Much more than a normal pipe

CBI.ATTRACT | Jul, 2024 | Final report | Team Ahead

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Summary

Our team is composed of students from different universities and different disciplines:

✨ **Priscilla Gaibini,** Business Statistics at the University of Bologna;

✨ **Giuseppe Carrino,** Artificial Intelligence at the University of Bologna;

✨ **Yousra Gottih,** Electronics Engineering at the University of Modena.

✨ **Karolina Bergamo,** Political Communication at the University of Bologna;

✨ **Marco Moriconi,** Civil Engineering at the University of Ferrara;

✨ **Ilayda Bagci,** Precise and Sustainable Agriculture at the University of Bologna;

Introduction

During the CBI.ATTRACT program, the team AHEAD was assigned with the technology created in the WAP project (a partnership between CERN and CSEM), which demonstrated the feasibility of 3D-printed pipe segments equipped with standard hydraulic fittings and integrated Aerosol Jet printed RTDs (Resistance Temperature Detectors) in direct contact with the fluid.

Building on these foundational technology bricks, the main goal of AHEAD is to develop a TRL7 (Technology Readiness Level 7) product, enabling fluid parameter sensing within a simple pipe segment at an industrial pre-production level, compatible with natural refrigerants.

Subsequent developments by CSEM, after the development of SWAP, project have significantly improved the quality of 3D printing, essentially eliminating the need for mechanical post-processing.

These improvements allowed for the full closure of the instrumented section by resuming 3D printing operations after sensor deposition.

Additionally, integrating COTS (Commercial Off-The-Shelf) miniaturised sensors into the 3D printing process has expanded the capability of the instrumented pipe to host elements not suitable for Aerosol Jet printing.

💡Key characteristics of AHEAD include:

- Integrated fluid sensing within the pipe wall
- Standalone wireless powering and monitoring
- Direct fluidic process monitoring in previously inaccessible areas
- Flexibility in geometrical shapes enabled by 3D printing

Our approach has involved several stages, each marked by significant milestones: the Discovery phase, the Design phase, and the Prototyping phase resulting with our final product SPipe.

> **Info** The following sections of this report will provide a detailed explanation of the technology, followed by a overview of the work done by the team AHEAD, from the initial exploration to the final prototype development.

The Discovery Phase

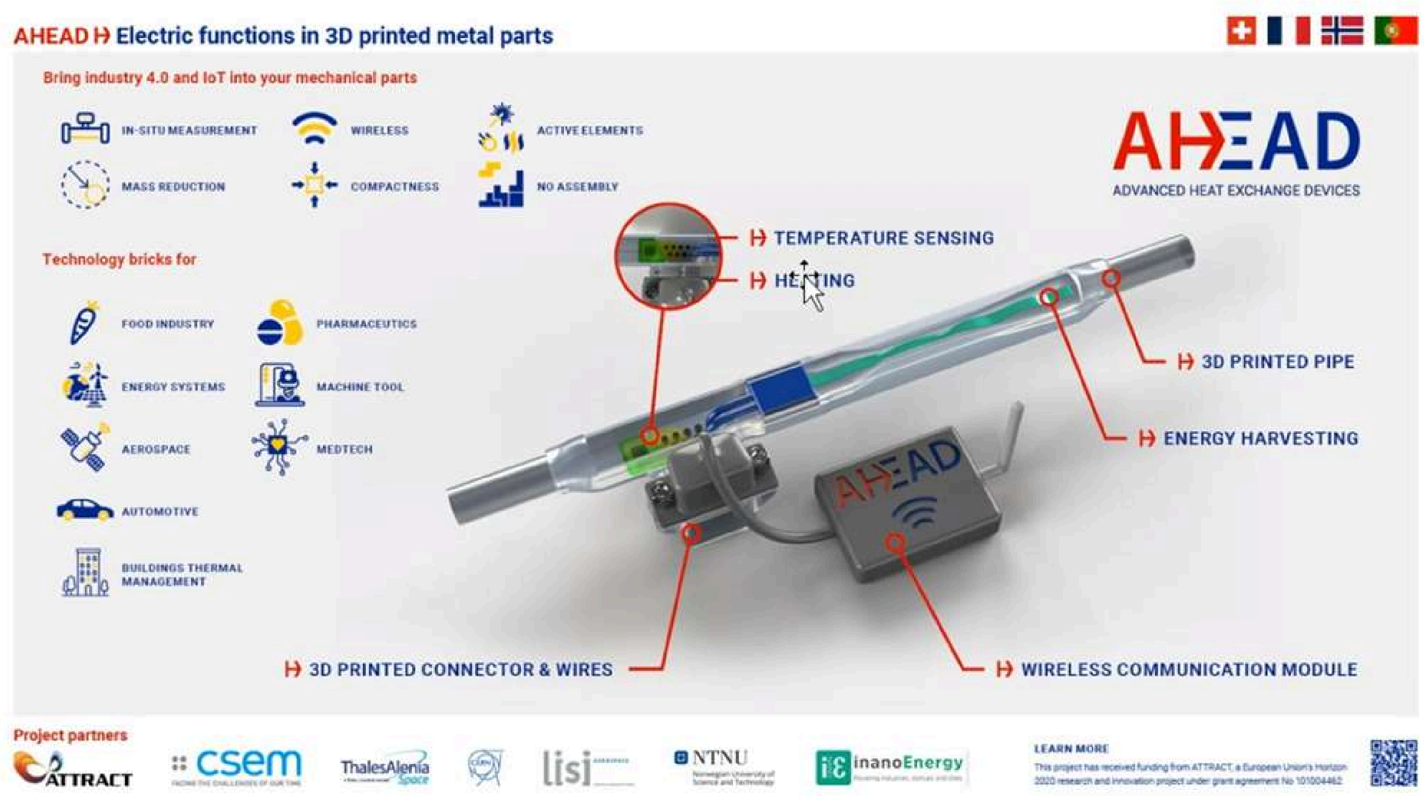
👀 TECH UNDERSTANDING

AHEAD (**Advanced Heat Exchange Devices)** is a 3D printed pipe in stainless steel with embedded sensors, it can monitor important parameters of the fluid, such as: flow rate, pressure and temperature. AHEAD is equipped with an energy harvesting system (triboelectric membranes) capable of converting the energy of the fluid in electrical energy, this energy is enough to power all the embedded sensors, so AHEAD is a stand-alone device and requires no external batteries.

AHEAD also has a wireless communication module by which it can share in real-time all the measurements of the parameters of the fluid.

Analysing the AHEAD tech card, the papers and talking with the tech partners at CERN, these are the 3 main features we discovered from our technology:

1. Freedom of design: thanks to 3D printing every form is imaginable. AHEAD could be printed with different shapes, changing the diameter and the length of the pipe. Also, the material could be changed in function of the field of application.
2. Embedded sensors: implementing an integrated temperature sensor printed with aerosol technique or COTS sensor in direct contact with the fluid ensure precise measurements and data.
3. Self- powered: thanks to the energy harvesting system AHEAD is considered a stand-alone device, so no batteries supplies are required. This feature is very important when AHEAD is installed in inaccessible area with space constraint.



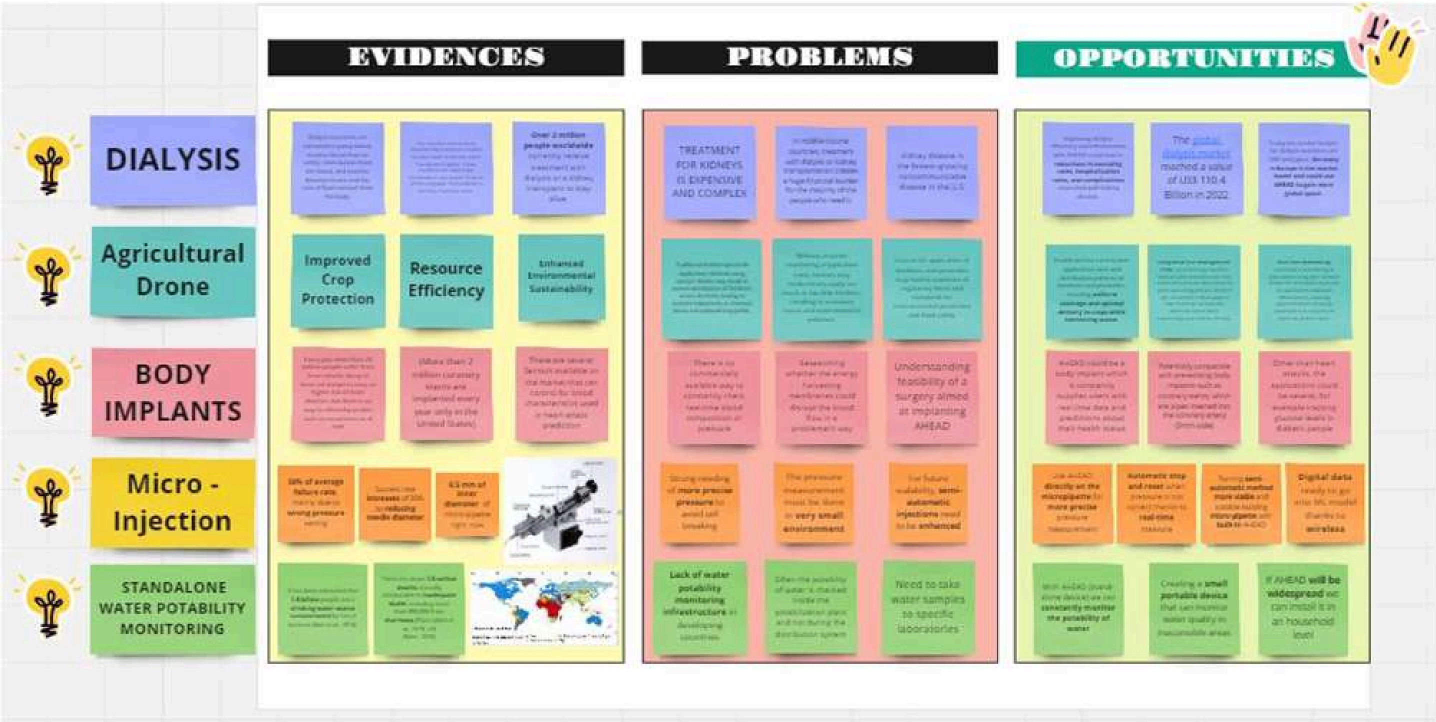
✍️ FIELD OF APPLICATIONS

After the tech understanding the divergent thinking phase began. The aim of this phase was to explore every single idea that came in mind to our team, trying to understand AHEAD potential in each field. After the divergent thinking phase, we came up with 5 field of applications:

💡

1. Dialysis
2. Agricultural drones
3. Body Implants
4. Micro-injection
5. Water potability monitoring

➡ For each, we created an **Evidence-Problems-Opportunities (EPO) diagram**, trying to find relevant data (assessing impact through numbers), defining the real problems and thinking about how our technology could address them.



1) Dialysis: We want to apply AHEAD technology to enhance the functionality of dialysis machines in medical facilities to help patients undergoing dialysis treatment, who require precise and efficient monitoring of their blood parameters, in order to optimize treatment outcomes, minimize complications, and improve the quality of life for individuals with kidney disease.

2) Agricultural drones: We want to apply AHEAD technology to enhance the process of fertigation in agriculture 4.0 systems to help farmers optimize water and nutrient delivery to crops without latency during application, reducing resource waste and environmental impact, in order to increase crop yields, improve soil health, and promote sustainable agricultural practices.

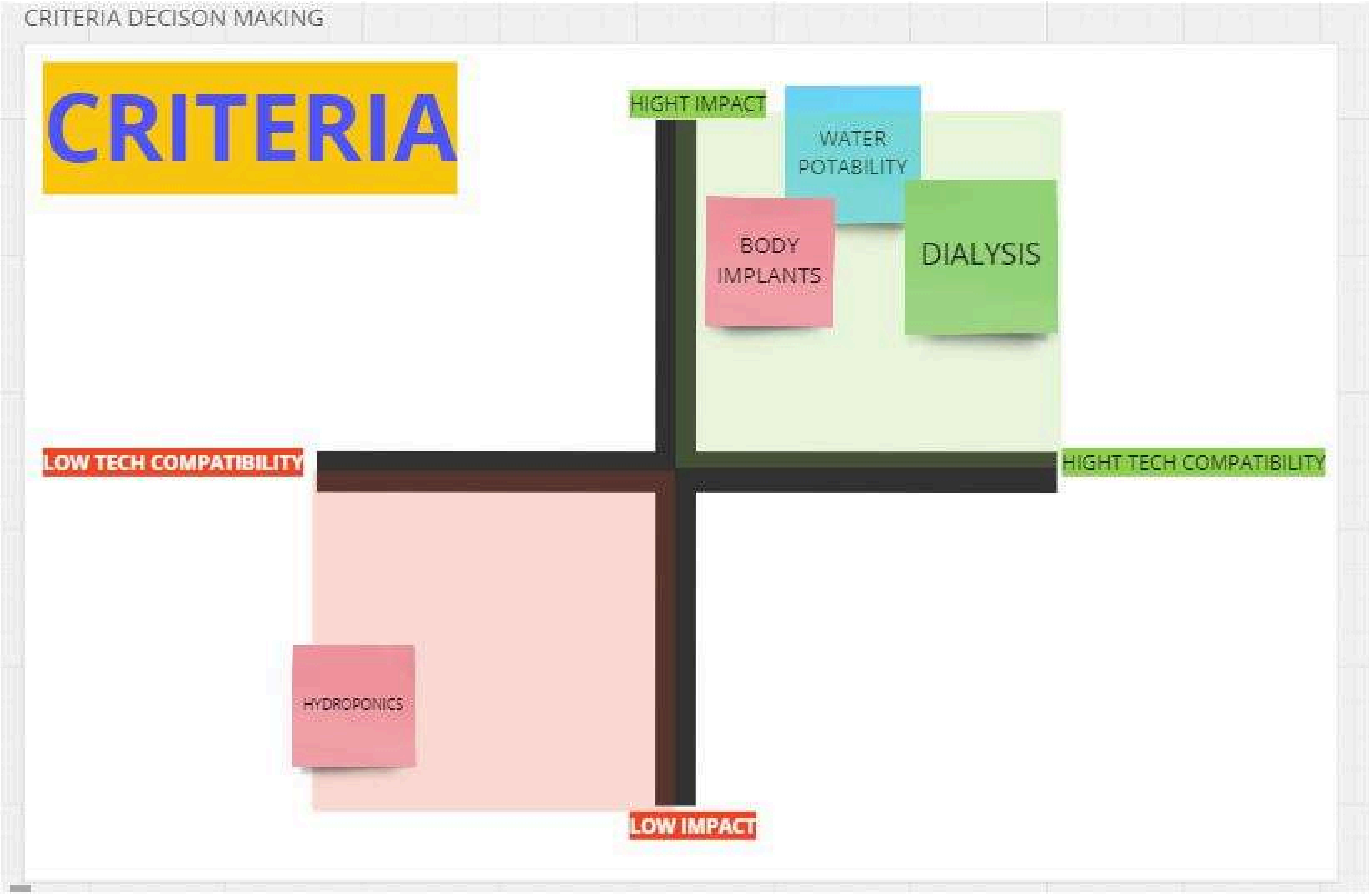
3) Body implants: We want to apply AHEAD technology to improve the creation of body implants for Health 4.0, aiming to enhance medical treatments and patient outcomes, in order to provide more effective and personalized healthcare solutions, reduce risks associated with implant surgeries, and improve the quality of life for patients.

4) Micro-injection: Micro Injection systems involve micro small needles used for injecting chemical substances into existing systems, like biological cells. These systems rely on the precision of the needle in order to avoid cell breaking, so pressure monitoring systems are used for controlling them. However, right now the pressure is sensed before the fluid goes inside of the needle itself. Our idea is to use AHEAD in the very last part of needle pipeline in order to have precise control on the pressure,

5) Water potability: We want to apply the AHEAD technology to enable real-time control of water potability, constantly monitoring parameters such as pH, chemical components and temperature. Thanks to the real-time monitoring of pressure and flow rate we can make forecasts and prevent possible future leakage. This AHEAD application could reduce water waste and increase people's health in developing countries.

🎯 To analyse this field of opportunities we used also some criteria:

- Impact (low impact and high impact of the opportunities)
- Tech compatibility (low tech compatibility and high tech compatibility of AHEAD if used in these opportunities)



The Design Phase

The second phase (Design Phase) of CBI.ATTRACT started with three fields of application which needed to be further understood, as suggested by our tech partner at CERN. The selected three topics have finally been Agricultural Drones, Healthcare (specifically, Dialysis Machines) and Water Potability.

The agricultural drone application, as *discovered* in the first phase, still has been the AHEAD implementation at the very end of each spraying nozzle, to both prevent and better understand eventual malfunctions during fertilisation.

The issue has been further explored thanks to our contact company Royal Tech for Agriculture, which seemed interested in our solution. The main objective for this field of application, in this phase, has been to understand the *magnitude* of the problem and the *impact* of our solution. The second application area, i.e., water potability infrastructures, has been at this point the most straightforward one: our idea was not to *modify* but to *enrich* AHEAD structure and function to use it in metropolitan water distribution systems.

The technology's ability to accurately measure temperature, pressure and flow rate of fluids inside of it would have been by itself an interesting property to be exploited in water monitoring systems, empowered by the AHEAD freedom of shape and the fact of it being stand-alone. In this phase got in touch with a company involved in providing measurement systems for big fluid systems (*Endress+Hauser*). The company seemed extremely interested in our assigned technology, so we also created a bridge between them and our tech partner for further technical collaborations.

The main objective in this phase for this second application has been the understanding of possible *issues* in our solution, other than understanding exactly what would have been our product offer and to which *market* it was proposed. Lastly, we tried to deepen our knowledge for the *dialysis* application, even though two areas should have been chosen in this phase.

> Our motivation behind this choice is the strong *impact* we had on this area, joined with the very good feedback we got from Professor Luca Pani from the University of Miami, who we interviewed in this same period. Our aim for this last area was basically to understand the *feasibility* of our solution.

🚀 Pretotypes

This phase started with the creation of some pretotypes for the three chosen areas:

Pretotype for Agricultural Drones

Pretotype for Dialysis Machine

Pretotype for Water Potability

Thanks to pretotyping we understood way better what our proposals were, also we first realized an *interface* for water potability, which will be the main part of our future proposal for that application. In this phase we also started to imagine AHEAD as implementable in city distribution systems, following the *districtualization* idea, placing it in key areas to keep track of water potability parameters.

🇨🇭 Tech Partner Second Visit

In our second visit to the Tech Partner, at CERN on 17/04/2024, we visited *Chrysoula Manoli* working place, which included laboratories where AHEAD was currently being tested. The main event that occurred during this visit was the presentation our team made for the whole tech partner team, including Project Coordinator *Hervé Saudan* (*CSEM*), Supervisor at CERN *Paolo Petagna* and also *inanoEnergy* company, which works on the energy harvesting system of AHEAD.

The presentation aimed at showing our three fields of application to all the experts to receive feedback, focusing on the market and societal impact of our proposals, highlighting our doubts on feasibility aspects. The present researchers reacted with many interesting questions and insights, which became our main study directions for the following weeks, other than with many compliments on our technology understanding and *technology-driven* approach. From their perspective, the application ranking was:

1. *Water Potability*;
2. *Agricultural Drones*;
3. *Healthcare*.

The first one has been considered the most feasible and impactful, also thanks to our open contact with Endress+Hauser. The second field was reviewed as very promising, but still, the problem magnitude was not clear, whereas the last one was hard to understand in all of its aspects.

After the Geneve trip, what the team decided has been to mainly proceed on the first two application fields, but to keep working on the healthcare field. This lead, also thanks to our contact Professor Luca Pani, to focus on implementing AHEAD in glucose monitoring systems.

Our idea was to use a micro-printed AHEAD to check the interstitial liquid in real-time, with a unique stand-alone device on patients' skin.

👀 Before the Milestone 🧩

What we decided to present to the second Milestone has been a focus on the *desirability* and *feasibility* aspects of our three fields of application.

Desirability:

1. Water checking would be done continuously and automatically, whereas now are manually done, going directly to the needed source which must be accessible
2. 1.8B people have no access to potable water, so our impact would be high
3. 27% of CAGR, which means a highly growing market
4. Thanks to 3D printing, it could be implemented in old piping systems too, which results now in one of the biggest issues for these kinds of systems, mainly in developing countries

Feasibility:

1. 3D printing allows us to put AHEAD almost everywhere
2. Currently measured parameters are already very interesting and COTS sensors could be added
3. Low need for maintenance thanks to energy harvesting and no need for a power connection
4. *Agricultural Drones*

Desirability:

1. 505k tons of pesticides are used every year in the EU
2. Currently, the drone's maintenance needs many days, we could reduce this thanks to an automatic fast precheck
3. There is no way now to customize the amount of sprayed pesticide nozzle-by-nozzle, our solution would allow it thanks to accurate and "*atomically made*" measurement
4. 31.5% of CAGR, which means a highly growing market

Feasibility:

1. 3D printing allows us to put AHEAD at the very end of each nozzle
2. No need for new sensors (*probably*), the flow rate would be enough
3. The cost of AHEAD should be very in line compared to drones one
4. *Glucose Monitoring*

Desirability:

1. "If your technology is able to have multiple sensors embedded allowing for different analysis, is the dream technology" - Prof. Luca Pani
2. Diabetes is the 9th leading cause of death, with 1 out of 16 people suffering from diabetes nowadays
3. Analysis needs to be done very often during the day with multiple devices

Feasibility:

1. 3D printing (*should*) allow AHEAD to be very small printed
2. AHEAD allows the implementation of multiple sensors inside it
3. But, we are not sure about the possible implementation of chemical sensors in it

The milestone presentation has been carried out using *Personas* for each field of application, highly improving our attention-grasping ability, which has been a weakness in the first milestone, jointly with the slides' *aesthetic*.

Personas

Alessandro and Luisa

Amina and Sofia

Anna Costa

Alessandro and Luisa

These are the personas used for the Agricultural Drones field of application. Their problem is that, when the drones stops working, they have **no idea of which of nozzle is broken**: they realize it only when the crops get severly damaged. Also, this leads to high times for repairing the drone, due to additional pieces getting broken in the process, too. The solution is the **monitoring of each nozzle**, in real-time and accurately, using AHEAD.

Amina and Sofia

Amina and Sofia are a mother and a daughter both suffering from diabetes. The issue of Amina is the almost **daily replacement** of both her and her daughter's CGM, who also tend to break it while playing due to its high **fragility**. Many analyses must also be done during the day to check, for instance, ketone levels. The implementation of AHEAD in a crafted monitoring system, which includes **many different sensors**, reduce the amount of daily checks and can **increase the durability** of the system itself.

Anna Costa

Anna Costa is an NGO worker that monitors water quality in a developing country. She has to go to the nearest **river every day**, with a 4 hours trip back and forth. Furthermore, the only **road** that can take her to the river **is interrupted by a sudden landslide**. Proposed solution is AHEAD to be used in a **potabilization centre** near the river, implemented in an IoT system. This could give **real-time and remote measurements**, allowing Anna to spend less time driving to the river, other than a **continuous check** even if the river is temporarily unacessible.

The prototyping phase

After the Milestone

The team started the third and final phase of research by making a final decision about which field and scenery to adopt for the final solution. After speaking with the tech partner *Chrysoula Manoli* following the Milestone on 08/05/2024, the choice came between the agricultural drone application and the water potability one.

In order to make an informed decision between the two possibilities, we invested in more research about the feasibility and need for the two scenarios, deciding to ultimately focus on the one that seemed more promising in that regard. On 16/05/2024 the team conducted two interviews to further investigate the potential impact of the two possibilities. For the agricultural drone one, the technician and security expert *Luca Raimondi* from the company *AgriGeoDron* in Ferrara was contacted.

> **The conversation was centred on understanding whether our solution matched the real-life necessities of companies in the sector. About this, the expert proved to be sceptical of the frequency of potential damages and clogs occurring in new-generation drones, which are well-equipped for detecting malfunctions and oftentimes do not even take off if they sense potential internal issues.**

On the other hand, we were able to talk to *Ivo Vasumini* and *Gilberto Forcellini Mazzoni*, responsible for production for the company *Romagna Acque*, which manages water potability in the region of Emilia-

Romagna.

They proved to be optimistic about the technology and its feasibility, bringing up some criticalities to face while outlining the final solution, particularly about maintenance and calibration for the sensors.

SPIpe

During the next meeting, on 20/05/2024, water potability was chosen by the team as the setting in which to develop the solution, given the promising response from the experts. We then started conceptualizing more precisely our solution, since during this last phase, the team was asked to finalize a solution concept and concretize it in terms of branding and business plan.

Our final result is *SPIpe* which gets its name from the SPA acronym, coming from the Latin phrase "*Salus per acquam*", meaning "health through water".

As of now, data on water conditions is scarce, and only obtainable in selected points of the distribution system: we can access information on the cleanliness of the water at the potabilization stage, but no data on what happens next is readily available.

As of now, to gather such data a researcher would have to acquire a sample and analyze it in a laboratory, which is a rare occurrence, and in any case is bound to create a delay of hours if not days between sampling and obtaining some answers. *SPIpe* is conceived as a solution to this, tackling two different issues and user bases: on one end it wants to create direct and transparent communication with citizens regarding the state of water, increasing the knowledge and reliance of people on the cleanliness and safeness of their water, while also providing quick information on potential risks.

This would happen via a free app which gives its users access to the area they are most interested in, including both general potability information and more in-depth parameters and statistics. On the other hand, it also provides vital data to distribution companies, which have been struggling with locating water leakages in obsolete piping, leading to up to 30% of water being lost in Bologna.

To reach a complete coverage, we would need to create an overarching system including all of the city's water piping, in our case with the collaboration of the municipality of Bologna, of the potabilization system from *Romagna Acque* and the distribution system managed by *HERA.*

👉 **This solution would lead to an overall cost reduction for both companies involved, allowing for less water going to waste, quick and precise maintenance required to keep the system in optimal conditions, decreased water contamination and potential health risks and longer longevity for the whole infrastructure. It would also greatly benefit citizens, allowing them to**

feel secure in using city water, reducing the economic and environmental issue of consuming large quantities of bottled water instead.

The ***SPIpe*** product consists of a device using *AHEAD* technology, embedded with sensors checking several crucial parameters in real time:

pH

The pH level of drinkable water should ideally be between 6.5 and 8.5 to prevent mineral deposits and corrosiveness. Extremes can increase water contamination and harm.

Turbidity

which is measured with an optical sensor recognising the presence of suspended particles in the water, typically traceable to algae, plankton, sewage or dirt coming from wind or water erosion

Temperature

The optimal water temperature is below 15°C to prevent bacterial growth, chemical reactions, and changes in oxygen concentration. Higher temperatures can cause bad taste and smell.

Flow

which allows to check for leakages in the system previous to the point where *SPIpe* is stationed, by registering the decrease from the previous flow measurements

To include all these sensors, *SPIpe* would be printed in a “T” shape, which makes space for the body of the pH sensor, which is a small cylinder about 12cm long, but it will also allow for easy access inside the system when performing calibration and maintenance.

Ever since our interview with *Romagna Acque* brought up the issue, we have looked for methods to make this process as quick and easy as possible, and we consequently implemented not only this peculiar shape, which is allowed thanks to *AHEAD*’s 3D printing process but also an installation system requiring some small wells for access.

This could both mean inserting *SPIpe* in the many focal points of the water distribution system where wells are already present but also creating new ones where needed for specific installations. This system would additionally grant stronger access to the wireless module for transferring data, whose connection could otherwise be obstructed by being underground.

The 3D printing characteristic of *AHEAD* is crucial to us also in the fabrication of the device since it is compatible with the restricted number of units we may need to cover a city, but it allows for easy fitting with any diameter and different attachment that could be present in the piping system, which could otherwise become an issue, given the vast differentiation in the pipes built over the years which characterises Italian systems. Moreover, the energy harvesting module posed at one end of the device allows for it to be completely self-sustained, without needing external powering.

Prototyping

During the Large Group Meeting on 21/05/2024, the team started working on ideating a functional prototype of the final solution, while continuing to deepen the technical part. On that day, *Giuseppe Mincolelli*, associate professor of industrial design at *Università degli studi di Ferrara*, reviewed our initial idea, including some precious feedback on the feasibility and how to better focus on the final users. We then decided to create a working water circuit connecting two tubs via flexible transparent pipes, powered by two small water pumps.

This circuit would allow sensors comparable to the ones that would be embedded in the final solution, showing at the same time the functionality of the information they provide to the users and the evident complications that could be solved thanks to *AHEAD*.

In fact, the prototype highlights the excessive space occupied by the singular sensors, that would be greatly decreased by embedding them in a unique technology, which would also simplify the overall system, not being bound by several cables and charging outlets thanks to the energy harvesting module.

While the first idea was to include four sensors, checking pH levels, turbidity, temperature and flow rate, the final prototype was reduced to only including sensors for pH and turbidity, since temperature and flow rate were not as intuitive to a final audience in their aim and they also posed several challenges when doing a real-time demonstration of their working.

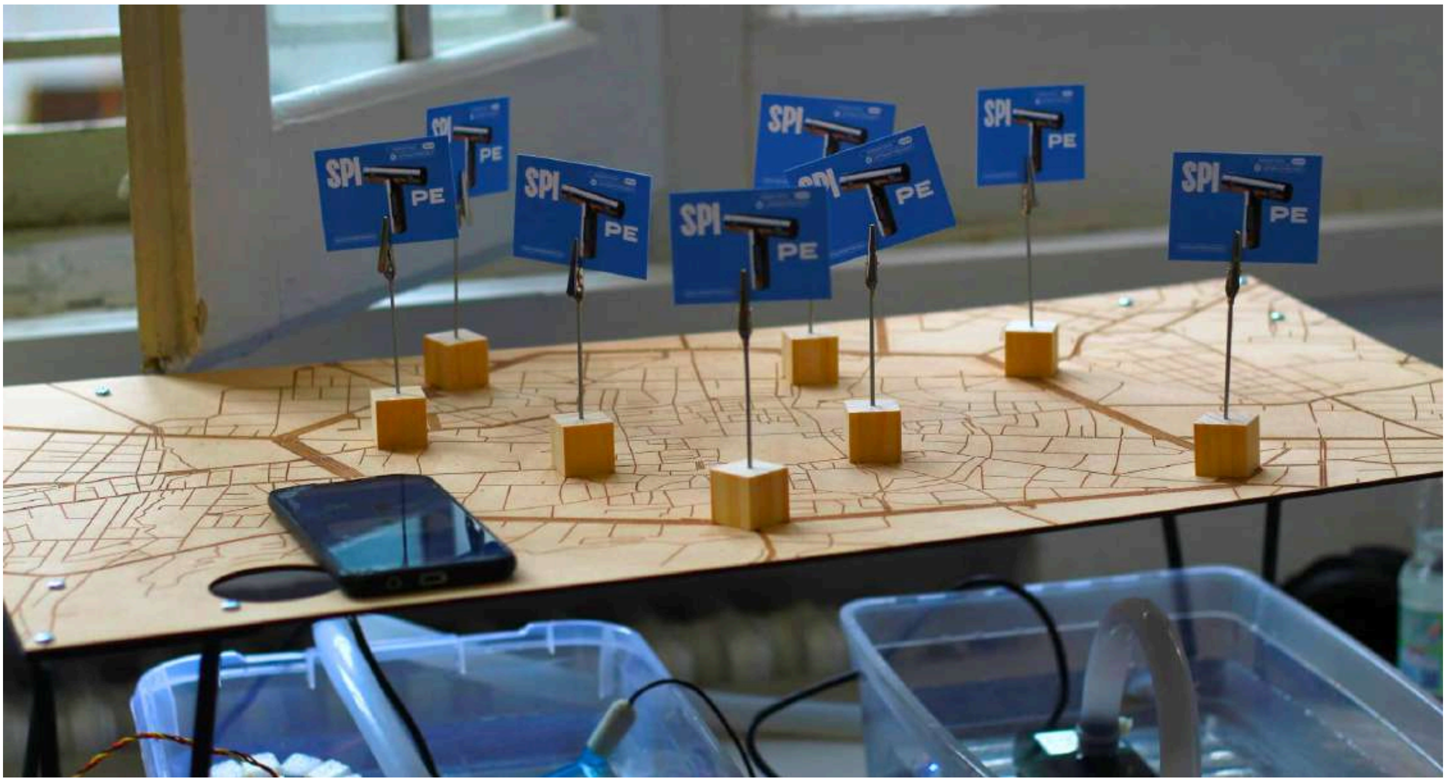
All sensors are compatible with and connected to an Arduino UNO, using a breadboard which is then connected to a laptop containing the code necessary to analyze the collected data.

The final product also included an app interface, showing the user real-time data on the potability of the water in the model. This has been done by using Python and the Flask library. The project was mainly constituted of two Python modules:

- *serial_reader.py*, which, using Pyserial library, gets output from Arduino serial monitor about sensors data;
- *app.py*, which is a local web app of the interface, done in HTML and JavaScript and changing the visualization of potability check automatically, based on the sensed parameters and some hand-crafted thresholds; the interface also includes a precise visualization of the data for expert users.

In this way, we were able to recreate the user experience of having updated information about the potability conditions of the water, plus in-depth parameters to have control over its current state.

To contextualize the solution in the city of Bologna, we added a wooden table with an engraving of the city map, plus some signposts representing the positioning of the devices over the most relevant intersections.



🇫🇷 Grenoble conference

Simultaneously, on 12/06/2024, *Yousra Gottih* took part in the Pre-final conference of the *ATTRACT* project, located in Grenoble, France. The day opened with a welcome breakfast leading to a presentation of all the involved tech partners and teaching teams coming from the various universities taking part in the project. The University of Bologna was represented by Matteo Vignoli, director of the course, and two other students from the program, *Eloisa Mazzocco* from team *Glass2mass* and *Athanas Kafia* from team *Hipmed*; each team was given the space to do a brief presentation of the proposed final solution to the public.

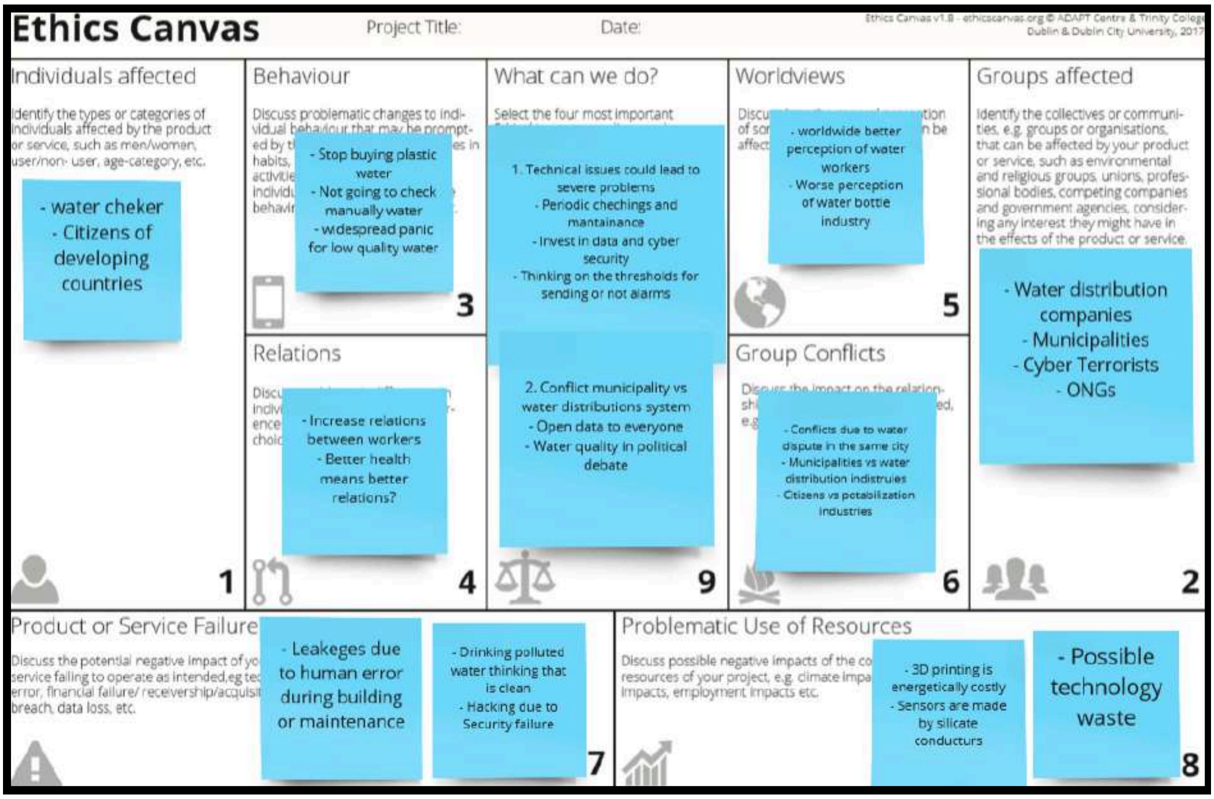
In the afternoon they joined students from all over the world to participate in a design thinking activity conducted by *Pablo Garcia Tello*, administrator of the *ATTRACT* project. On the second day, they attended presentations from past projects in the ATTRACT program, having different objectives and modalities, which inspired a lot of conversation among students about the different approaches they had to the open innovation challenges presented.

During the day they also participated in the EXPO, setting up the first draft of our prototype for participants to see and interact with, which led to a lot of interest in our project and some stimulating feedback from professors and researchers, including some interesting insights on how water potability and distribution works in different countries, which helped us in focusing the user interaction part of our solution.

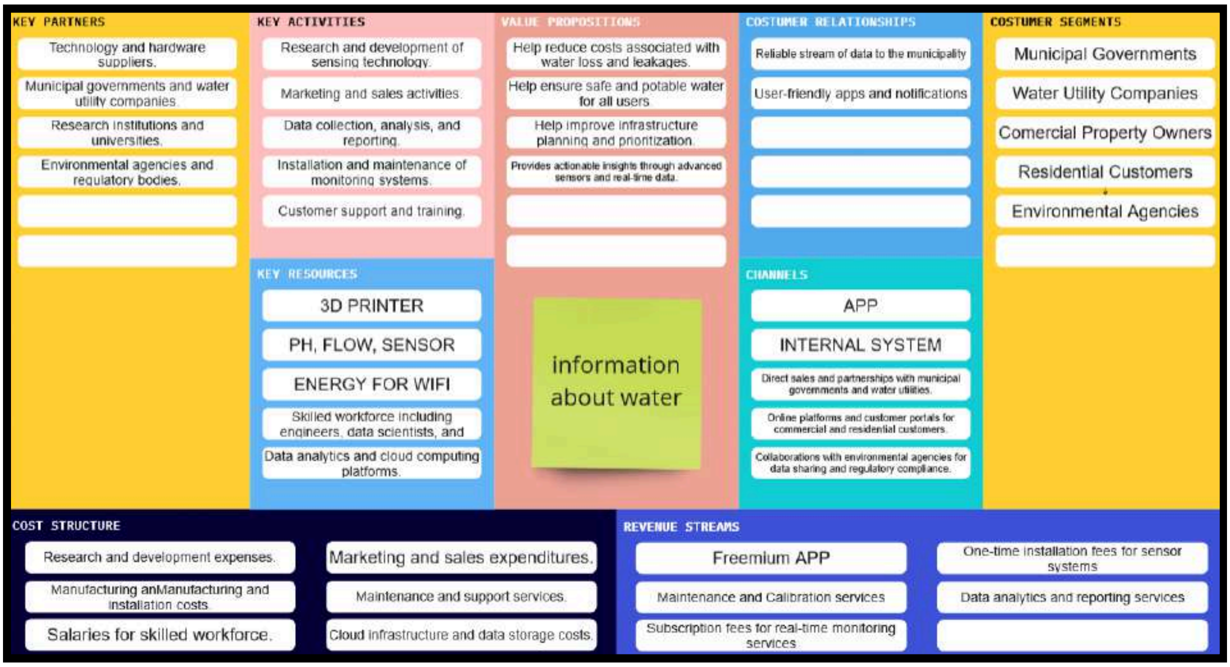
The final Milestone

The last month of the program was spent by the team mainly focusing on implementing the prototype and preparing for the *EXPO* and the final milestone.

The Large Group Meetings on 29/05/2024 and 05/06/2024 in particular were focused on deepening the understanding of the solution by using two specific tools: the *Ethics Canvas*, developed by the *Trinity College*, and the *Business Model*, which was then reviewed with the help of *Bernardo Balboni*, marketing professor at *Università degli studi di Modena e Reggio Emilia*. During this month the students also prepared some explicative posters about the technology and the team itself.



In the *Ethic Canva* the team focused on the moral implications of sPIPE. It resulted very useful to understand how the impact of the product was not only limited to the market, but also people behaviors and relations. The main issue that came out with this work has been the potential misinformation spread by the user application, which could be caused both by malevolous actions by a third party, or malfunctioning parts of the product. What the team decided to point out after this work was the high effort to be put on the cyber-security of the application, other than a constant maintanance and monitoring of the sPIPE implementation in the distribution system.



The reported *Business Model Canva*, on the other hand, focused on the market implications and premises of the proposed solution. This methodology pointed out the potential partners in the development of sPIPE, also helping to discern them from the end users. The middle column pointed out the strength of the solution and has been heavily used to produce the third milestone presentation, focusing on the value of sPIPE. The team also understood better the costs of an eventual startup working on the solution and the possible way to sustain them in a long-term perspective.

The end of the program was marked by the third and final milestone presentation on 25/06/2024, taking place in the Aula Magna, where all the five teams were given 12 minutes to explain the process and the final solution they arrived to. The team's presentation included a demonstration of the functioning prototype, conducted by first showing the clear, clean water circling under the engraving of the city, representing its water distribution system.

We then simulated two events altering the potability of the water: first 50mL of black coffee were poured into the input tank, quickly polluting the water until the tank containing the sensors, which generated a fast response from the turbidity sensor, which led the app interface to show users a warning of non-potability.

Then, 60g of sodium bicarbonate were added to the mixture, eliciting a change in the values shown to the public and, with some time, exceeding the threshold of potability.

For the sake of the experiment, the thresholds were set to be any changing exceeding the 5% of the initial value in clean water.

This demonstration was later repeated to the public during the booth expo of the final projects.

Reflections

The aim of the AHEAD project required design thinking, teamwork, and innovation. The team excelled in this environment and worked diligently to address any challenges that arose. Despite some initial struggles during the discovery phase, the interdisciplinary nature of the team proved to be a key factor in the project's success. The project was structured in a way that allowed each member to thrive by utilizing and expanding their various skills while simultaneously learning to trust and collaborate with one another.

As none of the team members were initially knowledgeable in design thinking, concepts such as user personas, feasibility, and other technicalities presented a thought-provoking challenge. **This project cultivated skills that the team will continue to practice throughout their careers, such as problem-solving and collaboration; it also helped to refine the expertise already held by the team members.**

The AHEAD team had the opportunity to grow together, experiencing many ups and downs while always maintaining focus on the project's goals and respecting each other. This journey has not only enhanced our technical capabilities but also strengthened our ability to work as a cohesive unit, preparing us for future endeavours in the field of fluid sensing and beyond.

Conclusion

The journey of the AHEAD project was an exciting blend of design thinking, thorough research, and creative problem-solving. From the start, our team embraced the challenge, dividing roles for interviews to ensure we captured all necessary data. This collaborative spirit carried us through every phase of the project.

In the design phase, we explored various applications for our technology, including agricultural drones, dialysis machines, and water potability. Pretotyping helped us refine our ideas and understand the practical implications of each application. After careful consideration and valuable feedback from industry experts like those at Endress+Hauser, we chose to focus on water potability due to its feasibility and significant impact.

Our decision-making process was thorough, involving additional research and interviews to validate our choice. We conceptualized SPIpe to address critical issues in water distribution systems, leveraging AHEAD technology to integrate sensors for real-time monitoring of pH, turbidity, temperature, and flow. This innovation promised substantial benefits for both water companies and consumers.

Prototyping was a pivotal phase. We built a functional water circuit to demonstrate our technology's capabilities. With guidance from experts like Professor Giuseppe Mincolelli, we refined our design to focus on user needs. Our working prototype effectively showcased SPIpe's potential to provide accurate, real-time data on water quality, underscoring its value in modern water distribution systems.

Presenting at the pre-final conference and final milestone event were significant moments. These platforms allowed us to share our work with a broader audience and receive insightful feedback. Our interactive prototype and detailed presentations highlighted SPIpe's practicality and societal impact, earning interest and praise from peers and experts alike.

Throughout this journey, our team demonstrated resilience, adaptability, and a commitment to excellence. We not only honed our technical skills but also developed essential collaborative and problem-solving abilities. This experience has prepared us for future challenges, giving us the confidence and knowledge to innovate and excel in our respective fields.