

Master Thesis

in the Master's Degree Program: Sustainable Water Management & Engineering

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Master of Engineering (M. Eng.)

Topic

**The Future of Sustainable Building: Potential Analysis of Green Buildings from a
Water Management Perspective exemplified by KSB SE & Co. KGaA**

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Abstract

Buildings are as diverse as people themselves. As a result, it has become difficult to keep track of the technologically possible measures. But climate change is advancing and those who do not adapt to this change will have a hard time in the future. The goal is to investigate Green Buildings and identify possibilities for KSB to adapt to the future.

The research topic is as follows: "The Future of Sustainable Building: Potential Analysis of Green Buildings from a Water Management Perspective exemplified by KSB SE & Co. KGaA." The research topic was approached in two ways. Firstly, a literature search was carried out on existing green buildings. Secondly, KSB internal and KSB external experts were interviewed to assess the future situation. In this way, potentials for KSB in the area of green building were identified. The potentials were subsequently evaluated using the Priority Model of Sustainability. For this purpose, beneficial attributes were named for the respective dimension of sustainability and the respective potential. The attributes are used for potential analysis and were all worth one point in each dimension. The point scale starts at 0 (if a potential in a particular dimension does not offer any namable advantages) and ends at a maximum score of 10.

The results suggest that increased digitalization of the company's own products will bring great opportunities in the future. In addition, the results and research show that in the future the focus will be much more on the natural handling of rainwater. Similar to the increase in interest in rainwater management, there are opportunities for OEM partnership with urban greening companies.

Continued engagement in these matters will be the way forward.

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1. Introduction

1.1. Initial situation

Climate change and the energy crisis are accelerating the need for building to become more ecological. In addition to the development of climate-neutral building materials and processes and low to energy-neutral energy use, buildings must also be designed to be climate resilient. According to the author, the center of sustainable and climate-resilient buildings will be a well-planned water management system, which, in addition to internal water reuse, must also address how to deal with heavy rainfall and periods of drought, both on the building envelope and on the wider property. In the context of internal water reuse, gray and black water, for example, are important sources of energy and raw materials. The projects "SPORE" (Sponge Region Obe4rranken) (University of Applied Sciences 17.06.2022), "BodenRadar" (Soil as Water Storage) and "Der Weg zur Schwammstadt - Stadtentwicklung in Zeiten des Klimawandels" (The Way to a Sponge City - Urban Development in Times of Climate Change) by the Water Infrastructure and Digitization Research Group at Hof University of Applied Sciences demonstrate the diversity and complexity of future urban and therefore building development, with the element of water playing a central role. It is not only a matter of removing excess water during heavy rainfall events without causing damage, but also of identifying and technically implementing options for precautionary water storage to reduce drinking water consumption. From current research results, it can already be deduced that climate-smart water management of Green Buildings can be realized neither sustainably nor future-proof without intelligent water distribution. Therefore, intelligent distribution technologies including pumps will increasingly become the focus of higher-level water management solutions.

It is not only energy and water efficiency that need to be considered, for example, the construction and operation of buildings worldwide accounts for

- 17 % of water consumption,
- 25 % of wood consumption,
- 33% of CO2 emissions,
- 30-40 % of energy and
- 40-50 % of raw material consumption.

In Germany, the building sector accounts for up to 40 % of primary energy consumption and a significant proportion of drinking water consumption. (Bauer et al. 2013, S. 6)

This means a high commitment of resources because the average lifespan of new and refurbished buildings is around 50 to 80 years. This means that these buildings will have a significant impact on energy and resource consumption in the near to medium term. For this reason, these buildings must already be planned, constructed, refurbished and operated today in a targeted manner under energy- and resource-efficient as well as climate-friendly premises. In order to achieve the globally and nationally formulated climate protection goals, new buildings and existing buildings are assigned an important part to play. (Bauer et al. 2013, S. 6)

That is why the European Commission is planning to make renovation of old buildings mandatory. In this way, the building stock in the European Union is to become climate-neutral by 2050. The EU Commission has presented a draft revision of the Energy Performance of Buildings Directive (EPBD). It states that new buildings are to be built as "zero-emission buildings" from as early as 2030. Public buildings are to be built in this way as early as 2027. The renovation obligation was also planned for existing buildings. In this wave of renovation, residential buildings will have to be renovated if they are among the 15% of the existing stock with the worst energy performance. These are to reach a higher standard in stages by the years 2030 and 2033. For non-residential buildings such as offices, schools and hospitals, the regulations will apply earlier. (Bayrische Staatsregierung 23.11.2022)

1.2. Focus and Goal

Green Building is a trend that KSB has identified as relevant for the Building Services and Water/Waste Water Sectors. The aim of this work is to identify any potential for future business development for KSB at the interface of these two market areas. The focus will be on current and future technological developments around the topic of green building. A potential analysis is to be developed. Actual example projects will be included in order to highlight the entire water cycle from a holistic perspective (inside and outside the building). The focus of the analysis will be from the point of view of a pump manufacturer and will answer the question, which systems or which type of pump will be needed today and in the future (~ 10 years).

1.3. Company Introduction

KSB is a leading supplier of pumps, valves and related services. The highly efficient and reliable products are used wherever liquid media needs to be transported or shut off. The product range is divided into the following market segments shown in **Figure 1**.

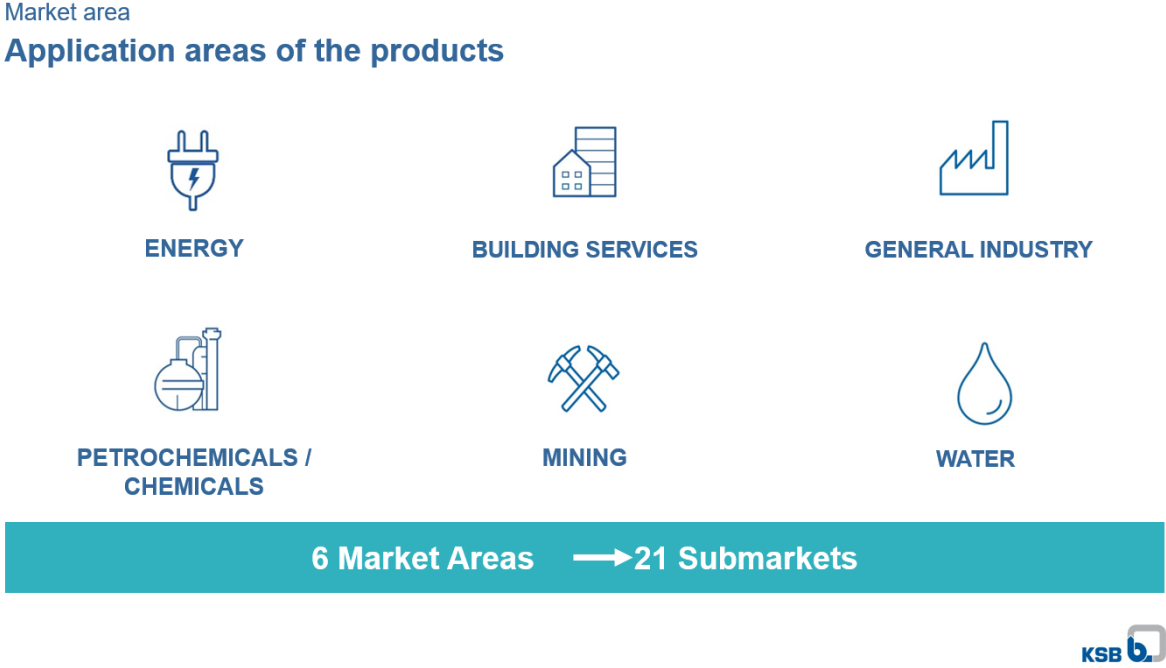


Figure 1 Market Area KSB SE & Co. KGaA (KSB SE & Co. KGaA 2021)

Founded in Frankenthal (Germany) in 1871, the company is represented on all continents by its own sales companies and manufacturing facilities. (**Figure 2**)

Global Presence



Figure 2 Global Presence KSB SE & Co. KGaA (dow-nachhaltigkeitsmagazin-data)

Over 150 years, KSB has only managed to grow so large by constantly adapting to the situation. (KSB SE & Co. KGaA 2021)

In order to be properly prepared today for tomorrow, trends are an important indicator.

KSB Trends of the Future

In the last sustainability magazine, KSB identified and named four trends. Trends influence and define the future fields of action of companies.

1. Increasing energy consumption
- 2 Energy and resource efficiency
3. Drinking water shortage
4. Circular economy

KSB has a strong focus on research and development and works closely with customers and industry partners to develop innovative solutions that meet market needs. The company prides itself on its comprehensive quality and environmental management systems and its commitment to sustainability and social responsibility.

Sustainability

When it comes to sustainability, KSB is broadly positioned. Companies contribute to a sustainable future through sustainable management and the responsible use of resources. These are KSB's sustainability efforts:

- 3 pillars of sustainability are implemented
- Follows the principles of the International Labour Organization and the United Nations Global Compact
- Supports the 17 Sustainable Development Goals of the United Nations
- natural resources and energy are used efficiently
- The energy efficiency of our products is continuously increased
- Respects the rules of free competition
- comprehensive sustainability management
 - Quality management system ISO 9001
 - Environmental management system ISO 14001
 - Occupational health and safety management system ISO 45001
 - Guideline for the social responsibility of organizations ISO 26000

KSB acts in accordance with the ten universal principles of the UN Global Compact.

The ten universal principles of the UN Global Compact are also firmly anchored in KSB's DNA and, alongside the 17 sustainability goals, form the basis for responsible action.

The Global Compact principles include:

- Human rights: companies should protect international human rights
- Labour standards: Companies should, among other things, stand up against forced and child labour as well as discrimination and ensure freedom of association.

- Environmental protection: Companies should act in the interests of the environment and promote environmentally friendly technologies.
- Anti-corruption: Businesses should work against corruption in all its forms. (Michalik R. 2023)

In summary, KSB SE & Co. KGaA is a leading supplier of pump and system solutions based on an unmatched history, a strong customer focus and a commitment to research and development. The company is a trusted partner for customers worldwide who require high-quality and reliable solutions for their applications.

2. Green Building – State of the Art in Water Management Science and Technology

In green building, the term water management mainly refers to its distribution and use. In water management, sustainable collection, multiple use of the same water, and a minimum amount of wastewater produced are important.

The current state regarding water management in most buildings is still thought and built in a very linear way, which in most cases makes it impossible to use it in a circular sustainable and resource saving way.

Energetic processes/flows can be found in every building, but they are linear. These linear energetic processes/flows are driven by classical and physical quantities such as heat, cold, electricity and water. The best way to explain these linear energetic processes/flows is to use a metaphor. Imagine a straight pipe that is open at both ends and represents any energetic flow in a building. Because no matter what people do in a building, whether food, whether liquids or whole rooms are heated or kept cool, the operation of electrical equipment, and so on. All this requires energy in the form of heat, cold, electricity or requires water that transports thermal energy or is slightly to heavily contaminated during usage. So if an empty straight pipe with two open ends represents the current state of our energetic processes in all buildings. Then the types of energy flowing in these energetic flows are our medium in the pipe.

In order to enable the residents to use everything according to their needs, this energy must also be available, and therefore there must be no outages during simultaneous use. This is symbolized by our filling level in the pipe.

In order to keep a straight pipe full, we always pump something in at one end that flows out at the other. Everything that flows out of the pipe in this metaphor is symbolizing our wastewater and our waste and our pollutions that we have added to the natural cycle. There is only one way to maintain a continuous filling level in such a structure, and that is by always pushing in new medium - in this case energy.

Looking at a building, many of these energetic processes are linear, in other words open, which means that at the end of the day, important things are lost at the end of our imaginary pipe. In the following chapters, such open energetic processes/flows are shown in order to provide know-how of what they actually are and that they can already be closed today.

But how can one close such a drain? Here is a small example. Imagine that a person is taking a shower. The water consumption depends on the water flow and the duration of the shower. Conventional shower heads consume about 12 to 15 liters per minute. In a worst-case scenario, where the person takes a shower for about 10 minutes and leaves the water running, 150 liters of water will flow through a non-water-saving standard shower head.. (co2online gemeinnützige Beratungsgesellschaft mbH 2018) If we now consider the fact that people do not shower with cold water, but with a temperature close to body temperature (approx. 37 °C) or higher, and that this water ends up in the sewage system in the shortest possible time, a large amount of heat energy is lost here. This is a prime example of a linear and open energetic process/flow that must be closed to form a circle.

The response of the technical side and the market to this and similar problems will be discussed in the following chapter. The author focuses on findings that are useful to KSB SE & Co. KGaA.

2.1. Historical development

The concepts of green buildings and sustainability in the construction industry have gained prominence in recent decades. This is in response to growing concerns about the environmental impact of building construction and use, and the need to improve energy and resource efficiency in the construction industry.

The historical development of green buildings can be divided into several key milestones:

1. 1970s: The oil crisis and growing environmental awareness (first “Earth Day”) led to increased interest in energy-efficient buildings and alternative energy sources. (Dannenmann T. 2023) (Yudelson J. 2023)
2. 1980s and 1990s: In the 1980s, the concept of green buildings was introduced in Europe and gained wider acceptance in the architectural and building world.
3. 2000s: The popularity of green buildings and sustainability grew, and the first certification systems such as LEED, BREEAM and Green Star emerged. These systems defined green building criteria and helped standardize and benchmark green buildings worldwide.
4. 2010 to present: Green buildings have become an integral part of the construction industry and are being built in urban and rural areas around the world. Governments and corporations are championing green building, providing financial incentives and regulations to improve energy and resource efficiency.

The historical development of green buildings indicates a growing need to make the construction and use of buildings more sustainable and energy efficient. It remains to be seen what progress will be made in the future, but it is certain that green buildings will continue to play an important role in improving the environmental impact of the construction industry.

2.2. Definition

This chapter defines the term green building. Buildings today can be very diverse and versatile, they can be 3D printed (Hous3Druck UG), they exist as prefabricated houses, as Tiny Houses (Mager J. 2022) or even foldable (Tiramani G. 2023). This is precisely why the author sees every green building of the future - for the moment irrelevant whether it is a new building or a renovated existing building - will be a **customized batch size 1 solution**. These buildings will have to be configured to suit the particular conditions on site and their purpose / use / building type. The climatic constraints for developing, designing and building are outdoor air temperature and humidity, solar radiation, wind speed and the variation between day and night and between seasons. The amount of precipitation has an influence especially on the shape of the roof. (Bauer et al. 2013, S. 67)

Green buildings can be:

- low-energy buildings
- zero-energy buildings or
- plus-energy buildings.

They combine a high level of comfort, optimum quality of utilization and minimized energy and resource requirements under economic conditions. (Bauer et al. 2013, S. 7)

The primary energy demand of buildings is made up of the individual demand values for heating, heated drinking water, cooling, ventilation and lighting and indicates the amount of energy purchased from the energy supplier, e.g., oil, natural gas, wood, electricity, etc. (Bauer et al. 2013, S. 53)

Countries such as Germany, the UK, the USA, Australia, and Japan have already started to define important assessment aspects. These are numerous, as shown in **Table 1**, and address the phases of the life cycle: design, construction and operation. The following table shows the various certification criteria of the different international certification organizations.

System (Country of origin)	DGNB (Germany)	BREEAM (United Kingdom)	LEED (USA)	Green Star (Australia)	CASBEE (Japan)
Since:	2007	1990	1998	2003	2001
important evaluation aspects and versions	Ecological quality Economic quality Socio-cultural quality Technical quality Process quality Location quality DGNB for: <ul style="list-style-type: none"> • Office building • Existing building • Retail • Industry • Portfolios • Schools 	Management Health and comfort Energy Water Material Site ecology Pollution Transportation Land consumption BREEAM for: <ul style="list-style-type: none"> • Courthouse • Ecological Houses • Education • Industry • Healthcare • Multi-family houses • Office buildings • Prison • Retail 	Sustainable locations Water Efficiency Energy & Atmosphere Material & Resources Indoor Air Quality Innovation & Design LEED for: <ul style="list-style-type: none"> • New buildings • Existing buildings • commercial interior design • shell and partial construction • neighborhood development • schools • Retail 	Management Living comfort Energy Transportation Water Material Land consumption & ecology Emissions Innovations Green Star for: <ul style="list-style-type: none"> • Office building - existing building • Office building - interior • Office building - design 	Certification based on building to environment efficiency ratio Q ... Quality (Ecological quality of the building) Q1- Interior Q2- Operation Q3- Environment L ... Loadings (Effects on the environment) L1- Energy L2- Resources L3- Material Main criteria: 1 Energy efficiency 2 Handling of resources 3 Building environment 4 Interior
Certification levels	Bronze Silver Gold	Passed good very good excellent outstanding	LEED Certified LEED Bronze LEED Silver LEED Gold	4 Stars "Best Practice" 5 Stars "Australian Excellence" 6 Stars "World Leadership"	C (bad) B B+ A S (excellent)

Table 1 Overview of certification systems (Bauer et al. 2013, S. 15)

Buildings can achieve different levels of quality in different countries. The importance of water in the future is great in view of the impending climatic changes, rising energy prices and population growth. Other common assessment factors for green building are energy and resource consumption during construction, operation, demolition and the specific conditions at the building's location.

From examining the literature on certifications, there is not much difference between the certification organizations. From an interview with Mr. Gerhard Hauber (Executive Partner at Henning Larsen) it appears that there are differences in the implementation of the requirements between the certification types of the countries. For further information on this interview, please also see **3.3. Consultation of External Experts**. In the end, they all more or less follow the "Three Pillars of Sustainability" model. Therefore, a comparison between a LEED and a Green Star certified building or any other comparison - would be much easier - if all countries followed the three pillars model more in their structure.

The evaluation aspects are divided into main categories in all evaluation systems. Each of these aspects is followed by one or more benchmarks. These must be implemented correctly in order to receive points in this category. After all benchmarks have been verified, depending on the evaluation system, either all points are first weighted and summed or first summed and then weighted to obtain a final result. This result is then used to determine the level of certification achieved. (Bauer et al. 2013, S. 16)

These rating systems are, according to the author a good structure that allows to benchmark buildings and pave the way for green buildings. But it should not mean that only new buildings can be green buildings. Because it is about all buildings. Talking about green buildings, one can't forget about existing buildings and except for the British BREEAM certification, this type of building is specifically mentioned everywhere.

The renovation of existing buildings is so important because Germany's building stock is to become almost climate-neutral by 2050. Maria Krautzberger, President of the Federal Environment Agency commented on this as follows: "The sooner we start to refurbish our houses for energy efficiency and supply them with renewable energies, the more cost-effective it will be - for us and for the climate." (Umweltbundesamt)

However, because green buildings are built with life-cycle engineering in mind, they are able to save resources throughout their life, from design to demolition and partial reuse of the building's materials. This is a key advantage of newly built green buildings compared to retrofitted buildings.

This also includes the trends of Circular Buildings, Design of Disassembly and Climate-resilient Architecture.

Green buildings are *customized batch size 1 solutions* that are designed and constructed using environmentally friendly technologies and materials to ensure sustainable and resource-efficient use. These buildings have lower energy consumption, better energy efficiency, improved indoor air quality, and reduced environmental impact.

Systems such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and DGNB (German Sustainable Building Council) are used to evaluate and certify green buildings. These systems evaluate factors such as energy efficiency, renewable energy, water and waste management, sustainable building materials and building automation.

Technologies and solutions used in green buildings include energy efficiency, renewable energy, water management, sustainable building materials, building automation, green roofs and walls, efficient air conditioning, waste management, ventilation systems, monitoring and measurement, and electromobility. These technologies help reduce energy consumption and CO₂ emissions and create a healthier and greener living environment.

2.3. State of the art in science and technology

There are already solutions on the market that offer an answer for all types of buildings through a smart symbiosis of different technologies such as wastewater flap, filters, heat sensors and heat pumps, for example. Through the use of such solutions, open linear energetic processes/flows can become closed energetic cycles. In the following chapters the author presents an overview of the available technologies and knowledge that can already be used in buildings to close linear energy processes/flows. Furthermore, the current situation in existing buildings is shown.

2.3.1. Potable Water

Clean drinking water is one of the most important resources for humans. The average consumption in Germany was approx. 127 liters per day and person in 2021. The development of per capita consumption of drinking water in **Figure 3** indicates a trend of increased consumption since the years 2010 and 2011.

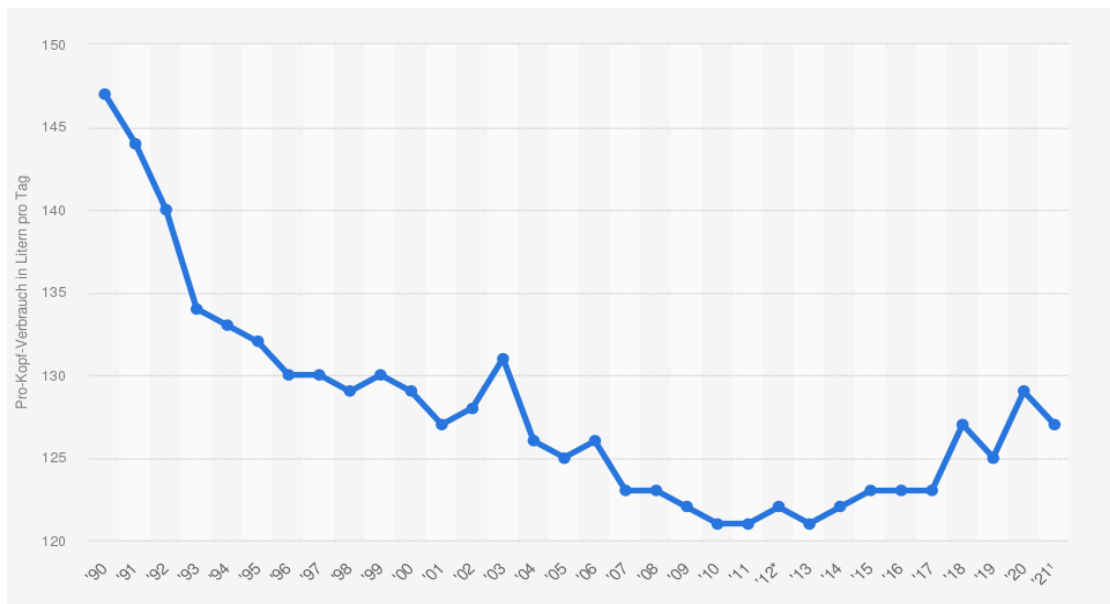


Figure 3 Development of water consumption per person and day in Germany from 1990 to 2021 (Statista 2022)

However, of these 127 liters per day, the very smallest proportion is used for drinking. **Figure 4** shows the percentage breakdown by type of use in the household. Particularly because the proportion used exclusively for drinking is so small (5%), it is essential to save as much water as possible in all other applications.

Distribution of Water Consumption - Household -

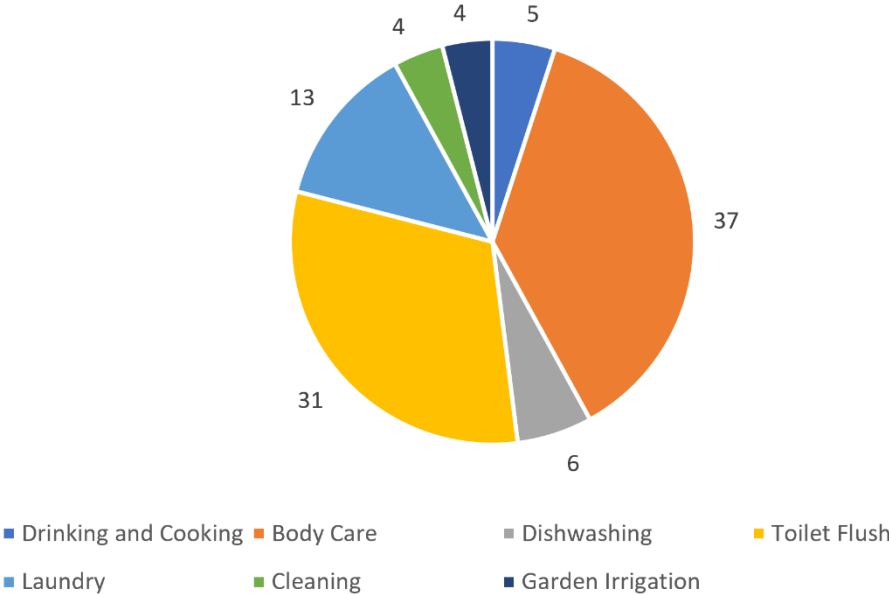


Figure 4 Distribution of Water Consumption (adapted from (Bauer et al. 2013, S. 62))

Depending on the type of building, more or less drinking water is needed. The main consumers of drinking water are households, small commercial areas and industry. (Bauer et al. 2013, S. 62)

Other large consumers can be seen in **Figure 5**, for example, hospitals are the number one water consumer with 200 liters per person per day.

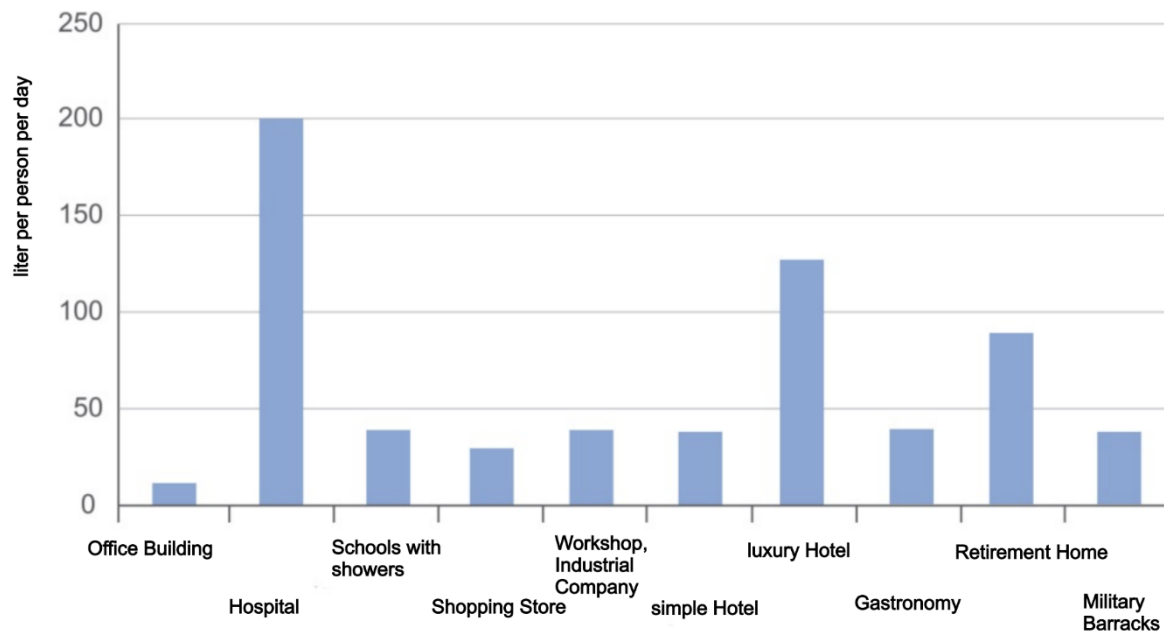


Figure 5 Demand Values for Drinking Water per Area of Use (Bauer et al. 2013, S. 55)

In the area of drinking water, there has been no increase in the efficiency of systems or processes in recent years. While heating energy requirements for retrofits and new buildings have been steadily reduced through improved thermal insulation and energy-efficient systems engineering, energy requirements for heating drinking water have remained unchanged. In buildings insulated to current standards, this energy requirement can even account for 20% of the total heating energy requirement. In residential and hotel buildings, as well as for kitchens, solar thermal systems, water-saving fittings, waste heat recovery, and circulation circuits for warm water with time and temperature controls are therefore the obvious choice to achieve savings.

The issue of drinking water and its heating is not of great importance in office buildings. Especially in offices without the possibility of showering, the heating energy consumption is manageable at up to 5%. This means that heated drinking water can usually be completely eliminated from most areas of the office building. (Bauer et al. 2013, S. 55)

Measures are necessary to avoid Legionella in drinking water. Legionellae are gram-negative, non-spore-forming aerobic bacteria belonging to the family Legionellaceae, genus Legionella. Currently, there are approximately 48 known species, which in turn comprise 70 different serogroups. All Legionella are classified as potentially human pathogenic. This means that they can cause diseases in

the human organism. The most significant species for human diseases is *Legionella pneumophila*, which is responsible for about 90% of all diseases. (Fleischer J. 2022)

The bacteria can multiply inside cells - especially in water in free-living amoebae - but also in human macrophages and are therefore considered intracellular parasites. *Legionella* can also survive in cold water but do not multiply significantly. Their ideal growth conditions are between 25°C and 45°C. Above a temperature of 55°C, growth is effectively inhibited and above 60°C the bacteria finally die.. (Robert Koch-Institut 2019)

Since *Legionella* cannot multiply significantly in cold water, the author does not see any danger in supplying an office building purely with cold water.

2.3.2. Rainwater

Rainwater is an important part of the water cycle and provides certain eco-services. Rainwater is responsible for refilling bodies of water, infiltration of rainwater raises the groundwater level, and it is the basis of life for animals and plants. People also use rainwater by collecting it over their roofs and storing it in tanks. When designing such a rainwater utilization system, the water yield from precipitation and the water demand are important parameters. The water yield depends on the local precipitation conditions and the water demand on the intended use. For example, for the irrigation of lawns and park areas, about 60 liters per m² per year is estimated and for a cultivated garden about 20 liters per m² per week. For use in one- and two-family houses, the Bavarian State Office for Environment estimates a quantity of 800 to 1000 liters per person. The technical requirements for the construction and operation of a rainwater utilization system are described in the standards DIN 1989, parts 1 to 4.

From this standard, the Bavarian State Office for Environment has derived and published a few important rules for rainwater harvesting:

- Use only roof runoff water from low-polluted roofs
- Fine filtering of the water before the storage tank
- Install the water storage tank in a cool and dark place
- Provide controlled water flow in the storage tank:
 - calmed inflow
 - withdrawal just below the surface or at least 10 cm above the ground
 - allow easy discharge of floating material
- If possible, allow overflow from the storage tank to infiltrate on site
- Use durable, corrosion-resistant and environmentally friendly materials
- Prevent connection between drinking water and rainwater network reliably
- Clearly mark all pipes and withdrawal points and secure them if necessary
- Report facility to county administrative agency and water supplier.

(Bayerisches Landesamt für Umwelt 2021)

The cost of the storage tank, piping, filters and pumps ranges from 2,500 to 5,000 euros, depending on the size of the tank. (Umweltbundesamt)

The payback period for a multi-person household is already more than 10 years in Germany, without taking interest effects into account. Such systems are not a desirable investment in rich countries where access to clean drinking water is available to the broad mass of the population and does not represent a major cost factor.

Depending on the type of collection areas and the type of service water use, more advanced treatment of the stored water may be required.

Further treatment steps are required if

- Roofs are heavily polluted, for example on busy roads,
- Water is collected from uncoated copper, zinc and lead roofs
- Rainwater comes from grass and bitumen roofs (can color the water)

(Bayerisches Landesamt für Umwelt 2021)

The following processes are basically applicable in the context of advanced treatment of rainwater:

- Flocculation
- flocculation filtration
- flotation
- biological processes
- advanced filtration
- disinfection
- membrane processes

The suitability of the respective processes must be checked on a case-by-case basis and they must be individually planned, constructed and operated in accordance with the rules of technology. (S. 13)

Today, rainwater can already be used in a variety of ways. For example, rainwater can be used to water the garden, to clean the house or to flush the toilet. As shown in the previous CHAPTER in FIGURE, especially the amount of drinking water that is flushed down the toilet is enormous. In the commercial and public sector, the proportion saved by rainwater - according to LfU Bavaria - can be far greater.

When using rainwater for flushing toilets, there is no risk of infection and double piping is usually not necessary, as the rainwater storage tank is refilled with drinking water during long dry periods. (Umweltbundesamt)

There are advantages and disadvantages in using rainwater for washing clothes. For instance, the use of rainwater has an ecological advantage, as the soft rainwater can save around 20% in washing powder. However, there are hygienic concerns that, although germs are largely killed by the high temperatures and the detergent, germs could be transferred to the laundry again during the subsequent flushing processes with cold water. This applies in particular to people whose immune system is not normally developed (small children, old and/or sick people). This risk can be eliminated by subsequent ironing of the laundry or suitable treatment. (Umweltbundesamt)

Many suitable treatment systems can be found on the market. In order to minimize the risk of microbial contamination, ultrafiltration and/or irradiation with ultraviolet light as described in CHAPTER 1 is mandatory. The ultrafiltration measure must be applied before the water is stored in a

cistern. Subsequent irradiation with UV light can ensure that the cistern remains permanently free of bacteria and viruses.

2.3.3. Wastewater

The subject of wastewater is divided into the two streams of graywater and blackwater.

According to ISO 6107-7:1997, blackwater in urban water management is domestic wastewater without graywater containing fecal solids. Accordingly, black water is the wastewater from toilets (Umweltbundesamt)

Graywater is the wastewater in the household that comes from bathtubs, showers, washing machines and sinks. This is defined in the European standard 12056-1. In the worksheet DWA-M 277 from the German Association for Water, Wastewater and Waste (DWA), graywater is divided into following categories for better handling. (Umweltbundesamt)

Type A: lightly polluted graywater, which means graywater without kitchen and washing machine drainage.

- Type A1: gray water from bathtub and shower
- Type A2: gray water from bathtub, shower and sink

Type B: heavily polluted graywater, which means graywater with kitchen and/or washing machine drainage

- Type B1: gray water from bathtub, shower, sink and washing machine
- Type B2: graywater from bathtub, shower, sink and washing machine and/or from the kitchen

(Bresser M. 2020)

This categorization is based on the degree of pollution of the wastewater. The degree of pollution increases from A1 to B2.

Since the largest share of graywater comes from the personal hygiene sector, the average temperature of graywater from baths and showers is 31°C. (Bresser M. 2020)

The daily volume of gray water is therefore around 60 liters per person per day. In times of increasing electricity and raw material costs, this results in a great potential for heat recovery and multiple use of the same water.

The second major advantage of graywater is that this water can be used several times. This is possible by treating it into service water and using it for toilet flushing, irrigation or cleaning purposes. Once treated, the graywater is hygienically safe and can be used a second or third time, but it is not of drinking water quality.

The treatment of graywater usually takes place in a biological, a mechanical process and a photocathalytic process. The suspended particles are filtered out with a filter and the water is then purified in an aerobic-biological stage and disinfected by UV radiation. Such systems are already commercially available. For Green Buildings, the application of water-saving measures is assumed for uses with increased water demand.

The smallest plants have a minimum daily filtration capacity of 200 l/d. These systems generally use A2 and B1 graywater types for water supply, i.e., co-treatment of kitchen wastewater is reserved for the larger systems in multi-family buildings due to the more complex technology and larger space requirements. The smallest treatment quantity of 200 l/d for the plants shows that in a 2-person household this quantity is not reached. (Bresser M. 2020)

Due to the fact that such treatment plants function like a small wastewater treatment plant, they rely on a steady inflow of graywater. This is related to the biological treatment stage of these units. Since the microorganisms in the second stage feed on the compounds in the graywater and thereby remove the unwanted substances, these would be killed off if the inflow were too low. This would cause the cleaning effect of the second stage to come to a standstill.

Therefore, it can be concluded that the treatment of gray water is only really profitable for buildings with a higher density of inhabitants. For buildings with few inhabitants, it is more advantageous to

replace drinking water with rainwater. If a treatment plant is nevertheless desired, graywater must be accumulated in an additional tank until a sufficient quantity is available to provide a continuous inflow.

This finding is supported by many practical examples. In 1997, for example, an alternative drainage concept was implemented in the "Flintenbreite" housing development project in Lübeck for approx. 350 inhabitants. In this example, vacuum toilets and pipes, with a biogas plant and decentralized graywater treatment, were implemented and have been operated ever since. A profitability analysis under general conditions of 2005 showed a profitability beginning at approx. 150-200 persons. (Bresser M. 2020)

Another example is a new student dormitory built in 2008 in the Freiburg district of Vauban, where a graywater recycling system with heat recovery was installed for 65 students. This resulted over time in a saving of 30 kWh per day, which corresponds to about 20% of the energy required for hot water preparation. (Bresser M. 2020)

If we consider only heat recuperation in addition to the treatment of graywater to process water, manufacturers such as Revincus already offer heat recovery solutions with integrated heat storage. These systems can be implemented with little effort in new and existing buildings, regardless of the type of drainage system.

Thanks to its integrated heat storage, this system can be used in single and multi-family homes, hotels, restaurants, industry and marine applications, as no continuous inflow is required. Existing heating systems and building services are supported by a revincus system, the energy efficiency of the building is improved and it saves extra costs. Whether hot wastewater from showering, washing hands or from the dishwasher and washing machine - the thermal energy contained in the wastewater has so far been discharged unused into the sewage system.

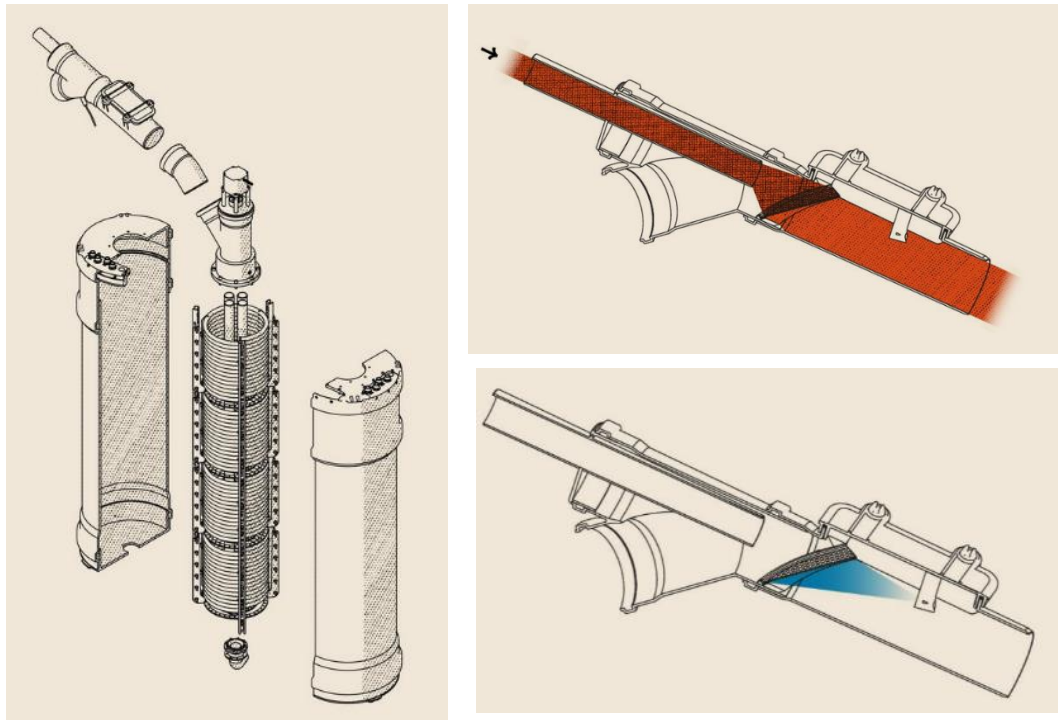


Figure 6 Revincus System Part1 (Revincus GmbH 2022)

In the explosion drawing on the left in **Figure 6** you can see the individual components. These are responsible for the pretreatment of the graywater, the analysis of the temperature, the storage and the recovery of the thermal energy.

In the first step, top right in **Figure 6**, the gray water (e.g., from a shower) is cleaned of suspended solids (e.g., hair) by a back flushable filter unit. The integrated backflushing system, shown at the bottom right in **Figure 6**, enables regular cleaning of the filter and low-maintenance operation.

After pre-filtering, the temperature of the gray water is measured by the system and compared with the temperature zones of the gray water already present in the storage tank (**Figure 7**, left). An algorithm then finds the most efficient temperature zone of the storage tank into which to stratify the graywater. After pretreatment and analysis, the distribution system then directs the graywater to the temperature zone of the storage tank predetermined by the algorithm.

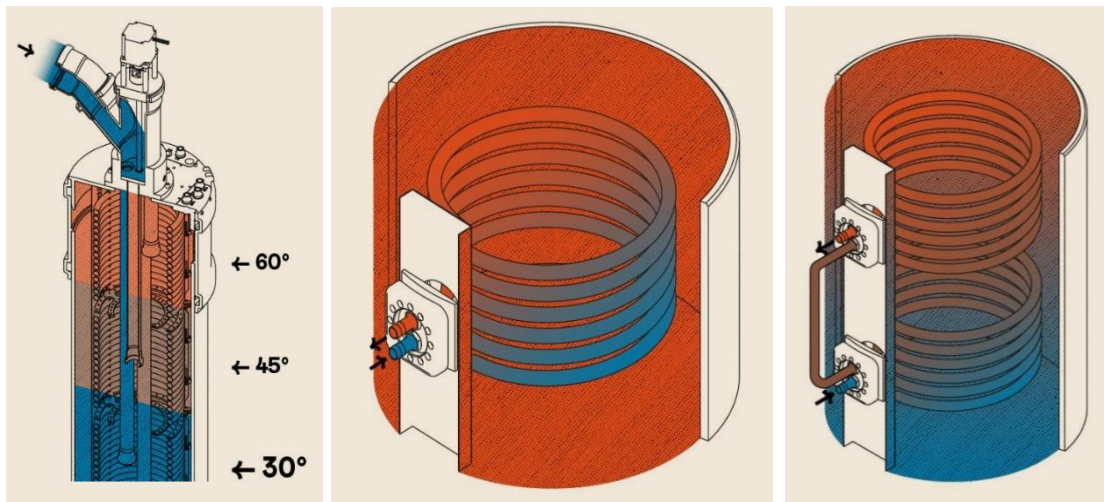


Figure 7 Revincus System Part2 (Revincus GmbH 2022)

Via the heat exchanger spirals in **Figure 7** middle, the extraction of the heat energy from the gray water begins. With this design, it is possible to pass different media, such as drinking or heating water, through the spirals and preheat them. Each zone of the storage tank contains at least one heat exchanger spiral (**Figure 7** on the right), which can be controlled individually and combined with spirals of different temperature zones. This makes it possible to control a flexible heat transfer of different temperatures to a liquid medium as required. (Polster 2022)

This system therefore solves a previous problem. This is because other systems that offer heat recuperation must also transfer this heat directly to a consumer. By efficiently introducing the water into the different temperature zones, almost all the heat energy can be recovered, and a long-term preservation and storage of the temperature level can be guaranteed. Through these technical extensions, it is possible to close and make the energetic recuperation circuits smaller and smaller.

Not only does gray water still contain valuable resources - such as thermal energy - that need to be recovered, but black water also conceals potential. Among the ingredients of black water are nitrogen, phosphorus, carbon compounds and potassium. (Knerr H. 2012). The first two are indispensable fertilizers and are already recoverable and reusable from urine. Like graywater, this is also divided into subcategories.

Black water is to be distinguished:

- Brown water: feces with rinsing water
 - feces: defecation, solid human excrements
 - Rinsing water
- Yellow water: urine with flushing water
 - Urine: liquid human excrements
 - Flushing water

The yellow water is what matters here. Important raw materials can already be recovered from it today. Alongside potassium and nitrogen, phosphate is one of the most important nutrients in agriculture. Phosphate is essential for plant growth and cannot be replaced by any other substance. For the production of phosphate fertilizers, the mineral phosphate is mined from rock. Deposits of phosphate-bearing rock are found in Morocco, Western Sahara, China, Jordan and South Africa. Mining causes environmental and social problems. Mining often releases heavy metals such as cadmium or radioactive uranium. The labor situation of the local people is an additional complicating factor. (Killiches F. 2013)

Graywater represents the least polluted sub-stream, but in terms of volume it takes up the major share of domestic wastewater. Urine, on the other hand, which makes up only about 1 % of the total domestic wastewater, contains the largest proportion of nitrogen, phosphorus and potassium.. (Knerr H. 2012)

The company Vuna GmbH has developed a mobile treatment plant that converts urine into liquid fertilizer and distilled water. The plant can recycle 70 liters of fertilizer and 930 liters of water from 1000 liters of urine within two to three days. This water could be treated to drinking water quality through further purification stages, but this is not practical. The water coming from the plant can be used to irrigate and fertilize an area of 2000 square meters.. (Vuna GmbH 2022)

The gray and black water are currently discharged into the sewer system via a combined system or a separate system. In **Figure 8** it can be seen that 40% of the sewer network in Germany is a combined system.

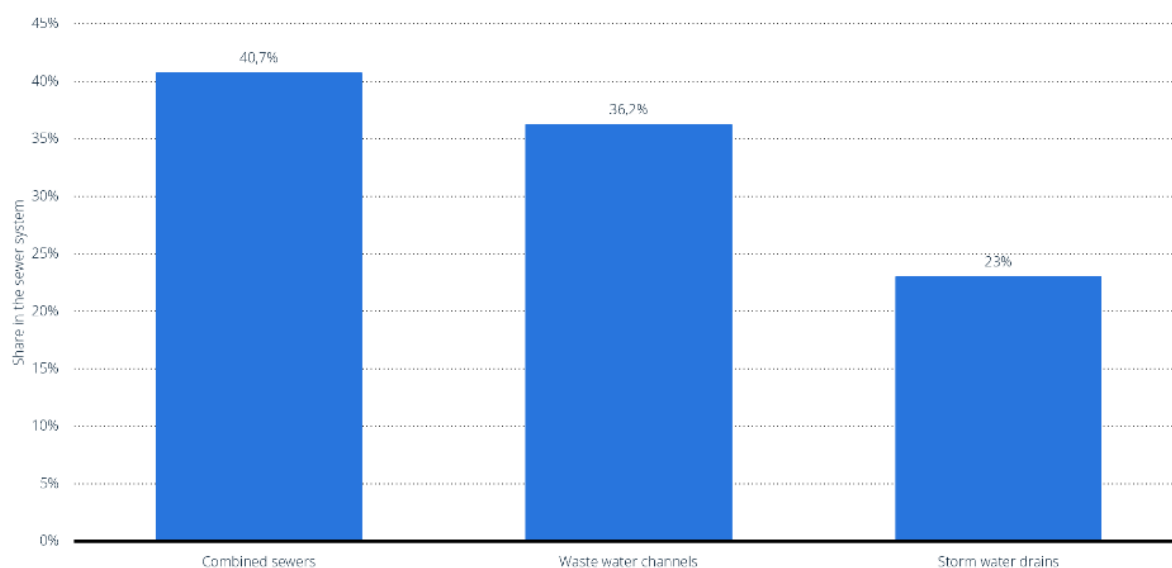


Figure 8 Structure of the sewer network in Germany by sewer type in 2019 (Statista 2022b)

A combined sewer system has mostly grown historically and can therefore be found in older settlements. Here, there is only one sewer system that drains all wastewater. In this system, wastewater from domestic sewage, industrial and commercial wastewater, and street sewage, such as rainwater, are discharged together as combined sewage in a single sewer system. In dry weather, the cross-section of the sewer system is only slightly utilized and is only filled during heavy rainfall. In such cases, therefore, combined sewer overflows are built which, above a critical rainfall intensity, discharge the untreated combined sewer water back into nature.

In a separation system, on the other hand, wastewater and rainwater are discharged in separate sewers. Here, the wastewater is transported in a pipe with a small diameter. This is buried deeper than the rainwater pipes in order to be able to drain cellars as well. Because these pipes historically also have to carry drainage water and drain garage driveways, for example, a surcharge of 100% is typically added to the maximum dry weather flow. The larger diameter storm drains at higher elevations receive roof water, street water, runoff seepage, and possibly stream water. This is usually released directly to nature sometimes via detention basins and stormwater clarifiers (Gujer W. 2006, S. 238)

In addition to the sewer system, the separation of material flows is already technically feasible at a smaller level (micro level) in the household. The basic principle of the novel sanitation systems - NASS - is the recovery and recycling of valuable materials from the wastewater. The most effective way to achieve this is to separate the types of wastewaters at the point of origin and to collect them before they are mixed. This offers the possibility of closing the water and material cycles to a large extent.

According to the "Investigation of the Use of Green and Blue Infrastructure at the Quartier Level and its Impact on Stormwater Management," NASS can not only compete with conventional drainage structures, but be better when environmental and social criteria are considered. (Bresser M. 2020)

2.3.4. Cooling and Heating

Currently, natural gas is still the most widely used heating energy source in Germany. Half (49.5%) of all existing buildings are heated with natural gas. The share of heating oil in existing buildings amounts to 24.8% in 2021. In existing buildings, the third-largest sector, at just under 15%, is district heating, of which almost 40% is also generated from natural gas (Figure 9) (Löffelholz J. 2020) (Statista 2022)

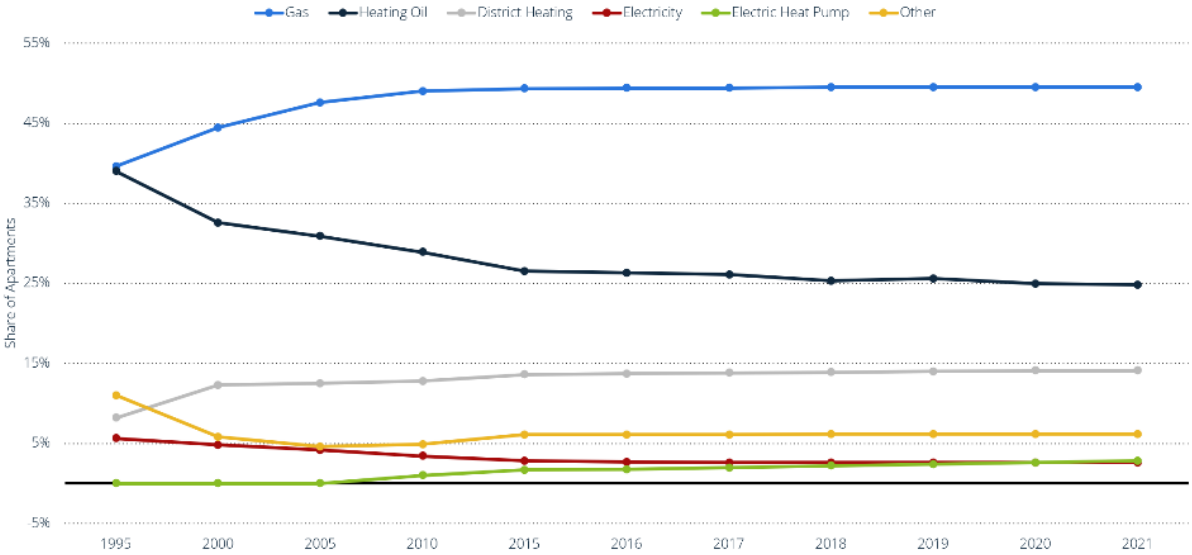


Figure 9 Heating Structure of the Housing Stock in Germany in the Years 1995 to 2021 (Statista 2022c)

If you compare this area with the heating structure in new residential buildings in Germany, you can see that people's willingness to use natural gas in the future is falling continuously. These developments are only being reinforced by the war in eastern Europe. **Figure 10** shows a trend reversal in the heating structure in new residential buildings since 2020. In that year, for the first time, more heat pumps were installed for heating than natural gas heating systems. This increase in the usage of heat pumps is noticeable again in 2021. In 2021, 22.7% of new buildings were still connected to district heating. At 0.3%, heating oil no longer plays a role in heating.

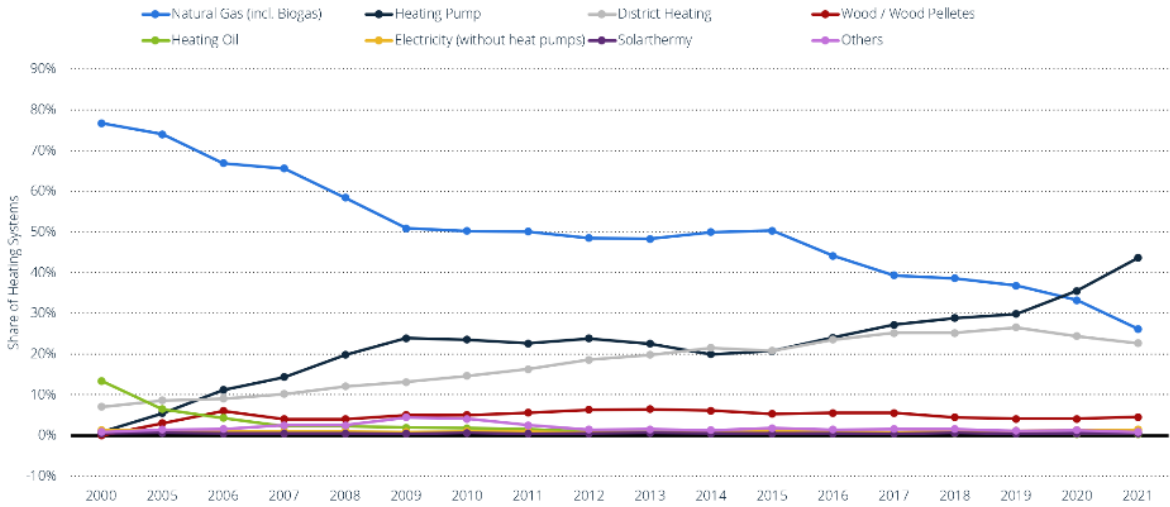


Figure 10 Heating Structure in New Residential Construction in Germany in the Years 2000 to 2021 (Statista 2022b)

Gas heating systems benefit most in urban areas. Here, they have the potential for rapid greenhouse gas reduction **if** they therefore **replace** petroleum heating. This circumstance is favored by the fact that, especially in the urban stock, a conversion to heat pumps, for example, is often associated with high effort. In addition, today's modern gas heating systems can be operated proportionally or 100% with green gases, e.g. biomethane. (Löffelholz J. 2020)

The technical status of green buildings built all over the world today already shows a big difference to the majority of all existing buildings. For newly built green buildings, this difference to the existing buildings of today is the biggest, therefore the retrofit buildings are even more important to reduce

this gap of technical potentials and possible savings. As mentioned at the beginning of this paper, newly built green buildings are a new class of buildings.

Therefore, when it comes to heating and cooling, it is important,

- how the building is originally placed,
- the perceived and actual temperature in interiors must be simulated beforehand,
- how and above all how much light and therefore heat enters the building at which time of year influences the size and number of windows and their insulating capacity,
- pollutants in the outside air must be tested, as these carry micropollutants from traffic and exhaust gases into the building, for example.

These and more topics, such as why building shape and orientation are important and how the building envelope contributes to thermal insulation and what building tightness has to do with this, can be read in the guide "Green Building - Guide to Sustainable Construction".

In the following, relevant ways to heat, cool and ventilate newly built green buildings are shown from this guide.

Due to the climatic conditions in Central Europe and in most industrialized countries, heating is required in almost all buildings in this region.

Care should be taken to ensure that internal heat sources, such as computers or entire servers, and passive solar energy use contribute as much as possible to warming the rooms, but do not overheat them. The way heat has been transferred to the room so far is crucial to save energy. This process is called heat delivery, because the heat produced by the heating system is delivered to the room, or more precisely, to the air in the room. Inadequacies and inefficiencies in the delivery of heat are taken into account by an increase in energy consumption in the day-to-day operation of the system. (Bauer et al. 2013, S. 112)

The focus of heating has changed as a result of continuous improvements in thermal insulation. Previously, the focus was on the available heating capacity; now, on the other hand, it is primarily a matter of providing heat as close to demand as possible. This means that heat is delivered locally and at the right time to meet usage requirements. To achieve this, the space heating systems, including

the room control equipment, must be able to react quickly and should have the lowest possible inertia. (Bauer et al. 2013, S. 112)

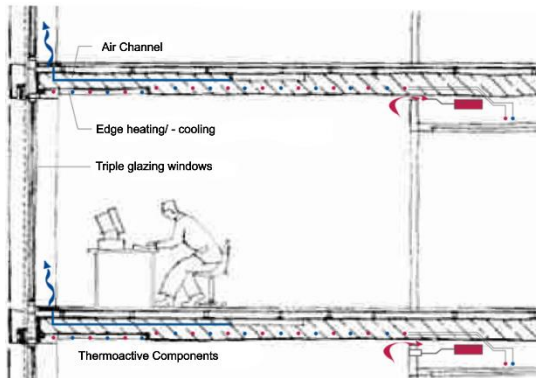
It is important that heating systems are operated at low temperatures. This can positively influence the control capability. Energy consumption for distribution can be significantly reduced due to the lower heat output of the pipes to their environment, and low heating temperatures are always perceived as very comfortable. (Bauer et al. 2013, S. 112)

For cooling systems, the larger the heat-transferring surface, the more the operating temperature can be selected close to the room temperature. Such systems are called high-temperature cooling systems, whereby cooling temperatures of approx. 18 to 20 °C are sufficient for office use. These relatively high operating temperatures allow regenerative energy systems to be optimally integrated. Especially in cooling, the outdoor climate can also be used for a resource-saving combination. (Bauer et al. 2013, S. 113)

With the Building Energy Act (Gebäudeenergiegesetz GEG), the minimum U-value requirement for new windows is 1.3 W/(m²K). From a value of 0.8 W/(m²K) and smaller, a window may even be called a passive house window. The U-value is the heat transfer coefficient for windows, front doors or balcony doors. The U-value is given in the unit W/(m²K), in other words watts per square meter and kelvin, and expresses the energy loss of the respective surface. The lower the U-value, the lower the heat loss in winter and the lower the heat transmission in summer. (Kögel A. 2018)

Thermo-activated elements

How space heating systems with a demand-based transfer of benefits can look like is shown in **Figure 11** based on the office building of the VHV Group in Hannover Germany.



- Facade with a triple glazing
- highly insulated panel as external sun protection (U-value of 0.7 W/m² K)
- The room heating system consists of a thermally activated ceiling for the base load
- and edge strip temperature control elements as heating ceilings with room controllers for the peak load (Bauer et al. 2013, S. 112)

Figure 11 Office building VHV Hannover by BKSP, architects, room climatic system section with edge strip tempering element (Bauer et al. 2013, S. 112)

The maximum flow temperature for the thermally activated ceiling is 28 °C in the heating mode and 35 °C for the edge strip temperature control elements. The combination of a base load system as a thermally activated ceiling and a peak load system as an edge-strip temperature control element ensures a demand-oriented utility transfer. The inertial thermally activated ceiling is controlled so that the surface temperature of the ceiling is a maximum of 2 to 3 Kelvin above the room air temperature. The edge strip temperature control elements are controlled discontinuously via the room regulators and are thus able to use short-term heat sources for heating purposes and to avoid overheating of the rooms. In addition, each user or user group in the open-plan room has an individual intervention option via the room thermostats and can set their own comfort temperature. (Bauer et al. 2013, S. 112)

Night Setback

In addition to the local specification of the temperature, the users also make temporal demands on the room conditions. One of the best-known time specifications is the night setback, where a lower room temperature is required at night. In office buildings this is mostly done for energy saving reasons, in residential buildings it is done for comfort reasons, e.g. to achieve a cooler sleeping temperature.. (Bauer et al. 2013, S. 112)

Cooling is provided either by cooled air or cooled surfaces in the room. The transfer of benefits from room cooling systems is the same as for heating systems, with the difference that the heat flow is reversed. Since water has a higher heat capacity than air, the energy required for cooling or heating with water is significantly lower. (Bauer et al. 2013, S. 113) In Green Buildings, care should be taken to ensure that functions such as "cooling" and "ventilation" are treated separately in the first step. In the best scenario, the water used should be rainwater in order to achieve an even greater effect on the environment and costs.

Because cooling requires a great amount of energy, attention must be paid as early as the planning phase to minimizing the amount of cooling energy required through structural measures and thus reducing the use of machinery to a minimum. (Bauer et al. 2013, S. 113)

If you want to reduce the room temperature in Europe by 1 Kelvin, the cooling energy requirement increases by approx. 10%. Due to different climate zones in Europe, this results in a difference of +/- 15%. While in Northern Europe there is a significant cooling energy demand only with high internal heat sources, in Southern Europe this demand is almost three times higher than in Central Europe. This means the further it gets towards the warm south, the more energy is required for cooling.

Figure 12 shows this using the cooling energy requirements in % of three locations in Europe. (Bauer et al. 2013, S. 57)

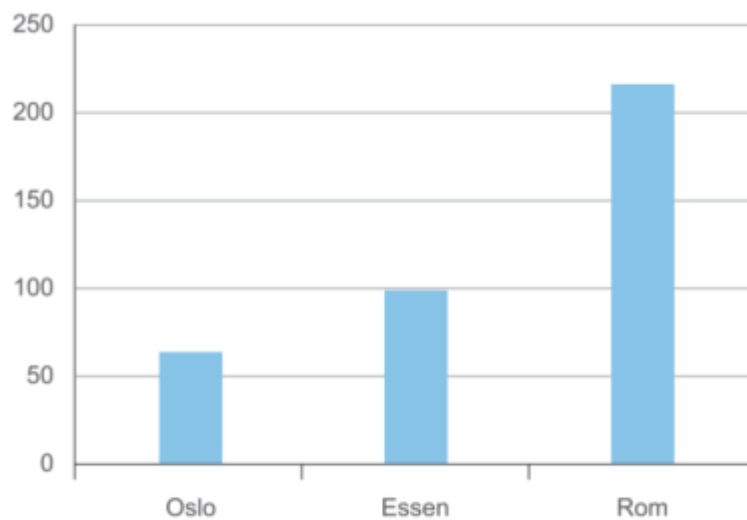


Figure 12 Cooling energy consumption at three locations in Europe

Therefore, the cooling effort depends on the solar radiation, the size, transparency and tightness of the facade and the internal heat sources.

Wind Tower

A well-known example of climate-adaptive building, where people take advantage of their environment to cool their buildings, is the wind tower in **Figure 13**. Wind towers originated in the Arab and Persian regions and are designed to direct cool air currents into the building's interior to cool it down and allow warmer air currents to flow over the building, depending on the direction of the wind. Since the tower is open on all sides at the top, it is able to direct cool air from all wind directions into the spaces below. At the same time, it also functions as a chimney, as warm air from the rooms below flows out over the leeward side of the tower due to the pressure difference.

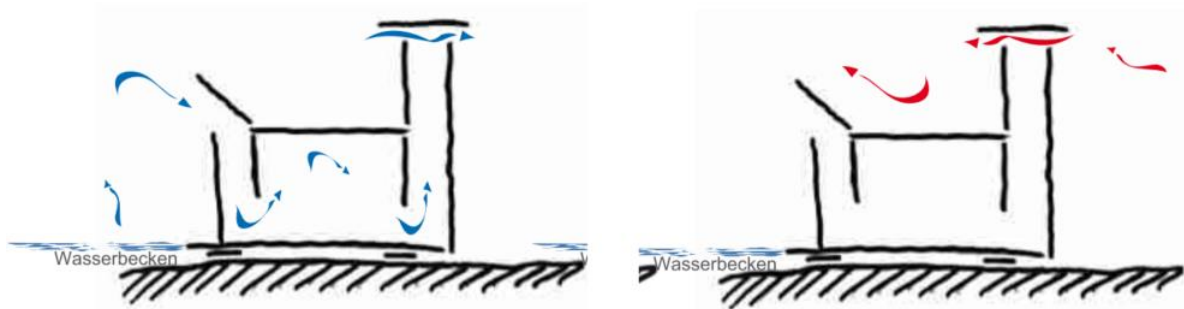


Figure 13 Wind Tower

In **Figure 13**, the function of the tower in cool air flows is shown on the left, with the wind being directed into the structure through an opening. Additional cooling is provided by a water surface in front of the building. The right side shows how the warm outside air is directed over the building and therefore does not enter the interior. (Bauer et al. 2013, S. 68)

Adiabatic Cooling

Adiabatic cooling makes use of the evaporative energy for cooling, which is required to convert water from the liquid to the gaseous state. Cooling is achieved either directly by fogging evaporators, which inject the cool water directly into the area that is to be cooled, or indirectly - **Figure 14** - by humidifying exhaust air in central ventilation systems and then transferring the cold to the supply air.. (Bürger V. et al. 2017)

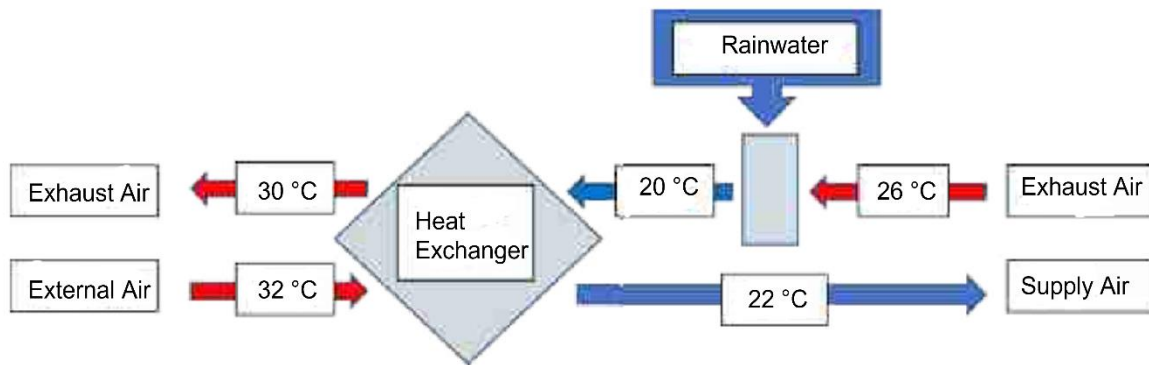


Figure 14 Mode of Operation of Adiabatic Cooling adapted from (Lagus GmbH 2017)

In the indirect variant from **Figure 14**, water is sprayed into the exhaust air before it leaves the building. The evaporative cooling pre-cools the supply air via a heat exchanger. Ideally, this system is operated with previously collected rainwater. Rainwater has the enormous advantage that it has a low conductivity due to its low water hardness. This eliminates the need for water softening, which would otherwise probably be required, when operating with rainwater. (Lagus GmbH 2017)

Geothermy

Rainwater can also be used in building services for cooling without evaporation. In addition to the classic geothermal use, heat is transferred to the ground via underground rain storage tanks. The heat can also be recovered from the rain storage tank and used for surface heating via a heat pump. (Lagus GmbH 2017)

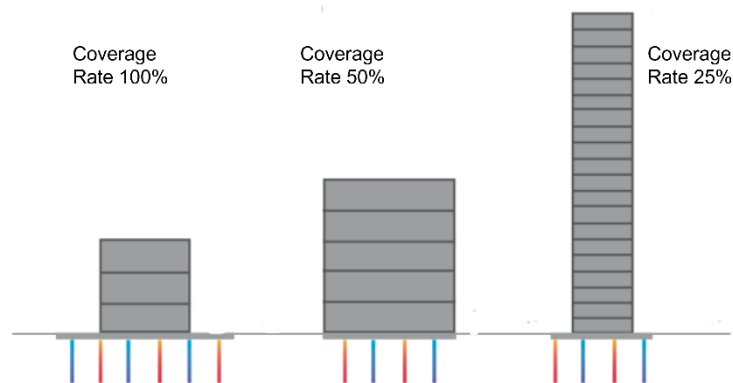


Figure 15 Potentials of geothermal energy use for different ratios of property area and building cubature. The potential share of geothermal energy for heating and cooling in buildings is shown. Adapted from (Bauer et al. 2013, S. 69)

In the case of classical geothermal energy, it should be noted that the integration of near-surface geothermal systems up to a depth of 200 m is only effective if sufficient land area is available for the placement of ground heat exchangers of various types. In this context, the number of floors in residential buildings, as shown in **Figure 15**, should be in the range of 3 to a maximum of 5. For office buildings, values of 3 to a maximum of 6 levels are desired. It shows how with increasing number of floors and therefore increasing number of users, the coverage rate of the geothermal system decreases. (Bauer et al. 2013, S. 70)

Ventilate

When it comes to ventilation, the simplest way is to open a window. Wind, pressure and temperature differences create air flow. However, natural ventilation always has priority, as long as the quality and temperature of the outside air, the outside noise and the type of use allow it. If natural ventilation is not possible, mechanical ventilation must be used. This then filters, heats, cools, humidifies and dehumidifies the outside air. It is important to recover as much as possible from the exhaust air by using suitable systems. And therefore both heating and cooling energy requirements can be reduced.. (Bauer et al. 2013, S. 57)

For mechanical ventilation, electrical energy is required and therefore the desired air volume reaches the rooms. The power requirement depends on

- the level of outdoor air exchange,
- the usage and therefore the required air treatment stages in the ventilation and air-conditioning system,
- the size and length of the duct system (high air velocities cause high pressure losses),
- the outdoor climate (partial shutdown in favor of natural ventilation)
- and the selected ventilation system (centralized, semi centralized or decentralized ventilation). (Bauer et al. 2013, S. 57)

Since water can transport many times as much heat as air for the same amount of energy, in energy-efficient buildings the transport of air is limited to the required quantity and its hygiene, which depends on the quality of the outside air, the density of people and the emissions of the building materials.

2.3.5. Green Roof

Roof areas account for 30-50% of sealed urban surfaces, but remain largely unused in many cities. (Brune M. et al. 2017) In this chapter, a possibility of reasonable use of the roof area is presented.

Many cities have been affected by climate change in recent years. Due to overheating and heavy precipitation, for example, green roofs are now increasingly in the focus of attention. Many cities are therefore giving green roofs a high priority as part of their climate change adaptation plans. The targeted expansion of green infrastructure on urban roofs is therefore seen by many municipalities as an important component of future-oriented urban planning. (Bundesverband GebäudeGrün e.V. (BuGG) 2021)

Generally, green roofs are divided into extensive and intensive green roofs, as seen in Figure 16.

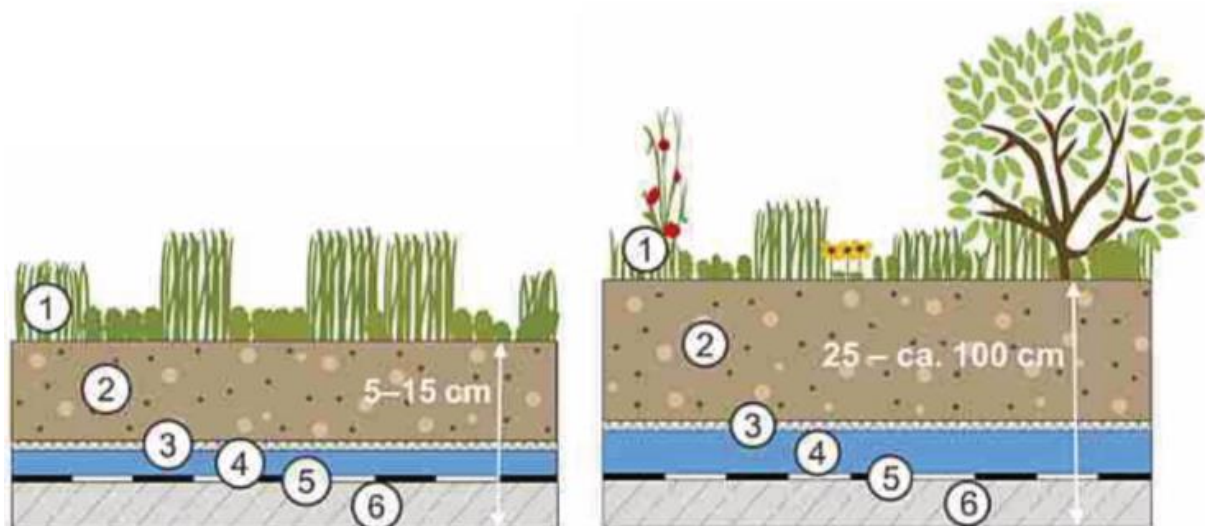


Figure 16 Schematic Structure Green Roof (Miriam Brune et al. 2017)

In **Figure 16**, the schematic structure of an extensive green roof is shown on the left and that of an intensive green roof on the right. The structure is relatively similar, so the numbers in **Figure 16** represent:

1. vegetation layer
2. substrate
3. filter fleece
4. storage & drainage layer

5. roof waterproofing
6. roof structure

The structural difference between extensive (left) and intensive (right) is the thickness of the substrate layer (2) and the thickness of the inserted fleece (3).

Further differences can be found in their function and effect in terms of retention and detention. Extensive green roofs are lighter and less expensive due to the narrower substrate layer and only need to be watered until the plants have established themselves on the roof and then no longer. Due to the different thickness of the layers, their rainwater retention capacity and climatic effects are less good compared to intensive green roofs. Extensive Green Roofs, however, are very well suited for retrofitting on previously ungreened flat roofs due to their low ballast. Mosses, grasses, sedums, succulents, herbs or similar plants that are drought-tolerant and easy to care for can be planted here. This keeps the maintenance and technical requirements for the structure low. This type of green roofs are not intended to be used by walking on the green area. (Sieker H. et al. 2019)

Intensive green roofs begin where the capacity of extensive green roofs to influence the climate and provide rainwater retention ends. Due to the partially much thicker substrate layer, much more diverse plants can be planted. A wide variety of plant specimens are possible, including perennial shrubs and trees, and often lawns. This requires a high level of maintenance, constant watering and a higher technical requirement, as the statics of the roof have to be checked for the large additional load. (Brune M. et al. 2017)

Intensive Green Roofs can extend to a complete garden landscape on the roof and can be used as a place of recreation. Underground garages are particularly suitable for intensive green roofs, as thicker layer structures are possible here from a structural point of view. For both types of greening, there are technical retention systems that can improve the efficiency of rainwater retention and at the same time ensure a longer water supply for the plants during dry periods. The water retention and therefore also the evaporation rate depend on the construction method, layer thickness and annual precipitation. (Sieker H. et al. 2019)

Measurements in Braunschweig showed an average 11 °C lower surface temperature on an extensively greened roof compared to a conventional roof on one summer day. The maximum measured reduction in this case was 17.4°C. (Brune M. et al. 2017)

Green roofs also generate certain synergy effects in combination with photovoltaic systems. For example, the efficiency of photovoltaic systems increases due to the cooler surface temperature created around the green roof by evapotranspiration. The power output of such modules drops by 0.5% for each degree Celsius that rises. (Bresser M. 2020)

The positive effects of extensive greening at the city level include the binding of particulate matter, reduction of CO₂, binding of nitrate and ammonium nitrogen from precipitation, and also a reduction in noise emissions from road traffic due to the additional insulation. The additional insulation layer already results in an enormous reduction of surface temperatures on roofs at the building level. **Figure 17** shows the temperature curve over 24 hours on different types of roofs.

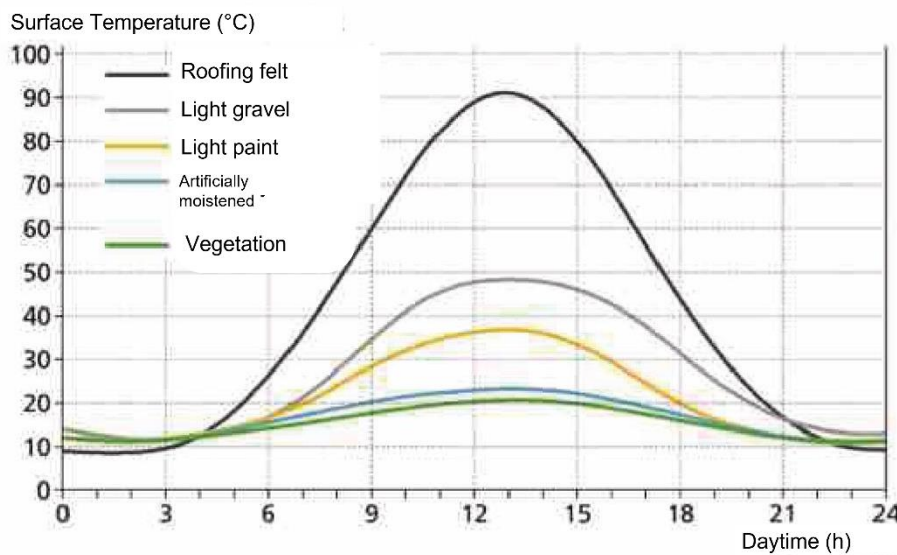


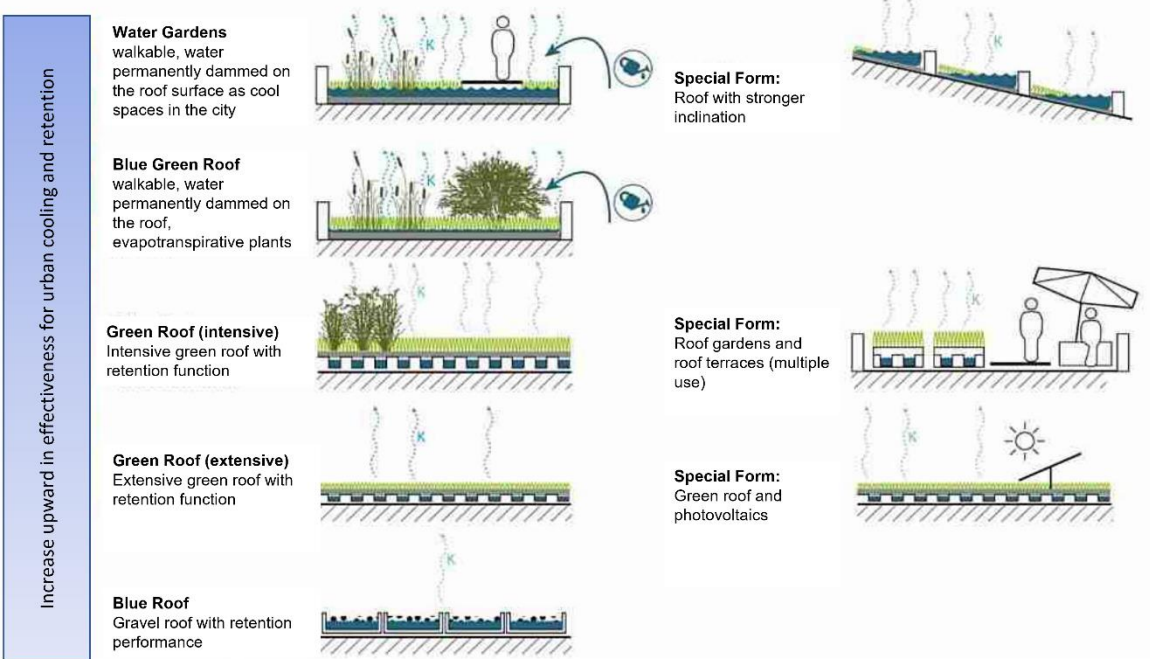
Figure 17 Surface temperatures of different roof coverings in the course of the day (Miriam Brune et al. 2017)

In the summer, greenery acts as a passive solution for cooling buildings in two ways - on the one hand.

- through the shading of the building envelope and
- through the increased insulating effect of the substrate and vegetation layer.

Conventional roofs are covered with dark bitumen membranes can reach temperatures of over 90°C at midday in summer. On green roofs, by comparison, both the peak temperature and the temperature amplitude during the course of the day are much lower. Due to the lower temperature

exposure, the material used can achieve a longer service life, which can reduce repair and renovation costs. Building green roofs also provide increased protection against UV radiation, hail, and other mechanical or chemical pollutant impacts to the building envelope.(Brune M. et al. 2017)



© SenStadtUm Berlin/bgmr (2016)

Figure 18 Different roof types and their effectiveness for evaporative cooling and water retention. (Sieker et al. 2019)

Figure 18 shows the variety of ways green roofs can be used and implemented. Green roofs shown in Figure 18 at the top also have the highest effectiveness for urban cooling and retention. The top two shapes and the intensive green roof require constant irrigation.

2.3.6. Purple Roof

In addition to the capabilities of extensive and intensive green roofs, the author considers the purple roof concept to be important. This is important because Green Roofs are largely designed for retention, while Purple Roofs keep the infiltrated rainwater from running off for up to 24 hours. This is due to their construction which can be seen in **Figure 19**.

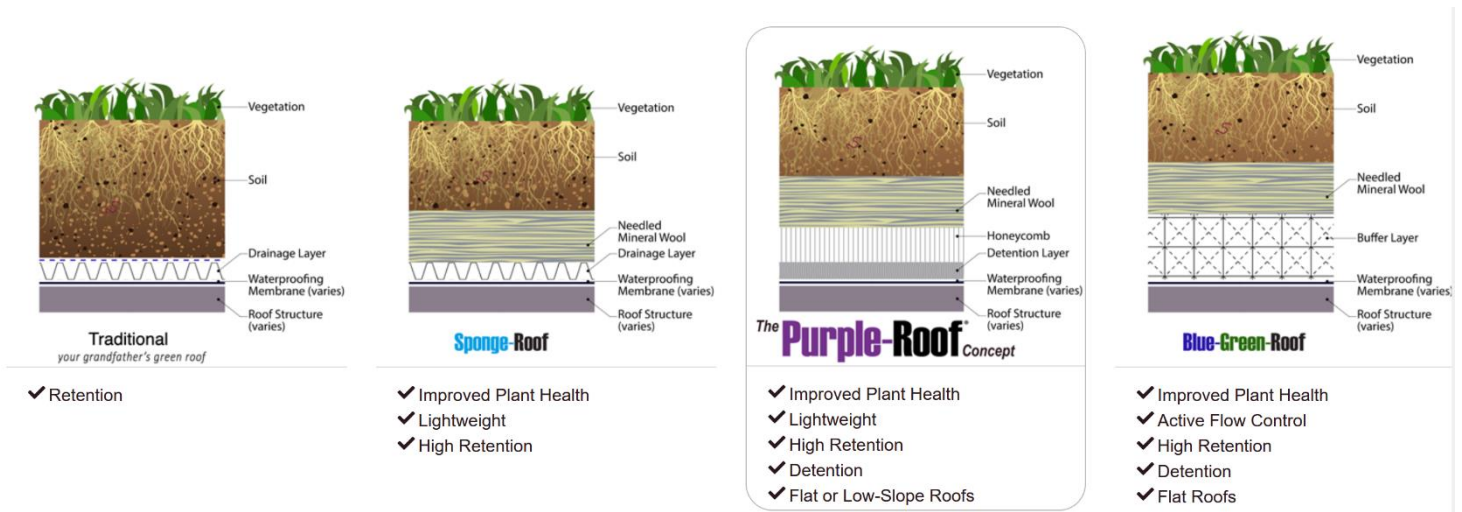


Figure 19 Roof Vegetation Systems in comparison (Purple-Roof 2019)

The far-left image shows the traditional construction method of Green Roofs. Extensive and intensive Green Roofs are combined into the term Sponge Roof in this illustration and reduced to their main functions. As soon as it starts to rain, the water on the roof starts to percolate. This seepage does not happen uniformly, water tends to move through the soil on preferential paths. Therefore, in traditional and extensive green roofs, the runoff of rainwater begins first, before the storage capacity of the roof has been reached, compared to the other systems. Therefore, the leftmost system has the least rainwater retention and only moderate to no detention. The Purple Roof Concept features an additional detention layer that resists runoff and therefore delays the runoff and allows the roof's storage capacity to be fully utilized. The Blue Green Roofs can be seen in **Figure 18** and **Figure 19**. (The Purple-Roof Concept 2022)

2.3.7. Green Wall

Green walls are similar to green roofs. One advantage of green walls compared to green roofs is the area available for greening. Depending on the height of the building, the facade area can easily exceed the building ground area. The use of building facades as "vertical green space" therefore has particularly great potential for tall structures with a large wall-to-roof ratio, but also offers advantages for low-rise buildings. While green roofs can provide thermal benefits primarily for the attic, the thermal benefits of green facades can extend to all vegetated floors. (Brune M. et al. 2017)

With green walls, a distinction is made between facade-bound greening - in which the plants are only connected to the support system and their pots - and ground-bound facade greening. In ground-bound green walls, the plant is directly connected to the soil in front of the building. **Figure 20** clearly shows this difference. The effectiveness for urban cooling and retention, increases from the bottom to the top, as in the **Figure 18** of green roofs.

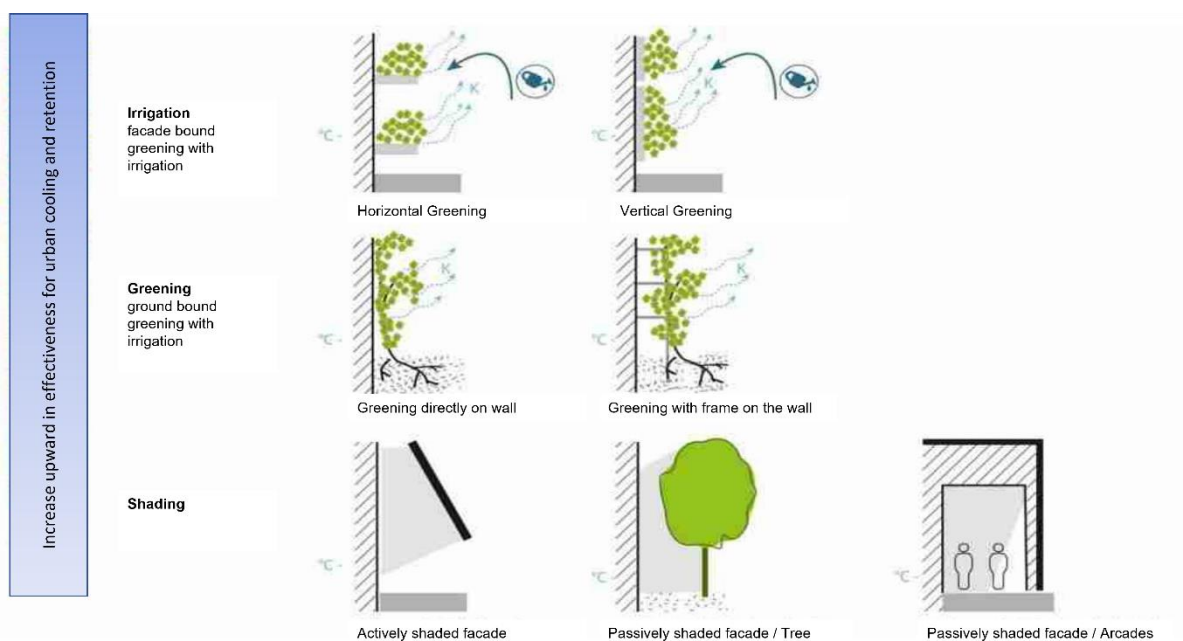


Figure 20 Different facade greening systems and their effectiveness for evaporative cooling. (Sieker et al. 2019)

As with intensive green roofs, façade bound green walls must also be permanently connected to an irrigation system. (Sieker H. et al. 2019) Some types of facade greening can be used for graywater utilization or graywater purification, for example (Bresser M. 2020)

Green roofs and facades have the potential to reduce overheating of urban areas, known as the urban heat island effect. Reduced surrounding temperatures lead to improved thermal comfort, reduced health-related heat stress, and improved nighttime conditions for restful sleep during summer heat periods. (Brune M. et al. 2017)

From various studies, a reduction of the surface temperature by 1.9 - 8.3°C, 12 - 20°C, 1.2 - 5°C and up to 15.5°C, could also be measured for greened facades. The different expression of the effects is due to different climatic conditions as well as the used vegetation. The main effect of surface cooling is mainly due to shading and to a lesser degree to transpiration. (Brune M. et al. 2017)

With the help of facade greening, the share of evaporation in the annual water balance can be increased. However, quantification is difficult due to the small number of literature values and the numerous influencing parameters. The effect of the measures, for example, depends on the type of façade greening, the geographical orientation and consequently the solar radiation, the water availability and the plant species. The final cooling effect of the façade greening is based not only on evaporative cooling but also on the simultaneous shading of the house wall. (Sieker H. et al. 2019)

Regular plant care (trimming, fertilization and watering if necessary) as well as maintenance of the technical components is not only necessary to maintain the functions of the greening as an adaptation measure to climate change, but also to prevent damage to the building. The costs accruing annually as a result of this should not be ignored. (Brune M. et al. 2017)

Facade-bound greenery requires artificial, automatically controlled irrigation, preferably fed from roof water as a rainwater harvesting system. Depending on the plant and surface roughness of the wall, a climbing frame is required. (Bresser M. 2020)

In addition, the insulating effect of vegetation reduces nighttime cooling, which means that green roofs and facades often have higher minimum surface temperatures and therefore a lower temperature amplitude. This leads to a reduction in the thermal stress on the building envelope and a resulting increase in the service life of the materials. (Brune M. et al. 2017) The additional insulation has the advantage of reducing the noise level of the road through sound absorption and leads to the

binding of air pollutants. (Bresser M. 2020) Green roofs and facades thereby contribute to an improvement in air quality by reducing air pollutants by means of dry deposition, as well as to the reduction of CO₂. Nitrate and ammonium nitrogen or other substances contained in precipitation can also be bound in this way. (Brune M. et al. 2017)

Furthermore, various bird species nest in the plants. In summary, the greening of the façade is attributed a high improvement of the environment. (Bresser M. 2020)

Finally, there is not yet a comprehensive green city to quantify the cooling effect of evapotranspiration from plants, but all the other effects of greening are very positive and already contribute a large part to climate adaptation without the cooling effect of evapotranspiration.

2.4. Real Estate

There are many possibilities for the nature-oriented use of rainwater. Green buildings not only serve the purpose of saving resources, but should also help people in the future to deal with the emerging climate scenarios. As the climate changes, rainfall events will become more intense, more frequent and more irregular. Because climate change will be different in other climate zones around the world and will manifest itself differently, this is another reason why green buildings need to be built and, above all, planned on a customized, batch-size-1 basis. The problems will be that we will periodically have either too much or too less water available. Here, depending on its size, the property around a building can contribute as much as the building. In the following, one will see the possibilities of using rainwater in a natural way in Green Buildings and examples will be given.

2.4.1. Nature-Oriented handling of rainwater

Falling precipitation of any kind has three possibilities on earth. Precipitation can evaporate, infiltrate or run off. In settlements and cities, it is common practice to drain water from sealed surfaces directly into the sewer system. As development increases, the amount of sealed land increases, so more and more water is collected and discharged into sewers and wastewater treatment plants, leading to increased costs and damage. At this point, cities are changing the natural water cycle through their construction, by not keeping the water on site, but rather trying to drain it away as much as possible,

making on-site infiltration or evaporation of rainwater no longer possible. The aim of a natural approach to rainwater is to have as little impact as possible on this rainwater cycle. This can be achieved through decentralized retention, surface infiltration, centralized retention for delayed discharge, and surface drainage.

Retention



In this context, decentralized retention helps, for example, to reduce the volume of rainwater that needs to be handled by greening facades and roofs.

(**Figure 21**) The storage of rainwater in the plants and substrate layers of green facades and roofs relieves the burden on the sewage system.

Figure 21 Green Roof as Components of the nature-oriented handling of rainwater (German Berger und Florian Ettinger 2016)

For instance, centralized retention for delayed discharge is shown in **Figure 22**. Here, rainwater is retained in a storage basin with a throttled discharge to delay and control inflow to the water body. This is more in the sponge city field than the green building field because of its size and purpose, but they address the same problem.



Figure 22 Storage Basin as Components of the nature-oriented handling of rainwater (German Berger und Florian Ettinger 2016)

However, retention does not only take place on roofs or in storage basins. Ponds as retention measures are nothing more than artificially created water basins which, if designed appropriately, can be aesthetically pleasing components of a near-natural rainwater concept. Since they are permanently filled with water, they have a high evaporation capacity. Depending on the space available, urban wetlands can also be implemented. Also known as evapotranspiration beds, urban wetlands are water-saturated vegetation beds. Urban wetlands can be a small water surface, such as a pond, or - depending on the available space - water features and fountains or floating vegetation islands. (Sieker H. et al. 2019)

This is the crossover point between green building measures and sponge city measures, which are not addressed in this paper. However, since in the future a sponge city will consist of green buildings and both green buildings and sponge city will address the same problems on a different scale, it is important to know that this issue does not stop at the property line.

Infiltration

When it comes to rainwater infiltration, there is a lot more that can be done in the green building sector before we reach the sponge city sector. The soil must not be sealed and therefore rainwater needs to be able to infiltrate into the ground. Infiltration is promoted by unsealing the soil. On a vegetated, unpaved surface, such as a lawn, nearly two-thirds of the rainwater evaporates, about one-fourth percolates deep into the soil and recharges groundwater reserves, and the small rest runs off on the surface. As a result, floods, inundations and flash floods do not occur as frequently.

However, due to the way people have built so far, more and more of these areas have been sealed, which means that most of the rainwater can no longer evaporate and seep away, but is forced to run off. Only a small part of the rainwater can evaporate here, an even smaller part of the rainwater manages to percolate through the sealed soil. All that remains for the water is a large and rapid surface runoff, since any - currently built - infrastructure for the drainage of rainwater is not designed for large quantities in a short time, it comes more and more frequently to flooding and high water. Especially in regions with a combined sewer system, there are more and more problems with increasing rain intensity and frequency

Surface infiltration favors evaporation, and the rainwater is sufficiently purified by the soil during infiltration to prevent contamination of groundwater with harmful substances. Surface infiltration can be encouraged by limiting the sealing of surfaces to what is absolutely necessary. If a surface necessarily needs to be paved, a permeable pavement can be created using a variety of pavements.

Figure 23 shows a series of permeable pavements, e.g. stone pavers with split joints on the left, a terrace with wooden grating on the upper right, where the underlying soil can infiltrate water, or grass pavers on the lower right.



Figure 23 Permeable surface coverings are, for example, lawn grids (below right) or paving stone with chippings joints (left) in driveways, wooden gratings on terraces (top right). (Bayerisches Landesamt für Umwelt)

For areas that are already sealed, "unsealing" or a more permeable design should be considered.

(Berger G. und Ettinger F. 2016)

Companies like Wavin GmbH are already addressing such issues today. In addition to ceiling heating and cooling systems, and sound-reducing piping, the company offers solutions for rainwater management. With the Wavin Q-Bic Plus, in **Figure 24**, Wavin offers a modular retention and infiltration system for rainwater. Made from polypropylene, the Wavin Q-Bic Plus retention and infiltration module is flexible enough to be used for projects of all sizes.

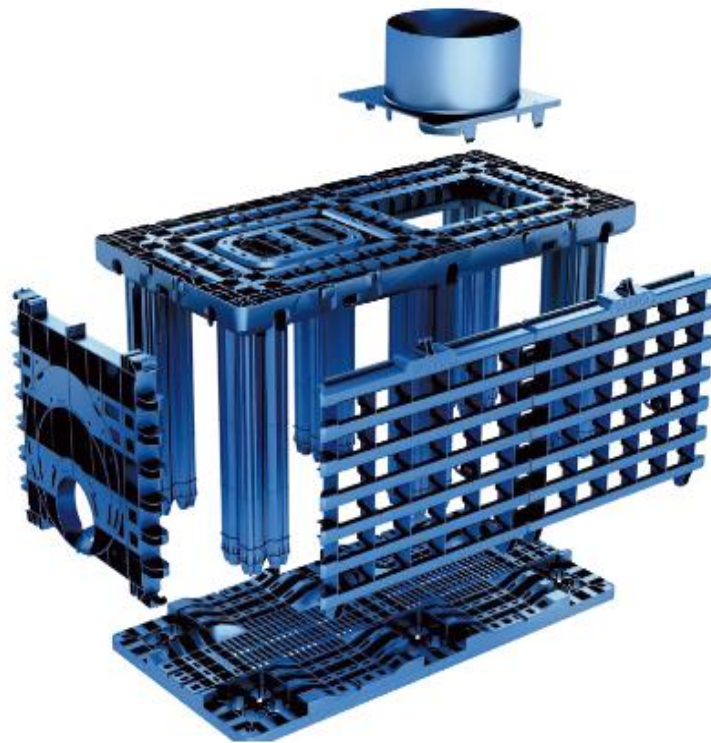


Figure 24 Q-Bic from Wavin GmbH (Wavin GmbH - Wassermanagement, Raumklima & Infrastrukturlösungen 2022)

The module is placed underground and helps in infiltration, and therefore retains water. The assembled device is covered with a waterproof film and can store rainwater. This can then be fed into the building as service water or used to replenish the fire-fighting water supply, as required.

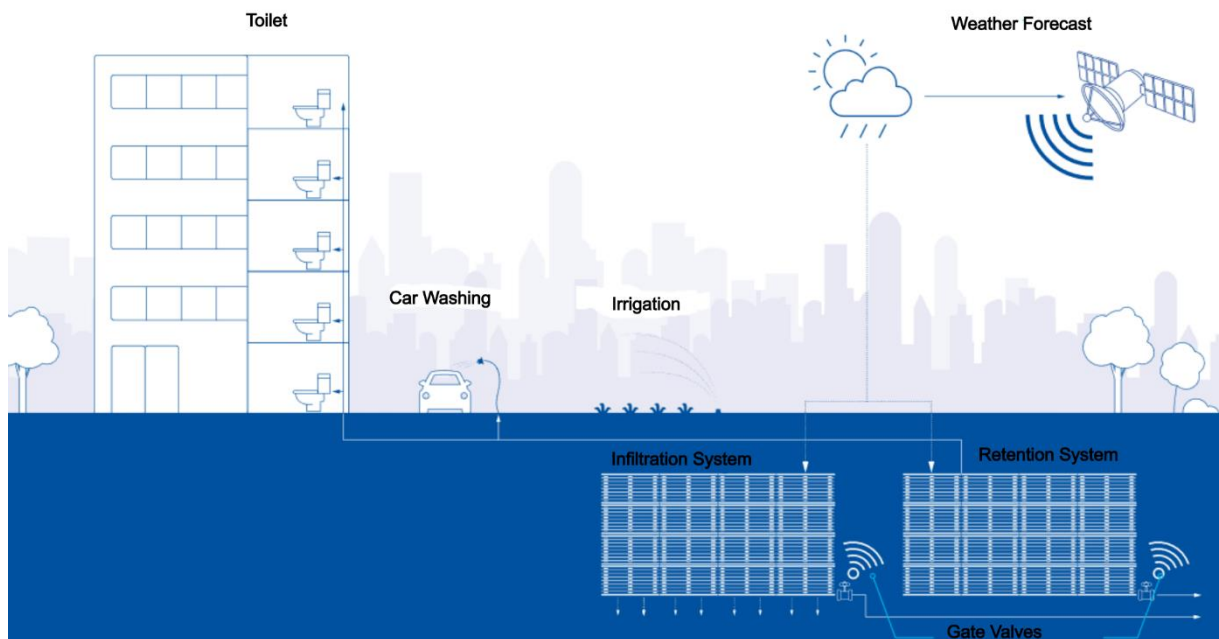


Figure 25 Storm Harvester from Wavin GmbH

Figure 25 shows how several Q-Bics can be joined together to form an infiltration unit, then covered with the waterproof film to form a retention system. While it used to be that detention systems sat empty most of the time and infiltration systems only worked when soil conditions were right, Storm-Harvester has an innovative solution for both requirements. The forecasting system allows stormwater to be stored for ongoing reuse. When rain is announced, the system's forecasting technology automatically adjusts the water level in the tank to ensure there is enough capacity to capture of rainwater - this process is then repeated the next time it rains.

2.5. Digitalization

If one considers digitization in buildings, there are a number of terms that are mentioned. First and foremost, the term smart home is now an established concept.

Things like

- automatic shutters for shading
- remote control of room temperature via app,
- automatic lighting or
- programmable garden irrigation,
- alarm functions that notify you through motion detectors or smoke detectors or
- the coffee machine that learns from the cell phone alarm clock when the user wakes up and is already making a cup of coffee
- and many more

They are already available today. Whether built system by system by yourself or bought as a complete system, these functions offer a big plus in comfort and can increase energy efficiency and security when used smartly. If all these functions are now not only controlled by a time switch, but also centrally linked to a superordinate system, a smart home environment has been created for the residents.

This is an important part, but it is only a customized interface between the building and the people living in the building. In a green building, a similar network of monitoring and control will be needed in the future to monitor building processes, make predictions, and remotely influence the situation. The previous example in **Figure 25** of the company Wavin shows a used case for this level of networking. Solid solutions in the context of a platform that can provide all of this, control, analyze, and present the live status of the building and its assets clearly in dashboards and reports, are still in their development phase. SIEMENS AG is working in this area, and with their platform called Building X, they have created a user interface that covers all areas and aspects of building operation and management. This platform includes an "Energy Manager", a "Security Manager" and an "Operations Manager". For example, "Energy Manager" monitors, analyzes and forecasts energy efficiency KPI's, associated CO2 emissions and therefore costs in near real time. "Operations Manager", for example, enables cross-

site monitoring and control of heating, ventilation, air conditioning and cooling technology. In addition, it is possible to plan preventive maintenance based on data insights. (SIEMENS AG)

The author sees important core functions of the user interface basically already present today

- Device recognition
 - Enables plug and play handling of devices
- Predictive maintenance
- Overall Equipment Effectiveness (OEE)
- Load profiling
- Load balancing
- near real time control of water management including prediction analysis
 - Rainwater management:
 - Control and distribution of rainwater to the required locations in the building (facade greening, toilets, infiltration or storage of rainwater).
- Wastewater management
 - Control of gray and black water with possible storage/regulation of the inflow into treatment plants.
- Digital twin management

KSB SE & Co. KGaA is already doing future-oriented work in this area in cooperation with the OPC Foundation and the German Engineering Federation ("VDMA").

Therefore, for a targeted, strategic operation and energy management, the instrumentalization of the facility technology has to be extended in such a way that energy flows, room temperatures, facility parameters, etc. are captured and recorded in the smallest possible, discrete time steps. This is then referred to as a measurement value acquisition concept. (Bauer et al. 2013, S. 142)

Pump manufacturers and the two divisions of the German Engineering Association "Pumps + Systems" and "Compressors, Compressed Air and Vacuum Technology" have now specified a manufacturer-independent management shell for pumps and vacuum pumps for applications in the process industry, building technology, the semiconductor and manufacturing industry, the food industry and water management. The models developed are communication-independent and apply to pumps of different functionality. (Both)

In cooperation with the Technical University of Cologne, a document was created in which use cases were compiled, examined for overlaps, combined into higher-level use cases, and mapped to Industry 4.0 application scenarios. In total, the three superordinate cases "Configuration", "Operation" and "Maintenance" were developed. (Both)

These have in turn been subdivided into the sub models from **Figure 26**.

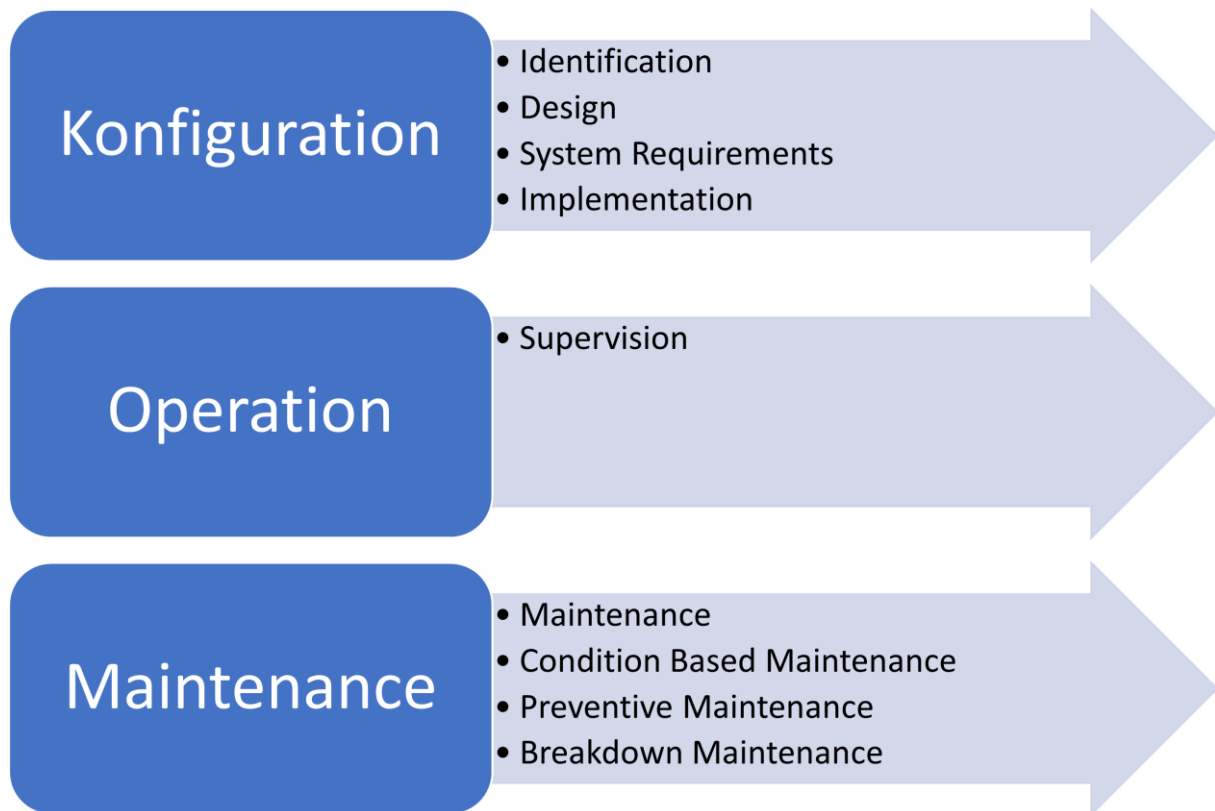


Figure 26 Used cases and their submodels (own creation)

2.6. Future Development

In the future, the author expects the following technologies to play a more important role in green buildings:

1. Connectivity in buildings: the networking of building systems, including heating, ventilation, air conditioning, lighting, and security surveillance, enables better monitoring and control of energy and resource use.
2. Smart home systems: The Internet of Things and smart-home systems enable easy monitoring and control of building systems and energy use, which can help improve energy efficiency and reduce environmental impact.
3. Energy efficiency: energy efficiency measures, such as the use of renewable energy and energy management systems, are becoming increasingly important to further improve the energy efficiency and carbon footprint of green buildings.
4. Building materials: the use of sustainable building materials, such as wood, bamboo, straw and recycled building materials, will continue to gain importance to reduce the use of resources and reduce the carbon footprint of green buildings.
5. Artificial Intelligence: artificial intelligence can be used to improve the monitoring and control of buildings and optimize the efficiency of energy and resource use.

The author also expects the following developments to be important in green building's networked building technology in the future:

1. Integration of building automation systems: Networked building technology is becoming more and more integrated to enable better monitoring and control of building systems and energy consumption.
2. Predictive maintenance: networked systems can be used to proactively perform maintenance and prevent breakdowns, contributing to better energy efficiency and reduced environmental impact.
3. Data analytics: the use of Big Data analytics and machine learning enables deeper analysis of building data to make better decisions regarding energy and resource use.

4. Real-time monitoring: real-time monitoring of building assets and energy use enables rapid response to changes and better management of energy and resource use.
5. Interoperability: interoperability between different systems and devices will become more important to enable easy integration and monitoring.

These and other developments are likely to help green buildings become even more efficient and environmentally friendly in the future.

These topics are important because they can help reduce the energy consumption and carbon footprint of green buildings. Efficient connected building technology enables better monitoring and control of energy and resource use, which can contribute to higher energy efficiency and lower environmental impact. Predictive maintenance and data analytics can help prevent breakdowns and optimize energy use by identifying and resolving problems early. Real-time monitoring and interoperability enable rapid response to changes and better management of energy and resource use, which can contribute to higher efficiency and lower environmental impact. Overall, these issues help make green buildings even greener and more efficient in the future, which is important to combat climate change and promote sustainability.

The following **Figure 27** shows what solutions are already available and what the author expects to see more of in the future. Software solutions are at the top, hardware solutions are at the bottom, the left side of the graph presents solutions that are already available on the market and the right side presents solutions that will be available in the future. This divides the graph into 4 sectors, whereby the position of the solutions within a sector has no significance. In **Figure 27**, the author is only interested in the classification of the solutions into the 4 possibilities.

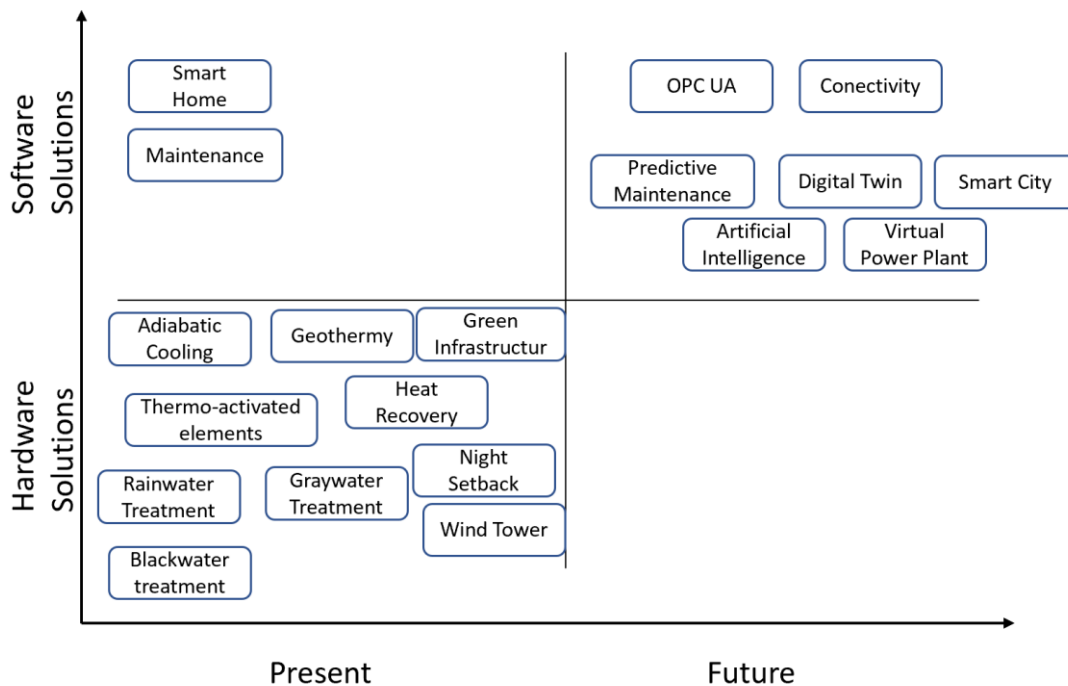


Figure 27 Categorization of green building measures by availability and type (own creation).

In the sector of future hardware solutions, no technologies are entered, since in the author's opinion there will only be improvements or combinations of already available solutions in this area and no new inventions.

Frequency Converter

In the future, more smart pumps will require the possibility of more precise control. In the case of pumps, frequency converters are needed for control. Such a device converts the AC voltage fed into it into a different one. Motor speeds of asynchronous motors or synchronous motors can be operated independently of the fluctuations of the public power grid by means of a frequency converter connected upstream of the motor. The basic tasks of a frequency converter include:

- Saving energy by improving the efficiency of technical systems

- the adaptation of process variables such as speed to meet specific process requirements
- adjusting and regulating the power or torque of a motor according to process requirements
- generally lower noise level of fans or pumps
- increased service life of the equipment due to reduced mechanical load
- stepless rpm control

70% of the world's applications for frequency converters are for pumps and fans. The advantage of these devices is that they can very precisely set the speeds required for fans and pumps. This advantage, which these devices are already providing in industry, will be an important factor in green building in the future. (Scherer R. 2022)

In the author's opinion, pumps and fans have so far been integrated into highly complex industrial processes, and similarly complex processes will increasingly require frequency converters in buildings as well.

As with all other systems, the further into the future one looks and the more complex the downstream processes are, the more they will require a connection to the building network and will have the ability to communicate with other building components.

Due to the complexity of the topic, it is not possible to make any further statements within the scope of this work. The potential for increasing demand for frequency converters in proportion to the growing number of pumps in the home is real. Further research in this area is needed to find connectivity and improvement opportunities and to fully explore the potential of frequency converters.

Heat pumps

By 2030, according to the plans of the Ministry of Economics - six million heat pumps are to be sold in Germany. Last year, according to the German Heat Pump Association, only 154,000 heat pumps were sold nationwide - but that was still 28 percent more than in 2020. The figures for the current year are likely to be significantly higher. Just four years ago, the global size of the heat pump market was just under \$55 billion. Depending on the estimate, it could swell to between \$95 billion and \$100 billion by 2026. (tagesschau.de)

3. Technical Application Opportunities for KSB Products

Technical application possibilities for a pump and valve manufacturer lie where a medium must be moved and reasonably controlled. In the opinion of the author, only certain areas of green buildings offer a possible use of pumps and valves. This is because some systems handle this by gravity. Or it is design related such as Green/Purple Roofs and Green Walls. Using selected buildings, the author shows where - in Green Buildings - possible applications exist.

In selecting the buildings in **3.1. Results of Literature Research**, attention was paid to three things.

- First, they should have as many closed energy loops as possible.
- Second, care was taken to ensure that the buildings demonstrated the diversity that was technically possible.
- Thirdly, attention was paid to the degree of climate adaptation. By this the author means that the implementation of a few/single measures already makes a difference for the environment.

For a better assessment of the possible applications for KSB products, a number of experts from the company were consulted on this topic. The results of these discussions are summarized in chapter 3.2.

In order to expand the author's knowledge, discussions were held with an architect with many years of experience in the field of green building for chapter 3.3.

Finally, Chapter 3.4 attempts to raise the reader's awareness of the green building concept.

3.1. Results of Literature Research

The examples shown here start with buildings where the main focus is on greening. This means they have adapted to the climatic change in rainfall events by implementing greening measures for retention and detention.

In the city of Berlin, projects can be found to help the city transform into a sponge city. Green buildings are an important part of becoming a Sponge City. Examples are the already finished residential complex "Rummelsburg" and the planned "Schumacher Quartier" based on the principles of the sponge city. Due to the fact that the project "Schumacher Quartier" is still in the making

(completion of the first residential buildings in 2027), it is not yet possible to name such concrete measures as in the case of the residential complex "Rummelsburg". However, it can be noted that a very large focus is placed on greening, evaporation, shading, retention, detention, solar reflection, ventilation and the creation of places for recreation.. (Tegel Projekt GmbH)

Also in Berlin is the already built residential complex which is presented next in bullet point form.

Rummelsburg (residential complex, Berlin)

- Green Roofs (8cm thick)
- Roofs direct rainwater into the courtyard
- Water infiltrates there in approx. 80cm thick soil
- Underneath is an underground garage
- Infiltration swales
- Urban wetlands distributed around the buildings
- No storm drain necessary

(Kaul I.) & (Ingenieurgesellschaft Prof. Dr. Sieker mbH 2018)

The Rummelsburg housing complex is a good example of how retention and detention systems can work purely by gravity.

A tower building has also already been successfully greened. Previously, the term greening, only grasses, moss and bushes were meant, but here a whole forest was attached to the facade. This forest consists of real trees, grasses and bushes and is mechanically watered with the gray water of the residents.

Bosco Verticale (Milan, Italy) - residential building

- facade greened with native trees and shrubs
- irrigation of the forest by grey water
- wind power
- solar energy

- Botanist Laura Gatti selected a total of 20 different deciduous and coniferous tree species and 80 additional plant species for the vegetation of the façade (Boeri S. 2014)

The same architectural office is building a Forest City. It is located north of Liuzhou, a Chinese city of about one and a half million people in the southern and mountainous province of Guangxi, one of the world's urban areas most affected by the smog problem resulting from urban overpopulation. This new urban organism can be seen in **Figure 28** and will be capable to annually (Boeri S. 2016)

- absorb 10,000 tons of CO₂
- absorb 57 tons of particulate matter
- produce 900 tons of oxygen
- Reduce heat islands
- Increase biodiversity



Figure 28 Forest City simulation of the future result (Stefano Boeri 2016)



The next green building also sets great value on green walls and green roofs, but it shows much more the technical creativity involved in directing the sunlight between the towers by means of several mirrors. The course of the sunlight directed thru One Central Park can be seen in **Figure 29**.

Figure 29 Path of redirected sunlight (Jean Nouvel und Bertram Beissel 2014)

One Central Park (Sydney, Australia) – Residential / small offices / retail

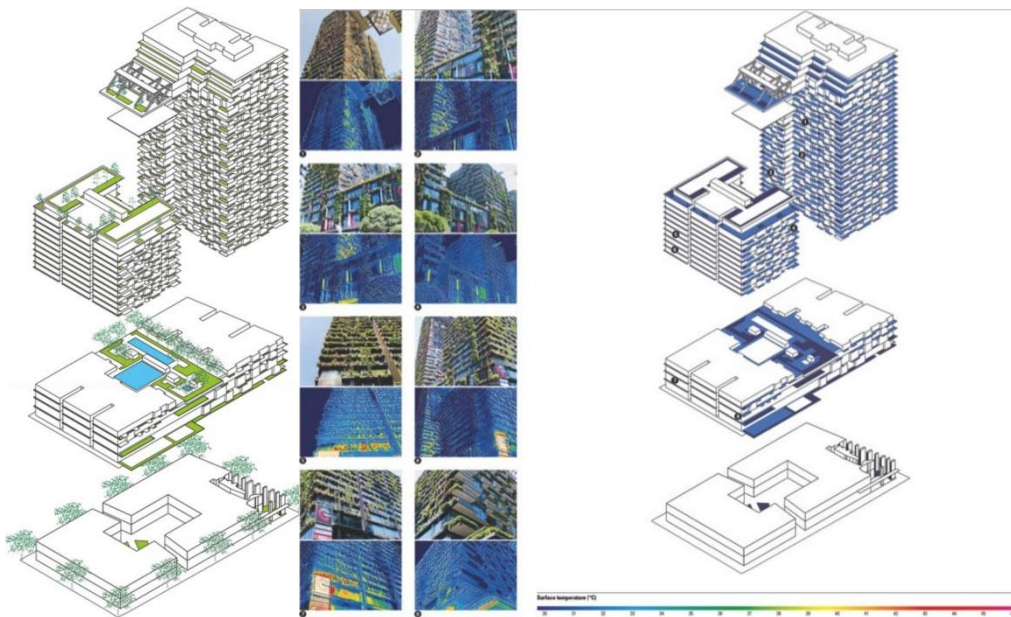


Figure 30 left: Exploded isometry with green spaces / right: Exploded isometry with surface temperatures (adapted from (Jean Nouvel und Bertram Beissel 2014))

- Greened facades here on this building are on average 2.6°C cooler than exposed non-greened parts of the facade of this building (**Figure 30**)

- Native bushes and climbing plants growing in planter boxes and along vertical stainless steel wires on the floor levels need to be watered
- Biodiversity increased by greening (various birds have recently begun nesting there)
- Reflection of sunlight by 42 sun-following mirrors from the roof of the smaller tower to the reflective heliostat at the top of the large tower and then down to warm and light areas between the towers (swimming pool, the park, the atrium)
- Natural ventilation
- Black water treatment plant produces water of sufficient quality for mechanical irrigation of plants

(Schröpfer T. 2021) (Nouvel J. und Beissel B. 2014)

With the One Angel Square in Manchester, the results of the literature research come to a building class that, in addition to retention and detention, also pays attention to cycles inside the building. In this building, savings can be achieved through the large glass facade and the atrium. These flood the building with light which leads to a reduction of artificial lighting. A parallel to the other buildings is the use of gray water and rainwater for flushing toilets and surrounding vegetation, since the facades of this building are not green.

One Angel Square (Manchester, UK) - Office

- - Large atrium for plenty of natural light and heat
- - Double glazed facades to minimize heating and cooling loads
- heat recovery from the IT systems that will also help to heat the building
- low energy LED lighting and IT equipment and systems
- greywater and rainwater recycling systems for toilet flushing and irrigation
- high efficiency passenger and service lifts.
- Earth tubes to bring in cool air via a heat exchanger

(BREEAM 2013) (BAM Construct & Ventures UK Ltd. 2013)

The Pixel Building convinces as a Green Building through its wide range of applied measures. Great importance was attached to creating as many closed energy cycles as possible. Technologies are used (Figure 32) in which it is not possible to transport the water used by gravity alone, as well as technologies that rely on mechanically generated vacuum or high pressure. For example, the 25,000-liter rainwater tank requires equipment. The toilets require a pressure reduction system as well as the process of reversed osmosis needs a pressure increase. In order to minimize gray water and therefore wastewater, a green wall is used here, where it is possible to water with gray water. Additional media transport of hot and cold water can also be seen in Figure 31, where the thermal activated components can be seen.

Pixel Building (Melbourne, Australia) – Future Office

In Figure 32 and Figure 31, the following important elements of this green building can be seen:

- Toilets, sinks and showers are powered by rainwater, potable water is available only at one tap per floor.
- Rainwater is collected by green roof and filtered by the vegetation + technical filtration (reverse osmosis) -> storage of the obtained drinking water in the basement
- Grey water is filtered through green walls (reed bed) on the house facade (Living Edge Planter), then it evaporates or is directed into the sewage system
- Vacuum toilets collect material for own biogas plant
- Biogas is used to heat water and building (anaerobic digester)
- solar panels,
- wind turbine
- 100% fresh air in the whole building air/air heat exchanger
- Use of cool night air
- Gas-fired ammonia absorption heat pump
- Pixelcrete, a specially designed concrete that contains half the embodied carbon of conventional concrete for the same structural properties

(deciBel(Architecture))) 2019)

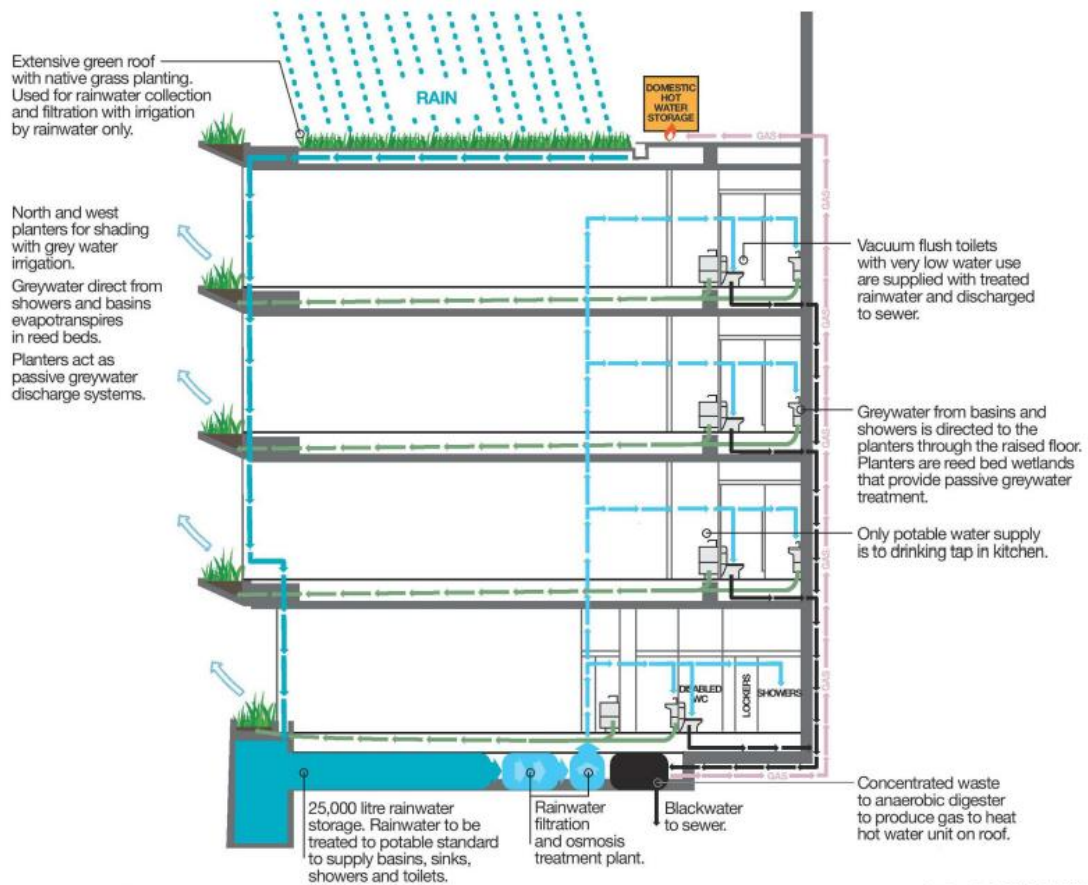


Figure 32 Water Cycle Pixel Building (decibel(Architecture))) 2019)

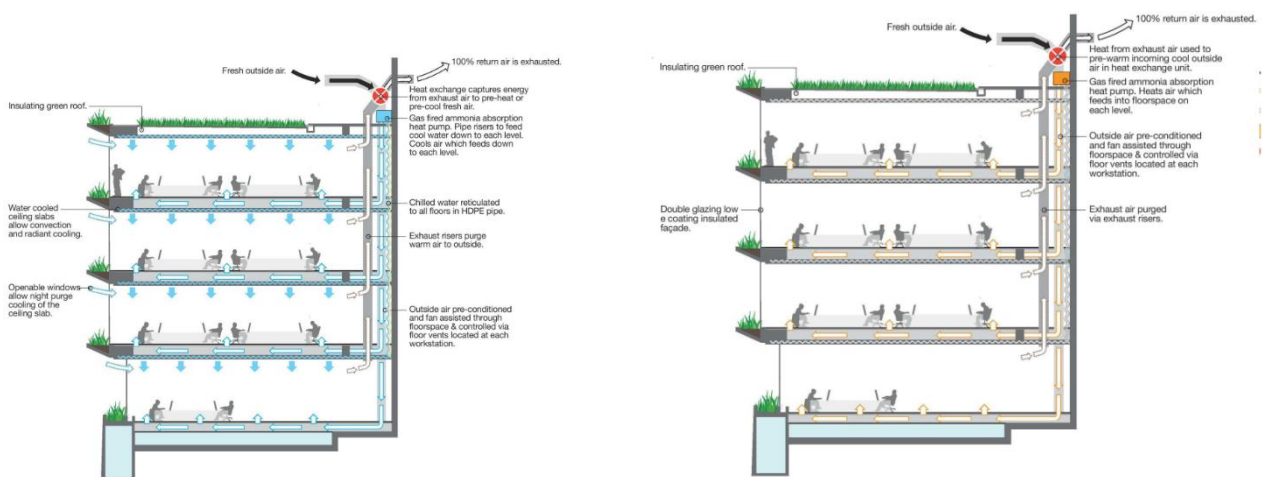


Figure 31 Cooling Strategy (left) and Heating Strategy (right) of Pixel Building (decibel(Architecture))) 2019)

You can see the entire water cycle in **Figure 33** in simplified representation. It can be clearly seen that great importance was attached to making as much as possible of the water collected on the roof during the planning phase.

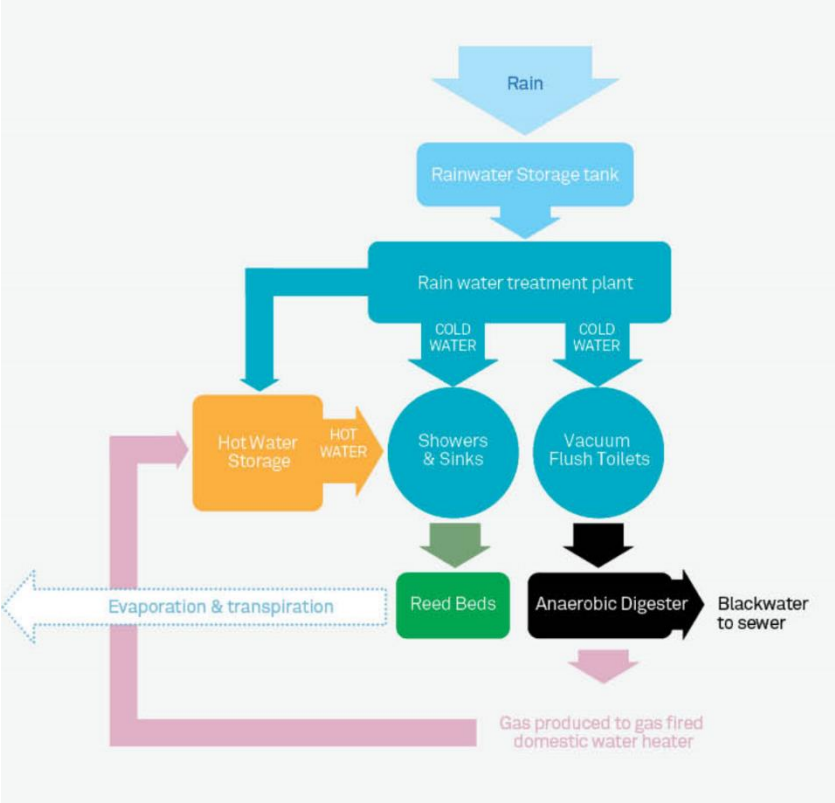


Figure 33 Pixel Cycle (deciBel(Architecture)) 2019)

Similar to the Pixel Building, the Bullitt Center features a wide variety of technologies (**Figure 34**). Like the Pixel Building, the Bullitt Center requires systems that transport rainwater from the cistern to the individual filtration and disinfection stations and finally to the tap.

Bullitt Center (Seattle, Washington, USA) Office

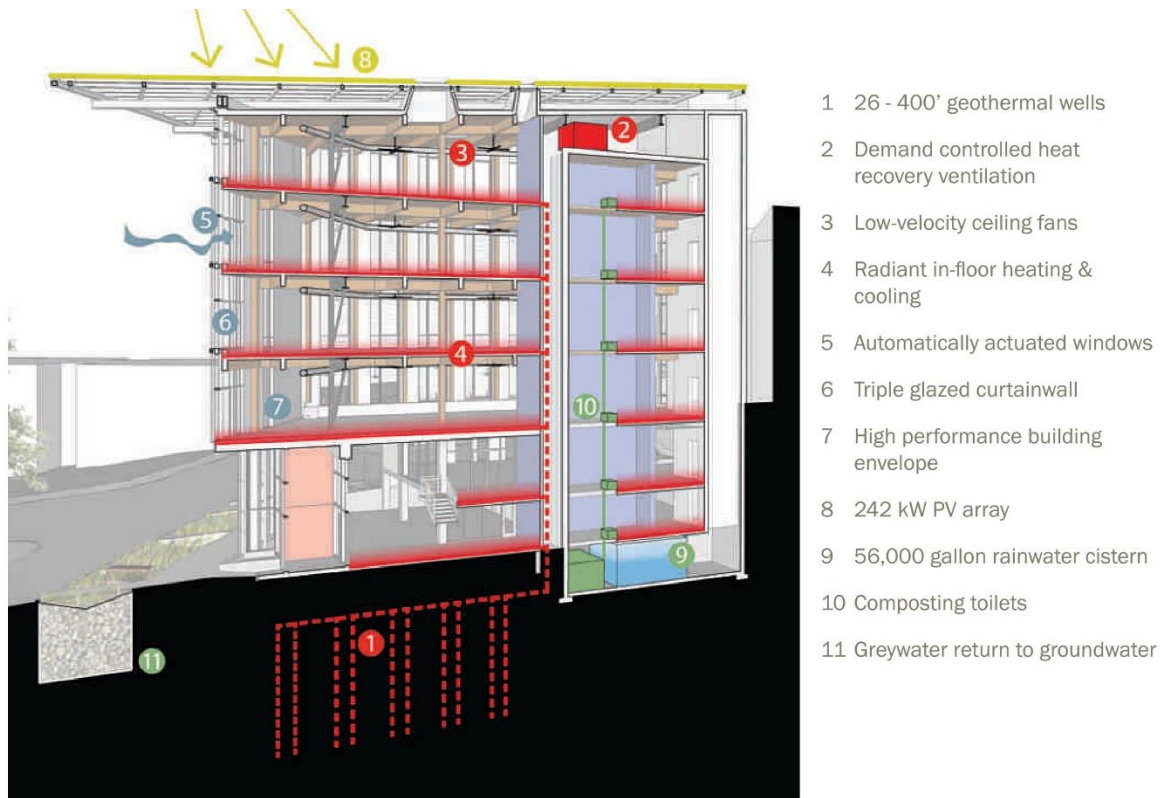


Figure 34 Bullitt Center integrated systems for power production, daylighting, heating, cooling and ventilation. (Pena R. 2014, S. 26)

In addition to the things shown in **Figure 34** the Building is also equipped with:

- 3 heat pumps for heating in winter
- 2 heat pumps for cooling in summer
- CO₂/°C sensors
- Rainwater treatment through ultrafiltration and ultraviolet disinfection
- Vacuumtoilets
- Additionally, the roof area, extends beyond the building footprint, improving the ratio of photovoltaic power to floor area

(Bullitt Foundation 2013)

The rainwater harvesting system is shown in **Figure 35**. The water is collected from the roof, treated, stored in a rainwater cistern, from there pumped to sinks and showers after it gets stored in another grey water cistern.

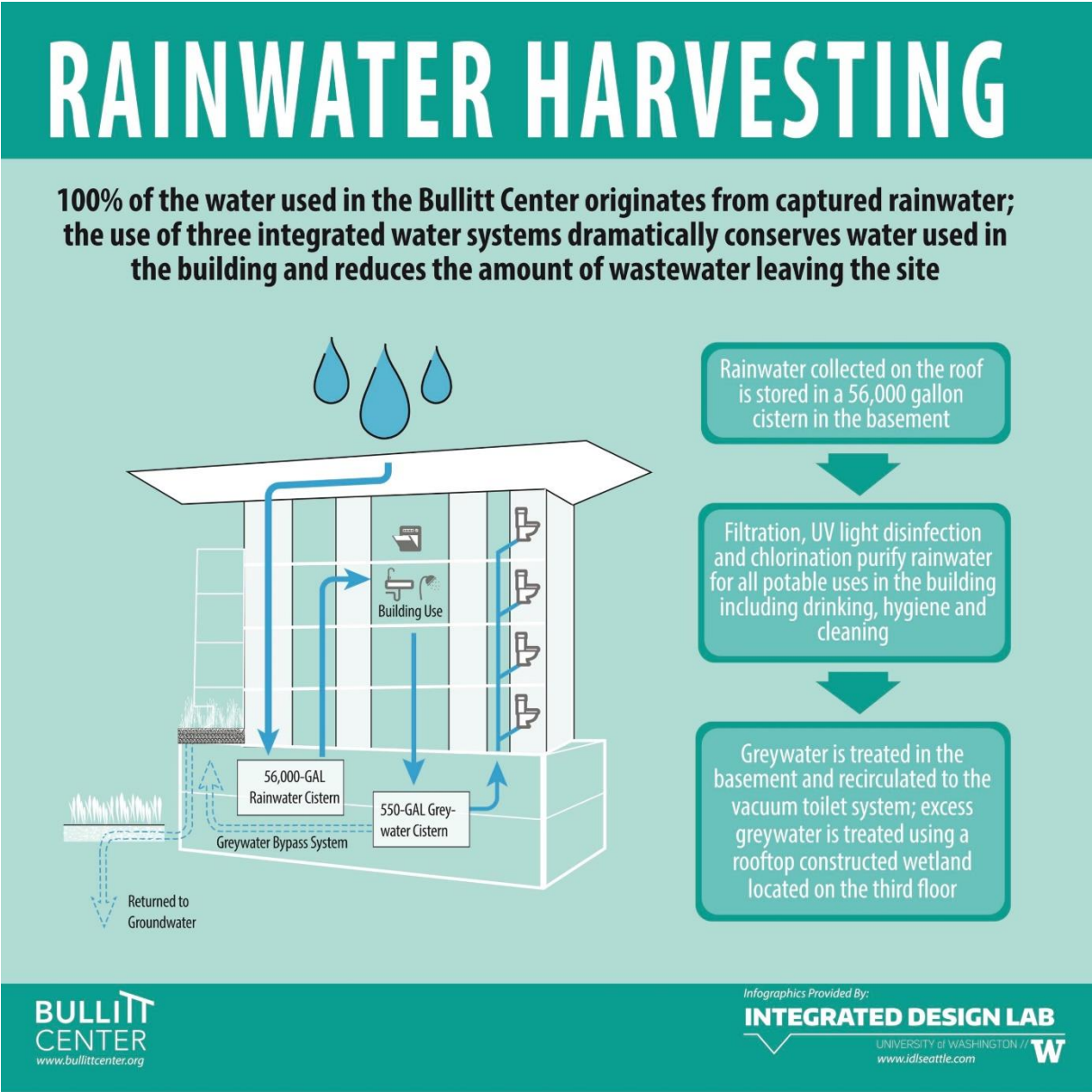


Figure 35 Rainwater Harvesting System (Bullitt Foundation 2023)

A case study done by the University of Washington Center for Integrated Design was conducted to see if the building delivers what it promises. This showed that the building is able to cover 100% of its

water needs by using the same rainwater several times. **Figure 36** also shows that the gray water generated on site is completely reused.

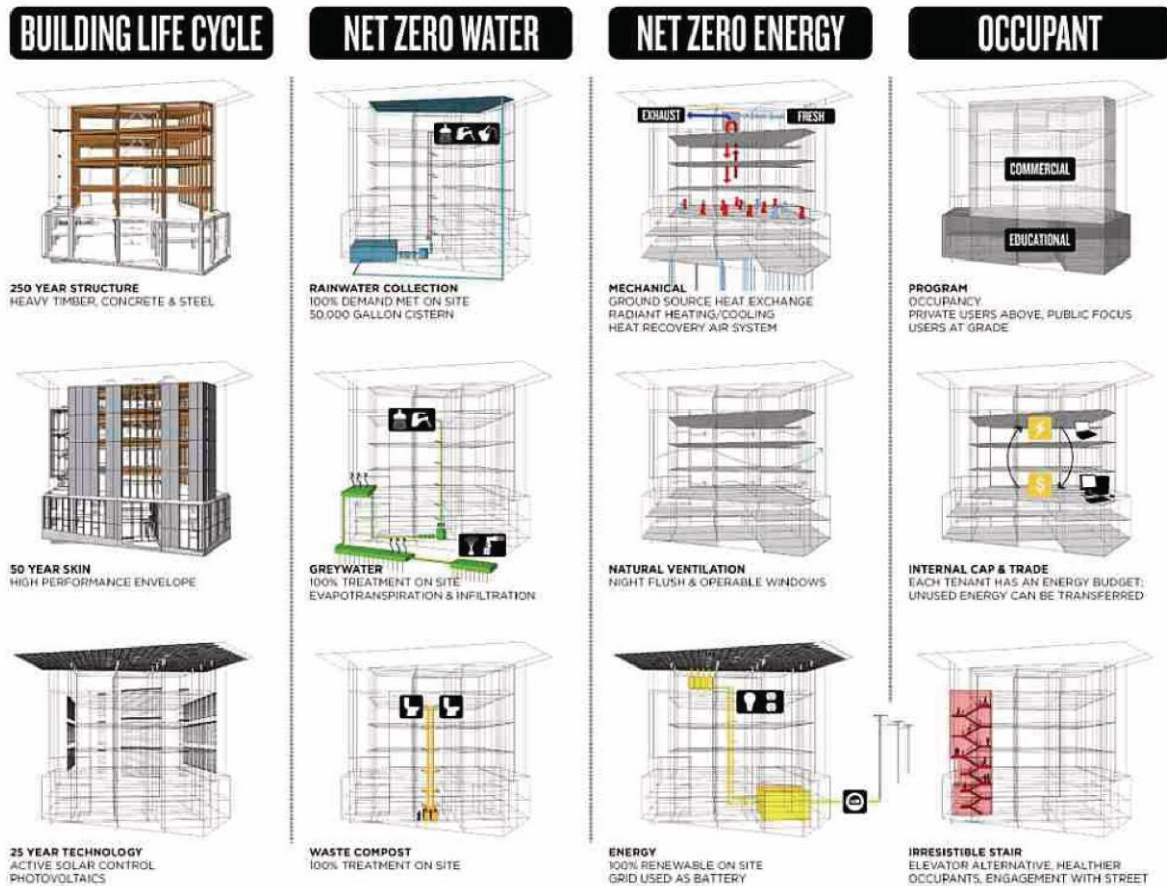


Figure 36 Integrated Design elements of the Bullitt Center (Pena R. 2014, S. 15)

The building is controlled by a Building Management System (BMS). The Building Management System controls the areas heating system, cooling system, passive and active ventilation systems, daylight control, the composters and the gray water cycle in the control room located in the core of the building. (Bullitt Foundation 2013)

3.2. Questioning KSB Experts

In-house experts from the Water and Building Technology divisions were consulted about green buildings. Participants of this discussion round were *Mr. Nierhoff Jonas* working in the area of *Market Development Water*, *Mr. Wenzel Frieder* working in the area of *Market Strategy & Business Development*, *Mr. Panthen Maximilian* Head of *Innovation Management* and the author. They were introduced chapters 1 to 3.1 in order to be able to assess future developments from a common level of knowledge. The participants then discussed whether, where and how there is potential for KSB products to be used in such buildings. Among other things, this discussion resulted in the following findings:

KSB has so far only had experience with heat recuperation on an industrial scale and not with such small heat recuperation systems as are required for green buildings.

KSB's goal is to establish itself as an Original Equipment Manufacturer (OEM). This is rather unlikely for heat pumps, but possible in the field of insensitive green roofs, purple roofs, blue green roofs, for water gardens on the roof and for facade-bound green walls.

KSB as an OEM for green infrastructure irrigation is an idea that the author sees as having great potential. This is because green infrastructure plays a major role in the climate adaptation of buildings and ultimately of cities. Here it is recommended to approach the manufacturers of green infrastructure who sell systems that need to be irrigated. In addition, it is important to make sure that the manufacturer has no ambition to make his system independent of irrigation in the future by using other plants or other substrate material.

3.3. Consultation of External Experts

As in the previous chapter, the author also consulted with experts on the subject of green building who are not part of the KSB Group. The VDMA e.V. (German Engineering Federation) is a German association that represents the interests of the mechanical and plant engineering industry. The VDMA offers its members comprehensive services, including political advocacy, technical support, industry information and many others.

Dipl.-Ing. (TH) Friedrich Klütsch, from VDMA e.V., Pumps + Systems, is of the following opinion, especially in the area of digitalization of building assets:

„The path taken from the start, to create a basis for the derivations of the OPC-UA Companion Specification and the bsDD (building smart data dictionary) implementation via the description of the Administration Shell, has proven to be the most effective and cost-efficient approach. The member companies of the trade association now have the necessary prerequisites for a solid and sustainable digitization of their products in the various application areas - industry and building technology - a standardization success that fills us with pride.“

Mr. Klütsch further emphasizes that the next step is now achievable and that the pump manufacturers are now in demand:

„A final step that seems necessary to convince the last doubters of the unlimited suitability, performance and possibilities of the digital data exchange of "Assets" in facilities has already been initiated - the practical implementation in the form of a pilot project. Together with a pump manufacturer and a major operator, a pump equipped with the VDMA pump model is to demonstrate its full suitability in everyday operation. The delays are related only to the war in Ukraine.“

This information will also appear in the annual report of the VDMA, which will be published in Feb/March 2023 and agrees with the opinion of the author.

Henning Larsen is an international architectural office specialized in the design of buildings with a focus on sustainability and social responsibility. The firm designs and plans buildings of all sizes, from public buildings and residential complexes to educational institutions and cultural centers. Henning

Larsen emphasizes the integration of nature, technology and community in its designs and works to create a better world through architecture. (Ramboll Group A/S 2023)

Gerhard Hauber, Executive Partner, Henning Larsen thinks that:

1. Buildings that receive green building certification today experience value stability or even an increase in value in the future due to their climate adaptation.
2. The trend of digitalization is becoming increasingly important. This applies to digitization in green buildings at the building level, as well as to digitization in sponge cities at the city level.
3. Asked if there are new stakeholders in the green building construction process since the certifications, Mr. Hauber replied that the certification organizations themselves are the new players. This refers to the audits that have to be planned into the construction process.
4. According to literature research, there are few differences between the certification procedures. However, when it comes to execution and certification, the differences quickly become apparent, as each certification system has a different focus.

The statements made by Mr. Klütsch and Mr. Hauber confirm each other when it comes to the topic of Digitalization. Mr. Hauber highlighted another important point at the meeting with the author. In his opinion, buildings with green building certification are becoming more popular. According to him, this is due to the fact that certified buildings are much more stable in value and therefore represent a more attractive investment than buildings that have not been adapted to the climate.

Prof. Dr. Manuela Wimmer:

In order to pursue this idea further, the author also consulted with Prof. Dr. Manuel Wimmer, Head of the Master Sustainable Water Management and Engineering program and Research Group Leader Sustainability and Projectmanagement in Water Management, on this topic. Her areas of focus include environmental engineering, project management and sustainability. In addition, she was the founding scientific director of the Institute for Water and Energy Management (iwe) at Hof University of Applied

Sciences in 2015. (Hölzel K. 2022) In her opinion, it is quite conceivable that certified buildings will experience value stability or increase. She reported from this area today there are already low-interest loans and more favorable conditions for building insurance. More legal requirements are needed to bring this topic forward noticeably.

3.4. Drainage and Supply Water in the House

3.4.1. General Explanation

Basically, **Figure 37** shows the schematic path of water through our current building. There is a fresh water pipe, which supplies cold potable water to the building. Directly after that, the typical consumers are supplied directly, such as washing machine, hand basin, shower, toilet and whatever else is needed.

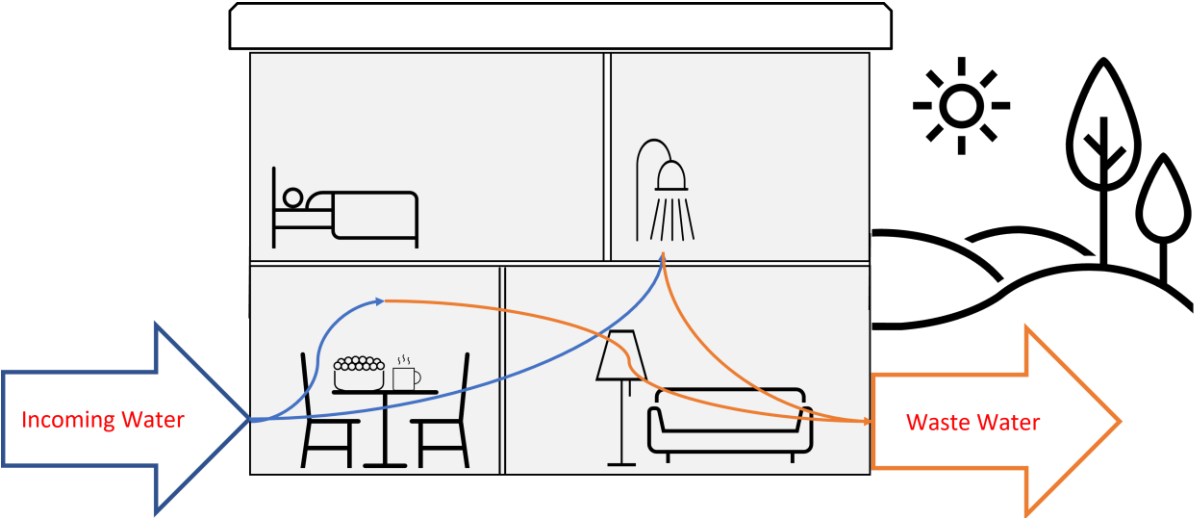


Figure 37 Schematic Water Cycle in normal household (own creation)

In many cases, this water is heated before use. After use, the water from all consumers is discharged directly into the sewer system. This results in an outflow of wastewater in approximately the same amount as there is inflow.

3.4.2. Possible Reuse of Wastewater, Rainwater and Supply Water

The path of the same water is significantly longer in a green building, as **Figure 38** shows. In a green building, the idea of circular economy and reuse counts. The first major advantage shown in **Figure 38** is the significantly reduced inflow of fresh water and outflow of waste water.

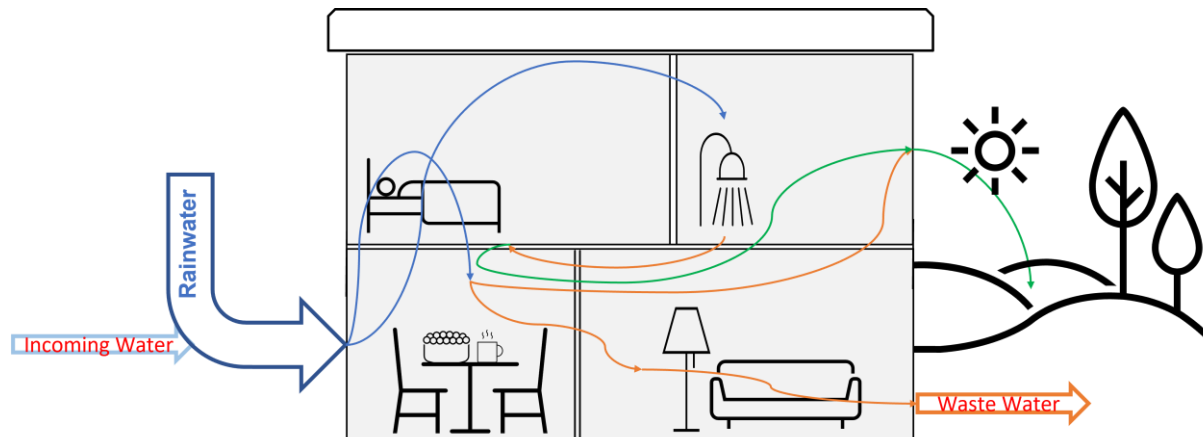


Figure 38 Schematic Water Cycle in Green Building households (own creation)

This can be achieved by collecting rainwater from the roof and replacing the incoming water. As described in the previous chapters, this can be processed into service water using special treatment units or the Green Roofs itself. The rainwater replaces a large part of the fresh water previously used. This can go so far that there is only one water tap with fresh and cold drinking water per residential unit and the remaining needs are to be supplied with treated rainwater.

The reduction in wastewater outflow results from the many small energy cycles that have been closed in comparison to normal households. These include:

- Using rainwater / graywater to flush toilets
- Use of more economical but technically more complex toilet systems (vacuum toilet, foam flush toilet)
- Black water and kitchen waste to produce biogas in own biogas plant
- Low-polluted grey water for watering green walls and gardens

- Infiltration of excess gray water via green walls into the soil

This leads to a significant relief of the sewage system and creates opportunities to think in terms of sponge city on a city level.

3.4.3. Pollutants Overview

Persistent organic pollutants (POPs) are chemical compounds that are persistent and toxic and can accumulate in the environment and human body. Some of the best known POPs are dioxins, furans, and polychlorinated biphenyls (PCBs).

These pollutants can come from a variety of sources, including industrial waste, agricultural practices, and household chemicals. Some of these pollutants eventually enter wastewater and can be released untreated into the environment.

The Stockholm Convention on the Control of POPs is an international agreement that aims to control and reduce these pollutants. It requires signatory countries to take measures to limit the production and use of POPs and to regulate the handling of waste containing these pollutants. (Secretariat of the Stockholm Convention 2019) (Umweltbundesamt)

It is important that domestic wastewater is monitored for POPs to ensure that these pollutants do not enter the environment and cause adverse health and environmental effects. Implementation of the Stockholm Convention can help reduce POPs in domestic wastewater and minimize their impact on the environment.

3.4.4. Water Treatment Technologies

Physical treatment processes are those processes whose effect is exclusively due to physical laws. This includes all techniques based on the following physical laws:

- Sedimentation
- Flotation
- Adsorption
- Filtration

(Wilhelm S. 2008, S. 110)

Figure 39 shows an overview of the filtration types of their range of action.

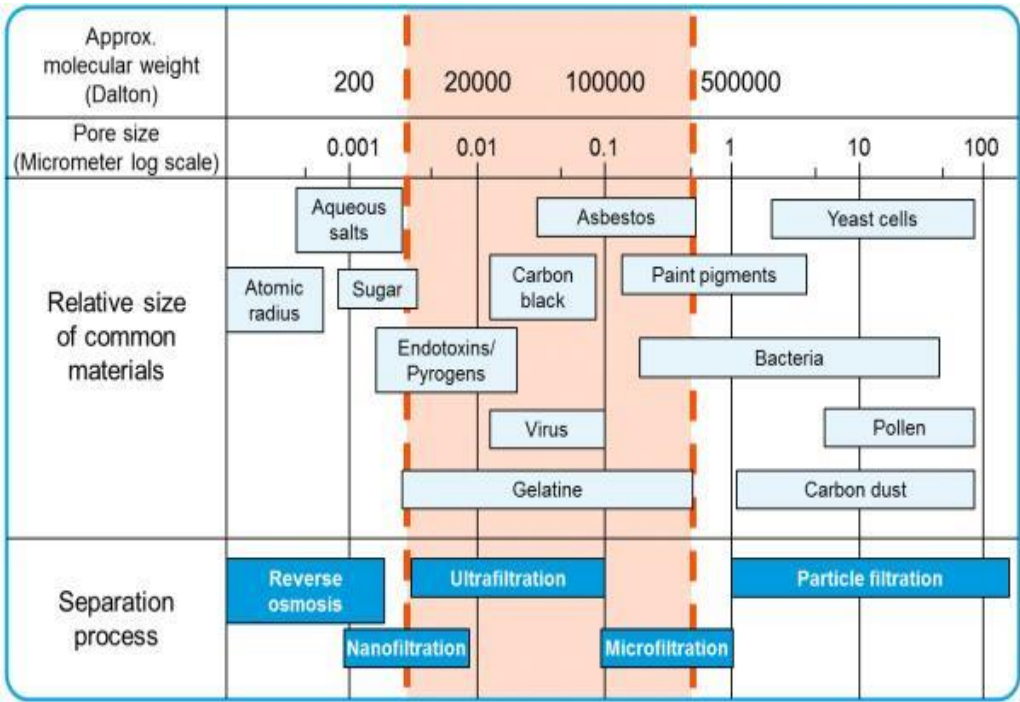


Figure 39 Classification of membrane processes (Alpha Plan 2021)

Most physical applications of treatment in green building are limited to filtration. In addition to these, the author considers ozonation and photocatalysis worth mentioning. These technologies need to be further monitored, as the author believes they will only receive potential attention for green buildings

in the future. Ozonation, photocatalysis, membrane filtration, and adsorption are measures that can help remove persistent organic pollutants (POPs) from domestic wastewater. For further information on these topics, the author recommends the book "Water Treatment Chemistry and Chemical Engineering" with the number ISBN 978-3-540-25163-7 .

3.4.5. Energy Recuperation

In the future, heat recuperation will be important in Green Buildings as it offers an efficient way to use heating and cooling energy while reducing energy consumption. This leads to a reduction in CO₂ emissions and lower energy costs for the building operator. It also contributes to sustainability and supports energy efficiency goals related to climate protection.

3.5. Stakeholder

Stakeholders play an important role in certified Green Buildings in Germany. The author was able to identify the following stakeholders with the help of brainstorming. These are people or organizations who are directly or indirectly affected by the construction and operation of a green building or who can influence it. Stakeholders can have very different interests and goals, such as investors and owners, tenants, government agencies and planners, architects and engineers, builders and contractors, facility managers, environmental organizations and sustainability consultants, residents, financial institutions, banks, and insurance companies.

For investors and owners, the profitability and long-term nature of the investment are crucial. They want to ensure that the building meets the highest standards in terms of sustainability and environmental protection, so that a high return can be achieved. Government agencies and planners want to ensure that the building is compliant with laws and regulations and contributes to the achievement of climate protection goals. Architects and engineers want to ensure that the building is technically sound and meets the requirements of the certification. Builders and contractors are responsible for constructing the building and want to ensure it meets the requirements of the certification. Facility managers are responsible for the operation and maintenance of the building and

want to ensure that it is operated in a sustainable and energy-efficient manner. Environmental organizations and sustainability consultants want to ensure that the building meets the highest standards in terms of sustainability and environmental protection. Residents want to live and work in an environmentally friendly and healthy environment. Financial institutions and banks want to ensure that the building is a safe investment and meets the highest standards in terms of sustainability. Insurance companies want to make sure the building is safe and has a low risk of damage.

It is important that all stakeholders are considered when planning and implementing green buildings in Germany. Successful implementation requires collaboration and alignment between all stakeholders to align the goals and interests of each stakeholder to create a sustainable and efficient building that benefits all stakeholders.

4. Method Description Potential Analysis

In the context of certified Green Buildings, the efficient use of resources and energy is becoming increasingly important. In this context, it is important to use suitable systems and devices. Pumps and valves are essential components of building technology and play a decisive role in the supply of water and the control of heating and air conditioning systems. In order to convey a picture of what the author sees as relevant areas for KSB products in certified green buildings, the method of potential analysis was chosen. In the following chapters, the underlying method will be discussed first. In the following, criteria are compiled and formed into potentials. The criteria of the potentials are then evaluated based on the preliminary model of sustainability, in a self-generated point system. The scoring reflects the opinion of the author and should help the readership to prioritize the potentials among each other. The information comes both from research on green buildings and from the findings gathered from interviews with various experts in relevant fields.

4.1. Theoretical / Scientific Background

The underlying literature contains many different sources on methods for comparing and evaluating potentials. Among the methods studied for their suitability are analogies, expert interviews, structured estimation methods, analytical estimation methods and customer responses. The authors, who have examined and compiled these methods, are of the opinion that: "From the mentioned advantages and disadvantages of the available methods for market and sales potential estimation it becomes obvious that there is no procedure which is clearly superior to all others. The selection of a certain method has to be made against the background of the given situational conditions [...]." (Holzmüller H. und Böhm B. 2007)

For these reasons and in view of the broad field of technology, the author of this paper decided to interview experts from the industry. Management consulting companies, for example, evaluate their potential with points in tables. (Gunter Becker Managementberatung GmbH 2019) This served as the basis for the author to build up his own point system in order to present and evaluate the potentials in this work. The experts' statements influence the scoring that follows later.

4.2. Derivation of Potential Criteria from Literature and Questioning

Previous chapters have presented the diversity of buildings and technology, now attributes from literature research and interviews are brought together to form Potentials. Deriving potential attributes from literature and interviews is a crucial step in defining the potential of pumps and valves in certified green buildings. This work therefore makes an important contribution to the promotion of sustainability in building services.

Some of the potentials that follow now will have the attribute "Global Green Buildings Strategy". The author aims to express that the respective technology behind the attribute and ultimately also behind the potential is used in most of the world.

Potential #1 – Heat Recuperation

The First Pyramid in **Figure 40** and therefore the first potential that certified Green Buildings offer is the topic of *heat recuperation*. Heat recovery by heat pumps is an important feature of sustainable buildings. In chapter **2.6. Future Development**, one can read about the future efforts of the German government on the point of heat pumps. The plan to have sold and installed 6 million heat pumps by 2030 is a specific objective of the German government for sustainable buildings and therefore an attribute for the potential of heat recovery. In the implementation of this project, it is assumed that the market volume will increase from 55 billion in 2018 to approximately double by 2026.

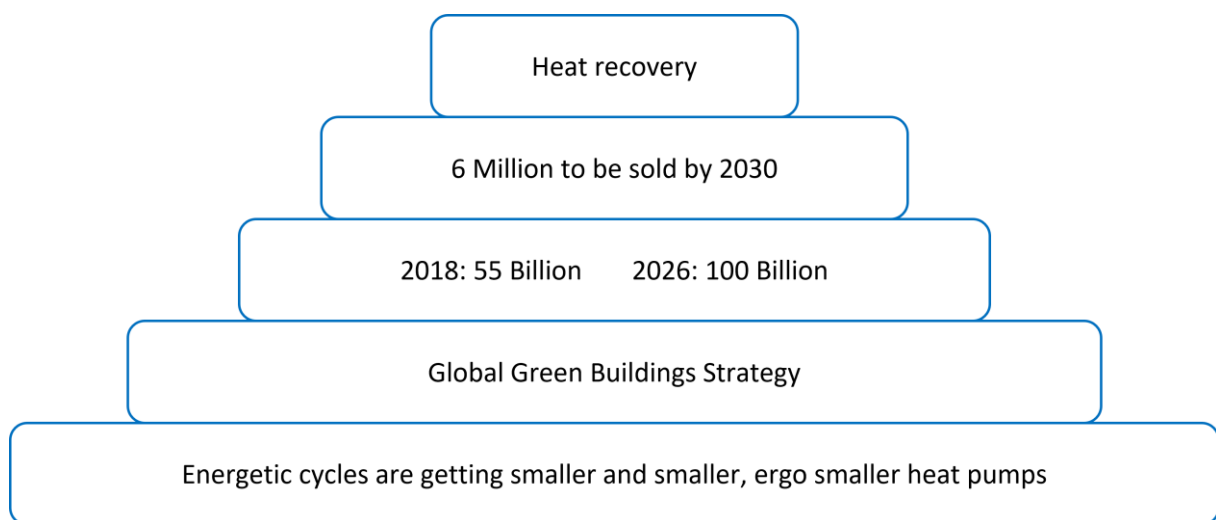


Figure 40 Potential #1 - Heat Recuperation (own creation)

According to the author's findings, the principle of heat recovery can be applied in most parts of the world and is an indispensable measure in terms of sustainable supply. This is the case, for example, for a building that is to be designed sustainably and achieve the highest possible rating in one of the certification systems. This helps the environment, conserves resources and raises or at least consolidates the value of the building for the future. For this reason, the attribute of a "Global Green Buildings Strategy" belongs to the potential of heat recuperation.

In chapter **3.4.1. General Explanation** and **3.4.2. Possible Reuse of Wastewater, Rainwater and Supply Water**, the energy cycles occurring in the household are discussed in more detail. It can be observed that the tapping of heat, preferably directly after the end of the use of the medium by the consumer,

is increasingly sought after. This means that heat recovery systems, such as Revincus from chapter 2.3.3. **Wastewater**, will have to rely on heat pumps with a lower nominal heat output.

Potential #2 – Original Equipment Manufacturer (OEM)

The potential that now follows in **Figure 41** represents an opportunity to position KSB and its products as an *OEM partner* for facade and green roof systems. It should be noted that not all systems and therefore not all manufacturers are eligible.

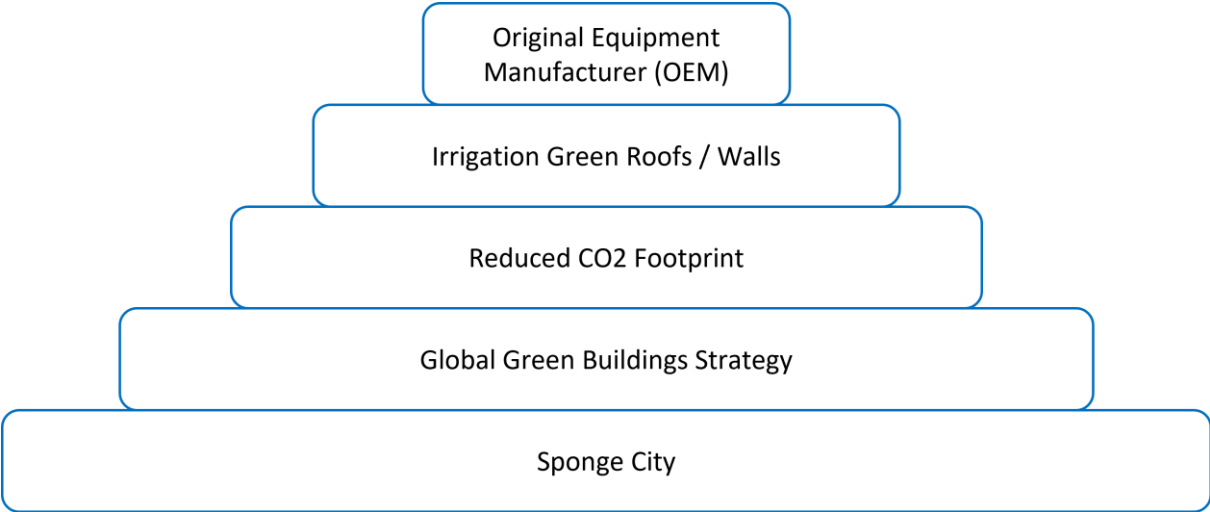


Figure 41 Potential #2 - Original Equipment Manufacturer (OEM), (own creation)

The literature research shows that this is possible for the following systems:

- All Facade Bound Green Walls
- Blue Roof
- Intensive Roof
- Blue Green Roof
- Purple Roof
- Water Gardens

After reviewing the literature, the author feels reinforced in his opinion that the principle of urban greening is present in large parts of the world and is therefore a “Global Green Buildings Strategy”. Some regions in the world are paying more attention to this issue. Thus, in areas that are definitely

more affected by climate change or pollution, larger and larger urban greening projects are emerging. In countries like Germany, this type of climate adaptation of buildings and cities is also already part of the future building strategy. This is shown by projects in Berlin or also Schauenstein in **5.1. Elementary School of Schauenstein - Example**. The idea OEM partners for greening systems does not end with urban greening. As a supplier of reliable pumps and gate valves, there is potential in projects related to Sponge City to establish the company as a reliable partner to various cities and regions. However, in order not to leave the scope of this thesis on Green Buildings, this is only one attribute of the potential and will only be treated superficially. In the area of Sponge City, an independent analysis is recommended due to the extensive subject area. Nevertheless, things like water storage basins or water retention basins are in the field of KSB and a Sponge City.

Potential #3 – Water Management

The third potential in **Figure 42** is *water management*. Water management includes various water lines in the house. These are rainwater, gray water from toilets, showers and others, and process water. These must increasingly be stored or moved in certified green buildings. Water management is one of the "Green Building Strategies" and is becoming essential for future sustainability in one form or another.

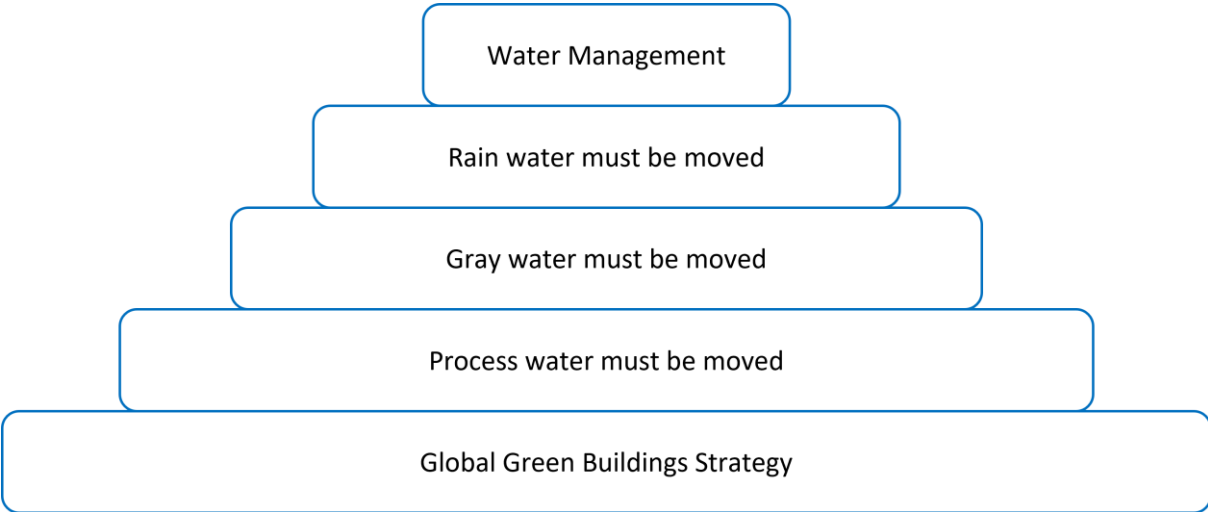


Figure 42 Potential #3 - Water Management (own creation)

In many countries around the world, access to clean drinking water is not as easy as in industrialized countries. The problems of getting clean drinking water on demand are not known in Germany. The absence of problems makes people less aware of the problem. This is the reason why the topic of water management is considered and implemented differently in different countries of the world. Nevertheless, the topic of water management is widespread throughout the world, a major task of Green Buildings and therefore a "Global Green Buildings Strategy".

Potential #4 – Connectivity

The last potential seen in **Figure 43** is about the *connectivity* of the future products. Digitalization is taking hold everywhere, including in the building sector. Chapter **2.5. Digitalization** and **2.6. Future Development** are intended to show the reader the direction in which things are developing. Thanks to the cooperation between KSB, the University of Cologne, and the German Engineering Federation (VDMA), an initial prototype is possible. The IT structure created there must be implemented and tested. The prototype is the chance to prove that the model is up to the demands of everyday life and capable of more.

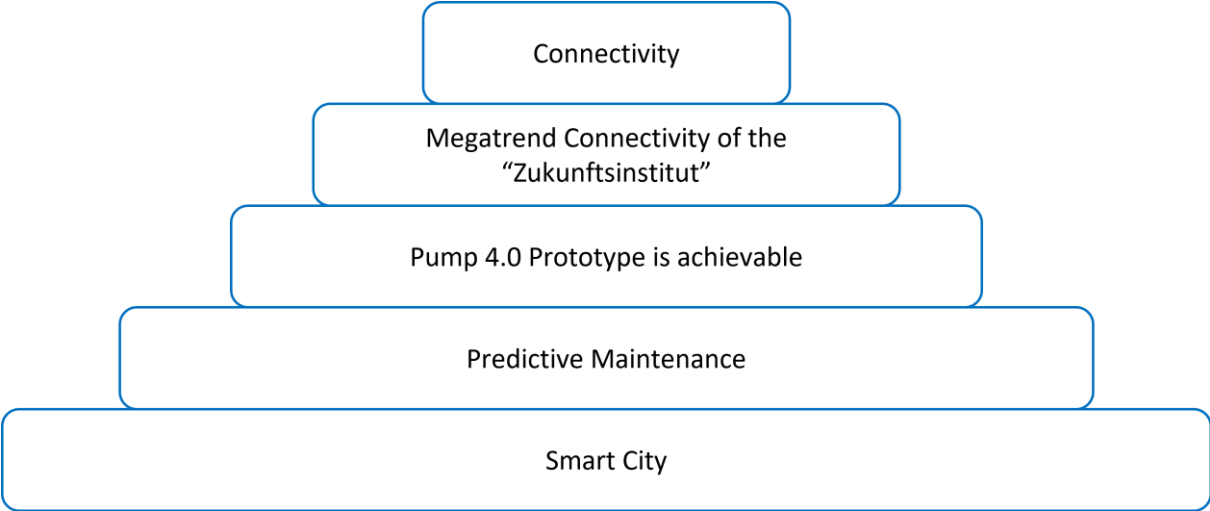


Figure 43 Potential #4 – Connectivity (own creation)

For the Zukunftsinstitut, the trend toward connectivity is even a megatrend. The Zukunftsinstitut was founded in 1998 and has played a key role in shaping trend and future research in Germany from the very beginning. In the course of progressive networking, basic human needs such as trust and security

as well as cultural and social aspects are becoming increasingly relevant for digital business models and for the design of products and services. (Zukunftsinstitut GmbH)

As in Trend #2 - OEM the potential is not only conceivable in the area of Green Building but also in the area of Sponge City, so it is here with Smart City. Connectivity and interoperability are important not only for the company's own products. Among other things, the author considers pumps and valves as the smallest unit in Green Buildings, which together represent a Green Building at the building level. If we look at the city level, these smallest units of a green building will no longer be seen. At the city level, the author again looks at a green building as the smallest unit, which together make up a green, sustainable, and digital city.

4.3. Development of the Potential Analysis Model

Now that the previous chapter has brought attributes together to form potentials, the following section will now evaluate these attributes. Looking at the heterogenic attributes, it is clear that a similarly broad model is needed for the evaluation. The model selected here is the priority model of sustainability and is a further development of the three-pillar model of sustainability. But why this model and why the priority model? So why this model? Simple, it was created specifically for sustainable development and is one of the most widely used models. And why priority model and not the three-pillar model?

To do this, one needs to take a closer look at the two models in **Figure 44** and **Figure 45** and think them through with a small example.

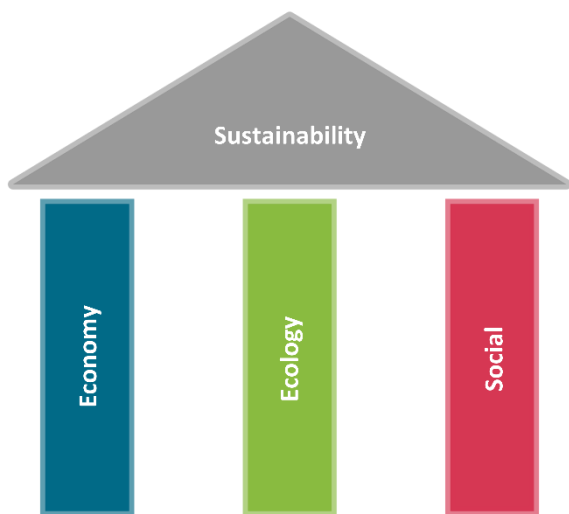


Figure 44 Three Pillars Model of Sustainability (Schwill M. 2023)

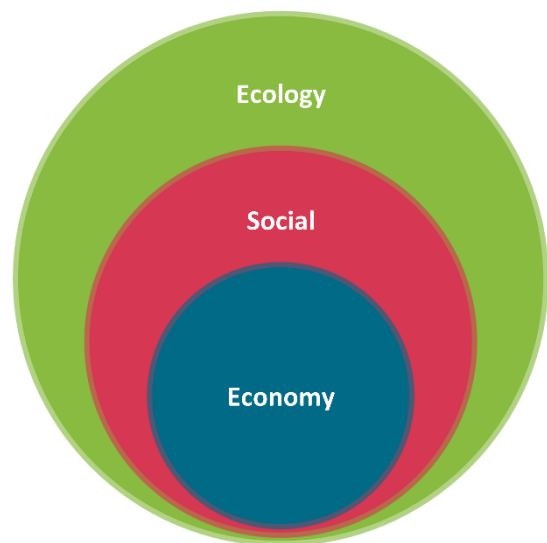


Figure 45 Priority Model of Sustainability (Schwill M. 2023)

The illustrations already show the most obvious difference, the three-pillar model pretends that all 3 dimensions are absolutely equally important and that deficits of one pillar can be compensated with plus points in one of the 2 other pillars without the roof collapsing. It stands for a balance of the three different interests. The goal here is to consider and improve economy, ecology, and social issues on an equal footing, since only the joint consideration of the areas leads to sustainable development. This is also to be understood as weak sustainability. (Schwill M.)

In the priority model, there is a clear weighting. The following applies here: ecology before social issues before economy.

What does this mean in an example? If, for example, a public swimming pool is built and a natural lake is filled in for it, this is acceptable in terms of the three-pillar model because the swimming pool improves social sustainability. Also, the destruction of the ecosystem "lake" is acceptable since the construction of the swimming pool creates jobs and thus increases economic growth.

The priority model sees the same situation quite differently. By the destruction of the ecology the basic condition for life is missing, without ecology no social stability and without social stability no useful economy. This view is called strong sustainability. Here the obeying of ecological borders is

indispensable, because only in such a way stable living conditions can develop on earth in the long term. The ecology forms the borders in which social and economy can be seen. (Schwill M.)

For these reasons, the author decided to use the Priority Model. The ranking of the sustainability dimensions will be reflected in the following evaluation of the potential attributes. For each of the attributes, benefits were collected and sorted into the different dimensions to enable an evaluation of the potentials. Since in this *priority model of sustainability* the dimensions Social and Economy take place within the boundaries of Ecology, benefits of this dimension are given 1 point/benefit. Benefits of the Social dimension are given 0.9 points/benefit. Following this logic, benefits of the Economic dimension will get 0.8 points/benefit. This is to bring the hierarchy from the model into the evaluation.

$$\begin{aligned} \text{Total score} = & \text{Number of environmental benefits} + (\text{Number of social benefits} \times 0.9) \\ & + (\text{Number of economic benefits} \times 0.8) \end{aligned}$$

Heat Recovery

For each figure with benefits like **Figure 46**, there is also a rating table that shows the achieved points in **Figure 47**. In the field of heat recovery, the advantages are primarily economic and secondarily ecological.

Heat Recovery	Environment	Social	Economic
6 Mio sell	<ol style="list-style-type: none"> 1. Technology upgrade 2. CO2 Reduction 3. Reducing the use of fossil fuels 	<ol style="list-style-type: none"> 1. Increase of comfort for the users through optimal control of room temperature and heating comfort 2. Increasing health through reduction of pollutant emissions 	<ol style="list-style-type: none"> 1. Cost savings through the use of renewable energy sources 2. Creation of jobs in the renewable energy sector 3. Support of the local economy 4. Cost savings through the use of renewable energy sources 5. Cost savings due to technology becoming more efficient
OEM for Heat Pumps		<ol style="list-style-type: none"> 1. Gaining customer trust 2. Contribution to the energy transformation: Partnering with a heat pump manufacturer can help drive the energy turnaround and therefore ensure a sustainable energy supply in the long term. 	<ol style="list-style-type: none"> 1. vertical / lateral diversification 2. Entering new markets 3. Improving own image 4. Increase in value added, in own production 5. Strengthening customer loyalty 6. Access to new technologies 7. Increasing sales
GGBS	<ol style="list-style-type: none"> 1. Reduce dependence on fossil fuels 2. Promote energy security 3. Reduce emissions of greenhouse gases and other pollutants that contribute to global warming. 4. Air quality improvement 5. Increasing the energy efficiency of buildings and industrial plants 6. Reduction of energy loss through improved use of waste heat 7. Reduction of primary energy demand through use of waste heat 8. Conservation of natural resources 	<ol style="list-style-type: none"> 1. Raising awareness of the importance of renewable energy and sustainable technologies 2. Reduction of noise emissions due to lower energy generation 3. Increasing comfort in buildings by reducing temperature fluctuations 4. Improvement of indoor quality 	<ol style="list-style-type: none"> 1. Cost savings through the use of renewable energy sources 2. Energy cost savings through efficient use of thermal energy directly on site 3. Increasing the efficiency and productivity of buildings through lower energy costs 4. Increasing the service life of equipment through reduced load and avoidance of overheating 5. Reducing dependence on fossil fuels and therefore securing energy supply and competitiveness 6. Revenue generation
smaller energy cycles	<ol style="list-style-type: none"> 1. More efficient 2. Prevention of energy waste 3. Reduction of primary energy demand 4. Conservation of natural resources 5. Reduction of greenhouse gas emissions through reduction of energy consumption 6. Improving water quality by reducing heat loads in rivers and water bodies. 7. Avoiding overloads in wastewater treatment plants that can result from high heat inputs. 8. Reducing environmental pollution by using fewer chemicals in wastewater treatment plants and in water treatment. 9. Preservation of natural habitats through reduced pollution of rivers and water bodies 10. Promotion of sustainable and resource-conserving water use 	<ol style="list-style-type: none"> 1. Raising awareness of the importance of renewable energy and sustainable technologies 	<ol style="list-style-type: none"> 1. Cost savings through the use of renewable energy sources 2. Cost savings due to technology becoming more efficient 3. Energy cost savings through efficient use of thermal energy directly on site 4. Increasing the efficiency and productivity of buildings through lower energy costs 5. Increasing the service life of equipment through reduced load and avoidance of overheating 6. Reducing dependence on fossil fuels and therefore securing energy supply and competitiveness 7. Avoiding penalties and fees: Some countries have legal requirements to reduce emissions of greenhouse gases and waste heat, which carry hefty penalties and fees if not met. By directly applying heat recovery, companies can meet these requirements and save costs 8. Revenue generation

Figure 46 Advantages of Attributes: Heat Recovery (own creation)

Heat Recovery	Environment	Social	Economic	Single result	Total
6 Mio sell	3	2	5	8,8	49,9
OEM for Heat Pumps	0	2	7	7,4	
GGBS	8	4	6	16,4	
smaller energy cycles	10	1	8	17,3	

Figure 47 Rating Table - Heat Recovery (own creation)

The author considers any type of heat recovery to be a "Global Green Buildings Strategy". Water to water or air to water heat recovery is essential to have a sustainable building. This technology is not only suitable for wastewater in green buildings, but also for the building's exhaust air.

Connectivity

Connectivity	Environment	Social	Economic
Megatrend	<ol style="list-style-type: none"> 1. Increase energy efficiency through precise monitoring and control 2. Resource efficiency by minimizing wastage 3. Smart grids: Connectivity enables the integration of renewable energy and the deployment of smart grids, leading to improved grid stability and better use of renewable energy. 4. Sustainable infrastructure: Connectivity enables buildings and housing developments to be better connected to sustainable infrastructure, such as public transport or bicycle paths 5. Optimizing building life: connectivity and predictive maintenance can detect and fix potential damage or problems at an early stage 6. Improving resource efficiency 	<ol style="list-style-type: none"> 1. Safety through monitoring and control of safety-critical systems such as fire protection systems. 2. Increased comfort for building users through optimized control of lighting, air conditioning and ventilation. 3. Smart building technology enables greater usability and comfort for building users 4. Increased security for residents can be achieved by networking building systems, e.g. automatic fire alarms or anti-intrusion systems 5. Smart technologies enable users to better control and optimize their energy consumption and costs 6. Increased awareness of sustainability among users who are involved in the process 	<ol style="list-style-type: none"> 1. Cost saving: Through the use of connectivity technologies, green buildings can collect and analyze data in real time, which can lead to cost savings in maintenance, repairs and energy management 2. Avoidance of downtime 3. Increase of productivity 4. New business opportunities: Connectivity enables companies to develop new business opportunities and innovative green building products and services 5. More efficient workflows: Connectivity can also lead to more efficient workflows by improving communication and collaboration between employees, helping to increase productivity.
Prototype achievable	<ol style="list-style-type: none"> 1. Energy efficiency 2. Ressource efficiency 		<ol style="list-style-type: none"> 1. Consolidate leading position in the market 2. Increase know-how 3. Future-oriented products 4. Competitive advantage 5. Opening up new markets 6. Increasing customer satisfaction: A smart and digital pump can help increase customer satisfaction by responding more quickly to disruptions and increasing the efficiency of processes 7. Increase maintenance efficiency
Predictive Maintenance	<ol style="list-style-type: none"> 1. Resource efficiency through extended product lifetime 2. Energy efficiency through avoidance of downtime 3. Avoid waste of resources through effective maintenance planning and execution 4. Reduction of waste and trash by avoiding unnecessary repairs and replacement of components. 		<ol style="list-style-type: none"> 1. Reduced maintenance costs through effective and forward-looking planning of repairs and replacement of components. 2. Increased availability of building technology, as unplanned downtime is minimized. 3. Extension of the service life of systems and equipment, generating investment in new technologies. 4. Increased energy efficiency through regular monitoring and optimization of systems and equipment. 5. Reduction of downtimes and therefore avoidance of production losses or operational interruptions. 6. Improvement of customer satisfaction through reliable and trouble-free building technology that enables smooth building operation. 7. Optimization of operating costs, as targeted investments are made in the maintenance of plant and equipment and unnecessary repair costs can be avoided. 8. Increased employee productivity, as they can focus on their work without being distracted by technical issues. 9. Improved data basis and decision-making through regular monitoring of systems and equipment. 10. Increased energy efficiency through optimized control and monitoring of energy consumption and demand
Smart City	<ol style="list-style-type: none"> 1. Energy efficiency 2. Sustainable mobility 3. Ressource efficiency 4. Water resource management 5. Traffic reduction 6. Preventing environmental disasters: Smart cities can help prevent environmental disasters such as floods and forest fires or reduce their impact by providing early warning and enabling rapid response actions 7. Emissions reduction 	<ol style="list-style-type: none"> 1. Improved quality of life through smart city management, e.g., optimized urban planning, improved public services and infrastructure 2. Improved public safety through monitoring and prevention of crime and emergencies, e.g. through intelligent video surveillance and rapid response to emergencies 3. Increased citizen participation in decision-making processes and stronger community building 4. Improved access to education, culture and sports through smart education and culture systems and digital platforms 5. Improved health care delivery and prevention through the implementation of health data management systems 6. Accessibility: Smart cities can use technologies that increase the mobility of people with disabilities, such as adaptive traffic lights or automated buses. 7. Inclusion: Smart cities can promote the inclusion of minorities and marginalized groups, e.g., by facilitating access to education and health services or solving language barriers 	<ol style="list-style-type: none"> 1. Risk mitigation: Smart cities can reduce the risks of natural disasters and infrastructure failures by using intelligent early warning systems and emergency management solutions 2. Ressource efficiency 3. Energy efficiency 4. Economic growth: Smart cities can spur economic growth by encouraging the creation of new jobs in areas such as technology and infrastructure 5. Increased revenue: By applying technologies and implementing smart grid solutions, smart cities can generate revenue, e.g., through the sale of surplus energy 6. Sustainable Economy: smart cities can contribute to a more sustainable economy by promoting the use of renewable energy and efficient resources 7. Tourism: smart cities can promote tourism by creating a positive and unique experience for visitors, e.g., by creating smart and green spaces 8. Increasing attractiveness: which can lead to more people moving to the city or companies settling there, thus strengthening the city's economic potential

Figure 48 Advantages of Attributes: Connectivity (own creation)

In **Figure 48** the benefits of the potential connectivity can be seen. With the increasing connectivity of an asset in a building, it is possible for the system to give feedback to the user about its current situation. This is important at the level of individual installations as well as at the city level. First,

individual assets such as pumps need to be able to give feedback on their situation before an overall report on the current situation and state of the building can be given from multiple feedbacks from multiple assets at the same time. Connectivity is a basic requirement for a smart city. **Figure 49** shows that there are many economic opportunities in the field of digitization.

Connectivity	Environment	Social	Economic	Single result	Total
Megatrend	6	6	5	15,4	54,7
Prototype achievable	2	0	7	7,6	
Predictive Maintenance	4	0	10	12	
Smart City	7	7	8	19,7	

Figure 49 Rating Table - Connectivity (own creation)

Original Equipment Manufacturer (OEM)

The potential seen in **Figure 50** to become an OEM partner for urban greening is an opportunity in several directions. First, the author is convinced that urban greening, regardless of its type, is a "Global Green Buildings Strategy". Projects like Forest City, Berlin or Basel show how much these concepts are coming and at the same time how much they are still at the beginning of people's perception.

OEM	Environment	Social	Economic
Irrigation	<ol style="list-style-type: none"> 1. Contributing to the creation of resilient, climate-friendly cities 2. Increasing the natural aesthetics and beauty of the environment 	<ol style="list-style-type: none"> 1. Increase brand awareness 2. Strengthening the community's identity and sense of belonging through joint work on greening projects 3. Improving the quality of life in urban residential areas by creating green spaces and parks 	<ol style="list-style-type: none"> 1. Increase awareness and realization in numerous large projects, e.g. Forest City, Berlin 2. Increasing the value of real estate in the surrounding area through the creation of attractive green spaces 3. Reducing energy costs by reducing heat islands and lowering building energy consumption through shading 4. Cost savings through the reduction of water runoff and storm water volumes 5. Synergy effects: The partnership can achieve synergy effects by both companies pooling their strengths and resources to achieve better results together 6. Innovation potential: the partnership can help increase the innovation potential of both companies by jointly developing new products and services 7. Reputation enhancement: cooperation with a company specialising in green technologies can help strengthen KSB's image as an environmentally friendly company 8. Expansion of the business area: The partnership enables KSB to expand its business areas and gain new customers who are interested in environmentally friendly and sustainable buildings 9. Increasing sales: Collaboration can help increase sales for both companies as demand for green buildings continues to grow 10. Market development: By working with a company that is already established in the industry, KSB can tap into new markets and customer segments
GGBS	<ol style="list-style-type: none"> 1. Retention 2. Detention 3. Insulation effect 4. Cooling of the building 5. CO2 reduction 6. Reduction of heat islands 7. Provides habitat and food sources for wildlife and insects in the city 8. Reduces air pollution and improves air quality by filtering pollutants from the air and producing oxygen 9. Prevents soil erosion and improves soil quality by adding nutrients and organic materials 	<ol style="list-style-type: none"> 1. Recreation in greened zones 2. Improving mental and physical well-being by creating natural environments and places of retreat in urban areas 3. Creation of community spaces and social meeting places 	<ol style="list-style-type: none"> 1. Intensive Green Roof 2. Facade Bound Green Wall 3. Purple Roof 4. Water Gardens 5. Forest City, Berlin 6. Increasing the value of real estate in the surrounding area by creating attractive green spaces 7. Increasing the value of real estate in the surrounding area through the creation of attractive green spaces
Sponge City	<ol style="list-style-type: none"> 1. Retention 2. Detention 3. Insulation effect 4. Cooling of the building 5. CO2 reduction 6. Reduction of heat islands 7. Provides habitat and food sources for wildlife and insects in the city 8. Reduces air pollution and improves air quality by filtering pollutants from the air and producing oxygen 9. Prevents soil erosion and improves soil quality by adding nutrients and organic materials 	<ol style="list-style-type: none"> 1. Recreation in greened zones 2. Increasing the resilience of cities to the impacts of climate change 3. Promote education and awareness of environmental issues by incorporating water management activities into educational and informational programs 4. Creates jobs in the field of landscape architecture and landscaping 	<ol style="list-style-type: none"> 1. Storage Basin 2. Tree Rigs 3. Wetlands 4. Retentionpond 5. Retaining basin 6. Increasing the value of real estate in the surrounding area through the creation of attractive green spaces 7. Wells and cisterns that can store and recycle rainwater 8. Drainage channels and drainage systems that transport stormwater to storage facilities 9. Pump stations and gates that can control the flow of water and detain or divert water in drainage channels as needed

Figure 50 Advantages of Attributes: OEM (own creation)

The Basel region has become a world center for green roofs. With the help of a funding program, more than 100 green roof projects were realized within one year. Today, the city of Basel has the highest green roof ratio in the world, with approx. 7 m² of green roof area per inhabitant. In the canton of "Basel-Landschaft", too, roof areas are being greened more and more frequently. (Brenneisen S 2020; Verein Dachbegrünung Region Basel)

From the distribution of points in **Figure 51**, it can be seen that there are great economic and environmental opportunities.

OEM	Environment	Social	Economic	Single result	Total
Irrigation	2	3	10	12,7	50,8
GGBS	9	3	7	17,3	
Sponge City	10	4	9	20,8	

Figure 51 Rating Tables - OEM (own creation)

Water Management

The potential water management in **Figure 52**, is also part of the "Green Buildings Strategy" according to the author. Due to the scarcity of clean drinking water in the world, water management is also an indispensable concept to address this problem.

Water Management	Environment	Social	Economic
Rain Water	<ol style="list-style-type: none"> 1. Reduction of the load on the public sewage system 2. Protection of water bodies from overloading 3. Protection of water bodies from pollutant inflow 4. Reducing the risk of flooding: Rainwater management systems can help prevent flooding in urban areas by storing and using rainwater safely and effectively 5. Protection of natural resources 6. Support of the local water balance and groundwater recharge 7. Promotion of biodiversity through creation of wetland biotopes 8. Reduction of CO2 emissions through savings in energy-intensive drinking water treatment and transport 9. Contribution to climate change adaptation through reduction of drought risks 10. Reduction of water consumption from the public network 	<ol style="list-style-type: none"> 1. Increasing water quality primarily in developing countries: rainwater systems help make water in buildings cleaner and safer by reducing the use of contaminated water from public systems 2. Improving awareness of resource use and its scarcity 3. Increasing responsibility and identification with the building 4. Integration of rainwater-based concepts into urban landscape planning 5. Improvement of the quality of life through an increased quality of time spent in the building and in the outdoor area 6. Promoting social community cohesion through joint rainwater harvesting projects 7. Increasing the attractiveness of the building by integrating sustainable technologies 8. Communicating ecological and sustainable values to the community 	<ol style="list-style-type: none"> 1. Increase the building's value 2. Reduce water and wastewater costs by using rainwater that would otherwise be discharged into the public sewer system 3. Increase energy efficiency by reducing the need for costly water treatment processes 4. Drinking Water reduction 5. Savings in the cost of disposing of rainwater 6. Reduction in maintenance costs of pumps, pipes and equipment due to lower water consumption 7. Increase in property value through integration of rainwater-based concepts
Gray Water	<ol style="list-style-type: none"> 1. Reduction of the load on the public sewage system 2. Protection of water bodies from pollutant inflow 3. Reduction of water consumption and water withdrawal from natural resources 4. Improving water quality by avoiding chemical detergents and soaps in wastewater. 5. Supporting the water cycle by reusing water for irrigation or toilets 6. Maintaining ecological diversity: reducing the extraction of fresh water from natural resources helps maintain ecological diversity by affecting fewer natural habitats 	<ol style="list-style-type: none"> 1. Improving awareness of resource use and its scarcity 2. Increasing responsibility and identification with the building 3. Raising awareness of the economical use of water and resources improving the image of the building through the use of sustainable and resource-saving technologies 4. Improving the image of the building through the use of sustainable and resource-saving technologies 	<ol style="list-style-type: none"> 1. Reducing water costs by using graywater instead of potable water for certain purposes such as toilet flushing, irrigation or cleaning 2. Reducing wastewater costs by generating less wastewater 3. Increased building value by implementing environmentally friendly technologies 4. Savings in energy costs as less water needs to be heated and pumped 5. Potential increase in building attractiveness to tenants or buyers who are environmentally conscious 6. Opportunity to receive public funding for green building technologies and systems 7. Avoiding penalties or fines for excessive consumption of potable water in buildings in areas where water is scarce
GGBS	<ol style="list-style-type: none"> 1. Conservation of natural resources 2. Increasing the energy efficiency of buildings and industrial plants 3. Stable water supply 4. Reduction of the volume of wastewater and therefore less stress on wastewater disposal systems and sewage treatment plants 5. Promotion of biodiversity through the creation of retention basins and green areas for the infiltration of rainwater 6. Improving the soil water table by infiltrating rainwater and therefore supporting plant growth 7. Preventing flooding through stormwater retention and infiltration. 8. Reducing water pollution by preventing combined sewer overflows during heavy rains 9. Preservation of water quality by preventing pollutant inputs through stormwater retention and infiltration 10. Prevention of soil erosion through stormwater retention and infiltration 	<ol style="list-style-type: none"> 1. Promoting health through access to clean water and a clean environment 2. Improving urban aesthetics by incorporating water management measures into the architecture of buildings and public spaces 3. Reducing flooding and therefore protecting people and property 4. Increasing the resilience of cities to the impacts of climate change 5. Promote education and awareness of environmental issues by incorporating water management activities into educational and informational programs 6. Improving social integration and cohesion through the creation of community spaces and projects related to water management 7. Reducing water conflicts through the efficient and sustainable use of water resources 	<ol style="list-style-type: none"> 1. Increase the building's value 2. Potential savings through the reuse of water in production processes or irrigation systems 3. Avoidance of water shortages through effective use and reuse of water 4. Risk reduction through the creation of redundancies and alternative water sources 5. Reduction of water costs through more efficient use and reuse of water

Figure 52 Advantages of Attributes: Water Management (own creation)

The table in **Figure 53** shows the great impact of water management in the economic dimension and especially in the environmental dimension.

Water Management	Environment	Social	Economic	Single result	Total
Rain Water	10	8	7	22,8	58,3
Gray Water	6	4	7	15,2	
GGBS	10	7	5	20,3	

Figure 53 Rating Table - Water Management (own creation)

5. Evaluation of Potential Analysis Model on a Example

The potential analysis prepared earlier is to be considered based on a real-life example. Here, the identified potentials are looked for in the concrete project. 95197 Schauenstein is a municipality in Bavaria. The town is located in the northern part of Bavaria, near the Czech border. The town of Schauenstein is a district municipality in the district of Hof, district, and administrative district of Upper Franconia and therefore part of the region of Upper Franconia. Schauenstein belongs to the planning association Upper Franconia East. (Stadt Schauenstein 2023)

An elementary school in Schauenstein is undergoing general refurbishment. In addition to numerous construction measures that are not relevant to this work, the following chapter deals with the things that are relevant and checks whether and which of the identified potentials are planned.

Subsequently, the results of the potential analysis are analyzed and the technical application potentials of pumps and valves in green buildings are discussed.

5.1. Elementary School of Schauenstein - Example

All information used here about the project, were released by the mayor of Schauenstein Mr. Florian Schaller for use in this framework. Other information has been marked separately.

The elementary school offers classes from 1 to 4. On average, 160 children attend the elementary school. It is attended by pupils from Schauenstein and Leupoldsgrün and the associated districts.

Figure 54 shows the ground plan of the school from a bird's eye view. Building parts A & B in **Figure 54**

are the school building, part C & D are a gymnasium with the associated changing rooms and sanitary facilities.

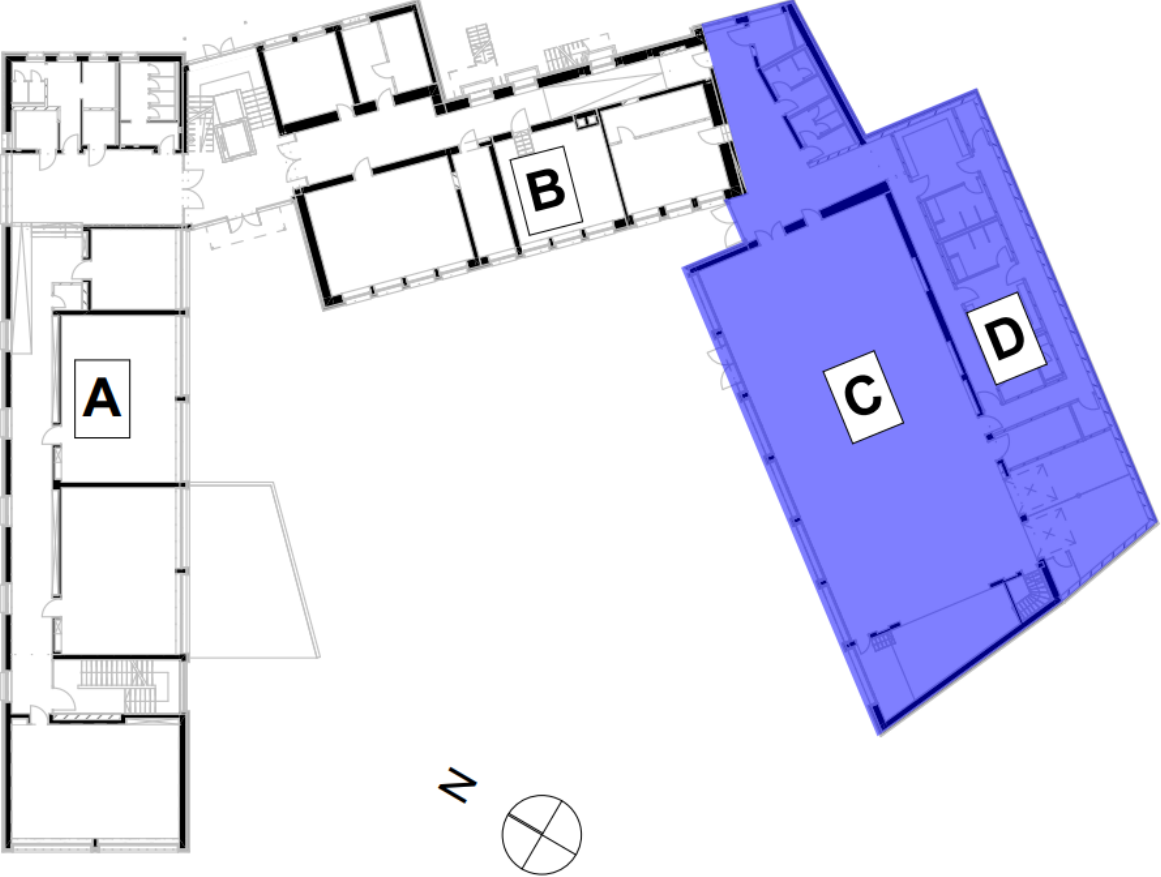


Figure 54 Elementary School Schauenstein Ground Plan

Water Management

In Schauenstein, an innovative rainwater management system is being implemented to deal with heavy rainfall and dry periods. This includes the preparation of a water balance for the Schauenstein elementary school, the calculation of the storage requirements for rainwater retention for heavy rain and dry periods and the preparation of a technical concept for rainwater storage and water distribution.

Gray water recycling **is not planned** for school buildings A & B. Also not in the gymnasium C & D. In the gymnasium, this would not make sense due to very low utilization of the restroom. Additionally, rainwater is used to conserve water on site.

Rainwater **is collected** through the roof of gymnasium C & D and used to irrigate the plants on the site. For this purpose, a 6.5 square meter cistern will be installed to store rainwater. This corresponds to a volume of 6,500 liters. The rainwater storage tank has an emergency overflow and discharges excess rainwater into the sewer system.

Heat Recovery

No measures are implemented on the subject of heat recovery.

Original Equipment Manufacturer (OEM)

The company Sempergreen was contracted to **build a detention roof** on the roof of the gymnasium. The system structure of the detention roof ensures that rainwater is temporarily held back and runoff is delayed. Even when the detention roof is fully saturated with water, it can fully hold back rainwater and delay the flow rates. In terms of irrigation, this type of green roof will rely on artificial irrigation during months with low rainfall, otherwise the vegetation layer would suffer critical damage. To irrigate the Green Roof, the rainwater stored in the cistern is transported back to the roof and used.

Sempergreen is a global company, headquartered in 3984 LR Odijk, the Netherlands. The company was founded in 1996 and is the world's largest and leading supplier of durable quality products for green roofs, green facades and prefabricated ground cover. Various international partners, including Sempergreen and Knauf Insulation, form the basis for the development of the detention roof concept used in Schauenstein. In collaboration with independent researchers, the partners have been conducting research for many years at the Green Roof Diagnostics research laboratory in 22741 Stevensburg, Virginia on the optimal green roof structure, in terms of delayed drainage of rainwater. (Sempergreen 2023)

Connectivity

The importance of building asset *connectivity* in such projects can be seen in the Schauenstein project. Here, work is being done on digital condition monitoring and water distribution control of the water cycle for water management. This is still in the design phase, but the following things are already known. Work is being done on:

- ... a control concept
- ... a monitoring concept and
- ... a data analysis concept.

For this purpose, the needs assessment of the data acquisition is created and the definition and selection of sensors and actuators in, for example, pumps and valves is upcoming.

The following **Figure 55** shows the architecture that will be implemented in Schauenstein, *green* arrows symbolise the exchange of sensor data while the *red* means data exchange and control.

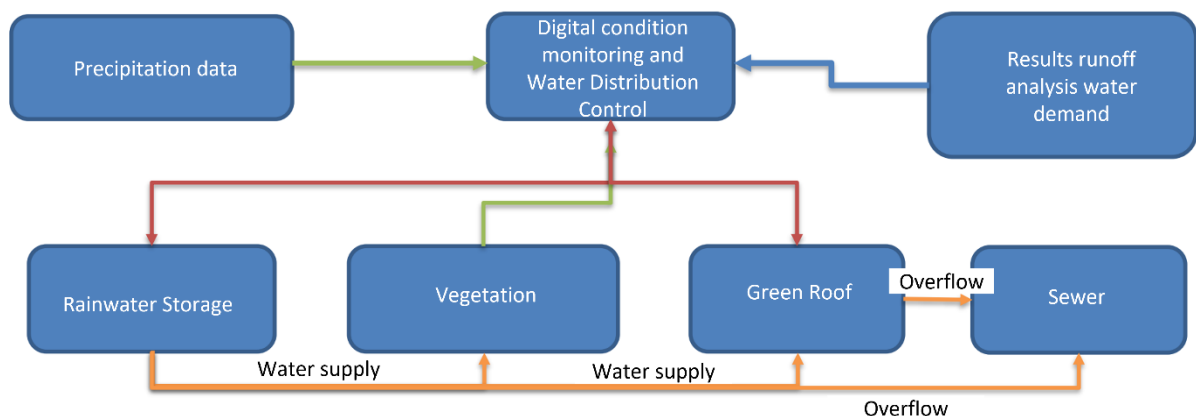


Figure 55 Digital condition monitoring and Water Distribution Control Concept (Müller-Czygan G. 2023)

Building assets need to be more interconnected to support the construction and operation of such systems. As seen in the **Figure 55**, all data converges centrally. Digital condition monitoring is already a precursor to predictive maintenance. This area will enjoy growing popularity in the future.

5.2. Result Analysis

If one puts all the evaluation tables from **4.3. Development of the Potential Analysis Model** next to each other, an order is recognizable. For better illustration, a new line has been added to the previously known tables, which should enable one to also compare the dimensions with each other.

4th Place

Starting with 4th place, the potential Heat Recovery in **Figure 56** has reached 49.9 points. The potential shows a very pronounced economic dimension in **Figure 56**. This is due to the fact that heat pumps are still not very common in the general household. Especially in times when war on Europe's borders makes the supply of energy sources difficult, the economic advantages and the increased independence are felt. Thus, this aspect is the second strongest of all 4 potentials. However, due to the chosen priority model of sustainability, the dimension of economy is not the driving force.

Heat Recovery	Environment	Social	Economic	Single result	Total/Attribute
6 Mio sell	3	2	5	8,8	49,9
OEM for Heat Pumps	0	2	7	7,4	
GGBS	8	4	6	16,4	
smaller energy cycles	10	1	8	17,3	
Total/Dimension	21	9	26		

Figure 56 Extended Rating Table - Heat Recovery (own creation)

Despite its placement in this analysis, fourth place is no reason to believe this would be negligible. Heat recovery technology is classified by the author as a *Global Green Building Strategy*. This potential is not used in the building in the Schauenstein project. From an environmental point of view, the reuse of heat from graywater in buildings where a lot of graywater is produced offers an enormous advantage for the environment. No new resources are consumed, but more benefits are extracted from them. Each heat pump is therefore a kind of Green Hero and contributes to climate-adapted living.

3rd Place

With just one point ahead, the OEM potential in **Figure 57** is in 3rd place. The projects highlighted so far should show the reader that urban greening is an essential trend. Through extensive greening, a city can become more climate resilient, the possibilities of detention and retention prevent or at least reduce the extent of heavy rain events or the reduction of heat islands. All these reasons and more from **Figure 50**, when considering the dimensions individually, make the ecological dimension of OEM the second strongest dimension. Together with the one from the previous potential. Economically, large-scale greening brings great opportunities, should one be a part of such projects.

OEM	Environment	Social	Economic	Single result	Total/Attribute
Irrigation	2	3	10	12,7	50,8
GGBS	9	3	7	17,3	
Sponge City	10	4	9	20,8	
Total/Dimension	21	10	26		

Figure 57 Extended Rating Table - OEM (own creation)

Considering that greening only makes sense on a large scale, it also explains how the economic dimension is also second strongest of all economic dimensions. However, these are not the dimensions that make the difference between 4th and 3rd place. Here it is the social dimension that is the decisive one. KSB's involvement in greening generates more benefits for people than their involvement in heat recovery. This lies in the nature of things, as people find it pleasant and much more when they are surrounded by nature.

2nd Place

The 2nd place is taken by the potential connectivity in **Figure 58**. This potential is very convincing due to its diverse economic follow-up possibilities. Once the basic capabilities of data exchange between building assets are given, the resulting follow-up possibilities are numerous. The area of connectivity and therefore digitalization can help to save resources, increase equipment lifetime, and can even contribute an important part to the general safety of people.

Connectivity	Environment	Social	Economic	Single result	Total/Attribute
Megatrend	6	6	5	15,4	54,7
Prototype achievable	2	0	7	7,6	
Predictive Maintenance	4	0	10	12	
Smart City	7	7	8	19,7	
Total/Dimension	19	13	30		

Figure 58 Extended Rating Table - Connectivity (own creation)

Of all the potentials here, the social dimension is in second place. If you think about the subsequent steps that need to be taken in terms of digitizing one building and digitizing several buildings that ultimately result in a smart city, you can see in **Figure 48** that digitization has multiple social benefits. For example, improved general safety and greater control over personal consumption are benefits that will only become effective once a prototype has been produced.

1st Place

Finally, in first place in **Figure 59**, is water management. The strengths of this potential lie in the ecological and social dimensions. Here, both dimensions are stronger than in any other potential. One can see from the benefits of the attributes in **Figure 52** that, according to the author, stormwater management is considered more important than graywater management. Nonetheless, managing both water strands - stormwater and wastewater - is part of the Global Green Buildings Strategy. They can and are already being used to solve the world's water supply problems.

Water Management	Environment	Social	Economic	Single result	Total/Attribute
Rain Water	10	8	7	22,8	58,3
Gray Water	6	4	7	15,2	
GGBS	10	7	5	20,3	
Total/Dimension	26	19	19		

Figure 59 Extended Rating Table - Water Management (own creation)

The awareness that clean drinking water is not as readily available and of such quality in all parts of the world as it is in Germany must be further communicated at the social level. In the countries that are currently suffering most from water scarcity, water management concepts are being advanced with much more vigor. In developed countries such as Germany that offer water cheaply to the end user, in turn, graywater management systems have problems operating profitably because no actual shortage is suggested by cheap prices.

Economically, water management also offers options, such as increasing the value of the building, for example, and increased energy efficiency through less consumption. For all these house installations, new equipment is needed to control the water.

5.2.1 Evaluated Technical Application Possibilities for KSB Products

In order to show and clarify all technical application possibilities for new and existing buildings, all technologies were clustered. This can be seen in **Figure 60**. The group to which a technology belongs is



Figure 60 General overview of technologies for Green Building Retrofit & New Construction (own creation)

inside the circle. In this way, the groups include rainwater, graywater and blackwater, as well as heating, cooling, energy, facade, and roof greening.

However, this is still too general and does not provide enough help to navigate through the vast field of technology. Therefore, in the next **Figure 61**, the same representation as in **Figure 60** has been slightly modified.

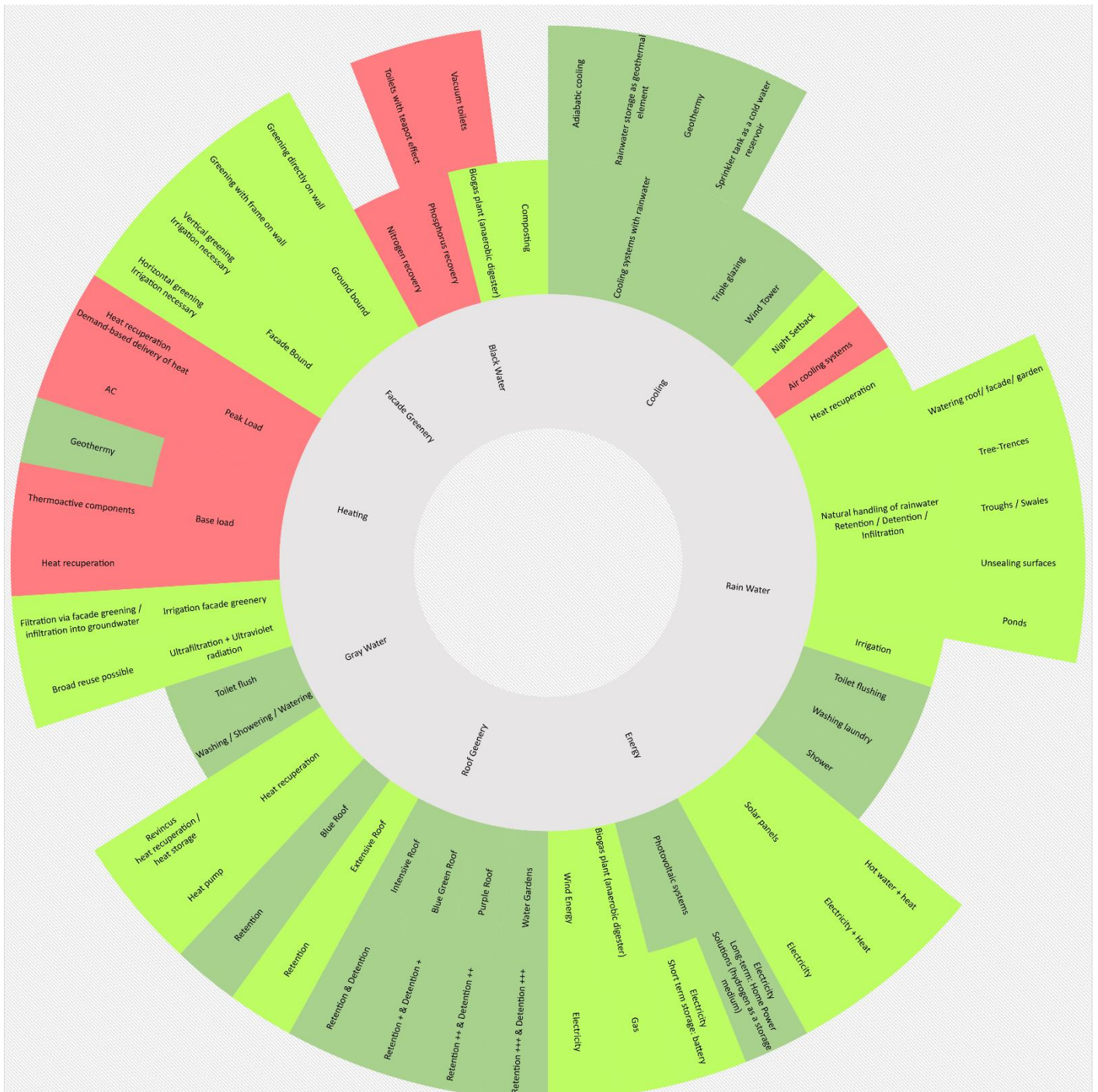


Figure 61 Overview of technologies for retrofit buildings (light green, dark green) & new buildings (red) (own creation)

One can see the same technologies clustered in the same groups again, only this time the colors have a special meaning. The colors are intended to clarify the information and show at a glance *which of these technologies are suitable for buildings that are being modernized or renovated and which are*

only conceivable in a new building. To be precise, the **Figure 61** shows in **light green technologies** that can be retrofitted. **Technologies in red**, on the other hand, require too much construction effort or the building would have to be dismantled to a large extent in order to be able to integrate the systems and this would not be profitable to retrofit. A perfect example of technologies that cannot be retrofitted, for example the thermoactivated components. In this representation there are **technologies in dark green** between light green and red. These are technologies that can only be integrated into existing buildings under certain circumstances, therefore they were provided with this color. In the case of dark green measures, a lot more has to be checked beforehand, such as whether the statics of the roof will support the planned blue, blue-green or purple roof. Another example is geothermy. There must be sufficient distance to the neighboring property, for this reason dark green.

This breakdown of technologies in **Figure 61** is already much more helpful than **Figure 60**, but it is still not enough to show which of these areas is actually interesting for a pump manufacturer. For this reason, another layer of information has been added to **Figure 61**. **Figure 62** again shows the same division into groups and colors. In addition, the technologies have been marked - framed in blue by the author - that would not work without the use of assets such as a pump or a gate valve.

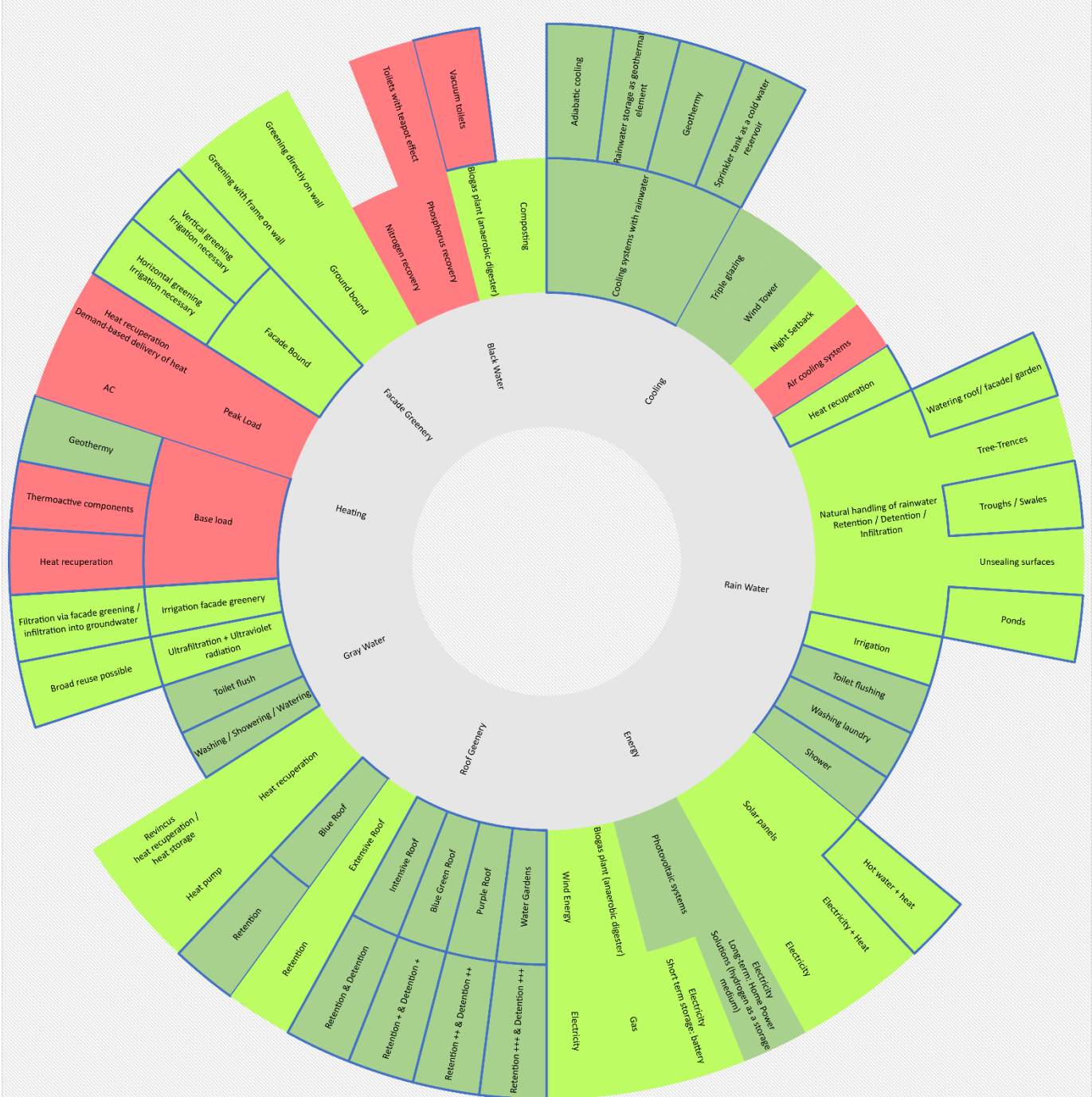


Figure 62 Overview of technologies for retrofit buildings (light green, dark green) & new buildings (red) & water relevant areas (blue framed) (own creation)

5.2.2. Requirements for KSB Products to be suitable for Green Building

In 2.6. Future Development, the author already mentions some points which, according to his experience, will occur more frequently in the next few years.

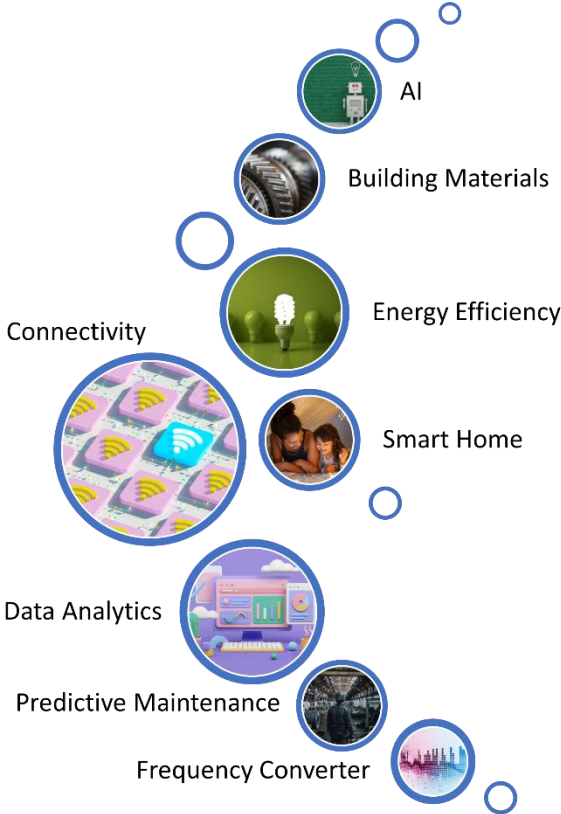


Figure 63 Future Requirements (own creation)

In Figure 63, the author has compiled these topics once again. Some of the topics are directly related to each other, such as data analysis and artificial intelligence. Other areas are only indirectly related, such as energy efficiency and frequency converters. These converters have the potential to increase energy efficiency and, in the author's opinion, should be investigated separately for their potential. Considering that green buildings are built in a circular concept, recyclable materials are to be considered. A direct requirement for a pump used in a certified green building could be that a certain percentage of the pump materials can be recycled.

6. Summary, Conclusions and Outlook

Ultimately, Green Buildings are no magic! The work on the topic of Green Buildings has led to the discovery of several things. Initially, an overview of Green Building technologies was provided with a focus on water-related aspects. Therefore, numerous other aspects were not examined in this work, such as demand-oriented building design, well-being and healthy indoor climate, comfort effect on residents, perceived temperature in common areas and atria, indoor air humidity, comfortable indoor air velocities, visual comfort, acoustics or electromagnetic compatibility of all electrical devices in the building with the human body, building shape and orientation. Several buildings were analyzed, including a closer examination of the refurbishing plans for Schauenstein Elementary School to investigate the implementation of water-related measures and to explore the found potentials. After conducting a literature review, four concrete potentials regarding KSB products and a list of additional requirements were identified.

The construction process is well represented by the Fee Structure for Architects and Engineers (HOAI); it is important to enter this process as early as possible.

Based on the buildings examined and the expert survey, the author would like to recommend starting with a prototype of the "Pump 4.0" for Green Buildings as soon as possible. If prototypes have already been started for industrial applications, the possibility of transferability to the building sector should be examined.

Clean water is scarce in many parts of the world and neglected in the rest of the world. When addressing water management issues, this work has focused exclusively on green building issues. It should additionally be examined to a similar extent what potentials the concepts of a Sponge City could bring to KSB. The author considers that a holistic strategy only leads to success in the interaction of Green Buildings measures and Sponge City measures.

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Declaration

I, Robert-Peter Kuhn

hereby declare that I have prepared this thesis independently and without the use of any auxiliary materials other than those indicated; any ideas taken directly or indirectly from outside sources are identified as such.

To the best of my knowledge, the work has not been submitted to any other examination authority in the same or a similar form and has not been published.

Hof, 13.03.23 
..... Place, date, signature