# Water Demand Management and Its Impact on Water Resources at the Building Level

**Z. Vranayová and D. Káposztásová**

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**Abstract** New reports of water scarcity and record droughts due to climate changes are becoming increasingly common. The costs of water infrastructure have risen dramatically. Discussing the water used in a good or bad (waste) way led us to think if we are using water in a sustainable way. A common characteristic of water demand in buildings means its relentless rise over many years and conception of continuous growth over coming decades. The main influencing factors of water demand patterns are population growth, lifestyle change depending on the region, demographic structure and the possible effects of upcoming changes in climate and other health risk factors.

In the European Union, it is common to use well and rainwater source for non-potable purposes (such as irrigation, toilet flushing, etc.). Grey water reuse is in our country still rare. Common household usage consumes a lot of water. There is a need to manage its end use as sustainable as our conditions allow us. Potable water consumption of the Slovak households isn't above average at all, but its use is inappropriate. Questionnaire on water, as one of data collection methods, gives a closer look at water habits of households. The results show that most of our citizens are pro water saving oriented and open to new water ideas – as in the building water cycle.

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The main goal of this chapter is to present the background for the water use, regulations and legislative framework in the context of a water conservation strategy and discuss water types in building water cycle connected to water-energy nexus in the wider environment.

There is a gap for water regulation and water supply of grey and rainwater systems. This chapter pointed out the challenges and recommendations to strengthen and enhance future of alternative water sources based on the scientific findings, policy, economic and social impacts.

**Keywords** Building water cycle, Questionnaire, Sustainability, Water sources

## 1 Introduction

It is increasingly obvious that the current use, development and management of the planet's water resources, and the services they provide are unsustainable. At the United Nations Conference on Sustainable Development in 2012 (Rio + 20), governments recognized that water is "at the core of sustainable development as it is closely linked to a number of key global challenges" [1].

While the world's population tripled in the twentieth century, the use of renewable water resources has grown sixfold. Within the next 50 years, the world population will increase by another 40–50%. This population growth – coupled with industrialization and urbanization – will result in an increasing demand for water and will have serious consequences on the environment [2].

The total volume of water in the world remains constant. What changes are its quality and availability. Water is constantly being recycled, a well-known system as the water or hydrological cycle [3].

According to the World Water Assessment Programme (WWAP) [4, 5], about 70% of water use in the world is used for irrigation, about 22% for industry and about 8% for domestic use. In many countries, the hydrological cycle is managed to provide enough water for industry, agriculture and domestic use. It requires the management of surface and groundwater resources, treatment and supply of water, its collection, reusing and returning back to the cycle. These facts lead us to start with the support of the "small" water cycle at the building level, by creating the building water cycle (see more in the following chapter).

It means that the freshwater – blue water – does not have to be the first choice for a water source [6]. People use a lot of water for drinking, cooking, washing and irrigating landscapes, but even more for producing food, materials products and manufactured items such as clothes and to run buildings [7].

As has already been mentioned, 8% of total world water resources are used for domestic purposes. Average water uses per person in selected countries are described in Fig. 1.

In Slovakia, the average consumption is around 109 L/per person/day, and it can be classified according to end purpose (Fig. 2).

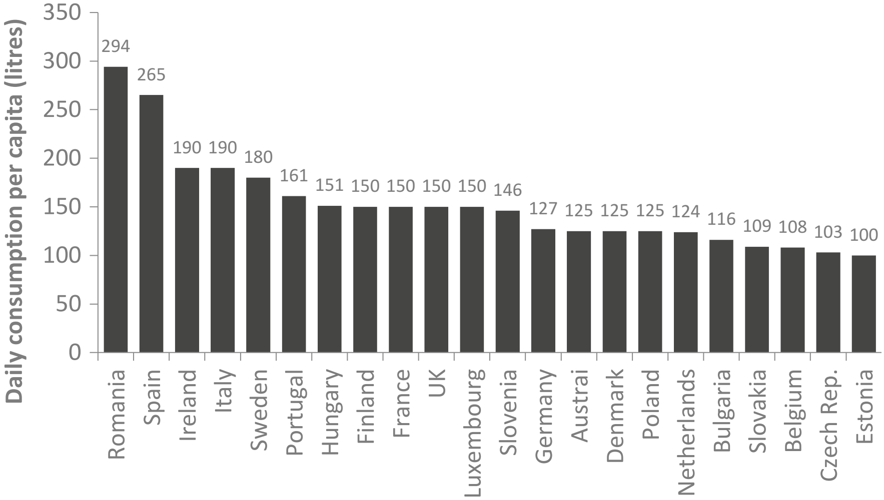


**Fig. 1** Average water use per person [8]

According to the Population and housing census results 2011, there was an increase of built houses around 3.2%. From the 2011 census results with an average of six inhabitants per household, average water use per household per day in Slovakia was 843,343,200 L/day. Moreover, therefore only households are yearly consuming around 308,000,000 $m^3$/year of potable water. It shows that about 55% of drinking water may be replaced by alternative water source as rainwater, grey water or water from well, etc.

This fact gives credit to reuse of potable water in building water cycle. We need very fast to change the thinking of all society which will be in the balance with nature to be more sustainable.

## 2 Regulation and Legislative Framework

In this part, we introduce basic information about the legislation in the water industry in general. Most of the directives deal with water quality since the main target of all legislations and standards is to obtain sustainable water quality globally. The main directive in Europe is the Water Framework Directive (WFD) 2000/60/EC [2] which establishes a legal framework to protect and restore clean water across Europe and ensure its long-term sustainability [4]. It is the most far-reaching piece of environmental legislation ever introduced by EU and will change the way in which water is perceived and managed in Europe forever [3].

This directive also sets rules for groundwater, and according to Davies and Butler implementation of the directive has more uncertainties, for instance, what

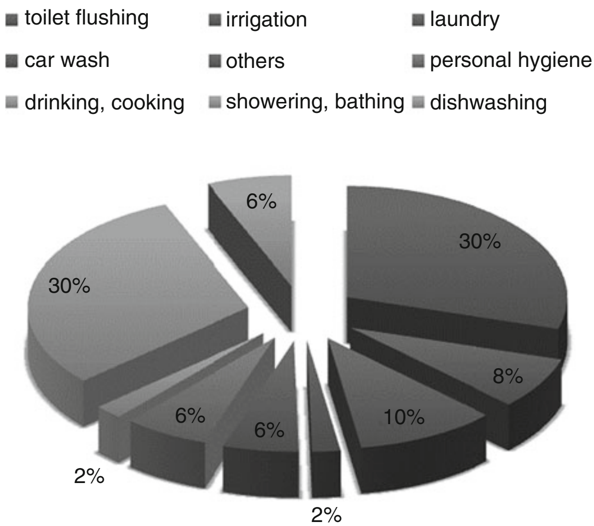


**Fig. 2** Average consumption of potable water in Slovakia according to end purpose water use per person [9]

implications will a prohibition of discharge to groundwater have on infiltration-based sustainable drainage systems [10].

The document similar to European WFD is the Clean Water Act (CWA) in the United States which was implemented in the early 1970s and has resulted in significant efforts to improve the quality of water bodies, much of which has included improvements to stormwater management [11]. Other related European directives or "WFD daughters" are the Urban Waste Water Treatment Directive 91/271/EEC, the Groundwater Directive 2006/118/EC, the Bathing Water Directive 2006/7/EC and the Flood Directive 2007/60/EC.

Quality control of drinking water and the health security in Slovakia is performed through a set of 82 indicators of water quality defined by Government Regulation Nr. 8/2016 Coll., setting down requirements for water intended for human consumption and control the quality of water intended for human consumption according to European Council Directive 98/83/EC on the quality of water intended for human consumption. The limit values of water quality parameters are according to their health significance distinguished as the recommended value, indicative value and the limit of a maximum limit value. The most serious health consequences of the crossing are the highest margins, which excludes the use of water as drinking.

The water legislation is covered by following acts and regulations. The first is the Water Act, Act No. 303/2016 Coll. on water sources and on the amendment of the Act of the Slovak National Council No. 372/1990 Coll. on offences in the wording of latter provisions. Water Act is the basic legal framework regulating water protection in Slovakia.

The Government Regulation No. 296/2010 Coll. establishes qualitative objectives for surface waters and limit rates of wastewater and special waters pollution indicators.

The Act No. 442/2002 Coll. on Public Water Systems and Public Sewage Systems and on amendment and supplement of the Act No. 150/2017 Coll. on Regulation of Network Industries states that “the owner of the sewage system can deny connection of property to public sewage system if for example the capacity of system or WTP is already exceeded or is possible to dispose runoff water from stormwater out of public sewage”.

Regulation of the Ministry of Environment No. 684/2006 is about technical requirements of design, project documentation and public water supply and public sewage construction.

Regulation of the Ministry of Environment No. 209/2013 sets out details about measuring the amount of supplied water and quantity of discharged wastewater and surface runoff.

Act No. 303/2016 Coll. on Flood Protection establishes measures how to prevent floods. The Slovak government approved the Programme of Landscape Revitalization and Integrated Watershed Management in the Slovak Republic by the decree No. 744/2010. The objectives of this programme regarding the topic of the thesis are flood protection and retention of stormwater in the country and support of stormwater management projects.

A series of European Standards aims to provide requirements and recommendations for all materials in contact with drinking water. Whether you have responsibilities for local authority mains, building sites or public and private buildings, these publications need to be consulted.

The design applies to new installations, pipework as well as alterations and repairs. STN EN 806 Specifications for installations inside buildings conveying water for human consumption divided into five parts were fully adopted by the Slovak Republic.

## 3 Water Types and Quality

In the environment exist many types of water as defined by Kinkade-Levarios [6]:

- *Atmospheric water* – as rain and fog
- *Blue water* – water from lakes, rivers
- *Green water* – soil moisture
- *Stormwater* – rainwater that has hit the ground
- *Grey water* (light or dark) – wastewater from laundry, bathtub, shower, basin
- *Alternate water* – water that has been used previously
- *Black water* – water from toilets and kitchen sinks
- *Reclaim water* – water that has gone through a sewer treatment process and has been filtered and processed for reuse in various ways
- *Sea water* – from desalination

We would like here to concentrate on four water types that are the most common and available source in buildings, mostly family houses (Fig. 3):

1. *Potable water* – water from tap, source of water for potable purposes

2. *Water from well* – a source of water for potable and non-potable purposes
3. *Rainwater* – collected water from the roof during precipitation; source of water for non-potable purposes
4. *Grey water* – wastewater from bathtubs, shower and basin; source of water for non-potable purposes

At the building level, we are using the fastest, easiest and most reliable source of water that we have – the water from municipal water supply system that goes through the highest level of testing. Of course, there are many cases when this source of water is unavailable (no water supply, water supply failure, damage, technical problems, disasters, etc.). Most people do not think about water storage or what would happen if there is no water available.

There are also many issues that need to be taken into account when considering the water source and its quality (see Table 1).

Water quality consists of several issues:

- *Aesthetic parameters (colour, odour and turbidity)*
- *Microbiological content (bacteria and photogenic organisms)*
- *Chemical and physical parameters (pH, dissolved solids, disinfectants,* etc.*)* [13].

Aesthetic parameters vary significantly between rainwater, grey water, potable water and water from well. The acceptability of reclaimed water depends on personal preferences and the end use (filtration can help in this problem) [13].

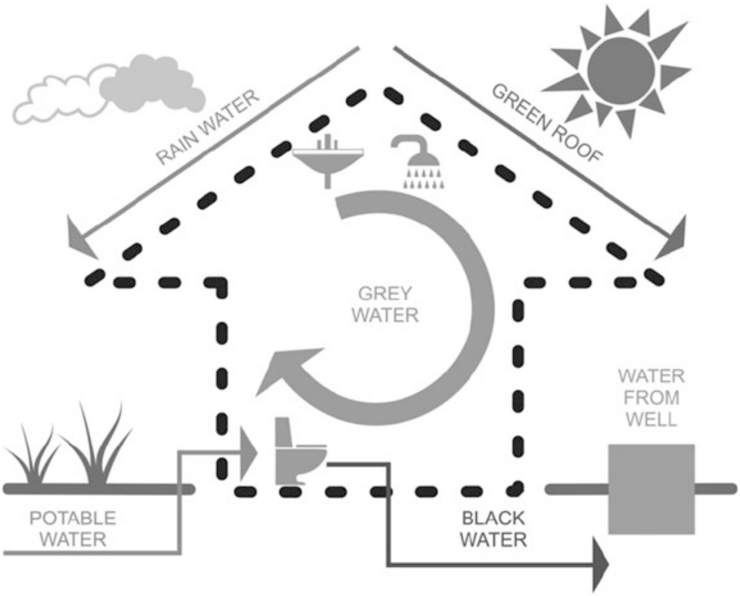


**Fig. 3** Sources of water at the building level [12]

**Table 1** Comparison of guidelines for drinking water and bathing water quality

| Water | Potable water | Bathing water |
|---|---|---|
| According to | Directive 98/83/CE | Directive 2006/7/CE |
| Colony count 22°C | 100/mL | – |
| Colony count 37°C | 20/mL | – |
| Total coliforms | 0/100 mL | – |
| *Escherichia coli* | 0/100 mL | Between 500 and 1,000 UFC/100 mL |
| *Enterococci* | 0/100 mL | Between 200 and 400 UFC/100 mL |
| Anaerobic sulfato-reducing bacteria | 0.5/mL | – |
| *Legionella* | 1,000 UFC/L | – |
| *Pseudomona aeruginosa* | 0/250 mL | – |
| Staphylococcus | 0/100 mL | – |
| Surface active substances | | Between 0.3 mg/L and no lasting foam |
| Ammonia nitrogen | 0.1 mg/mL | – |
| Conductivity | <2,500 | – |
| Colour | Acceptable to consumers and no abnormal change | No abnormal change |
| Turbidity | 1 NFU | – |
| Taste and odour | Acceptable | – |
| Hardness | >15°F | – |
| Nitrates | 50 mg/L | – |
| Nitrites | 0.5 mg/L | – |
| Oxidizability | 5 mg/L O2 | – |
| pH | Between 6.5 and 9 | Between 6 and 9 |
| Iron | 200 μg/L | |
| Mineral oils | – | Between 0.3 mg/L and no visible film on water surface |
| Phenols | – | 0.005 mg/L |
| Transparency | – | Between 1 and 2 m |
| Dissolved oxygen | – | Between 1 and 2 m |
| Floating residues | – | – |

Microbiological quality should be controlled on the high level. Thus there is no recorded mortal case caused by rainwater or grey water, but it can cause illnesses and in extreme cases death when it is used in no appropriate way [13].

Chemical and physical parameters should follow the requirements set by local standards and Water Framework Directive. Parameters as pH and dissolved solids may not only be relevant to the end user, but may have an impact on disinfection processes and the life of the whole system. Metals from rainwater or grey water could make reclaimed water not suitable for irrigation purposes [13].

**Table 2** Water quality according the end use [14]

| Category | Maintenance | Irrigation | Flushing toilet |
|---|---|---|---|
| Total coliforms c/100 mL | 10 | 1,000 | 1,000 |
| *Escherichia coli* c/100 mL | 1 | 250 | 250 |
| *Enterococci* c/100 mL | 1 | 100 | 100 |
| *Legionella* cfu/L | 100 | 100 | 100 |
| Residual chlorine ppm | < 0,5 | <0,5 | < 2 |
| Residual bromine ppm | Not applicable | Not applicable | < 2 |
| Dissolved oxygen | >10% of saturation or >1 mg/L of oxygen (which is smaller) | | |
| Floating residues | Visually clear without floating residues | | |
| Colour | Not unsatisfactory | Not applicable | Not unsatisfactory |
| Transparency | <60% for 254 nm | Not applicable | <60% for 254 nm |
| Turbidity | <10 | Not applicable | <10 |
| pH | 6.8 | 6.8 | 6.8 |

According to EA (Environmental Agency) guidance on how microbiological composition should be either rainwater or grey water for further use is not drinkable [14] should be used Table 2.

## 4 Questionnaire on Water Use

Massive use of rainwater or reused water for non-potable purposes in buildings promotes the conservation of natural resources, water, and thus the overall sustainability in water management.

Potable water consumption of the Slovak households is not above average at all as was mentioned before but we use it in inappropriate ways. We used the Questionnaire on Water, as one of data collection methods gives a closer look at water habits of households.

As a first step, existing methodologies, standards and guidelines have been analysed. Therefore questionnaire has been sent out to the respondents to identify the water habits in their countries from all over the world (Fig. 4).

In 2014 the questionnaire was completed by the group of 200 people from different spheres of society divided to 85 male and 115 female respondents. The average age of respondent is 43 years. The 75% of them live in the family houses. The questionnaire consisted of ten questions. The last our question was about their opinion on water-energy nexus.

The most important and serious fact is that 80% of respondents use potable water for all domestic purposes such as flushing toilets and watering the garden or washing their cars.

A brief overview of final results will show the attitude and differences between the Slovak respondents and respondents from foreign countries. As described in Fig. 5 in Slovakia, no grey water use was identified, and part of houses are not

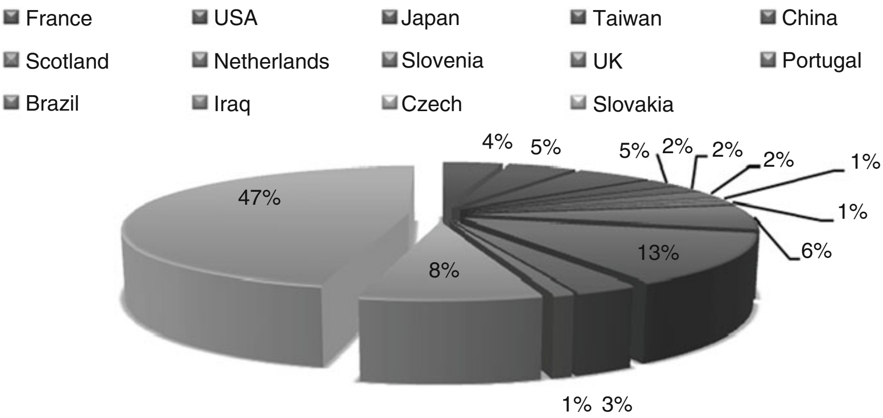


**Fig. 4** Countries of respondents' origin

connected to main water supply for different reasons (good quality of the water in the well, no water supply connection).

Our respondents were asked if they were afraid of grey and rainwater use. In fact, Slovaks were more afraid of grey water than rainwater, due to the lack of information about such system of application. Respondents from foreign countries were not so afraid of reusing grey and rainwater (Fig. 6).

It is interesting that even though Slovaks are afraid of reuse of water around, 85% of them would think about sustainable solutions (Fig. 7) if they built a new house.

About 55% of all respondents would consider installing such system if the return on investment is from 6 to 10 years (Fig. 8).

The main reasons for water saving measures application were the water bill reduction – in 49% of respondents, 41% for sustainability and reservoirs saving only 10% (Fig. 9).

Our foreign respondents see the biggest potential in installing the grey water system in industrial buildings than other types (Fig. 10).

The last question of our questionnaire was about the relatively newest idea: the water-energy nexus.

Our respondents have expressed their opinions, e.g., in the following way:

- *The nexus between energy and water has not been understood by general population and decision makers yet. This must be fully discussed by all.*
- *It is an equation that should always be weighed against the shortage of drinking water on the planet. However, it should be environmentally friendly energy sources used for that also they do not become a problem.*
- *It is the way we need to follow.*
- *Reducing the grey water treatment will reduce the energy necessary for its treatment.*
- *Further studies need to be conducted in order to evaluate the real cost of water usage in energy production and* vice versa *(financial and environmental).*
- *It is a future. This theme is very interesting; I work in this area* [12].

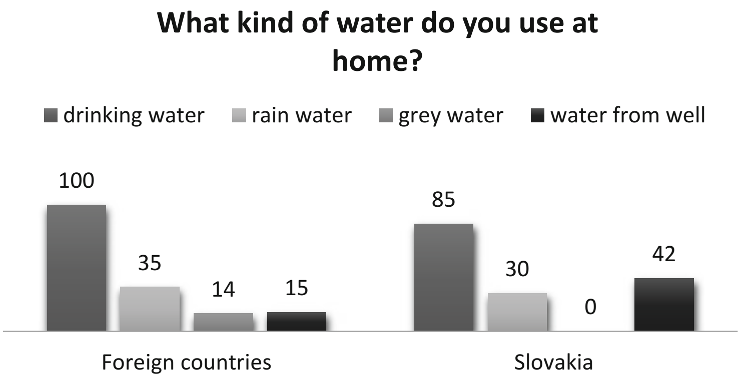


**Fig. 5** Comparison of water types used in Slovakia and abroad

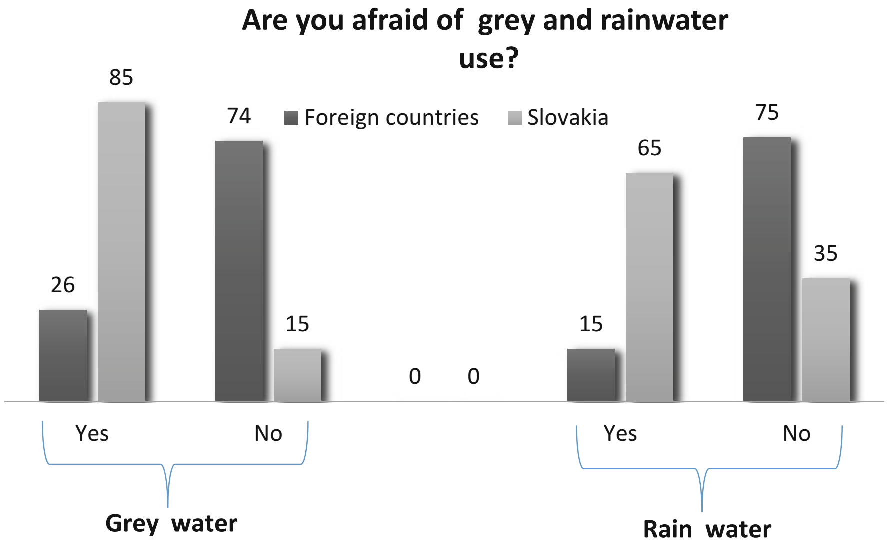


**Fig. 6** Comparison of afraid of grey and rainwater systems

The questionnaire shows people's willingness to use an alternative water source for different non-potable purposes rather than potable water. Its results give us a closer look at people's attitude to sustainable water resources for building supply as well as water consumption habits of water users.

The gratifying conclusion is that most of our citizens are pro water saving oriented and very open to new water ideas as closed in-building water cycle. In Slovakia, this area has not been so developed yet. It is necessary very fast to define regulation and set standards for designing such hybrid systems (see Sect. 5.3), e.g., according to foreign national standards and performed experiments in Slovak conditions.

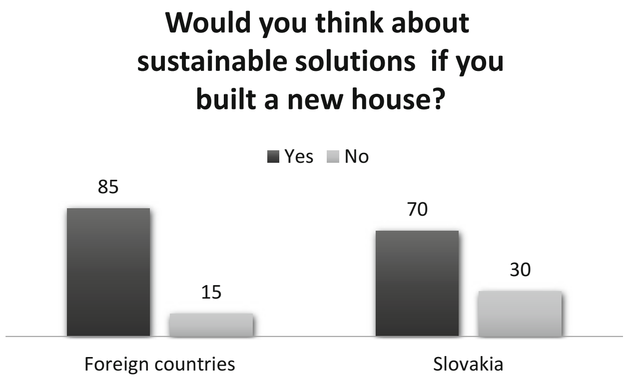


**Fig. 7** Sustainable solutions volition

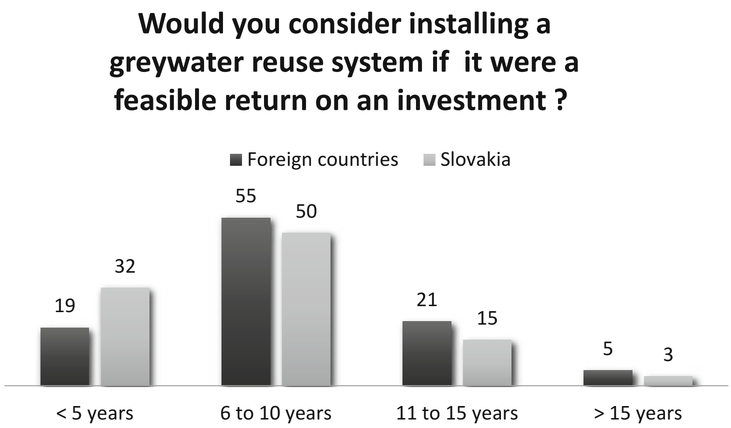


**Fig. 8** An acceptance of return on an investment

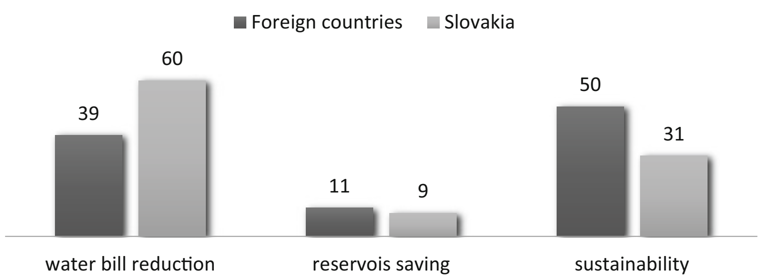


**Fig. 9** Reasons for water saving

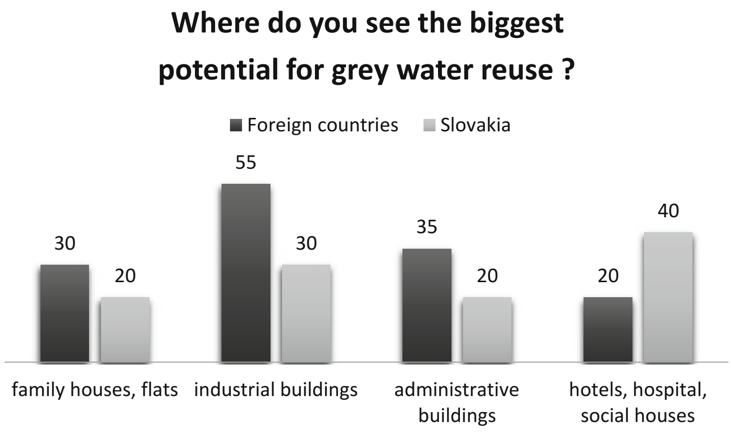


**Fig. 10** Potential for grey water reuses according to building type

## 5 Water in Building Cycle

The quantity of water used by European households has increased significantly over the past decades and now represents approximately 70% of the total water use in buildings [15]. A report by the Office of Community and Economic Development [5] estimates that 35–40% of household water consumption is used for personal hygiene (shower and bath), 20–30% for toilet flushing and 10–20% for laundry.

The research has shown that replacing high water-using devices with water-efficient alternatives can reduce annual water consumption by 32–50% [7, 15]. Focusing on household water consumption and, in particular, the use of water-efficient devices offers significant potential for water savings.

Water can create a building water cycle. An installation of the rainwater harvesting system and system of grey water reuse or the use of water from well or other alternative is bringing many advantages, but also if not treated well the disadvantages and possible risks. When recycling water, it is essential to protect the health of both the public and the environment, and a risk management approach is the best way to achieve this.

As prof. Afonso presented at the Symposium of CIB in Brazil 2014, it can be stated that water efficiency, which implies conservation of water, is the best way to contribute to policies for sustainable use of water [16].

Expressed by his words:

The interventions leading to an efficient use of water in the building cycle can be systematized by a guiding principle called “the 5R principle” (Fig. 11).

The 1st R
Reduce consumption includes the adoption of efficient products and devices, without prejudice to other measures of an economic, fiscal or sociological nature. For this, the labelling of the water efficiency of products similar to strategies for energy efficiency is considered as an essential measure to provide information to consumers.

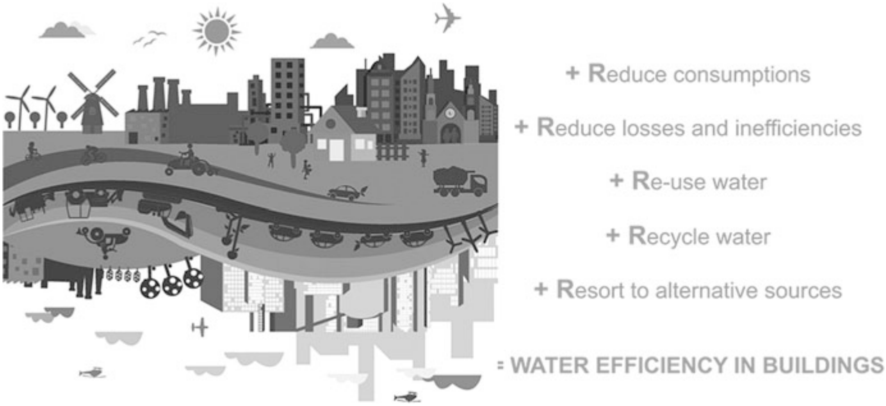


**Fig. 11** 5R principle content (according [12] and [16])

The 2nd R
Reduced losses and waste may involve interventions such as the monitoring of losses in building networks (in flushing cisterns, sprinklers, etc.) or the installation of circulation and return circuits of sanitary hot water.

The 3rd and 4th R
The reuse and recycling of grey water/wastewater, meaning a use in "series" or the reintroduction of water at the start of the circuit after treatment, can be relevant in relation to the use of grey water, not excluding the possibility of using treated wastewater for some purposes, such as watering gardens.

The 5th R
The last resort is alternative sources. This may involve the use of rainwater, groundwater and salt water. These measures can be easily considered for new or refurbishment buildings. For existing buildings, water efficiency audits and risk management methods are a more appropriate procedure, as is the case with energy efficiency [17].

It is known that around 60% of drinking water may be replaced by an alternative water source (rainwater, well water, grey water). This fact gives credit to reuse of potable water in building water cycle and better percentage weight in building environmental assessment [18]. Water management field in the environmental assessment system (BEAS) used in Slovakia has a percentage weight of 8.88% (see chapter Vilcekova et al.). Buildings that have attained a specific green building level of LEED Certification or any of similar certification are meeting the future sustainable challenge, which means we can reduce our water footprint.

Following sections will give us a closer look at different water types used in building cycle and the brief description of such systems.

### 5.1 Building Potable Water Sources

Household water use is water used for indoor purposes from drinking, food preparation, washing clothes and dishes, bathing and showering, flushing toilets to outdoor purposes such as garden watering. Domestic water use includes potable and non-potable water provided to households by a public water supplier or domestic deliveries and self-supplied water [12].

Drinking or potable water is water safe enough to be consumed by humans or used with low risk of immediate or long-term harm. In most developed countries, the tap water supplied to households, commerce and industry meet the water quality and portability standards.

Most of the population in Slovakia (86%) is supplied from public water mains. In Slovak republic, downward trend in the consumption of drinking water from public water supplies is recorded last years. More and more people preferred the water from their own source – wells or buying bottled water.

Potable water could be to the building supplied from several possible sources:

- Municipal water supply (1)
- Water wells (2)

1. *Tap water* (or running water, city water, municipal water, etc.) is water supplied to all taps or valves in the house. Its typical uses include washing, toilets and irrigation. Indoor tap water is distributed through indoor plumbing (Fig. 12). This type of installation has existed since antiquity but was available to very few people until the second half of the nineteenth century. Water used for abstraction of drinking water is now covered by the Water Framework Directive (WFD). The Directive does not itself set mandatory standards but relies on national and other legislation. In the most of EU countries directives and guidelines, the value limits are given more straighten that are set in WFD [3].

2. *Water from wells* is water supplied from groundwater sources. It could be used for both potable and non-potable purposes according to its quality (Fig. 13).

Today about 14% of the Slovak population is individually supplied from well water. Eighty to eighty-five percent of water resources for individual supply does not meet the hygiene requirements or has poor sensory properties and are a permanent risk to user's health. The most common case is a faecal pollution, nitrate and iron. Water quality in individual water sources is affected by the poor technical condition of wells, lack of depth and/or poor disposal of sewage in the neighbourhood. High risk of infectious diseases is increasing especially in times of flood and in case of drainage failures.

Right well construction and continued maintenance are keys to the safety of building water supply. State water-well contractor licensing agency, local health department or local water system professional can provide information on well construction for users [19].

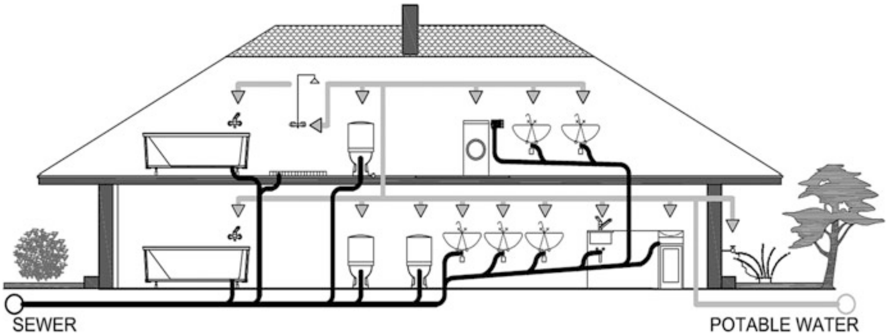


**Fig. 12** Potable water in building water cycle [12]

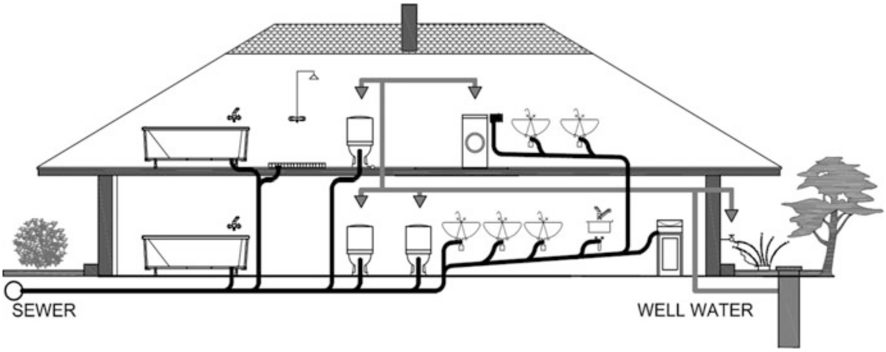


**Fig. 13** Water from well in building water cycle [12]

Quality check of raw water sources and water quality control in the distribution network ensures the owners/operators of public water supplies. Operators of public water may be water companies, municipalities or other legal/natural persons having trade licence to operate a public water supply.

These two types of water described above are suitable for all domestic purposes, but this is not a sustainable solution for today situation.

Common vision in leading foreign countries is the use of all source of water that consumer have at his property. Reclaimed water is water that has been collected and treated, so it is suitable for its indented use.

## *5.2 Non-potable Water Sources*

Non-potable (reuse) systems typically have lower water quality than potable systems. The level of water treatment varies depending on the end use. Non-potable reuse usually requires a dual distribution system – it means separate systems of pipes for distributing potable and non-potable water. Depending on the extent of a community's water distribution system, non-potable reclaimed water can be used mainly for flushing toilets, watering parks or lawns, supplying fire hydrants, washing cars and streets, filling decorative fountains and many other purposes.

Rainwater and grey water are both water sources for reclaimed water for non-potable end use, and they need to be well labelled. Watering or washing devices, indoor or outdoor, must be marked with warnings similar as in Fig. 14, together with appropriate symbols, and their taps fitted with a detachable handle to prevent the improper use [20].

As presented in Portuguese study by prof. Afonso [17], it is considered that reclaimed water can be used in flushing of toilets, washing clothes and watering gardens, all after appropriate treatment.

The quantitative characterization and a physicochemical and microbiological analysis of light grey water were presented, e.g., in Aveiro Symposium of CIB W062 by C. Matos and I. Bentes. Grey water use at the domestic level may well be the simplest form of water reuse and should be investigated as a means to reduce the impact of residential developments on water resources worldwide [21]. Reuse of grey water can also reduce the load on septic tanks and drain fields. In the United States, they have the Green Plumbing and Mechanical Code Supplement (IAPMO) that in the chapter titled "Decision Analysis Tool for Appropriate Water Source in Buildings" by D. Káposztásová and Z. Vranayová in this volume, deeply describes the construction, alteration and repairing of grey water systems [22].

*Grey water* refers to water sourced from the kitchen (depending on national regulation), laundry and bathroom drains, except toilets. Grey water may contain urine and faeces from nappy washing and showering, as well as kitchen scraps, soil, hair, detergents, cleaning products, personal-care products, sunscreens, fats and oils [17, 23–25].

We called domestic wastewater (excluding faecal matter and urine) from bathrooms, basins and showers *light grey water*. We called contaminated or difficult-to-handle grey water, such as solids-laden kitchen sink water or from laundry, *dark grey water*.

Grey water systems depend significantly on the behaviour of the people using the appliances, as well as the quality and volume of water collected (Fig. 15). There exist many different methods used to filter and treat collected grey water, which ranges in complexity and the level of treatment.

**Fig. 14** Label of non-potable water tap

Grey water systems consist of one or more storage tanks, pump, filtration unit, chemical dosing and connecting pipework (Fig. 16).

Grey water according to treatment could be:

- Reused – that water has not undergone treatment.
- Recycled – this water has undergone at a minimum through the filters and disinfection.

*Rain* – a form of precipitation is the first form of water in the natural hydrological cycle. It is a primary source of water that feeds rivers, lakes and groundwater aquifers, and they became the secondary source of water [6].

*Rainwater* may be collected from any hard surface, such as concrete or stone patios, and asphalt parking lots. However, once the rain hits the ground, it is no longer referred as rain, but as the *stormwater* (Fig. 17). The landscape can also be contoured to retain the stormwater runoff. Rainwater harvesting captures precipitations and uses it as close as possible to where it falls [26].

The potential of rainwater harvesting depends on location and weather. Precipitation monitoring is a very a common process all around the world. In Slovakia monitoring is provided by the Slovak Hydro-meteorological Institute (SHMU).

Stormwater management has been changing throughout years, and it was caused by extensive urbanization which changed stormwater runoff and infiltration patterns. Rainwater harvesting supports sustainability in stormwater management which in principle means managing stormwater as a resource and as close to the source as possible [27].

Rainwater harvesting system is much more sophisticated today since our demand is higher and necessity of water quality is taken into consideration. We usually collect water from impervious surfaces (roofs, paths and parking lots). It is further transported by gauges and downpipes through filter or screen to prevent organic material particles and debris reaching the system.

Very important part of the system is the first flush device. This equipment retains initial runoff because of the stored water quality. It is possible to instal the system

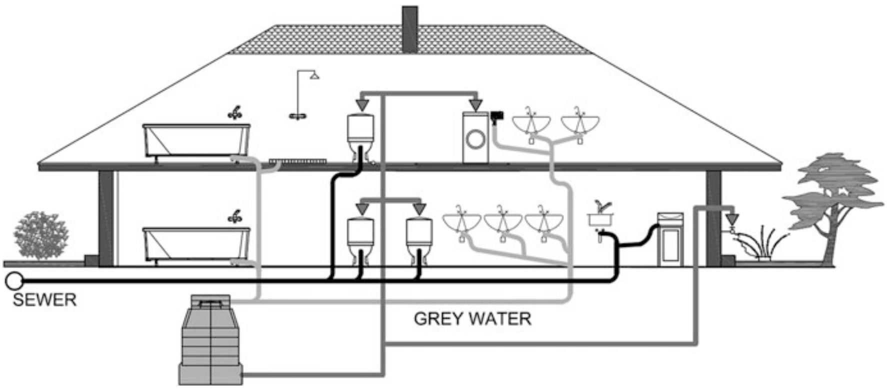


**Fig. 15** Grey water in building water cycle [12]


**Fig. 16** Most used grey water system parts [12]

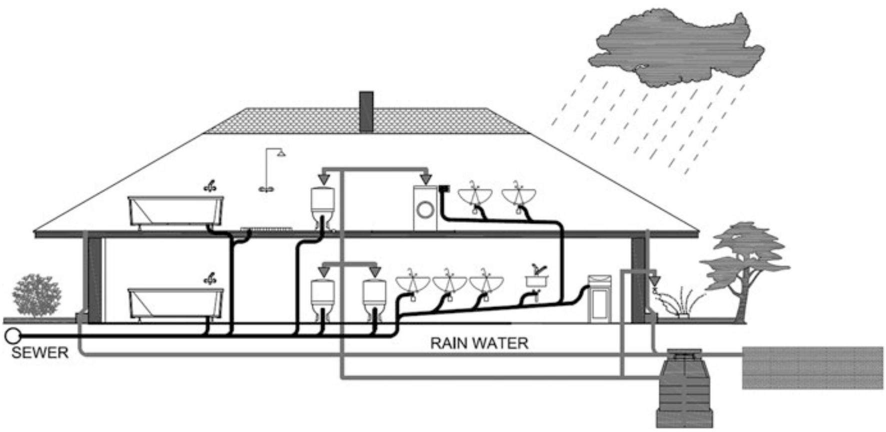


**Fig. 17** Rainwater in building water cycle [12]

different types of filters and treatment devices. The level of treatment of the stored water depends on the purpose for what the water will be used. There are different disinfection devices using, for instance, UV radiation, chlorine or activated carbon filters on the market (see Fig. 18).

Pumps and pipes, necessary for transporting the water to the consumer, are inseparable parts of the system and cannot be interconnected with potable water network [28, 29].

Keeping rainwater and grey water isolated from each other and/or combining the reclaimed water prior to use is another option. This means that two separate systems are required, and higher costs and maintenance will be necessary.

While undertaking a water audit, it may be identified that rainwater and grey water are insufficient on their own to meet a part of the water demand in the building. It may be possible to combine rainwater, grey water, water from well and potable water to provide a viable water source to cover the whole water demand at the building level (see following chapter).


**Fig. 18** Most used rainwater harvesting system parts [12]

## 5.3 Hybrid Systems

Grey and rainwater systems vary significantly in their complexity and size and can be grouped according to the type of filtration or treatment they use as follows as described in British standard BS 8525-1:2010 [30]:

1. Direct reuse systems (no treatment).
2. Short retention systems.
3. Basic physical/chemical systems.
4. Biological systems.
5. Biomechanical systems, the most advanced for domestic grey water reuse, combine biological and physical treatment, e.g., removing organic matter by microbial cultures and solid material by the settlement. They encourage bacterial activity by bubbling oxygen through the collected water
6. Hybrid systems – integrated with rainwater, or other water sources.

*The hybrid system* represents the vision of building water cycle. Potential uses for grey and rainwater depend on the quantity and quality of water available. Each case must be assessed by the individual plan to design the most efficient and green sustainable water system (see Fig. 19).

Figures 20 and 21 describe a real scheme and technical drawing of a hybrid system for a building.

When recycling water, it is essential to protect the health of both the public and the environment, and a risk management approach is the best way to achieve this issue. The quality of water is very important and depends on the end use.

According to the critical review from Sapkota et al. [31], the fact that hybrid water supply systems are not free of challenges can't be ignored. The question is if these calls for extensive collection and distribution systems are necessary for reclamation and reuse of waste water, especially in the case of centralized, non-potable systems that need separate distribution of drinking and non-potable water. The need for dual water supply systems signifies increase in cost and energy consumption for our urban area and for the transfer of waters. There are no known impacts of water hybrid supply systems on aspects such as flow changes, nutrient and sediment regimes, greenhouse gas emissions and impacts on rivers,

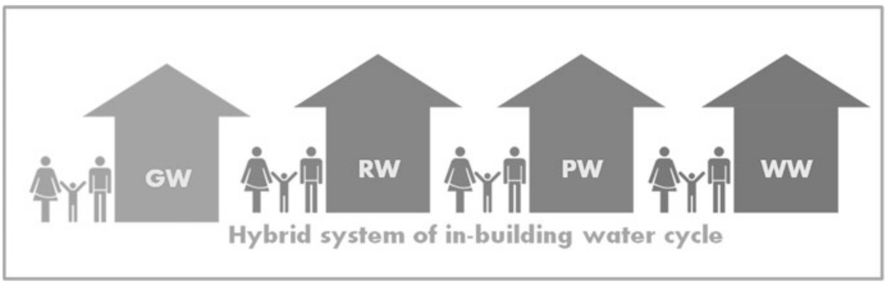


**Fig. 19** Hybrid system of in-building water cycle [12]

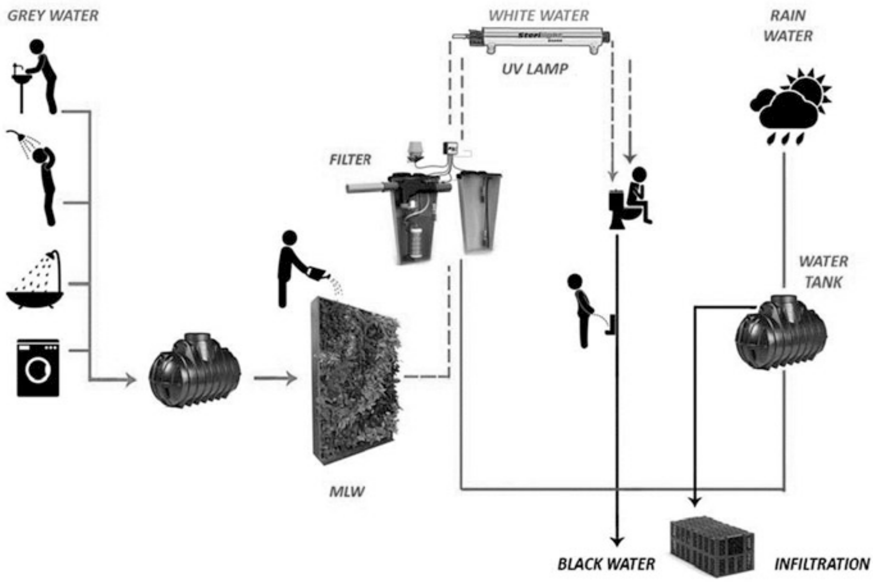


**Fig. 20** Hybrid system of in-building water cycle – combined application using grey water, rainwater, vegetated wall and infiltration

aquifers and estuaries. A sophisticated sewage treatment technology requires a considerable amount of energy. It is, however, possible to use sludge from wastewater treatment to the current generation of energy.

## 6 Conclusion and Recommendations

Water harvesting is not so much different than renewable energy – opportunities abound in the building to capture a free resource and turn it into an economical solution. The key is to have the right systems in place.

Energy efficiency and sustainability are key drivers of water reuse, which is why water reuse is so integral to sustainable water management. The water-energy nexus recognizes that water and energy are mutually dependent – energy production requires large volumes of water, and water infrastructure requires large amounts of energy [32].

Therefore, sustainable water management can be defined as water resource management that meets the needs of present and future generations. A “net-zero” water building is an innovative strategy that pushes our buildings to be fully responsible for generating its potable water needs and treating all discharge waste.

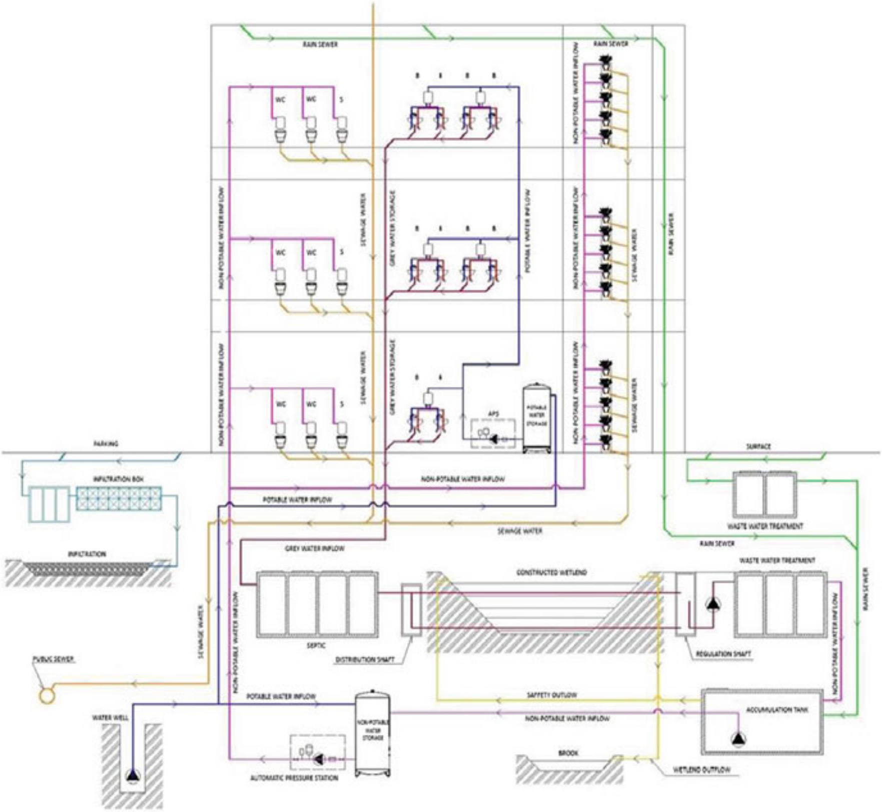


**Fig. 21** Hybrid system of in-building water cycle – combined application using grey water, rainwater, well water and infiltration

Water reuse is integral to sustainable water management because it allows water to remain in the environment and be preserved for future uses while meeting the water requirements of the present. Water and energy are interconnected, and sustainable management of either resource requires consideration of the other. Water reuse reduces energy use by eliminating additional potable water treatment and associated water conveyance because reclaimed water typically offsets potable water use and is used locally. Although additional energy is required to treat wastewater for reclamation, the amount of energy required for treatment and transport of potable water.

The energy required for capturing, treating and distributing water and the water required to produce energy are inextricably linked. Water reuse can achieve two benefits: offsetting water demands and providing water for energy production (Fig. 22).

Understanding that reuse is one of the tools that urban water/wastewater/stormwater managers have at their disposal to improve their existing systems' energy efficiency. EPA

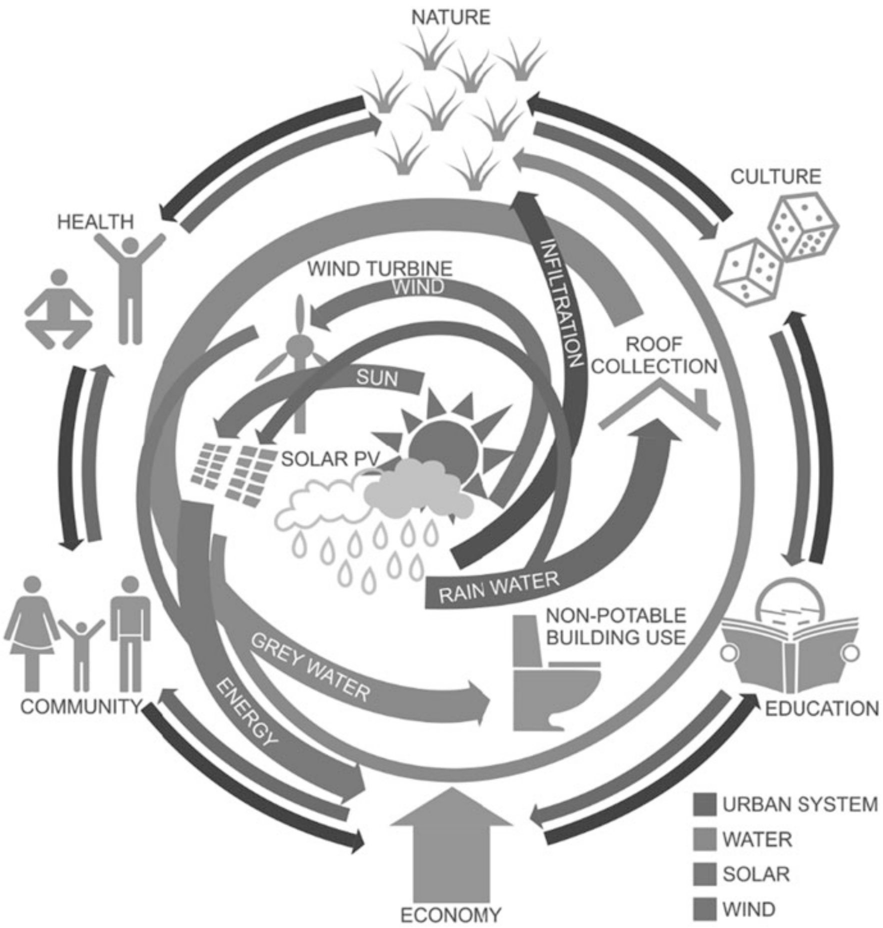


**Fig. 22** Water-energy nexus (according to [32])

is currently developing a handbook titled Leveraging the Water-Energy Connection – An Integrated Resource Management Handbook for Community Planners and Decision-Makers, envisioned to be an integrated water management-planning support document. The manual will address water conservation and efficiency as well as alternative water sources (reclaimed water, grey water, harvested stormwater, etc.) as part of capacity development, building codes for improved water and energy-use efficiency and renewable energy sources from/for both water and wastewater systems.

These results in Portugal underscore the importance of water efficiency in buildings, not only as a means for rational use of water but also for its significant contribution to the energy efficiency of buildings and reducing the emission of greenhouse gases [17].

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## References


1. UN-Water (2014) Water for a sustainable world. Annu Rep. https://sustainabledevelopment.un.org/content/documents/2071ANNUAL_REPORT_2014_Final.pdf
2. Global Goal for Water. Synthesis of key findings and recommendations from UN-Water. Executive summary: a post 2015. [Online]. [Cit. 2014–10-15]. http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/Topics/UNWater_technical_advice_post_2015_global_goal_ES_final_highres.pdf
3. Gray NF (2010) Water technology. 3rd edn. IWA Publishing, London, 747 p
4. World Water Assessment Programme. http://www.worldwatercouncil.org/library/archives/water-crisis/
5. http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2017-wastewater-the-untapped-resource/
6. Kinkade-Levario H (2007) Design for water. New Society, Gabriola Island, p 240
7. Stec A, Kordana S, Słyś D (2017) Analysing the financial efficiency of use of water and energy saving systems in single-family homes. J Clean Prod 151:193–205
8. Human Development Report (2006) [Online] [Cit. 2014–07-15]. http://hdr.undp.org/en/content/human-development-report-2006
9. http://ec.europa.eu/eurostat/statistics-explained/index.php/Water_statistics
10. Butler D, Davies D (2015) Urban drainage. 3rd edn. Spon Press, Taylor and Francis Group, London, New York, 543 p
11. Ashley RM et al. (2008) Active learning: building the capacity to adapt urban drainage to climate change; 11th international conference on urban drainage, Edinburgh, Scotland, UK
12. Kaposztasova D (2015) Integrated water management at the building level, Habilitaton work, Technical University of Kosice, p 180
13. Rainwater and Greywater, Decision-Making for Water Conservation (PR80) CIRIA (2001) Project website: http://web.stanford.edu/group/narratives/classes/08-09/CEE215/Projects/greendorm/water/GraywaterCD/greywater/pr80.pdf
14. Environment Agency (2010) Harvesting rainwater for domestic uses: an information guide [online]. 30 p. [cit. 2015–02-15]. http://webarchive.nationalarchives.gov.uk/20140328084622/http:/cdn.environment-agency.gov.uk/geho1110bten-e-e.pdf
15. European Commission (2009) A report by the Office of Community and Economic Development. http://ec.europa.eu/environment/water/quantity/pdf/Water%20efficiency%20standards_Study2009.pdf 2009
16. Silva-Afonso A, Rodrigues C (2008) Water efficiency of products and buildings: The implementation of certification and labelling measures in Portugal. In: Proceedings CIB W062 2008 34th international symposium of water supply and drainage for buildings. HKPU, Hong-Kong
17. Silva-Afonso A et al (2011) Grey water in buildings. The Portuguese approach. In: Proceedings of 37th international symposium CIB W062 on water supply and drainage for buildings. Aveiro
18. Krídlová Burdová E, Vilčeková S (2013) Building environmental assessment system in Slovakia. LAP LAMBERT Academic Publishing, Saarbrücken, p 114
19. EPA Basic Information (2015) [Online] [Cit. 2015–03-05]. http://water.epa.gov/drink/info/well/basicinformation.cfm
20. ANQIP (2011) ETA 0905 systems of reuse and recycling of grey water in buildings (SPRAC). Portuguese Association for Quality in Building Installations, Aveiro, Portugal
21. Matos C, Bentes I (2011) Water supply and drainage in buildings considering grey water use. In: Proceedings of 37th international symposium CIB W062 on water supply and drainage for buildings. Aveiro
22. Green Plumbing and Mechanical Code Supplement (2012) IAPMO, chapter 5 [Online] [Cit. 2014–10-15]. http://www.iapmo.org/Documents/2012GreenPlumbingMechanicalCodeSupplement.pdf
23. Eriksson E, Auffarth K, Henze M, Ledin A (2002) Characteristics of grey wastewater. Urban Water J 4:85–104

24. Novotny V, Ahern J, Brown P (2010) Water centric sustainable communities: planning, retrofitting, and building the next urban environment. Wiley, Hoboken, NJ, p 606
25. Penn R, Hadari M, Friedler E (2012) Evaluation of the effects of greywater reuse on domestic wastewater quality and quantity. Urban Water J 9:137–148
26. Lancaster B (2012) Rainwater harvesting for drylands and beyond. Tucson, Arizona, p 282
27. Słyś D, Stec A, Zeleňáková M (2012) A LCC analysis of rainwater management variants. Ecol Chem Eng 19(3):359–372. www.scopus.com
28. Fryer J (2012) The complete guide to water storage: how to use gray water and rainwater systems, rain barrels, tanks, and other water storage techniques for household and emergency use 2012, Atlantic Publishing Group Inc., p 336
29. Hlavínek P et al (2007) Hospodaření s dešťovými vodami v urbanizovaném území. Brno ARDEC s.r.o., p 164
30. British Standard BS 8528-1 (2010) Geywater systems – part 1: code of practice. BSI, UK
31. Sapkota M, Arora M, Malano H et al (2015) An overview of hybrid water supply systems in the context of urban water management: challenges and opportunities. Water 7:153–174
32. Conceptual creating the nexus by Payette (2015) [Online] [Cit. 2015-03-08]. http://www.payette.com/post/1391669-conceptual-creating-the-nexus