Environmental Impact Assessment of Water Management: A Case study at the University of Twente Campus

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Compiled August 8, 2020

1. INTRODUCTION

The management and availability of the world's freshwater, along with the effects of human water consumption on the environment is one of the significant challenges that humans are currently facing. The earth's total freshwater reserves are about 35 million km3, being the 2.5% of the total stock of water on the Earth (Chowdhary, Bharagava, Mishra, & Khan, 2020). In other words, the freshwater reserves on earth are limiting, thus being a pressing issue for humanity's survival. The ecosystem's health and yield depend on humanity's efficiency on securing water in several sectors including delivering humanity with drinking water, food and fish, hygiene and sanitation, industrial resources, transportation and energy (UNEP 2009). Finite natural supply is increasing the competition between communities, industries and agricultural practices and nature. A great and recognized example to illustrate our human competition with nature is Central Asia's Aral Sea shrink (Chowdhary et al., 2020).

By understanding the relevance of this issue, this paper aims to explore to what degree the University of Twente's water management has a relation to the pressing issue described above. Concerning this aim, this paper will consist of a research report on the environmental impact assessment (EIA) of the University of Twente's (UT) water management. A case study of the UT campus, including a detailed description of several components of water management along with a set of methods to perform an EIA of the UT, are showcased in this research report.

2. CASE STUDY

A. Study Site

The University of Twente is located in the municipality of Enschede in the east side of the Netherlands where the province of Overijssel takes place. Although Enschede is mostly composed of rural regions, the University of Twente campus is highly urbanized. The university has in total 11,136 students and 3,150 administrative staff. The university campus occupies an area of 146 hectares where several facilities are located. There are 2575 student apartments on campus, 60 staff housing and a total of 65 buildings dedicated for educational and other purposes. Although the campus is urbanized, it also provides several green spaces including several ponds, water reserves and channels.

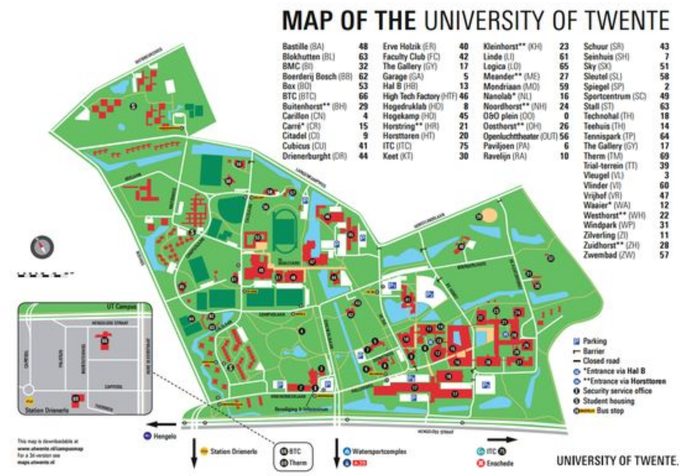

Fig. 1. Map of University of Twente Campus

B. Water supply

The water at the University of Twente is supplied by Vitens. Vitens is considered one of the biggest water supply companies in the Netherlands. High-quality drinking water is provided to 5.6 million costumers 24 hours a day and seven days a week by Vitens with a workforce of nearly 1400 employers (Vitens, 2016). Vitens' mission is to have a reliable source of high-quality and affordable drinking water to everybody in their supply area in the Netherlands as a sustainable business in a circular economy (Vitens, 2018).

Near Enschede, one of the most significant drinking water extractions is done by Vitens at van 't Klooster near Hengelo (Rijn en IJssel, 2014). The extraction in 't Klooster pumps about 4.8 million m^3 of groundwater annually. Groundwater extraction is also necessary for dry periods to irrigate the lands. In total, about 10 million m^5 of water is extracted annually, and nearly half of the groundwater is used for drinking water near Hengelo (Rijn en IJssel, 2014).

As observed by the numbers, a lot of groundwater is needed to satisfy the needs of thousands of people in the city of Enschede, including the water footprint of the University of Twente. For this reason, Vitens has also considered their impact on nature and how they can assure water availability in the future.

According to Vitens (2018), everybody should have access to clean and reliable drinking water not only today but also in one hundred years. Therefore, the protection of groundwater resources is one of the company's most important tasks. This includes maintaining healthy soil conditions and exosystem dynamics in the water extraction areas. In addition, Vitens has also set a series of values for nature management and conservation. Since the company manages 2600 hectares of land, there is a lot of work to be done. In 2016 and 2017, Vitens achieved Gold-level certification according to the Barometer for Sustainable Land Management (Barometer Duurzaam Terreinbeheer) (Vitens, 2018). Besides, the water company has several plans that intend to keep nature management sustainable with the purpose of conservation. Vitens also contributes towards achieving the Sustainable Development Goals (SDGs). The SDG's reflect the companies policy and the impact the organization wants to accomplish through its objectives (Vitens, 2018).

SDG	Vitens' contribution (including Vitens Evides International)	Link to materially important topics
6 CLEAN WATER AND SANITATION	Clean drinking water and good sanitation facilities This goal is our primary focus and our core task. In the Netherlands, we supply high-quality water at a low cost to society twenty-four hours a day and seven days a week. Internationally, we and our partners help local organisations provide clean drinking water in developing countries (VEI). We are actively involved in 46 projects in twenty countries, scattered across three different continents.	• Protection of groundwater resources. • Drinking water quality. • Drinking water delivery dependability. • Partnerships. • Nature management and conservation.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Innovative and sustainable infrastructure The infrastructure for water is an essential precondition for prosperity and well-being in our country. Each year, we invest approximately €130 million (gross) in replacing and developing our infrastructure. New technology is tested within the 'Infrastructure of the future' (Infrastructuur van de toekomst) programme. Such as our project in Friesland, where we are testing innovative technology for a data-driven infrastructure. In 2018, we also took action together with our suppliers of pipe material in order to adapt our network to the requirements of the circular economy. They have prepared raw material passports that identify the materials used in our infrastructure, in support of circular innovations.	• Drinking water delivery dependability. • Dialogue and lobbying. • Innovation. • Material flows. • Data-driven processes.
11 SUSTAINABLE CITIES AND COMMUNITIES	Sustainable cities and a sustainable living environment Water is a basic human need, and therefore an important factor in a sustainable community or city. In the Netherlands, we are actively pursuing infrastructure innovations in this field. In our international work, we are active in rapidly urbanising areas such as Nairobi and Bangladesh, where we focus on creating a balance between the living environment and water management.	• Drinking water delivery dependability. • Dialogue and lobbying. • Innovation. • Partnerships. • Nature management and conservation. • Data-driven processes.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Responsible consumption and production Vitens sustainably manages and ensures efficient use of natural resources. Our residual materials, by-products that are directly generated during the drinking water production process, are sold as a high-value raw material wherever possible. If the residual materials cannot be sold as a high-value raw material, they are put to good use. We try to reduce our production of waste as much as possible. If waste is unavoidable, we investigate how it can be recycled or utilised in some way.	• Material flows.
15 LIFE ON LAND	Repairing ecosystems and preserving biodiversity Natural processes and biodiversity provide a strong defence for our groundwater resources. Our sites are managed in accordance with the requirements of the Sustainable Land Management Certificate. We have been awarded Gold-level Sustainable Land Management certification. We actively invest in increasing our nature values and protection through nature area development to store water or create water catchment areas.	• Protection of groundwater resources. • Nature management and conservation.
17 PARTNERSHIPS FOR THE GOALS	Partnerships for our goals We collaborate with various parties in order to carry out our primary mandate. For example, we jointly participate in campaigns for a clean habitat. In support of this, we also work together with parties that share the same concerns or have the same ambition, even though they may be motivated by other interests. Such as our participation in the soil coalition with a.s.r. and Rabobank. Our shared concerns about the soil are the common factor and this activity also helps us achieve SDG 6 and SDG15. We also collaborate internationally with local water utilities in order to implement projects.	• Protection of groundwater resources. • Nature management and conservation. • Dialogue and lobbying. • Innovation. • Partnerships.

Fig. 2. Vitens Sustainable Development Goals (Vitens, 2018)

As observed from Figure 2, Vitens does take their impact on the environment seriously; however, several actions still have to be shown in practice. For example, several drinking water companies are still not consulted during the licensing procedure for mining/drilling and related activities such as water injection (Vitens, 2016). In the region of Twente specifically, Vitens was not consulted on the storage of wastewater in various sites. This caused several uncertainties in the possible consequences drinking water companies may have in the groundwater system. For this reason, Vitens proposes that provincial authorities and drinking water companies have to take the advisory role in regards to licence applications that must be registered under the Mining Act (Mijnbouwwet) (Vitens, 2016).

As described from the information above, the company that supplies water to the University of Twente has already considered several values and actions regarding environmental impact assessment. Making sure the water extraction process does not harm the environment is not only a responsibility of Vitens but also of the drinking water consumers. For this reason, it is essential for the University of Twente to inform the organization (staff, students and teachers) that the drinking water at the University of Twente campus comes from a company that invests a lot of time and money in preserving the environment and guaranteeing drinking water in the future. Of course, a lot of work and improvement still can be made in the process of extracting drinking water. However, it is a relief to observe already several sustainable initiatives and environmental impact assessments in Viten's annual reports.

C. Water Consumption

The water consumption at the University of Twente is not an easy process to calculate. This is mainly done to the number of facilities and consumption by student, teachers and staff which can be seen at the university campus. If water consumption is calculated per consumer, the process becomes even more difficult. According to the ARCADIS (2011) report, the water consumption per student/employee is not possible to be determined from the available information the university currently has. However, since housing units are critical factors of the water consumption at the university, data from the association of water supply companies VEWIN can be taken into account.

As seen in Table 1, this data is a useful way to visualize the water consumption per household. However, even though the household water consumption plays a crucial role in the overall water footprint of the university, it is still far from the precise consumption values. For this reason, the University of Twente has developed a website in which water consumption data can be visualized in clear bar graphs (UT Energy Data, 2020).

As seen from the graphs (Figure 1 & 2) the dark green bars represent the water consumption of the university facilities while the light green bars represent the water consumption of the whole campus. It is clearly seen that the water consumption of the entire campus is more significant since it also includes the households which represent a big share of the water footprint. It can also be seen from the bar graphs that water consumption is increasing per year. This may be something for the university to take into account. As the university grows, more people consume water. This can cause the university to reach a very high water footprint in the future. For this reason, reducing peoples water consumption and building more efficient ways to manage water is essential to the university.

Table 1. Water consumption at households in the Netherlands (ARCADIS, 2011)

Water Consumption (liters/inhabitants/day)	2001	2004	2007
Bath	3,7	2,8	2,5
Shower	42	43,7	49,8
Sink	5,2	5,1	5,3
Toilet flush	39,3	36	37
Washing machine	24,5	19,5	17,2
Dish washer	6	6,9	6,8
Food preparation	1,6	1,8	1,7
Drinks (cofee, tea, water)	1,5	1,6	1,8
Other	6,7	6,4	5,3
Total	131	124	128

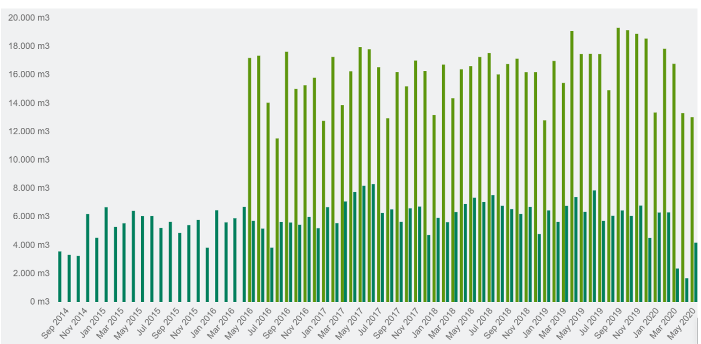

Fig. 3. Water consumption of the university facilities (light green) and campus (dark green) per month (UT Energy Data, 2020)

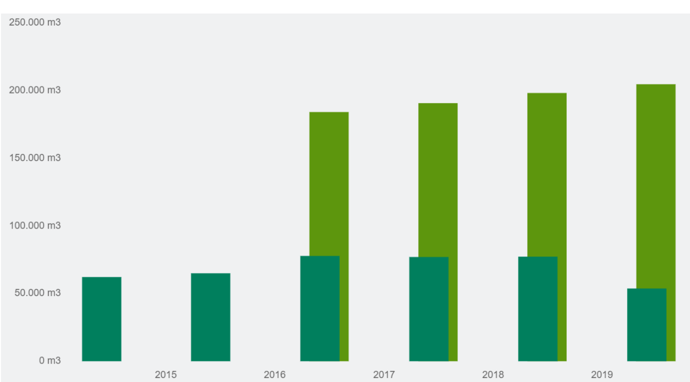

Fig. 4. Water consumption of the university facilities (light green) and campus (dark green) per year (UT Energy Data, 2020)

D. Waste Water

The wastewater treatment of the University of Twente is directly done by The Vechtstromen Water Board (UT, 2020). The University of Twente produces wastewater from different sources, including domestic use, sewage, laboratory use, commercial activities (restaurants, cafes) and also agricultural activities. The wastewater eventually passes through a pumping station located at the university campus, and it is directed to the Water Board's water treatment plant in Enschede (UT, 2020). After the water passes through the treatment plant, it is released to Kristalbad. Kiristalbad is a The area between Hengelo and Enschede and between Driene and Twekkelo. This area is responsible for two large water discharges from both the cities of Enschede and Hengelo. The Vechtstromen Water Board also monitors the wastewater at the UT. The procedure consists of quarterly monitoring of samples from the University of Twente's pumping station, which are then tested in the laboratory (UT, 2020). Finally, a specific fee is charged at the UT depending on the number of pollution units recorded in the wastewater. The pollution units are based on a variety of data which is recorded from the wastewater samples such as the concentration levels of heavy metals and oxygen-binding substances in the wastewater (UT, 2020). Since the fee charged to the University of Twente is dependant on the number of pollutants released, there are several procedures which take place. A good example is the strict procedures which are applied in every laboratory at the university campus. A concrete example is the cleaning procedure of the used glassware in the laboratories. Three rinses with a small amount of water are required since it reduces water wastage, and it allows a more effective cleaning. The water with high levels of chemical concentration from the material rinsed for a second time is then collected and disposed of as hazardous waste. In this way, only the water from the third rinse of the glassware can be flushed down the sewer (UT, 2020).

According to the ARCADIS (2011) report, the University of Twente has envisioned more cost-efficient and less impactful management of the wastewater purification. The plan describes a decentralized wastewater purification system which would reuse the wastewater within the campus vicinity. The main idea is to have a closed water chain on campus that would be able to reduce treatment costs of wastewater up to 30 to 50% (ARCADIS, 2011). However, there are two main constraints to this project which have also been considered and limited the implementation process. In the first place, changing to decentralized wastewater treatment, or in other words, disconnecting from the existing purification capacity can lead to understaffing, thus increasing the treatment charge (ARCADIS, 2011). In the second place, a closed wastewater system would entail a disconnection of rainwater from the wastewater, and a separation of black and grey water is necessary. This would imply additional cost to the university and infrastructural limitations which might not be worth going through (ARCADIS, 2011).

E. Rainwater & Sewage System

The hydrological cycle plays a pivotal role in the water distribution system at the University of Twente. A significant part of the rainwater, which falls on the campus area ends up in the sewer and eventually passes through the treatment plant (ARCADIS, 2011). Another part of the rainwater goes directly to the ponds located in the campus vicinities. Rainwater reaches the ponds through two main processes. In the first place, there is a lot of rainwater that directly falls into the ponds serving as natural water storage. Secondly, most of the water that falls into the facilities buildings eventually end up in the ponds via drain-pipes (UT, 2020). In summary, the rainwater at the University of Twente has a strong connection to the sewage system and the water storage in the campus ponds.

Considering the current situation regarding rainwater on campus, ARCADIS (2011) have considered as part of their plans to make the water management at the UT more sustainable and cost-efficient an innovative way to utilize the rainwater on campus. By disconnecting the rainwater from the sewage system, there is less wastewater from campus grounds to be transported to the water treatment plant. This would also imply that the pumping station will need a renovation with fewer pumps since the rainwater is excluded from the process (ARCADIS, 2011). In addition, currently, most of the buildings at the University of Twente use drinking water to flush the toilets. ARCADIS (2011) proposes a new solution by utilizing rainwater, grey water or possibly process water to flush the toilets. This has already been tested and put into practice by the university in the Technohal facilities (UT, 2020). The drinking water consumption is already significant at the university, especially the high-quality water demands of certain laboratories such as the laser laboratory. For this reason, making use of rainwater for flushing the toilets would entail a large amount of savings not only economically but also in relation to drinking water (ARCADIS, 2011). However, as mentioned in the previous section, using grey water, rainwater and / or surface water for flushing the toilet would require an extra distribution system, thus increasing the infrastructural costs.

Apart from the interconnection between rainwater and the sewage system, ARCADIS (2011) has also considered a heat exchange mechanism of the sewer. By installing a heat exchanger integrated with the sewage pipe system, there are opportunities to save residual heat from the sewer. This heat exchange method is created by a technological innovation denominated as PKS-Thermpipe. The PKS-Thermpipe saves thermal energy from various sewage output factors (volume and temperature of sewage, filling level in canal, etc.) and from the surrounding soil of the pipeline zone for the purpose of energy supply (FRANK, 2016). This means that the entire environment involving the pipelines is used for heat exchange with several energy benefits to the overall sewage system. Taking this into account, rebuilding the current sewage system could also entail the addition of PKS-Thermpipe as a way to save energy and costs.

Fig. 5. PKS-Thermpipe (FRANK, 2016)

F. Rainwater Storage

As mentioned in the previous section, a significant amount of rainwater is stored in the ponds of the university campus. In addition to the ponds, rainwater is also stored in a large basin 10 metres deep and 36 metres wide that holds 10 million litres of cold water in front of the Horst building at the university campus. This water is treated by means of a helophyte filter to prevent deposits and corrosion (UT, 2020). Helophyte filters, also known as planted soil filters, are reed beds in which macrophytes grow and produce bacteria in the roots of the plant that can treat the surrounding water (Nanninga, 2011). The plants are located behind the Horst building in two fields which are covered in gravel, sand and anti-root foil. The macrophytesfiltrate the water and leave the necessary nutrients for the plants. After the water is treated, it is used for a cold circulation system. Ten million litres of cold water is used to cool the building and research equipment, saving a significant amount of energy and costs.

In addition to the Helophyte filters and the cold circulation system, the university campus has also installed water storage under the Facility Club Park. This water storage system consists of a buffer infiltration system with a hollow space under the car park of the Faculty Club (UT, 2020). The infiltration is made by permeable stones with small spaces in between them to allow the necessary water flow and infiltration capacity. This allows the water retention to last for more extended periods of time, thus infiltrating into the soil more slowly. Consequently, it contributes to the water-robust design of public space, and it is also possible to respond to the prevention of heat stress and drying of the subsurface (AquaBASE, 2020).

Apart from the innovative water storage methods, there is an installation placed in the Hogekampplein denominated as the Waterlab, which is being put into use to treat rainwater and store it. A lot of research is in progress into water purification methods with membranes of water storage for irrigation purposes on campus. Since a lot of water is needed for the sports fields in the university campus, replacing the current use of tap water would provide a lot of savings. In addition, precipitation intensity is increasing and putting at risk the capacity of the existing sewage system. For this reason, being able to collect rainwater with innovative and useful methods will definitely improve the water management at the University of Twente.

3. ENVIRONMENTAL IMPACT ASSESSMENT

This section of the paper aims to showcase a series of methods that can be used to develop a complete environmental impact assessment of the water management at the University of Twente. As a research report, this paper has considered several papers in order to figure out a methodology for an in-depth environmental impact assessment. Three essential components can help measure the impact the water management at the University of Twente has on the environment: sustainability framework, water footprint calculation, water-energy nexus and life cycle assessment.

A. Sustainability Framework

The first step is constructing a sustainability framework that can quantitatively and qualitatively assess the water management at the UT. This is a fundamental step since it helps to construct the necessary base for the rest of the environmental impact assessment. Hellström, Jeppsson, & Kärrman (2000) have developed a framework for systems analysis of sustainable urban water management. The paper describes a framework with a set of sustainability criteria for urban water and wastewater systems. The criteria can be divided into five main categories:

1. Health and hygiene criteria
2. Social-cultural criteria
3. Environmental criteria
4. Economic criteria
5. Functional and technical criteria

Each criteria inside the categories enumerated above are connected to a series of measurable indicators. This can be better exemplified in the following Table 2:

Table 2. Environmental criteria with indicators (Hellström, Jeppsson, & Kärrman, 2000)

Criterion	Indicator
Environmental criteria	
Groundwater preservation Eutrophication	Groundwater level N to water (kg/p, year)
	P to water (g/p, year)
	OCP* (kg O2/p, year)d
Contribution to acidificationc	H+-eqv. (mol/p, year)
Contribution to global warmingc	CO2-eqv. (kg/p, year)
Spreading of toxic compounds to water	Cd, Hg, Cu, Pb (g/p, year)
Spreading of toxic compounds to arable soile	Cd, Hg, Cu, Pb (g/p, year)
Use of natural resources	Utilization of available landf (m2/p)
	Use of electricity and fossil fuels (MJ/p, year)
	Total energy consumptiong (MJ/p, year)
	Use of fresh water (m3/p, year)
	Use of chemicals: Fe, Al (kg/p, year)
	Use of materials for
	construction of
	infrastructure (m pipe/p)
	Potential recycling of
	phosphorush (g/p, year)

As observed, the table shows a series of indicators for each environmental criteria. Therefore, research can be devoted to the process of data collection at the University of Twente for these indicators. In addition, the research also includes the indicators for the other criteria categories mentioned above, which also serves as a research framework.

B. Water Footprint

The second step towards completing an environmental impact assessment is calculating the water footprint of the University of Twente. As seen from the water consumption section, there is already data provided for the consumption of water of the facilities on campus. However, a precise footprint calculation is needed for a more in-depth environmental impact assessment.

The water footprint assessment manual developed by Hoekstra, Chapagain, Mekonnen, Aldaya (2011) describes the necessary methodological steps to calculate the water footprint, which can be applied to the University of Twente. In the first place, there needs to be a distinction between three essential water footprints: blue, green and grey water footprint. The blue water footprint is an indicator of the consumptive use of fresh surface or groundwater. The blue water footprint measures the water availability in a certain period of time that it is consumed or not returned to the catchment or ground (Hoekstra et al, 2011). In addition, the collection of rainwater that would become run-off is also considered as blue water. Taking this into account, two sources of blue water can be identified within the consumption of the University of Twente. In the first place, the rainwater which is harvested from the rooftops, hard surfaces and ponds is categorized as blue water consumption. Secondly, the university uses drinking water which is extracted from groundwater by Vitens. This is also a clear example of blue water consumption. Similarly, green water consumption is also related to the water retained from precipitation. Green water refers to the precipitation on land that does not run off or recharge as groundwater but is stored in the soil, or it temporally stays on top of the ground or vegetation (Hoekstra et al., 2011). This water becomes productive for plant growth since it is eventually evaporated or transpired through the plants. Therefore, green water can be particularly important for the vegetation at the University of Twente. By measuring the amount of water that the plants and trees consume, the university can have a better idea of the productivity and health of the campus vegetation. Finally, the grey water footprint is an indicator of the degree of freshwater pollution generated. It is recognized that the size of water pollution can be defined as the volume of water needed to dilute pollutants such that they become harmless (Hoekstra et al., 2011). As mentioned in the wastewater section, this is already being measured by the Vechtstromen Water Board. Samples are being taken regularly to measure the number of pollutants that the wastewater at the university produces. This is a very important process which could be made open for the students, teachers and staff of the university to know what quantity and kind of pollutants they produce as consumers.

Apart from identifying and calculating the blue, green and grey water footprints, it is also important to understand the amount of water the university demands as a group of consumers. For this reason, the water footprint manual also describes how to calculate the water footprint of a group of consumers. According to Hoekstra et al. (2011), the water footprint of a group of consumers is defined as the total volume of freshwater consumed and polluted for the production of goods and services used by a consumer. Taking this definition into account, it can be understood that the calculation of the water footprint of the university as a group of consumers can be a very complex process. This is mainly do to the reason that the people at the UT vary a lot on their consumption behaviour, and there are many possibilities and variables that can be taken into account. Even though, this process requires a high level of complexity it shouldn't be discarded as a possible research topic since there is a lot to learn from the water consumption behaviour of the people at the University of Twente.

C. Water Energy Nexus & Life Cycle Assessment

As seen from the previous section, the water footprint of the UT is essential to understand the consumption and pollution patterns of freshwater at the university campus. Even though the blue, green, grey and group of consumers water footprint is essential, the environmental impact assessment is incomplete without two major analysis: water-energy nexus and life cycle assessment. This section aims to showcase to studies executed at other universities which have considered life cycle and water-energy nexus in their environmental impact assessment.

Gu, Wang, Robinson, Wang, Wu, Li, & Li (2018) have made a case study at Keel University in the UK as an example of green campus assessment. The study identifies a research gap in the sustainability assessment of university campuses. Most of the efforts in literature are devoted to single areas such as waste management causing a lack of integrated efforts. For this reason, the study determines a food-water-energy nexus to establish a comprehensive evaluation system and green campus methodology. For this research report, the water-energy nexus very relevant since it proposes a new dimension to the sustainability assessment of water consumption. For the water-energy nexus, not only the water needed to produce energy is considered but also the energy needed to produce and treat the freshwater at the university campus. In addition to this, the CO2 releases are also considered for the energy process involving water.

Bhakar, Sihag, Gieschen, Andrew, Herrmann, & Sangwan, (2015) also analyze the water supply, its consumption, recycling and related energy consumption at a university campus in India. The environmental impact assessment has been quantitatively determined by conducting a life cycle assessment using computer software such as Umberto NXT and ReCiPe. With this life cycle assessment, the study was able to determine which consumption of water at the university had more impact on the environment. In other words, collected data of water supply, demand and energy consumed was evaluated and visualized as an analysis of the environmental effects of the water supply system.

As observed from both studies, there are existing methods that are able to quantitatively assess the impact the water management at the University of Twente has on the environment. For this reason, this paper encourages future studies that are able to calculate and conduct this life cycle assessment and water-energy nexus research since it could give several benefits to a more sustainable implementation of a new water supply system at the university campus.

4. EVALUATION & CONCLUSION

By considering water security and the impact that urban water management has on the environment, this research report aimed to relate this pressing issue with the University of Twente as a case study. The paper has described several components of the water management at the UT, including water supply, water consumption, wastewater, rainwater & sewage system and finally rainwater storage. In each component, the university has shown to be very actively studying possibilities to make the water management more sustainable by reducing its impact on the environment. Although the UT has implemented and considered several solutions and plans to become more sustainable in managing water, an EIA is still needed for a more precise conclusion. For this reason, this research report also has provided theoretical steps to achieve a precise EIA of the water management at the UT. This paper is only a stepping stone towards a complete improvement of a sustainable water management at the UT campus.

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