Sensorita – Data-Driven Waste Management

Waste collection is an area that has seen little innovation over the last few decades, and there is hardly any transparency in the value chain. Lack of sufficient information makes it problematic for stakeholders within the industry to make informed decisions, to measure the effect of initiatives and to increase their efficiency.

Sensorita's mission is to help our customers increase the rate of recycling by providing cutting-edge analytics. Insight into consumer behavior and waste trends enables more efficient waste management through better planning, logistics and waste collection. By using Sensorita in operations, the customers will cut costs and CO_2 emissions associated with ineffective waste collection.

By the project launch, the team behind Sensorita has completed the preparatory phase, including the development of an MVP and initial testing. Sensorita has already generated interest in the existing market and in February 2020, the team signed a contract with Asker municipality worth 99 500 NOK (excl. MVA) for a pre-study testing 22 prototypes. The intention is to complete a pilot project with an added 200 sensors by August 2021, generating a revenue of 150 000 NOK. The estimated potential of recurring revenue in Asker municipality is 7 MNOK annually. Sensorita aims to become a global supplier of data-driven waste management analytics. Enabling large-scale implementation of sensors in household bins will provide end-to-end data insights that result in a more transparent value chain.

The goal of the STUD-ENT-project is to utilize the collaboration with Asker to gain more insight into the customers' demands and how they can be met effectively. Asker will be used as a reference case to illustrate where Sensorita can generate the most value for the customer and to develop a plan for further scale-up. The project results will be used to develop and verify the business model as a basis for further commercialization.
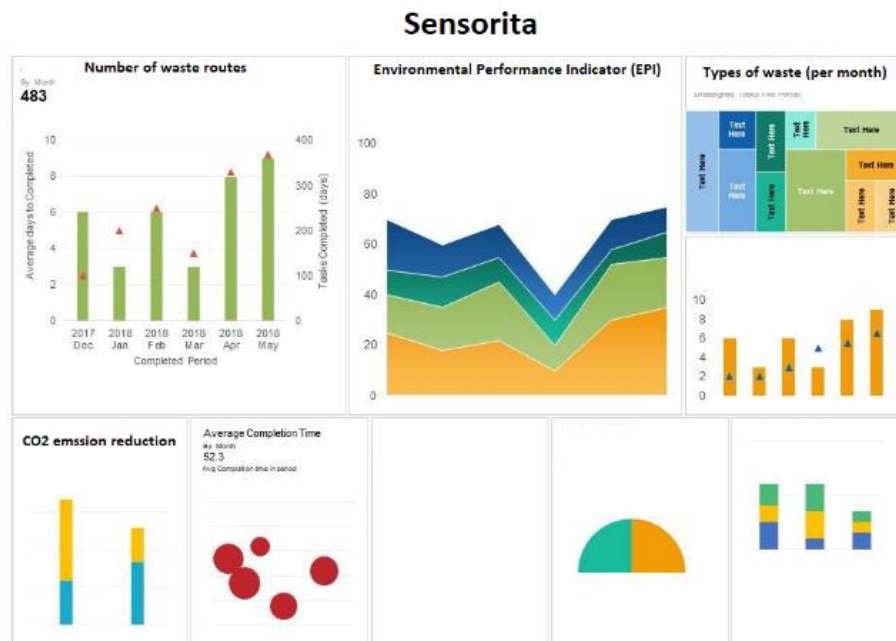

Figure 1: Overview over the Sensorita API.

1   Research and innovation

Research and/or knowledge:

Both project initiators are students at NMBU, about to complete a Master's of Science in Industrial Engineering and Management. Emil Skar is specializing in Data Science with a focus on digitalization and digital business models. He has four years of experience as a consultant working in different optimization projects for Asker municipality. In addition, he has experience from data science projects in Avinor. Skar is currently writing his master's thesis on optimizing energy usage in sensors. Ulrikke Lien specializes in innovation and entrepreneurship and has wide experience in organization development, leadership and administration. She has work experience from Aggrator, an Ås-based incubator, and has served as the Director of Administration in UWC Norge, a large non-governmental organization with an 18 MNOK budget.

Together the duo has strong contacts in the field of waste management in Asker municipality and a wide network in the innovation and startup scene. This project has evolved in the context of the comprehensive expertise in the data science and sensor community at NMBU, and the project initiators are completing courses where the development of this concept is a key component. The project has reached TRL level 4, with the next step, TRL 5, being the pilot with a demanding client.

Level of innovation

Around 21% of Norway's waste is generated by private households.[1] This waste is collected based on static route models, independent of how full the containers are. Studies in other European cities have shown that both costs and emissions associated with waste collection can be reduced by 30-60% by implementing sensor technology.[2] At present, little has been done to introduce this technology to a Norwegian context, something Sensorita wants to change. Through dialogue with Asker municipality, Sensorita has identified additional demands for change. Asker expresses a wish to introduce weight based fees for households, as this has shown to improve the inhabitants' recycling habits in comparable European cities.[3] They also wish to measure the effect of different efforts targeting waste reduction and increased recycling.

The Sensorita System contains a Hardware (HW) component, the sensor, and a Software (SW) component enabling data collection and processing. The sensor collects data from household waste bins, such as volume, temperature and weight. This is processed to give information about waste volume increase-rate and the degree of utilization, which in turn predicts the need for pickup. Metadata such as neighborhood and category of household will be utilized to further increase the accuracy of predictions. The system uses historical data and machine learning to predict consumer behavior as a tool for smart collection, which is shared with the client through an API. Route optimization based on machine learning and predictions, in combination with live level measurements, minimizes the consequences of potential defects on sensors or data errors. Sensorita's information can easily be combined with existing technology, such as

Figure 2 Sensorita sensor installed in waste bins

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[1] https://www.ssb.no/avfregno

[2] https://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=5235

[3] Ålander, J. (2013). *Economic incentives to reduce waste: The effect of weight-based fee on household waste* (Master thesis). Stockholm University, Stockholm.

RFID chips already implemented in many municipalities, to support the clients in exploiting their resources efficiently.

Today, there are no existing big scale sensor systems implemented in household waste bins, despite the big potential market and the clear needs of the industry. The existing solutions are made up of expensive sensors, whereas Sensorita's business model is based on cheap sensors with the software as the main asset. New methods, such as on-edge computing and effective data processing, will prove the system scalable. Through data collection and big data, Sensorita can evolve over time to include new services and products.
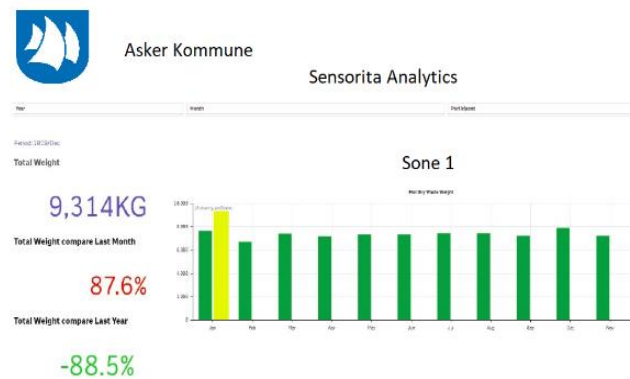

Figure 3 Overview of the Sensorita sensor and analytics API.

2   Impacts and outcomes

Market insight and areas of application

The international Smart Waste Management market is estimated to reach 4 billion USD by 2025.[4] The overall narrative of the industry is rather conservative. However, the Norwegian market is known to have a high degree of willingness to innovate, with the return system for plastic bottles as an excellent example of this. Sensorita initially targets the Norwegian household waste collection market, which in 2016 had a turnover of over 10 billion NOK.[5]

Through the initial phase and dialogue with Asker municipality the team has gained a realistic understanding of the demands of a municipality when it comes to utilizing its financial resources. The collaboration is providing valuable insight into the space for improvement within waste management, and moreover the willingness to innovate in favor of environmental and economic benefits. When contracting, all municipalities have to make a call for tenders; a process in which the financial aspect is often weighted more than the environmental. With Sensorita, the municipalities will be able to provide a fair benchmark for contractors, benefiting both environmental and financial considerations. With access to this type of data and all the possibilities that comes with it, Asker municipality can promote a more sustainable lifestyle through implementing gamification of recycling habits and waste reduction in their own app, Min Renovasjon.

Due to the project team's unique insight and network in the municipal management, this sector is a natural starting point for Sensorita. The system is designed to easily be modified to fit other sectors in the future, such as the construction industry, which produces 25% of Norway´s waste,[6] and containers for clothes' donations.

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[4] https://www.internationaldataspaces.org/wp-content/uploads/dlm_uploads/2019/07/20190625-1400-Use-Case-Pitch-Smart-Waste-Managment-by-Alexandros-Nizamis.pdf
[5] https://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/vekst-for-avfallshandtering
[6] http://www.byggemiljo.no/rapport-hvor-mye-avfall-produserer-bygg-og-anleggsnaeringen/

Competitor Analysis- There are a range of providers of sensors for waste bins, but none of these are implemented on a big scale. They are usually expensive and/or overengineered, and not within the financial reach of the municipalities.

Some of the models, such as Europress SMART, are systems combining sensors with compressors, targeting large producers that generate large amounts of waste. These are large installments and complex machines operating in a different market segment than Sensorita. Throughout 2019 and 2020 Oslo is piloting three smaller models that both compress and measure the waste. The models Solarbin, FinBIN and Farsite are robust and designed for urban areas, such as parks, and are too expensive to introduce to private waste management.

There are a few providers of simple sensors that can easily be installed inside existing bins. Waste Hero and IoT Hardware are small businesses, while Enevo and Farsite are larger companies providing sensors. These are placed in a rather high price range, with a price of around 5 000 - 10 000 NOK per sensor. Although Enevo introduced dynamic route planning for Norway in 2018, this is only implemented in some larger buried containers, and their system is based on data solely from the 30 last days.[7]

Sensorita aims to develop a simple and robust system that enables a large-scale implementation of sensors in household bins that will provide the user with end-to-end data insights resulting in a more transparent value chain.

Strategy for realisation

The project is currently in the TRL level 4, with the aim of reaching level 5 in fall 2020 in cooperation with the demanding customer, Asker municipality. Developing and testing a prototype with support from the expertise in Asker municipality will help the team develop and verify the business model. This will result in a version 2.0 of the product and an up-scaled pilot of 200 sensors.

Sensorita will simultaneously meet other potential customers in order to make it feasible for the product to cover multiple market segments.

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[7] https://www.miljokommune.no/Documents/Klima/Klimasats-erfaringer%202016/Halden%20avfallssensorer%20rapport.pdf

Position in the value chain - The project team's initial aim is to enter the waste collection value chain for private households. The municipalities will be the natural client as they already own other permanent installations, such as the waste bins itself. However, waste truck operators would also benefit from Sensorita, increasing their efficiency and profitability to win tenders. In the value chain, Sensorita will operate as a sensor integrator, providing information to the municipalities' current systems such as KOMTEK. Installation and maintenance will in most instances be outsourced to a third party. This could either be a subcontractor or a partner contractor.
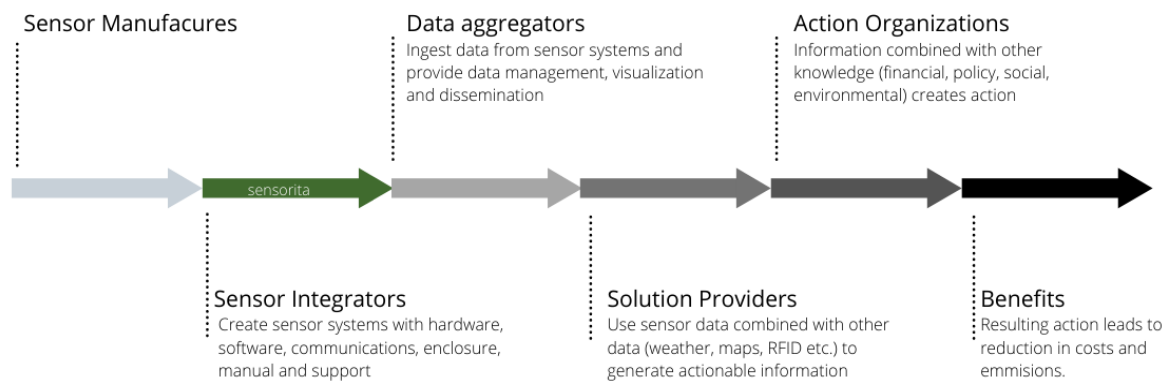

Figure 3 The value chain within Smart Waste management sector.

Business model - Sensorita's concept is B2B, where our ambition is to sell each sensor at a low unit price estimated to 100-500 NOK. The model is based on recurring revenue, through different options of subscriptions. The pilot of 200 sensors will give a monthly revenue of estimated 100 NOK per sensor per month, resulting in a 150 000 NOK income the second half of the project period. Through further scaling, the estimated subscription cost will be around 5-10 NOK. In the case of Asker municipality, this will mean a 7 MNOK annual income for Sensorita.

In addition to the fixed entry cost, the customers pay a monthly fee to receive the collected data through an API. Different subscription plans will be available, where processed data and added information will cost more than raw data. Over time, Sensorita will accumulate valuable information about estimates, trends and predictions in relation to household category and neighborhoods. As the predictions get more accurate, the need for a high number of sensors will decrease, and the data and software will be Sensorita's main asset. The team will use the initial phase of the project period to research and assess different business models aiming for a rate of return of less than four years.

By using Asker municipality as a reference point, the potential in the Norwegian market is estimated to be 1 500 MNOK.

Conditions and rights

Through the ratification of the Paris Agreement, Norway has pledged to reduce its CO_2 emissions by 40% by 2030. The transport sector, with around 30% of Norway's total emissions,[8] is a major contributor, and in the last few years the emissions from this sector have increased.[9] In 2019, the Norwegian government raised the benchmark for this sector to a 45% reduction, while EU recently implemented new measures to reduce emissions from heavy vehicles in their Mobility Package "Europe on the Move." There is political will to meet the required CO_2 reductions; the introduction of logistics optimizing technology for waste management can be an important step towards achieving this.

SWOT for StudENT Forny project period - The SWOT analysis gives an overview of Sensorita's preconditions and identifies obstacles and opportunities.

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[8] https://www.avfallnorge.no/bransjen/nyheter/flere-avfallsselskaper-gj%C3%B8r-grep-for-%C3%A5-kutte-utslipp-fra-transport
[9] https://www.tu.no/artikler/norske-klimagassutslipp-synker-for-sakte-ma-ned-40-prosent-pa-ti-ar/477940

Strengths – Specialized competence in the core team and a user based approach
- The project has signed a contract with a demanding customer that accommodates a user based approach in the development.
- The core team has competence in data science, machine learning, digital business models, organization development, administration and leadership. Complementary competence and equipment is available at the innovation lab "Eik Idéverksted."

Weaknesses – Lack of experience in public contracting
- Despite the team's competence they lack experience in markets regulated by tender regulations, especially regarding public contracting in Norway.
- Sensorita is lacking a detailed estimate of the national and international market. This is something the team will work on in the beginning of the project period.

Opportunities – Innovation in waste management and Smart cities
- The waste industry is entering a new era with emphasis on smart technology and innovation. This is still in an early stage, and the time to ride the wave is now. Smart cities are on the rise and is a focus area both nationally and internationally.
- The Norwegian government wants to reduce CO_2 emissions by 40%, which means that every sector has to contribute. Technology that enable CO_2 cuts, such as Sensorita's sensor system, will be essential in achieving this reduction.
- The recent merge of municipalities has given the local centers of administration larger areas to manage. This is a good opportunity to rethink and optimize waste collection.

Threats – Small company
- Sensorita is a small business without an established brand. Sensorita will use the project with Asker to promote the brand, network and create ties to other municipalities.
- Weak IP on the hardware. Senorita's asset is mainly the software and complex prediction algorithms.

Benefit to society and sustainability
Sensorita works to follow the guidelines as defined by the UN in the Global Compact and in the Guiding Principles and by the OECD in the Guidelines for Responsible Business. Furthermore, a fully developed system will contribute to the UN's sustainability goals through innovation. In addition, Sensorita's work supports the idea of a circle economy.

3   Implementation

Project plan

The team behind Sensorita has already signed a contract[10] with a demanding customer, Asker municipality, that has expressed vast interest in Sensorita's technology. The municipality is investing 99 500 NOK in an innovative prototype project taking place in the fall of 2020. During the course of spring 2020, Sensorita will have developed an MVP with the supporting backend. Close cooperation with key personnel in Asker's waste management allows for an in-depth understanding of the market at an early stage.

The project will fully launch in August along with the prototype installation in Asker municipality. At this point, the core team will be ready for full devotion to the company. Several professors at NMBU have agreed to use Sensorita's project as a case-study in a number of courses at the university. Thus August falls as a natural time to launch the project. This will contribute to reduce the risks throughout the implementation stage.

Milestones and activities		2020 - 2021											
		A	S	O	N	D	J	F	M	A	M	J	J
M1	**Market, user, opportunity, IPR and cooperation analysis**			■									
A1.1	Market clarification – bottom-up estimates of potential	■	■	■									
A1.2	IPR analysis – Freedom to Operate	■	■										
A1.4	Analysis of stakeholders - Which stakeholders have overlapping interests, identify potential partners	■											
M2	**Prototype demonstrated in field**							■					
A2.2	Complete production of sensors	■											
A2.3	Installation of sensors in Asker municipality		■										
A2.4	Development of data platform; storage, reports, visualization.	■	■	■	■								
A2.5	Data collection, building experience		■	■	■	■	■						
A2.6	Analysis of prototype testing. Determine requirement specification.						■	■					
M3	**Business development and capacity building**									■			
A3.1	Business model development	■	■	■									
A3.2	Price calculation and pricing strategy.									■	■		
M4	**Network and financing**										■		
A4.1	Cooperation with Asker municipality	■	■	■	■	■	■	■	■				
A4.2	Examine other partner possibilities.	■	■	■	■	■	■	■	■				

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[10] The contract is signed through Lien Engineering, which will be reregistered as Sensorita AS before the project launch.

A4.3	Building investor relations and participation in relevant arenas.
M5	**Pilot Sensorita 2.0 with Asker kommune**
A5.1	Develop sensor unit based on field testing
A5.2	Production of sensors for testing with multiple customers
A5.3	Technical verification with third party, certification.
A5.4	Collection of data from 2.0

Financing before and after Stud-ENT project period- Before the project period begins, Sensorita will be using facilities, personnel and equipment provided by Eik Ideverksted and through student projects. The project is largely built and financed by the core team's work effort. The first phase, including the development of an MVP, will be partly financed through the contract with Asker municipality. In addition, one of the key activities during the project period is to develop investor relations and a financially viable business model.

The aim of the StudENT period is to build and demonstrate a Sensorita version 2.0, which in turn will trigger sales. The objective is to develop a commercial product ready for upscaling through sales and/or innovation contracts.

Management, team and expertise

Project team

Name	Role/contribution to the project	Percentage of full-time equivalent
Emil Skar	CTO – project manager	100%
Ulrikke Erdal-Aase Lien	CEO	100%

The members of the student team will be engaged through the student consultation company, Ledo, on an hourly basis. The students who excel during the project period will have the opportunity to obtain shares in Sensorita. Any redistribution of shares in the project period has to be approved by NFR.

Student team

Name	Role	Percentage of full-time position
Kristian Gunder Kramås	Electronics and Frontend	20%
Anders Mathisen	Product development and backend	20%

Mentors

Name	Role / contribution to the project	Workplace/Position
Kristian Omberg	Technical advisor – Sensor development	NMBU/Overingeniør
Oliver Tomic	Technical advisor – Data analysis	NMBU/Førsteamanuensis

Simen Hesleskaug	Business development and investor networking	Grindøy Rådgivning AS/ CEO

Partners

Name	Role / Contribution to the project
Dynamic Precision AS	Third party developer
Asker municipality	Demanding customer

Contribution from university/university college

Contribution	Supplementary description of contribution	Mark if yes
Office space	NMBU has the opportunity to offer office spaces at the innovation lab at Eik Ideverksted during the project period.	X
Access to lab and test facilities	The project group will have the opportunity to use the electronics lab and NMBU's ITS test field during the project period, and have the opportunity to order parts from the prototype workshop.	X
Access to specific scientific expertise	At NMBU the project group will have access to the relevant technical expertise within the fields of data science, product development, applied robotics, industrial engineering and entrepreneurship.	X
Other advisory services	NMBU will, to the best of our ability, provide the project group with other expertise e.g. through Inkubator Ås.	X
Assistance in carrying out tasks	NMBU will include the project as a case in relevant courses within the fields of business development, sensors and electronics and other.	X
Other		

All the contributions from NMBU will be provided at a market competitive level.

Budget

To execute STUD-ENT Sensorita applies for 1 000 000 NOK, where 55 % of the budget is dedicated to salary for the project team, due to project teams' interdisciplinary competence. The student contributions will be covered through the student consultancy company, Ledo, which are an active part of the innovation ecosystem at NMBU.

Budget for the project period August 2020 - August 2021.

Activities	Cost (NOK)
Salary project team (including student team)	680
Compensation mentors	30
Development of a production ready prototype	300
Market work	60
Production of pilot series	150
IPR process with Patentstyret	40
Project documentation, accounting	20
Total	**1 280**

Amounts shown in 1000 NOK.

Financing plan for the project period August 2020 - August 2021.

	2020	2021
Private startup capital	30	
Forskningsrådet, StudENT FORNY	600	400
Income sale	100	150
Total	**730**	**550**

Amounts shown in 1000 NOK, the financing plan only shows the financing in the project period.