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A REFLOW CASE STUDY

Is Berlin getting into hot (waste)water?

Data-driven solutions towards climate neutral heating in the city

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

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Figure 1: Photo by Claudio Schwarz on Unsplash

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Introduction

Climate change was predicted to exacerbate in 2022. Cities and the people that inhabited them continued to use more resources than they produced. It was an unsustainable path. It was with this urgency in mind that the R&D team at Berliner Wasserbetriebe (BWB) sat down alongside their partners in the Berlin REFLOW pilot team. The team had a goal: transitioning Berlin towards becoming a circular and regenerative city. How was this to be done? Harnessing renewable energy was certainly necessary. And fortunately, it was also possible. There was an underutilized renewable energy source already at their disposal: wastewater heat. Little did they know when they sat down to work, that their biggest headache would not be the source of energy, but the data that came with identifying it.

In a city like Berlin, with a population of 3.6 million people, vast amounts of wastewater were being produced from both private households and industry. Much of the wasted water was still warm or even hot as it entered the sewage system, and the heat could be reused for heating or cooling activities around the city. Wastewater heat recovery was the key to bringing Berlin to climate-neutral heating – advancing the city forward in their circular and regenerative transition.

The problem was that many potential users were unaware that the heat from wastewater could be reused, and therefore much of the energy went to waste. In fact, while existing wastewater heat potential was around 275 megawatts, only 3 megawatts of wastewater heat was tapped into Berlin. It was clear that there was a stark gap between supply and demand. To address this deficit, the team began their development of a solution that would make this invisible and unexploited potential visible and mainstream as a heat supply. Through this, the pilot team sought to work towards generating impact through a higher recovery rate of wastewater heat and reduction of CO_2 emissions related to energy production and consumption. Further, the Berlin pilot team had their goals set high and aimed for their solution to be the catalyst for further uptake across the entire metropolitan area of Berlin and other cities across Europe and beyond. To do this, they landed on the development of a technological solution which would openly publish data and create matches between where the critical infrastructure for wastewater heat was in supply and where there was demand through the mapping of buildings which could utilize and benefit from the heat. For this, it all had to start with the data.

As the Berlin REFLOW pilot team progressed with the development of this solution, the R&D team at BWB, who were involved in coordinating and undertaking the work as part of the Berlin REFLOW pilot, received some concerning news from their colleagues in the

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Wastewater Department at BWB, who were not part of the Berlin pilot's REFLOW activities.

After 2.5 years of developing a data-driven solution, known as the Wastewater Heat Radar, under the impression that the publishing of this critical infrastructure data would be possible, news from the BWB Wastewater Department – the owners of the data – now stated that they were investigating this matter further after identifying potential risk in it being publicly open. Within the BWB Wastewater Department, internal discussion on the publishing of critical infrastructure data had started to spur, and the head of the department relayed this message to the Berlin REFLOW pilot team.

On the one hand, the data on critical infrastructure was needed to utilize wastewater heat and transform Berlin into a sustainable, circular, and regenerative city. On the other hand, there were risks in releasing the data, particularly as it could show the vulnerabilities of infrastructure around openly publishing the data.

With only six months remaining in the three-year REFLOW project, an answer was urgently needed from the Wastewater Department. This timely decision was not only crucial so that the Berlin pilot team could present their finalized and tested solution to the European Commission, the funders of the REFLOW project they were a part of, but more importantly, they needed to showcase how this solution could set the example of a successful and sustainable model to turn linear heating in Berlin and other metropolitan areas towards more circular practices.

To respond to this call for action, the Wastewater Department gathered for an internal discussion to consider the question at hand: should *a stop be put on the release of wastewater heat potential data or risk the potential security threat to critical infrastructure in Berlin?* BWB's Wastewater Department evaluated this dilemma both as a partner in the Berlin REFLOW pilot team, but also as a separate organization outside of this partnership responsible for supplying citizens with uninterrupted water and treatment services alongside their own economic and environmental goals, BWB's Wastewater Department evaluated this dilemma.

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Context

The City of Berlin's Strategy for Climate Neutrality

In 2016, Berlin set out a strategy to become climate-neutral by 2050. At the heart of this strategy was the Berlin Energy and Climate Protection Programme. The plan encompassed all relevant fields of action in the city – energy supply, buildings and urban development, industry, traffic, and private households. The short-term goal was to reduce the total amount of carbon dioxide emissions by at least 60% before 2030. By 2050 this number was set at 85% compared to 1990 levels.

The ambitious strategy meant that new and existing buildings needed to become more energy efficient. Public transportation and cycling had to be made more attractive to encourage people to leave their cars at home. More green spaces were to be developed to make the city adaptable to rising temperatures. The city needed to move away from conventional energy sources that impacted the environment through the extraction of scarce resources, while polluting the soil, water, and air. These dirty energy sources contributed to increased greenhouse gas emissions. Often overlooked by citizens and decision makers was also the impact of heating systems. With a district heating system supplying about three quarters of Berlin households with heat produced from mainly hard coal, transitioning this heating system was a core component towards climate neutrality. Change was needed to move to a decentralized, socially responsible supply system based on renewable energy. A circular economy model was needed. One way to do that was to tap into wastewater heat.

Wastewater Heat

Wastewater was produced from industrial processes, commercial use, and everyday activities such as showering, dishwashing, and laundry. Heat was generated as a by-product from wastewater as it often contained high amounts of thermal energy. This wastewater initially had a temperature of more than 25 degrees Celsius. On the way to the sewage treatment plant, the temperature dropped to 15 degrees Celsius. Both temperatures – 25 and 15 degrees Celsius – were too low to sufficiently heat radiators. But with the use of heat pumps, temperatures could be raised to 65 to 50 degrees Celsius – for heating.

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As only less than one percent of this heat was being captured and used, there was great potential for a new source of energy. There was a potential of 275 megawatts from wastewater heat. But only three megawatts out of the 275 were currently being recovered. This meant that while Berlin had the existing infrastructure – pipes, pumps, and other hardwire – to facilitate the recovery of wastewater heat, a huge amount of energy was being wasted. There was a large untapped potential for circular heating.

The advantages of extracting energy through this method were significant. Unlike heating systems with fossil fuels, natural gas, and coal, electric heat pumps used to generate energy through wastewater heat produced no emissions on site, no pollutants like CO_2, NOX, and soot. The energy extraction method was not dependent on energy sources abroad. It produced no combustion, flames, or fuels in the house. No fuel delivery and disposal were needed. Wastewater heat was much more environmentally friendly.

With so much potential and many advantages, the question was why the energy from wastewater was often wasted. The answer: lack of knowledge surrounding wastewater. Many people didn't know the benefits and potential of wastewater heat recovery. Gaining access to information was hard and slow, making it difficult to research whether there were even good conditions for the use of wastewater heat at certain properties. For example, real estate developers, urban planners, and ordinary citizens had to go through a formal process of inquiry with the municipal water suppliers to understand whether wastewater was available to them. The Berlin REFLOW pilot team sought to change this. The need for easier access to more information was why data was so critical to the project's success. The team needed to close the gap between supply and demand.

Data was the key to success

To close the gap between the potential and recovery of wastewater heat, the Berlin pilot team was convinced that technological hardware was not the best answer. This was because wastewater heat recovery technology – in the form of heat pumps – was already a highly efficient and mature technology. Instead, with the use of quantitative data, the team created a solution in the form of an app - the Wastewater Heat Radar (hereafter WWHR). The WWHR was a web application which would serve as an intelligent radar to guide urban planners, real estate developers and other initiatives towards more circular heating in Berlin, and thus pinpoint these actors to spots in the city where they could intervene and implement wastewater heating systems. With data laying the foundation of the WWHR, the solution would also provide a facts-based feasibility assessment for these

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actors and act as a surefire way to push forward the transition towards circularity in Berlin and beyond. Having BWB, Berlin's public water utility company, on-board as partners in the Berlin REFLOW pilot team played a critical role in gaining access to the data needed for the app.

BWB also had great expertise and knowledge in the area of water management. BWB was an innovation leader in its industry and a respected member of relevant associations including their active participation in public-funded research projects. Their position as a leader in one of Europe's largest cities meant that BWB was of tremendous value to the Berlin pilot, including their rich set of data which was necessary for implementing the WWHR solution in Berlin.

The Supply

Armed with an innovative solution and a team of researchers, innovators, and wastewater experts, the Berlin pilot team got to work on the data they needed to fulfill the development of the WWHR. The first step involved accessing infrastructure and city structure base data from BWB. With this data, the team could build a digital map of existing sewer system infrastructure. From there, the team could identify and filter through the buildings in the city which had high potential for the supply of wastewater heat, and which had existing wastewater infrastructure in its vicinity. As a result, the team would be left with a supply of wastewater and thus places where wastewater heating systems could be installed to tap into as a potential heating source.

The Demand

Next, was finding out where the biggest demand for energy lay. To do this, data was needed on the energy consumption rate for the buildings that were previously identified as being near wastewater infrastructure. After experiencing some difficulties with energy supply companies unwilling to share their data, the Berlin pilot team found a workaround. For this demand component of the WWHR, the team constructed a data simulation showing the space of buildings, number of levels, and existing heat supply sources – providing a realistic set of data needed.

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Matchmaking

The two datasets – wastewater heat potential and energy consumption – were then combined to draw matches from both data pools (the supply and demand). Based on the matches, it was possible to see where wastewater heat systems made sense both ecologically and economically. From combining these datasets came the creation of the WWHR prototype ready for being released to the public and available for testing and implementation. The hope was that this tool would serve as a blueprint for more cities, allowing for easy replication and implementation of circular economies.

The REFLOW Berlin Goals

The REFLOW Berlin team considered the project a success if there was a significantly increased interest in wastewater heat recovery. This would mean that more private households, industrial sites, technology parks, building owners and managers, property owners and other stakeholders subscribed to the technology, WWHR. Another measure of success was if other European cities showed interest in the solution. Specifically, if three additional European cities (those with more than 500,000 inhabitants or that had sufficient hardware and technology) showed interest, the project would be seen as successful.

Because of the focus on replicating the project, the team put emphasis on analyzing the legal and regulatory environment in other parts of Europe. They wanted to ensure that the necessary data, infrastructure, and technology was available. The pilot team expected other European cities to be similar to Berlin's market structure - highly regulated with difficult to access data. The learnings of the pilot would hopefully ease future exploitation efforts as access to sufficiently large and meaningful data sets was of critical importance to adapt the WWHR in other cities. In the longer term, a successful project would mean higher recovery rate of wastewater heat, more municipal procurement, less CO_2 emissions, and the mainstreaming of wastewater heat. With the necessary datasets needed and the WWHR developed, the Berlin pilot was well on their way to reaching their goals as part of the REFLOW project – or so they thought.

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The Issue of Critical Infrastructure Data

Critical infrastructure was the physical and organizational structures and facilities that were imperative for a country's society and economy to function. This included telecommunication networks, transportation, public health, agriculture, and water. While societies around the world were moving more and more towards opening up and sharing data with the public as way to increase transparency, accountability, and even stimulate circular transitions, technological innovation and economic growth, increased threats and vulnerabilities to the security of critical infrastructures were becoming hot topics of debate. While the threats and vulnerabilities to critical infrastructure had in the past solely focused on the physical realm of these infrastructures whether induced through climate change, physical attacks or natural disasters, the growing threat of cyber-based and malicious attacks were becoming an important agenda item across cities and nations around the world. This was no different for Berlin. With the water sector identified as a critical infrastructure in Germany, it was the task of BWB to ensure that the safe and continued operation of their water supply and wastewater treatment was left uninterrupted.

On the other side of the coin, critical infrastructures were key points of intervention in transitioning towards circular economy as they were responsible for using up vast amounts of resources. At the national level, over 90% of heating systems were run on oil and natural gas at the time. Moreover, almost a third of the country's total consumption of energy was connected to space and water heating in buildings. In Berlin, three quarters of the city's households were supplied with heat through district heating, which was for the most part run on fossil fuels. To reach climate-neutrality by 2050, incorporating at least 30% of energy from renewable sources was a target for 2030. On top of environmental downfalls of heating systems that relied on fossil fuels, households across Europe were also experiencing sharp spikes in their electricity and gas bills as they heated their homes in the cold winter season. It became ever more apparent that leveraging into climate-neutral sources of energy through critical infrastructure for heating was needed. Integrating technology into existing infrastructure and extracting and using valuable critical infrastructure data fostered enhanced connectivity and optimization of resources. Moreover, the incorporation of digital platforms fed with datasets derived from critical infrastructures was key in being able to link resource supply and demand in an efficient way. The WWHR provided this link.

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After just over two years of developing the WWHR and with just a little over six months left in the REFLOW project, the Berlin pilot team was ready to showcase and test their prototype to the public. However, just before the launch of the WWHR, a memo from the Wastewater Department at BWB landed in the mailboxes of the Berlin pilot team. The release of the WWHR prototype needed to be ceased until the Wastewater Department had decided on the case of openly publishing critical infrastructure data. After important considerations to the potential risk of security-related threats and vulnerabilities related to publishing critical infrastructure data in the WWHR were brought up in an internal BWB meeting, the Wastewater Department needed to take a moment to understand the pros and cons of the issue before they relayed their final call to the Berlin pilot team.

The Pros

The problem was that there were risks of publishing the data on critical infrastructure and private citizens that were needed for the success of the project. The first good reason for publishing the data was that the data was needed for BWB to achieve its ambition of becoming a climate-neutral company by 2045. Wastewater heat recovery was essential to hitting this target. Since 1990, BWB had already reduced its CO_2 emissions by half. With the implementation of the WWHR across the city of Berlin, it was expected that the full-blown potential of this Berlin pilot solution could save 45,500 tons of CO_2 a year[1] when compared to gas-based heating systems. These numbers were huge not only for BWB, but also in the fight against climate change. It would be tough for the company to reach this impact without the data that was needed to create the WWHR. Additionally, with the WWHR, BWB could be seen as a forerunner in enabling critical transitions towards climate-neutrality and circular economy. This frontrunning position would not only feed into the image of the organization but would also benefit them economically through the success of the WWHR and increased uptake of tapping into their infrastructure they operated in the city. The WWHR solution was also a promising help for the city of Berlin to achieve its goal of cutting its emissions by 2050 – something that BWB contributed towards through increasing their utilization of wastewater heat.

Additionally, by allowing the implementation of wastewater heat recovery, BWB would be closer to reaching a certification as a climate-neutral organization. With such a classification, BWB could showcase their active commitment to climate protection and

[1] Based on rough calculations done by BWB.

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social responsibility, strengthen their image, and set the standard for other organizations to follow suit.

The third compelling reason to publish the critical infrastructure data was that doing so would be more efficient for BWB. By publishing the data, BWB would no longer have to manually process and match every demand for wastewater heat recovery with supply availability – leading to increased use of resources. If the data were openly available, the WWHR would be able to automatically take care of these requests, making it much easier for the user to understand the availability of wastewater heat, thus generating more interest and awareness - two key goals of the Berlin pilot.

The Cons

The trouble was that there were also good reasons not to release the data. For one, as a water utility, BWB was obligated to ensure that their infrastructure which supplied water and treated wastewater for the citizens of Berlin, complied with security standards in Germany. This included ensuring that additional risks of cyber or physical attacks to critical infrastructure were not made possible through data access or hacking into their information deposits. The breakdown of any of these services could have severe and cascading societal and economic consequences. Additionally, they also needed to ensure that they abided to data privacy regulations of citizens which was a very meticulous road to navigate.

The hyper-connectedness of infrastructures across countries and sectors was also an important to consider, as even the slightest disruption to the water and wastewater infrastructure had the potential to cause disturbances across sectoral and national boundaries. Water was a highly interdependent sector with many other functions in society and the economy relying on it while conversely being vulnerable to disruptions occurring in other sectors. Hacks like the Wannacry Ransom attack in 2017 where 150 countries were affected by a cyberattack resulting in major disruptions across organisations and institutions across the globe, including many companies having to stop operations and even crippling the UK's healthcare system can create huge damages. This was of course an extreme anecdote, but it was nonetheless the present reality of understanding and mitigating risks on critical infrastructure and potentially releasing data.

Finally, every new installation in the sewer system could potentially cause problems for the operation of the sewer. Because the new solution meant that they would be increasing

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installations in the sewage systems, this posed a potential, unknown risk to the sewage operation.

Conclusion

In order to reach the goals of the Berlin pilot in REFLOW, these pros and cons had to be thoughtfully considered while also paying mind to BWB's own interests and the protection of society as a whole.

At the heart of the decision whether to publish the data was balancing the interests of BWB and the goals of the REFLOW project. A data-driven approach was essential to transition Berlin to a circular economy, but at the same time critical infrastructure data needed to be protected. The data protection meant that there were hurdles BWB had to carefully navigate were they to release the data. Furthermore, the city of Berlin needed to cut down its emissions to become climate neutral. Similarly, BWB also had goals to become climate neutral. But was it worth it to risk Berlin's critical infrastructure to achieve these goals?

To transition Berlin towards a circular economy and for the REFLOW project to meet its goals, data on critical infrastructure was crucial. The reliance on data meant that the Wastewater Department at BWB either had to risk publishing data on critical infrastructure data or go without it, meaning that the solution of a WWHR would be hindered. Without such an app, it would be much more difficult to bridge the gap between the supply and demand of wastewater heat recovery, and the energy source would continue to go to waste. A decision had to be made by weighing the goals of the REFLOW project, the interests of BWB, and the needs of the city of Berlin.

Data was key to a climate-neutral Berlin and a circular economy, but should they risk the repercussions that might result from publishing the data? The data-driven solution would make the work easier for BWB and more efficient, but did they even have the capacity to carry out the number of projects they aimed for? Should they risk the potential threats and increased vulnerability of their infrastructure for the protection of the climate? There were no clear answers to these questions. But what was clear was that data was a key to unlocking full circular potential.

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End Notes

- https://reflowproject.eu/blog/wastewater-heat-recovery/
- https://use.metropolis.org/case-studies/climate-neutral-berlin-2050#:~:text=The%20objective%20of%20climate%20neutrality,both%20in%20comparison%20to%201990
- https://reflowproject.eu/blog/wastewater-heat-berlin/
- https://www.bsi.bund.de/EN/Topics/Industry_CI/CI/criticalinfrastructures_node.html
- https://www.cleanenergywire.org/news/heat-make-german-buildings-nearly-climate-neutral

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