
<td>Used emissions factors:

• EF (District heating):
• Local emissions factor - if accessible
• 0,059 kg CO2e/kWh (national average emissions factor – if local is missing)</td>
</tr>
<tr>
<td>Comments:</td>
<td>Comments:</td>
<td>Comments:</td>
<td>Comments:</td>
</tr>
</table>

3. Sold Electricity			
Reporting data: • Electricity sold kWh/year	Reporting data: Electricity sold kWh	Reporting data: Electricity sold MWh/a	Reporting data: • Electricity sold – kWh
Used emission factors: • 0,365 kg CO2e/kWh	Used emissions factors: • Norwegian_electricity mix: 0,0361 kg CO2e/kWh	Used emission factors: a) 89 kg CO2e/MWh b) 259 kg CO2e/MWh	Used emissions factors: • EF(Electricity): 0,111 kg CO2e/kWh (national average emissions factor)
Comments:	Comments:	Comments:	Comments:

4. Sold heat/energy			
Reporting data: • District heat sold kWh/year + emission factor • Biofuel sold kWh/year	Reporting data: • District heat sold kWh • Biomethane/biofuel sold Nm3 and % CH4	Reporting data: • Total sum of heat sold MWh/a	Reporting data: • Heat/energy sold – kWh • Heat to District heating - kWh • Emission factor local district heating kg CO_2/kWh: • Biogas sold for natural/town gas • converted to kWh – used for energy balance • Biomass to external energy producer – converted to kWh
Used emission factors: • Biofuel sold: 0,231 kg CO_2e/kWh	Used emissions factors: • District heating 0,182 kg CO_2 ekv/kWh District heat sold 0,18 kg CO_2/kWh • Biomethane/biofuel sold 2,98 kg CO_2/Nm3 CH_4	Used emission factors: a) 177 kg CO_2e/MWh (local emission factor) b) 125 CO_2e/MWh (local emission factor)	Used emissions factors: • EF (district heating): • Local emissions factor - if accessible • 0,059 kg CO_2/kWh (national average emissions factor – if local is missing) • EF (Natural gas): 0,204 kg CO_2 / kWh – find factor fra gas til CO_2 • EF (Town gas/LPG): 0,227 kg CO_2 / kWh find factor fra gas til CO_2
Comments:	Comments:	Comments: Heat recovery from effluent MWh is not included in the total sum but calculated separately.	Comments: Not wastewater related biomass supplied directly to the biogas plant is not included is extracted from the balance.

<table>
<tr><td colspan="4">5. Consumption of fuel for cars/vans/trucks</td></tr>
<tr><td>Reporting data:

• Used diesel MK1 – Liters/year
• Used gasoline MK1 – Liters/year
• Used ethanol – Liters/year
• Used HVO (100%) – Liters/year
• Used FAME (100%) – Liters/year
• Used biogas internally produced – Liters/year
• Other fuels + emission factor</td><td>Reporting data:

• See Norwegian model</td><td>Reporting data:

• Used diesel dm3/a
• Personnel pcs, driving distance per day km,

working days/a

• Other car rides km/a</td><td>

Not included</td></tr>
<tr><td>Used emission factors:

• Diesel MK1 indirect emissions: 0,621 kg CO2e/kWh
• Diesel MK1 direct emissions: 2,06 kg CO2e/kWh
• Gasoline MK1 indirect emissions: 0,749 kg CO2e/kWh
• Gasoline MK1 direct emissions: 2,11 kg CO2e/kWh
• Ethanol: 1,138 kg CO2e/kWh
• HVO (100%): 0,695 kg CO2e/kWh
• FAME (100%): 1,108 kg CO2e/kWh
• Biogas internally produced: 0,443 kg CO2e/kWh</td><td>• See Norwegian model</td><td>Used emission factors:

a) -

b) Diesel 2,2 kg CO2e/dm3

151 g CO2e/km</td><td></td></tr>
<tr><td>Comments:</td><td>Comments:</td><td>Comments:</td><td>Comments:

Consumption of fuel for transportation is not included In the Paris-model.

Some companies have made their own calculations, but we do not have a commonly used method.</td></tr>
</table>

6. Consumption of chemicals			
• Type pf precipitation chemical (tons/year) + type of transport • Type of polymer (tons/year) + type of transport • Type of carbon source (tons/year) + type of transport • Other chemicals used + type of transport	<u>Reporting data in the Norwegian calculator:</u> • Type of precipitation chemicals, tons/km/type trasnport Type of carbonsource N-cleansing, tons/km/type transp. • Type cemicals for pH adjustments, tons/km/type transp. • Polymers and other chemicals, tons/km/type transp. • Emission factors for each chemical, if not standard	<u>Reporting data:</u> • Type of chemical tn/a + type of transport km/a or tkm/a	Not included
Used emission factor: • See Swedish model manual.	Used emission factor: • See Norwegian model manual.	<u>Used emission factor:</u> • Check “climate model Finland”	
<u>Comments:</u>	<u>Comments:</u> The factors for chemical are exclusive transport	<u>Comments:</u>	<u>Comments:</u> Some companies have made their own calculations, but we do not have a commonly used method.

7. CH4 – methane – biogas plants			
Reporting data: • Amount of produced biofuel – kWh/year	Reporting data: Amount produced biogas – Nm3 and % CH4 Amount hot flare Nm3 Amount leakage/cold flare Nm3 Calculated leakage upgrade to biomethane, kg CO2e Calculated leakage distribution of biomethane, kg CO2e	Reporting data: a) - b) Amount of produced biogas – m3/a Leakage factors	Reporting data: • Amount of produced biogas - Nm3 • Maybe own leakage factor in % • Maybe results from own calculation report estimating the CO2e contribution from biogas plant
Used emissions factors: • 0,231 kg CO2e/kWh	Used factors: Direct leakage: 0,66 kg CH4/m3*% CH4 *28 kg CO2/kg CH4 Calculating leakage for production and distribution of biomethane/biofuel according to BNB (Bransjenorm – sector norm)	Leakage factors: a) - b) anaerobic digestion 0,4 % biogas processing 1,0 % Used emissions factors: a) b) EF (Methane): 28 kg CO2e/kg CH4	Used factors: • Leakage factor: 1,3 % (national factor) – used if not own is available • Conversion from Nm3 to kg: Nm3 * 0,65 % CH4 content * 0,72 kg/Nm3 Used emissions factors: • EF (Methane): 25 kg CO2e/kg CH4
Comments:	Comments:	Comments: Case a cannot be separated between 7 and 8, therefore all CH4 is calculated in 8.	Comments:

8. CH_4 – methane - from aerations tanks/processes			
Reporting data: • Organic material in inlet to WWTP - COD in kg/year • Measured CH_4 emissions if availa-ble		Reporting data: • BOD7 t/a	Reporting data: • Organic material in inlet to WWTP - COD in kg
Used emission factors: • EF Methane from process 0,011 kg CH_4/kg COD inlet		Used emission factors: a) 12,5 kg CH_4/t BOD influent b) 18 kg CH_4/t BOD, influent EF(Methane): 28 kg CO_2e/kg CH_4	Used factors: • DNIR: 0,0008 kg CH_4 / kg COD inlet Used emissions factors: • EF(Methane): 25 kg CO_2e/kg CH_4
Comments:	Comments: Methane from aeration tanks is not included in the Norwegian model	Comments:	Comments: Not included in the first Paris model – but will hopefully be in the next.

<table>
<tr><td colspan="4">9. N2O – Nitrogen oxide–processes</td></tr>
<tr>
<td>Reporting data:

• Nitrogen reduced in the WWTP, kg Tot.N/år
• Measured N2O emissions if available</td>
<td><u>Reporting data:</u>

• Nitrogen reduced in the WWTP, kg Tot.N
• Result from estimated N2O emission kg N2O/kg N reduced</td>
<td><u>Reporting data:</u>

a) Q, influent m3/a

b) N, load t/a</td>
<td>Reporting data:

• Nitrogen in influent (inlet) to WWTP - N in kg
• Maybe results from own report estimating the CO2 contribution from N2O processes</td>
</tr>
<tr>
<td>Used emission factors:

• EF N20 from process: 0,0157 kg N2O/kg reduced N</td>
<td><u>Standard emission factor:</u>

0,031 kg N2O/kg N treated.</td>
<td><u>Used emission factors:</u>

a) 0,92464 kg N2O/1000 m3 / measured

b) N2O from processes 1,6 % N2O-N/N, influent

EF(N20): 265 kg CO2e/kg N2O</td>
<td>Used factors:

• DNIR: 0.0084 kg N2O / kg total N inlet.
• N emitted as nitrous oxide from total N: 44/28

Used emissions factors:

• EF(N20): 298 kg CO2e/kg N2O.</td>
</tr>
<tr>
<td><u>Comments:</u></td>
<td><u>Comments:</u>

The companies can use different factors</td>
<td><u>Comments:</u></td>
<td><u>Comments:</u></td>
</tr>
</table>

10. N_2O – emission in effluent from WWTP			
Reporting data: • Type of water in recipient (sea-water or lake) • Amount of Nitrogen discharged to recipient. kg N/year	<u>Reporting data:</u> • Nitrogen discharged to recipient total kg Tot.N	<u>Reporting data:</u> • Nitrogen discharge to recipient, effluent from WWTP tn/a	Reporting data: • Nitrogen discharged to recipient – sum of: • Effluent (outlet) from WWTP - kg total N • Discharged from overflow from combined sewer systems - kg total N • Discharged with rainwater from the rainwater sewer system - kg total N
Used emission factor: Seawater recipient: 0,003 kg N20/kg N discharged Lake/river recipient: 0,0005 kg N_2O/kg N discharged	<u>Used factor:</u> • 0.008 kg N_2O/kg tot.N • 265 kg CO_2e / kg N_2O Factor used by Norwegian government	<u>Used emission factor:</u> a) 0,002kg N_2O-N/kg N, effluent b) 0,005 kg N_2O-N/kg N, effluent	Used factors: • DNIR: 0.005 kg N_2O-N / kg total N discharged • N emitted as nitrous oxide from total N: 44/28 Used emissions factors: • EF(N20): 298 kg CO_2e/kg N_2O.
<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u>	<u>Comments:</u>

<table>
<tr><td colspan="4">11. Emissions from sludge</td></tr>
<tr><td>Reporting data:

• Amount of sludge used for making of soils – tons TS/year
• Amount of sludge spread on farm-land – tons TS/year
• Type of transport for transport of sludge</td><td></td><td><u>Reporting data:</u>

produced digestate tTS/a</td><td>

Not included</td></tr>
<tr><td>Emission factors used:

• Avoided emissions making of soil: 13000 kg CO2e/ton
• Avoided emissions spread on farm-land
• Nitrogen: 4420 kg CO2e/ton
• Phosphorus: 640 kg CO2/ton</td><td></td><td><u>Emission factors used:</u>

a) N/dried digestate 0,03 kg TN/kgTS

P/dried digestate 0,03 kgTP/kgTS

b) N/dried digestate 0,04 kg TN/kgTS

P/dried digestate 0,03 kgTP/kgTS

N2O/dried digestate 0,01 kg N2o-N/kg N</td><td></td></tr>
<tr><td><u>Comments:</u></td><td><u>Comments:</u>

Not included in the Norwegian model so far</td><td><u>Comments:</u></td><td><u>Comments:</u>

Sludge is a very important CO2-emissions factor but we don’t have a common model for including it yet.</td></tr>
</table>

12. CO2 reducing activities – substitution of products			
Included in parts above		Substitution of artificial fertilizers	Reporting data: The Danish Paris Model allowed individual reporting of self-selected CO2 reducing activities. Ex: • phosphorus recovery
		Emission factors used: • Phosphorus 0,51 kg CO2/kg P available in sludge (sewage sludge P availability in sludge 40%) • Nitrogen: 3,9 kg CO2e/kg N available in sludge (sewage sludge N availability in sludge 32,5 %)	Emission factors used:
Comments:	Comments:	Comments:	Comments: • Maybe sludge to biooil (HTL technology)

13. CO2 – carbon capture			
			Reporting data:
Comments: It is considered to include it in a future version of the model	Comments:	Comments:	Comments: • Sludge handling can be an issue – eq. Pyrolysis, HTL (biofuel) and landfill and agriculture.
14. List of emissions not included in the comparison			
	• Calculated emissions of methane from septic tanks are included in the Norwegian model		• Emissions of methane from septic tanks because the main part is private owned • Avoid N2O in nature based on the removed Nitrogen by WWTP
Comments:	Comments:	Comments:	Comments: • The Paris model included the avoid N2O to the water environment based on the removed nitrogen at WWTP. The reason is that the wastewater companies does not like the factor and therefore it is excluded.

5. Results from utility companies in the four countries

The following figures shows real data from a range of utilities in the four Nordic countries, more specifically

- 14 Waterworks: 5 in Denmark, 5 in Norway, 2 in Finland, and 2 in Sweden
- 12 Sewer systems: 5 in Denmark, 5 in Norway, 2 in Finland (none from Sweden, electricity data included in Wastewater Treatment)
- 16 Wastewater Treatment Plants: 6 in Denmark, 5 in Norway, 2 in Finland, and 3 in Sweden.

The results should be considered preliminary since a thorough quality assurance has not been made so far. However, the results can be seen as a very good starting point and a prove, that climate accounting models can be compared, even though differences occur.

Since the results are preliminary, the WWTPs are anonymous and are named after the country of origin (Denmark 1, Denmark 2, etc.).

The results are shown in the figures below.

Water works / Drinking water

The sum of emissions and avoided emissions from the 14 Water works are presented in Figure 1, with indications of the different contributors.

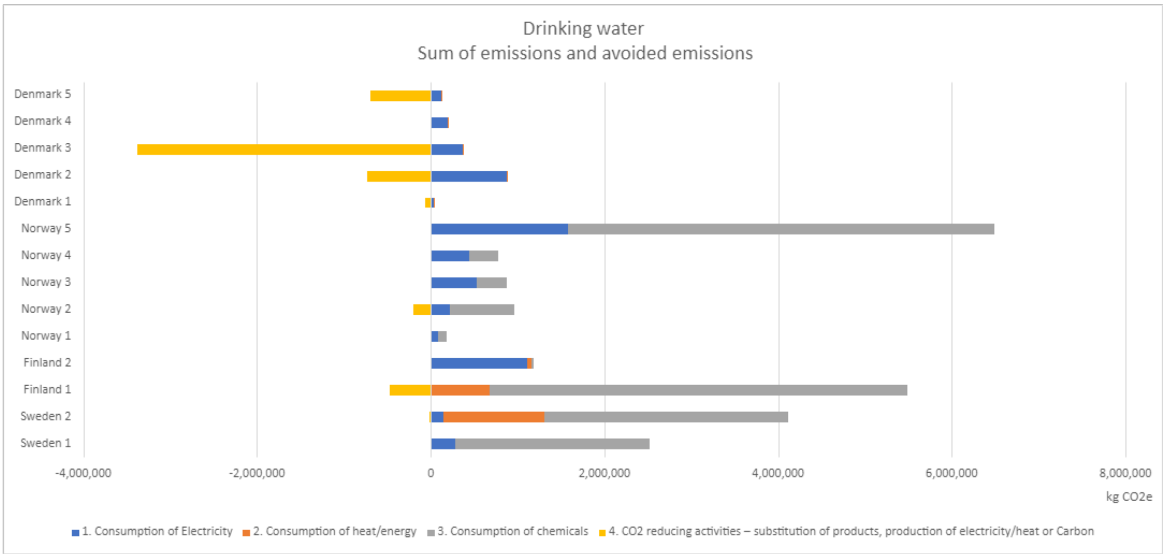


Figure 1. Sum of emissions and avoided emissions from 14 Water works in the Nordic countries.

In general, there are quite large differences in emissions (and avoided emissions) between the 14 water works. The largest contributor to the overall emissions is chemicals. One exception is the utilities in Denmark since no chemicals are used or the treatment of water. Consumption of electricity and heat is also significant. Denmark is also standing out in the "CO_2 reducing activities parameter" since afforestation is accounted in Denmark as avoided CO_2 emissions.

Figure 2 shows the sum of the emissions (and avoided emissions) as a key figure, namely kg CO_2-e per produced m^3 drinking water. Figure 3 shows the same numbers, but without the avoided emissions.

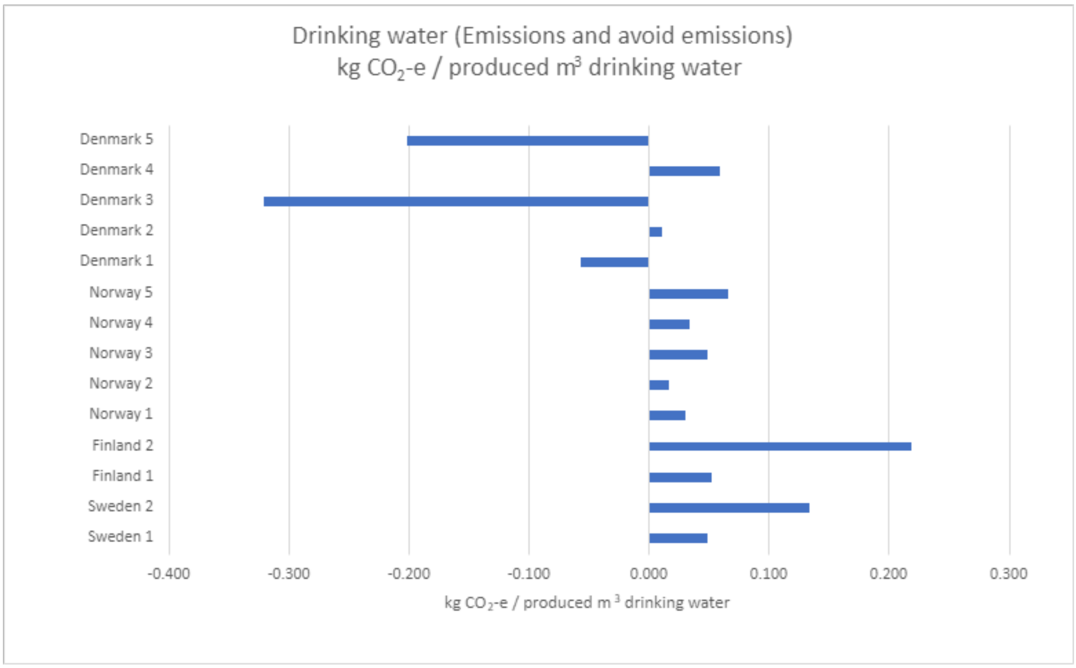


Figure 2. Emissions and avoided emissions of CO_2-e from 14 Water works in the Nordic countries (calculated as kg CO_2-e per produced m^3 drinking water.

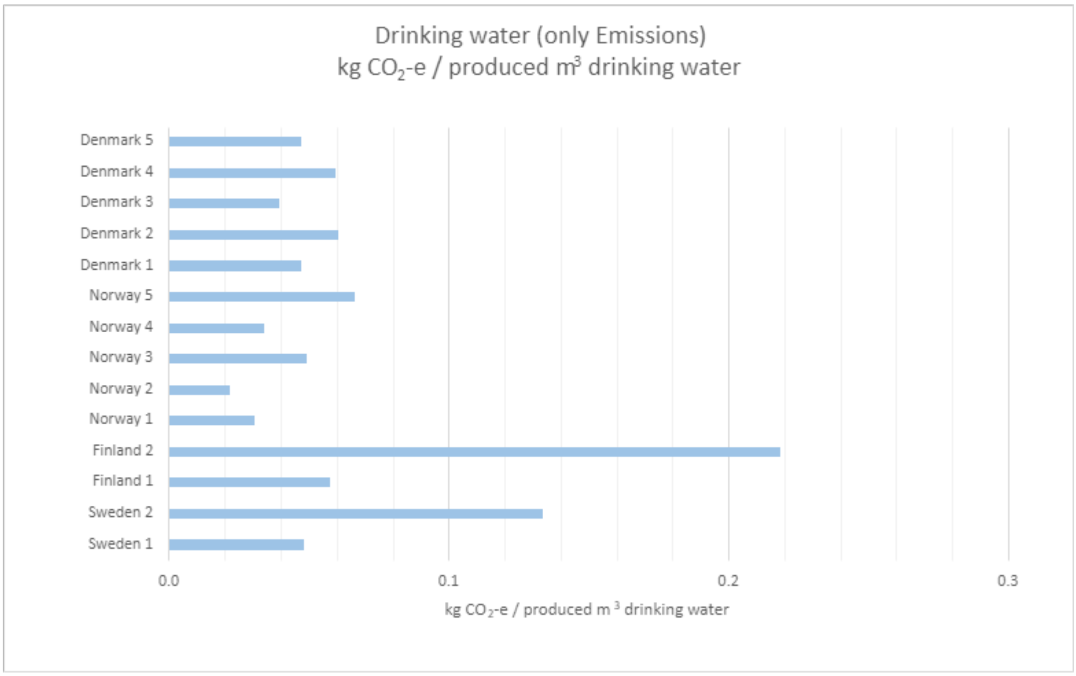


Figure 3. Emissions emissions (avoided emissions excluded) of CO_2-e from 14 Water works in the Nordic countries (calculated as kg CO_2-e per produced m^3 drinking water.

The variation in overall emissions is quite significant. The emissions differ from 0,02 to 0,22 kg CO_2-e per produced m^3 drinking water.

Transportation / Sewer system

The sum of emissions and avoided emissions from 12 Sewer system are presented in Figure 4, with indications of the different contributors.

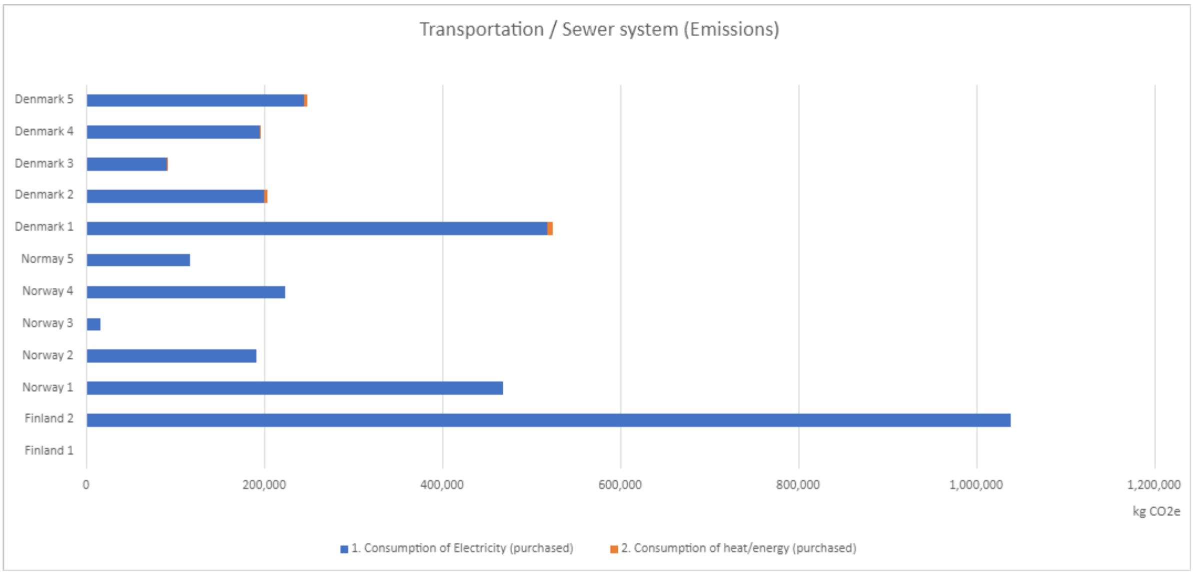


Figure 4. Sum of emissions from 12 sewer systems in the Nordic countries.

There are no numbers from Sweden, since the Swedish data is incorporated under Wastewater Treatment. "Finland 1" has reported an emission factor for electricity of zero, thus the emissions are also zero.

The only significant emission in relation to sewer systems is consumption of electricity.

Figure 5 shows the sum of the emissions (and avoided emissions) as a key figure, namely kg CO_2-e per 1000 m^3 inlet to the Wastewater Treatment Plant.

The differences in emissions are quite significant, especially "Finland 2" is very large compared to the others.

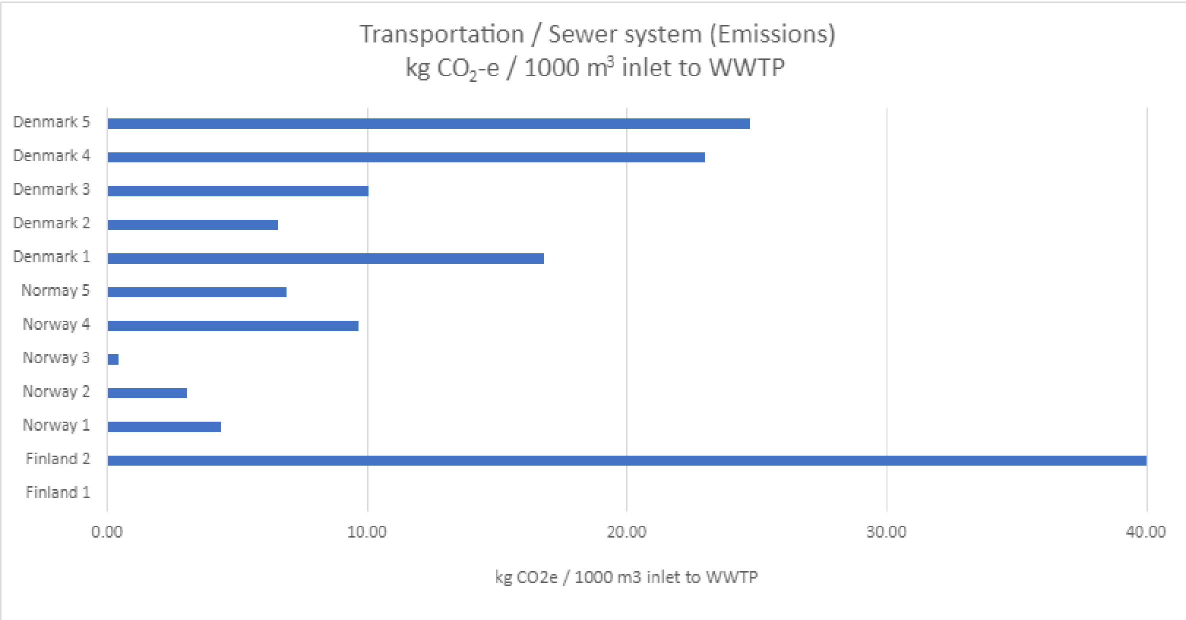


Figure 5. Emissions of CO_2-e from 12 Sewer systems in the Nordic countries (calculated as kg CO_2-e per 1000 m^3 inlet to the Wastewater Treatment Plant.

Wastewater Treatment Plants

The sum of emissions and avoided emissions from 16 Wastewater Treatment Plants are presented in Figure 6, with indications of the different contributors.

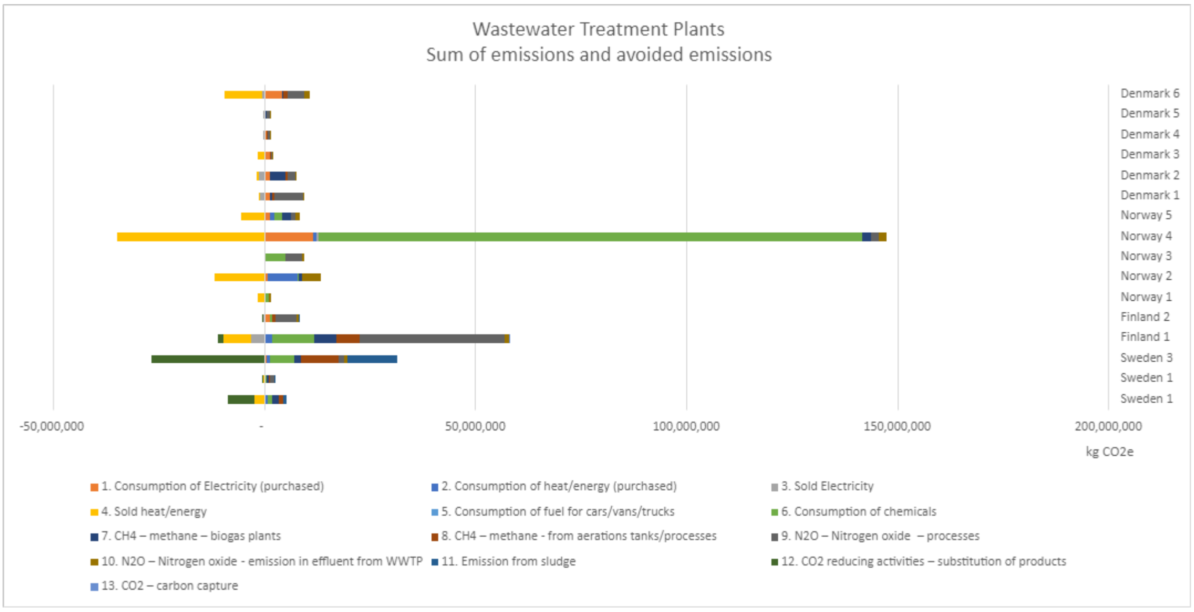


Figure 6. Sum of emissions from 16 Wastewater Treatment Plants in the Nordic countries.

Emissions from Wastewater Treatment Plants include many contributors. The most significant are N_2O emissions from the secondary process step (2 Norwegian WWTPs have reported zero for N_2O emissions), consumption of chemicals, and consumption of electricity.

The avoided emissions are mainly from sold heat/energy and substitution of products.

The Danish model does not include consumption of chemicals, so it is not included in the Danish numbers. Thus, the numbers from the 16 WWTPs are not 100 % comparable.

The same numbers are shown in Figure 7, but in this case the emissions are fitted to 100 % and the avoided emissions are related to these. Thus, it is easier to see the contributors between each other.

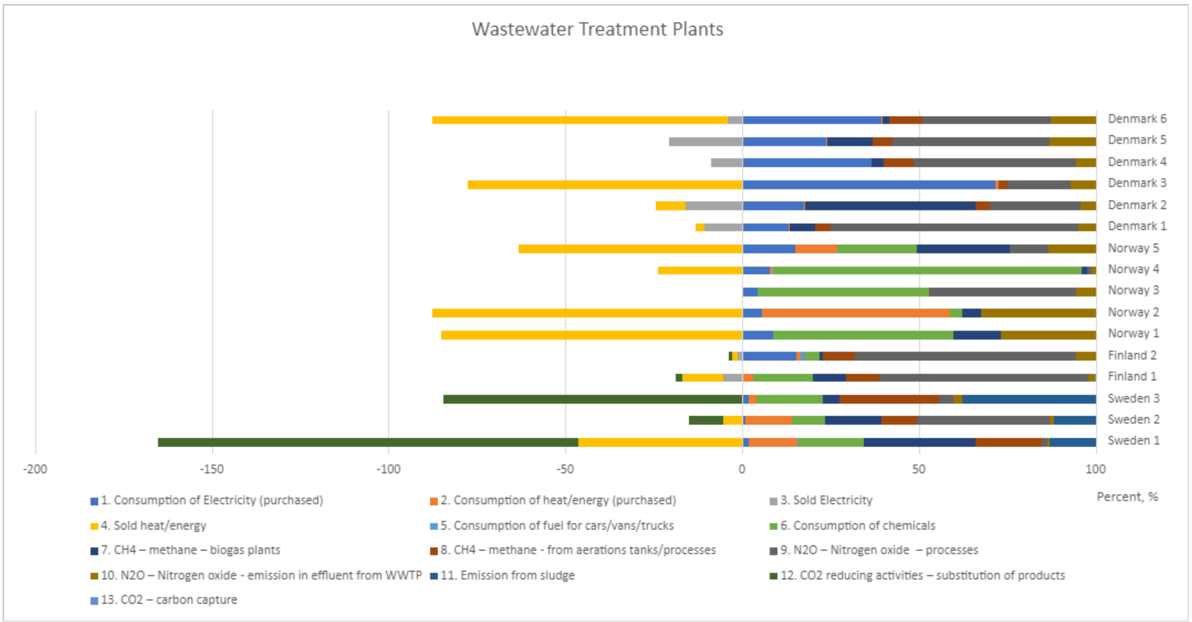
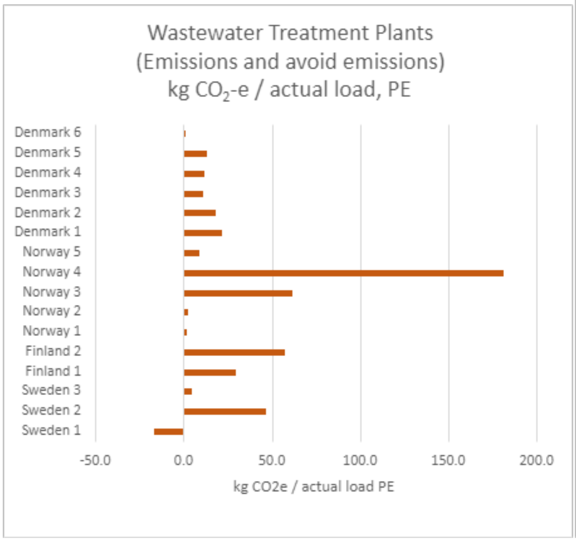


Figure 7. Emissions and avoided emissions for 16 Wastewater Treatment Plants in the Nordic countries. The emissions have been set to 100 % and the avoided emissions have been related to these.

Figure 8 shows the sum of the emissions (and avoided emissions) as a key figure, namely kg CO_2-e per actual load (PE) and inlet to the Wastewater Treatment Plant



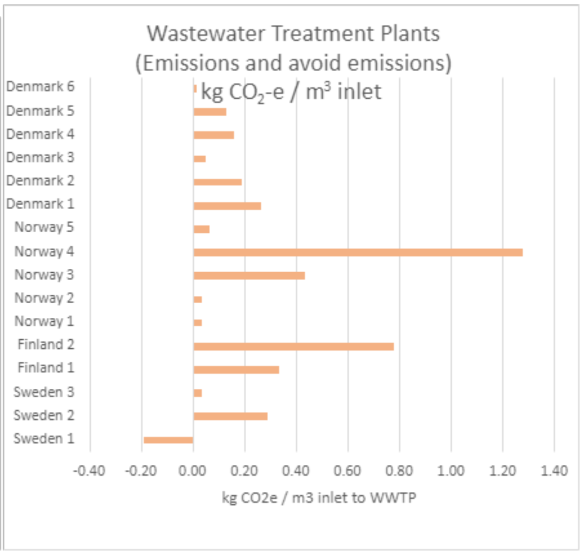


Figure 8. Emissions of CO_2-e from Wastewater Treatment Plants for 15 utilities in the Nordic countries (calculated as kg CO_2-e per actual load, PE (left) and per m^3 inlet (right).

6. Final remarks

Part I of the report presents the background of climate accounting in the four Nordic countries: Denmark, Sweden, Norway, and Finland. The common principles are a platform for Part II, where real data has been collected and is used to demonstrate how climate accounting can be done in the Nordic countries.

For further information, refer to the conclusions from part I – Where to go from here.

The data in Part II showed significant differences between countries, but also between utilities in the countries. The differences can e.g., be a result of actual differences in treatment in the different countries (e.g., no consumption of chemicals in Danish water treatment), it can be a result of different focus in operation of different plants (high chemical consumption in Norwegian WWTPs), or it can be a result of differences in reported parameters (e.g., afforestation in Denmark).

The data cannot be compared directly since some parameters are not included in some countries and others are. The collected data shows us, that the common Nordic Principles can serve as an important guideline for monitoring emissions in the water sector even though there must be local and regional adjustments to the model.

It is also clear from this work that we have the data needed in the water sector to set a zero emissions target and track progress in the years to come. In this way the collection of data from 12-16 utilities demonstrates that the approach in this joint effort is valuable for reaching the goal of climate neutrality in the water sector. To repeat a few key conclusions from this work:

- Select the key parameters that are most relevant for your utility and/or national model
- Establish a baseline of emissions
- Set an ambitious target for when to achieve climate neutrality
- Track progress towards the target
- For a start - focus on largest emissions from the sector (Minor emissions, supply chain and construction may come as a next phase

This is possible to achieve, and we look forward to further cooperation on the road towards climate neutrality in the Nordic, European and global water sector.

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