Final report

1. Project details

Project title	Flow Loop retrofit energy-saving shower system
File no.	64020-1031
Name of the funding scheme	EUDP
Project managing company / institution	Flow Loop Aps
CVR number (central business register)	38046349
Project partners	DTU Environment, DTU Chemical Engineering, DTU Fotonik, DTU Electrical Engineering & IPU
Submission date	05 August 2024

2. Summary

Describe the objectives of the project, the obtained results and how they will be utilized in the future.

Summary (English)

Flow Loop has with DTU (Sustain, Electro, Photonics and Chemical) and IPU conducted a project titled “Flow Loop retrofit energy-saving shower system”.

In Western and Northern Europe showering accounts for 36% of water consumption and 25% of heating in an average household. Showering and personal hygiene consume 48% of all water used domestically in Denmark. During a traditional shower nearly 80L of warm and relatively clean water go directly down the drain during the average 8½ minutes shower.

The overarching objective of the EUDP project was to reduce energy (and water) consumption during showering. More specifically the aim was to mature the early prototypes of Flow Loop’s retrofittable recirculating shower so it could be turned into a product that can be commercialized. The expected outcomes of the project are optimization of the shower system for market introduction (incl. fully automated drain), establish market access to key target groups through validation at test partners and identification and implementation of a durable low maintenance filter solution.

In the project, there has been development activities into a few key areas:

- Automated drain solution that can be installed in existing bathrooms
- Long durability filter solution that provides excellent bathing water quality for max. 50 Euros/year

- Design an easy to install, low-cost shower panel that includes an electronic monitoring system to illustrate obtained savings to the customer

Solutions for both point drains (drains in the middle of the shower floor) and linear drains (drain at one wall of the shower) were developed. The solution for the point drain was battery operated and due to user feedback, this idea had to be abandoned and thus manual operation was needed. For the linear drain, a fully automated solution was implemented and tested under lab conditions, including a water sensor which was not ready for the demonstration projects. The implementation provides a way to get quickly back to recirculation after release of soap, urine, or blood in the shower water. Furthermore, the suction from the floor also allowed an efficient way of emptying the floor after the shower.

Filter solutions that was self-cleaning was tested, but the backflush ability was not satisfactory. Similarly, pasteurization up to 72°C was impractical, but reduced the microbial activity significantly. Instead, a polymer pleaded filter was implemented and qualified with a maintenance paradigm ensuring excellent bathing water for less than 50 Euros/year.

The prototypes along the way and the products tested in different environments such as housing associations, hotels, and workplaces. There was also an ambition to demonstrate in fitness facilities, but it was abandoned quickly as the majority of these are common showers with shared drains, which goes against the Flow Loop promise to only recirculate the bather's own water during the shower.

To conclude the project, Flow Loop have piloted 5 showers: Three in private homes and two showers at Comwell Hotel in Holte.

Based on the project, Flow Loop has put two recirculating shower panels on the market, LOOP and EcoLoop. Both products have an IOT solution connected that can provide users and operators with bathing data, communicating the savings in a nice and easy way through the Flow Loop website. Flow Loop will continue to market the products, improve them as needed and create follow-up offerings to expand the product market fit.

Summary (Danish)

Flow Loop har sammen med DTU (Miljø, Elektro, Fotonik and Kemi) og IPU gennemført et projekt med titlen "Flow Loop retrofit energy-saving shower system".

I Vest- og Nordeuropa tegner brusebade sig for 36 % af vandforbruget og 25 % af opvarmningen i en gennemsnitlig husstand. Brusebad og personlig hygiejne forbruger 48 % af alt vand, der bruges i hjemmet i Danmark. Under et traditionelt brusebad løber næsten 80L varmt og relativt rent vand direkte ned i afløbet I løbet af et gennemsnitligt 8½ minutters brusebad.

Det overordnede mål med EUDP-projektet var at reducere energi- (og vand)forbruget for brusebade. Mere specifikt var målet at modne de tidlige prototyper af Flow Loops reinstallerbare recirkulerende bruser, så den kunne omdannes til et produkt, der kan kommercialiseres. De forventede resultater af projektet er optimering af brusesystemet til markedsintroduktion (inkl. fuldautomatisk afløb), etablering af markedsadgang til nøglemålgrupper gennem validering hos testpartnere og identifikation og implementering af en holdbar filterløsning med lav vedligeholdelse.

I projektet har der været udviklingsaktiviteter inden for en række nøgleområder:

• Automatiseret afløbsløsning, der kan monteres i eksisterende badeværelser

• Filterløsning med lang holdbarhed, der giver fremragende badevandskvalitet til max. 50 euro/år

• Et let-at-installere, billigt brusepanel, der inkluderer et elektronisk overvågningssystem for at illustrere opnåede besparelser for kunden

Der blev udviklet løsninger til både punktafløb (afløb i midten af brusegulvet) og lineære afløb (afløb ved brusenichens ene væg). Løsningen til punktafløbet var batteridrevet og på grund af brugerfeedback måtte denne idé opgives, og derfor var manuel betjening af denne løsning nødvendig. Til det lineære afløb blev en fuldt automatiseret løsning implementeret og testet under laboratorieforhold, herunder en vandsensor, som ikke var klar til demonstrationsprojekterne. Implementeringen giver en måde at komme hurtigt tilbage til recirkulation efter frigivelse af sæbe, urin eller blod i brusevandet da bruservandet på gulvet hurtigt bliver udskiftet. Ydermere muliggjorde suget fra gulvet også en effektiv måde at tømme gulvet efter badet.

Selvrensende filterløsninger blev testet, men tilbageskylningsevnen var ikke tilfredsstillende. Tilsvarende var pasteurisering op til 72°C upraktisk, men reducerede den mikrobielle aktivitet betydeligt. I stedet blev der implementeret et polymer-foldet filter og kvalificeret et vedligeholdelsesparadigme, der sikrer fremragende badevand for mindre end 50 Euro/år.

Prototyperne undervejs og produkterne testet i forskellige miljøer som boligforeninger, hoteller og arbejdspladser. Der var også en ambition om at demonstrere i fitnessfaciliteter, men det blev hurtigt opgivet, da størstedelen af disse er almindelige brusere med fælles afløb, hvilket går imod Flow Loop-løftet om kun at recirkulere den badendes eget vand under bruseren.

Som afslutning på projektet har Flow Loop afprøvet 5 brusere: Tre i private hjem og to brusere på Comwell Hotel i Holte.

På baggrund af projektet har Flow Loop sat to recirkulerende brusepaneler på markedet, LOOP og EcoLoop. Begge produkter har en IOT-løsning forbundet, der kan give brugere og operatører badedata og kommunikerer besparelserne på en nem og praktisk måde gennem Flow Loop-hjemmesiden. Flow Loop vil fortsætte med at markedsføre produkterne, forbedre dem efter behov og skabe opfølgende tilbud for at udvide markedspotentialet.

3. Project objectives

In Western and Northern Europe showering accounts for 36% of water consumption and 25% of heating in an average household[1]. Showering and personal hygiene consume 48% of all water used domestically in Denmark[2]. Standard shower heads have a maximum flow rate of 9L/min; resulting in a consumption of nearly 80L of warm and relatively clean water going directly down the drain during an average 8½ minutes shower. Flow Loop's solution allows energy savings of up to 75 % of energy related to heating of water, potentially delivering a substantial reduction in the energy consumption of buildings. Furthermore, savings up to 85% of water consumption can be achieved. The savings can be realized by recirculating the still hot water used in the shower instead of flushing it down the drain. Moreover, the system increases the overall shower experience through a larger water flow (up to 12L/min) and (in some cases) a higher quality of water, as the system eliminates bacteria and impurities in the water (including legionella from the hot water source if present).

[1] DANVA, Vand et al, 2016
[2] https://www.bolius.dk/saa-meget-el-vand-og-varme-bruger-en-gennemsnitsfamilie-279

Flow Loop have during the project period developed two products:

- LOOP (left picture) a recirculating shower for retrofit in bathrooms with point drains. LOOP requires the user to step on a drain cover to fill and empty a reservoir at the floor. The recirculation is engaged by a timer 30 seconds after starting the shower and can be disengaged and subsequently reengaged by pressing a button.
- EcoLoop (right picture) a recirculating shower for retrofit in bathrooms with linear drains, with a semiautomatic shift between normal and circulation mode (you only need to press the button, the floor reservoir is automatically filled and emptied).

Both products can be installed in existing shower spaces in only a couple of hours, no construction needed. Flow Loop calls this retrofit. The difference between the products is the drain type they are made for and that you don't need to step on the drain to activate circulation with EcoLoop.

When the shower is in circulation mode a lot of energy is saved. The recycled water only lose 3-6 degrees in temperature when it is collected for recycling at the shower floor (depending on room temperature and floor and wall materials). Hence a comfortable shower flow of 12 liters/minute can be maintained by adding 1-2 liters of hot water per minute when recirculating.

LOOP has been piloted in collaboration with Realdania and approximately 50 showers are operating today at different customer premises.5 EcoLoop showers has been piloted as a part of this project. Three showers in private homes and two showers at Comwell hotel in Holte.

3.1 Project objectives

The overall objective of the project is to significantly develop and demonstrate the existing prototype developed by Flow Loop to make it fully automatic and thereby pave the way for commercialization.

The specific objectives were defined in the application as:

1. Develop a fully automatic drain solution to optimize resource savings that is compatible with Flow Loops patent pending retrofit drain solution
2. Develop a filter of long durability aiming for a self-cleaning filter
3. Develop a filter with much lower maintenance costs than competing solutions that cost up to 250Euros/year in filter changes alone. To reduce payback time, it is a goal to reduce filter maintenance to below 50Euros/year including time for exchange of filter
4. Design an easy to install low-cost panel cabinet including an electronic monitoring system to illustrate obtained savings to the customer
5. Demonstrate and test the solution in different environments such as hotels, workplaces, housing associations and health & fitness industry

Expected outcomes of the project

- Optimization of the shower system for market introduction (incl. fully automated drain)
- Established market access to key target groups through validation at test partners
- Identification and implementation of a durable low maintenance filter solution (max. 50 Euros/year)

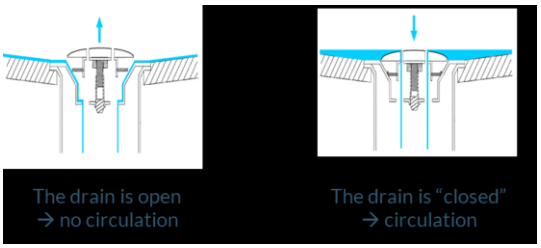
4. Project implementation

There was a clear workplan for the project in the application – this workplan set the direction for approximately the first year of the project, whereas the second year and the extension of the project needed an alternative workplan. The reason for the change in plans was initiated by the Covid-19 lockdown and the subsequent change of attitude from hotels where we could demonstrate the solution. Because of the challenges in the hotel business during 2020[3] and early parts of 2021, it became clear that the premise of doing a larger scale test at hotels was not feasible, thus a change request early 2021 was issued to extend the project with an extra year and in 2022 a new change request to test fewer units.

The schedule for the project concentrated on the technical development during the first part of the project and the demonstrators in the second part of the project. This premise was largely held, yet practical challenges with the automatic functionality led to several workarounds that ultimately changed the premise of the first objective of the project, the automation of the floor drain that was changed from focus on point drains to linear drains.

Flow Loop's uniqueness in the market so far revolves around the retrofit concept: The Flow Loop shower panels are installable in existing bathrooms in a couple of hours without construction work. That means that the traditional shower solution is removed from the wall and the shower panel installed in its place.

On the floor, the cover over the drain (typically a grate) is replaced by a patented solution with a dome that can stem up water, so a small reservoir is created. The patent states two different modes of the drain cover: one that has the dome down, creating the water reservoir and any excess water is overflowing the dome to keep a defined depth of the reservoir (sufficient for the operation of the recirculation). The other mode lifts the dome, allowing for water to run under and down without creating the reservoir.



In Denmark, most older bathrooms are having point drains in the middle of the floor. To allow for the highest market potential it was decided to create a prototype for a square point drain which has a market proportion of approx. 75% of older Danish bathrooms.

Product development

Several design workshops were held in the project, and for the first workplan, it was decided to obtain the functionality of the automated drain solution using 3 different components: 1) a sensor to analyze the content of recirculated water, 2) a powered drain to create and remove a reservoir for recirculation at the shower floor and 3) a method to signal between the sensor and the drain, so the drain would create and release the water reservoir as needed.

[3] https://www.pwc.dk/da/publikationer/2020/covid-19-okonomiske-konsekvenser-dansk-erhvervsliv.pdf, page 4 ff.




It was decided the best solution would be without wires across the floor from the panel to the drain, thus requiring a battery-operated drain with wireless activation of the toggle between reservoir and no reservoir at the floor.

For the first part, a water sensor was prototyped by DTU. The sensor uses different frequencies of UV light to detect the impurities of shower water that is not fit for recirculation: soap, urine, and blood. Performance under lab-conditions were good, as drops of the detectable substances could be detected in approximately 5 liters of water, which is the relevant volume for a recirculating shower. Conclusion was the functionality was adequate for the automated solution, however a more robust solution was needed so a more robust pre-build was made for the demonstration at the end of the project.

A prototype of the battery-operated wireless drain cover was designed and developed in the project, dubbed the powered drain. The technical functionality of the powered drain was tested and found adequate; however, the power demands of the prototype was rather large, resulting in an operational lifetime of the batteries was only around 50 activations, which would be approx. 10 showers with 5 activations per shower.

In the electronic package of the powered drain was also a wireless receiver that could toggle the drain based on a control signal from the shower panel based on the input from the water sensor. Prototype boards for both the shower panel and the powered drain were developed and functionality proven adequate by DTU.

While the automation of the point drains was successful under lab-conditions, it became clear during the first part of the project that the proposed concept would never become successful in the market. Feedback from the future demonstration hotels was the entire idea of changing batteries in a drain would not be an acceptable solution from a practical perspective: With a shower frequency of 2 showers a day in a hotel room, this would translate to less than a week before batteries should be changed. While it was clear that significantly better lifetime could come from improvements of the electrical design, the entire premise of changing batteries on a regular basis for a recirculating shower was unworkable from a conceptual point of view.

Alternative concepts were considered to remedy the shortcomings of the battery operation: For instance, a wire across the floor would remove the need for both batteries and the wireless communication between the shower panel and the drain. However, input from the demonstration partners suggested that this would not be seen as good solution either as the wire across the floor would give hotel customers the wrong impression, as nobody wants to take a bath with an unknown wire in the shower.

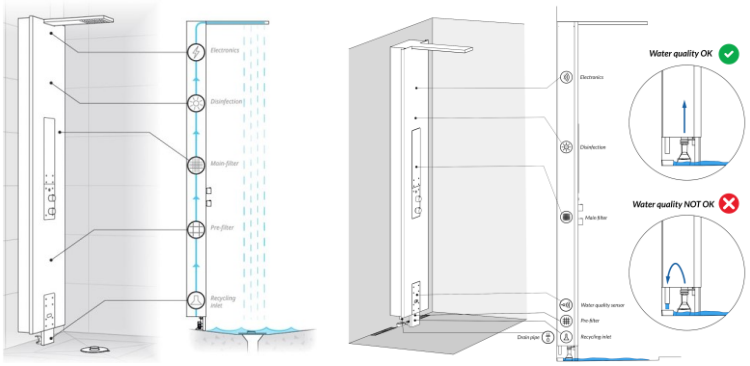
As an alternative solution that became the second workplan, a different type of drain showed more promise: Since Unidrain introduced the linear drain[4] 20 years ago, more design conscious users have installed more

[4] https://www.unidrain.com/about-unidrain/

than 1.000.000 of the drains that are placed against the wall of the shower space. Many of these drains are installed in hotels and thus also fits the purpose of this project. From a retrofit perspective, the advantage is that the panel will typically be placed on top of the drain, thus allowing a direct contact without any wires across the floor. Furthermore, the slope of the floor is one-directional towards the wall, allowing for a smaller reservoir of water that is also concentrated along the wall, leaving most of the shower area free from standing water.

To create a solution for the linear drain, Flow Loop engaged the consulting company DIS[5] to come up with concepts for the creation of the water reservoir in the linear drain. The most promising concept was a passive barrier that performed similarly to the closed dome of the point drain, proving the reservoir during the shower, and allowing overflow of any excess water added to compensate for the heat loss of the recirculated water. Furthermore, a change of the hydraulic design of the recirculating shower allowed the shower panel to discharge water unfit for recirculation directly to the drain. This provides a way to get quickly back to recirculation after release of soap, urine, or blood in the shower water. Furthermore, the suction from the floor also allowed an efficient way of emptying the floor after the shower, effectively removing the need for the “dome-up” position of the point drain solution.

IPU and Flow Loop made initial investigations on how to extend the lifetime of the filters in the shower panel. Basically, there are two filters: a prefilter that removes hair and larger particles at the inlet of the shower panel where water is pulled from the reservoir and a main filter that removes visible particles (eg. skin cells and makeup residue) but let bacteria and other microbes through. Bacteria are inactivated by the UV to maintain the microbial water quality of the recirculated water from the shower panel.



LOOP EcoLoop

The prefilter is backflushed after each shower, using the remaining water after a shower is over. This way, no water is shared between users and the maintenance burden of cleaning the prefilter is effectively eliminated as the backflush is very efficient. Every 2 weeks, it is recommended to inspect the filter for stuck hair but active cleaning is rarely needed.

As the main filter, several types of microfilters have been tested in the project: pleaded paper, and polymer as well as metallic single and multilayer filters. An initial investigation showed that a 10 micrometer filter reduced the internal fouling of the system compared to larger mesh size and smaller mesh sizes increase the pressure drop across the microfilter over time at a much higher rate.

[5] www.creadis.dk

To increase the lifespan of the microfilter, IPU conducted a series of experiments to quantify the lifetime measured as increased pressure drop over time, the ability to recover pressure drop using backflush and find an effective method for pasteurizing stainless-steel cartridge and thereby prevent bacterial growth. Furthermore, a secondary goal was to ensure a simple and energy-effective solution which could be easily integrated into the existing shower system.

A reliable testbench was developed for the pressure drop tests and it was tested using both real shower water, artificial shower water and a simple fouling using precisely size polymer particles. While a suitable metallic filter was identified, the long-term recovery using backflush was inadequate for the use case and out of place recovery using a dish washer or special chemical cleaning was needed and only partially successful. For the project, this was not an acceptable solution, and contact to several 3rd party filter suppliers did not give a solution within the available time in the project.

IPU investigated a simple and effective method for pasteurizing filter cartridges, effectively killing all microbial life in the filter cartridges: Four test rounds were conducted, continuously advancing towards achieving efficient pasteurization. It was determined early on that incorporating a heating element into the filter head would offer a straightforward and energy-efficient solution, potentially eliminating the need for mechanical modifications to the rest of the shower system. However, initial tests revealed that convection in the water inside the filter head did not occur as fast and effectively as anticipated. Despite extended test durations, the top half of the water would heat fast while the bottom half remained close to starting temperatures, increasing only 5-6 °C.

To address the insufficient water mixing in the filter house, a pump was integrated into the system, creating a small, closed circuit. This successfully resolved the mixing issue. However, a new challenge emerged, namely the extended time required for the entire water volume in the system to reach the target temperature of 72°C. Several modifications were implemented to minimize heat loss within the system, primarily originating from the tubes. Despite these efforts, the time required for complete heat-up was reduced to a minimum of 50 minutes. Subsequently, the pump was replaced with an acrylic pipe featuring bottom holes, referred to as the "chimney," to enhance water circulation with convection within the filter house without relying on a pump. Measurements indicated that water mixing predominantly occurred around the location of the chimney holes, while the region below this point remained difficult to heat evenly. Nevertheless, satisfactory temperatures were reached within approximately 38 minutes.

A test was conducted using a dirty filter cartridge. Water samples were collected before and after pasteurization demonstrated a significant reduction in microbiological content, yet not complete disinfection. Thus, the pasteurization method proved a partial solution eliminating bacteria from the cartridge. However, there are significant practical challenges implementing the electric water heater and the chimney in the available filter house.

For this reason, Flow Loop decided to implement an economical and simple solution that provided sufficient filtering of the water, was recovered by replacement, and met the economical requirements: A pleaded polymer filter cartridge with a suitable low price was identified and tested successfully. It was shown that provided periodical CIP (Clean In Place) with a cleaning tablet was conducted bi-weekly, the filter could last 200 showers or 4 weeks in the shower panel. The cost price is in line with the requirements with less than 3 Euros per filter in volume pricing.

An investigation was made for a UV-LED to replace the mercury lamp in the shower. The short version of the investigation is that while performance in comparable, the price is 5-10 times higher for a relevant replacement. The reason for the high cost is the high flow (12L er minute) and compact footprint. Most UV-LED units these days are either made for water faucets with 3-4 L/min or large, industrial scale units for water processing plant.

For this reason, the mercury UV was accepted in the product and it is also confirmed by EU providing dispensations for water cleaning use at least up to 2027 where it is up for renewal.[6]

To make a marketable product, Flow Loop has been through several iterations of the mechanical and hydraulic design and layout of the recirculating shower. The hydraulic design was initially created as a normal motorized shower (as sold eg. in the UK) with a pump to create the shower pressure from gravity fed hot and cold tanks. On top of this, the recirculation was added with water pumped from the floor, through pre- and microfilter, ultimately to replace the cold water supply to the recirculating shower. Hot water is then added as needed to maintain the shower temperature and compensate the heat loss to the environment during the recirculated shower.

Through the iterations, simplifications have been made and performance constantly improved. Below illustration of the progress.

The cabinet was designed together with the external designer Anders Hermansen and the first prototypes with this design have been tested in private homes. The hydraulic product architecture has been updated and simplified significantly, and the function in relation to relevant standards (e.g. EN1717 about backflow to the public water supply and EN1111 about thermostat function) has been confirmed using the test house KIWA in the Netherlands.

The recirculating shower has been made market-ready and introduced in the summer 2022 market. The first product does not have all the functionalities that have been developed, but a subset of the solutions that have been worked on in the project. The cabinet is in production and undergoing continuous cost reduction. Mechanical solutions based on 3D printing have been made, which were first done in-internally and are to an external supplier of higher quality.

The maintenance solution is defined, qualified and automated in the products sold – the user has manually to add a cleaning tablet to the floor and press a button every 2 weeks and replace the filter through a maintenance hatch every month. While not the optimal solution, it works well and is qualified through many measurements of microbial water quality over time in many different showers.

There have been production challenges with the water quality sensor at DTU, so the first units for testing in the project have been installed at test users without. A short test was made at the 5 demonstration units in August 2023, yet the water sensor is still not market ready and it needs to be outsourced to an electronics

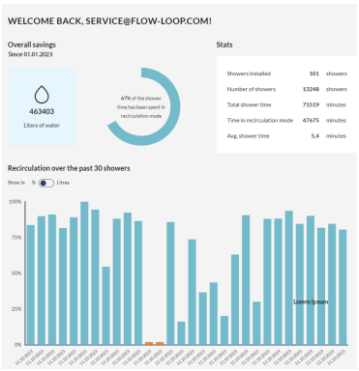
[6] https://www.dwi.gov.uk/private-water-supplies/pws-installations/uv-systems/

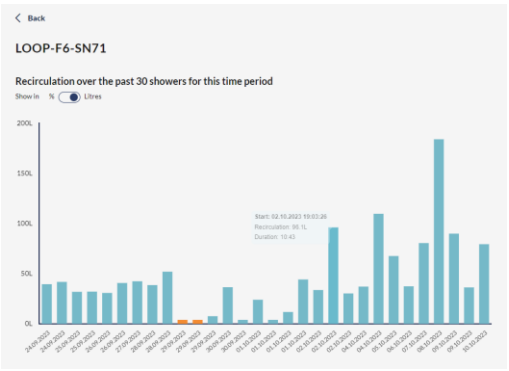
manufacturer before it can be implemented in commercial system. A practical workaround has been to implement timer-based operation of the recirculation, so the shower automatically starts to recirculate after 30 seconds and then press a button for switching the recirculation on and off as needed to ensure the optimal shower experience for the user.

In the project both electronics and software were developed from scratch using the external supplier Etteplan (initially called Tecpartner, but changed name during the project). There have been significant problems in producing sufficient printed circuit boards (PCBs). The first development print could not subsequently be delivered due to part shortage during and after the Covid-19 pandemic and it has since been a constant struggle to build the panel with the desired functionality. Therefore, there has been continuous adaptation of the components from which the electronics are built, so that the PCB has the desired functionality while components can be obtained. This has resulted in continuous adjustments and reductions in functionality and the associated software. Despite these problems, software for basic functionality has proven stable and reliable. Analyzes of 100 baths with the manual version of the product have been carried out and the algorithms for savings have been optimized and qualified, confirming the savings as 85% water and 75% energy under standardized conditions. To allow for product and shower space variance, the market claim has been set to 80% water and 70% energy saving under recirculation.

IOT functionality has been implemented and tested and the result is that the desired demonstration of savings to end customers can be estimated based on pumping speed and recycling percentage. The internet connection of the panels is enabled by a 4G-modem and a SIM-card – in most cases, this has been a reliable and efficient solution. Yet at some customers, the shower panel has been placed in rooms without mobile reception and thus connection has been limited, resulting in difficulties to provide the shower data to the customers. Ideas have been presented to include a wireless modem, but that poses other challenges with connection of the panel to a business wireless network where IOT devices are not allowed. For now, the 4G solution has been seen as an acceptable 1 generation solution. Unfortunately, the architecture suggested by Etteplan proved to be less scalable than expected, so the performance of the IOT solution is less than desired but acceptable for the numbers of showers in the market now.

Despite the challenges, the IOT solution has been well received by customers – it shows data about individual showers and groups of showers under shared ownership, so it can be used to optimized individual shower habits as well as follow up on general use:





CE certifications and other certification tests (e.g., EN1111 and EN1717 at KIWI in the Netherlands) have been carried out along the way. Late 2022, the first product based on elements of the project came in general commerce and in total is approx. 50 units have been sold and installed and ongoing data is received from the installations and feedback and interviews provide input for improvements. In 2023, improvements of the first

product in the market (LOOP) has been conducted. All algorithms, both for function, calculation of savings and automatic cleaning of the system have been implemented and are part of the marketed product. A website has been created where users can log in and see their usage and savings. Customer feedback has been received in several rounds and ongoing improvements and a new iteration of the IOT system are underway and will be implemented after completion of this project.

Flow Loop's product has been presented at several conferences, e.g. TechBBQ 2022, World Water Congress 2022, Building Green 2022 and 2023, Property Fair 2023 and COCONF23. The main market segments are boarding-schools, hotels, and the housing market with a focus on rental properties.

Risk management

In general, the risk management in the project has been working well. The main risk categories that were identified in the application and early in the project was well managed and the effect on the project was acceptable due to effective mitigation.

Water quality was initially the greatest concern of the project. The are no directly applicable standards for water quality in recirculating showers, but during the project, knowledge found, experience gained and the confidence in the solution has been build up. The starting point was the bathing water directive – while it sounds applicable, it is only partially relevant, as it specifically states recreational bathing and not showering. To remedy this, a strategy for maintaining the microbial water quality was formulated in cooperation between DTU sustain and Flow Loop with three distinct domains: removal of bacteria during the shower, reduce microbial growth during the shower and reset of the recirculating shower to the starting point by chemical disinfection. All showers tested during the project with more than 500 water samples, showed consistently that the cleaning technology lived up to the numbers for excellent bathing water and kept other microbial indicators under control. More specifically, testing was conducted in a property infected by legionella, and that showed the recirculating shower consistently reduced the levels of legionella to acceptable numbers, often non-detectable or negligible numbers.

Cost has been a concern during the entire project and cost of goods sold (COGS) remains high even at the end of the project. During the project, there has been a constant focus of balancing the COGS with necessary investments at suppliers to make production tools for plastic and metal parts that will really reduce the COGS. The focus initially was to simplify the product as much as possible and 3D print plastic parts instead of investing in plastic mould early, which would limit the ability to perform necessary changes fast and efficient. A cost-down roadmap is developed with two main elements: component changes to reduce cost and volume effects driven by larger number of units sold. After the project, focus will be on executing this roadmap to increase the profit margin to ultimately create a cash-positive business.

Maintenance improvements have generally been positive during the project. There was initial doubt on whether the microbial water quality could be maintained during normal operation, but that has been shown to be acceptable. Unfortunately, it was not practical to do this with a reusable filter, so a replaceable filter was the mitigation. However, then focus was on automating the bi-weekly cleaning process and the result became acceptable with only user interaction being placing a cleaning tablet on the floor and press a button for automatic cleaning. Similarly, great care was taken regarding ease of changing the filter every month. Cleaning of limescale is as easy as the bi-weekly cleaning, except that a commercial product for descaling of coffeemakers is used. The interval of this process is depending on the hardness of the supply water, but the reuse of the supply water during the shower reduces the limestone scaling very significantly.

Retrofit centres around the creation of the reservoir of water at the floor as well as placement of the shower panel at the wall. The point drain solution with the dome and clicker (original Flow Loop patent) fits in more than 75% of the cases, however several cover plates are needed due to lack of standardization of the drain opening. A mitigation has been identified and a new patent has been applied in April 2023, allowing for a

passive solution that is put on top of the existing drain cover. The mounting on the wall has been possible in all cases, so this is seen as unproblematic.

UV-LED was simply not feasible from a COGS perspective, and therefore UV mercury was qualified in the project. As it turned out, the CE marking of the product is made on a standard for UV-disinfection that specifically mentions UV mercury lamps[7].

Several risks were considered in the risk management, but either mitigated efficiently or not appearing at all. This includes noise concerns, as well as lifetime concerns for components where high quality (and thus expensive) components were chosen to avoid troubles.

The most notable risk not considered initially was obviously the Covid-19 pandemic. This has impacted the project massively, both directly in the team due to the lockdown and indirectly through changes at the demonstration partners at hotels and shortage of parts during both 2021 and 2022 for development and production.

Appraisal of the implementation

In general, the project was executed and implemented according to the original plan, however several changes and mitigations were necessary, largely due to the Covid-19 influence, but also technical challenges not foreseen.

Some choices have been made throughout the project, where development did not quite provide the desired function at the right price and quality in Flow Loop's product: First of all, it turned out that the automatic drain did not have the necessary product qualities to be marketed for point drains in the middle of the floor – it was tested successfully in the laboratory, but as the solution was based on batteries in the automatic drain, it was not acceptable in the product: customers do not want to change batteries in their drain with the frequency it required. Similarly, it has taken a long time to create a water quality sensor that could be produced in 10 copies affecting the project all the way to the end.

None-the-less solutions have been found which give the customer a good and acceptable user experience with simpler means, eg. solution for line drain with passive drainage under the panel, timing, and push button to activate recirculation and replaceable filter cartridges with the necessary maintenance paradigm.

The delays with the water quality sensor have meant that the testing in test installations is less extensive than originally planned, but on the other hand, Flow Loop's commercialization of the other solutions in 2022 and 2023 has provided feedback from more than 25 pilot installations and 5 demonstration installations. Furthermore 50 commercial installations during first half of 2023 have shown a successful product implementation.

The technical milestones stated for the project have all been met and are reported in the previous pages:

M1 Automated drain and filter solutions tested and approved

M2 Shower panel cabinet design finalized

M3 Electronic systems supporting hydraulic system tested and ready

M4 Demonstration units produced and installed

M5 Documentation for certification purposes produced

[7] IEC 60335-2-109:2010 Household and similar electrical appliances - Safety - Part 2-109: Particular requirements for UV radiation water treatment appliances

The commercial milestones of the project are met:

CM1 Demonstration of user savings of water and energy: Savings are demonstrated in the lab under standardized conditions, at a third-party lab in the Netherlands KIWA and at customer installations.

CM2 New go-to-market strategy: Described further in the end of the next chapter.

5. Project results

As stated in chapter 3, the overall objective of the project is to significantly develop and demonstrate the existing prototype developed by Flow Loop to make it fully automatic and thereby pave the way for commercialization.

Flow Loop's uniqueness in the market revolves around the retrofit concept: The LOOP is installable in existing bathrooms. That means that the existing shower solution is removed from the wall and the shower panel installed in its place. On the floor, the cover over the drain (typically a grate) is replaced by a patented click solution with a dome that stems up water, so a small reservoir of water can be created. An inlet in the bottom of the shower panel sucks water from the floor reservoir through a filter, mixes hot water through a thermostat to compensate for the heat loss and then disinfects with UV before reshowing over and over.

The objective of the project was obtained: The prototype of the Flow Loop product was matured into the LOOP product that came in the market in 2022. Full automation with switching between normal shower and recirculation to avoid soap, urine and blood was demonstrated in the lab, but not made into a commercial product during the project. However, workarounds were identified so most of the product vision was in the LOOP, and even more in the EcoLoop being introduced Q3 2023 with first customer installations early 2024.

Comments on the specific objectives:

1. Develop a fully automatic drain solution to optimize resource savings that is compatible with Flow Loops patent pending retrofit drain solution.

This has been achieved in the laboratory. However, the battery-operated point drain solution was problematic from a usability standpoint and thus not developed beyond a prototype. Instead, a solution for the linear drain was developed, prototyped, and demonstrated successfully in the project. This also revolves around the Flow Loop patent that has been granted and issued during the project period.

2. Develop a filter of long durability aiming for a self-cleaning filter

A lot of work went into finding a self-cleaning and reusable filter that could be recovered though CIP (clean in place) and COP (clean out of place). Despite the effort, the reusable solution was not market ready and thus a solution was developed based on a replaceable filter with a durability of 200 showers or a month lifetime in the shower panel. While not everything the project wanted, it is seen as an acceptable solution. To make the solution even more acceptable, automatic CIP was developed and filter change made very easy. Less than a minute

3. Develop a filter with much lower maintenance costs than competing solutions that cost up to 250Euros/year in filter changes alone. To reduce payback time, it is a goal to reduce filter maintenance to below 50Euros/year including time for exchange of filter.

With the polymer pleaded replaceable filter, the cost target is met and thus a profit is possible.

4. Design an easy to install low-cost panel cabinet including an electronic monitoring system to illustrate obtained savings to the customer

Objective me and roadmap for cost-down activities defined.

5. Demonstrate and test the solution in different environments such as hotels, workplaces, housing associations and health & fitness industry

Further details on the specific steps to overcome the obstacles are in the previous chapter.

The expected outcomes of the project are met:

Optimization of the shower system for market introduction (incl. fully automated drain): Yes, at lab-level for both point and linear drain, demonstrated only for linear drain.

Established market access to key target groups through validation at test partners: Yes, see below.

Identification and implementation of a durable low maintenance filter solution (max. 50 Eu-ros/year) : Yes.

Overall, it is assessed that the project's purpose and results have been met at the end, although there will obviously be improvements after the project is over.

Commercial results

Flow Loop have piloted 5 showers as a part of the project. Three in private settings and two showers at Comwell Hotel in Holte.

As mentioned in chapter 3 the water sensor was only tested in lab and not in the pilot as it was not mature enough for customer pilot's daily use. The bathers have therefore overseen whether the shower was in circulation mode or not and hence also for obtaining the savings. The showers installed in private homes have had very different circumstances for obtaining savings compared to ones at the hotel. In the private homes were the family educated in how to use the shower and obtain the savings. At the hotel was the hotel staff educated in how to use the shower and obtain the savings, while the hotel guests using the shower were left with a guide on the wall.

Both the private users and the hotel are very happy with the sustainable shower experience.

The **private users** give very positive feedback:

"It ticks all my boxes for a good shower experience".

"The very idea of recirculation. I want to live sustainably".

"We don't run out of hot water anymore; it removes that stress feeling".

"It's just really good to know that you can relax with a good conscience while recirculating".

The private customers are recirculating 70-90% of the time. This is very satisfying results and gives great water and energy savings.

The feedback from the hotel is also very positive. Flow Loop have not had the opportunity to interview or conduct a survey at the hotel. However, the Hotel manager Peter Gerløv Feddersen says: "*It is of crucial importance that we have not received any feedback from our guests regarding the showers. Our guests pay a lot of money to stay at our hotel, so if something is wrong, we expect to be notified."* Furthermore, Peter stress how important sustainability is to Comwell and how it is a part of their values, guest experience and

branding strategy. By installing Flow Loops shower Comwell is taking a step towards their 2030 ambition about being CO2 neutral in their own value chain (scope 1 & 2). The hotel guests are recirculating 40-70% of the time. This is satisfying results taking into consideration that they have not been educated and that they don't get benefit of the savings. It also stress the importance of automation to ensure savings.

Flow Loop is in negotiations with Comwell about increasing the number of showers. Comwell Holte is considering installing an additional 20 showers but also other Comwell hotels are considering installing Flow Loops shower.

Maintenance has been working very smoothly and done according to plan at both the private and hotel installations. The feedback to the maintenance processes are very positive and users find it acceptable that they have to conduct filter change on a monthly basis and run a rinse process every 2 weeks.

The pilots have been very successful and are supporting our commercial journey. The learnings obtained from the pilots are crucial for our market roll out. We use references from the EUDP project in our commercial material.

In 2022 Flow Loop made a manual version of our recirculating shower. This shower is called Loop and is now installed at app. 50 locations mainly boarding schools, changing facilities at companies and private homes.

Recirculating showers are a new category in the market. Even though we can install in existing shower spaces are lead-times and decision processes very long. Purchase decisions are dependent of overall building plans, budget approval and various stakeholders. Over the past year we have worked systematically with building up a solid pipeline. Flow Loop is now at a stage very we are being prescribed for large projects, especially in the residential rent segment. Flow Loop have now built up a solid pipeline and we expect a high growth rate going forward.

Target group and added value for users

LOOP (the manual version) is targeting the private consumer segment and other segments where the same people use the shower daily for instance boarding schools and companies. Flow Loop sales focus is at B2B customers. To service the B2C customers a wholesaler agreement with A&O are under negotiation and are expected to be signed before end of year. The main segments for LOOP are:

- **Residential rent market**. Property owners with a strong sustainable profile that want to offer their tenants a sustainable shower experience. ESG reporting requirements and CO2 reduction drive market interest from this segment.
- **Boarding schools**. 3-8 students share the same shower which gives a fast return on investment. Boarding schools are looking for savings and would like to strengthen their sustainable profile.
- **Companies**. Shower facilities at companies. At some companies' employees shower as a part of their daily work routine while other do it in connection with a gym. Depending on the daily number of showers companies can get high savings with LOOP. ESG reporting requirements and CO2 reduction also drive market interest from this segment along with return on investment.

EcoLoop (the automated shower) is targeting the B2B segments especially the hotel segment. Hotel guests often take very long showers and expect a comfortable shower experience when they have been paying 1.500 DKK or more per night. ESG reporting requirements and CO2 reduction also drive market interest from this segment but the return on investment is challenged by a low number of daily showers.

Dissemination

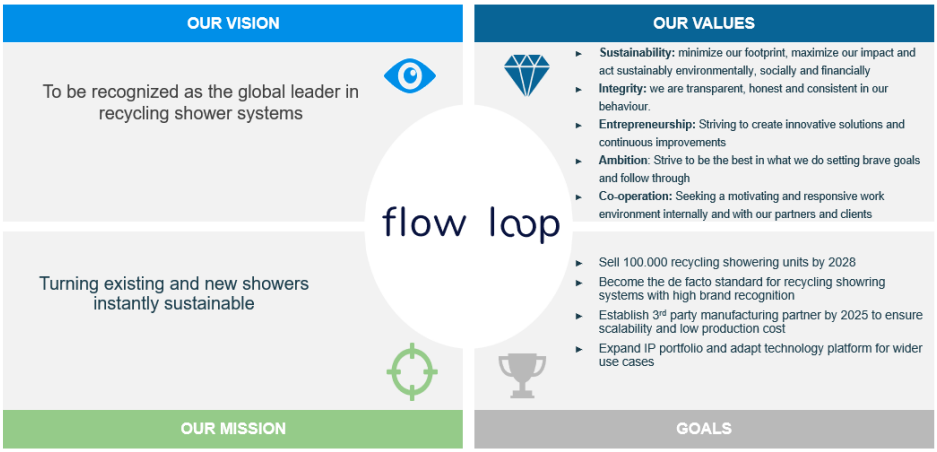
Flow Loop showers have been presented at conferences: TechBBQ 2022, World Water Congress 2022, Building Green 2022 og 2023, LOOP messen (2023), Ejendomsmessen 2023 og COCONF23. We always receive high interest when we showcase our shower technology at fairs. The interest both comes from traditional customers and from shower manufacturers interested in integrating our technology into their brands.

An article has been written about the design of the wireless solution by participants in the project, which is expected to be published in Electronic Letters, which is a peer-reviewed journal: "Wideband patch antenna with defected ground structure for smart drain applications" by Dong, Yunfeng; Hansen, Soren; Olsen, Brian; Ji, Jiank-ang; Jakobsen, Kaj

6. Utilisation of project results

The technology developed in the project is highly relevant for Flow Loop's recycling showers and will be commercialized in Flow Loop's present and future products.

The funding from EUDP have supported the development LOOP and EcoLoop that now are ready for commercialization. It has been a challenging journey to fund the product development and EUDP's support have been crucial in making it to this point. Flow Loop have bold ambitions and want to become the market leader in recycling shower systems.

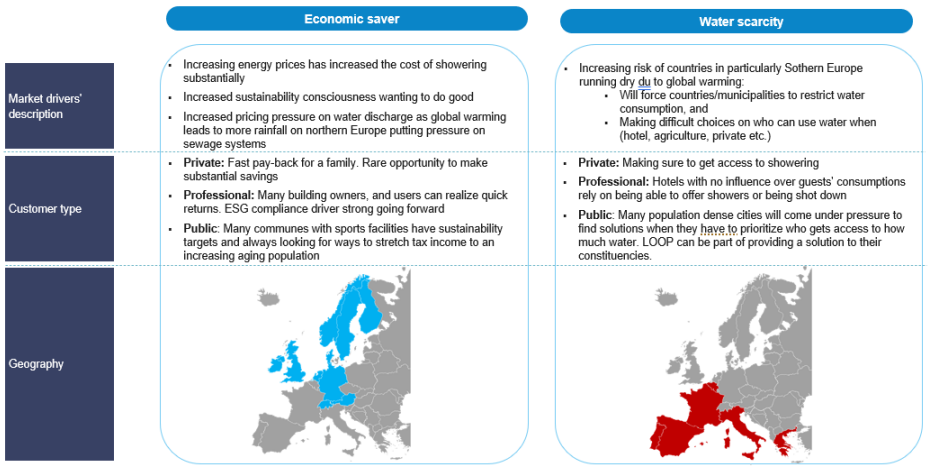


When selling new technology into the market (blue ocean) reference cases are crucial for the first customers to convince them that it is safe to invest in the new technology. Flow Loop is utilizing the reference cases from the demonstration under this project in our commercial material explaining the use case, savings, customer quotes etc.

The success of LOOP and EcoLoop will be crucial for Flow Loops revenue generation. In 2022 Flow Loop had a little revenue from the commercial pilots while real sales of LOOP first was started in 2023. EcoLoop has been piloted in 2023 as part of the EUDP project and has just been released for sales.

In 2024 Flow Loop forecast a revenue of a double-digit million amount DKK. In 2025 to 2030 Flow Loop forecast yearly revenue growth rates of 50-100%. Flow Loop receive great interest from developers, property owners and hotels. These segments find Loop and EcoLoop attractive when they upgrade or refurbish their existing buildings. Flow Loop are currently in dialogue with app. 50 B2B customers about installing our showers in their buildings. While this is positive, we see very long lead times for conversion from interest to sales. In some of the cases the return on investment is to long for the customers to find our solution interesting, we expect to be able to convert app 25% of our present dialogues to paying customers.

In 2024 will Flow Loop start internationalisation. Our international roll out have two main drivers water scarcity and return on investment. In Southern Europe is water stress rapidly increasing and increasing temperature due to climate changes will accelerate water stress dramatically. Our market roll out in Southern Europe will be driven by water stress and restrictions on water use while market roll out in Northern Europe will be driven by financial savings. The most interesting market outside Europe is the American market and the Middle East. We get a lot of requests from these markets especially from the US.



Flow Loop have high growth ambitions. To drive this growth Flow Loop will increase its number of employees from currently 18 to +100 in 2030. Flow Loops team will span from product innovation over production to sales and marketing with the necessary support functions.

Being a hard tech company with high growth ambitions is expensive and capital requiring. We are in dialogue with investors to fund the market roll out of LOOP and EcoLoop. We have been in dialogue with multiple investors about investing in product development without success (apart from IKEA, which basically invested to get access to a technology that they can sell in their warehouses). Regarding next generation of products focused on new build, there has been very limited interest from investors as they focus on scaling up LOOP and EcoLoop in the markets. New investors in Flow Loop are interested in market roll out, not in taking the risk of product development followed by market rollout as it takes too long for their return on investment.

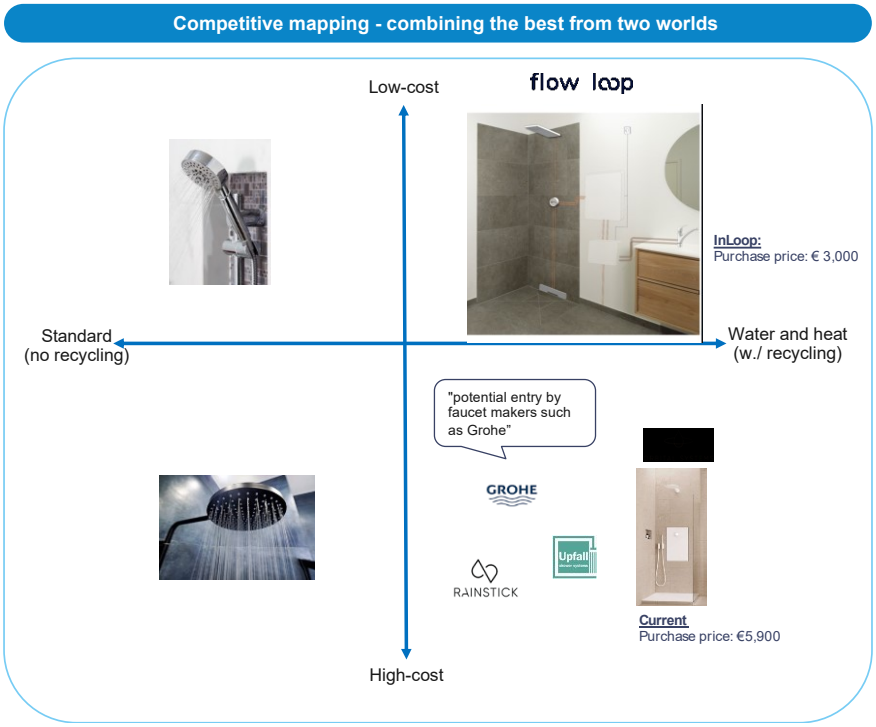
Flow Loop will in 2024 raise money to fund the growth of the company. Flow Loop expect to raise +30m DKK from investors to fund the market roll out and to reach cashflow equilibrium in 2025. We are in dialogue with potential investors and are currently preparing investor material and expect to close investment in first half of 2024 to fund the market roll out of LOOP and EcoLoop.

To have products that fit all market segments Flow Loop would want a recirculating shower for new build, where the recycling unit can be built in or placed in a cabinet. In new build there is an opportunity to further optimize the energy infrastructure in the building so heat loss in hot water piping is minimised. If Flow Loop is todevelop this product within a foreseeable future, we need soft funding for it since investors don't show interest.

Direct competitors

Kommenterede [JS1]: Are the recirculating showers the only competitor group here, when we are talking about replacing the whole DHW infrastructure?

There are several direct competitors who offer a recirculating shower product. These are typically more basic products than the InLoop Comfort in that they do not seek to fully optimise hot water infrastructure simultaneously and as such, do not offer such a far-reaching value proposition. InLoop Comfort is a unique solution that is therefore unmatched in the market. Moreover, none of the existing solutions have managed to gain any real market traction within their target segments, leaving a gap in the market for InLoop Comfort and an opportunity for Flow Loop to establish ourselves as a market leader.



Orbital Systems AB is a Swedish company established in 2012. They launched their recirculating shower in 2013. Similarly to the InLoop Comfort solution they also target new builds and the refurbishment market. They are currently active in both Denmark and Sweden. There are several key differences between Orbital's solution and InLoop Comfort. Orbital is reliant on having technical installation teams available on the ground which has limited its market penetration as this is a cumbersome and expensive task. Orbital's solution does not fully take advantage of the opportunities to maximise impact by targeting the new build and refurbishment segment

and therefore its potential for reducing environmental impact is limited in comparison to InLoop Comfort. Specifically, they do not address the highly inefficient hot water infrastructure systems, a major source of energy losses and inefficiency within bathrooms. Finally, despite being in operation for over a decade, Orbital has yet to achieve profitability and has limited R&D activities. This is in part because of their customer acquisition strategy and reliance on specialised installation teams.

Upfall Shower BV is a Dutch company, active since 2013. They offer a single basic product with minor design variations that do not enhance the fundamental functionality. The Upfall shower employs physical filtration for water purification, lacking an additional UV step to eliminate microorganisms. This omission could potentially impact the product's hygiene standards. Moreover, the filter requires weekly maintenance, and the recirculation mode is not automatically activated, which could impact user convenience. Finally, the solution does not have the additional features as InLoop Comfort does and in this sense the impact is reduced in comparison, whilst still requiring a full refurbishment with the associated costs and time that this process requires. The Upfall shower system is primarily marketed within the Netherlands and lacks a commercial presence in other countries and will not be a main competitor for Flow Loop in our target markets.

RainStick Shower, established in 2019, is a nascent player in the recirculating shower market, focusing primarily on the North American continent. The company's product is still in the development phase and has not yet entered the market, although pre-orders are currently being accepted. The RainStick shower system is designed for a specific bathroom configuration, necessitating a tiled bathroom surface and a shower stall for installation. This requirement significantly limits its applicability as it cannot be installed on non-tiled bathroom surfaces such as shower floor plates or bathtub inserts. Given these factors, it is anticipated that the RainStick shower system will face challenges in gaining widespread market acceptance due to its high cost and specific installation requirements.

Indirect competitors

The competitors all offer a recirculating shower product, with key differences when compared to the InLoop Comfort which possesses numerous competitive advantages as outlined above. Critically, none of our competitors offerings address the issues with hot water infrastructure systems. It is also pertinent to mention that there are several different hot water systems which provide an alternative solution to address the problems associated with hot water infrastructure. However, these do not cover the same scope as InLoop Comfort, as they do not include the recirculating shower element which is central to our solution. These competitors include centralized heat pumps and district heating systems. Both solutions confront a key barrier that domestic hot water systems (DHW) require 55 ºC which obligate that they must operate at elevated temperatures and therefore suffer from low efficiencies and with high distribution losses. The proposed InLoop Comfort solution has very significant potential to reduce the most dominant demand for domestic hot water activity.

Market barriers

Flow Loop is currently selling our recirculating showers into a blue ocean market where knowledge and awareness about recirculating showers are very limited. We hence must educate and convince the market about the benefits of our products. Some customers have pay back times of 5 or more years.

To succeed in the market are we looking for innovators and early adapters that are willing to invest in new technology to achieve the benefits. To further reduce the burden for early adapters have we secured co-financing from Innovation to Market (Realdania) so the first customers can buy EcoLoop at a reduced price.

In the B2B segment we have 3 different stakeholder groups around our product:

- The ones using our product
- The ones taking care of maintenance

Kommenterede [JP2]: Flow Loop / AAU: please elaborate here, as concisely as possible, with a focus on why ILC has advantages over alternative heating systems.

Kommenterede [SH3R2]: @troels, @Brian: Can we update some of the stuff from the EIC slide deck?

Kommenterede [BOO4R2]: Please do

- The ones taking the purchase decision

In the hotel market the decision makers can be worried about if they will achieve the savings because the guest is not motivated from a financial point to recirculate. To address this problem our shower is programmed to deliver a flow like a water saving shower when it is not in circulation mode, while the comfortable rain shower experience only is available in circulation mode. The automatic function of EcoLoop shall further ensure that circulation is maximized.

In the rental market the tenants get the savings which make it challenging to convince property owners to buy our solution. To address this issue, we would like to develop InLoop Comfort in another EUDP application as it comes with other savings in the construction phase. In the rental market are the decision makers also questing if tenants will conduct maintenance according to schedule. This issue is addressed by a notification once maintenance need to be carried out. If maintenance not is carried out with in X days of deadline recirculation is deactivated and the tenant will not receive the savings and the comfortable shower experience in recirculation mode.

In new build customers expect a solution that is integrated in the wall or hidden in a cabinet. Currently can't we address this design requirement. We have applied for EUDP funding to fund the development of InLoop Comfort that will address this issue and provide additional benefits.

Finally, we receive a few questions on how is to shower in recirculated water. Here we compare to using a bathtub, in bathtub the user is in control of when the drain is plugged, and water is not shared from shower to shower. The same count for Loop and EcoLoop – the bather can decide to take the shower out of circulation and the shower is emptied from water between shower so no water is shared. In a traditional bathtub, the bather is exposed to his or her own contamination without filtration or disinfection, while the Flow Loop recirculating shower continuously filters the water for suspended solids and disinfects the microbes with high-intensity UV. After telling this at least 90% feels comfortable in using LOOP or EcoLoop.

Households spend app. 40% of their water consumption on showering and 15-30% of their energy consumption on heating this water. Recirculating showers therefore have the potential to significantly reduce water and energy consumption. Flow Loop have had Niras to document the benefits of LOOP (see appendix). The conclusion is from the report is that LOOP can reduce energy consumption per square meter year with up to 23%. If all adults in Denmark showered with a LOOP or EcoLoop shower, we would annually save:

- 73 million m3 of water
- 1.9 tWh
- 200.000 tonnes of CO2 equivalents

On top of this comes indirect savings from reduced energy consumption in the water supply and waste water treatment and reduced requirements to water infrastructure.

7. Project conclusion and perspective

As described in this final report, the objectives are met with the necessary adaptations. The adaptations relate to more advanced functionality (eg. automatic switching of recirculation based on water content during the shower and self-cleaning filters) that due to lack of maturity is not present in the demonstration units nor the first generation of the two products based on the project (Loop and EcoLoop). The consortium of partner in the project have worked well together and contributed greatly to the success of the project.

The technology will be used in the LOOP and the EcoLoop and in future Flow Loop products. Work will continue the water sensor and the self-cleaning filter, as both technologies showed considerable promise during the lab testing, even if they did not develop fast enough to be included in the demonstration projects.

Focus of the project has been to create the functionality in the lab to verify and then accept that it was not possible to mature fully within the time and resources allocated in this project. Guided by feedback from our customers will we continue to mature the developed functionality so it can be used commercially.

Appendices

- www.flow-loop.com
-