Projektakronym

iWater

Projektnamn

Water Monitoring Networks

Projektfakta

Sökt belopp från VINNOVA:	4 326 000 SEK
Sökande organisation (Koordinerande projektpart):	Stockholms Stad, Miljöförvaltningen Org. Nr. 212000-0142
Projektledare:	Juha Salonsaari, Stockholms Stad, Miljöförvaltningen
Övriga organisationer som deltar i projektet:	Ericsson AB Org. Nr. 556056-6258 Kungliga Tekniska Högskolan Org. Nr. 202100-3054 Linköpings Universitet Org. Nr. 202100-3096 Stockholms Universitet Org. Nr. 202100-3062 Stockholm Vatten & Avfall AB Org. Nr. 556175-1867 Telia Sverige AB Org. Nr. 556430-0142
Projektperiod:	2017-09-01 till och med 2020-06-30

1 Sammanfattning

The scope of the Connected Water Monitoring project is to develop a solution to measure water quality in real time. Focus is on a water life cycle perspective – from the water source, through the distribution network and back to the source through the sewage system. Sensors will be deployed and connected through cellular networks to an IoT platform, where advanced analytics are performed to introduce early warning functionalities. There are today no commercial water monitoring solutions available globally, that can measure, detect, and serve as early warning systems. The main innovative part of the project is to develop algorithms and big data functionalities to be used for the analytics of the raw sensor data and thereby create predictability and early warning capabilities. Hence, it is expected that the project will produce proof points for research and the industry related to IoT capability, as well as benefits to the society in terms of increased water monitoring efficiency and water safety.

The project is proposed by the city of Stockholm, Stockholm Vatten & Avfall, Ericsson, Telia Sverige, KTH, Stockholm University and Linköping University. The project will continue until the end of the funding period in 2020.

2 Projektets bakgrund och utvalt profilområde

The project, Water Monitoring Networks, is a project under Digital Demo Stockholm (DDS), an initiative by the City of Stockholm. The purpose of DDS is to enable

Stockholm to become the world's most innovative city by 2040. The scope of Water Monitoring Networks is to create a digital real time solution to measure the city's water quality from a life cycle perspective. The project is divided into three sub-projects:

- 1A Monitoring of water quality into and in Lake Mälaren: focus on identifying changes to the water composition to detect pollution and discharges and to serve as an early warning system.
- 1B Monitoring of sewage water: monitoring of outgoing water into the sewage and storm water system to be able to detect pollution from, e.g., industries, and thus serve as an early warning system as well as a pollution tracking system.
- 1C Monitoring of pressurized drinking water pipes: monitoring of drinking water from treatment plant to consumer taps to detect possible pathogens and prioritized polluting substances.

The profile area for the project originates from an analysis by the city of Stockholm where improvement areas have been identified and where there is a need to investigate the potential and any further implementation of IoT solutions. Water was one of the areas of interest for the city and thus has been assessed as a priority area and incorporated in the DDS initiative[1].

During the fall 2016, the project received funding under the IoT Sverige umbrella to start up the work and develop a cloud based IoT solution for measuring the water quality of the source water for the city (Sub-project 1A above). During 2016 and 2017, the following activities have been performed:

- Defining the needs, scope, and expectations for involved parties in general and the city and water utility in specific.
- Development of the concept study for all project phases.
- Defining a digital architecture, connectivity, and service model for the application.
- Understanding the sensor market, define sensor needs, identify sensor vendors and initiate sourcing processes.
- Set up basic structures for development of data management, analytics, and development of algorithms.
- Integration of the IoT platform with sensor modules, connecting sensors to the platform, initiate deployment of sensors in the water recipient.
- Initiate collection of data.
- Initiate development of basic GUI.

3 Beskrivning av projektet

The proposed project is a continuation of the DDS Water Monitoring project, where we will continue to develop an IoT solution for measuring water quality. The proposed project will implement Sub-projects 1B and 1C, and link these to Sub-project 1A, as described under section 2, continue the development of data analysis algorithms,

[1] http://www.stockholm.se/OmStockholm/Smart-och-uppkopplad-stad/Vara-samarbeten/

finalize visualization tools and develop a service model for and integration of the three Sub-projects under a common platform. The project will also examine and further develop two new sensor systems, in collaboration with Linköping University, for the detection of pathogens (electronic tongue) and oil spillage (electronic nose). Further on, the project will investigate how a Water Monitoring Networks solution can be implemented into other decision platforms within the city or water utility as well as potential introduction of actuator systems.

Similar to the already funded Sub-project 1A[2], sensors will be placed at strategic locations where data is collected to determine the presence of pollutants and pathogens. In Sub-project 1B, sensors will be placed in the storm water system to detect pollutants before they enter the recipient or treatment plants. In Sub-project 1C, sensors will be placed in the water distribution network with the main goal to target pathogens and certain chemicals. During this phase, novel research sensors targeting pathogens (electronic tongue), developed at Linköping University, will be tested in a live environment.

Since sensors will be placed under ground in pipeline systems, there will be a need to test and verify several connectivity alternatives to secure deep coverage, such as variations of LTE (Narrow Band-IoT[3]), 5G (if available) or connecting the devices through ground level antennas.

Sensor data will be collected and managed in a cloud based IoT platform. To be able to interpret and understand the data as well as to perform predictions analysis, algorithms must be developed. Investigation will also be done if it is possible to simulate the presence of certain chemicals and/or pathogens based on sensor data for different parameters. For example, changes in Dissolved Oxygen levels indicate the presence of microorganisms from sewage, urban or agriculture runoff or discharge from factories[4]. It is expected that the development of these algorithms and data analytics will be the main time and cost consuming part of the continuation of the project. Based on these algorithms and simulations, trigger functions and early warning systems can be introduced to be able to alert for pollution, certain substances, or pathogens present in the water system.

3.1 Potential

The City of Stockholm has identified water quality issues as a prioritized area of concern and water quality monitoring is therefore a tool to take sound water management actions with increased social benefit for the habitants of the city. An introduction of an end-to-end water quality monitoring solution can greatly enhance the knowledge of the status of the water in the recipient as well as in the commercial distribution and sewage networks. Further on, early warning functions can lower mitigation costs and minimize potential impacts on human health and the environment.

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[2] Vinnova Dnr 2016-03918

[3] https://www.ericsson.com/publications/ericsson-technology-review/archive/2016/nb-iot-a-sustainable-technology-for-connecting-billions-of-devices

[4] https://archive.epa.gov/water/archive/web/html/vms52.html

The city of Stockholm has a goal to become the most innovative and digitalized city in the world by 2040. DDS is one key arena to achieve this goal. The city has identified that digitalization and IoT is an area that must be developed.[5]

The potential for the project is to obtain a better knowledge about value creation for the city and IoT related issues in the public sector as well as to develop a commercially viable product for the companies involved in the development of the project. The gain for participating companies is to better understand the city needs and thereby be able to develop new products, solutions and services that can be offered to other actors within water management. Water monitoring could be an important tool in many parts of the world that has challenges with quality issues for the drinking water and where the source water faces severe damages from industrial pollution.

Thus, a sharing and distribution of the project results to other cities, municipalities in Sweden or abroad can either be performed through pure commercial channels, i.e. sales, or through partnerships between municipalities and cities. The city of Stockholm collaborates and share information and good practice with the adjacent municipalities as well as the municipalities around lake Mälaren within the MER-collaboration (Mälaren - en sjö för miljoner) and larger cities as Malmö and Gothenburg. The city of Stockholm will use the website Miljöbarometern[6] and/or Miljödata[7] to distribute and share information from the project. Furthermore, a website describing all the projects included in the DDS initiative is planned to be launched during end of Q2 2017.

Additionally, there is an interest to share the results through regional activities such as partnerships with, e.g. Race for the Baltic[8], where several municipalities in Sweden and the countries around the Baltic sea are partners. Finally, the project results will also be shared through activities by the academic partners, such as publishing of reports and academic papers.

There is today no commercially available system to remotely monitor water from a life cycle perspective (water source, supply, and outlet). The strength and innovative proposal of the Water Monitoring Networks project is to gather data in real time and to be able to develop and use predictive algorithms for early warning and mitigation purposes. Most existing digitalized water monitoring systems today are focusing on water sources (rivers and lakes) and do not take into consideration any predictive and analytics solutions to create true early warning functions. The development of these functions together with the real time collection of data is the main advantage of the solution in the proposed project, compared to existing methods and solutions.

3.2 Aktörer

For this application for funds from Vinnova and IoT Sweden, the project management will switch from Ericsson to the city of Stockholm that will lead the project and be the main interface towards IoT Sweden and Vinnova. However, the coordination of development and technical resources will still be managed by Ericsson. Further on,

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[5] http://smartsthlm.stockholm.se/

[6] http://miljobarometern.stockholm.se/

[7] http://dataportalen.stockholm.se/dataportalen/

[8] http://raceforthebaltic.com/

new partners will be added to the project – Telia Sverige and LiU. Additionally, existing partners from academia and the water utility in Stockholm will participate in the project and contribute with e.g. know-how, access to facilities and development. Finally, ABB will leave the project and not be a part in this application.

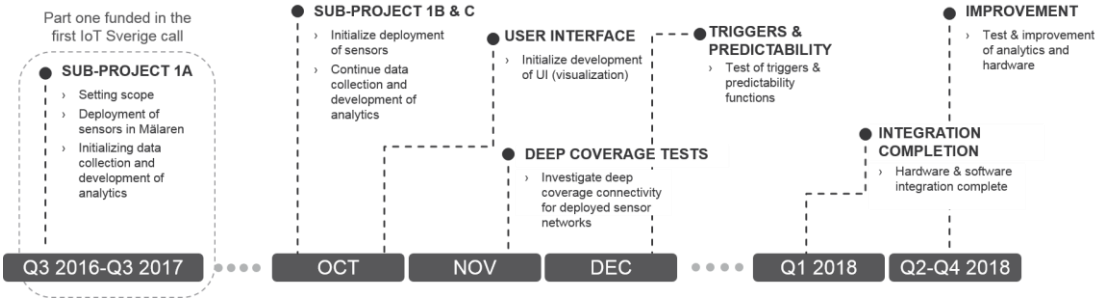
- City of Stockholm: Environment and Health Administration will be responsible for the overall coordination and be participating with detailed knowledge of water quality issues in the water sources as well as defining the requirements for the solution.
- Ericsson: Ericsson will lead the project from a technical and development perspective, and contribute with development of IoT platforms, connectivity and integration of sensors as well as contribute to the UI development.
- Telia Sverige: Telia will contribute with network connectivity and technical expertise related to IoT, visualization and big data management.
- KTH Electrical Engineering, with a substantial research experience within IoT systems, will perform an investigation of the IoT solutions for water monitoring, including sensing, networking and optimal decision making and their cross relation.
- KTH Water Resources Engineering and Stockholm University: will participate from different departments, Water Resources Engineering, and Physical Geography. The academia will primarily contribute with the development of the algorithms and data management.
- Linköping University (LiU): LiU will participate from the Department of Physics, Chemistry, and Biology, with innovative sensor solutions for water monitoring that will be tested and further developed.
- Stockholm Vatten och Avfall (SVOA): The water company of the city will be participating with knowledge of water management and water supply in the city as well as defining the requirements for the solution.

The different actors within the project will contribute with expertise within their fields. IoT expertise will mainly be contributed by Ericsson, Telia and academia, water management and environmental management by the city of Stockholm, SVOA and academia and sensor system expertise by LiUas well as KTH. Further on, the end user needs and wanted outcome for the water monitoring solution, are defined by the public partners to the project.

Since the project is a part of the DDS initiative, there is a strong foundation and commitment from all partners. The city of Stockholm and SVOA considers the project to be an innovative development within the water management area and a solution that potentially could be scaled within their operations. For Ericsson and Telia, the water area is interesting from a commercial perspective where Water Monitoring services could be a nation-wide and global offering. For the academia, there is an interest to explore real time sensor networks as well as to perform long term studies on water quality and its ecological and health risk implications and mitigation solutions.

3.3 Genomförbarhet

The proposed project is a continuation of the project that was funded by the IoT Sverige call under the autumn of 2016. This first phase of the project was focusing on development of the concept and deployment of sensors in the source water as well as to start up the development of basic algorithms for analytics and predictability. In this project description, we propose to continue this development, and finalize the whole project by further implementation also of Sub-projects 1B and 1C, as well as to fully develop the algorithms to be able to interpret the collected data and establish early warning functions. Different sensors and connectivity approaches will be investigated (such as deep coverage Narrow Band IoT) and novel innovative sensor solutions will be tested in a live environment. The project expects to deliver the following technical development during 2017 and 2018:



Deployment of sensors in the water distribution network as well as in the storm water system will be initiated during Q3/Q4 2017 and data from these sensors will be included in the development of algorithms for the analytics functions. Testing and development of the analytics will be continued during the whole life of the project to obtain an optimal result. During the autumn of 2017, interpretation algorithms and trigger functions, as well as the final visualization development will be implemented. Hardware and software is expected to be fully integrated during the first half of 2018.

The remaining project period 2018-2020 will focus on developing, testing, and demonstrating the transferability, applicability, and usefulness of results also for other places and water-quality contexts, nationally and internationally. The developments in this project phase will include extended simulation-interpretation approaches and models, based on observed and interpreted patterns in sensor data for monitored water-quality parameters. Specifically, the driver-effect implications of these interpretation will be generalized and made transferable, primarily through tested significant monitored-data correlations with other relevant catchment and source-water data and parameterizations. The developed models will comprise “intelligent interpretive algorithms”, while methodological developments will include tested approaches for establishment of baseline water-quality conditions and early-warning identification of changes from these. The usefulness of such changes will be demonstrated for early identification and warning of increased health and/or ecological risks, and realistic identification of the main causes of increased risks. Through the latter, effective and efficient (upstream and proactive) risk mitigation solutions are expected to be found and applied.

Additionally, the project will investigate how the solution can be integrated into existing decision platforms within the city or the water utility and how to implement different actuator systems. Examples of this can be how to react if the system triggers

any alarms related to pollution levels or if pathogens are found in the distribution network. Actuator systems could be redirection of water flows and introduction of anti-polluting agents, as well as to understand the level of automation of these kind of systems.

The overall duration of the project is estimated for three years (until 2020), with the following high level mile stones:

Based on the experiences from the first stage of the project, initiated in 2016, the project partners estimate the project plan to be realistic and feasible.

The results from the project are expected to give value to all involved parties;

- The city of Stockholm will use the knowledge and data from the project to better understand the temporal and spatial variation in conventional environmental monitoring data. Furthermore, the output will serve as an early warning system for contamination within the storm water system, which will contribute to the ongoing work with measures to reach and maintain good ecological and chemical water status.
- Ericsson will evaluate if water monitoring should be included in the company's offerings.
- KTH – EE School will receive contribution for research within IoT, with particular reference to sensing, networking, and optimal decision making, whereas the KTH Water Resources Engineering Institute will perform further research activities within the water technology area.
- LiU will get experience from field tests of both sensor hardware and sensor algorithms. Experience of different connectivity approaches will be important in order to establish which applications that are feasible for the sensor technology.
- Stockholm University will contribute to and benefit from significant advancements in scientific knowledge, database development and accessibility, and capability to couple sensors and database developments, and the syntheses and interpretations in a real-time information system.
- SVOA will use the result from the project as a steppingstone toward a water distribution system that is fully monitored from source to end recipient regarding water quality.
- Telia Sverige will use the result of this project to better understand the requirements on connectivity to retrieve required data in selected use cases. We will also better understand the requirements for value creation within the digital eco-system, including city of Stockholm.

Arbetspaket	Deltagare
WP 1, Projektledning, (Estimated Time: 2863 h; Estimated Cost: 2 289 600 SEK))	*City of Stockholm*
The Environment and Health Administration within the City of Stockholm will be responsible for the overall coordination of the project. Coordination between the Digital Demo Stockholm steering group and the project steering group will be performed by Ericsson and the Stockholm city Environment and Health Administration. Coordination of the technical development of the project, i.e. selection of sensor solutions, integration into IoT platforms, and testing of connectivity solutions.	*City of Stockholm* *City of Stockholm/ Ericsson* *All parties (Ericsson lead)*
Leverabler Coordination of funds & development, regular project meetings and reports as well as coordination with Digital Demo Steering Group	

WP 2, Projektets roll i behovsägarnas organisation, (Estimated Time: N/A; Estimated Cost: N/A)	*City of Stockholm /SVOA*
The city of Stockholm will use the knowledge and data from the project to better understand the temporal and spatial variation in conventional environmental monitoring data in order to enhance models used to calculate pollutant loads and make predictions of measures more accurate. The output will serve as an early warning system for contamination within the storm water system, which will contribute to the ongoing work with measures against accidents and larger contaminations to reach and maintain good ecological and chemical water status. The project is also a key part to the Digital Demo Stockholm initiative to be able to explore the possibilities with IoT, digitalization and innovation within the city.	*City of Stockholm*

For SVOA, the integration of a Water Monitoring solution would serve as a complement to existing analyses as well as an early warning function. Further on, the knowledge of the status of water in the distribution network can prevent potential problems with the fresh water systems.	*SVOA*
Leverabler Understanding the role of digitalization and IoT for monitoring environmental data and to utilize this data in developing mitigation efforts and improved management of the daily business.	

WP 2, Plan för hur projektresultaten ska kunna överföras till andra sammanhang, (Estimated Time: 1255 h; Estimated Cost: 950 801 SEK)	*City of Stockholm*
The city of Stockholm collaborates and share information and good practice with the adjacent municipalities as well as the municipalities around lake Mälaren within the MER-collaboration (Mälaren - en sjö för miljoner) and larger cities as Malmö and Gothenburg. The city of Stockholm will use the website Miljöbarometern and/or Miljödata to distribute and share information from the project.	*City of Stockholm*
Participate in developing information for the generic Digital Demo Stockholm website with information on the projects and their outcome and general participation in marketing campaigns.	*City of Stockholm/ Ericsson/Telia*
SVOA will spread the results from the project through articles and participation in seminars.	*SVOA*
Investigation of collaboration with multilateral parties such as Race for the Baltic and Stockholm International Water Institute (SIWI).	*Ericsson/Telia*
Coordination of scientific developments, testing and demonstration of transferability, applicability and usefulness of methods, databases, interpretation models, and results for various places and water-quality contexts, nationally and internationally.	*Stockholm University*
Development of externally published academic reports and papers and of new national and international application proposals.	*KTH, Stockholm University and LiU*
Leverabler Press releases, web based information, media coverage, academic papers and a generally increased interest in IoT and water monitoring technologies.	

WP 3, Technical Development, (Estimated Time: 1155 h; Estimated Cost: 881 522 SEK)	*Ericsson*
Architecture development, roll out of sensors and integration of the IoT platform, connection of sensors and development of basic web interfaces for the developer versions.	*Ericsson/Telia*
Wireless transmission from underwater or from in-pipe sensors is challenging due to the high signal attenuation. Evaluation of connectivity models (e.g. CAT M, NB-IoT, 5G) will be investigated and tested to achieve deep coverage in pipeline distribution systems	*Ericsson /Telia Sverige/KTH*
Basic investigation of service models and business evaluation.	*Ericsson/Telia*
Evaluation of solutions from a sustainability perspective, with the aim to understand how the solution affects Swedish Environmental goals as well as UN Sustainability Development Goals.	*Ericsson/Stockholm University/Telia*
Leverabler Finalization of the technical development and integration of applications and devices into Ericsson IoT platforms (Ericsson IoT Accelerator). Understanding deep coverage technologies to optimize connectivity performance from device to networks. Evaluation of the solution from a service, business, and sustainability perspective.	

WP 4, Data Management and Development of Algorithms, **(Estimated Time: 3386 h; Estimated Cost: 2 447 871 SEK)**	*KTH*
Development of predictability and early warning functions based on sensor data received from deployed sensors. The emerging technology of IoT for water distribution systems consists of networked computing, sensing, and actuator devices used to monitor, connect, and control the water distribution lines, often with heterogeneous networking technology. In order to economically and sustainably operate these IoT systems, the analysis of the data has to be timely and provide reliable spatial and temporal distribution of events. A challenging aspect in the design of data analysis algorithms is that while the technology advances and the networks grow larger, the communication bandwidth available to move the sensed data to a centralized IoT platform remains limited, whereas the networking technology may be heterogeneous. Motivated by these challenges, this WP will investigate novel data analysis algorithms and their interaction with the networking protocols, where sensors' information is communicated using limited bandwidth of the IoT devices. The impact of data delays, missing data or high data quantization, and networking protocols on the task of data analysis will be investigated. New algorithms that are provably robust to these issues will be proposed. Privacy and security issues in the data analysis will be incorporated for the relevant use cases.	*KTH/ Stockholm University/ Ericsson/Telia*
Interpretation of real-time data on chemical and pathogen dynamics over time. Development and use of "intelligent interpretive algorithms".	*Stockholm University/KTH*
Leverabler Development and integration of algorithms for analysis of sensor raw data and implementation of predictability analyses.	

WP 5, Visualization and development of UI, (Estimated Time: 972 h; Estimated Cost: 627 464 SEK)	*Stockholm University*
Development of a final UI based on needs from ends users (city of Stockholm and SVOA) as well as the outcome from WP4. Generalized and extended use of "intelligent interpretive algorithms". Establishment of baseline water-quality conditions. Identification of main change drivers in catchment and source water, e.g. in hydro-climatic and associated anthropogenic chemical input variability and change. Identification of effective measures for mitigation and control of health and/or ecological risks affected by main driver-effect relations. Development and visualization of higher-level synthesized data products, based on interpreted real-time dynamics and co-evolution of chemical and pathogen data and hydro-climatic catchment and source-water data over time UI will be developed for different web based services (web pages and web applications) and possibly also for cellphone based apps.	*Stockholm University/KTH/ Ericsson/Telia*
Leverabler Delivery of a visualization platform for professional users.	

WP 6, IoT Sensor Development, (Estimated Time: 474 h; Estimated Cost: 331 464 SEK)	*LiU*
Sensor technology for drinking water quality monitoring (electronic tongue): The electronic tongue is an electrochemical sensor technology based on pulsed voltammetry that detects anomalies in the drinking water properties. The electronic tongue is known to be sensitive to a wide range of anomalies in the drinking water quality. In particular the electronic tongue is very sensitive to the presence of sewage in drinking water and can therefore detect an important marker of the presence of pathogenic microorganisms. LiU will provide sensor systems based on the electronic tongue for both field tests and lab tests.	*Mats Eriksson, LiU*
Sensor technology for raw water quality monitoring (electronic nose): The electronic nose detects petroleum products in water by transferring them to the gas phase where they are detected by an array of gas sensors. Detection limits in the lower ppb range have been achieved even in source water with high humus content. LiU will provide sensor systems based on the electronic nose for both field tests and lab tests.	*Fredrik Winquist, LiU*
Leverabler Sensor equipment for field tests of drinking water monitoring (electronic tongue). Sensor equipment for field tests of raw water monitoring (electronic nose). Report of field tests with the sensor equipment.	

WP 7, Integration into existing systems and examination of actuator controls, (Estimated Time: 1232 h; Estimated Cost: 968 278 SEK)	*KTH*
Examination of decision processes within cities and how Water Monitoring Solutions can be integrated into these. In this task, we will investigate how the information collected and analyzed by the IoT system will be used for automatic monitoring of the water collection and distribution. We will consider which decision mechanisms are currently in use and which can be made automatic thanks to the IoT platform.	*KTH/Ericsson/Telia*
Investigation of actuator systems and integration with Water Monitoring Solutions. In this task, we will consider how to optimally allocate water resources and monitoring resources in an automatic manner, based on the new data analysis available from the previous WPs. We will consider which actuators are currently used and which of them can be made automatic by using the information available on the IoT platform.	*KTH/Telia/Ericsson*
Investigation of possible integration of the Water Monitoring solution into existing control systems of SVOA	*Ericsson/SVOA*
Leverabler Understanding of how the solution can be integrated into existing systems used by cities/water utilities as well as to define how different actuator systems could function.	

4 Projektets kostnader och finansiering

The estimated costs per partner are reported in the table below.

PARTNER	TOTAL PERSONELL COSTS (SEK)	TOTAL HARDWARE/ SOFTWARE COSTS (SEK)	OWN CONTRIBUTION (SEK)	EXTERNAL FUNDING APPLICATION (SEK)
City of Stockholm	1 320 000	0	942 000	378 000
Ericsson	2 414 400	155 000	1 881 600	687 800
KTH	1 491 588	0	0	1 491 588
LiU	441 952	0	0	441 952
Stockholm University	828 660	0	0	828 660
SVOA	170 000	0	120 000	50 000
Telia Sverige	1 830 400		1 382 400	448 000
TOTALS	**8 497 000**	**155 000**	**4 326 000**	**4 326 000**

The project budget is 8 652 000 SEK for the whole period, where the participating companies will contribute with, in total 73 % of in-kind contribution based on their costs, as well as with some technical products and services, such as connectivity, IoT platforms and deep coverage chipsets. The actual value for these products and services can however not be specified at this point since many of them are internal developer products. Main costs items are personnel costs and the own contribution from the participating partners is mainly in-kind and related to work hours.

The estimated project costs related to relevant tasks are reported in the table below:

TASK	COST (SEK)	IN-KIND CONTRIBUTION (SEK)	EXTERNAL FUNDING (SEK)
Project Management	2 289 600	1 987 200	302 400
Technical Development	1 036 522	320 000	716 522
Analytics Development	2 779 335	380 800	2 398 535
Communication & Results Spreading	950 801	726 000	224 801
Hardware/Software	155 000	0	155 000
Others	1 595 742	912 000	683 742

5 Övrigt och referenser

A gender analysis for the project has been made. The water monitoring solution and the outcome of the project is gender neutral, i.e. affecting both male and female positively. The project composition of personnel is biased towards men, where at the date of the application there were 11 males and 6 female involved in the project development. This ratio may change during the coming years when the project is running.

Further on, please find references in the footnotes of this application.