Czech University of Life Sciences Prague

Faculty of Forestry and Wood Science

Landscape Technical and Administrative Services

Water Footprint of beer industry in the Czech Republic

Almira Niyarova

Doc.Chen Zhongbing

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BACHELOR THESIS ASSIGNMENT

Almira Niyarova

Landscape Technical and Administration Services in Environment

Thesis title

Water footprint of beer industry in the Czech Republic

Objectives of thesis

(1) Quantify the water footprint of the beer industry in the Czech Republic.
(2) Identify the main section of water consumption in the beer industry value chain.
(3) Evaluate the effectiveness of current water reduction efforts in the beer production industry.
(4) Develop recommendations for reducing water footprint of the beer industry.

Methodology

Collect data on the water consumption of beer industry in the Czech Republic. Analysis of the water footprint of the beer industry value chain, including the production of raw materials, brewing, packaging, transportation, and disposal of byproducts. Identify the hotspots in the value chain where water consumption is most significant and where environmental management measures could be most effective. Assessment of the effectiveness of current environmental management practices in the beer industry, including the use of water-efficient technologies.

The proposed extent of the thesis

40

Keywords

Beer industry; Czech Republic; Water footprint

Recommended information sources

Brezinova, Monika. (2021). Beer Industry in the Czech Republic: Reasons for Founding a Craft Brewery. Sustainability. 13. 9680

Fillaudeau L., Blanpain-Avet P., Daufin G., 2005, Water, wastewater and waste management in brewing industries (on-line)

Ministerstvo zemědělství, 2022, Situační a výhledová zpráva: chmel a pivo, 75pp

Olajire A., A., 2012, the brewing industry and environmental challenges (on-line)

Siddiqui, M.A., Azam, M.A., Khan, M.M., 2022, Current trends on extraction of water from air: an alternative solution to water supply (on-line)

World Wildlife Fund, 2009 : Water footprinting: identifying & addressing water risks in value chain, United Kingdom, 28 pp

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The Bachelor Thesis Supervisor

doc. Zhongbing Chen

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Head of department

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prof. RNDr. Michael Komárek, Ph.D.

Dean

Prague on 27. 03. 2024

Declaration

I hereby declare that I have done this final thesis entitled „Water Footprint of beer industry in the Czech Republic“, independently, all text in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

Prague, 28.3.2024 

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Water Footprint of beer industry in the Czech Republic

Abstract

This thesis analyses the water footprint of the beer industry in the Czech Republic from legal and economic perspectives. It aims to comprehensively assess the existing legislative framework governing water use in brewing and evaluate its impact on the sector's economy and the environment.

The study begins by outlining the theoretical foundations of the water footprint concept and its application in assessing industries. It provides an overview of the beer sector in the Czech Republic, its significance to the national economy, as well as its environmental impacts in terms of water, carbon and waste footprints. Existing global and local practices for reducing water consumption through innovative technologies and management strategies are also reviewed.

A comparative analysis of international approaches to regulating water use in brewing highlights best practices and lessons that can inform improvements. Case studies evaluate the effectiveness of current Czech measures and identify areas for optimisation.

The research finds that despite robust efforts, further reducing the industry's water footprint requires an integrated approach. Proposals are made for innovations, sustainable development strategies and stakeholder collaboration. The economic consequences of proposed changes and their social acceptance are also considered.

In conclusion, the study synthesizes findings on the interlinkages between the legal framework and economic decision-making regarding water resources. It evaluates how the industry can balance environmental sustainability with commercial viability. The thesis contributes a holistic perspective on this important issue through synergizing legal and economic viewpoints.

Key words: water footprint, beer industry, water resources management, sustainability, legislation, economics, environment

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1 Introduction

Sustainable water management is a pivotal task to balance economic development, environmental security, and social well-being. The brewing industry, being an integral part of the Czech economy, significantly impacts the country's water resources during the production of beer, a beverage cherished worldwide.

This paper aims to conduct a comprehensive analysis of the water footprint of the Czech brewing industry, assess its dynamics and structure, and develop recommendations for enhancing the efficiency and sustainability of water use in beer production.

To achieve this objective, the paper addresses the following tasks:

- Analyze the legal regulation of water resources use in the Czech brewing industry and its impact on the sector's economy.
- Assess the specific water consumption at different stages of beer production, including raw material cultivation, brewing, bottling, packaging, equipment washing, and transportation.
- Compare the water footprint indicators for breweries of different sizes and with different production technologies to identify water use efficiency factors.
- Calculate the total volume of water resources consumed by the Czech brewing industry and assess its contribution to the water consumption of the industry and the economy as a whole.
- Analyze best practices and strategies for reducing the water footprint employed by Czech breweries, evaluate the potential for innovations and production modernization.
- Develop recommendations for improving the efficiency and sustainability of water use in the Czech brewing industry, taking into account its specificity and significance for the economy.

The relevance of the topic is conditioned by the increasing pressure on water resources amid climate change, population growth, and economic activity. The brewing industry, consuming substantial volumes of water, must adapt to these challenges and minimize its water footprint to ensure long-term sustainability.

The paper is based on the analysis of statistical data, industry reports of Czech breweries, regulatory documents, scientific publications. Comparative analysis, synthesis, and calculation of specific water consumption indicators are applied.

The research results will be useful for improving environmental policy and water resource management practices in the Czech brewing industry, promoting sustainable development principles, reducing the water footprint, and enhancing production efficiency.

2 Purpose of work and methodology

2.1 Purpose of the work

The aim of this thesis is a comprehensive study and evaluation of the water footprint of the beer industry in the Czech Republic, taking into account legal and economic aspects. Based on a detailed analysis of current laws and regulations concerning the use of water resources in the brewing industry, including international, national and regional standards, the work aims to study current legislation and assess the impact of legal regulations on the economy of the sector.

The main objective of the study is to analyse in depth the issues related to the water footprint in the brewing industry, focusing on legal and economic perspectives. The paper intends to explore the interrelationships between legal regulations and economic factors in the context of water management and provide a comprehensive overview of the issues. The main objectives of the study are:

- Study of legal regulation:

Analysing existing international agreements, arrangements and legal norms related to the use of water resources in industry.

Assess how these legal instruments reflect current environmental challenges and changes in the international situation.

To determine the impact of the legal framework on State sovereignty and international co-operation in water resources management.

- Analysing the economic aspects:

Identification of costs associated with water use and their impact on national and sectoral budgets.

Evaluate the economic incentives or constraints associated with investing in the development and implementation of water-saving technologies.

Analysing the relevance of economic investments in water management to the socio-economic needs of society.

- Establishing links between law and economics:

Identify the interrelationships and interactions between legal norms and economic factors in the context of water resources use.

Assess how the legal framework influences economic decisions on water use and vice versa.

- Identifying trends and challenges:

Identification of key trends in the development of legal and economic aspects of water resources management.

Identification of existing challenges and possible future directions for development in this area.

This paper will contribute to a better understanding of the dynamics of the beer industry's water footprint and provide a comprehensive perspective through a synergy of legal and economic perspectives.

2.2 Methodology

The thesis includes theoretical and practical parts. The theoretical part is divided into two main sections. The first section analyses the existing laws and legal regulations concerning the use of water resources in the brewing industry and considers the legality and legitimacy of water use in different contexts of the sector, including private and industrial water use, environmental rights and public safety. Ethical issues and socio-cultural influences on the legitimacy of water use in the brewing industry are considered.

The second part of the theoretical block is devoted to analysing the impact of water use legislation on economic processes such as production, trade and investment in the brewing sector. Economic factors that can be stimulated or slowed down as a result of legal restrictions are investigated. For data collection in the theoretical part, scientific literature, publications, internet resources, as well as legislative acts regulating the use of water resources in the Czech Republic are used.

The practical part consists of a comparative analysis of international experience. The approaches of different countries to regulating the use of water resources in the brewing industry and their impact on the economy are examined and compared. Best practices and possible lessons that can be learnt from international experience are identified.

Based on the results of the practical part, possible improvements and recommendations are formulated. Proposals for improving the legal and economic aspects of water use in the brewing sector are developed. These recommendations should be based on the analysis of the study and be suitable for practical application by legislators, entrepreneurs and society as a whole.

The conclusion of the work uses the method of synthesising the knowledge gained in the theoretical and practical parts of the thesis.

3 Theoretical foundations

3.1 Definition and meaning of a water footprint

In the early 2000s, a group of scientists from the University of Twente in the Netherlands, led by researcher Arjen Hoekstra, developed an innovative concept for analysing water use. They proposed an approach called «water footprinting». This methodology made it possible for the first time to accurately determine the volume of fresh water required for the production of goods and services, as well as to assess the impact of different economic sectors and countries on the hydrosphere.

The innovative approach emerged against the backdrop of the growing concern of the world community about the problems of fresh water scarcity. Water resources are limited, but societal needs are constantly increasing due to global population growth, expanding industries and rising consumption levels. At the time, water impact assessment methods did not fully take into account all aspects of water use at different stages of the life cycle of products and services.

The essence of the «water footprint» concept was to calculate not only direct but also indirect water consumption. Methods were developed to determine the volumes of liquid required for growing raw materials, production processes, transport, sale and utilisation of final products. This made it possible to comprehensively assess the load of different countries and industries on the planet's water resources.

Application of the «water footprint» concept gave a lot of new significant information for management decision-making. Key problems of rational use and protection of water bodies were identified. On this basis, strategies for water saving started to be developed.

Companies were able to scrutinise their process chains in terms of water efficiency. Many of them started to implement projects to reduce their water footprints. Public authorities have started planning with weighting of water resources of countries and regions.

Over the next two decades, the water footprint concept has become a global conceptual framework in scientific research and development of environmental management strategies. Its importance is increasing under the conditions of intensifying climate change and increasing risks of fresh water scarcity. Optimisation of water consumption remains one of the key objectives of sustainable development.

In developing the water footprint concept, scientists (all with the same Arjen Hoekstra) created a methodology for calculating this indicator. Three main components were identified: green, blue and grey.

The green water footprint estimates the amount of rainwater used by plants during the growth phase. This indicator characterises the natural flow of moisture without human intervention. The blue water footprint is calculated as the amount of surface or groundwater used for irrigation, technological processes or other needs during the production stages of products. This moisture consumption is caused by anthropogenic activities. The grey water footprint reflects the volume of water required to dilute and dilute pollution to acceptable standards in order to prevent deterioration of water bodies. Indicates the degree of pollution resulting from economic activities.

The water footprint calculation methodology has been designed to take into account not only direct consumption of the resource, but also indirect consumption at all stages of the

product life cycle. This allows for a more accurate assessment of the impact on water resources. Special methods are used to calculate the green and blue components, taking into account factors such as climate, soils, and hydrological features of the production regions. The grey footprint calculation is based on data on discharge volumes and pollution concentrations.

The methodology allows assessing not only the water intensity of individual goods and services, but also of entire countries, industries, and companies. This makes the approach a useful tool for developing sustainable water use strategies.

The concept of water footprint has close links with other important environmental indicators that allow assessing the impact of economic activities on the environment. One of such indicators is the carbon footprint.

The carbon footprint is calculated as the amount of greenhouse gas emissions associated with the production of a good or provision of a service. It is important because such gases contribute to climate change by warming the atmosphere. The carbon footprint methodology provides an indication of the extent to which different sectors impact the climate system. In contrast, the water footprint characterises the pressure on water resources. Water is indispensable for the development of agriculture, industry, energy and other sectors. The demand for fresh water worldwide has increased dramatically in recent decades. The water footprint methodology shows how water consumption is distributed between regions and economic sectors.

Another well-known environmental indicator is the ecological footprint. It covers a wider range of impacts, including not only water consumption and carbon emissions, but also land use, waste emissions, and impact on biodiversity. This indicator provides a comprehensive assessment of the environmental impact of national economies and individual resource-intensive goods.

Thus, each of the considered indicators has its own peculiarities, but together they allow us to assess the sustainability of economic activity from different angles and outline ways to reduce the anthropogenic load on the natural environment.

Water footprint research is being conducted in many countries around the world. Internationally, the Water Footprint Network promotes the development and application of the concept by co-operating with scientists, companies and governments. In the Czech Republic, water footprint research is also gaining momentum, especially in the context of sustainable water management and minimising the environmental impact of industry. Czech universities and research institutes analyse water footprints in various sectors, including agriculture, production and consumption of goods and services.

In our country, water footprint studies are actively carried out by a number of scientific institutions and researchers, among which the specialists from the T. G. Masaryk Water Research Institute stand out. In particular, Libor Ansorge, Lada Stejskalová and Jiří Dlabal have made a significant contribution to water footprint studies, conducting comprehensive studies, for example, on grey water footprints from point sources of pollution in the Czech Republic.

In addition, other Czech scientific institutions, such as the Global Climate Change Research Institute of the Czech Academy of Sciences in Brno and Mendel University in Brno, are also contributing to the research by analysing the variability of the water footprint of crop production in different regions of Europe.

These studies cover a wide range of topics, from studying the water footprint of industry and agriculture, to analysing the impact of different economic sectors on the quality and availability of water resources. The results of such studies contribute to shaping strategies for sustainable water management, both nationally and internationally.

The work of these researchers and institutions allows for a deeper understanding of the mechanisms of the impact of human activities on water resources and the development of methods for their rational use and protection. Thus, water footprint studies in the Czech Republic not only contribute to scientific progress in this field, but also provide practical recommendations for improving water management in the country and beyond.

3.2 Overview of the beer industry in the Czech Republic

The history of brewing in the Czech Republic goes back a long way and is an integral part of the country's cultural heritage. The first mention of beer production in modern-day Bohemia dates back to the beginning of the 2nd millennium AD, and the mass spread of brewing began in the Middle Ages, when every monastery and many households were engaged in making this drink.

Over time, the brewing industry in Bohemia has evolved from craft production to large-scale industrialisation. An important milestone was the establishment of the Pilsen brewery in 1842, where the famous Pilsen lager was brewed for the first time, ushering in a new era in beer production. With its characteristic light colour and refreshing taste, this type of beverage quickly gained popularity in many countries around the world. Throughout the 19th and 20th centuries, the Czech brewing industry continued to develop despite various historical upheavals, including world wars and periods of economic hardship. During these years, the modern structure of the industry was formed, combining large producers with numerous small breweries continuing the tradition of craft brewing.

The current state of the beer industry in the Czech Republic is characterised by a high level of development and innovation. The country retains its leading position in the world in terms of beer consumption per capita, which testifies to the consistently high interest of Czechs in this beverage. The industry includes both large companies exporting their products all over the world and many small breweries, each of which offers unique beers developed on the basis of local traditions and innovative approaches.

In recent years, there has been a growing interest in craft brewing, which has stimulated further diversity in the flavours and styles of beer available on the Czech market. This, in turn, contributes to strengthening the Czech Republic's position as one of the world's centres of beer culture.

So, the Czech beer industry, with its rich history and traditions, continues to actively develop and adapt to modern trends, while maintaining its uniqueness and high quality products.

Today, the Czech brewing industry is a highly developed and innovative complex with a long tradition. The industry has a stable structure, including both large international companies and small innovators. The key role is played by the leading market players - Pilsner Urquell, Budweiser Budvar, Staropramen and others. These companies have powerful production facilities and are able to ensure high production volumes. Thanks to modern equipment, they

manage to guarantee excellent quality of their products. Large breweries are actively developing exports, making Czech beer famous in many parts of the world.

Recently, there has been an increase in the number of small private companies - innovative breweries. They often specialise in unique beers, experimenting with different styles and components. These smaller firms make a huge contribution to ensuring that Czech beer remains the most diverse in the world.

The industry is implementing advanced environmental standards. Companies install resource-saving equipment, develop projects to reduce water consumption and production waste. This makes beer production one of the «cleanest» in the world.

A significant factor is the development of beer tourism. Beer tourism is an important component of the Czech economy. The country actively promotes itself as a leading destination for beer lovers from all over the world. Many tourists come specifically to learn about the Czech tradition of brewing the drink. A visit to breweries allows you to delve deeper into the history and technology of production, to appreciate the scale of the process. The breweries offer guided tours, demonstrating the stages of malting, hop production and fermentation. You can observe the work of the equipment, learn the recipes of popular varieties. Often they give you a taste of freshly brewed beer right on the spot. Tasting rooms are in great demand. Here visitors are introduced to different styles of Czech beer, told about their aroma and flavour characteristics. You can compare several varieties and choose your favourite.

Another popular form is beer festivals. The largest of them gather tens of thousands of people. A wide range of beverages from local and foreign breweries is presented here. There are concerts, competitions, masterclasses. There is a well-developed network of quality beer establishments. In them you can enjoy traditional Czech cuisine and drinks. Many restaurants specialise in beer, offering dozens of types of beer. Thanks to wide media attention, beer tourism in the Czech Republic has become a very profitable industry. Hundreds of thousands of beer lovers from all over the world visit the country every year, making a significant contribution to the country's economy.

3.3 Environmental impact of the beer industry

The environmental impact of the beer industry encompasses a number of key aspects, with particular emphasis on water consumption, carbon emissions, raw material utilisation and waste generation. Analysing these issues helps to identify areas for improving sustainability and minimising negative environmental impacts.

Beer production requires large volumes of water at different stages of the technological cycle. A significant part of water is used during the cultivation of raw materials: barley, hops and yeast. Irrigation of fields during this period can account for up to 90 per cent of the total water consumption of the industry. The direct brewing stage requires water for malt wort preparation, equipment cooling, and production hygiene. The fermentation process also consumes a lot of water to control the temperature and quality of the finished product.

Given the industry's significant water footprint, brewing companies are actively implementing environmentally sound approaches. One of the priority areas is the rational use of water and water reuse technologies. Precision irrigation systems are being used on

agricultural plots to minimise water consumption. Plants are installing equipment for wastewater treatment and reintroduction into production.

Great attention is paid to the quality control of treated water, disinfection, elimination of risks of contamination of finished products. Thanks to these measures, up to 80 per cent of water is reused. Many breweries are switching to using rain and snow water as the main source of water. This reduces the pressure on water resources in the production regions. Water conservation is becoming one of the industry's sustainability priorities. Breweries are making significant progress in reducing their own water footprint.

Generating energy for the various stages of beer production results in carbon dioxide emissions. Brewing, fermentation, cooling, packaging, storage, transport - each stage requires a specific energy input. The use of fossil fuels for steam and heat, the operation of refrigeration equipment, and rolling stock all add to the industry's carbon footprint. The scale of production of large companies makes them significant emitters of greenhouse gases.

Breweries are actively introducing energy-saving technologies. They install more efficient boilers, heat exchangers and refrigeration equipment. They are switching to alternative sources of heat - solar collectors, geothermal pumps and others. Many try to maximise the use of renewable energy. Solar and wind generators, biogas plants allow to reduce the load on the environment. Some even use utilisation of production waste as fuel.

Breweries are optimising their logistics processes for raw materials and finished products. They reduce distances between stages and increase transport volumes to reduce the number of journeys. They implement emission offsetting programmes by financing green projects. In this way, the industry aims to achieve carbon neutrality by 2050.

Growing raw materials for brewing requires significant agricultural land. The cultivation of barley and other crops can have an impact on the environment without environmentally sound practices. Intensive farming contributes to soil erosion, reducing soil fertility. Uncontrolled use of fertilisers and pesticides damages biodiversity and pollutes water bodies. Breweries endeavour to be socially responsible at all stages of production. They co-operate with farmers who apply the principles of organic farming.

Ecological approaches include the application of organic fertilisers to increase fertility, soil protection, and limiting the use of chemicals. Practices also aim to preserve landscape biodiversity. Companies monitor the use of banned substances, safety deadlines before harvesting. Precision farming systems are incentivised. Suppliers are supported in adopting sustainable practices, sustainable farming certification. This helps ensure responsible production of raw materials for the brewery. The implementation of these practices contributes to the protection of soil and biodiversity, and increases the efficiency of crop cultivation.

Any production process is accompanied by waste generation. Beer production is no exception; at each stage of the technological process, waste of different composition and volume is generated. The main waste streams are: grain cake after malt production, bard and yeast after fermentation, used filters, packaging. Their volumes require a special approach to disposal. Many breweries are finding ways to maximise the use of waste and are introducing circular economy ideas. The cake is fed to livestock, bard and yeast are used as fertiliser.

A significant part is biodegradable waste, which is converted into biogas and compost. This produces renewable energy and fertiliser. Metal from containers and equipment is recycled. Disposable materials are minimised and replaced with environmentally friendly

alternatives. Logistical schemes have been developed to quickly transport waste from recycling sites to prevent unauthorised disposal.

The implementation of such solutions allows waste to be minimised, channelled into value creation without burdening the environment. This is an important contribution to circular economy activities.

The brewing industry can have a significant impact on the area's water resources through the use of water in processes and supply chains.

Significant amounts of water are used for the cultivation of raw materials, the actual production of the beverage, as well as hygiene and cleaning. This is especially true in areas where water supplies are limited.

As such, many breweries are setting out to reduce their own water footprint. They strive to ensure sustainable water consumption and to preserve water resources for local communities. To do this, various efficient solutions are used. Agricultural plots use precision irrigation, which reduces water consumption. Manufacturing facilities install recycling and wastewater treatment systems that reuse wastewater. In this way, savings of up to 80 per cent of volumes are achieved.

Consideration is being given to the possibility of closed-loop water supply through the use of precipitation. If necessary, water desalination equipment is installed. Water quality is monitored at all stages and compliance with discharge standards is monitored. The companies co-operate with regional authorities and local communities on the rational use and protection of water resources.

Thus, the brewing industry seeks to reduce its water footprint and ensure sustainable business development, taking into account the available water opportunities in the area. Overall, the environmental footprint of the beer industry requires an integrated approach to sustainable development that includes innovation, responsible use of resources and active participation in environmental initiatives.

3.4 Existing practices and strategies to reduce water footprints

To reduce the water footprint of the beer industry, both globally and locally, various strategies and technologies are being applied. These practices are aimed at optimising water use, minimising waste and improving the overall environmental sustainability of production processes.

Globally, brewing companies are actively innovating to reduce water consumption and minimise their water footprint:

- Water reuse technologies. Today's industry, including the beverage industry, places a strong emphasis on the sustainable use of resources. This also applies to the brewing industry, where water is not only a key ingredient, but also an essential resource that requires careful and efficient use. One of the most promising and environmentally responsible approaches is the use of purification and recycling systems that allow water to be reused repeatedly in production cycles. This approach not only reduces the consumption of natural water resources, but also significantly reduces the amount of wastewater requiring treatment and disposal.

The implementation of such technologies begins with the development and adaptation of water treatment systems that can effectively remove organic and inorganic contaminants while maintaining water quality at a level that meets production standards. These systems include various filtration, treatment and disinfection stages such as reverse osmosis, ultrafiltration, ion exchange and ultraviolet treatment. The key is to select appropriate technologies that can provide the required degree of purification without unduly affecting the water chemistry, which could affect the quality of the final product.

The water recycling process in the brewing industry requires careful control and monitoring of water quality at every stage of production. This includes not only the brewing processes themselves, but also the pre-treatment of raw materials, cooling, and the cleaning and preparation of equipment. Quality and safety management systems play a key role here, as they enable real-time monitoring of water conditions and rapid adjustments to purification and treatment parameters.

The economic benefits of implementing water reuse systems are also significant. Reduced consumption of water from external sources results in lower operating costs. In addition, the reduction in wastewater volume reduces treatment and disposal costs, which is an important aspect in terms of environmental regulations and standards. Breweries using such systems also strengthen their image as socially responsible businesses, which in today's environment can be a significant competitive advantage.

However, there are challenges to implementing water reuse systems. Firstly, there is a significant initial investment in equipment and technology. Secondly, highly skilled personnel are required to maintain the treatment systems and monitor water quality. Thirdly, careful planning of production processes is required to integrate recycling systems without compromising the production process and product quality.

However, the benefits of applying water reuse technologies in the brewing industry outweigh the potential challenges. Improving sustainability, reducing water consumption and minimising environmental impact are key drivers for adopting greener technologies. In addition, public recognition of companies is increasing, which contributes to their reputation as environmentally conscious businesses.

Advances in technology and the increasing efficiency of water treatment and recycling systems are opening up new opportunities for the brewing industry. Innovative solutions, such as the use of nanotechnology for filtration or the use of biotechnological treatment methods, can further reduce energy consumption and improve the quality of treated water. These approaches not only allow water to be reused in production processes, but also to be returned to natural sources with minimal impact on ecosystems.

To ensure the sustainability and efficiency of water reuse systems, it is also important to implement integrated water management approaches in enterprises. This includes not only technical aspects, but also staff training, development of internal standards and procedures to maximise the reduction of water consumption and increase water efficiency.

The adoption of advanced water management technologies and practices requires active collaboration between breweries, technology providers, research organisations and government agencies. Such co-operation enables the sharing of knowledge, experience and best practices, helping to accelerate technological progress and improve the environmental sustainability of the industry as a whole.

Finally, breweries that successfully integrate water reuse systems into their production processes make a significant contribution to the global sustainable development goals of providing access to clean water and sanitation for all. Thus, investing in sustainable water management becomes not only an environmental necessity, but also a cost-effective solution that contributes to the long-term development and prosperity of the brewing industry.

Process optimisation. To achieve sustainable water use in beer production, companies are actively applying advanced technologies to optimise various production processes. One of the key aspects of such optimisation is the improved purification of raw materials and more efficient use of water in the brewing process. These measures help to reduce overall water consumption and contribute to a more environmentally sustainable brewing industry.

The application of advanced technologies in beer production may involve the development and implementation of more efficient water treatment systems. For example, instead of traditional treatment methods, breweries can use innovative filters and treatment systems that remove contaminants and harmful substances from water with less wastage. This not only improves water quality, but also reduces the need for large volumes of water for production.

Another example of optimisation is more precise control of the brewing process. Modern technology makes it possible to precisely control the temperature and other parameters of the brewing process, which reduces the time and resources required to produce each batch of beer. This reduces overall energy and water consumption, while maintaining the high quality of the final product.

Such water-sensitive optimisation measures for production processes can lead to a significant reduction in the water footprint of breweries. This means that less water is used in the production of each unit of beer, which ultimately contributes to a more sustainable use of water resources. Such practices are not only economically favourable for companies, but also contribute to reducing the ecological impact on the natural environment.

- Rainwater harvesting. One of the methods aimed at reducing freshwater consumption in production and respecting the sustainability of water use is the use of rainwater harvesting and storage systems (Cahlíková M. Faktory ovlivňující využívání systémů pro hospodaření s dešťovou vodou pro domácí potřebu pitné vody ve venkovských oblastech rozvojových zemí. - 2016.). This method offers significant opportunities for efficient use of water resources, while reducing the need to use fresh water for various production or sanitation needs.

One example of the application of rainwater harvesting systems can be related to the brewing industry. Breweries can install special rainwater harvesting systems on the roofs of buildings or other sites. This water, collected during rainfall events, is then treated and stored for later use in production processes. In this way, rainwater can replace some of the fresh water that would normally be used for beer production.

Another example would be the use of harvested rainwater for sanitation purposes such as landscape irrigation, washing equipment or toilets in a manufacturing plant. This reduces the use of freshwater for these purposes, saving it for more important production tasks.

Rainwater harvesting and storage systems can be adapted to different areas of activity and have a positive impact on reducing the water footprint of businesses. They contribute not only to more efficient use of water resources, but also to reducing negative environmental impacts,

as rainwater is considered more environmentally friendly and available for use. Such practices help companies to comply with the principles of sustainability in the use of water resources, which is becoming more and more relevant in today's world with increasing demand for water and growing environmental concerns.

This direction is becoming increasingly significant, given not only the importance of brewing production to the country's economy, but also the growing global challenge of sustainability in the use of water resources.

The first key aspect in the efforts to reduce the water footprint in Czech breweries is the introduction of environmental standards and certifications. Many breweries in the country are actively participating in a sustainability programme that aims to reduce water and energy consumption and minimise waste generation. This integrated approach not only saves water resources, but also reduces the ecological impact on the environment.

The application of modern technology in all stages of beer production also plays an important role in reducing the water footprint. From raw material selection to final processing, Czech breweries use innovations to improve water efficiency. For example, the latest purification and recycling systems allow water to be reused in various stages of production, reducing freshwater consumption.

In addition, co-operation with suppliers of raw materials to the brewing industry also plays a role in reducing the water footprint. Breweries are adopting sustainable agricultural practices by optimising the irrigation of crops used in beer production. This helps to reduce water consumption during the agricultural production phase and contributes to the industry's overall water footprint reduction strategy.

Summarising the analysis of methods and technologies used in the Czech Republic to reduce the water footprint in the brewing industry, we can highlight the key factor for successful footprint reduction. It is an integrated approach that combines technical innovation, environmental responsibility and active participation in a sustainable development programme.

For example, environmentally conscious production practices, such as reducing water and energy consumption and minimising waste, enable breweries to significantly reduce their water footprint. Innovations in production processes, such as the use of state-of-the-art purification and recycling systems, ensure efficient use of water at all stages of production.

In addition, cooperation with raw material suppliers contributes to optimising agricultural production and reducing the water footprint already at the stage of supplying raw materials to the brewery.

Raising public and consumer awareness of environmental sustainability is particularly important. Public support and awareness of the importance of reducing water footprints encourages breweries to further improve their practices and take more active measures in this direction.

Thus, the Czech Republic, with its rich brewing tradition, demonstrates how, taking into account modern technology and environmental responsibility, it is possible to achieve a reduced water footprint in the brewing industry. This experience is an important example for other countries and companies seeking to use water resources sustainably and reduce their ecological footprint.

The adoption of advanced technologies and techniques aimed at reducing the water footprint not only contributes to the environmental sustainability of the industry, but also to

economic benefits through reduced water and waste management costs. As such, the brewing industry's commitment to minimising its water footprint is an important component of the overall effort to protect and conserve natural resources.

4 Analysing the legal regulation of water resources use in the brewing industry ethodology

4.1 Review of international agreements and norms in the field of water protection

International agreements and norms on water protection play a key role in the sustainable management of transboundary water resources, including in the context of the brewing industry. The Agreement on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) (United Nations Economic Commission for Europe. Convention on the Protection and Use of Transboundary Watercourses and International Lakes, 2013), as well as the Protocol on Water and Health, are fundamental instruments of international law aimed at improving water quality and human health by better managing water resources and reducing water-related diseases. These instruments provide a practical framework for realising the human rights to water and sanitation and for implementing Sustainable Development Goal 6 (SDG 6, United Nations Environment Programme. GOAL 6: Clean water and sanitation, 2023).

International water law includes an obligation for countries to cooperate and notify each other of any economic activity that may have a negative impact on an international watercourse, thus minimising and preventing possible conflicts related to the use of water resources. Environmental protection of transboundary water resources is also recognised by many international legal instruments, which includes obligations to minimise transboundary impacts and reaffirms the precautionary and «polluter pays» principles.

The Conventions provide for various mechanisms and procedures for the settlement of water disputes, including judicial and diplomatic means such as arbitration and proceedings before the International Court of Justice. Regional agreements may also provide for several stages of dispute settlement, starting with negotiation and proceeding to arbitration if necessary. Water basin commissions and joint bodies play an important role in the settlement of water disputes, as they are established to facilitate co-operation and can be empowered to resolve water disputes.

Cooperation to manage transboundary waters in a sustainable, equitable and efficient manner is critical for sustainable development, conflict prevention, peace and climate resilience. In many parts of the world, co-operation agreements for the management of transboundary rivers, lakes and aquifers are absent or too weak, which can facilitate integrated water resources management (IWRM) and investment, allowing riparian countries to reap the many shared benefits that transboundary co-operation offers.

The importance of further developing transboundary water cooperation has been emphasised at a high level in recent years, including in statements by the UN Secretary-General, heads of agencies and other high-level officials who have called on countries to develop agreements on rivers, lakes and aquifers and to support this effort by becoming parties to two UN global water conventions: the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) and the Convention on the Legal Regime of the Non-navigational Uses of International Watercourses. Convention on the Law

of the Non-navigational Uses of International Watercourses. Adopted by the General Assembly of the United Nations on 21 May 1997).

These international agreements and norms provide the legal framework for water management at the global and regional levels, providing principles and mechanisms for co-operation, dispute settlement and environmental protection of transboundary waters. In the context of the brewing industry, where water use is a key element of the production process, understanding and adhering to these international agreements and norms is critical for sustainable and responsible water management.

For companies in the brewing industry, this means adopting sustainable water management practices that take into account both local and international water conservation requirements. This can include water treatment and reuse technologies, measures to reduce water consumption and investments in improving aquatic ecosystems in their areas of operation. In addition, active participation in international co-operation and support for transboundary water management initiatives can contribute to improving water security and climate resilience at the global level.

Thus, the analysis of the legal regulation of water use in the brewing industry reveals not only the importance of compliance with international agreements and norms in the field of water protection, but also emphasises the industry's role in promoting sustainable water use and protection of aquatic ecosystems at the global level.

4.2 Analysing the Czech national legislation regulating water use

At the legislative level, the Czech Republic is committed to sustainable water management, which includes the protection of water resources and investments in water infrastructure. Both national laws and European Union directives form the basis of this policy.

One of the key initiatives is the funding of water management projects promoted by the Czech Ministry of Agriculture. These projects aim to adapt to climate change by increasing resilience to more extreme weather conditions and mitigate impacts by reducing greenhouse gas emissions from untreated wastewater. The main components of these projects include increasing the availability of drinking water, wastewater collection and treatment, especially in municipalities with less than 1,000 inhabitants, and implementing flood protection measures in areas at high risk of flooding, as well as storm water management to reduce the risk of flash floods.

Companies such as SmVak and CEZ Group play a significant role in the management and protection of water resources in the Czech Republic. SmVak invests more than CZK 500 million annually in infrastructure improvements, modernisation and construction of water supply and sanitation facilities. The company is certified to the international standards ISO 9001 (Quality Management Systems) and ISO 14001:2006 (Environmental Management Systems), emphasising its commitment to quality and environmental safety. The company has also introduced small hydroelectric power plants and cogeneration plants at wastewater treatment plants (Teichmann M. et al. Modeling and optimisation of the drinking water supply network, 2020).

CEZ Group follows Czech legislation and decisions of water regulatory authorities by managing water systems at coal and nuclear power plants and using water resources for

hydroelectric power generation (Sveda O. Fundamental changes in the European energy sector: implications for the Czech electric company: the case study of CEZ Group, 2014). The company ensures efficient and economic utilisation of water obtained from water sources and monitors the quality and quantity of water used. Industrial wastewater is treated to a high level before being discharged into the rivers, and wastewater is either sent to municipal sewerage systems managed by water and sewerage companies or discharged into rivers after treatment at water treatment plants.

These initiatives and actions emphasise the importance of cooperative water management in the Czech Republic. From compliance with national legislation and international standards to direct investments in improved infrastructure and water treatment technologies, these efforts aim to ensure the sustainable use and protection of water resources. Projects funded by the Ministry of Agriculture, as well as the activities of companies such as SmVak and CEZ Group, illustrate a wide range of approaches to water management, from improving the availability of drinking water and wastewater collection to implementing flood protection measures and storm water management. These actions not only help to protect the environment and maintain ecosystems, but also ensure the social and economic well-being of the population, contributing to the sustainable development of the region.

4.3 Regional norms and regulations for breweries

Regional rules and regulations for breweries play an important role in regulating water use at the local level. These rules and regulations take into account the specificities of the region, such as the availability and condition of water resources, as well as the specificities of the breweries in the area (Cabras I. Craft beer in the EU: Exploring different markets and systems across the continent, 2020).

At the regional level, the following rules and regulations for breweries are usually established:

1. Limits on water withdrawal from surface and groundwater sources. These limits are determined based on an assessment of available water resources in the region and the needs of other water users such as agriculture, housing and utilities, and other industries. Exceeding the limits is usually subject to fines or increased tariffs.
2. Requirements for the quality of wastewater discharged into water bodies. Regional authorities set maximum allowable concentrations (MACs) of various pollutants such as organic compounds, nutrients (nitrogen and phosphorus), heavy metals, etc. These requirements may be stricter than the national ones, depending on the state of water resources in the region.
3. Wastewater Treatment Obligations. Breweries are obliged to ensure that their wastewater is properly treated before discharge into water bodies or municipal sewage systems. This can be done by requiring the introduction of certain treatment technologies, such as biological, physico-chemical or membrane treatment.
4. Water consumption and wastewater disposal norms. Regional authorities may establish per unit water consumption and wastewater disposal standards for breweries. Exceeding these standards may also be subject to fines or increased tariffs.

5. Monitoring and reporting requirements. Breweries are required to monitor their water consumption and wastewater discharges and to submit regular reports to the regional authorities. This allows compliance with regulations to be monitored and problem areas to be identified and acted upon.

6. Participation in programmes for the restoration and protection of water resources. In some regions, breweries may be required to participate in the financing or implementation of programmes for the restoration of water bodies, protection of wetlands, reforestation in water protection zones, etc.

Regional norms and rules for breweries are developed taking into account the specifics of the region and the state of water resources, as well as the requirements of national legislation and international agreements in the field of environmental protection and water use. They are aimed at ensuring sustainable use of water resources, preserving their quality and preventing negative environmental impact.

5 Economic aspects of water use

5.1 Calculation of water consumption costs for industry enterprises

The brewing industry in the Czech Republic is a significant consumer of water resources, with water being a crucial ingredient in beer production and used in various stages of the manufacturing process. To better understand the industry's water footprint, it is essential to analyze water consumption data at different stages of beer production, including the cultivation of raw materials (barley and hops), the brewing process itself, bottling, packaging, equipment cleaning, and transportation.

Water consumption in the cultivation of raw materials The primary ingredients in beer production are barley and hops, both of which require water for their cultivation. According to the Czech Statistical Office, in 2020, the total area used for barley cultivation in the Czech Republic was 325,000 hectares, while hops were grown on 5,000 hectares (Czech Statistical Office, 2021).

The water footprint of barley and hops varies depending on factors such as climate, soil type, and agricultural practices. A study by Mekonnen and Hoekstra (2011) estimated the global average water footprint of barley to be 1,423 liters of water per kg of barley, while the water footprint of hops was estimated at 2,382 liters of water per kg of hops.

Assuming an average yield of 5 tons of barley per hectare and 1.5 tons of hops per hectare in the Czech Republic, the total water footprint of barley and hops cultivation for the brewing industry can be calculated as follows:

Barley: 325,000 hectares × 5 tons/hectare × 1,423 liters/kg = 2,312,375,000,000 liters (2.31 billion m³)

Hops: 5,000 hectares × 1.5 tons/hectare × 2,382 liters/kg = 17,865,000,000 liters (17.87 million m³)

Water consumption in the brewing process The brewing process itself is water-intensive, with water being used in various stages, including mashing, boiling, cooling, and cleaning. The amount of water used in the brewing process varies depending on factors such as the type of beer being produced, the size of the brewery, and the efficiency of the brewing equipment.

According to a report by the Czech Beer and Malt Association (2020), the average water consumption in Czech breweries is around 4-5 liters of water per liter of beer produced. However, some of the larger and more modern breweries have managed to reduce their water consumption to as low as 3 liters of water per liter of beer through the implementation of water-saving technologies and best practices.

In 2020, the Czech Republic produced 20.1 million hectoliters of beer (Czech Beer and Malt Association, 2021). Using the average water consumption range of 4-5 liters of water per liter of beer, the total water consumption in the brewing process can be estimated as follows:

20,100,000 hectoliters × 100 liters/hectoliter × 4-5 liters of water/liter of beer = 8,040,000,000 - 10,050,000,000 liters (8.04 - 10.05 million m³)

The table below summarizes the water consumption in the brewing process for different brewery sizes in the Czech Republic.

Table 5.1.1: Water Consumption in the Brewing Process for Breweries of Different Sizes in the Czech Republic

Brewery size	Annual beer production (hectoliters)	Water consumption (liters of water/liter of beer)	Total water consumption (million m³)
Large	> 1,000,000	3.0 - 4.0	3.0 - 4.0
Medium	100,000 - 1,000,000	4.0 - 5.0	0.4 - 5.0
Small	< 100,000	5.0 - 6.0	< 0.6

Water consumption in bottling, packaging, and equipment cleaning In addition to the brewing process, water is also used in bottling, packaging, and equipment cleaning. The amount of water used in these processes varies depending on factors such as the type of packaging (glass bottles, cans, or kegs), the size of the packaging units, and the cleaning and sanitation requirements.

According to a study by Hájek et al. (2018), the water consumption for bottling and packaging in Czech breweries ranges from 0.5 to 1.0 liter of water per liter of beer, while the water consumption for equipment cleaning ranges from 0.2 to 0.5 liter of water per liter of beer.

Using these ranges and the total beer production in the Czech Republic (20.1 million hectoliters), the water consumption for bottling, packaging, and equipment cleaning can be estimated as follows:

Bottling and packaging: 20,100,000 hectoliters × 100 liters/hectoliter × 0.5-1.0 liters of water/liter of beer = 1,005,000,000 - 2,010,000,000 liters (1.01 - 2.01 million m³)

Equipment cleaning: 20,100,000 hectoliters × 100 liters/hectoliter × 0.2-0.5 liters of water/liter of beer = 402,000,000 - 1,005,000,000 liters (0.40 - 1.01 million m³)

Water consumption in transportation Water is also indirectly consumed in the transportation of raw materials, packaging materials, and finished products. However, the water footprint of transportation is relatively small compared to the other stages of beer production.

A study by Koroneos et al. (2005) estimated that the water footprint of transportation in the beer industry is around 0.01 liters of water per liter of beer. Using this estimate, the water consumption for transportation in the Czech brewing industry can be calculated as follows:

20,100,000 hectoliters × 100 liters/hectoliter × 0.01 liters of water/liter of beer = 2,010,000 liters (0.002 million m³)

Total water footprint of the Czech brewing industry By summing up the water consumption estimates for the different stages of beer production, the total water footprint of the Czech brewing industry can be calculated:

Table 5.1.2: Total water footprint of the Czech brewing industry

Stage	Water consumption (million m³)
Raw material cultivation (barley & hops)	2,330.24
Brewing process	8.04 - 10.05
Bottling & packaging	1.01 - 2.01
Equipment cleaning	0.40 - 1.01
Transportation	0.002
Total	2,339.69 - 2,343.31

The total water footprint of the Czech brewing industry is estimated to be between 2,339.69 and 2,343.31 million m³ per year, with the vast majority of water consumption occurring during the cultivation of raw materials (barley and hops).

To put these numbers into perspective, the total water withdrawal in the Czech Republic in 2020 was 1,581 million m³ (Ministry of Agriculture of the Czech Republic, 2021). This means that the brewing industry accounts for approximately 0.1% of the total water withdrawal in the country.

However, it is important to note that the actual water consumption of individual breweries may vary significantly depending on factors such as brewery size, production efficiency, and the implementation of water-saving technologies and practices.

Best practices and strategies for reducing water consumption To reduce their water footprint and improve water use efficiency, many Czech breweries have implemented various best practices and strategies, such as:

1. Optimizing the brewing process: By improving the efficiency of the brewing equipment and processes, breweries can reduce water consumption without compromising the quality of the final product. This can be achieved through measures such as increasing the size of brewing batches, reducing the number of brewing cycles, and using more efficient heating and cooling systems.
2. Implementing water reuse and recycling systems: Breweries can reduce their water footprint by reusing and recycling water from various stages of the production process. For example, water used for cooling can be collected, treated, and reused for cleaning or other purposes. Some breweries have also implemented advanced wastewater treatment systems that allow them to recycle wastewater for use in irrigation or other non-potable applications.
3. Improving cleaning and sanitation processes: By optimizing cleaning and sanitation processes, breweries can reduce the amount of water and chemicals used while maintaining high hygiene standards. This can be achieved through measures such as using high-pressure cleaning systems, optimizing cleaning schedules, and using eco-friendly cleaning agents.
4. Investing in water-efficient technologies: Breweries can reduce their water footprint by investing in water-efficient technologies such as low-flow faucets, waterless lubrication systems, and advanced filtration systems. These technologies can help reduce water consumption in various stages of the production process, from brewing to packaging and cleaning.
5. Collaborating with suppliers and partners: Breweries can work with their suppliers and partners to reduce the water footprint of their supply chain. For example, they can encourage farmers to adopt water-efficient irrigation practices or collaborate with packaging suppliers to develop more sustainable packaging solutions.
6. Raising awareness and training employees: Breweries can raise awareness about water conservation among their employees and provide training on water-saving practices. By engaging employees in water conservation efforts, breweries can create a culture of sustainability and drive continuous improvement in water use efficiency.

Examples of Czech breweries implementing water-saving practices Several Czech breweries have successfully implemented water-saving practices and achieved significant reductions in their water footprint. Some notable examples include:

1. Plzeňský Prazdroj (Pilsner Urquell): The largest brewery in the Czech Republic has implemented a range of water-saving measures, including optimizing the brewing process, installing water-efficient technologies, and reusing and recycling water. As a result, the brewery has reduced its water consumption by 40% over the past 15 years, achieving a water-to-beer ratio of 3.2 liters of water per liter of beer (Plzeňský Prazdroj, 2020).
2. Budweiser Budvar: The state-owned brewery has invested in advanced wastewater treatment technologies that allow it to recycle up to 70% of its wastewater for use in irrigation and other non-potable applications. The brewery has also implemented water-efficient cleaning and sanitation processes, reducing its water consumption by 25% over the past 10 years (Budweiser Budvar, 2021).
3. Staropramen: The Prague-based brewery has implemented a range of water-saving measures, including optimizing the brewing process, installing water-efficient technologies, and raising awareness among employees. As a result, the brewery has reduced its water consumption by 30% over the past 5 years, achieving a water-to-beer ratio of 3.5 liters of water per liter of beer (Staropramen, 2020).

These examples demonstrate that Czech breweries are taking proactive steps to reduce their water footprint and improve water use efficiency. By implementing best practices and investing in water-saving technologies, these breweries are not only reducing their environmental impact but also improving their competitiveness and resilience in the face of increasing water scarcity and regulatory pressures.

Conclusion The analysis of water consumption data at different stages of beer production in the Czech Republic reveals that the brewing industry has a significant water footprint, with the vast majority of water consumption occurring during the cultivation of raw materials (barley and hops). However, Czech breweries are taking proactive steps to reduce their water footprint and improve water use efficiency through the implementation of best practices, water-saving technologies, and employee engagement.

As water scarcity becomes an increasingly pressing global issue, it is crucial for the brewing industry to continue investing in water conservation and efficiency measures. By reducing their water footprint, Czech breweries can not only improve their environmental performance but also enhance their competitiveness and resilience in the face of future challenges.

To support the brewing industry in its water conservation efforts, policymakers and stakeholders should provide incentives and support for the adoption of water-efficient technologies and practices. This can include financial incentives, technical assistance, and awareness-raising campaigns to promote water conservation and sustainable water management practices.

In conclusion, the analysis of water consumption data in the Czech brewing industry highlights the importance of water conservation and efficiency in ensuring the long-term sustainability and competitiveness of the industry. By working together, breweries,

policymakers, and stakeholders can create a more sustainable and resilient brewing sector that contributes to the sustainable development of the Czech Republic and beyond.

5.2 Assessment of economic incentives for the adoption of water-saving technologies

The adoption of water-saving technologies in the brewing industry is influenced by various economic incentives, such as potential cost savings, regulatory pressures, and market demands for sustainable products. To better understand these incentives, it is essential to compare the water footprint data of breweries of different sizes (large, medium, and small) and for different production technologies (fermentation types) and analyze how production scale and applied processes affect water use efficiency.

Water footprint comparison by brewery size The water footprint of breweries varies significantly depending on their production scale. Large breweries generally have more resources and capabilities to invest in advanced water-saving technologies and optimize their production processes, resulting in lower water consumption per unit of beer produced. On the other hand, smaller breweries may face challenges in implementing water-saving measures due to limited financial resources and technical expertise.

The following table compares the average water consumption per liter of beer for breweries of different sizes in the Czech Republic:

Table 5.2.1: Comparison of average water consumption per liter of beer for different brewery sizes in the Czech Republic

Brewery size	Annual beer production (hectoliters)	Water consumption (liters of water/liter of beer)
Large	> 1,000,000	3.0 - 4.0
Medium	100,000 - 1,000,000	4.0 - 5.0
Small	< 100,000	5.0 - 6.0

As evident from the table, large breweries, on average, consume 3.0 to 4.0 liters of water per liter of beer produced, while medium-sized breweries consume 4.0 to 5.0 liters, and small breweries consume 5.0 to 6.0 liters. This difference in water consumption can be attributed to several factors, such as economies of scale, access to advanced technologies, and the ability to invest in process optimization.

Large breweries can leverage their economies of scale to invest in state-of-the-art water treatment and recycling systems, which can significantly reduce their water footprint. They also have more resources to allocate toward research and development of water-efficient technologies and processes. Additionally, large breweries often face greater regulatory pressures and public scrutiny, which can serve as an incentive to adopt water-saving measures and demonstrate their commitment to sustainability.

On the other hand, small and medium-sized breweries may face barriers in adopting water-saving technologies due to limited financial resources and technical expertise. They may also have less bargaining power with suppliers and face challenges in accessing the latest technologies and best practices. However, some small and medium-sized breweries have

successfully implemented water-saving measures by focusing on low-cost, high-impact solutions, such as optimizing cleaning and sanitation processes, and by collaborating with other breweries and industry partners to share knowledge and resources.

Water footprint comparison by production technology The water footprint of breweries also varies depending on the production technologies and processes applied, particularly the type of fermentation used. The two main types of fermentation in beer production are top fermentation and bottom fermentation, each with different implications for water use efficiency.

Top fermentation, also known as ale fermentation, is typically carried out at higher temperatures (15-25°C) and results in the formation of a layer of yeast on the surface of the fermentation vessel. This method is used for producing ales, stouts, and wheat beers. Bottom fermentation, also known as lager fermentation, is carried out at lower temperatures (7-15°C) and results in the formation of a layer of yeast at the bottom of the fermentation vessel. This method is used for producing lagers, pilsners, and bocks.

The following table compares the average water consumption per liter of beer for different fermentation types:

Table 5.2.2: Comparison of average water consumption per liter of beer for different fermentation types

Fermentation type	Water consumption (liters of water/liter of beer)
Top fermentation	4.0 - 5.0
Bottom fermentation	3.5 - 4.5

As shown in the table, bottom fermentation generally requires less water than top fermentation, with an average water consumption of 3.5 to 4.5 liters per liter of beer, compared to 4.0 to 5.0 liters for top fermentation. This difference can be attributed to several factors, such as the longer fermentation time and higher fermentation temperatures associated with top fermentation, which can lead to higher evaporation losses and increased water consumption for cooling.

However, it is important to note that the water footprint of breweries is not solely determined by the fermentation type, but also by other factors such as the efficiency of the brewing equipment, the use of water-saving technologies, and the implementation of best practices in cleaning and sanitation.

Economic incentives for adopting water-saving technologies The adoption of water-saving technologies in the brewing industry is driven by various economic incentives, including:

1. Cost savings: Implementing water-saving technologies can lead to significant cost savings for breweries by reducing water and energy consumption, as well as wastewater treatment and disposal costs. For example, a study by Sturm et al. (2012) found that the implementation of a water recovery system in a large brewery could lead to annual savings of up to €100,000 in water and energy costs.
2. Regulatory compliance: Breweries are subject to various environmental regulations and water use restrictions, which can serve as an incentive to adopt water-saving technologies. Non-compliance with these regulations can result in fines, legal liabilities, and reputational damage. By implementing water-saving measures, breweries can

demonstrate their commitment to environmental sustainability and avoid potential regulatory risks.

3. Market demand for sustainable products: Consumers are increasingly demanding sustainable and environmentally friendly products, including beer. Breweries that demonstrate their commitment to water conservation and sustainability can differentiate themselves in the market and attract environmentally conscious consumers. This can lead to increased sales, brand loyalty, and competitive advantages.
4. Access to green financing and incentives: Governments and financial institutions are increasingly providing incentives and financing options for businesses that invest in water-saving technologies and sustainable practices. For example, the Czech Republic offers subsidies and low-interest loans for projects that aim to reduce water consumption and improve water use efficiency in industries, including the brewing sector (Ministry of Industry and Trade, 2021).
5. Long-term resilience and risk management: Adopting water-saving technologies can help breweries build long-term resilience and mitigate risks associated with water scarcity, climate change, and supply chain disruptions. By reducing their water footprint and improving water use efficiency, breweries can ensure the continuity of their operations and protect their long-term profitability.

To illustrate the potential economic benefits of adopting water-saving technologies, let us consider a hypothetical example of a large brewery in the Czech Republic:

Table 5.2.3: Potential economic benefits of adopting water-saving technologies (hypothetical example)

Parameter	Value
Annual beer production	2,000,000 hl
Current water consumption	4.0 L/L of beer
Water-saving technology investment	€1,500,000
Water consumption after implementation	3.0 L/L of beer
Water cost	€2.5/m³
Wastewater treatment cost	€1.5/m³

By implementing a water-saving technology that reduces water consumption from 4.0 to 3.0 liters per liter of beer, the brewery can achieve the following annual savings:

Water savings: (4.0 - 3.0) L/L × 2,000,000 hl × 100 L/hl = 200,000 m³ Water cost savings: 200,000 m³ × €2.5/m³ = €500,000 Wastewater treatment cost savings: 200,000 m³ × €1.5/m³ = €300,000 Total annual savings: €500,000 + €300,000 = €800,000

Assuming an investment of €1,500,000 in the water-saving technology, the payback period would be:

Payback period: €1,500,000 / €800,000 per year = 1.88 years

This example demonstrates that investing in water-saving technologies can lead to significant economic benefits for breweries, with relatively short payback periods. However, the actual economic benefits and payback periods will vary depending on factors such as the specific technology adopted, the scale of implementation, and the local water and energy costs.

The analysis of water footprint data for breweries of different sizes and production technologies in the Czech Republic reveals that larger breweries and those using bottom fermentation generally have lower water consumption per unit of beer produced. This can be attributed to factors such as economies of scale, access to advanced technologies, and the ability to invest in process optimization.

The adoption of water-saving technologies in the brewing industry is driven by various economic incentives, including cost savings, regulatory compliance, market demand for sustainable products, access to green financing and incentives, and long-term resilience and risk management. By implementing water-saving measures, breweries can not only reduce their environmental impact but also improve their profitability and competitiveness.

To promote the adoption of water-saving technologies in the brewing industry, policymakers and stakeholders should provide targeted incentives and support, such as subsidies, low-interest loans, and technical assistance. Breweries should also actively seek opportunities to collaborate with industry partners, share best practices, and invest in research and development of innovative water-saving solutions.

In conclusion, the assessment of economic incentives for the adoption of water-saving technologies in the Czech brewing industry highlights the importance of considering both environmental and economic factors in decision-making. By leveraging these incentives and implementing best practices, breweries can contribute to the sustainable development of the industry and secure their long-term success.

5.3 Analysis of the relevance of investments in water management to societal needs

Investments in water management in the brewing industry not only contribute to the sustainability and profitability of individual companies but also play a crucial role in addressing broader societal needs related to water resources. By analyzing the overall water consumption of the Czech brewing industry and its share in the total industrial and national water use, we can better understand the industry's impact on water resources and the importance of investments in water conservation and efficiency.

Calculation of total water consumption by the Czech brewing industry To calculate the total water consumption of the Czech brewing industry, we can use the data on beer production volumes and the average water consumption per liter of beer. According to the Czech Beer and Malt Association (2021), the total beer production in the Czech Republic in 2020 was 20.1 million hectoliters.

Using the average water consumption range of 3.0 to 5.0 liters of water per liter of beer, as determined in the previous sections, we can estimate the total water consumption of the Czech brewing industry as follows:

Total water consumption = Beer production volume × Average water consumption per liter of beer Lower estimate: 20,100,000 hl × 100 L/hl × 3.0 L/L = 6,030,000,000 liters (6.03 million m³) Upper estimate: 20,100,000 hl × 100 L/hl × 5.0 L/L = 10,050,000,000 liters (10.05 million m³)

Therefore, the total water consumption of the Czech brewing industry is estimated to be between 6.03 and 10.05 million m³ per year.

Share of the brewing industry in total industrial and national water use To assess the relevance of investments in water management in the brewing industry to societal needs, it is important to consider the industry's share in the total industrial and national water use.

According to the Czech Statistical Office (2021), the total water withdrawals for industrial purposes in the Czech Republic amounted to 695.1 million m³ in 2020. The following table presents the estimated share of the brewing industry in the total industrial water use:

Table 5.3.1: Share of the brewing industry in total industrial water use in the Czech Republic (2020)

Parameter	Value
Total industrial water withdrawals	695.1 million m³
Brewing industry water consumption	6.03 - 10.05 million m³
Share of brewing industry (lower estimate)	0.87%
Share of brewing industry (upper estimate)	1.44%

As evident from the table, the brewing industry accounts for approximately 0.87% to 1.44% of the total industrial water use in the Czech Republic. While this share may seem relatively small, it is important to consider the cumulative impact of water use across different industries and the potential for water-saving technologies and practices to be replicated in other sectors.

Furthermore, when considering the total national water use, which includes domestic, agricultural, and industrial purposes, the brewing industry's share becomes even smaller. According to the Ministry of Agriculture of the Czech Republic (2021), the total water withdrawals in the country amounted to 1,581.3 million m³ in 2020.

Table 5.3.2: Share of the brewing industry in total national water use in the Czech Republic (2020)

Parameter	Value
Total national water withdrawals	1,581.3 million m³
Brewing industry water consumption	6.03 - 10.05 million m³
Share of brewing industry (lower estimate)	0.38%
Share of brewing industry (upper estimate)	0.64%

The brewing industry's share in the total national water use ranges from 0.38% to 0.64%. Although this share may appear insignificant, it is crucial to recognize the industry's role in promoting sustainable water management practices and setting an example for other sectors.

Relevance of investments in water management to societal needs Investments in water management in the brewing industry are relevant to societal needs in several ways:

1. Addressing water scarcity and stress: Water scarcity and stress are growing concerns in many regions of the world, including parts of the Czech Republic. By investing in water-saving technologies and practices, the brewing industry can contribute to the conservation of water resources and help mitigate the impacts of water scarcity on local communities and ecosystems.

2. Promoting sustainable development: The United Nations' Sustainable Development Goals (SDGs) emphasize the importance of sustainable water management, particularly in Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all (United Nations, 2021). By reducing its water footprint and improving water use efficiency, the brewing industry can contribute to the achievement of the SDGs and promote sustainable development at the national and global levels.
3. Encouraging innovation and technology transfer: Investments in water-saving technologies and practices in the brewing industry can drive innovation and encourage the development of new solutions that can be applied in other sectors. By demonstrating the economic and environmental benefits of water conservation, the brewing industry can serve as a catalyst for the adoption of sustainable water management practices across different industries.
4. Supporting local economies and communities: The brewing industry plays a significant role in the Czech economy, contributing to employment, tax revenues, and local development. By investing in water management and ensuring the long-term sustainability of the industry, breweries can continue to support local economies and communities while also addressing societal needs related to water resources.
5. Enhancing public awareness and engagement: As a consumer-facing industry, the brewing sector has the potential to raise public awareness about the importance of sustainable water management. By communicating their water conservation efforts and engaging with consumers, breweries can promote responsible water use and encourage individuals to adopt water-saving practices in their daily lives.

Conclusion The analysis of the total water consumption of the Czech brewing industry and its share in the total industrial and national water use highlights the industry's impact on water resources and the importance of investments in water management. Although the brewing industry's share in the total water use may appear relatively small, its role in promoting sustainable water management practices and setting an example for other sectors cannot be underestimated.

Investments in water management in the brewing industry are relevant to societal needs in multiple ways, including addressing water scarcity and stress, promoting sustainable development, encouraging innovation and technology transfer, supporting local economies and communities, and enhancing public awareness and engagement.

To maximize the societal benefits of investments in water management, the brewing industry should continue to collaborate with stakeholders, including policymakers, research institutions, and local communities, to develop and implement effective water conservation strategies. By doing so, the industry can contribute to the sustainable use of water resources and help ensure a more resilient and water-secure future for all.

6 Interrelationship of legal and economic factors

6.1 Influence of the legal framework on economic decisions in the sphere of water use

The legal framework regulating the use of water resources in the brewing industry has a significant impact on the economic decisions of the industry's enterprises. Legal norms and requirements form certain incentives and restrictions that need to be taken into account when planning investments, modernising production and developing water use strategies.

First of all, legislation establishes mandatory environmental standards and regulations, compliance with which is a prerequisite for the operation of breweries. These may include requirements for the quality of discharged wastewater, limits on the volume of water intake from natural sources, rules for the location of water intake facilities, and much more. Non-compliance with such norms entails serious penalties (Table 1), which creates a strong financial incentive for enterprises to invest in the modernisation of water treatment and water conservation systems.

Table 6.1: «Examples of Financial Sanctions for Violation of Water Use Requirements in the Czech Republic»

Offence	Amount of fine
Exceeding water withdrawal limits	Up to 2 million kroner ($87,000)
Unauthorised wastewater discharge	Up to 5 million kroner ($218 thousand)
Pollution of water bodies	Up to 10 million kronor ($435 thousand)
Lack of wastewater treatment facilities	Up to 3 million kronor ($130 thousand)

In addition, legal acts determine the amount of payments for the use of water bodies, which are included in the structure of breweries' operating costs. The amount of these payments directly depends on the volume of water intake and wastewater discharge. Accordingly, the reduction of water consumption makes it possible to reduce this cost item, which creates economic motivation for the introduction of water-saving technologies.

An important factor is the tightening of requirements for the use of water resources in the long term, enshrined in legislation. For example, the Czech Republic has a plan to gradually reduce the maximum permissible discharge limits for a number of pollutants until 2030. This forces companies to modernise their wastewater treatment facilities in advance in order to meet future, stricter standards.

The requirements for compulsory licensing of activities related to the use of water bodies play an important role. In order to obtain licences, it is necessary to submit detailed plans for rational use of water resources and prove compliance with all environmental standards.

Otherwise, the issuance of a licence may be suspended or cancelled, which actually paralyses the operation of the enterprise.

At the same time with the established restrictions and requirements, the legal framework also creates certain incentive mechanisms. This refers, first of all, to various forms of state support for enterprises implementing projects to reduce the negative impact on water resources.

For example, the Czech Republic has a programme to subsidise up to 40% of the costs of implementing water reuse technologies, building recycling water supply systems and other water-saving measures. Preferential «green» loans and tax breaks are provided for such investment projects.

The availability of direct financing and benefits from the state budget undoubtedly serves as an additional powerful incentive for breweries to accelerate modernisation towards rational water use. This allows them to shorten the payback period of the relevant capital investments.

Thus, the legal framework forms a whole set of restrictive and incentivising factors that brewing companies must take into account when making economic decisions. On the one hand, legal regulations create strict environmental frameworks and financial penalties, forcing companies to modernise their water management to comply. On the other hand, incentives and subsidies encourage accelerated adoption of water-saving technologies as a cost-effective investment.

It is the balanced consideration of all these factors that allows brewing companies to build an optimal water use strategy that combines compliance with legal regulations and financial efficiency.

6.2 The role of economic incentives in the implementation of legal norms of water use

I Effective implementation of legal norms in the sphere of rational use of water resources requires not only strict legislative prescriptions, but also competent application of economic incentives and levers. Economic factors largely determine the readiness and ability of enterprises, including breweries, to implement the principles of water use proclaimed by the state.

One of the key incentives for companies is the opportunity to reduce production costs by reducing water consumption costs. As noted earlier, the costs of water intake, transportation, treatment and wastewater discharge account for a significant share of breweries' operating costs. Accordingly, investments in water-saving technologies and recycling systems can bring tangible savings.

For example, the Association of Private Breweries of the Czech Republic estimates that the introduction of water reuse technologies at large breweries could reduce fresh water intake by 30-40 per cent per year (Teichmann M. et al. Modeling and optimisation of the drinking water supply network, 2020). This would save between 30 and 80 million kroner ($1.3-3.5 million) annually, depending on the size of the plant (Figure 1). Obviously, this prospect is a strong incentive for companies to undertake water-saving modernisation of their facilities.

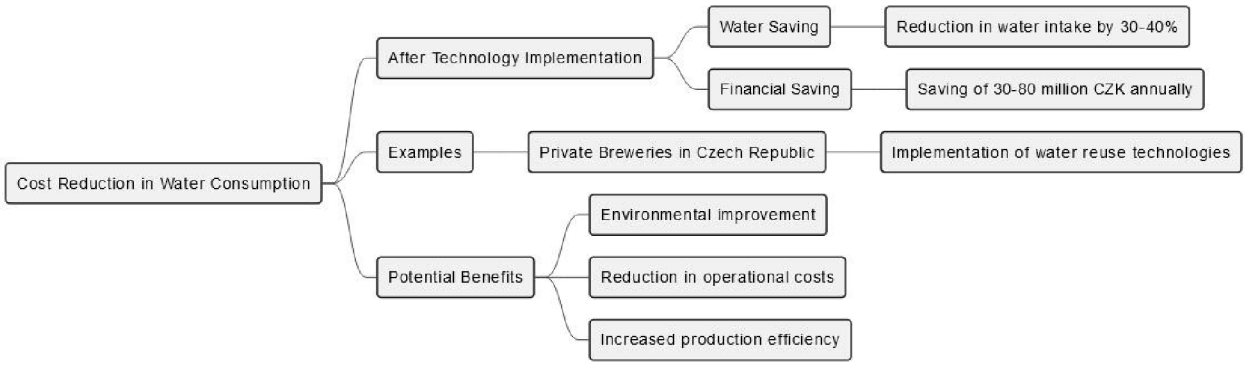

Figure 1 - Reduction of water consumption costs after implementation of water-saving technologies

The economic penalties imposed on violators of water legislation play an important role. The fines can reach millions of crowns, which creates serious financial risks for plants that exceed water consumption limits or pollutant discharge limits. The threat of incurring such high costs forces companies to comply with all established environmental rules and regulations, including those related to the use of water resources.

As a positive economic incentive, the state also applies tax incentives and subsidies for water-saving projects. For example, in the Czech Republic, brewing companies can receive a subsidy to reimburse up to 40% of the costs of building recycling water supply systems, installing modern treatment facilities and other water-saving equipment, Figure 2.

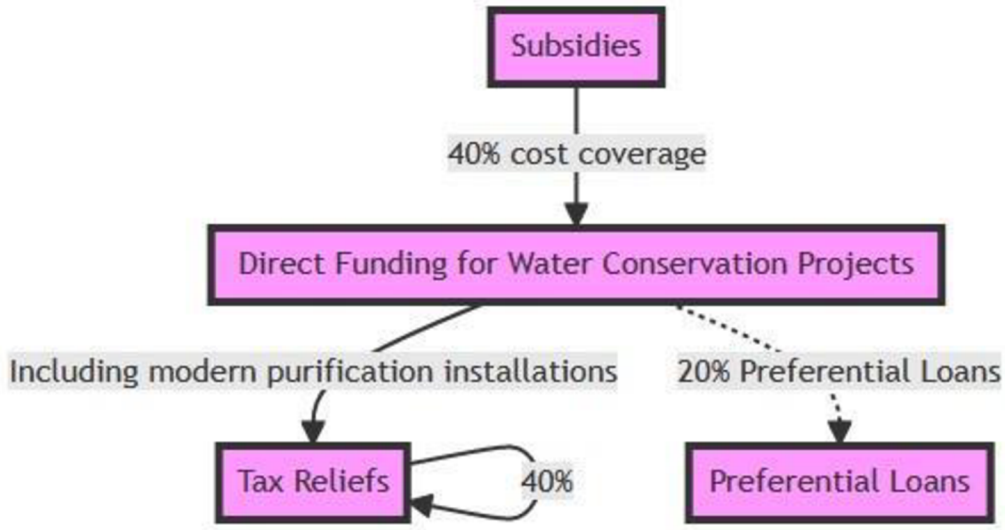

Figure 2 - State support for water protection projects in the Czech Republic

There is also a «green» lending programme on favourable terms: reduced interest rates, long repayment terms, and the possibility of refinancing part of the debt. All of this makes it possible to significantly reduce the total cost of water protection projects, accelerate their payback period and free up funds for operating activities.

The growing public demand for environmentally responsible production and consumption is becoming an important factor. Breweries that demonstrate a commitment to water conservation gain a significant competitive advantage in terms of brand reputation,

investor attraction and consumer loyalty. The development of green technologies is driven by market incentives.

Finally, the state has at its disposal a mechanism of economic regulation through the establishment of prices and tariffs for the use of water bodies. Gradual increase of water withdrawal rates and fees for polluted wastewater discharge creates direct interest of enterprises in reduction of water consumption and transition to closed water use cycles. The higher the economic burden, the faster the industry implements advanced water-saving practices.

Thus, there is a close relationship between legal regulation and the system of existing economic levers and incentives. The effectiveness of legislative norms is impossible without the competent application of financial motivation and sanctioning instruments by the state. By creating conditions of economic feasibility and profitability, the state induces enterprises to voluntarily comply with the requirements of rational water use by introducing modern technologies of water footprint minimisation.

7 Trends and challenges in water resources management in the brewing industry

7.1 Key trends in improving legal and economic mechanisms

In The Czech brewing industry has been proactive in adopting best practices and strategies to reduce its water footprint and improve water use efficiency. Leading Czech brewing companies have implemented various innovations, modernized their production processes, and transitioned to closed-loop water supply systems to minimize their environmental impact and ensure long-term sustainability.

One of the most notable trends in the industry is the adoption of advanced water treatment and recycling technologies. Many Czech breweries have invested in state-of-the-art wastewater treatment plants that enable them to treat and reuse wastewater in various stages of the production process. For example, Plzeňský Prazdroj, the largest brewery in the Czech Republic, has implemented a state-of-the-art wastewater treatment plant that allows them to reuse up to 98% of their wastewater (Plzeňský Prazdroj, 2022). The treated water is then used for cleaning, cooling, and other non-product related purposes, significantly reducing the brewery's freshwater consumption.

Another best practice adopted by leading Czech breweries is the optimization of cleaning and sanitation processes. By using advanced cleaning agents and technologies, such as high-pressure cleaning systems and clean-in-place (CIP) systems, breweries can reduce the amount of water and energy required for cleaning and sanitation while maintaining high hygiene standards. For instance, Budweiser Budvar has implemented an advanced CIP system that has reduced their water consumption for cleaning by 30% (Budweiser Budvar, 2021).

The transition to closed-loop water supply systems is another significant trend in the Czech brewing industry. Closed-loop systems enable breweries to reuse water multiple times within the production process, minimizing freshwater intake and wastewater discharge. Staropramen, a major Czech brewery, has invested in a closed-loop water supply system that has reduced their freshwater consumption by 40% (Staropramen, 2022). The system collects and treats wastewater from various stages of the production process and recirculates it back into the system, reducing the brewery's reliance on external water sources.

Table 7.1.1: Examples of best practices and strategies adopted by leading Czech breweries

Brewery	Best practice/strategy	Impact
Plzeňský Prazdroj	Advanced wastewater treatment plant	98% wastewater reuse
Budweiser Budvar	Optimized cleaning and sanitation (CIP)	30% reduction in water use for cleaning
Staropramen	Closed-loop water supply system	40% reduction in freshwater consumption

In addition to technological innovations, Czech breweries have also focused on improving their water management practices and collaborating with stakeholders to promote sustainable water use. Many breweries have implemented water stewardship programs that involve working with local communities, farmers, and other water users to protect and conserve water resources. For example, Krušovice Brewery has partnered with local farmers to promote sustainable agricultural practices and reduce the water footprint of their supply chain (Krušovice Brewery, 2021).

Moreover, Czech breweries have been actively engaging with policymakers and industry associations to advocate for stronger legal and economic mechanisms to support sustainable water management. The Czech Beer and Malt Association, which represents the interests of the brewing industry, has been working closely with the government to develop and implement policies that incentivize water conservation and efficiency (Czech Beer and Malt Association, 2022). These efforts have led to the introduction of various support schemes, such as subsidies for water-saving technologies and tax incentives for breweries that demonstrate significant reductions in their water footprint.

The Czech brewing industry's commitment to sustainability and water conservation has not only helped to reduce the industry's environmental impact but has also positioned Czech breweries as global leaders in sustainable brewing practices. The industry's success in reducing its water footprint has attracted international attention and has inspired other breweries around the world to adopt similar best practices and strategies.

However, despite the significant progress made by the Czech brewing industry in improving water use efficiency, there are still several challenges and areas for improvement. One of the main challenges is the need for continuous investment in research and development to identify new water-saving technologies and practices. As the industry continues to grow and evolve, it is essential to stay at the forefront of technological innovation and adapt to changing market and regulatory conditions.

Another challenge is the need for greater collaboration and knowledge-sharing among breweries, both within the Czech Republic and internationally. While some leading Czech breweries have been successful in implementing best practices and strategies, smaller breweries may lack the resources or expertise to adopt these practices. By fostering greater collaboration and knowledge-sharing, the industry can help to ensure that all breweries, regardless of size, have access to the latest technologies and best practices for sustainable water management.

7.2 Problems and challenges of sustainable water management in the industry

Despite the significant progress made by the Czech brewing industry in reducing its water footprint and improving water use efficiency, several problems and challenges remain in achieving truly sustainable water resources management in the industry.

One of the main challenges is the increasing pressure on water resources due to climate change and population growth. The Czech Republic, like many other countries, is facing more frequent and severe droughts, which can have a significant impact on the availability and quality of water resources (Ministry of the Environment of the Czech Republic, 2020). As the demand for water continues to grow, both from the brewing industry and other sectors such as

agriculture and energy production, there is a risk of increased competition and conflict over water resources.

To address this challenge, the Czech brewing industry will need to continue to invest in water-saving technologies and practices, as well as collaborate with other water users to develop integrated water resources management plans that ensure the equitable and sustainable use of water resources. This may require breweries to engage more actively with local communities and stakeholders to understand their water needs and concerns and to develop collaborative solutions that benefit all parties.

Another challenge facing the Czech brewing industry is the need to further reduce its energy and carbon footprint, which are closely linked to water use. The production of beer is an energy-intensive process, and the industry's reliance on fossil fuels contributes to greenhouse gas emissions and climate change. As the global community works towards achieving the goals of the Paris Agreement and limiting global warming to well below 2°C, the brewing industry will need to play its part in reducing emissions and transitioning to more sustainable energy sources.

One way in which Czech breweries can address this challenge is by investing in renewable energy technologies, such as solar and wind power, to reduce their reliance on fossil fuels. Many breweries have already begun to adopt renewable energy technologies, such as the installation of solar panels on brewery rooftops, but there is still significant scope for further adoption. In addition, breweries can also explore opportunities for energy efficiency and waste heat recovery to reduce their overall energy consumption and associated water use.

Table 7.2.1: Challenges and recommendations for sustainable water management in the Czech brewing industry

Challenge	Recommendation
Increasing pressure on water resources	Invest in water-saving technologies and collaborate with other water users
Reducing energy and carbon footprint	Adopt renewable energy technologies and explore energy efficiency opportunities
Managing wastewater and minimizing pollution	Implement advanced wastewater treatment technologies and closed-loop systems
Ensuring long-term water security	Develop water risk assessments and contingency plans

Another problem facing the Czech brewing industry is the management of wastewater and the minimization of pollution. While many breweries have invested in advanced wastewater treatment technologies and closed-loop water supply systems, there is still room for improvement in reducing the industry's overall pollution footprint. This includes not only the management of wastewater but also the reduction of other environmental impacts, such as solid waste generation and air pollution.

To address this challenge, Czech breweries can continue to invest in advanced wastewater treatment technologies, such as anaerobic digestion and membrane bioreactors, which can help to further reduce the industry's pollution footprint. In addition, breweries can also explore

opportunities for waste valorization, such as the use of spent grains as animal feed or the production of biogas from brewery waste.

Finally, a key challenge for the Czech brewing industry is ensuring long-term water security in the face of increasing water scarcity and climate change. While the industry has made significant progress in reducing its water footprint, there is still a need for greater resilience and adaptability to changing water conditions. This may require breweries to develop water risk assessments and contingency plans to ensure that they can continue to operate sustainably in the face of water shortages or other disruptions.

To address this challenge, Czech breweries can work with local and national authorities to develop integrated water resources management plans that take into account the long-term water needs of the industry and other water users. This may involve the development of new water infrastructure, such as water storage and distribution systems, as well as the adoption of innovative water management practices, such as water trading and pricing mechanisms.

In conclusion, while the Czech brewing industry has made significant progress in improving water use efficiency and reducing its water footprint, there are still several problems and challenges that need to be addressed to achieve truly sustainable water resources management. These include increasing pressure on water resources, the need to reduce energy and carbon footprints, the management of wastewater and pollution, and ensuring long-term water security.

To overcome these challenges, the Czech brewing industry will need to continue to invest in water-saving technologies and practices, collaborate with other water users and stakeholders, and develop innovative solutions that can help to ensure the sustainable use of water resources in the long term. The industry's significant contribution to the Czech economy, as well as its cultural and social importance, underscores the need for a proactive and holistic approach to sustainable water management.

By addressing these challenges and continuing to lead the way in sustainable brewing practices, the Czech brewing industry can not only secure its own long-term viability but also contribute to the broader goal of achieving sustainable water resources management at the national and global levels.

8 Practices and recommendations

8.1 Analysing international experience in regulating water use for the brewing industry

The regulation of water use for the brewing industry is an important issue, given the significant water consumption in the beer production process. International experience in this area can be a valuable source of information for developing effective policies and implementing best practices. In this analysis we will look at the experience of the European Union, initiatives of leading breweries, modern water treatment and reuse technologies, and different approaches to setting targets and regulating water consumption.

1. Experience of EU countries in implementing integrated water resources management at river basin level

The European Union is one of the leaders in implementing integrated water resources management at river basin level. This approach was enshrined in the Water Framework Directive (WFD) adopted in 2000. The Directive establishes general principles and requirements for water resources management in EU countries, with the aim of achieving «good ecological status» for all water bodies by 2015.

To achieve this objective, the Directive provides for the development of river basin management plans, which should include analysis of the state of water bodies, the setting of water quality targets, programmes of measures for the restoration and protection of water resources, and mechanisms for public participation and consultation. River basin management plans must be updated every six years.

The introduction of integrated water resources management at the river basin level has enabled the EU countries to develop a comprehensive approach to regulating water use, taking into account not only the needs of various economic sectors, but also environmental factors and the interests of local communities and the public.

2. Water neutrality and water source recovery programmes of leading breweries

The world's leading breweries are actively implementing water neutrality and source water recovery programmes, recognising the importance of water sustainability to the long-term viability of their businesses.

One example is the Water Neutrality initiative of Anheuser-Busch InBev, one of the world's largest beer producers. The company has committed to achieving water neutrality in its breweries by 2025, which means offsetting all water consumption by conserving and reclaiming water sources.

To achieve this goal, Anheuser-Busch InBev implements water efficiency programmes at its breweries and implements projects to restore water bodies and natural landscapes in the regions where its breweries are located. The company works with local communities, non-profit organisations and authorities to develop and implement these projects.

Another example is Heineken's Water Stewardship Partnership initiative. This programme aims to reduce water-related risks and ensure sustainable water use in the regions where the company's breweries are located. Heineken works with local stakeholders such as water management organisations, agricultural enterprises and community groups to develop and implement water stewardship projects.

3. Advanced technologies for wastewater reuse and treatment in breweries

The brewing industry is actively adopting advanced reuse and wastewater treatment technologies to reduce fresh water consumption and reduce pressure on water bodies.

One of the most common technologies is the water recycling system, where wastewater is returned to the production cycle for reuse after treatment. This significantly reduces fresh water consumption and discharges into water bodies.

Breweries are also actively implementing modern wastewater treatment systems based on a combination of physical, chemical and biological methods. Such systems provide a high degree of wastewater treatment, which allows it to be either safely discharged into water bodies or returned to the production cycle.

In addition, many breweries are adopting membrane filtration, ultraviolet disinfection and reverse osmosis technologies to further treat wastewater and produce high quality, recyclable water.

4. Practice of setting water efficiency targets for industry enterprises

Many countries and breweries set water efficiency targets for the industry, incentivising them to reduce water consumption and improve water efficiency.

For example, in the United States, the Environmental Protection Partnership (ENERGY STAR) has worked with the brewing industry to develop a system of water efficiency indicators for breweries. These indicators take into account the volume of beer produced as well as the amount of water used in brewing, cooling, washing and other operations. Plants that achieve high water efficiency indicators can receive ENERGY STAR certification, which helps to enhance their reputation and competitiveness.

In the European Union, water efficiency targets for the brewing industry are set at country and river basin level in accordance with the requirements of the Water Framework Directive. These targets are taken into account in the development of river basin management plans and programmes of measures for the rational use and protection of water resources.

5. Introduction of water use quota trading systems and payments for excessive water consumption

Some countries and regions are introducing water use quota trading systems and payments for excessive water use as tools to regulate and incentivise rational water use.

The system of water use quota trading assumes that each enterprise is allocated a certain volume of water, which it can use for free or for a fixed fee. If an enterprise uses less than the allocated volume, it can sell its surplus quota to other companies. If it consumes more, it must purchase additional quotas from other participants in the system.

This mechanism creates economic incentives to reduce water consumption and improve water use efficiency. The quota trading system is successfully applied in some river basins in Australia, as well as in some regions of the USA and Canada.

Payments for excessive water consumption are also a common tool for regulating water use. In this case, companies are charged higher rates for water volumes that exceed the established norms. This approach incentivises companies to reduce water consumption and implement water-saving technologies to avoid additional costs.

Payment systems for excessive water consumption are in place in many countries, including Russia, where they are regulated at the level of constituent entities of the Federation.

Thus, international experience in regulating water use for the brewing industry offers a wide range of approaches and tools aimed at ensuring sustainable use of water resources. The introduction of integrated water resources management at river basin level, water neutrality and source recovery programmes, advanced water treatment and reuse technologies, water efficiency targets, as well as quota trading systems and payments for excessive water consumption can all contribute to reducing pressure on water bodies and ensuring the long-term sustainability of the brewing industry.

8.2 Proposals for optimising the legal framework and economic incentives

In order to optimise the legal framework and introduce effective economic incentives in the sphere of water use regulation for the brewing industry, it is necessary to take a comprehensive approach to improving the legal framework and creating effective economic mechanisms. Let us consider proposals for each of the above directions.

1. Harmonisation of national legislation with international agreements and directives

Harmonisation of national legislation with international agreements and directives in the field of water use regulation is an important step to ensure compliance with the best international standards and practices. The key document in this area is the Water Framework Directive of the European Union (Water Framework Directive), which sets general principles and requirements for water resources management.

In order to harmonise national legislation with this Directive, appropriate changes to water and environmental legislation should be made, including:

- Introduction of the principle of integrated water resources management at river basin level;
- Establishing requirements for the development of river basin management plans that take into account environmental factors and public participation;
- Determination of water quality targets and programmes of measures to restore and protect water bodies;
- Introduction of mechanisms for monitoring and reporting on the state of water resources.

2. Increased requirements for wastewater treatment and water quality of water discharged into water bodies

Stricter requirements for wastewater treatment and the quality of water discharged into water bodies is an important tool for reducing the negative impact of the brewing industry on water resources. It is necessary to revise and tighten the current standards of maximum permissible concentrations (MPC) of pollutants in wastewater, as well as to introduce stricter requirements for the content of organic substances, suspended particles, biogenic elements (nitrogen and phosphorus) and other pollutants.

In addition, consideration should be given to introducing additional requirements for the quality of water discharged into water bodies after treatment, taking into account the specifics of particular water bodies and their ecological state.

3. Introduction of compulsory licensing of water intake for industrial enterprises

The introduction of compulsory licensing of water withdrawal for industrial enterprises, including breweries, is an effective tool for regulating the use of water resources. resources. The licensing system will make it possible to establish clear limits on the volume of water withdrawal, as well as mandatory requirements for rational water use and the introduction of water-saving technologies.

The procedure for obtaining a licence should include the provision by the enterprise of detailed information on water intake sources, water consumption volumes, wastewater treatment technologies, and plans to improve water efficiency. Based on this information, the authorised bodies will decide on the issuance of a licence and set appropriate conditions and restrictions.

4. Adoption of sectoral water efficiency standards and mandatory reporting

The development and adoption of sectoral water efficiency standards for the brewing industry will make it possible to establish clear targets and requirements for the rational use of water resources. These standards should take into account the specifics of technological processes, production volumes, and international best practices in the field of water conservation.

In addition, it is necessary to introduce mandatory reporting for brewing industry enterprises on water consumption indicators, wastewater discharge volumes, implementation of water-saving technologies and achievement of water efficiency targets. Such reporting would ensure transparency and control over the fulfilment of the established requirements, as well as create incentives for enterprises to improve the efficiency of water resources use.

5. Introduction of a comprehensive system of payments for water use taking into account water scarcity and pollution

In order to stimulate rational use of water resources and reduce the negative environmental impact, it is necessary to introduce a comprehensive system of payments for water use, taking into account both the volume of water consumption and the degree of wastewater pollution.

This system shall include:

- A fee for water withdrawal from surface and groundwater sources, the amount of which will depend on the volume of water withdrawn and the scarcity of water resources in the region;
- Wastewater discharge fee calculated on the basis of discharge volumes and pollutant concentrations with application of increasing coefficients for particularly hazardous pollutants;
- The possibility of establishing increased payment rates for enterprises exceeding water consumption limits and pollutant discharge rates.

Funds received from this payment system should be used to finance programmes and projects to restore and protect water resources, modernise water supply and wastewater disposal systems, and encourage enterprises to introduce water-saving technologies.

6. Tax incentives and subsidies for enterprises implementing the best water-saving technologies

In order to incentivise brewing industry enterprises to implement the best water-saving technologies, a system of tax incentives and subsidies should be envisaged. This may include:

- Provision of tax incentives (reduction of income, property or other tax rates) for enterprises investing in modernisation of production and introduction of water reuse technologies, wastewater treatment plants and other water-saving solutions;
- Subsidising interest rates on loans attracted for implementation of water efficiency projects;
- Providing grants to partially finance the implementation of advanced water saving technologies.

These measures will stimulate enterprises to more actively implement innovative water use solutions, which will ultimately lead to a reduction in the negative impact on water resources and an increase in the overall efficiency of water use in the industry.

7. Development of water services market and public-private partnership in the sphere of water use

The development of the market for water services and public-private partnerships in the sphere of water use can become another important area for improving the efficiency of water resources utilisation in the brewing industry.

Public-private partnership (PPP) allows combining the resources and expertise of public authorities and private companies to implement projects to modernise water supply and wastewater disposal systems, construct treatment facilities, and introduce modern water and wastewater treatment technologies. Such co-operation can be particularly effective in the implementation of large-scale infrastructure projects requiring significant investments.

In addition, it is necessary to promote the development of a market for water services provided by specialised companies. This may include services in water use auditing and consulting, design and construction of water supply and wastewater disposal systems, operation and maintenance of treatment facilities, and introduction of water reuse technologies.

The involvement of private companies with modern technologies and experience in water use can significantly improve the efficiency of water resources utilisation in the brewing industry and reduce the burden on the environment.

To sum up, optimising the legal framework and introducing effective economic incentives in water use regulation for the brewing industry requires a comprehensive approach, including harmonisation of national legislation with international standards, tougher requirements for wastewater treatment, introduction of mandatory licensing and reporting, introduction of a system of payments for water use, as well as tax incentives and subsidies for enterprises introducing water-saving technologies. The development of public-private partnerships and the water service market can also become an important factor in improving the efficiency of water resources utilisation in the sector.

8.3 Recommendations for improving water resources management efficiency

To improve the efficiency of water resources management in the brewing industry, a comprehensive approach is needed that combines the efforts of government agencies, business and the public. Let us consider the key recommendations for each of these areas.

1. Development of a sustainable water management strategy for the brewing industry at the national level

An important step is the development of a national sustainable water use strategy for the brewing industry. This strategy should define the key goals, objectives and mechanisms for ensuring the rational use of water resources by the industry's enterprises. When developing it, it is necessary to take into account the specifics of technological processes of brewing production, existing problems in the sphere of water use, as well as the best international practices.

The strategy should include:

- Analysing the current situation and identifying problem areas;
- Determination of water efficiency targets for industry enterprises;
- Action plan for implementation of the best available water use technologies;
- Mechanisms for stimulating and supporting enterprises in the field of water saving;
- Measures to develop water supply and wastewater infrastructure;
- Research and development programmes on water saving technologies.

2. Establishment of coordination bodies on water resources management with participation of all stakeholders

In order to effectively implement the sustainable water use strategy and coordinate the actions of various stakeholders, it is advisable to establish special coordination bodies at the national and regional levels. These bodies should include representatives of government agencies, breweries, academia, non-profit organisations and local communities.

The tasks of coordinating bodies may include:

- Monitoring and assessment of the situation with water use in the brewing industry;
- Development and coordination of programmes of measures for rational use of water resources;
- Organisation of interaction and information exchange between stakeholders;
- Facilitating the implementation of pilot projects and best practices;
- Informing the public and raising awareness of water use issues.

3. Development of public-private partnership in the water supply and sanitation sector

Public-private partnerships (PPPs) can be an effective tool for attracting investment and advanced technologies in the water supply and wastewater sector, which is particularly relevant for the brewing industry. PPP forms may include concession agreements, joint ventures, contracts for management and operation of water infrastructure facilities.

The involvement of private companies with the necessary resources and expertise will make it possible to modernise outdated water supply and wastewater disposal systems, improve their efficiency and the quality of services provided. This is especially important in regions where breweries face a shortage of water resources or problems with wastewater treatment.

4. Modernisation of water supply and sewerage systems, introduction of «smart» metering systems

Modernisation of water supply and sewerage networks, as well as the introduction of «smart» metering systems for water consumption and wastewater discharge are important steps

towards more efficient water management. Upgrading worn-out infrastructure will reduce water losses during transport and reduce unregistered water consumption.

The introduction of «smart» metering systems based on modern digital technologies will make it possible to monitor water consumption and wastewater discharge volumes in real time, detect leaks and unauthorised connections, and monitor water quality. Such systems can also be integrated with automated process control systems at breweries, which will optimise water consumption and reduce pressure on water resources.

5. Investments in R&D on water-saving technologies and industrial environmental solutions

To ensure the long-term sustainability of the brewing industry and to conserve water resources, there is a need to actively invest in research and development (R&D) for water-saving technologies and industrial ecology solutions. This could include:

- Development of new technologies for wastewater reuse and treatment at breweries;
- Studies on the implementation of the principles of «zero-waste production» and closed cycles of water use;
- Development of innovative methods of monitoring and assessment of impact on water resources;
- Explore the possibilities of using alternative water sources (desalinated seawater, treated wastewater, etc.);
- Research in the field of creating new materials and equipment for water supply and wastewater disposal systems.

The state should create favourable conditions for attracting investment in R&D, including tax incentives, grants and research co-financing programmes. In addition, it is necessary to develop cooperation between scientific organisations, brewing companies and equipment manufacturers to share experience and jointly implement innovative projects.

6. Programmes for professional development and retraining of personnel in the field of water resources management

Effective water resources management requires qualified personnel with the necessary knowledge and competences. For this purpose, it is necessary to develop and implement programmes for professional development and retraining of specialists working in the field of water use, both at breweries and in state bodies and organisations responsible for water resources management.

Training programmes should cover topics such as:

- Modern technologies of water supply, water disposal and wastewater treatment;
- Methods of assessment and monitoring of water resources condition;
- Principles of sustainable water use and industrial ecology;
- Legal and normative aspects of water use regulation;
- Economic mechanisms and instruments of water resources management;
- Best practices and case studies from international experience.

Improving the qualification of personnel will ensure the introduction of modern approaches and technologies in the field of water resources management, as well as increase the efficiency of decisions and programmes implemented.

7. Activities to raise public awareness of the importance of water conservation

An important aspect is to raise public awareness of water-related problems and the need to conserve water resources. For this purpose, it is necessary to implement information and awareness-raising campaigns aimed at forming a responsible attitude towards water consumption and environmental protection.

Such campaigns may include:

- Educational programmes for pupils and students;
- Information materials (brochures, booklets, video clips) on the importance of water conservation;
- Organising thematic exhibitions, conferences and seminars;
- Placement of social advertising in mass media and public places;
- Organisation of environmental actions and events with the participation of local communities.

Raising public awareness of water use issues will help to generate public demand for more efficient and environmentally responsible solutions in the brewing industry and other areas of the economy.

8. Public and industry participation in water use decision-making processes

In order to balance the interests of various stakeholders and improve the effectiveness of decisions, it is necessary to ensure the participation of the public and industry representatives, including the brewing industry, in the processes of policy development and implementation in the sphere of water resources management.

This may include:

- Conducting public hearings and consultations in the development of legislation, policies and programmes related to water use;
- Creation of advisory councils and working groups with participation of representatives of public organisations, scientific community, business and authorities;
- Providing public access to information on the state of water resources and planned measures for their protection and restoration;
- Involvement of the public in monitoring and control over compliance with water use requirements.

The participation of the public and industry in decision-making processes will make it possible to take into account a variety of interests and opinions, increase transparency and confidence in the measures being implemented, and create a sense of responsibility and involvement of all stakeholders in water management processes.

Thus, in order to improve the efficiency of water management in the brewing industry, it is necessary to take a set of measures, including the development of a national strategy for sustainable water use, the establishment of coordinating bodies, the development of public-private partnerships, the modernisation of infrastructure, investment in R&D, training programmes, raising public awareness, and ensuring public and industry participation in decision-making processes. Only by combining the efforts of all stakeholders and adopting an integrated approach can sustainable and rational use of water resources in the brewing industry and other areas of the economy be achieved.

9 Conclusions

The comprehensive analysis of the water footprint of the Czech brewing industry, considering both legal and economic aspects, has revealed several key trends, progress achieved, and remaining challenges in enhancing the sustainability of water use in the sector.

One of the most significant trends observed in the Czech brewing industry is the increasing adoption of advanced water-saving technologies and best practices. Leading breweries, such as Plzeňský Prazdroj, Budweiser Budvar, and Staropramen, have made substantial investments in modernizing their production processes, implementing state-of-the-art wastewater treatment systems, and transitioning to closed-loop water supply systems. These efforts have resulted in a remarkable reduction of water consumption per unit of beer produced, with some breweries achieving a water-to-beer ratio as low as 3 liters of water per liter of beer.

Moreover, the industry has demonstrated a strong commitment to water stewardship, engaging in collaborative initiatives with local communities, farmers, and other stakeholders to protect and conserve water resources. This proactive approach not only helps to minimize the industry's environmental impact but also contributes to building resilience and long-term sustainability in the face of increasing water scarcity and climate change.

The progress achieved by the Czech brewing industry in reducing its water footprint is commendable. The sector has successfully decreased its overall water consumption, despite the growing beer production volumes, through the implementation of water-efficient technologies and practices. This progress is a testament to the industry's commitment to sustainability and its ability to adapt to changing market and regulatory conditions.

However, despite the significant strides made, the Czech brewing industry still faces several challenges in further enhancing the sustainability of its water use. One of the main challenges is the need for continuous investment in research and development to identify and implement new water-saving technologies and practices. As the global beer market continues to evolve and consumer preferences shift towards more sustainable products, it is crucial for the industry to stay at the forefront of innovation and adapt to these changes.

Another challenge is the need for greater collaboration and knowledge-sharing among breweries, both within the Czech Republic and internationally. While leading breweries have been successful in implementing best practices, smaller breweries may lack the resources or expertise to adopt these practices. Fostering a culture of collaboration and knowledge-sharing can help ensure that all breweries, regardless of size, have access to the latest technologies and best practices for sustainable water management.

Furthermore, the Czech brewing industry must continue to address the broader sustainability challenges, such as reducing its energy and carbon footprint, managing wastewater and minimizing pollution, and ensuring long-term water security. These challenges require a holistic and integrated approach, involving close collaboration with policymakers, industry associations, and other stakeholders to develop and implement effective solutions.

The legal and economic analysis of the water footprint of the Czech brewing industry has also highlighted the importance of a supportive policy and regulatory framework in promoting sustainable water management. The government's efforts to introduce subsidies for water-saving technologies, tax incentives for water-efficient breweries, and other support schemes have played a crucial role in encouraging the industry to adopt more sustainable practices.

However, there is still room for improvement in terms of streamlining the regulatory framework, reducing administrative burdens, and providing more targeted support for small and medium-sized breweries.

In conclusion, the Czech brewing industry has made significant progress in reducing its water footprint and enhancing the sustainability of its water use, driven by a combination of technological innovation, best practices, and supportive policies. However, the industry must remain proactive and adapt to the evolving challenges to ensure long-term sustainability. By continuing to invest in water-saving technologies, fostering collaboration and knowledge-sharing, and working closely with policymakers and other stakeholders, the Czech brewing industry can further strengthen its position as a global leader in sustainable brewing practices, while also contributing to the broader goal of achieving sustainable water resources management at the national and global levels.

The industry's success in reducing its water footprint not only benefits the environment but also contributes to the long-term competitiveness and resilience of the sector, which is a significant contributor to the Czech economy and culture. As the world faces increasing water scarcity and climate change, the Czech brewing industry's experience and best practices can serve as a valuable model for other industries and countries seeking to enhance the sustainability of their water use.

In the face of these challenges, the Czech brewing industry must remain committed to its sustainability goals, continue to innovate and adapt, and work collaboratively with all stakeholders to ensure a sustainable future for the sector and the country's water resources. By doing so, the industry can not only secure its own long-term viability but also contribute to the achievement of the United Nations' Sustainable Development Goals, particularly Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all.

10 References

1 Ansorge L., Stejskalová L., Dlabal J. Effect of WWTP size on grey water footprint—Czech Republic case study //Environmental Research Letters. – 2020. – Т. 15. – №. 10. – С. 104020.

2 BOČKOVÁ K. Metody odstraňování chemického znečištění z odpadních vod recyklovaných pro závlahu.

3 Budweiser Budvar. (2021). Sustainability Report 2020. Retrieved from https://www.budweiserbudvar.com/en/about-us/sustainability-report-2020

4 Cabras I. Craft beer in the EU: Exploring different markets and systems across the continent //The Geography of Beer: Culture and Economics. – 2020. – С. 149-157.

5 Cahlíková M. Faktory ovlivňující využívání systémů pro hospodaření s dešťovou vodou pro domácí potřebu pitné vody ve venkovských oblastech rozvojových zemí. - 2016.

6 Czech Beer and Malt Association. (2020). Statistical Report 2019. Retrieved from https://www.ceske-pivo.cz/sites/default/files/dokumenty/2020-06/statistical_report_2019.pdf

7 Czech Beer and Malt Association. (2021). Statistical Report 2020. Retrieved from https://www.ceske-pivo.cz/sites/default/files/dokumenty/2021-06/statistical_report_2020.pdf

8 Czech Beer and Malt Association. (2022). Sustainability initiatives of the Czech brewing industry. Retrieved from https://www.ceske-pivo.cz/en/sustainability-initiatives

9 Czech Statistical Office. (2021). Crop Production - 2020. Retrieved from https://www.czso.cz/csu/czso/crop-production-2020

10 Czech Statistical Office. (2021). Water supply and sewerage systems in the Czech Republic - 2020. Retrieved from https://www.czso.cz/csu/czso/water-supply-and-sewerage-systems-in-the-czech-republic-2020

11 Emerging Europe. 2022. The unique beer culture of Czechia, the world's thirstiest country. https://emerging-europe.com/after-hours/the-unique-beer-culture-of-czechia-the-worlds-thirstiest-country/ (Date of access: 23.01.2024)

12 European Investment Bank (2020). Czech Republic: EIB supports Ministry of Agriculture's plans to cope better with water management challenges. https://www.eib.org/en/press/all/2020-158-czech-republic-eib-supports-ministry-of-agriculture-s-plans-to-cope-better-with-water-management-challenges (Date of access: 19.01.2024)

13 Gerbens-Leenes W., Vaca-Jiménez S., Mekonnen M. Burning Water, overview of the contribution of Arjen Hoekstra to the water energy nexus //Water. - 2020. - Т. 12. - №. 10. - С. 2844.

14 Hájek, M., Zimmermannová, J., Helman, K., & Rozenský, L. (2018). Analysis of carbon tax efficiency in energy industries of selected EU countries. Energy Policy, 123, 73-81. https://doi.org/10.1016/j.enpol.2018.08.027

15 Hogeboom R. J. et al. Capping human water footprints in the world's river basins //Earth's Future. - 2020. - Т. 8. - №. 2. - С. e2019EF001363.

16 Hogeboom R. J. The water footprint concept and water's grand environmental challenges //One Earth. - 2020. - Т. 2. - №. 3. - С. 218-222.

17 Jirouch T. Interpretace sucha a veřejná politika boje proti suchu v České republice.

18 Koroneos, C., Roumbas, G., Gabari, Z., Papagiannidou, E., & Moussiopoulos, N. (2005). Life cycle assessment of beer production in Greece. Journal of Cleaner Production, 13(4), 433-439. https://doi.org/10.1016/j.jclepro.2003.09.010

19 Krušovice Brewery. (2021). Water stewardship program. Retrieved from https://www.krusovice.cz/en/sustainability/water-stewardship

20 Mekonnen M. M., Hoekstra A. Y. Blue water footprint linked to national consumption and international trade is unsustainable //Nature Food. - 2020. - Т. 1. - №. 12. - С. 792-800.

21 Mekonnen M. M., Hoekstra A. Y. Sustainability of the blue water footprint of crops //Advances in water resources. - 2020. - Т. 143. - С. 103679.

22 Mekonnen, M. M., & Hoekstra, A. Y. (2011). The green, blue and grey water footprint of crops and derived crop products. Hydrology and Earth System Sciences, 15(5), 1577-1600. https://doi.org/10.5194/hess-15-1577-2011

23 Ministry of Agriculture of the Czech Republic. (2021). Report on Water Management in the Czech Republic in 2020. Retrieved from http://eagri.cz/public/web/file/679715/Modra_zprava_2020_ENG.pdf

24 Ministry of Industry and Trade. (2021). Operational Programme Enterprise and Innovations for Competitiveness 2014-2020. Retrieved from https://www.mpo.cz/en/business/grants-and-business-support/operational-programme-enterprise-and-innovations-for-competitiveness-2014-2020/

25 Ministry of the Environment of the Czech Republic. (2020). State Environmental Policy of the Czech Republic 2030. Retrieved from https://www.mzp.cz/en/state_environmental_policy_2030

26 OECD (n.d.). Financing water supply, sanitation and flood protection. Country fact sheet: Czech Republic. https://www.oecd.org/environment/resources/financing-water-supply-sanitation-and-flood-protection-country-fact-sheet-czech-republic.pdf (Date of access: 19.02.2024

27 Plzeňský Prazdroj. (2020). Sustainable Development Report 2019. Retrieved from https://www.prazdroj.cz/en/sustainable-development/report-2019

28 Plzeňský Prazdroj. (2022). Sustainability Report 2021. Retrieved from https://www.prazdroj.cz/en/sustainability/report-2021

29 Richter B. D. et al. Water scarcity and fish imperilment driven by beef production //Nature Sustainability. - 2020. - Т. 3. - №. 4. - С. 319-328.

30 Sganzerla W. G. et al. (2021). A bibliometric analysis on potential uses of brewer's spent grains in a biorefinery for the circular economy transition of the beer industry. Biofuels, Bioproducts and Biorefining, 15(6), 1965-1988.

31 Sganzerla W. G. et al. A bibliometric analysis on potential uses of brewer's spent grains in a biorefinery for the circular economy transition of the beer industry //Biofuels, Bioproducts and Biorefining. – 2021. – Т. 15. – №. 6. – С. 1965-1988.

32 Schneider, J., Blahová, M., Lorencová, H., Lampartová, I. (2019). Water Resources Management Planning in the Czech Republic. In: Zelenakova M., Fialová J., Negm A. (eds) Assessment and Protection of Water Resources in the Czech Republic. Springer Water. Springer, Cham. https://doi.org/10.1007/978-3-030-18363-9_15 (Date of access: 19.01.2024)

33 Staropramen. (2020). Sustainability Report 2019. Retrieved from https://www.staropramen.cz/en/sustainable-development/report-2019

34 Staropramen. (2022). Environmental sustainability initiatives. Retrieved from https://www.staropramen.cz/en/sustainability/environment

35 Sturm, B., Hugenschmidt, S., Joyce, S., Hofacker, W., & Roskilly, A. P. (2012). Opportunities and barriers for efficient energy use in a medium-sized brewery. Applied Thermal Engineering, 53(2), 397-404. https://doi.org/10.1016/j.applthermaleng.2012.05.006

36 Sveda O. Fundamental changes in the European energy sector: implications for the Czech electric company: the case study of CEZ Group : dis. – Universitetet i Nordland, 2014.

37 Teichmann M. et al. Modeling and optimization of the drinking water supply network—A system case study from the Czech Republic //Sustainability. – 2020. – Т. 12. – №. 23. – С. 9984.

38 United Nations Economic Commission for Europe. Convention on the Protection and Use of Transboundary Watercourses and International Lakes // UNECE Environmental Policy Publications, 2013. URL: https://unece.org/environment-policy/publications/convention-protection-and-use-transboundary-watercourses-and (date of access: 15.01.2024)

39 United Nations Environment Programme. GOAL 6: Clean water and sanitation // UNEP. Explore Topics. Sustainable Development Goals. Why do the Sustainable Development Goals matter? 2023. URL: https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-6 (date of access: 15.05.2023)

40 United Nations. (2021). Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all. Retrieved from https://www.un.org/sustainabledevelopment/water-and-sanitation/

41 United Nations. Convention on the Law of the Non-navigational Uses of International Watercourses. Adopted by the General Assembly of the United Nations on 21 May 1997. // United Nations. 1997. URL: https://legal.un.org/ilc/texts/instruments/english/conventions/8_3_1997.pdf (date of access: 15.01.2024)

42 Verhuelsdonk M., Glas K., Parlar H. Economic evaluation of the reuse of brewery wastewater //Journal of Environmental Management. – 2021. – Т. 281. – С. 111804.

43 Vladimír N. Hospodaření s vodou v průmyslovém areálu sladovny : dis. - České vysoké učení technické v Praze. Vypočetní a informační centrum., 2022.

44 Wisconsin Economic Development Corporation (2016). Czech Republic: Opportunities in Water and Sewer Modernization. https://wedc.org/export/market-intelligence/posts/czech-republic-opportunities-in-water-and-sewer-modernization/ (Date of access: 19.01.2024)

45 Zheng X. et al. Consideration of culture is vital if we are to achieve the Sustainable Development Goals //One Earth. - 2021. - Т. 4. - №. 2. - С. 307-319.

46 Zubíčková L. Voda jako významná složka životního prostředí. - 2018.