SMART
WaterDomain

Organisational Decision-Making in Water Reuse for Smart Cities (SMART-WaterDomain)

CASE STUDY REPORT

WATER AS A STRATEGIC RESOURCE

2024

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ABOUT THE SMART WATER PROJECT

Water scarcity, exacerbated by the ongoing effects of climate change, poses ever-increasing and formidable challenges to not only the sustainability of global economies and societies but also to the very essence of life on our planet. The consequences of rising temperatures, altered precipitation patterns, and more frequent extreme weather events are becoming alarmingly evident, significantly impacting the availability and distribution of freshwater resources. Reusing wastewater (WW) in agricultural and industrial domains offers a promising strategy to alleviate water stresses and enhance sustainable water management. However, the widespread adoption of wastewater reuse faces complexities ranging from technical limitations to societal acceptance.

In particular, the industrial sector has been slow to adopt water reuse practices, despite the growing urgency to do so. Industries often lag in incorporating water reuse technologies into their value chains and embracing water reuse as an integral component of their smart water management approach. Thus, there is a pressing need to encourage and facilitate the adoption of fit-for-purpose water reuse within these sectors.

The SMART-WaterDomain project emerges as a pivotal bridge, facilitating the exchange of technology and know-how among the IT sector, industry, and the wider community. Its overarching aim is to address the existing gap between theoretical technical capabilities and the actual application of these solutions within socio-political and cultural contexts. By fostering synergy between stakeholders, the project seeks to overcome barriers to adoption, drive innovation, and promote sustainable practices.

At its core, SMART-WaterDomain not only focuses on technological advancement but also prioritizes the dissemination and integration of water reuse practices as part of a smart water management strategy. The project recognizes that successful adoption is not solely dependent on technological progress; it involves understanding and navigating the social, political, and cultural dimensions that influence decision-making processes.

The SMART-WaterDomain aims to address the growing challenges by bridging the gap between technological capabilities and their application in socio-political and cultural contexts. Through pilot studies across European countries (Germany, Poland, Slovakia) and Japan, critical stakeholders engage in the development of autility operational framework.

The project capitalizes on cutting-edge digital decision support and monitoring tools, which leverage real-time data and climate change projections. The advanced framework will serve as a demonstrative platform for implementing water reuse practices in diverse contexts. By integrating digital decision support and monitoring tools, stakeholders will gain access to data-driven insights, enabling them to make informed and precise decisions. The use of real-time data and projections will empowers industries and agricultural entities to optimize their water usage, effectively mitigating the impact of water scarcity and climate variability.

The project's key objective is to develop a systematic framework to facilitate the uptake of smart reuse of wastewater (WW) resources and serve as an assessment mechanism for companies to integrate these techniques into their value chains

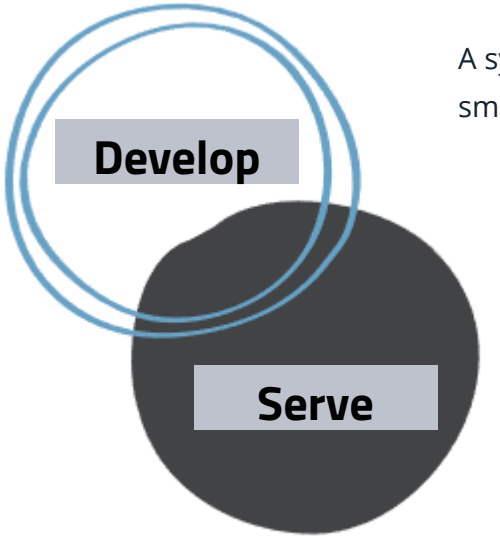
The SMART-WaterDomain puts a particular emphasis on elaborating how an increased uptake of reused wastewater in industrial/agricultural value chains can serve as a technique for reducing demands for freshwater, equalizing the distribution of water to reflect global demographic changes and increase environmental resilience.

With pilot studies carried out across Europe (Germany, Poland, Slovakia) and Japan, the project will develop a utility operational framework with critical stakeholders to produce digital decision support and monitoring tools that utilise real-time data and climate change projections.

The project's outcomes are expected to demonstrate how the systematic framework can be used in practice, drawing from expert evaluations and end-user experiences. The project aims to enhance the implementation of strategies that would increase the acceptance of water reuse practices for the local economy and society.

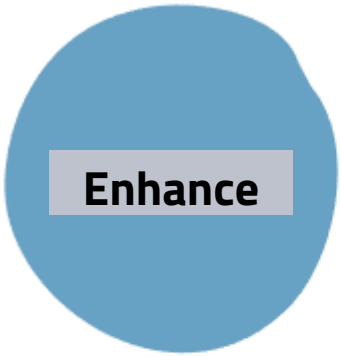
OUR GOAL

Our goal is to support the development of efficient and sustainable water management systems that optimize the quality and quantity of water at stages of its supply, discharge, reclamation and resource recovery.



A systematic framework to facilitate the uptake of smart reuse of wastewater (WW) resources

As an assessment mechanism for companies to integrate these techniques in their value chains



The adoption of fit-for-purpose reuse water in the industrial/agricultural sector

A framework for organisational decision-making processes for companies and utilities to facilitate the uptake of water reuse practices in their operations

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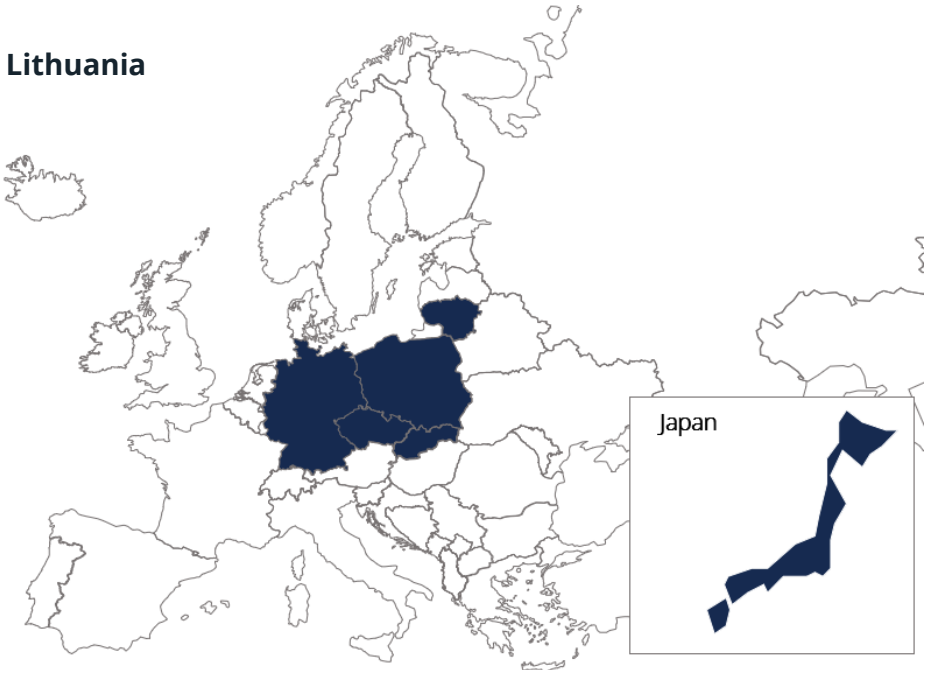

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1. INTRODUCTION

Water quality and industrialization are two aspects that are closely interrelated and continuously co-dependent. Especially in areas with intense industrial activity, water quality and availability can be heavily affected by the companies' water and wastewater management policies. Water reuse can, therefore, offer a circular economy solution to sustainable industrial activities, promoting water use reduction and alleviating water pollution and its subsequent effects on the environment.

The SMART-WaterDomain Project's main objective is to provide a framework for organizational decision-making processes for companies and utilities to facilitate the uptake of water reuse practices in their operations. To meet this aim, the project partner countries have prepared this report, showcasing the different business models for water reuse in industries in the project's participating countries.

Since May 2020, the Project partners, under the guidance of the partners in TUD, prepared and distributed an online survey targeting industries in the most water-intensive sectors in each country, resulting in 83 responses from 5 countries. The outcome of the survey conducted under Work Package 2 (WP2) highlighted the variation in the level of acceptance for water reuse applications in different countries and contexts. Stakeholder perceptions, national policies related to water pricing and governance, water availability, and the level of necessary water quality affect companies' decision-making on water management and the business model they adopt. It is, therefore, important to understand the locality of the factors to the geographical and sectorial characteristics of industries. This report provides a synthesis of the case studies in Germany and Poland and summarizes the outcomes of the analysis.

The report's main objective is to provide an overview of the various organizational structures and decision-making processes in industries regarding water management and sustainability and propose business models incorporating smart and sustainable water management practices. Different aspects of water and wastewater

management are reported and compared from the most water-intensive sectors in each country, namely Chemical, Pulp and Paper, and Energy production for Germany, and Chemical, Food and Beverages, Oil, Gas and Mining, and Water and Wastewater for Poland.

The case study structure and strategy were developed under WP5 by the University of Lodz, Faculty of Management in collaboration with all the partners of the Project. The Project partners proceeded to select the case studies based on two criteria: the water consumption intensity of the sectors in their respective countries and the potential impact of the industrial applications on the quality of the water bodies. Data from secondary sources and primary data from private and public stakeholders were used to analyse the case study.

This report is structured per country. Sections 2, 3 and 4 present the German context and case studies, while Sections 5, 6 and 7 present the Polish one, respectively. Each case study represents a specific sector in a country and follows the same structure. Section 8 presents the report's summary and provides recommendations for future steps.

2. NATIONAL CONTEXT IN GERMANY

Germany has potentially available water resources of 188 billion cubic meters, equivalent to an annual supply of 2,292m³ of water per person (for its 82 million population), equivalent to 6,279 litres per person per day (BMU/UBA, 2018). However, the distribution of water is uneven, with the southwest of the country receiving higher annual average precipitation and lower levels in the East. As a result, the southern federal state of Baden-Württemberg has potential water resources of 49 bn m³ per annum compared to 3.7 bn m³ per annum in the eastern state of Brandenburg (BMU/UBA, 2018). Water supply is the responsibility of the Federal State (Länder) and provision is split between diverse public and private providers. 64% of the organisations providing drinking water operate under public law, however, private companies provide 61% of the water supply. Public law companies, most notably public municipalities, predominantly dispose of wastewater (BMU/UBA, 2018).

In Germany, more than 96% of wastewater from public households and public facilities is discharged into sewage treatment plants, with the Federal Water Act prohibiting direct discharge into water bodies (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, 2022). Germany must implement European Union directives, for example, the EC Urban Waste Water Directive (91/271/EEC), law. The Urban Wastewater Directive was developed to *protect the water environment from the adverse effects of urban wastewater and certain industrial discharges* (European Commission, 2023). Implementing the EC Urban Waste Water Directive and the AbwV: Wastewater Regulation provide threshold values for the quality of treated wastewater that can be discharged to the receiving water source. The wastewater regulation specifies minimum requirements for the discharge of treated water concerning COD, BOD5, nitrogen, and phosphorus (SUNAWU-Europe, 2021).

The Surface Waters Ordinance (Oberflächengewässerverordnung, OGewV) is a law that implements the Environmental Quality Standards Directive and the enforcement of EU law that relates to protecting surface waters. This involves requirements governing surface water characteristics relating to chemical status and

ecological status. The Federal Water Act (WHG) aims to protect groundwater, placing a requirement to preserve and rehabilitate groundwater – including its chemical status. This requires identifying and reversing significant, sustained upward trends in pollutant concentrations in groundwater bodies, specifying threshold values for assessment of chemical status, and limiting input of pollutants into groundwater. The Wastewater Charges Act (Abwasserabgabengesetz, AbwAG) regulates the charges for direct wastewater discharge into a water body and applies the polluter-pays principle into practice. Charges levied are based on the quantity and toxicity of discharges (BMU/ UBA, 2018).

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3. CASE STUDIES IN GERMANY

3.1 CHEMICAL SECTOR

3.1.1 INTRODUCTION

The Chemical Industry in Germany is the largest in Europe and the third largest in the world with an approximate global market share of 15% (Germany Trade & Invest 2017; Cefic, 2022). According to the European Chemical Industry Council (Cefic), the industry is responsible for the direct employment of 464,437 people and generates an annual turnover of €190.6 billion.

The industry is a major driver of innovation and a primary investor in research and development. With an investment of € 11.7 billion per year into R&D activities, it brings together business and research institutes, which leads to the development of new materials, high-performance chemicals and plastics (Germany Trade & Invest, 2017). In 2017, there were approximately 3300 chemical companies in Germany, and 97% had less than 500 employees. These SMEs account for approximately 1/3 of the workforce and make up the chemical industry's backbone. However, the German chemical industry is also notable for containing several large global corporations, including well-known names such as BASF, Bayer, Henkel, Lanxess, and Altana (Germany Trade & Invest, 2017).

The sector has taken important steps towards sustainability. The Responsible Care initiative for the Chemicals Industry was founded in 1985 and has led to companies in the industry dealing with a range of sustainability topics, including safety, risk management, and impacts on the environment and health arising from stringent regulations and growing public awareness. Chemical companies are expected to improve their own footprint as well as promote sustainable solutions and innovative strategies (Pwc 2022).

According to Geißen et al. (2012), the chemical industry accounted for 35% of treated wastewater quantities of key industries in 2007 (327 million m3). Usual wastewater treatment processes include anaerobic treatment, as well as ceramic membranes, which are given high mechanical, chemical, and thermal stability, especially in comparably small process flows (DECHEMA, 2017).

Regulations introduced for the sector have been introduced at the EU level (e.g. ban on single-use plastics) as well as national regulations (Pwc, 2022). Within Germany, Chemie3, the German Chemical Industry's sustainability initiative (founded by the German Chemical Industry Association (VCI), the German Federal Employers' Association for the Chemical Industry (BAVC) and the IGBCE) has drawn up 12 guidelines for sustainability in the chemical industry in Germany, accompanied by 40 indicators. However, none of these explicitly address water use (Stiftung Arbeit und Umwelt der Industriegewerkschaft, 2022).

3.1.2 BASF

BASF is the largest Chemical company in the world and is Headquartered in Germany (C&EN, 2022), with a sales value of 78.6€ billion in 2021 (BASF, 2023a). BASF is a co-founder of the UN Global Compact, focusing on managing its water resources and external environmental impacts on water (BASF, 2023b).

The company's products include chemicals, plastics, performance products, agricultural solutions, oil and gas, and functional materials. BASF is one of the largest employers in Germany, with more than 30,000 people working at its sites across the country. The company offers various career opportunities, from research and development to production and logistics.

BASF has set ambitious sustainability targets in its German sites in areas such as climate protection, circular economy, water stewardship, sustainability in products and in the supply chain.

For BASF, water is of fundamental importance in chemical production. It is a key resource for the company, used as a coolant, solvent, cleaning agent, and ingredient in final products. Cooling purposes account for 87% of its consumption, and 13% is accounted for by dissolution and cleaning processes. Additionally, water is used for logistics, transporting goods via waterways. However, BASF is aware of water becoming scarce in more and more of its regions and, therefore, is determined to promote responsible use of water resources within sustainable water management (BASF, 2021).

According to BASF's website, 1,695 million Cubic meters of total water were abstracted in 2021. Of this abstracted water, 84% came from freshwater abstraction (e.g. lakes and rivers), and BASF's production sites discharged 1503 million cubic meters of water, 177 million of which was wastewater from production. BASF reported their water abstraction, supply and discharge according to the following figures in millions of cubic meters per year (BASF 2021):

Source	Abstraction/Supply	Discharge
Surface water/fresh water	1,308	1,239
Brackish water/seawater	259	245
Groundwater	100	1
Drinking water	100	-
Reusable water from third parties	3	-
Water from raw materials	5	-
External treatment plant	-	18

BASF themselves outline their wastewater management as to:
"Reduce wastewater volumes and contaminant loads at the source in our production processes and reuse wastewater and material flows internally as far as possible. To treat wastewater, we use both central measures in wastewater treatment plants and the selective pre-treatment of individual wastewater streams before these are sent to the wastewater treatment plant. Suitable methods are used, depending on the type

and degree of contamination – including biological processes, chemical oxidation, membrane technologies, precipitation or adsorption." (BASF 2020, p141). The company participates in the CDP water disclosure, where it received a score of A-. The following water-related measures are provided in the GRI and Global Compact Reporting from the BASF website (BASF, 2021).

GRI	Standard
103-1	Management Approach: Explanation of the material topic and its Boundary
103-2	Management Approach: The management approach and its components
103-3	Management Approach: Evaluation of the management approach
303-1	Interactions with water as a shared resource
303-2	Management of water discharge-related impacts
303-3	Water withdrawal
303-4	Water discharge
303-5	Water consumption

As highlighted earlier in the report, BASF requires water for its products and logistics. Low water levels in August 2022 on the River Rhine led to fears that the company would have difficulties carrying out its logistics and cooling (Lopez, 2022). In 2018, low levels on the river led to an estimated drop in earnings of 50€ million due to reductions in logistics capacity (OEVZ, 2018). Meanwhile, 25% of BASF's sites are located in water-stressed areas (where industry, households and agriculture use more than 40% of available water), accounting for 1% of total water abstraction (BASF 2021). The main stakeholders identified by BASF include customers, politicians, NGOs, community groups, investors, suppliers, and employees (BASF, 2022). These stakeholders are either responsible for implementing water sustainability practices, placing pressure on the companies to act, or are affected by BASF's activities relating to water issues.

BASF conducts wastewater reuse activities through the use of its wastewater treatment plants. BASF has one of Europe's largest wastewater treatment plants,

which was established in 1974. The plant purifies almost 100 million m3 of production water annually and 20 million m3 of wastewater from Ludwigshafen and Frankental in the Federal State of Rhineland Palatine (BASF 2023).

Regarding technology, the wastewater treatment plant uses biological wastewater treatment processes (Völker et al., 2007). This was first implemented in 1974 and its operation has led to improvements in the biodiversity of fish as a result of an improvement in water quality to the "optimum which can be expected for this river section (water quality index of about 2.0 – 2.3)" (Pawlowski et al. 2012). Four hundred thousand tonnes of sewage sludge (approximately half of which comes from the company) can be disposed of yearly. The sludge is incinerated, with the steam used to generate electricity and stored in a district heating network. The company also sets out its commitment to avoiding waste generation in the first place, highlighting how the company has reduced its water contamination by 23% between 2010 and 2015 (BASF 2023b).

From BASF's current operations, there exist opportunities to increase further the efficiency of wastewater reuse and water consumption in their operations. This would involve the company expanding its targets and reporting against the GRI and CDP. The main opportunities involve increased use of wastewater for cooling processes. However, the company should also implement methods to improve the local water availability for communities and protect crucial shipping lanes in navigation rivers around their West German base. Addressing this critical water risk will require substantial technological change and collaboration with neighbouring industries to improve river navigation resilience in the face of climate change.

3.1.3 ALTANA

ALTANA is a global speciality chemicals company Headquartered in Wesel, Germany, in the Federal State of North-Rhine Westphalia in North West Germany (ALTANA, 2023). The company has 48 production facilities and 65 service and research laboratories and employs over 6500 people (ChemEurope, 2023). The company is one of the largest companies in speciality chemicals, producing products including

additives, adhesives, sealants and varnishes for coating manufacturers, paint and plastic processors, and the cosmetic and electronics industries. These products are designed to be innovative and environmentally sustainable (ChemEurope, 2023). ALTANA is a global speciality chemicals company Headquartered in Wesel, Germany, in the Federal State of North-Rhine Westphalia in North West Germany (ALTANA, 2023). The company has 48 production facilities and 65 service and research laboratories and employs over 6500 people (ChemEurope, 2023). The company is one of the largest companies in speciality chemicals, producing products including additives, adhesives, sealants and varnishes for coating manufacturers, paint and plastic processors, and the cosmetic and electronics industries. These products are designed to be innovative and environmentally sustainable (ChemEurope, 2023). Water is essential for the production processes of the ALTANA Group. It is used as a raw material, as a cleaning agent, coolant, and as a reaction solvent (ALTANA, 2021a; ALTANA, 2023). As a result, ALTANA states that the company aims to keep water consumption as low as possible and to use cooling water in closed-loop systems (ALTANA, 2021; ALTANA, 2023).

Wastewater is produced as a result of ALTANA's business activities. ALTANA has objectives to reduce the amount of water that it uses through technical measures such as through the realization of closed-loop cooling systems, replacement of water ring pumps for vacuum generation, avoiding water-intensive process steps and detecting leaks and repairing them early (ALTANA, 2021). ALTANA established a system for recording water consumption worldwide (from drinking, surface, groundwater, and rainwater) and established wastewater recirculation. Each of its manufacturing sites is required to report quarterly on water consumption and volume of wastewater, which are then stored in a database (in absolute terms and standardized according to volume manufactured), which is reported in ALTANA's corporate reports and displayed on their website (ALTANA 2021a, b). In terms of drinking water, the company recorded drinking water consumption at 1250000 cubic meters in 2019, falling to 1150000 in 2020 and 1360000 in 2021. The drinking water ratio compared to the volume of finished goods was 2.22 cubic meters per tonne of output in 2021, an increase from 2.19 per tonne in 2020 (ALTANA 2020, 2021b). The 2021 Facts and Figures Report provides the following water consumption data.

Table. Water withdrawal (without consideration of water as a raw material):

Total	absolute in m³	Related to produced finished goods in 1/kg
Water form third parties (drinking water)		
2018	1,344,023	2.42
2018	1,369,549	2.43
2019	1,220,617	2.35
2019	1,251,147	2.38
2020	1,122,645	2.2
2020	1,147,735	2.19
2021	1,355,198	2.24
2021	1,361,001	2.22
Groundwater		
2018	706,936	1.26
2019	645,295	1.23
2020	568,981	1.09
2021	593,391	0.97
Surface water (river and precipitation water)		
2018	154,590	0.27
2019	135,675	0.26
2020	252,026	0.48
2021	273,379	0.45
From regions with water stress		
Water from third parties (drinking water)		
2021	102,825	1.76
Groundwater		
2021	0	0
Surface water (river and precipitation water)		
2021	0	0

Table. Water recirculation.

Total	absolute in m^3	Related to produced finished goods in 1/kg
Water form third parties (sewage)		
2021	1,071,948	1.75
Surface water (river water)		
2021	428,041	0.7
From regions with water stress		
Water from third parties (sewage		
2021	18,590	0.32
Surface water (river water)		
2021	47,046	0.81

Table. Water consumption.

Total	absolute in m^3	Related to produced finished goods in 1/kg
2021	727,782	1.19
From regions with water stress		
2021	32,032	0.55

ALTANA bases its reporting on the following GRI standards as documented in its GRI content index in the 2021 Facts and Figures report.

ALTANA applies the “water depletion” criteria proposed by the GRI and has used this to identify sites located in “water stress” areas. From this activity, ALTANA believes it has sufficient water of appropriate quality. Its analysis of the information available suggests that ALTANA’s manufacturing sites have no negative effects on the local drinking water supply (ALTANA 2021b). ALTANA describes its commitment to sustainability beyond the reduction of greenhouse gas emissions. The sustainability objectives of the company and the activities taken to achieve them extend beyond reducing greenhouse gas emissions (ALTANA, 2023) and minimising the impact on people and the environment (ALTANA, 2021b).

GRI	Standard
102-21	Consulting stakeholders on economic, environmental, and social topics
102-29	Identifying and managing economic, social, and environmental impacts
102-31	Review of economic, environmental, and social topics
102-32	The highest governance body's role in sustainability reporting
102-40	List of stakeholder groups
102-42	Identifying and selecting stakeholders
102-43	Approach to Stakeholder Engagement
303-1	Interactions with water as a shared resource
303-2	Management of water discharge-related impacts
303-3	Water withdrawal
303-4	Water discharge
303-5	Water consumption

ALTANA describes its "ambitious" targets for waste reduction and responsible drinking water use. For example, targets for drinking water are defined annually to achieve an overarching goal to ensure a reduction in drinking water at all manufacturing sites, especially in water stress areas (ALTANA, 2021b). To achieve this, the company introduces pre-defined checklists to determine water consumption and the appropriate action (ALTANA, 2021b).

ALTANA extracts water from rivers and groundwater and is then treated to ensure the quantity of water required for production (including areas at risk of water stress). Rainwater is utilised for cooling and watering green areas (ALTANA, 2021b), while more generally, in terms of wastewater reduction, ALTANA states that they aim to avoid or reduce wastewater and waste discharge to minimize negative effects on people and the environment from the use of suitable raw materials and cleaning agents (ALTANA, 2023). Strategies to achieve this include reducing waste volumes at numerous sites through recycling, such as reducing solvents, using more efficient cleaning agents, and revising cleaning regulations (ALTANA, 2023). These practices are

part of the company's strategy for ensuring sufficient quantity and quality of water from certain sources meet legal specifications with monitoring by local authorities (ALTANA 2021b).

Regarding activities, ALTANA treats its wastewater (chemically contaminated) internally through effluent treatment plants or externally, for example, through discharge to the local sewage system (according to legal requirements). The quantity and quality of the effluents are required to meet legal regulations for wastewater discharge. Environmental effluent risks are avoided by feeding chemically contaminated wastewater into separate sewers. Part of the process is to take and examine regular samples from chemically contaminated wastewater treated on-site in biological clarification tanks. Water is only used for cooling methods and is not from contaminated sources. This cooling water is returned to surface water or the local sewage system (ALTANA, 2021b).

ALTANA's main direct opportunities are reducing water consumption and improving wastewater processing. From a marketing perspective, ALTANA may reduce their water consumption and increase water availability through wastewater reuse to promote itself further as a sustainable company. On-site treatment at a high level may also assist the company in reducing the need for separate discharge infrastructure and more easily comply with local regulations.

3.1.4 SYMRISE

Symrise was founded in 1874, with its Corporate Centre in Holzminden, Germany. It is a company that develops, produces, and sells materials relating to fragrance, flavouring, food ingredients, and active ingredients for cosmetics (Symrise, 2021a; Global Nature Fund 2023). The company currently holds a global market share of 10%, with over 100 sites containing 11000 employees. The company sells to over 6,000 customers in over 150 countries (Symrise, 2021a). In 2012, Symrise was awarded the German Sustainability Award (Sielaf et al., 2015; Global Nature Fund, 2023).

According to Symrise's responses to the CDP water questionnaire, sufficient freshwater is considered "vital". In contrast, adequate amounts of recycled, brackish

and/or produced water available for use is regarded as “not important at all” for direct use and “not very important” for indirect use (Symrise, 2022). Most of the company's water is attributed to cooling towers, boiler houses, and vacuum generation with liquid water ring pumps (Symrise, 2021b). The company also chose its site in Holzminden as its raw materials grew close to the banks of the River Weser (lavender, reseda and lupin), which could be easily and cheaply extracted (Sielaf et al., 2015). Additionally, the river could be used for transportation across Europe (Sielaf et al., 2015).

Symrise supports the CEO Water Mandate to promote the protection and sustainable use of freshwater bodies and water used in direct business activities along the value chain. The company has implemented a water use strategy committing the company to the following actions (Syrise 2021b):

1. Ensuring compliance with water-related legislation and voluntary standards in countries where they operate;
2. Attain sustainable use of freshwater resources, taking into consideration regeneration rates of local water bodies and sources;
3. Conduct regular analysis, monitoring, control and sustainable management of water quality and quantity of outputs and inputs;
4. Raising awareness among customers, suppliers and interest groups regarding the critical importance of water for achieving sustainable development and delivering company success;
5. Integrate water-related performance criteria into supplier screening;
6. Provide information to customers regarding the water output of the compounds and ingredients they purchase from Symrise;
7. Collaborate with multiple interest groups in the area of water management and perform regular water risk assessments of operations and value chains;
8. Promote sustainable innovation along the value chain to conserve freshwater resources and protect water quality and the aquatic environment – for example, in the distillation process;
9. Improve water efficiency at all production locations in areas with high water stress according to the local water availability for human and environmental needs.

In 2021, the company recorded the following information relating to the GRI standards (Symrise 2021a,b):

GRI 303-3 Total Water Withdrawal by Source (million m³)	2021	2020	2019	2018
Surface water	835	849	871	761
Groundwater	2,736	2,871	2,453	2,880
Municipal water	2,810	2,697	1,635	1,689
Other	143	41	12	15
TOTAL WATER WITHDRAWAL	6,524	6,458	4,947	5,345
GRI 303-4 Water discharge by destination (in 1,000 m³)	**2021**	**2020**	**2019**	**2018**
Surface water	4,276	4,517	3,501	3,372
Groundwater	0	0	0	0
Seawater	0	0	0	0
TOTAL WATER RETURN	4,276	4,517	3,501	3,372
GRI 303-5 Water Consumption (in 1,000m³)	**2021**	**2020**	**2019**	**2018**
Water consumption in all areas	6,524	6,459	4,947	-
Of which water consumption in areas with water stress	232	216	398	-

The company uses tools to assess the water footprint of raw materials and products, enabling developers to access data and select water-efficient raw materials for products. Additionally, an Environmental Management System (EMS) is in place to guide local environmental managers and production engineers towards optimizing water-related production processes and technologies to reduce local water usage at manufacturing sites (Symrise, 2022).

Symrise recognises climate-related risks to its operations. It has purchased and operates businesses relating to water-intensive agricultural commodities (e.g. tomatoes, vanilla). Rising temperatures connected to climate change increase the risk of crop losses for suppliers due to water scarcity, leading to cost pressures on the company (Symrise, 2021b). Protecting water supplies has become part of its corporate strategy, particularly in sites with high levels of water stress (e.g. in Egypt, Spain, India and Mexico). The company believes that protecting water is essential for enabling it to continue to operate (Food Ingredients First, 2023). As a result, Symrise has reduced its water consumption in these countries by 12% compared to 2020 (Food Ingredients First, 2023) and has a stated aim of reducing water consumption by 15% at all production sites in Arid regions by 2025 (Symrise, 2021b). The company conducts comprehensive international surveys of its major stakeholder groups, covering over 600 customers, employees, investors, NGOs, and industry associations, to review its materiality matrix critically (Sielaf et al., 2015).

Symrise does not consume significant amounts of water in areas with water stress and has overarching objectives to reduce water use and withdrawal as much as possible. Symrise assesses freshwater availability at all its sites by determining the catchment area, identifying water-related hazards and risks, and assessing the potential consequences for its business activities. Where water scarcity risks emerge, mitigation measures are put in place, such as water transfer from neighbouring sites with higher levels of water availability (Symrise, 2021b). Water is an ingredient input and is used for cleaning production facilities and cannot be easily substituted, therefore Symrise considers that water is vital for its direct operations but also recognises the importance of water in its supply chain, especially for agricultural suppliers (Symrise, 2022).

Symrise is under consumer pressure to utilise natural ingredients over synthetic ones, which are more water-intensive and increase water dependence in indirect operations (Symrise, 2022). The shortfall cannot be met using brackish or recycled water, which is not compliant with food safety regulations or good manufacturing standards (Symrise, 2022). Recycling water could be used to irrigate crops; however, this is still not considered very important for the company, even over the next five years (Symrise, 2022).

Symrise's diverse water demands within its supply chain present challenges in developing a standardised water management strategy but also offer opportunities to utilise treated wastewater across different sites. While the company doesn't yet consider using recycled water in irrigation as an essential tactic, developing infrastructure in this area could help improve the resilience of agricultural suppliers to future water stress. The company also requires technological enhancements to make recycled wastewater a viable substitute for the use in its natural ingredients cultivation, which will help satisfy consumer demands as well as improve water security, efficiency and sustainability.

3.1.5 SUMMARY & REFERENCES

Given the status of the chemicals industry as a major driver of innovation and a large wastewater generator (Germany Trade & Invest, 2017), several practices from the case study companies could be identified that could be applied to other industries. Water sources vary between the three companies analysed in this project. The largest company, BASF, reports that it obtains most of its water from surface water (BASF, 2021). The two smaller companies, Symrise and Altana, report receiving their water primarily from groundwater and municipal water supplies ALTANA 2021; Symrise, 2021a,b). Therefore, water is not easily substituted and is a vital resource for company operations. Still, due to the scarcity of water near their production sites, there are strong drivers to increase water use efficiency and reduce consumption. BASF and Symrise explicitly state that they are located near water sources for access to water resources as well as the use of rivers for transportation, and therefore, water scarcity can have further impacts on logistical operations for the company (Lopez, 2022; BASF 2021; Sielaf et al., 2015).

The industry consumes water as a primary product in chemical production and is required for dissolution, cleaning processes and cooling. Cooling demands comprise the bulk of water demands (in the case of BASF – 87% of total water consumed). The cooling process is an area all the companies have identified as an opportunity for a closed-loop system. The companies also state that they are committed to reducing

wastewater discharge. For example, BASF built one of Europe's largest wastewater treatment plants, allowing it to purify almost 100 million m3 of wastewater each year (BASF, 2023). ALTANA use separate sewers for chemically contaminated wastewater (ALTANA, 2021b). Meanwhile, Symrise requires additional investment to take advantage of water recycling opportunities (Symrise, 2022).

The recommendation for the industry is to formalize the guidelines and regulations for companies in the industry. All three companies report according to GRI standards and discuss other reporting and standards organizations they follow or are members of. These include the UN Global Compact, CDP water disclosure (BASF and Symrise); The World Wildlife Fund (WWF) Risk Filter (ALTANA); and the CEO Water Mandate (Symrise).

Additionally, it should be possible for the industry to ensure larger companies provide support for smaller companies to either be able to afford or to share the use of technologies and equipment that help to lower the amount of wastewater discharge.

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3.2 PAPER/PACKAGING SECTOR

3.2.1 INTRODUCTION

In Germany, the paper industry is the fourth largest in the world, with a production volume of 23 million tonnes of paper and board (behind China, USA and Japan). Companies in the paper industry are involved in the processes of manufacturing pulp, paper and board. In Germany, approximately 3,000 different grades of paper are produced. In terms of organisations, there are approximately 160 companies employing 40,000 people and generating a turnover of €14 billion. The companies involved in the industry range from large global corporations to family-owned SMEs (VDP, 2016). Fibres, water and energy are needed in large quantities to produce cardboard, paper or pulp (Das Environmental Experts 2022) and water use in paper production is substantial, involving processes such as pulping of raw materials, creation of chemical pulp through cooking, addition of water and chemicals for wood chips, removal of printing inks (VDP, 2016). In 1950, 1kg of produced paper required as much as 170 litres of water, which has reduced to an average of 10 litres per 1kg of product, achieved by the closure of water mill circuits (VDP, 2016).

Companies operating in this industry are trying to cut their costs to remain competitive domestically and internationally. Therefore, water reduction is a way to do this, e.g., through a well-designed wastewater treatment system, which can help reduce freshwater and energy demands (Das Environmental Experts, 2022). To re-use water in the production process, purification must be carried out to high quality as wastewater from paper factories includes de-inking chemicals, bleach, and process chemicals and additives. Wastewater in the industry is characterised by a high chemical oxygen demand (COD) and is treated first mechanically and then followed by full biological treatment. This can occur in either the factory or in a municipal treatment plant (up to 10 times before discharge) and paper mills often take over sewage treatment from neighbouring municipalities (VDP, 2016).

3.2.2 LOUISENTHAL

Louisenthal specialises in producing paper for banknotes and is one of the main suppliers of paper for the euro to the European Central Bank. In addition, their manufactured security paper is used for passports and other identity documents. The Company was founded in Gmund am Tegernsee, Bavaria in 1964 and as two plants, one located in Bavaria (south of Munich) and another in Saxony (east of Dresden). The plants employ over 1100 people and have an output capacity of 20000 tonnes (Louisenthal website 2022).

Water is a critical resource for the company and is used to cool their combined heat and power plants. Water is used directly from the Mangfall River between November and April. In addition, the site in Louisenthal is located in the middle of the drinking water catchment area for the City of Munich. As a result, the company is committed to environmental protection and controlling water pollution by rules that go beyond national and European law (Louisenthal website, 2022). The production that is undertaken within the catchment area is highly regulated.

In 2010, a biological wastewater treatment plant was installed, where bacteria purify the process water. Through a membrane filtration system, the bacteria are separated and recycled and the purified water is then reused in production. As a result, the company's water consumption was reduced by 40%, from 1,600 m3 to 900 m3 per day. With this biomembrane reactor, the company reduced fresh water consumption to a minimum and created a closed water cycle in the production process. (Louisenthal, 2021).

Since 2017, the company has reduced the abstractions from the river Mangfall to more than the required amount, resulting in 650 l/s more water available in the river than the amount defined in the regulations. The factory is located in the middle of a drinking water catchment in Munich (Louisenthal, 2023). Company use water is sourced directly from the Mangfall River. Land use changes and sedimentation of the Mangfall River may alter future discharge and water levels. (Dittes et al., 2018).

The Louisenthal site consumes the equivalent of 16000 single-family homes, has spent over 15 million euros on sustainability projects, and is moving towards generating electricity through water turbines – currently owning three such turbines (Louisenthal, 2022).

The plant's location is a challenge for the region's sustainability as it is located in the drinking water catchment of Munich (Louisenthal, 2021). The company has implemented sustainability practices to reduce the impacts on the local environment and ensure safe operations. This is achieved by developing an environmental management system that defines responsibilities, processes, guidelines, and operational measures that address resource conservation and reduce environmental impact and costs. This system is based on ISO 140001, ESO 50.001 and OHSAS 18001 standards. Both company production sites in Louisenthal and Königstein are certified following global standards (Louisenthal, 2021).

One of the practices undertaken by the company is the ownership of a 55-hectare forest around the factory which is responsible for storing 300,000 tonnes of CO2. Installing a bio-membrane reactor is also responsible for saving 700m3 of wastewater daily, reducing the wastewater discharge into the environment. This is combined with an onsite purification process that treats highly contaminated wastewater from the foil production process (which is impacted by heavy metals from the ink), purifying the water before discharge to the municipal wastewater treatment plant (Louisenthal, 2021). The result of engaging in this wastewater management is that the company can reduce water consumption by 40% since the plant became operational in 2009, and since 2017, it has voluntarily left more water in the Mangfall River than is legally required (Louisenthal, 2022).

For implementing effective water reuse, the company can follow the example of other companies and set a water risk management plan. This plan identifies specific threats for the local environment, for which solutions can then be implemented. An overarching water management system will allow for effective and targeted solutions to the identified threats. Technological solutions, such as reverse osmosis, can be

efficient for the further treatment of the processed water. However, the company already has advanced water treatment processes in place.

3.2.3 MERCER (ZELLSTOFF STENDAL GMBH)

Mercer Stendal is a papermill producing high-quality pulp using softwood chips purchased from regional sawmills and roundwood from northern European countries. It is part of the Mercer company. Pulp is used to produce printing, hygiene and speciality papers, as well as in the recycling of waste paper.

The mill processes approximately 3.5 million cubic meters of wood annually. Its parent company's goal is to maximise the utilisation of wood, for example, going beyond pulp production to also produce bioenergy, biochemicals and other bio-based products from the wood, maximising the value of wood biomass. To achieve its sustainability goals, the company operates the Mercer Stedal site to use wood as efficiently and sustainably as possible, implementing the principle of bio-refineries, notably: the wood is broken down into its basic components and used as extensively as technologically possible. The mill extracts various biochemicals from the wood, including turpentine and tall oil, which are used to replace fossil-based raw materials. Stendal operates Germany's largest biomass power plant and generates energy from the organic components that remain after biomass utilisation (Mercer, 2022).

The company includes its Sustainable Water Use as one of the topics for its sustainability report. The company places limiting water use and protecting water quality as an important part of its sustainability objectives for its operations. These include water conservation and efficiency goals, which are justified for better preparedness in times of water shortage, contributing to ecosystem stability, and supporting best practices. Water is used throughout the pulping process – most of the water extracted is used for cooling and is not treated in any way other than to clean the water, with some water used to generate electricity. In Germany, most of this water is from extensive waterways, e.g. the Elbe and Saale Rivers. Back-up water supplies are taken from wells. The Stendal Mill also operates a reverse osmosis treatment plant,

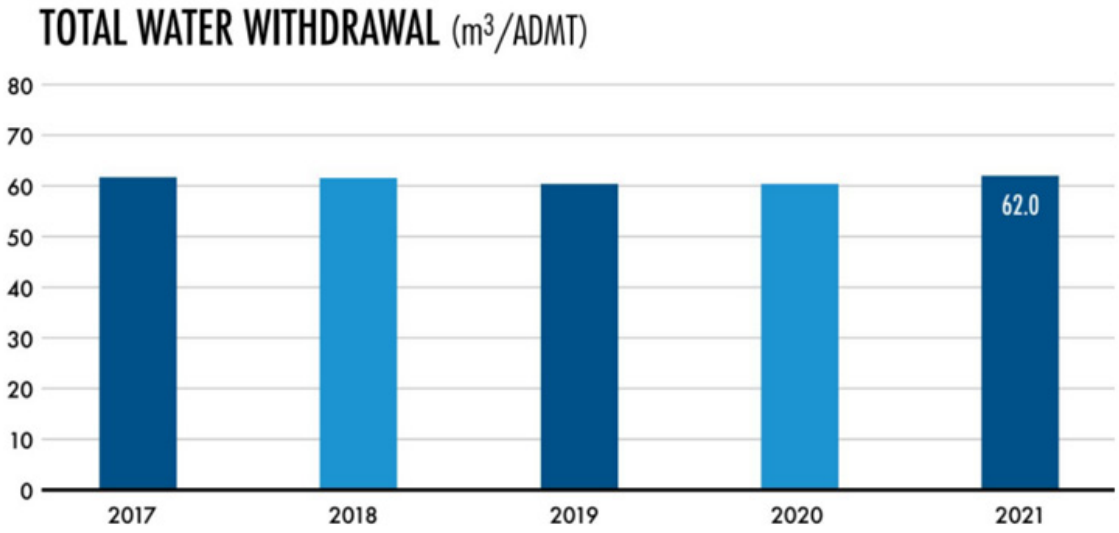
and the cleaning process removes sediment and chemicals (such as phosphorous) which are present in the water due to agricultural runoff.

Pulping processes require water, but the company states that it seeks to limit water use, reducing unlimited usage and ensuring water is treated and returned to its source at the appropriate temperature, with the majority of the water consumed returned to the same waterway from which it was extracted (Mercer, 2023).

The company mainly uses abstracted water for cooling, which receives treatment after the abstraction. No further treatment is being done to the processed water. The primary focus of this water is to limit losses to the air through steam and to keep the water as close as possible to the temperature of its source when it is returned. The company complies with the permits on water temperature limits, which the government imposes.

According to the 2022 Environmental Product Declaration certificate for the Mercer Stendal papermill in Arneburg, Saxony-Anhalt, Germany, the Stendal mills have been able to reduce water consumption intensity over the last few years and have invested in new modern plant technology to increase the environmental performance, decrease GHG emissions, and improve the effluent quality (Mercer, 2022a).

The company's process water volumes per tonne of pulp have remained stable over the past 5 years, recording a 3% increase in 2021 compared to 2020 values due to an extended outage at the Mercer Peace River. Mercer's total water usage includes cooling water, which is necessary to ensure safe and efficient power generation from condensing turbines at the pulp mills. Meanwhile, the company has established a goal to reduce water consumption by 20% by 2030 against a baseline of 2019. Each mill is set continuous improvement activities to achieve this goal (Mercer, 2021a). The main progress has seen a stabilisation of process water volumes per tonne of pulp over the past 5 years, with only a 3% increase in usage in 2021 compared to 2020 due to an extended outage at the Peace River.
The company has also established goals to reduce water consumption by 20% by 2030 against their 2019 baseline.



For its corporate sustainability reporting, Mercer follows the Global Reporting Initiative (GRI) Sustainability Reporting Standards. These are listed in table.

The holding company for Mercer Stendal recognise that access to freshwater is essential for human life and well-being, following the declaration by the United Nations that water is a human right. The company identifies that access to freshwater is essential for human life and well-being (Mercer, 2022). Direct impacts on a watershed can have broader effects on the quality of life in an area, including the social and economic consequences for local communities and Indigenous Peoples. On top of this, the company recognise that monitoring and measuring water quality provides empirical evidence to support compliance with environmental laws and regulations (Mercer, 2022).

According to the 2022 Environmental Product Declaration certificate for the Mercer Stendal papermill in Arneburg, Saxony-Anhalt, Germany, the company complies with strict requirements which the company constantly monitors. Large amounts of water are taken from the Elbe River for production purposes and returned to the river following a complicated mechanical and biological cleaning process. The Elbe is part of the “Middle Elbe Biosphere Reserve”. The Stendal mill is further surrounded by nature reserves and conservation areas and is located at the edge of a “NATURA 2000” area (Mercer 2022a).

GRI	Standard
103-2	Management Approach: The management approach and its components
103-3	Management Approach: Evaluation of the management approach
102-29	Identifying and managing economic, environmental, and social impacts
102-31	Review of economic, environmental, and social topics
102-40	List of stakeholder groups
102-42	Identifying and selecting stakeholders
102-43	Approach to stakeholder engagement
102-32	The highest governance body's role in sustainability reporting
102-31	Review of economic, environmental, and social topics
2-2	Entities included in the organization’s sustainability reporting
2-3	Reporting period, frequency and contact point
2-14	Role of the highest governance body in sustainability reporting
303-1	Interactions with water as a shared resource
303-2	Management of water discharge-related impacts
303-3	Water withdrawal
303-4	Water discharge
303-5	Water consumption

Substantial advancements have been achieved over time in the treatment of processes and wastewater to limit the use and improve effluent discharge quality to receiving waters. The effluent discharge is controlled to ensure the maintenance of aquatic health of ecosystems, safe and secure drinking water supplies, and reliable water supplies for a sustainable economy (Mercer, 2023).

Water is used as a carrying medium for the fibre and chemicals required in the kraft process. To meet strict wastewater technology-based standards and environmental quality objectives, appropriate reduction and control technologies are

utilized to minimize the release of pollutants to the nearby waters through advanced effluent treatment systems. Over the past three years, a decrease of 6% in AOX per tonne of pulp has been observed. During this period, the AOX at the Celgar mill was reduced by over 10%, primarily through an increased focus on process optimization and the adoption of a 4-stage bleaching process (Mercer, 2023).

In bio-basins, water treatment is undergone through anaerobic processes, where a series of vessels and basins reduce the depletion of oxygen caused by organic material in receiving waters. A critical element of this system is a meticulously controlled population of microbiotic organisms, known as "bugs," that feed on any remaining organic matter. To optimize the treatment process, anaerobic systems are employed with the addition of air via submerged jet aeration systems and nutrients, including nitrogen, to maintain a high level of organisms. After the organics are consumed, the short-lived bugs expire and are removed from the system, where they are burned in an electricity-generating power boiler. Modern effluent treatment systems can remove chemical, organic, and suspended solids to a high level. This is another example of working towards environmentally sustainable processes. (Mercer, 2023).

The company is committed to improving effluent quality, using best practices, investing in the best available technology, exceeding regulatory requirements, and minimising environmental impact (Mercer, 2022). The company has an Environmental Management System certified according to ISO 140001 at each pulp mill. This provides a rigorous approach to managing water and effluent quality and, therefore, incorporates practices that are concerned with internal water monitoring, spill control and contaminant procedures, which the company hopes to ensure the expansion projects reduce the overall environmental footprint (Mercer 2022).

In order to minimise the impacts on the Elbe River, Mercer could adopt water reuse practices for their paper mill. As a guiding process, the GRI indicator for water intensity can highlight the processes where water consumption is the highest.

3.2.4 KABEL PREMIUM PULP & PAPER GMBH

Kabel Premium Pulp & Paper is a German company that produces graphic and packaging paper. The company was initially founded in 1896 and took its current organizational form in 2016. It has more than 500 employees, although the number is decreasing. The company is targeting high-quality production and uses a new fibre mill for this. Their mill is processing only wood and pulp and no waste paper. Kabel has focused on sustainability actions mainly through social engagement and carbon footprint assessment of its activities (Kabel 2023a, b).

Recently, the company has shifted its focus to energy-saving activities due to the rising energy prices, reducing thus the production to 1/3 of its full capacity (data gathered from interview).

Kabel Premium Pulp & Paper is a high-water-intensive industry. As a medium-sized company with a production site in only one location in the Ruhr area in Nord Rhine Westphalia, Kabel is heavily dependent on water.

The provided information is based on the survey response and a short interview with the water manager. Very little information on the company's water consumption and management is available on their website.

Kabel uses its water mainly during pulp production in the cooling systems for paper slurry. The water consumption ranges from 800-1200 m3 per hour of fresh water (6 million m3 annually), 45% of which comes from the municipality. Furthermore, 5 wells are being used as an additional source of water.

The area is a highly densely populated part of the country with many industrial activities. The region had a long tradition of mining activities that seized in 2016 (Tran et al. 2020). Furthermore, the region is below sea level, making constant pumping necessary as part of their water management strategy to avoid flooding.

Due to a lack of water availability during the dry seasons, water is collected in dams during the rainy seasons, which is then released into the river to complement the lower water level (Ruhrverband, 2023).

The company is treating its wastewater before it releases it to the environment. The wastewater receives treatment mainly by flocculation and microfiltration (sand-gravel filtration).

Overall, the company uses water as frequently as possible due to the highly contaminated process, which would then incur high costs for wastewater treatment. They identified health problems with a specific bacteria in the wastewater (legionella), which is stronger during Summer time.

Wastewater from power generators and internally recycled water are being used for cooling purposes in the double-press. The amount of recirculated water has decreased over the years due to the lack of financial feasibility.

The company had made calculations regarding the costs of a process water treatment facility for recirculation that would include nano-filtration and reverse osmosis processes. The facility would receive 400m3 wastewater, half of which would return in the process. However, the project was deemed unfeasible due to the high costs of maintenance from the short membrane lifetime and the high energy demand. Furthermore, the facility would have high personnel costs due to its labour-intensive activities.

According to Bracke (2020), the Fraunhofer IEG, together with the Kabel Premium Pulp & Paper (KPPP) paper mill, is exploring the possibility of converting the energy-intensive process step of drying at 100 to 200°C from natural gas to sustainable geothermal energy. A known fault zone runs through KPPP's premises, which gives the possibility of increased water permeability (Bracke, 2020).

3.2.5 SUMMARY & REFERENCES

The competitive pressures of the paper industry are leading to a drive to cut costs, of which water costs are identified as one way to achieve this (Das Environmental Experts, 2022). The use of treated wastewater is seen as one mechanism that can help achieve these cost-reduction measures. The three companies all operate with different specialities regarding paper production, but there are similarities in terms of their water practices. Louisenthal, a company producing paper for banknotes and security paper for passports, abstracts surface water from the Mangfall River (Bavaira, Germany) during the winter months for cooling processes in their combined heat and power plant (Louisenthal, 2021). Mercer, a papermill, abstracts water from large waterways such as the Saale and Elbe (in North/Eastern Germany) for cooling, with some water used to generate electricity (Mercer, 2023). Kabel Pulp & Paper, based in the industrial Ruhr Valley in North Rhine Westphalia (Western Germany), stands out from the companies, as it obtains 45% of its water resources from municipal supplies, supplemented by access to five water wells.

The industry consumes water for cooling. The companies describe how water is used for energy or heat-generating activities (Louisenthal, Mercer) and for pulp production (Kabel). Mercer and Louisenthal's consumption of abstracted surface water (from rivers) is limited to the wetter winter months. The companies are also wary of the impacts of their wastewater on the quality of drinking water in their river catchments. Louisenthal for example are committed to environmental protection and controlling water production that goes beyond National and EU law due to their production locations in the catchment area for the City of Munich (Louisenthal, 2020), while Mercer complies with Government regulations regarding issues such as water temperature limits and has environmental management systems at its sites which are ISO 140001 certified (Mercer, 2022). Both companies are engaged in wastewater treatment.

Meanwhile, Kabel faces different challenges, located in an area below sea level and facing water scarcity in dry seasons. As a result, Kabel collects water in dams during the rainy season and releases this into the river during times of scarcity. The

altitude and mining history of the local area requires Kabel to pump water constantly to avoid flooding the area. All the companies use wastewater treatment practices. Kabel uses micro-filtration and flocculation, although plans for a process water treatment facility with reverse osmosis were dropped due to cost. Louisenthal uses an on-site purification plant before discharging to municipal wastewater treatment plants (Louisenthal, 2021). Mercer, meanwhile, uses anaerobic processes to reduce oxygen depletion in water before discharging into receiving waters (Mercer, 2023).

The recommendation for the industry is to adopt indicators relating to water intensity and measure the impacts of wastewater discharge on river levels. For the companies, evidence of well-developed water management strategies. Using developed indicators and engagement with wider sustainability guidelines and organizations (such as the CDP or WWF) could help further enhance water sustainability for the case companies.

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3.3 ENERGY PRODUCTION SECTOR

3.3.1 INTRODUCTION

The location of Germany in Central Europe and its market size makes it a hub for European electricity flow, with cross-border flows of electricity occurring between neighbouring countries (BDEW, 2020). The Power Generation Industry in Germany is the largest in Europe and the market for activities relating to power generation and supply is comprised of over 2250 active companies, covering processes and activities relating to generating electricity, operation of energy storage facilities and supply to local and regional end-users (BDEW, 2020). Four companies dominate the power generation market: E.ON, RWE, EnBW and Vattenfall, responsible for the bulk of electricity generation (56%) and retail supply (45%) (Agora Energiewende, 2015). However, the country is also undergoing an energy supply transition (the Energiewende) associated with an increasing proportion of energy generated from renewable sources and the specific phasing out of nuclear power (BDEW, 2020). These changes and acts, such as the Renewable Energy Sources Act (2014, 2017), may alter the composition of the energy sector in Germany. Funding towards renewable energy is oriented towards more competition and greater cost efficiency, and the deployment costs of wind and solar photovoltaic have reduced rapidly, as well as increasing the viability of Biomass (IEA, 2020). Climate change remains a challenge for the sector. As well as political and societal pressure to reduce CO2 emissions, drought and changes to precipitation patterns add an additional challenge of ensuring sufficient cooling water for the industry (IEA, 2020).

3.3.2 RWE

RWE is a multinational energy company headquartered in Essen, Germany (in the Federal state of North-Rhine Westphalia). As well as operating in Germany, it also trades electricity across Europe, the USA and the Asia-Pacific region (RWE 2022) and is ranked as the 297th largest company in the world (Forbes, 2020). It is one of the four major power generation companies in Germany.

Water is seen as vital for the company, and it is extracted from groundwater and surface water. The water is used mainly in their operations as cooling water and is then discharged into the environment. In order to minimise the effects of their operations on the ecosystem, the company has put in place procedures where supplying thermal power plants with cooling water and keeping open-cast mines dry by extracting groundwater are kept to a minimum. Part of their environmental management is to record and evaluate the environmental impacts of their operations on surface water and groundwater, where they record the type of contact with the water body and the accompanying impact. Then, following their permits, thresholds and reports of the previous year, they adapt their risk-minimisation (RWE, 2023).

RWE has its own internal wastewater treatment system. The regulatory authorities set control values to restrict the concentration of pollutants. These values are monitored using internal control systems. In addition to internal monitoring, official third-party monitoring ensures that any potential contamination is prevented in many areas. Complying with the permitted control values ensures that wastewater discharges do not conflict with surface water management objectives (RWE, 2023).

RWE uses GRI Standards within its reporting on its water consumption and management. The report specifically references GRI 303 Water and Effluents (303-3 Water withdrawal by source; 303-4 Return of water by destination), which are relevant to the topics of water consumption and sewage generation. The company also documents its environmental disclosure and performance scores, achieving a B- for Water Security (RWE 2021).

In 2021, the company recorded the following information against the GRI standards (source is the 2021 Sustainability report). The water risks for the energy generation sector relate to ensuring sufficient water for transporting materials and ensuring sufficient water for cooling (RWE, 2021). RWE also recognise that there are reputational risks from damaging aquatic habitats and other ecosystems from their operations (RWE, 2021).

GRI 303-3 Total Water Withdrawal by Source (million m^3)	2021
Surface water	1520
Groundwater	502
Municipal water	3
Seawater/brackish water	2722
TOTAL WATER WITHDRAWAL	4747

GRI 303-4 Water discharge by destination (in 1,000 m^3)	2021
Surface water	3382
Water from third parties	38
Seawater/brackish water	1160
TOTAL WATER RETURN	4580

GRI 303-5 Water Consumption (in 1,000m^3)	2021
Total water consumption (million m^3)	6,524
Specific total water consumption (million m^3/MWh)	232

The company recognises the importance of water and its status as a limited resource. Since Power Generation has impacts on the condition of water bodies and sources, and therefore, knock-on effects on the environment and society – the company considers it a duty to use water responsibly. RWE considers that these actions should apply both to water consumption and water use during extraction and discharge into surface water or groundwater. The company wishes to prevent, or at least minimise, the adverse effects of operations on water bodies and ecosystems. Therefore, company operations and procedures such as supplying thermal power plants with cooling water and keeping open-cast mines dry through extracting groundwater are performed as sparingly as possible with unavoidable consequences offset as best as possible. RWE manages its operations that affect or may affect water bodies according to the contracts

with water bodies and the types of impacts it might have on the water. Environmental impacts for surface water and groundwater are recorded and evaluated with adaptations made to risk-minimisation and accident-prevention measures (RWE Waste and Water Management, 2022).

RWE states in their 2021 Sustainability Report that the company carries out regular checks and runs its own treatment plants for wastewater to minimise contaminants in surface waters and groundwater. RWE describes how they document all activities that could impact the ecosystem, rivers, surface waters, and groundwater. This is to comply with legal requirements (RWE Sustainability Report 2021). RWE also maintains and uses its own wastewater treatment system and ensures it complies with permitted control values, using official third-party monitoring to meet surface water management objectives (RWE Waste and Water Management, 2022).

In order to minimise water withdrawal from the groundwater and surface water bodies in the area, RWE could repurpose their treated wastewater in their operations. This would also allow for the reduction of wastewater discharge in these bodies and the associated pollution effects.

3.3.3 SIEMENS ENERGY

Siemens Energy operates globally along almost the entire energy value chain, producing gas turbines, steam turbines, generators, transformers, and compressors. The company owns a 67% stake in Siemens Gamesa Renewable Energy, making it a global market leader in renewable energies (Siemens, 2023a).

Siemens Energy states that they aim to minimize their environmental impact through the reduction of waste, reducing the volume of freshwater withdrawal, reducing emissions and protecting biodiversity. The operations of the company are guided by the objectives of contributing to the Sustainable Development Goals (SDGs), including – 6 (Clean Water and Sanitation); 7 (Affordable and Clean Energy), 12 (Responsible

Consumption and Production) and 13 (Climate Action). Siemens Energy developed a Zero Harm Framework, which sets out environmental protection requirements for customers and improves positioning as a sustainable company. The main objectives of this framework are focused on improving environmental performance relating to energy, air, water and waste, which include:

1. Increasing energy efficiency through the use of energy management systems at sites.
2. Adapting purchasing strategy towards green electricity by 2023.
3. Controlling air-pollutant emissions.
4. Implementing local water strategies and risk analysis.
5. Zero waste to landfill by preventing landfill waste and reducing waste materials.

In the fiscal year 2021, the volume of eaters abstracted was 4.10 million cubic meters, an increase from 2020 (3.23 million cubic meters). The water intensity was 1.44x10-4 cubic meters per € of revenue. Overall, there was an increase of 27.2% in absolute water consumption and 22.6% in water intensity compared to the 2020 Fiscal Year. The company explains this partially through changes in the specification of the extrapolation method, which increased the recorded water consumption and wastewater amount. Wastewater from facilities and manufacturing processes was calculated as 4.06 million cubic meters (increased from 3.11 million cubic meters in 2020) and a wastewater intensity of 1.42x10-4 cubic meters per € of revenue. This is an increase of 30.6% in absolute wastewater and 25.9% in wastewater intensity compared to fiscal year 2020 (Siemens, 2021). According to the Siemens Energy 2021 Sustainability Report, the company declared the following water-related statistics:

- Freshwater 2.99 million cubic meters
- Groundwater and surface water for cooling (returned to receiving water body chemically unchanged but warmed) 1.08 million cubic meters
- Water intensity was 1.44x10-4 cubic meters/€ revenue.

Siemens Energy abstracted 3.45 million cubic meters of water in FY 2022 (2.8 freshwater use and 0.6 ground/surface water for cooling), a decrease of 16% from the

previous year. Water intensity was 1.19x10-4 cubic meters per € of revenue, down 17% from FY 2021. Implementing the global EHS reporting tool contributed to the increase in transparency. Wastewater from facilities and manufacturing processes amounted to 3.46 million cubic meters in FY 2022, a decrease of 15% from the previous year. Wastewater intensity was 1.19x10-4 cubic meters per € of revenue, down 16% from FY 2021 (Siemens, 2022). This data is highlighted in full below:

Water (cubic meters)	**2022**	**2021**	**2020**
Fresh water use	2,80	2,99	2,59
Ground and surface water for cooling (returned to receiving water body, chemically unchanged, but warmed)	0,62	1,08	0,64
Total	3,45	4,10	3,23
Water intensity (cubic meters/€ of revenue)	$1,19x10^{-4}$	$1,44x10^{-4}$	$1,17x10^{-4}$
Wastewater (million cubic meters)	**2022**	**2021**	**2020**
Wastewater from employee facilities	1,44	1,50	1,24
Wastewater from manufacturing processes	0,24	0,36	0,31
Other (incl. losses)	0,51	0,67	0,55
Conditioned cooling water discharged as waste-water	0,60	0,43	0,36
Total wastewater without chemically unchanged cooling water	2,79	2,99	2,47
Cooling water (returned to receiving water body, chemically unchanged but warmed)	0,67	1,07	0,64
Total	3,46	4,06	3,11
Water intensity (cubic meters/€ of revenue)	$1,19x10^{-4}$	$1,42x10^{-4}$	$1,13x10^{-4}$

According to the Siemens Energy 2021 Sustainability Report (2022), water is an important topic for the company and the company aims to manage the use of

fresh water in operations and the subsequent impacts on water resources in the surrounding areas. The company reports that water consumption primarily concerns manufacturing centres and office facilities. To facilitate the assessment of the water-related effects, the company is applying the World Resources Institute Aqueduct tool to help efficiently evaluate water risks locally. The company also has a Global Water Footprint Dashboard to map their sites and display results of water stress assessment of the Aqueduct Tool in order to make it easier to identify areas with high water risk. This information supports planning and implementing effective water management strategies, considering factors such as water stress, water pollution and flooding. Siemens Energy locations aim to reduce water usage and other related risks to water through integrated management systems and individual mitigation plans.

The company is also analysing water risks as part of the climate change risk assessment, making it easier to identify sites that are in high-water risk areas. Factors such as water stress, water pollution and flooding are taken into consideration for effective water management planning and implementation in their locations. They aim to reduce water usage, consumption and other related risks through their integrated management systems or by means of individual mitigation plans. (Siemens, 2023b).
Part of the business environmental management goals is the minimization of their impacts to the environment by reducing waste, freshwater withdrawal and emissions and biodiversity protection.

The company commits to SDG 6, 7, 12 and 13 contributions. Through the Zero Harm Framework, the company takes measures to comply with the environmental protection requirements of its customers. Furthermore, the company follows the ISO 14001 guidelines. According to the 2022 Sustainability Report, the company has set out the following objectives:

1. Increasing energy efficiency by using energy management systems at sites.
2. Adapting the purchasing strategy toward green electricity by 2023.
3. Controlling air-pollutant emissions by replacing ozone-depleting substances and reducing solvents.

4. Assessing climate change risks, including water risks, and implementing local mitigation and prevention strategies.
5. Promoting zero waste to landfills by consistently preventing landfill waste and reducing waste materials.

Siemens Energy reported increased water consumption and withdrawals last year, making water reduction and efficient water practices a priority the company should take for its future activities. Recycling water through closed-loop systems can be an effective way of minimising water withdrawal from the local environment. Furthermore, the treatment of the wastewater and repurposing it in the cooling towers can help minimise wastewater discharge.

3.3.4 ABWASSERVERBAND BRAUNSCHWEIG

The Abwasserverband Brauchschweig are a water and soil association on the basis of the Water Association Law (1991). The wastewater treatment plant “Steinhof” uses the latest technology to purify wastewater produced by the city of Braunschweig and additional boroughs covered by the Gifhorn water board. The mechanically and biologically purified water is subsequently used in agricultural areas belonging to their members. Farmers who are members are able to use purified wastewater, which provides plants and crops with water and important nutrients at the same time and, therefore, links to the production of food, fodder, and plants for energy. Additionally, the organization can develop an ecologically valuable landscape through the planting of hedges and woodland copses, thereby linking biotopes.

The biological wastewater system began in Braunschweig by constructing absorption fields (via ground filtration) at the Steinhof monastery in the north of the city. The area covers 460 hectares with an absorption capacity of 10,000 cubic meters per day when the city had a population of approximately 100,000. In 1953, the City of Braunschweig finalised the reorganisation of its wastewater disposal within the framework of measures concerning pollution control in public waters (initiated

by the federal government and regional authorities). The insufficient capacity of the absorption fields and the resulting wastewater problem led to a necessary enlargement of the wastewater utilisation area. A new pumping facility was constructed, as well as a new organisational structure to deal with the increased utilisation of wastewater for agriculture via irrigation (Abwasserverband Braunschweig 2022a, b).

The organisation considers that the task of securing a reliable and sustainable supply of energy is fundamental for society. For decades, wastewater from Braunschweig has been purified in the Steinhoff treatment plant and used to irrigate the fields of the Association to improve the ground yield. These fields are used to cultivate renewable raw materials such as maize and rye, which are fermented in a biogas plant. The biogas plant produces methane (approximately 1200 cubic meters per hour), and this is utilised in a manner that optimises profit and ecological performance by transporting the majority of the gas via gas dehumidification and compression facility through an underground gas pipe to Ölper in Braunschweig. Biogas is used to produce electricity and heat for city households. The electrical energy of 20.1 million kilowatt hours per year provides 6000-7000 households with electricity and 1000-1500 households with heating. Daily biogas production is 26500 cubic meters, and daily electricity production is 55000 kilowatt hours. The Steinhof treatment plant block heating and power station utilises energy from renewable sources for the production of electricity and heating, predominantly used by the plant itself (Abwasserverband Braunschweig 2022a, b).

The Braunschweig Wastewater Association recycles the wastewater of around 260,000 citizens and irrigates an area of around 2,700 hectares using 10 million m3 of treated wastewater and liquid sewage sludge. The plant has an inflow of 20 million m^3 of municipal wastewater per year, half of which is rained over the dressing from February to November. Apart from water, farmers in the area are also purchasing sewage sludge (Abwasserverband Braunschweig, 2022a; Profi, 2023).

The drought in the summer of 2018 revealed that the maximum amount of groundwater discharge (according to the local water authority) wasn't exceeded –

therefore, the irrigation of reclaimed water preserved the groundwater level even in drought years (SUNAWU Europe, 2021).

The Braunschweig Wastewater Association takes several actions to minimize negative effects on the environment in the water area. They use e-vehicles and operate a photovoltaic system. They have developed the Braunschweig wastewater model that combines wastewater and bioenergy to form a water-nutrient-energy cycle. The association also maintains a partnership with the Schwülper secondary school and is socially involved in various projects related to environmental education and water protection. They are also TSM-certified and fulfil the strict requirements of Technical Safety Management (Profi, 2023; Abwasserverband Braunschweig, 2022a, 2022b).

The company has already put in place effective repurposing of their wastewater for irrigation. However, the reduction of water consumption could help increase the sustainability in the area. This could be done by adopting GRI indicators, such as 303-2, 303-3, 303-4 and 303-5. Furthermore, water-efficient technologies could be implemented in their operations to assist in water withdrawal minimisation.

3.3.5 SUMMARY & REFERENCES

Germany's location in Central Europe and the size of its market make it an important hub for energy generation, and the size of its market means that it can influence the practices of companies across the continent (BDEW, 2020). The industry is undergoing a transition towards increasing renewable energy generation. The large energy generation companies (RWE and Siemens Energy) require water for cooling processes, while the Abwasserverband Braunschweig is primarily concerned with treating wastewater and creating energy from biogas and recycles wastewater for irrigation purposes, enabling opportunities for farmers to purchase sludge and receive water for irrigation. (Abwasserverband Braunschweig 2022a, b). Siemens Energy states a set of objectives relating to the Sustainable Development Goals regarding a series of environmental performances, including water (Siemens Energy 2022). RWE go further

by investing in wastewater treatment infrastructure, therefore ensuring a supply of water for cooling processes and avoiding the pollution of surface water (RWE, 2022). Siemens Energy and RWE use GRI standards in the production of their water use statistics (RWE, 2021; Siemens Energy, 2021). For RWE, the main sources of water are seawater/brackish water and surface water, while this water is mostly returned to surface water. In the case of Siemens Energy, water is abstracted from surface water and groundwater, which is primarily returned to the receiving water body chemically unchanged but warmed. The Braunschweig Abwasserverband differs as the organisation is set up primarily to deal with wastewater.

Siemens Energy uses the World Resources Institute Aqueduct tool to evaluate water risks and has a Water Footprint dashboard to map their results and display water stress assessment (Siemens Energy, 2021). The RWE has its own internal wastewater treatment system with official third-party monitoring (RWE, 2022). Here, RWE and Siemens Energy are linked in their use of external verification sources to assess their water risks, although the Abwasserverband operates differently from the energy generation companies and is primarily focused on the volume of wastewater that is retreated and subsequently repurposed. The recommendations for the industry are to increase the amount of internal reuse of water and reduce the dependency on surface water for their operations. For the Abwasserverband, the opportunities to collaborate with similar organisations in other parts of Germany could open up interesting and valuable opportunities to further increase the amount of reuse of treated wastewater for a wide range of stakeholders, including the agricultural and energy sectors.

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4. NATIONAL CONTEXT IN GERMANY - SUMMARY

From the case studies provided, there are opportunities for increased efficiency of water use, of which wastewater reuse can play a crucial part. However, there remain difficulties in accessing high-quality data on water issues in the industry – from our case studies, significantly less data was available from the Paper & Packaging industry compared to the Energy and Chemical industries.

Increasing wastewater reuse in Germany through regulations is complicated by the country's federal structure. From the German Government's own reports against the Sustainable Development Goals, the following recommendations can be made:

- Improvement in quality of water discharge regarding the level of nitrates and especially the level of phosphorous (6.3.2)
- Improvement in water efficiency in agriculture, forestry and fishing (6.4.1)
- Increase the level of integrated water resources management (6.5)

Comparing the descriptions of the SDGs from the German statistical office (DESTATIS, 2023) against the case industries in this research, opportunities exist to facilitate greater cooperation between high water consuming and discharging industries and agricultural stakeholders. A more significant number of organisations following practices similar to the Abwasserverband Braunschweig could greatly increase the potential for the use of industrial wastewater for agricultural practices, and identifying processes where water does not meet the required quality standards can be repurposed for other economically valuable activities. This could help Germany meet the objectives of its Federal Water Act regarding the rehabilitation of groundwater sources and build resilience against forecasted changes to precipitation patterns under climate change.

5. NATIONAL CONTEXT IN POLAND

In Poland, water is mostly used in agricultural production and consumption and in industrial production and consumption. In fact, domestic water use was estimated at 13.5 m3 /cap/year in the years 2006-2011. At the same time, industrial production and consumption were estimated at 145.6 m3/cap/year (more than ten times this amount), while agricultural production and consumption were estimated at 1,241.4 m3/cap/year, which is almost 100 times domestic water use (Stępniewska, 2015).

According to OECD (2023a), there are several issues related to water management in Poland that should be highlighted:

- moderate pressure on limited water resources;
- inadequate wastewater treatment leading to pollution and nitrification of the Baltic Sea;
- increasing risks of river and coastal floods;
- robust financial capacities. EU transfers are large in absolute terms but relatively small compared to domestic sources.

About 80% of Poland's water needs are met by surface waters, with groundwater primarily used for drinking water. Furthermore, about 12% of the Polish population was still not connected to the water supply in 2015 (OECD, 2023a). However, according to a different data source, it was 8% in 2016 (OECD, 2023b).

Major water users (aquaculture, irrigation) are no longer exempt from water abstraction charges (at least for groundwater abstraction) as of January 2018. Hydropower generation is requested to pay (assuming that water intakes are monitored). This is an improvement over the previous situation, which was not only expensive in terms of lost fiscal revenue, but also did not provide incentives for water conservation.

As previously stated, the water sector reforms implemented in 2017 significantly expanded the list of users and uses subject to fees in order to better align with Article 9 of the Water Framework Directive (Water Framework Directive, 2000). This is a positive development that can provide incentives for more efficient water use as well as raise funds for water management initiatives (OECD, 2023b).

The share of water supply and sanitation expenditures in households' disposable income in Poland is 4th for the years 2011-2015 and 4th in Europe, after Romania, Bulgaria and Italy (OECD, 2020).

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6. CASE STUDIES IN POLAND

6.1 CHEMICAL SECTOR

6.1.1 INTRODUCTION

The chemical industry in Poland encompasses a wide range of products, including petrochemicals, plastics, fertilisers, agrochemicals, pharmaceuticals, and specialty chemicals.

The chemical sector has been a significant contributor to Poland's economy in terms of revenue, employment, and exports. It plays a vital role in both domestic consumption and international trade.

Chemical production is concentrated in various industrial regions across Poland, with significant clusters in places like Plock, Tarnów, and Gdańsk. These areas host numerous production facilities and research centres.

Research and development play an important role in the Polish chemical sector's growth. There's a focus on innovation and technological advancements to enhance product quality and sustainability.

Like many chemical industries worldwide, Poland's chemical sector faces challenges related to environmental impact and sustainability. Balancing growth with eco-friendly practices and regulatory compliance is crucial.

The chemical industry is a major player in Poland's trade, with both exports and imports of chemical products. The country exports various chemical goods to international markets while importing raw materials and specialised chemicals.

The industry is subject to local and European Union regulations governing safety, environmental protection, and product standards. Adherence to these regulations is a priority for both domestic and international market access.

The chemical industry provides employment opportunities for a significant number of people in Poland, ranging from skilled labour in manufacturing plants to research scientists and engineers in R&D centres.

The chemical industry is influenced by global market trends, supply chain dynamics, and shifts in demand for various chemical products. Economic fluctuations and geopolitical factors can impact the industry's performance.

Source: https://pipc.org.pl/en/chemical-industry-in-poland/
https://pipc.org.pl/wp-content/uploads/2022/07/PIPC-Annual-Report-online.pdf

6.1.2 GRUPA AZOTY

Grupa Azoty is one of the leaders in the fertiliser and chemical industry in Europe, operating in mineral fertilisers, engineering plastics, as well as OXO products and other chemicals. It comprises, among others, Grupa Azoty S.A. (parent company based in Tarnów), Grupa Azoty Zakłady Azotowe "Puławy" S.A, Grupa Azoty Zakłady Chemiczne "Police" S.A, Grupa Azoty Zakłady Azotowe Kędzierzyn S.A and Compo Expert Holding GmbH.

At present, Grupa Azoty ranks second in the European Union in the production of nitrogenous and compound fertilisers, and products such as melamine, caprolactam, polyamide, oxo alcohols and titanium white have an equally strong position in the chemical sector, finding their way into many industries. Grupa Azoty is seeking growth opportunities intensively not only in the Polish market but also abroad. A significant step in this direction was the acquisition in 2018 of Compo Expert Group, one of the leading players in the global speciality fertiliser market.

Grupa Azoty has been changing the face of Polish chemistry for several years. Its activities are making it one of the most innovative industries in Europe. This is the result of the long-term strategy adopted by the Group, one of the pillars of which are new investments. One of these is Polimery Police, a project being carried out by a special purpose vehicle belonging to the Grupa Azoty Group - Grupa Azoty Polyolefins S.A., formerly PDH Polska S.A. This is one of the largest investments in the Polish and European chemical industry, which will enable the diversification of Grupa Azoty's business activities, but will also have a positive impact on Poland's position in the plastics segment and strengthen the country's energy and raw material independence. The project is scheduled for completion in 2022.

The company has been listed on the Warsaw Stock Exchange since June 30, 2008. It is currently included in the WIG-CHEMIA, WIG30, mWIG 40, WIG, and WIG-Poland indices. Since 2009, Grupa Azoty has been a member of the RESPECT Index, Central and Eastern Europe's first index of companies adhering to the principles of responsible business (Grupa Azoty, 2023a).

Grupa Azoty is currently implementing the ESG (Environmental, social, and corporate governance) Strategy for 2021-2030. The priorities of the strategy are sustainable development, implemented by taking measures to protect the environment, care for society and manage corporate governance responsibly. Although the strategy covers important aspects such as decarbonisation and reduction of emissions, energy transition and energy efficiency, it does not explicitly focus on water-related targets (Grupa Azoty, 2022a, 2023b).

According to the 2021 integrated report, Grupa Azoty uses water for technological purposes, cooling, treatment for drinking purposes, as a raw material for the production of special waters and for fire protection.

Grupa Azoty S.A. uses water for technological purposes, cooling, treatment for drinking, as a raw material for the production of special waters and for fire protection. The water the company uses comes from a surface intake on the right bank of the

Dunajec River and an underground intake from Quaternary boreholes from the first aquifer. The volume of water intake is regulated by water-legal permits.

Grupa Azoty uses the GRI methodology to report the use of water. The scope of reported data has risen over the past few years. Grupa Azoty Police is supplied with water from two primary sources - the western branch of the Oder River and the Gunica River.

Water abstracted by the Company is used for technological, cooling and fire-fighting purposes. Water intake is measured continuously, based on flow meter readings, while water quality measurements are carried out at regular intervals with a frequency of once every two months by an accredited laboratory. Water abstraction from the River Oder does not significantly affect the water status of the river.

The company's water footprint, i.e. the amount of water it uses directly and indirectly, is monitored. As the main source of water abstraction by Grupa Azoty Police is internal marine waters, there is no threat of a deficit in the abstraction of these waters. Such a deficit occurs in the case of the Gunica River, from which water abstraction takes place periodically depending on the salinity of water from the Oder River. An intake from the Gunica River has been built together with a retention and equalisation reservoir to ensure adequate water supply without disturbing the river's hydrological resources. Due to the high salinity of the River Oder, the company also invested in building a desalination plant for internal marine waters to eliminate the risk of exceeding the annual limit of water intake from the River Gunica.

Grupa Azoty Puławy draws surface water from the Vistula and Kurówka rivers and groundwater for industrial, power and household purposes at its own facilities and for the needs of external customers. The company has its own water intake and water treatment systems. Depending on the needs, water used for production and cooling purposes is subjected to decarbonisation or demineralisation processes.

At Grupa Azoty Kędzierzyn, water is used for technological, cooling, social and domestic purposes and as a raw material for special waters and for fire protection. The Group obtains water from a surface intake from the Oder River, from a surface intake from the Łącza stream, from tertiary and quaternary groundwater (from deep wells) and also purchases water from the dewatering of the Kotlarnia S.A. sand mine. The year 2021 was another year in which the volume of water abstracted decreased - a 3.6% decrease compared to 2020, with a simultaneous increase in the production of products (by 2.9%). This is the result of modernisation work at the ammonia plant, which was carried out as part of the New Energy Concept. The company also saw a favourable change in the structure of water abstraction in 2021, with a decrease in the share of groundwater in total water abstraction (from 22% to 15%). The improvement was made possible by the greater availability of surface water from the Łącza stream (an increase in abstraction of 509.8 thousand m3, or 18.3%).

At Grupa Azoty SIARKOPOL, a closed water cycle was used at the Osiek Mining Plant, resulting in no discharge of wastewater into the environment. As a result, the volume of recycled water amounted to 2.202 million m3, which is 83% of the company's total water intake.

COMPO EXPERT - At the production site in Krefeld (Germany), most of the surface water (from the river) is reused up to three times before being discharged into the public sewage system.

Grupa Azoty Puławy and Grupa Azoty Kędzierzyn do not operate in areas with an existing water deficit.

Selected information about the use, discharge and treatment of water is presented in the following tables. Data for 2020 is presented in cubic metres. From 2021 onwards, water data will be reported in mega-litres (Grupa Azoty, 2022b).

Table. Water abstraction from all areas, by source [m3/Ml]

Source of water	Grupa AZOTY KĘDZIERZYN		Grupa AZOTY POLICE		Grupa AZOTY PUŁAWY		Grupa AZOTY S.A.	
	2020	2021	2020	2021	2020	2021	2020	2021
Other groundwater	0	0	5	14	0	0	0	0
Fresh groundwater	1 542 174	974	0	0	5 325 331	5 875	395 000	327
Other water from external entities	0	0	0	0	0	0	0	0
Other water internally produced	0	0	0	0	0	0	0	0
Other seawater	0	0	148 739 456	144 884	0	0	0	0
Fresh seawater	0	0	0	0	0	0	0	0
Fresh surface water	3 747 795	3 654	1 785 700	1 693	72 987 482	77 850	10 770 000	10 994
Fresh groundwater from external entities	1 773 026	2 404	311 085	274	0	0	0	0
TOTAL	**7 062 995**	**7 032**	**150 836 246**	**14 6851**	**78 31 2813**	**83 725**	**11 165 000**	**11 321**

Table. Water discharge by destination [m3]

Place of discharge	Grupa AZOTY KĘDZIERZYN		Grupa AZOTY POLICE		Grupa AZOTY PUŁAWY		Grupa AZOTY S.A.	
	2020	2021	2020	2021	2020	2021	2020	2021
Other organisations	0	0	116 000	0	0	0	0	0
External entities without other organisations	0	0	0	0	0	0	1 370 000	0
Sea water	0	0	110 669 343	108 268	0	0	0	0
Surfacewater	6 412 268	5 981	142 723 638	32 540	68 053 158	67 238	3 523 000	4 739
TOTAL	**6 412 268**	**5 981**	**253 508 981**	**140 808**	**68 053 158**	**67 238**	**4 893 000**	**4 739**

Table. Water discharge for all areas by water type [m3/Ml]

Type of water	Grupa AZOTY KĘDZIERZYN		Grupa AZOTY POLICE		Grupa AZOTY PUŁAWY		Grupa AZOTY S.A.	
	2020	2021	2020	2021	2020	2021	2020	2021
Fresh	6 412 268	5 981	0	0	0	67 238	4 893 000	4 739
Other	0	0	110 669 343	140 808	0	0	0	0
TOTAL	**6 412 268**	**5 981**	**110 669 343**	**140 808**	**0**	**67 238**	**4 893 000**	**4 739**

Table. Water discharge to areas with water deficit, by water type [m3/Ml].

Type of water	Grupa AZOTY KĘDZIERZYN		Grupa AZOTY POLICE		Grupa AZOTY PUŁAWY		Grupa AZOTY S.A.	
	2020	2021	2020	2021	2020	2021	2020	2021
Fresh	0	0	0	0	0	0	4 893 000	4 739
Other	0	0	0	0	0	0	0	0
TOTAL	**0**	**0**	**0**	**0**	**0**	**0**	**4 893 000**	**4 739**

Table. Water discharge by treatment level [m3/Ml].

Degree of purification	Grupa AZOTY KĘDZIERZYN		Grupa AZOTY POLICE		Grupa AZOTY PUŁAWY		Grupa AZOTY S.A.	
	2020	2021	2020	2021	2020	2021	2020	2021
Lack of purification	0	0	110 669 343	108 268	0	0	287 000	268
Degree 1	2 452 010	2 429 (1)	32 054 295	32 540 (2)	1 392 210	1 623 (3)	3 236 000	3 158 (4)
Degree 2 (5)	2 452 010	2 429	0	0	1 683 820	1 644	1 370 000	1 313
Degree 3	6 412 268	5 981 (6)	0	0	68 044 158	67 238 (7)	0	0
TOTAL	**11 316 288**	**5 981**	**142 723 638**	**140 808**	**68 044 158**	**67 238 (8)**	**4 893 000**	**4 739**

Comments to the presented values:
Azoty S.A. does not disaggregate between low-mineralised and other water due to the lack of application of such a division within its operations.

(1) The mechanical wastewater treatment process includes the removal of screenings and sand from wastewater and the removal of grease from wastewater.

(2) Neutralisation, aeration, coagulation, sedimentation separation of sludge, and treatment of treated effluent in retention and averaging tanks.

(3) Central Industrial Wastewater Treatment Plant (COŚP) node - mechanical-chemical treatment plant.

(4) Cooling water.

(5) Applied mechanical-biological process.

(6) Applied process for the removal of screenings and fatty substances from wastewater at the "Piskorzowec" treatment plant. Wastewater is subjected to self-treatment processes in a complex mixture of earth-settling tanks and an averaging tank.

(7) Node (pond) III° biological treatment - natural processes of biological and physicochemical self-purification from nitrogenous and organic compounds. Via the discharge canal, the wastewater generated by the Company, including that treated at the individual treatment plants, flows into the node (pond) III° of biological wastewater treatment.

(8) All wastewater discharged by Grupa Azoty PUŁAWY, including that from Stages 1 and 2, is directed to Stage 3 of treatment.

Grupa Azoty S.A. generates process wastewater, domestic sewage, cooling water and rainwater. These are directed to the treatment plant. The Central Wastewater Treatment Plant receives industrial wastewater along with social wastewater, and the Biological Wastewater Treatment Plant receives industrial wastewater containing biologically degradable substances. This type of wastewater is additionally sent for treatment at the Tarnów Waterworks wastewater treatment plant. Precipitation and drainage water from the Azoty Group S.A. site is discharged by a separate collector through a retention tank, and the "Sutro" overflows into the surface waters of the Dunajec River.

The company has implemented solutions to prevent the negative effects of a possible failure of one of the elements of wastewater management. The possibility of completely closing the outflow from the rainwater collector and pumping the entire volume of wastewater to the Central Treatment Plant eliminates the risk of pollution. It is also possible to transfer the entire volume of wastewater generated by Grupa Azoty S.A. to the Wastewater Treatment Plant of Tarnów Waterworks.

The company monitors wastewater parameters on an ongoing basis using automatic analysers. In addition, laboratory analyses of contaminants in wastewater are conducted. The conditions for wastewater discharge specified in the integrated permit are met.

Grupa Azoty S.A. has invested in the construction of a semi-technical installation for the biological treatment of wastewater from the company's production facilities. Implementation of the project makes it possible to carry out research to develop assumptions for the modernisation of the Biological Wastewater Treatment Plant.

Azoty Group S.A. has successfully carried out semi-technical scale tests of turning back wastewater after the Central Wastewater Treatment Plant into the industrial water network. Different measures are taken by different entities within Grupa Azoty S.A. in order to minimise the business impact in the area of water.

Azoty Kędzierzyn Group

The company generates process wastewater, cooling water and rainwater. The company has a modern, multi-stage and systematically upgraded wastewater treatment and disposal system. The system makes Azoty Kędzierzyn Group self-sufficient in wastewater treatment.

The treatment system includes the Central Mechanical Wastewater Treatment Plant, the Central Mechanical-Biological Wastewater Treatment Plant and the "Piskorzowiec" Treatment Plant. Treated wastewater is discharged into the Oder River.

The modernisation, completed in 2018, allowed for improvement in the nitrification and denitrification process carried out. The installed unique sewage heating node allows it to effectively remove nitrogen compounds, even in winter. The modernisation also included the replacement of the fine-bubble deep aeration system, the replacement of air blowers and the automatic control system for the oxygen dosing process. Wastewater at Azoty Kędzierzyn Group is carefully monitored - both at the stage of generation at individual installations and discharge.

The wastewater treatment system at Azoty Kędzierzyn Group meets the CWW BAT Conclusions, i.e. standards much more stringent than the requirements set forth in the relevant regulation of the Minister of Water Management on substances particularly harmful to the environment.

In 2021, the company recorded no exceedances of any parameter determining wastewater quality. The volume of wastewater decreased compared to 2020 by 431.4 thousand m^3, or 6.7%. The decrease was due to the high level of use of the wastewater return system for industrial water production (an increase of 1,050.0 thousand cubic meters, or 65.5%). Also, in terms of discharged pollutant loads, there was a decrease for both organic compounds (by 17.5%) and nitrogen compounds (by 32.7%).

Azoty Pulawy Group

The Azoty Pulawy Group produces industrial wastewater, including water from the cooling circuits of technological installations, domestic wastewater, rainwater and cooling water from the cooling processes of thermal power plants.

The company has implemented a multi-stage system for treating its wastewater. The first element is sub-treatment plants located at individual installations. From there, the wastewater goes to a central wastewater treatment plant. It is formed by a multi-node treatment system that uses technologies adapted to the characteristics of wastewater. The plant consists of a biological faecal wastewater treatment plant node, a biological industrial wastewater treatment plant node, a central mechanical-chemical industrial wastewater treatment plant node and a III° biological treatment node.

The collecting element of the wastewater system is the wastewater discharge canal. This is an open sewer that collects, through separate connections, wastewater treated at individual nodes of the wastewater treatment plant, as well as other wastewater directed to it from the company's facilities and wastewater from external entities. The discharge canal brings wastewater to node III° of biological treatment, where processes of biological and physicochemical self-purification from nitrogenous and organic compounds take place, and then it is discharged into the Vistula River.

The sewage discharge canal is equipped with a system that connects it to the backflow channel of surface water collected by the company and allows the return part (about 15-30%) of the sewage discharged through it.

The permissible values of discharged pollutants are specified in the company's integrated permit. The system does not ensure compliance with the requirements of the BAT CWW conclusions, so Azoty Pulawy Group began the process of implementing the construction of a new central biological wastewater treatment plant. Work continued in 2021 to select a contractor for the project. Laboratory testing of discharged wastewater streams had already been completed, final test reports had been received, and documentation for the tender was being prepared. The company has obtained a temporary derogation from meeting the BAT CWW Conclusions to allow the completion of the new treatment plant.

Azoty Police Group

During production processes, industrial (technological) wastewater is generated and directed to the plant's wastewater treatment plant. On the other hand, absorption and rainwater from the site are discharged directly into the surface waters of the Oder River. The absorption waters are subject to constant automatic pH monitoring.

In order to comply with the legal requirements imposed on the company, monitoring of treated wastewater is carried out in accordance with the provisions of the integrated permit decision. Wastewater flow is measured continuously, while the quality of discharged wastewater to water is measured at regular intervals by an accredited laboratory.

The company complies with all the requirements set forth in the integrated permit, the regulation of the Ministry of the Environment and the BAT Conclusion (Grupa Azoty, 2022c).

The risk management in Grupa Azoty S.A. (focused in particular on climate risk) is conducted in line with the group's ESG strategy. In order to identify and monitor the risks (including water-related risks), the company is using recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD) and, in their actions, is focusing on the reduction of water use. One of the key risks identified in line with climate-related opportunities and risk areas is related to wastewater management. Specific units operating with the group (Grupa Azoty S.A.) identified wastewater risks and appointed a person or entity responsible for managing it (Grupa Azoty, 2022d).

Grupa Azoty S.A. identified different stakeholders in their ESG strategy and reports, such as:

- Shareholders, investors, brokerage houses, analysts, rating agencies,
- Capital market institutions and associations,
- Capital market media,
- Local communities,
- Suppliers,

- Customers,
- Industry organisations,
- Environmental organisations,
- Local government, central administration, regulator,
- Scientific institutions.

Not all of these stakeholders are related to water management; therefore, only selected ones will be analysed in detail in terms of water-related risks and opportunities (Grupa Azoty, 2022e).

Stakeholder	Risks and opportunities
Customers	Risks: Customers may be concerned about the environmental impact of the products they purchase, especially if water pollution or scarcity is involved. Opportunities: Developing sustainable and water-efficient products can be a selling point for the company, attracting environmentally conscious customers and potentially increasing market share.
Suppliers	Risks: Suppliers might face water-related risks, especially if they rely on water-intensive processes or are located in water-scarce regions. This can affect their production capacity and costs. Opportunities: Collaborative efforts with suppliers to reduce water usage, adopt efficient technologies, and source responsibly can lead to cost savings and resilience in the supply chain.
Local Communities	Risks: Local communities may face water scarcity or pollution risks due to the company's operations. This can impact their access to clean and safe drinking water, agricultural activities, and overall quality of life. Opportunities: The company can engage in sustainable water management practices, which may include conservation efforts, pollution control, and community engagement. This can enhance the company's reputation and foster positive relations with local communities.
Environmental Organisations	Risks: Environmental organisations may scrutinise the company's water-related practices and may advocate for stricter regulations or public awareness campaigns if they perceive the company as a water polluter. Opportunities: Engaging with environmental organisations and working on joint projects or initiatives to improve water quality and availability can enhance the company's environmental credentials.

In recent years, Grupa Azoty S.A. has made a number of investments that have enabled more efficient use of water and increased the safety of the water and sewage network. The actions taken included the elimination of unprofitable installations, modernisation of production and adaptation to increased environmental standards and norms. All these measures have translated into a significant reduction in the amount of wastewater produced. Grupa Azoty S.A. also recycles water. The company supplies drinking water to external entities - both companies and private households. The drinking water treatment plant is covered by the HACCP system, according to which the drinking water production process is monitored throughout the entire chain - from intake through treatment to distribution. A food safety management system in accordance with the requirements of ISO 22000:2005 ensures the high quality of the water offered.

At Grupa Azoty S.A., industrial water drawn from the network after use at the Luwa Plant is reused in three cooling circuits to supplement losses. Unused excess water from Luwa is returned to the industrial water network. The Group has also implemented a reverse osmosis plant and water recovery from the condensate treatment station. Steam condensates are returned from the production facilities to the condensate treatment plant. The condensate treatment station receives the condensates, treats them in the demineralisation process and passes them on to the customers in the form of so-called prepared water - demineralised water. This water feeds the utilisation boilers. It is also used to start up the Tarnoform plant and to supplement the heating water network. The excess is directed to the demineralised water network. In 2021, the volume of water reused amounted to 1.484 million m3, or 13% of the company's total water intake (Grupa Azoty, 2019, 2020, 2021).

Grupa Azoty is very active in terms of introducing pro-environmental activities and technologies, as well as declaring continuous actions towards the minimisation of the use of water and wastewater production. On the strategic level, the company can adapt to the regulations of the European Green Deal. The process can be supported by various tools, including the “Fit for 55” package by the European Union, which includes a number of directives and proposed changes that are primarily related to the idea of sustainable development and decarbonisation plans.

Grupa Azoty can further improve its water consumption effectiveness:

• Continue to implement water treatment technologies to recycle and reuse water within the manufacturing process to reduce water intake further.

• Invest in research and development to optimise chemical production processes, making them more water-efficient without compromising product quality.

• Collaborate with stakeholders to conduct comprehensive water risk assessments that identify specific areas where the company can reduce water consumption and improve efficiency.

Grupa Azoty can also minimise water-related risks:

• Strive for minimal/zero wastewater discharge by treating and reusing all water within the manufacturing process, reducing the risk of water pollution.

• Set specific, measurable, and time-bound targets to reduce water consumption and improve water use efficiency, with a focus on high-water-intensity processes.

• Develop goals to engage with local communities, address their water-related concerns, and actively participate in water resource management programs.

• Set goals to comply with and often exceed water-related regulations and standards, ensuring that the company operates within legal boundaries (European Council, 2023).

6.1.3 CIECH GROUP

CIECH Group is the second-largest manufacturer of sodium carbonate and sodium bicarbonate in the European Union, the largest manufacturer of evaporated salt in Poland, the largest supplier of sodium silicates in Europe, the largest Polish manufacturer of plant protection products, and a leading producer of polyurethane foams in Poland (Chemia i Biznes, 2022; Parkiet.pl, 2022; Zygmunt, 2021). It operates in Poland, Germany, and Romania, employing more than 3000 people in the UE (Kalinowski, 2020). CIECH Group is also one of Poland's largest exporters, and its global operations influence numerous economic sectors: construction, automotive, agriculture, chemistry, food, and pharmaceuticals. CIECH Group has been implementing its ESG strategy since 2021 (CIECH Group, 2023c). During the COVID-19 pandemic, it also launched the production of protective masks complying with European standard EN 149:2001, with filtration efficiency up to class FFP2 (Ciosek, 2020; rynekzdrowia.pl, 2020).

The companies operating within the CIECH Group include CIECH Soda Polska, CIECH Soda Deutschland, CIECH Soda Romania, CIECH Sarzyna, CIECH Vitrosilicon, CIECH Vitro, CIECH Pianki, CIECH Trading, CIECH CARGO, CIECH R&D, Algete, CIECH Maintenance, Smart Fluid, Proplan Plant Protection Company S.L.U., CIECH Salz Deutschland GmbH, El-Pomiar, Verbis Eta, Verbis Kappa, and Ciech Nieruchomości. For many years, CIECH Groupas been one of the biggest companies in the Polish chemical industry (Buda, 2018). Formerly, CIECH Group also included Żywice, Poland's only manufacturer of epoxy resins and an important supplier of polyester resins used, among other things, in the paint industry (Bankier.pl, 2020; BiznesRadar.pl, 2020; Plastech, 2021).

CIECH Group achieved in 2022 record results in terms of EBITDA (+45% y/y), revenues (5.4 bln PLN, +54% y/y) and net profit (565 mln PLN, +158% y/y) while maintaining a decrease in its negative environmental impacts, e.g. carbon dioxide emissions – 7,5% y/y decrease in 2022 (CIECH Group, 2023f).

CIECH manufactures products that help to reduce water usage for industries and households. Such products include:

- Sodium bicarbonate (NaHCO3), which is used by power and heating plants in order to reduce HCl and SO2 emissions and to lower energy and water consumption;
- salt (NaCl) for water treatment, which is used to reduce the use of water, detergent, and fuel; it also extends the life of household appliances;
- calcium chloride (CaCl2), which is used in wastewater treatment plants for water purification (CIECH Group, 2023a, 2023b).

Exemplary uses of CIECH's products include water treatment systems, e.g., on exchanger regeneration, water softeners, and multifunctional filters (CIECH Group, 2023b). CIECH's plant protection products also influence water use levels by increasing the efficiency of harvesting, maximising the efficiency of energy and water use (CIECH Group, 2023b).

The declaration of using water "in a sustainable manner, minimising its consumption and taking care of the quality of local resources" is included in the CIECH Group's Code of Conduct (CIECH Group, 2021a). Furthermore, "protecting water quality and resources" is among the requirements in CIECH's Code of Business Partner (CIECH Group, 2021b).

One of CIECH's commitments stated in its ESG strategy is that circularity is seen as "a key efficiency lever". Furthermore, the same document includes declarations of closing water cycle installations "wherever feasible" and that the water management strategies are "under preparation" for all CIECH plants (CIECH Group, 2023a). Reducing water consumption in the following years, improving the quality of wastewater, and rational management of water are among the goals stated in CIECH's Non-financial Report 2022 (2023b). Water is a crucial resource for CIECH Group. It is used, among other things, to produce evaporated salt (NaCl).

Water is consumed by CIECH in such processes as MEE (Multi-Effect Evaporation) technology-based or MVR (Mechanical Vapor Recompression) technology-based production of evaporated salt (CIECH Group, 2023b). This process is shown in Figure 1.

Figure 1. Salt production process
Source: (CIECH Group, 2023b).

These products are marketed as Aqua Pro Salt Tablets and G-Salt Granulate (CIECH Group, 2023b). The total water intake by CIECH was equal to 35 960 216 m3 in 2022 year. The structure of total water intake in CIECH Group in 2022 is visualized in Figure 2.

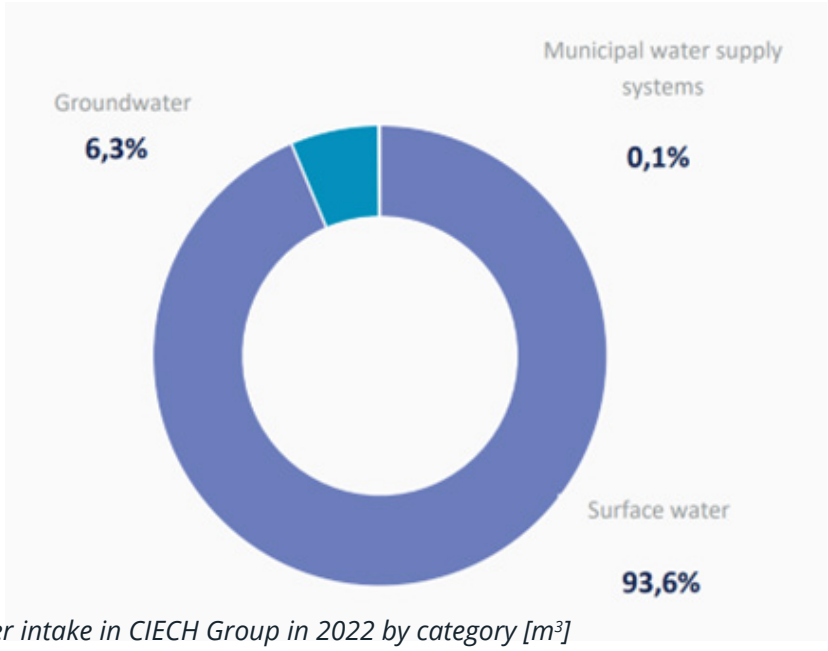

Figure 2. Total water intake in CIECH Group in 2022 by category [m³]
Source: (CIECH Group, 2023b).

CIECH Group companies use water from both natural sources and municipal water supply systems. It is used for production, social and living purposes, cooling and energy. To reduce its consumption, our plants operate closed-loop water cycles, which is part of the implementation of the circular economy. The use of water circulation in a closed-loop cycle is aimed at reducing water consumption from natural sources (CIECH Group, 2023b). On the other hand, the total sewage discharge of CIECH Group in 2022 was equal to 35 638 943 m3.

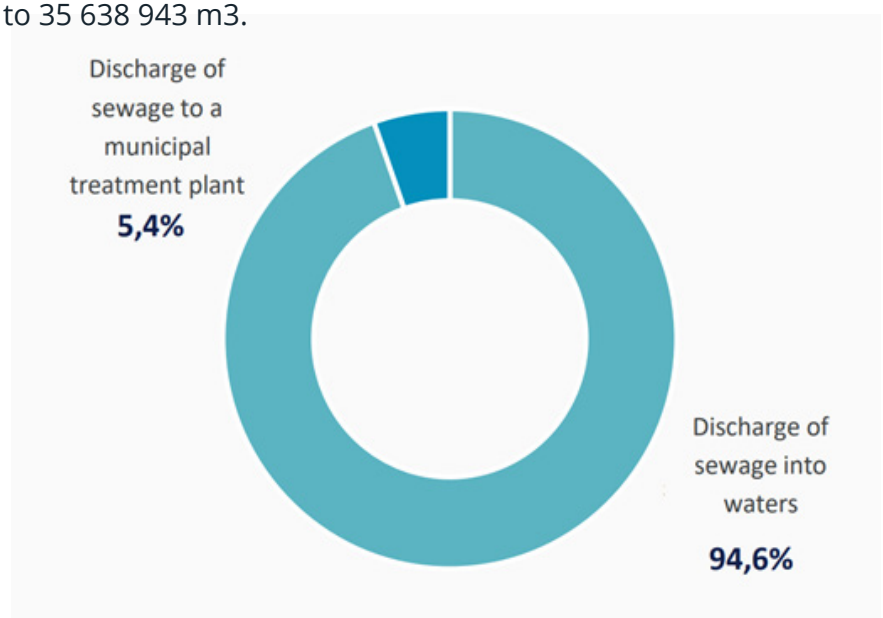

Figure 3. Total wastewater discharge by CIECH Group in 2022 by category [m³]
Source: (CIECH Group, 2023b).

The change in total water intake by CIECH in the years 2019-2022 is shown in Table 1.

Table 1. The change in total water intake by CIECH Group in years 2019-2022 by category

CIECH Group	2019	2020	2021	2022
Surface water	41 721 743	31 905 286	32 288 603	33 666 130
Groundwater	2 931 806	2 523 176	2 443 404	2 264 075
Water supply networks	36 888	27 078	35 493	30 011
Total water intake	**44 690 437**	**34 455 540**	**34 767 500**	**35 960 216**

Source: (CIECH Group, 2023b).

The change in total water discharge by CIECH in the years 2019-2022 is visualized in Table 2.

Table 2. The change in total wastewater discharge by CIECH Group in years 2019-2022 by category

CIECH Group	2019	2020	2021	2022
Discharge of sewage into waters	42 917 646	34 133 155	33 780 598	33 701 753
Discharge of sewage to a municipal treatment plant	1 314 668	1 619 433	1 902 573	1 937 190
Total water discharge	**44 232 314**	**35 752 588**	**35 683 171**	**35 638 943**

Source: (CIECH Group, 2023b).

In order to limit the generated wastewater and improve its quality in 2022, the following measures were taken:

- modification of the water glass filtration technology, which results in reduced water consumption;
- modernisation of steam vent-reducing devices to limit steam emissions from the steam installation to the environment;
- using the flocculants to improve the quality of the sludge for a significant reduction of suspended solids in the wastewater directed to the clarifying and cooling pond (CIECH Group, 2023b).

It should be noted that both the water intake and the wastewater discharge by CIECH Group decreased in the years 2019-2022 despite the company's record financial results in 2022 (CIECH Group, 2023f).

One of the innovations developed by CIECH's research and development team is a method of recovering the so-called waste salt formed during the soda ash production process. This method allows the reduction of chloride emissions in wastewater by approx. 7.5 thousand tonnes per year and to improve the energy efficiency of the calcium chloride production process (approx. 7.5% less energy consumed per tonne) (CIECH Group, 2023b).

CIECH also submitted to the Energy Regulation Office (pl. Urząd Regulacji Energetyki) applications for white certificates for 1520 toe (tonne of oil equivalent) in the 2022 year due to the use of DEMI (demineralized) water heaters (CIECH Group, 2023b).

The environmental goals of CIECH Group include decreasing emissions by 33% by 2026 against 2019 levels and reaching net-zero emissions by 2040 (CIECH Group, 2023a). The company scored 67% (which is approximately the average for the chemical industry worldwide) in the CSRHub ESG Ranking in 2023 (CSRHub, 2023). CIECH Group is also a member of Global Compact Network Poland, the European Chemical Industry Council, the Polish Chamber of Chemical Industry, and the Confederation of Polish Employers (CIECH Group, 2023d). Furthermore, limiting the negative environmental impacts is a part of CIECH's Corporate Strategy for the years 2022-2024 (CIECH Group, 2022a).

CIECH Group is committed to engaging in biological restoration and reclamation projects. One example of ongoing reclamation is the restoration project of the post-production wastewater retention reservoir. In this case, the process of reclamation is carried out with the use of processed sewage sludge from the municipal biological sewage treatment plant. This way, a wooded retention zone is to be created in the reclaimed area (CIECH Group, 2023b). Furthermore, CIECH Group implemented innovations that might result in reducing negative environmental impacts, including wastewater emissions. Examples of this kind of innovation are introducing an Advanced Process Control system (CIECH Group, 2022c) and waste salt recovery, which might reducthe generation ofechnological steam (Zielona Gospodarka, 2022). CIECH also invested in the deep tech startup DePoly, which uses a scalable, advanced solution that reduces carbon footprint and creates economic added value (CIECH Group, 2023e). Another example of this kind of business activity is establishing cooperation with a Latvian start-up developing CO2 separation technology in order to reduce environmental impacts (CIECH Group, 2022b). Other investments by CIECH Group that are aimed at limiting negative environmental impacts include building a modern thermal waste treatment plant in Poland (Nawrocki, 2022; Piątek, 2023).

6.1.4 SUMMARY & REFERENCES

Effective water management is crucial in the Polish chemical industry due to its heavy reliance on water for various processes. Grupa Azoty and CIECH Group, prominent players in this sector, demonstrate innovative approaches to water use, showcasing the industry's potential for sustainable practices. These companies have implemented strategies like advanced water treatment, recycling, and closed-loop systems, setting benchmarks for efficient water usage. Their case studies underline the importance of water conservation and highlight how proactive water management can lead to environmental sustainability and operational efficiency in the chemical industry.

Grupa Azoty and CIECH Group have adopted innovative practices in water management, exemplified by closed-loop systems and advanced treatment technologies. These systems enable them to significantly reduce water waste by recycling and reusing water in their processes. The advanced treatment technologies ensure that the water is cleaned and purified to a high standard, making it suitable for reuse. Such practices not only demonstrate their commitment to environmental sustainability but also serve as a model for efficient water use in the chemical industry.

Recycling and reusing water in industrial processes, as demonstrated by Grupa Azoty and CIECH Group, offer significant benefits. This approach reduces the demand for freshwater, lowers environmental impact, and can lead to cost savings. By treating and reusing water, industries can maintain a more sustainable operation, minimizing their ecological footprint. These methods involve treating wastewater to a suitable quality for reuse in various processes, ensuring both resource efficiency and environmental compliance. Modernizing production processes significantly enhances water efficiency. By updating equipment and adopting new technologies, industries can reduce water usage and waste. These modernizations lead to more precise control of water usage, minimizing excess and optimizing recycling and reuse. The impact is a more sustainable operation with reduced environmental impact and potentially lower

operational costs. Such modernizations also allow for better control and reduction of water wastage, demonstrating how technological advancements can enhance water management in the chemical industry. Environmental regulations and sustainability goals are key drivers in improving water management in industries like the chemical sector. These regulations often set standards for water usage and discharge, compelling companies to adopt more efficient and eco-friendly practices. Sustainability goals, whether internal or part of broader initiatives, also push companies to innovate in water conservation and treatment as they seek to reduce their environmental footprint and align with global sustainability trends. This combination of regulatory requirements and sustainability aspirations fosters a culture of continuous improvement in water management practices.

In the case studies of Grupa Azoty and CIECH Group, environmental regulations and sustainability goals have been pivotal in driving water management improvements. These companies have responded to regulatory requirements and sustainability objectives by adopting advanced water conservation and treatment practices. This approach reflects a broader industry trend where regulatory compliance and commitment to sustainability are key motivators for adopting more efficient and environmentally friendly water management strategies. The practices adopted by Grupa Azoty and CIECH Group, such as investing in advanced water treatment technologies and modernizing production processes, can be applied across the Polish chemical industry for overall improvement in water management. These methods demonstrate a successful blueprint for enhancing water efficiency, reducing consumption, and promoting sustainability, which can be replicated by other companies within the industry to achieve similar results.

The case studies of Grupa Azoty and CIECH Group offer key lessons for the Polish chemical industry: the importance of modernizing production processes, investing in advanced water treatment technologies, and prioritizing sustainability goals. These practices demonstrate significant improvements in water efficiency and environmental impact. Finally, the industry should focus on adopting similar strategies, emphasizing innovation and compliance with environmental standards to achieve sustainable water management.

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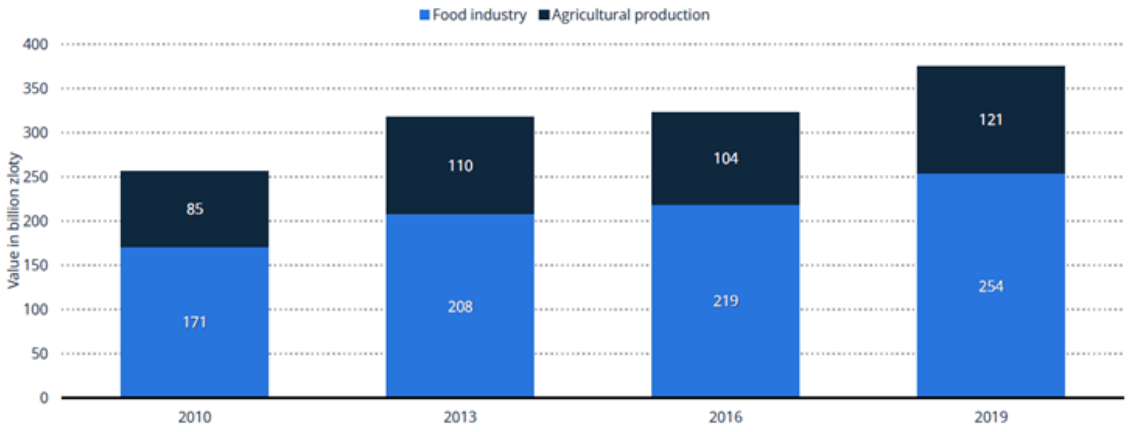
6.2 FOOD AND BEVERAGES SECTOR

6.2.1 INTRODUCTION

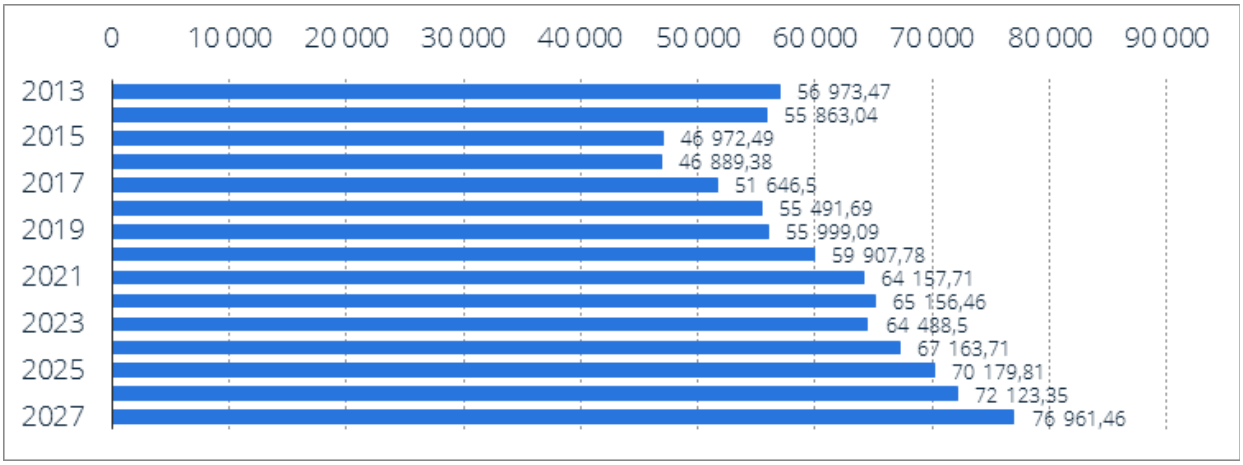
The food and beverage industry in Poland is an important element of the national and the EU economy. The value of the industry in Poland is shown in the below graph.



Graph: Agri-food production in Poland from 2010 to 2019 (in billion zloty)

Source: FMCG market in Poland, Statista, Bank Pekao SA; Central Statistical Office of Poland derived from STATA

European consumers spend 21.5% of their monthly expenditures on food and drink products. The European Union is a significant exporter of consumer goods. In the food industry, 99.2% of companies are SMEs. It is the largest employer in half of the EU countries, including Poland (FoodDrinkEurope, 2021). 411.90 thousand people are employed in this industry in Poland (Central Statistical Office of Poland). As the data on future consumption trends show, this market will grow constantly (graph).



Graph: Forecast of the total consumer spending on food & non-alcoholic beverages in Poland from 2013 to 2028 (in million U.S. dollars)

Source: Statista; IMF; United Nations; World Bank; Eurostat

Due to its specificity, the industry bears great responsibility for society's health and quality of life. By providing food and beverages, it influences the creation of eating habits. Thanks to the common nature of goods and their availability, it also affects the ecological attitudes of consumers. Like every industry, it is also accountable for the emission of greenhouse gases into the environment, the production of waste, including plastic waste, and the waste of resources. It is estimated that 20% of food produced is wasted annually, including over 50% in households. Considering that water is used to produce any food product, it becomes an essential resource next to energy.

Consumers have certain expectations towards food companies related to actions supporting sustainable development (FoodDrinkEurope, 2021). As a result, companies are looking for opportunities to save water both at the level of their plants and in the local community, which is associated with a solid relationship with agriculture (WWF, 2022). The quality and quantity of crops determine the ability to meet consumption needs. According to estimates, the amount of water needed for production processes will increase (Mekonnen & Gerbens-Leenes, 2020) which in pessimistic climate scenarios means the need to take strategic actions related to maintaining its availability, reducing consumption and improving the level of water reuse.

6.2.2 DANONE S.A.

The food and beverage industry in Poland is an important element of the national and the EU economy. The value of the industry in Poland is shown in the below graph. Danone S.A. is an international food company headquartered in France. It produces dairy and plant-based food products, water and beverages, and specialised nutrition. The company's mission is to provide good products for the people and the Planet. Danone highlights its role in the prevention of dietary-related illnesses and support for people who suffer from health issues. The strategic role of Danone in the society is seen as: “inspire to make the right food choices, help to understand the consequences of these inappropriate, pass on knowledge and share information about proper nutrition.” (Danone, 2023). The company focuses on balancing nutritional needs as adopted in its mission: "Bring health through food to as many people as possible" (Danone, 2023). Danone is the global and European leader of dairy and plant-based products, medical nutrition and products for infants, small children, and water. The company employs over 3,000 people in Poland and has factories in 7 locations, mainly in the south of Poland. It is known for brands such as Danone, Actimel, Activia, Danio, Żywiec Zdrój, Bebilon and Nutridrink.

Żywiec Zdrój is one of the most recognised brands. Polish market of bottle water is valued 5mld zł (Wiadomości Spożywcze, 2023a). Poles drink approx. 6 litres of mineral water annually (Central Statistical Office of Poland; 2010 to 2021). Żywiec Zdrój poses 25% of the bottled water market. It’s valued at 471,8mln zł, and it is the strongest brand among the non-alcoholic beverages (Żywiec Zdrój, 2023).

The company is aware of the environmental issues related to its activity. Therefore, its ambition is to minimize the adverse effects on the whole group. Water is a fundamental natural resource that is inevitable for any human activity. The amount of water required to produce the final good is much higher than one can expect. To produce 250ml of milk, we need to use 255 litres of water (Hydrotech Group, 2023). The enormous amount of water used in food production makes it endangered of scarcity.

The food industry is based on agriculture. Therefore, what happens in agricultural production strongly affects how the industry operates.

Agriculture will continue to be the largest water user globally in 2050. It is accountable for 70 per cent of water use for industry purposes, which affects the volume of water available for agriculture in many areas (Food and Agriculture Organization of the United Nations (FAO) and World Water Council (WWC), 2015). Water, as a fundamental production resource, may be scarce and polluted. The challenging situation is related to the progressing climate change and the disturbance of the natural balance in the environment. Hence, there is a need to redefine the approach to water and the protection of its resources. Nowadays, companies face the challenge of ensuring water safety. The solutions apply to meet plant production needs and within the supply chain processes. Danone strives to respond to both of these needs. Strategies that increase the value of water in food production are becoming crucial. These are:

- improving water management in areas irrigated by rainfall;
- transition to sustainable agricultural intensification;
- sourcing water for irrigated agriculture, in particular from nature-based and unconventional sources;
- improving water use efficiency;
- reducing the demand for food and the resulting water use,
- improving knowledge and understanding of the use of water in food production. (Raport ONZ o stanie zasobów wodnych na świecie w 2021 roku, p.5.)

The first step for implementing smart water management is to monitor the resources used. According to the data, Danone monitors water resources and sets concrete goals for this area (table). It set ambitious plans to implement circularity in water stewardship by 2030 in 100% of its facilities. The water stewardships covers reduce, recycle, reuse and reclaim approaches. In 2021, 55% of facilities implemented these solutions (Danone, 2023a).

Danone monitors the water resources using a risk water management approach. It assesses the risk of physical risks according to the WRM tool. Danone audits sites and production locations to evaluate the water risks. The company follows the amount of water consumed and withdrawn from the operations.

Table. Environmental indicators in Danone

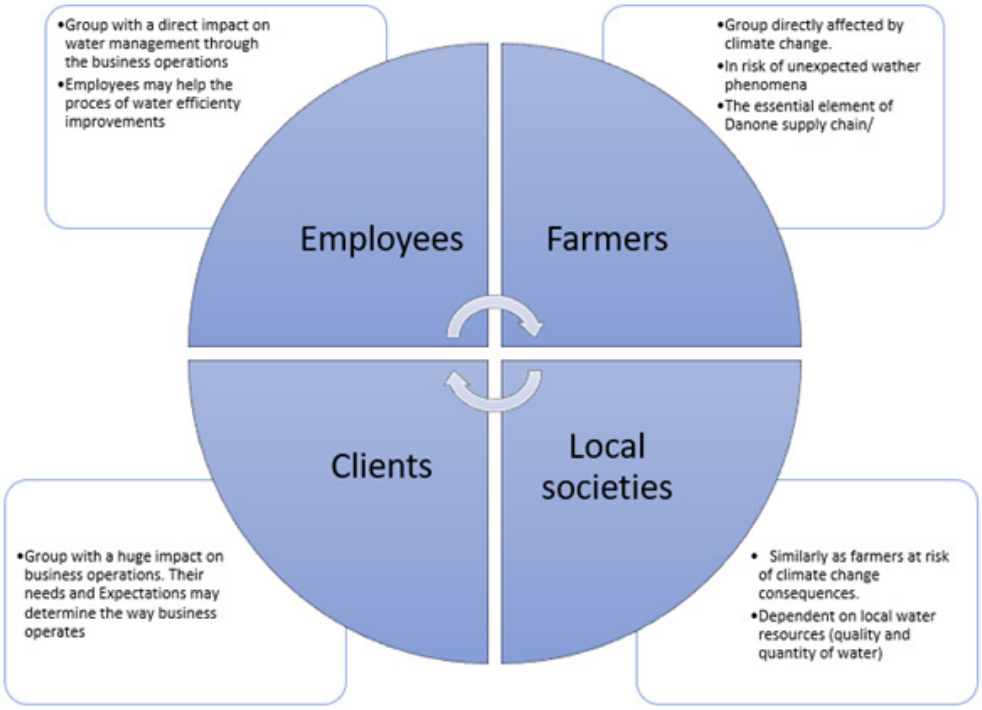
Water withdrawal at production sites		**2021**
River water withdrawal from the surrounding area	thousands of m^3	2,822
Municipal water withdrawal from the surrounding area	thousands of m^3	22,475
Well-water withdrawal from the surrounding area	thousands of m^3	42,452
Total water withdrawal from the surrounding area		**2021**
Water used in finished products and water co-products	thousands of m^3	29,009
Water consumption in the production processes	thousands of m^3	38,559
Water consumption intensity related to the production processes	thousands of m^3	1,11
Total reduction of water intensity from 2000	50%	
Wastewater		
Final discharge of chemical oxygen demand (COD)	thousands of tones	5,06
COD ratio	Kg/tone of product	0,15
Compliance with Clean Water Standards of production sites by discharging wastewater directly to nature		
% of clean wastewater returns to nature		
% of facilities that have a 4R action plan	%	55
WASH pledge self-assessment initiative	%	89
Number of watershed plans deployed	Number of plans	11

Source: Exhaustive 2021 Environmental Data, https://www.danone.com/content/dam/danone-corp/danone-com/investors/en-sustainability/reports-and-data/planet/danone2021environmentaldatav2.pdf, accessed 20.01.2023

Danone uses GRI methodology to disclose about water performance. Additionally, it matches GRI indicators with SDGs' goals to show its input to achieving global sustainability. The company has a mature approach to water management. The figures in the table above show a comprehensive approach to water reduction and reuse. In addition to indicators related to non-financial reporting, the organisation has implemented an additional solution that allows it to assess the risk related to water safety.

Danone is listed on the CDP rank with a triple-A score (Danone, 2023b). The company takes real responsibility for natural resources management in strategic areas: climate change, forest preservation and water security. Companies with score A "will have undertaken actions such as setting science-based targets, creating a climate transition plan, developing water-related risk assessment strategies, or reporting on deforestation impact for all relevant operations, supply chains and commodities." (CDP, 2023). Danone conducts water risk assessment as included in the CDP methodology. It must justify if it "has identified any inherent water-related risks with the potential to have a substantive financial or strategic impact on your business?" The company is asked for detailed data about the type of risk, the potential impact, magnitude and likelihood. It has to provide information about the financial aspects related to the identified risks and the approach used to respond to the risks, including costs. A score means the organisation could present reliable data on the requested topic. There are also other tools that the company uses that are helpful in risk analysis. The WWF risk filter identifies and visualises water-related risks (Risk Filter, 2023). It means that the decision-making processes are based on factual data. Both approaches allow to recognise the critical points for the company and be a starting point for further improvements.

Due to its global character, Danone affects many groups of stakeholders who are sensitive to water use. The graph below presents the key groups.



Graph: The key stakeholders in water management

Source: Own elaboration

Danone also reports its operations' objectives related to drinking water, sanitation, and hygiene. WASH pledge is a tool invented by WBCSD that aims at assessing the company's compliance with hygiene standards in the workplace (WASH Pledge, 2023). This supportive tool is used as an element of water governance in the business. The impact of climate change on water resources increases the need to implement initiatives to prevent the depletion of water resources. The approach is essential for the food industry directly related to agricultural activity. According to the data from the report "Climate change and water resources in the Żywiec region", an increase in the average annual temperature is a greater risk for unpredictable phenomena such as floods, droughts and erosion that threaten food production (Dbamy o wodę, 2023).

The interventions undertaken in water management contribute significantly to the global need to ensure water resource stability.

Danone takes care of sustainable supply chain management. It cooperates with suppliers of milk, vegetables and fruits in regenerative agriculture. There are three pillars of it:

- protection of soil, water resources and biodiversity,
- support for current and future generations of farmers,
- concern for animal welfare on farms.

In 2021, 25% of milk supply farms were audited for regenerative practices. By the end of 2023, 100% of farms are to be covered by the programme. Regenerative farming practices aim to regenerate soils, restore biodiversity and increase soil water retention (Responsible Business Forum, 2023).

The company is aware of the interconnections between ecosystems. Hence, as part of water stewardship, it has established a project "Po stronie natury". It is the flagship program of one of Danone's brands - Żywiec Zdrój. It aims to strengthen forest systems necessary for the proper hydrological cycle. The company has already planted 8 million trees. The clue of this initiative is to increase water resources by planting and enabling groundwater supply while filtering it. Planting trees is a protection against floods and drought and is part of a broader activity that food companies can undertake to protect environmental resources. The planting of flower meadows in the area of 60 ha in Beskid Żywiecki has a similar character. This initiative allows to achieve the company's goal related to "Active protection of natural habitats and water resources in selected areas of the Żywiec district." https://www.postronienatury.pl. Project activities also intend to educate stakeholders about the value of water resources (Press, 2023). As part of the activities undertaken to protect water resources, Żywiec Zdrój became one of the partners of the Dbamy o wodę Coalition. It is a program focused on "conducting

research and educational activities around hydrological and climatic issues, presenting good practices and presenting the benefits of implementing retention solutions at the local, national and global level, taking action to develop systemic solutions for small retention (Dbamy o wodę, 2023).

Actions to protect water resources have been implemented consistently for many years. The first attempts to reduce water consumption were carried out in 2011. Danone achieved a 6.4% reduction in water consumption per tonne of manufactured products in Poland compared to 2010 (Zinczuk, 2012).

PLN 14 million was the current cost incurred for environmental protection and water management in 2016, resulting from the activities of Żywiec Zdrój S.A. (Żywiec Zdrój, 2020).

In Polish bottling plants, water consumption is at the lowest level among all Danone plants worldwide and amounts to 1.24 litres per litre of produced product. Zywiec Zdrój uses the Total Water Utilisation indicator to know how much water is used to extract and bottle the still water. In this case, the TWU is ~1.08. It means that to produce 1 litre of bottled water, 8% more water is needed. The extra water is used for sanitation processes like cleaning the line and living goals (Żywiec Zdrój, 2023).

An example of care for water resources can be the plant in the Radziechowy-Wpieprz commune, which strives to be environmentally neutral. As part of the work carried out, it is assumed, among others, to reduce water consumption and collect rainwater. "Only the amount considered surplus in groundwater sources is extracted in the water harvesting." In Bieruń, work is being carried out at the sewage treatment plant to achieve the highest environmental standards beyond the law's provisions. The goal is to reduce nutrients while minimizing the use of energy and chemicals (Danone, 2021).

Danone has been taking a strategic approach to water management for many years. Awareness of the value of water for people's health and life means that its business model includes products such as water to support human health and products that use water in production. The company is aware of the risks related to water resources and has implemented an indicator that allows it to control what is happening with this resource globally. Danone's systemic approach to water saving can be developed through further investments in infrastructure at the level of industrial plants and cooperation with local communities to strengthen the local biodiversity. One possible solution is implementing closed-loop water management in plants for heating purposes. Another possibility is the use of the Best Available Technologies, which are oriented toward environmental efficiency, e.g.: optimisation of water flow, separation of water streams, dry cleaning or cleaning under pressure (European Parliament and the Council, 2019).

Each proposed solution must be considered, including the safety of the processes. It is vital to find new ways of water savings considering the climate risks and consequences related to the climate scenario for the next few years. As mentioned in the previous part, Danone cooperates with farmers and educates them about the role of biodiversity. This direction seems very needed according to the gained experiences and future possibilities. As a global corporation, it plays a crucial role in setting new standards for smart water management. The system could be based on the number of sensors and applications implemented in the fields that will help monitor the required amount of water, improve irrigation systems and control water quality. It would extend the already implemented practices and follow the strategy aimed at improving the positive impact on the environment. It is essential for sustaining the water resources and meeting the company's business goals.

6.2.3 KOMPANIA PIWOWARSKA

The brewing industry in Poland is quite diversified. Apart from large corporations offering traditional beer, the development of small craft beers has been observed for several years. In 2020, there were a total of 363 breweries in the country. However, the majority of the market is occupied by the largest companies (84%) like Kompania Piwowarska (34,2%), Grupa Żywiec (29,9%), Carlsberg (19,9%), 12% of the market belongs to the medium companies and 4% to regional and craft companies.

According to a Deloitte report, large breweries account for the vast majority (84%) of market shares. Among them, 34.2% is attributable to Kompania Piwowarska, 29.9% to Grupa Żywiec and 19.9% to Carlsberg. The remaining market is divided between medium-sized breweries (12%) and regional and craft breweries (4%). Some statistical data illustrating the scale of business activities are presented here:

- Market value in Poland: PLN 17.97 billion
- Beer production volume in Poland: 38.4 million hl.
- Beer sales volume in Poland: 35.9 million hl.
- Employment: approx. 9.5 thousand people.
- Imports: 1.01 billion hl.
- Export: 4.37 billion hl.
- Number of breweries: 363.

On average Polish people drink more than 93 litters of beer per year (data from 2020). Poland is one of European liders in beer producion (Browary Polskie, 2022). The brewery industry is aware of its environmental impacts. The companies see the need to take actions oriented toward the savings of natural resources. They are aware of challenges related to the increasing energy costs and resources needed for beer production. There is also a reflection on the disruptions in global supply chains, which may affect the way beer is produced. On the other side, the industry stresses its preparedness to transit under the sustainability framework. Polish brewery has a closed loop of bottle usage.

Next to the recycling issues, the other environmental priorities are: “decreasing CO2 emissions, protection of water resources and support for responsible consumption” (Żywiec Zdrój, 2023)

The industry is also responsible for consumers’ attitudes to alcohol drinking. The companies are obliged to comply with the law regulations about the harmful effects of alcohol drinking and driving cars and promote responsible consumption of alcohol. The growth of non-alcoholic beers is observed in Poland. The fast development has been noticed since 2017 thanks to the new technological improvements (Browary Polskie, 2023).

Kompania Piwowarska is one of the largest companies selling more than 30% of beer on the polish market. Historically it was the part of SmABMiller corporation acquired by Ashai in 2017. The company produces a few well recognised brands of beer such as: Tyskie, Dębowe, Żubr, Książęce, Wojak, Gingers, Pilsner Urquell, Grolsch, Kozel, Lech oraz Redd’s. (Spiderweb, 2023). The company’s mission is: “keeping the promise of great taste and making life more enjoyable”, and its vision is “to be a value creator on a global and local level, basing its development on brands with high added value.”. The brands belonging to the company have centuries of history and brewing traditions.

Kompania Piwowarska underlines its responsibility for society and the environment. An example of its environmental engagement is that 100% of energy comes from wind power. The organisation is firmly committed to lowering its negative impact on the environment in the water management area and packaging (Kompania Piwowarska, 2023). it strives for being carbon neutral in plants till 2030 an in the whole supply chain till 2050 (Wiadomości Spożywcze, 2023).

The water resources are essential for brewery operations. It’s entirely dependent on the water availability and its quality. Moreover, one needs to realise that all the processes vital for beer production, including bottle or can production, demand water supplies

and generate sewage. The brewery industry made a massive effort to decrease the amount of water required for beer production. The motivation for it could be both environmental and economic ones. Hence, the described company has been actively managing water for a couple of years. It sets ambitious goals to control the production processes and to limit the amount of water.

The company identifies environmental aspects, including water use. The company has implemented an environmental management system, which helps to follow the ecological processes and procedures. It has set the water KPI management, which is unified for the whole group. It assumes that to produce one litre of beer, the company needs 2.65 litres of water. Meanwhile, the average for the brewery is 3-6 litres of water. Other water statistics are included in the below table.

Table Water-related statistics

Total water withdrawal (m^3)	Białystok Brewery	Poznań Brewery	Tychy Brewery
Groundwater	-	-	1 050 725
Municipal waterworks	401 744	1 612 487	495 171
Total	401 744	1 612 487	1 545 896
Total water consumption = water withdrawal – water discharged	114 271	534 044	703 672
Total water withdrawal	401 744	1 612 487	1 545 896
Total water discharge (waste water)	287 473	1 078 443	842 224

Source: Raport Zrównoważonego Rozwoju 2021, https://www.kp.pl/files/Raport-zrownowazonego-rozwoju-2021.pdf, accessed 12.02.2023

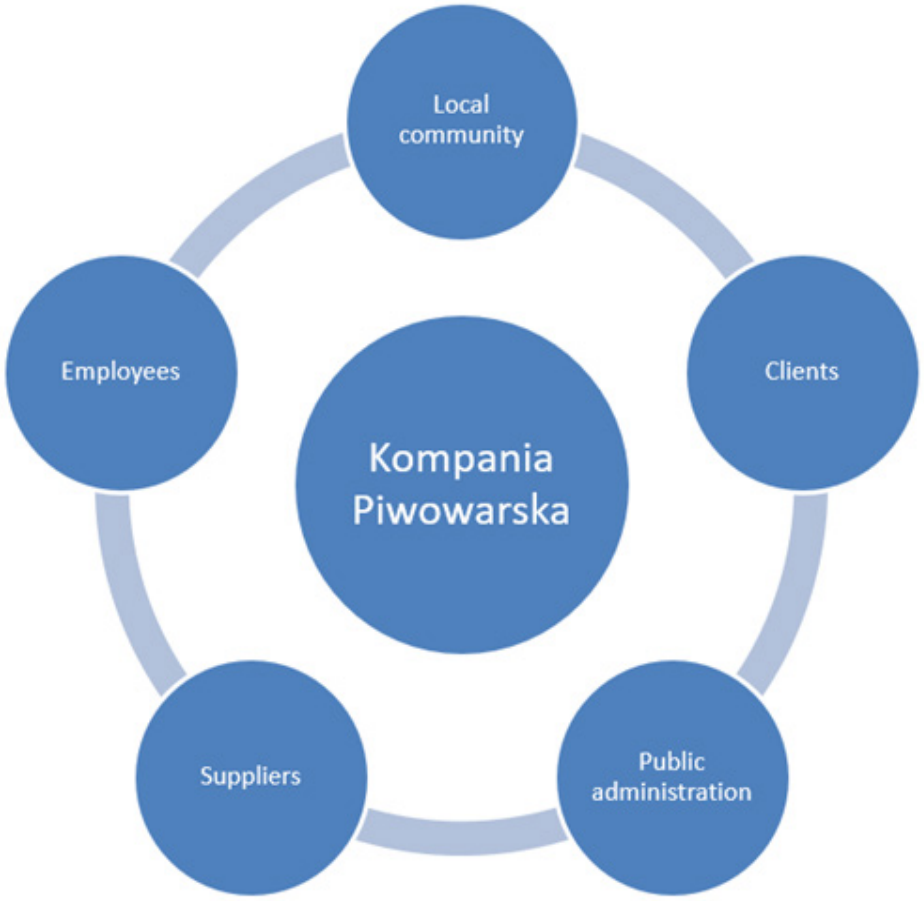
As noted in the sustainability report, breweries in Bialystok and Poznan do not use pre-treatment of water (no treatment 1,365,916 m3) and dump them directly to municipal treatment plants (the total amount of water waste: 2,208,140m3).

The company reflects on the water-related risks and does not use the water from endangered areas. In 2021, total water withdrawal for the needs of the plants amounted to 3,560,127 m3, and its total consumption - 1,351,987 m3 (Kompania Piwowarska, 2022).

Kompania Piwowarska, who belonged earlier to the SABMiller corporation, followed the principles set by this company. The SABMiller has been sensitive to water risk management for many years. The situation remained the same after being sold to the new owner.

The whole industry is prone to the physical and business risks related to the water, like water scarcity, its quality or competition for water (Water Foodprint, 2023). As declared: “We have examined in detail the risk of water shortage corresponding to quality. Appropriate development for all of us establishments, the so-called Source Vulnerability Assessment excludes the possibility of such a scenario materializing in the visible future. The conducted analysis confirmed that there is no water intake for the needs of our breweries, which has a significant negative impact on the level of its resources in the regions.” (Kompania Piwowarska, 2022).

There are some groups of stakeholders that are essential for water management. They are related to the risk of water management by, e.g. developing law regulations, setting common reduction goals or being affected by business decisions. All of these groups should be taken into consideration in the process of risk management and during planning and implementing business activities.



Graph: The key stakeholders in water management of Kompania Piwowarska
Source: Own elaboration

The food and beverage industry in Poland is an important element of the national and the EU economy. The value of the industry in Poland is shown in the below graph.

Already in 2010, Kompania Piwowarka had the goal to decrease the amount of water used in the plant in Poznań. It took care of the water management system, including sewage control. The amount of generated sewage was reduced by 51%. It was possible thanks to their initial purification before being introduced to the environment. The company analysed the possibilities of using its own water resources

as groundwater (Kompania Piwowarska, 2023a). Currently, the water management policy is continued. The company managed to lower the amount of water to 2.65l, what is one of the best worldwide results (Wiadomości Spożywcze, 2023). There were no water resources which were negatively affected by the business operations. It intends to have 100% sustainable water use. The company uses new technologies and improves processes, allowing water reuse from production processes for technical purposes. Additionally, it has a smart system of water use. They use a water cascade to reduce the amount of water consumed. The new ways of water saving are tested, like water cascading from the filtration department in Tyskie Browary Książęce and Lech Browary Wielkopolski. Kompania Piwowarska is also preparing a project to reuse water from the centrifuge in the Dojlidy Brewery in Białystok and optimise the cleaning processes of the installations (Wiadomości Handlowe, 2022).

It monitors "the quantity and parameters of the products produced on an ongoing basis wastewater and strictly comply with their rules treatment before release into the environment." The company has a modern on-site anaerobic pre-treatment plant in Tychy. Poznań and Białystok sewage is directed to the city's purification plants. The organisation uses grey water. "An example can be washing empty boxes with water from a bottle washer or lubricating not the transporters with water from can washers." Furthermore, in 2013, Kompania Piwowarska signed the agreement with the District z o.o. Waterworks Company and Sewerage in Tychy agreement, under which in particular circumstances, such as war or disaster, the inhabitants will retain available water from Tyskie Springs Princes' Breweries. (Kompania Piwowarska, https://www.kp.pl/files/Raport-zrownowazonego-rozwoju-2021.pdf, accessed 15.02.2023.

The described company conducts conscious water management. It takes into account the need to implement solutions for sustainable development. In this case, saving water is related to the production process based on this resource. A possible solution would be to close the water circulation in the toilets. The grey water reuse in bathrooms is not an essential process considering the business model, but it is important for the overall balance of water used by the company.

6.2.4 SUMMARY & REFERENCES

The food and beverage industry is water-based. Water consumption is linked to obtaining a strategic resource for production and maintaining the safety standards of the products offered. Water is also used to clean production equipment. The way in which water is used means that there is a high demand for water for both food and, in particular, beverage companies. Furthermore, the sector's business model and ability to create value depends on the availability and quality of water. The industry is sensitive to disruptions in water supply and unexpected weather phenomena, such as prolonged droughts or sudden storms, which affect the physicochemical parameters of water and can exacerbate this sensitivity. Equally important is the biological safety of this resource.

Estimates show that water consumption for industrial purposes will increase in Poland. In view of the growing risk of climate change, it should be considered to promote initiatives and implement techniques aimed not only at water treatment and purification but also at efficient consumption and closing the cycle in areas where recycled water can be reused for the needs of this industry. Recycled water can be used for cleaning equipment, cooling and heating, or irrigation. Closing the loop does not mean that the recycled water comes into contact with the products offered. This can be a critical factor in inhibiting the business case for water reuse.

When it comes to manufacturing processes, technology can be a critical factor. Modern technologies, sensors and measurements to monitor water flow will be required.

It is also important for the industry to work with the local community to take care of ecosystem services, which can provide greater resilience to environmental instability. As part of these activities, consideration should be given to re-naturalising areas and planting or ensuring the uninterrupted water cycle by leaving part of the area unconcreted, which prevents natural circulation. Working with the local community

also means educating them about water conservation and techniques for effective water collection and recycling in the case of food industry companies that have a significant impact on agriculture.

Awareness of the industry's role in global water conservation efforts is growing. This is due, among other things, to economic factors related to rising raw material prices and wastewater disposal costs, the risk of lack of availability and quality of resources, a lower valuation by investors or the need to maintain current value. Other factors include the potential loss of image and the desire to protect the environment in line with sustainability goals.

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6.3 OIL, GAS AND MINING SECTOR

6.3.1 INTRODUCTION

The oil, gas and mining sector is one of the most important industries in Poland and is a subject of studies related to Corporate Social Responsibility (Suska, 2021).
In Europe and Poland, there are restrictive legal regulations governing the operation of mining waste facilities, such as:

• Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC - Statement by the European Parliament, the Council and the Commission (DIRECTIVE 2006/21/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, 2006);

• Extractive Waste Act, pl. Ustawa o odpadach wydobywczych (Ustawa o Odpadach Wydobywczych, 2008).

Mining & Energy sector in Poland is also an object of interest of numerous research studies (Jędrych et al., 2021; Pactwa & Woźniak, 2017; Woźniak & Pactwa, 2018).

6.3.2 KGHM POLSKA MIEDŹ S.A.

KGHM Polska Miedź S.A., formerly Kombinat Górniczo-Hutniczy Miedzi (pl. Copper Mining and Smelting Combinat), is a Polish mining company and one of the largest producers of copper and silver in the world. It also produces molybdenum, nickel, gold, palladium, platinum, lead and, as the only company in Europe, rhenium and ammonium perrhenate. KGHM operates on three continents. It has nine mines in Poland, the USA, Canada, and Chile and three smelting plants in Poland (KGHM, 2023b).

The ESG Risk Rating for KGHM calculated by Sustainalytics is 36,6, described as “High Risk” (Sustainalytics, 2022). KGHM is also ranked by CSRHub in the 45% percentile among all ranked companies in terms of conducting ESG activities, less than the average in the mining industry (CSRHub, 2023).

Water is a key resource in copper mining and processing. It is used in ore enrichment (flotation), waste hydro transport, and smelting plants' process lines (KGHM, 2023a). The water management issues are also included in the environmental policy of mining companies in Poland (Pactwa & Woźniak, 2017). The goal of the water management system is to ensure that the water introduced into the system is used as long as possible while maintaining its parameters at the required level to establish both an efficient concentration process and a safe discharge of water. In the case of KGHM S.A., this goal is to be maintained using, among others, a closed water cycle between copper mines, smelting plants and industrial wastewater treatment plants.
Water and flotation tailing management in KGHM Polska Miedź S.A. is a system that uses water exclusively from its own resources, which consists of water from mine drainage (mine water), wastewater, water from refreshing cooling circuits, and, above all, return waters from the concentration process. It has a positive water balance, which requires only periodic discharge of excess water to the environment (Witecki & Grotowski, 2019).

KGHM also recovers heat from mine water using heat pumps (KGHM, 2019; Suska, 2021). It is significant because, from a legal point of view, mine water in Poland is a waste, the same as the water used in industrial cooling systems (Andrusikiewicz, 2014).

KGHM operates mainly in the B2B market. There is no evidence that the water management is a priority for its suppliers. Therefore, with regard to water management, the following KGHM stakeholders can be distinguished: local communities, local authorities, national environmental regulators and clients with expectations regarding water management.

KGHM uses the most water for flotation, around 4-5 m3/t. The total water consumption in Polish companies such as KGHM alone exceeds 20 million m3. Water used in production processes is diverted back for treatment. Industrial wastewater treatment plants working for smelting plants specialise in the removal of heavy metals, including particularly difficult arsenic compounds, as well as mercury and cadmium. As a result of the high quality of the wastewater, about 30% is reused in the smelters' technological processes. The remaining treated wastewater is discharged into local rivers (KGHM, 2023a).

Furthermore, one of the results of mining operations is mine water, which is transported to Żelazny Most Mining Waste Disposal Facility for storage. Then, it is circulated back to be used for flotation (Mirończuk, 2019).

In 2021, the total water intake by KHGM, surface water, groundwater, seawater, postproduction water, and water from other sources was 41,893,681 m3. In the same year, the total use was 4,548,449 m3, and the total wastewater discharge was 37,345,232 m3 (KGHM, 2021c, 2022). There are three types of processed water in the KGHM closed water cycle (Witecki & Grotowski, 2019):

- supernatant water – a clear, free of-suspension water, accumulating over settled flotation tailings at Żelazny Most, collected using the so-called overflow towers and returned to concentrators or discharged to the Odra River;
- return water – a part of the supernatant water returned to a concentrator. It is the most important component of the water used for the flotation process;
- discharge water – a part of overflow waters that are directed to the Odra River through the control and discharge node in Głogów due to the fact that more water comes from the mines than is consumed by technological processes.

During the last decade, the discharge volume of KGHM wastewater was decreasing, for example, during the period between 2014 and 2015 (Woźniak & Pactwa, 2017).

Some of KGHM's mines are located in areas where water is a particularly precious commodity. These include, for example, the Atacama Desert in Chile, one of the driest places in the world, or the semidesert in US Arizona, where no more than 25 cm of rain falls annually (KGHM, 2023a).

The objective of KGHM at such sites is to take the utmost care of existing natural water resources and to prevent the risk of their depletion. In the case of the Sierra Gorda project, out of concern for the environment, the company uses seawater in its process line from the cooling systems of the power plant located near the town of Mejillones. Previously discharged back into the ocean, it is now pumped through a 142.6 km long pipeline and stored in a retention tank (KGHM, 2021c).

The Sierra Gorda plant is expected to use 92 million m3 of water per year in its first phase of operation. At the same time, the company is monitoring identified natural water sources in these areas, investigating whether their levels are declining and whether contamination is occurring. In those plants where resources are particularly limited, water from, for example, wastewater treatment plants is reused to, among other things, spray roads and landfills to reduce dust. (KGHM, 2023a).

It should be noted that Żelazny Most is not only the largest waste disposal facility of its kind in Europe but also the only copper mining waste disposal facility in the region (KGHM, 2014b; Stefanek & Wrzosek, 2015; WP.pl, 2019). It is also the best-monitored facility of its kind in Europe (KGHM, 2021b). Furthermore, it is still being expanded (Kanikowski, 2018; KGHM, 2018; Ministry of State Assets of Poland, 2021; naszemiasto.pl, 2021; Wójcik, 2021).

The tasks of the KGHM technological water (also called mine water) hydro transport network are the following (Witecki & Grotowski, 2019):

- collection of water from mines;
- collection of treated sanitary sewage and treated rainwater;
- transport of technological waters to the discharge node in Głogów, with the necessary

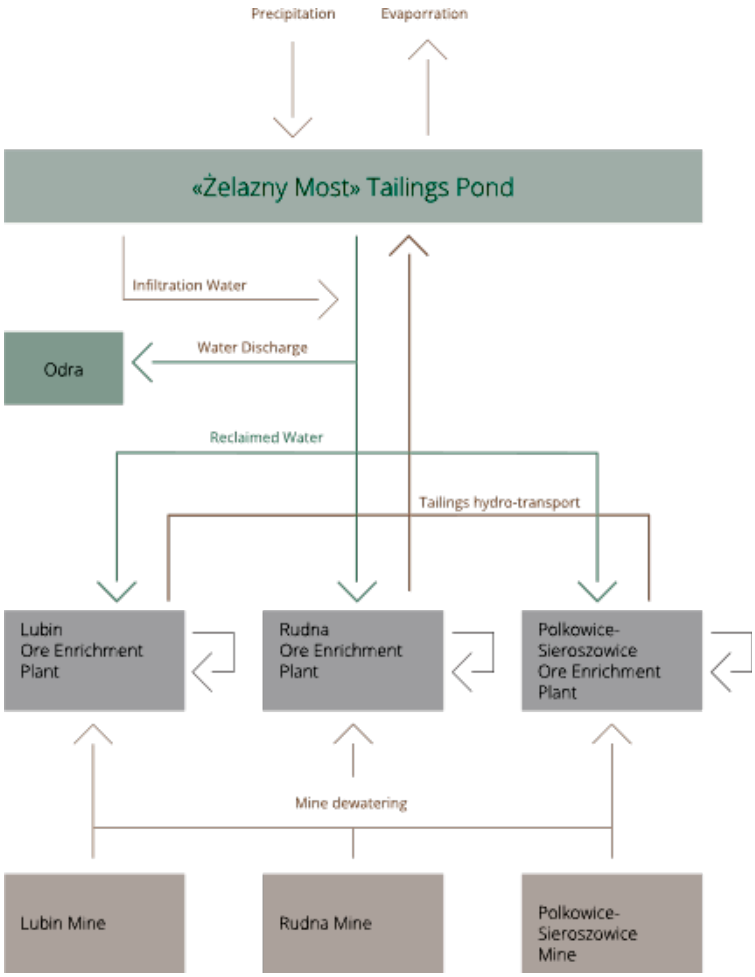

Figure. Water in the ore enrichment (flotation) process

Source: (KGHM, 2021d)

• assistance from Żelazny Most;
• receiving the clarified return water from Żelazny Most and its delivery to Ore Enrichment Plants;
• collection of excess water from other reservoirs;
• transport of excess water from Żelazny Most to the control and discharge node;
• in necessary cases, purification of the supernatant waters stored in the Żelazny Most from the suspension in the treatment plant next to the facility.

In some foreign KGHM plants, the situation related to water management is more problematic due to water scarcity. The KGHM Carlota mine in the USA operates with a total absence of water discharge used in the production process. The rare plant species found at the mine site are given special protection. (KGHM, 2023a; SUPERexpress, 2019). In Sierra Gorda, the KGHM mine uses water from the cooling systems of a thermal power station in Mejillones, a small city in the region (KGHM, 2014a).

6.3.3 ORLEN GROUP

ORLEN is a multi-energy company with operations in Central Europe and Canada. It provides energy and fuel to more than 100 million Europeans and its products are available in nearly 100 countries on six continents. It introduces clean, environmentally friendly technologies and energy based on both low- and zero-carbon power generation sources. Its activities are subordinated to the implementation of the strategy to achieve carbon neutrality by 2050 (ORLEN Group, 2023c). ORLEN is in the process of acquiring Poland's leading energy companies, LOTOS Group and PGNiG (ORLEN Group, 2023b).

The main source of water for ORLEN is surface water, which is extracted by the largest companies in the Group: ANWIL, IKS Solino, PKN ORLEN, ORLEN Południe, ORLEN Lietuva, Unipetrol, Paramo and Spolana, and then distributed through the water supply network to their own production plants and those of other companies (Suska, 2021).

The main stakeholders related to water management in ORLEN Group are local communities, local authorities, national environmental regulators, and institutional and individual clients with expectations regarding water management (ORLEN Group, 2022c).

Group water intake was constantly increasing between 2014 and 2019 (Suska, 2021). The total intake of surface water, groundwater, and tap water in the ORLEN Group in 2021 was bigger than 518 million m3, of which the largest share was contributed by Energa Elektrownie Ostrołęka, which was able to intake 419.1 million m3 of surface water and 383,000 m3 of underground water. The increase in water abstraction was related to the increase in electricity and heat production to ensure the safe and economical operation of the National Power System Electricity System (ORLEN Group, 2022c).

It should be noted that the total yearly water intake of ORLEN Group is equal to approximately 0,2% of total water used by the whole Polish economy (Kamiński & Garstka, 2019).

Wastewater from all ORLEN Group companies is directed to industrial and stormwater drainage systems and then subjected to treatment processes. The volume of wastewater discharged to the environment is measured, and in 2021, the ORLEN Group totalled almost 503 million m3, of which 494 million m3 consisted of industrial wastewater.

Approximately 3.7 m3 of wastewater per year is recycled to produce water for fire protection purposes at the Płock production plant. A significant volume of wastewater was discharged by Energa Elektrownie Ostrołęka, i.e. 416.8 million m3 (ORLEN Group, 2022c).

The main procedure in the ORLEN Group related to managing water-related risks is the Environmental monitoring procedure to ensure proper monitoring of air (immissions), wastewater and rainwater and snowwater generated at fuel terminals and groundwater around and within the Plock Production Plant and fuel terminals (ORLEN Group, 2022c).

The main identified risks related to water management in ORLEN Group concern access to usable water due to climate change, technical issues, and natural disasters (ORLEN Group, 2022c).

The ORLEN Group mitigates the risks related to water management by including the following indicators related to water management in its Code of Conduct (ORLEN Group, 2023a):

• the supplier strives to reduce and rationally manage the consumption of raw materials and natural resources, including water;
• the supplier has water metering and takes measures to reduce water consumption in its business.

ORLEN takes initiatives to limit environmental impacts with respect to water consumption. Apart from PKN ORLEN, their own wastewater treatment systems companies have Energa Elektrownie Ostrołęka, Energa Kogeneracja, ANWIL, Ship-Service, Spolana, Paramo, ORLEN Unipetrol, ORLEN Lietuva, ORLEN Południe, ORLEN Paliwa, ORLEN Budonaft, Naftoport, IKS Solino, Benzina and ORLEN Baltics Retail. All wastewater is subjected to treatment by mechanical, physicochemical, and/or biological means. The treated wastewater, in accordance with the permissions held, is discharged into local rivers (ORLEN Group, 2022c; ORLEN Lietuva, 2023; Rules on Waste Management, 2017).

It is worth noting that the ORLEN Lietuva refinery and the Płock Production Plant partially recover the treated wastewater, which limits the water intake from the environment for domestic and fire protection purposes. In 2021 ORLEN Lietuva reused 4.1 million m3 of wastewater and PKN ORLEN Płock refinery reused over 3.5 million m3 of wastewater. On the other hand, the PVC plant at ANWIL carries out heat recovery from industrial process wastewater (ORLEN Group, 2022c).

In the Płock Production Plant, the water source for power and cooling needs is water from the Vistula River, while water for technical safety purposes is produced entirely from treated wastewater from the site, which is part of a partially closed water cycle, which is visualised in Figure 1.

Figure 1. Water circulation in the Płock Production Plant
Source: (ORLEN Group, 2021d)

Water for cooling purposes is Vistula water subjected to a treatment process that removes its impurities. This water, called process water, is directed to the Water Blocks, where it supplements the water that circulates in the closed circuit between the Water Blocks and the production installations. The need to replenish the cooling water

results from its cooling processes in the Water Blocks, where it is partially evaporated. Therefore, it is necessary to replenish these losses, which account for approximately 2% of the total cooling water.

Water for technical safety purposes is produced from treated wastewater and subjected to a final purification process. As firefighting water, it is diverted to the plant's fire hydrant network and provides the plant with protection in the event of a fire. Some of this water is directed to the domestic water hydrant network and is used for other technical purposes in the Plant. The Plant also produces potable water for its own use. The source of water for drinking water production is water drawn from its own deep wells located in the Biała Stara area and further treated at the Płock Production Plant (ORLEN Group, 2022a). Measures taken by the ORLEN Group to reduce water consumption are visualized in Figure 2.

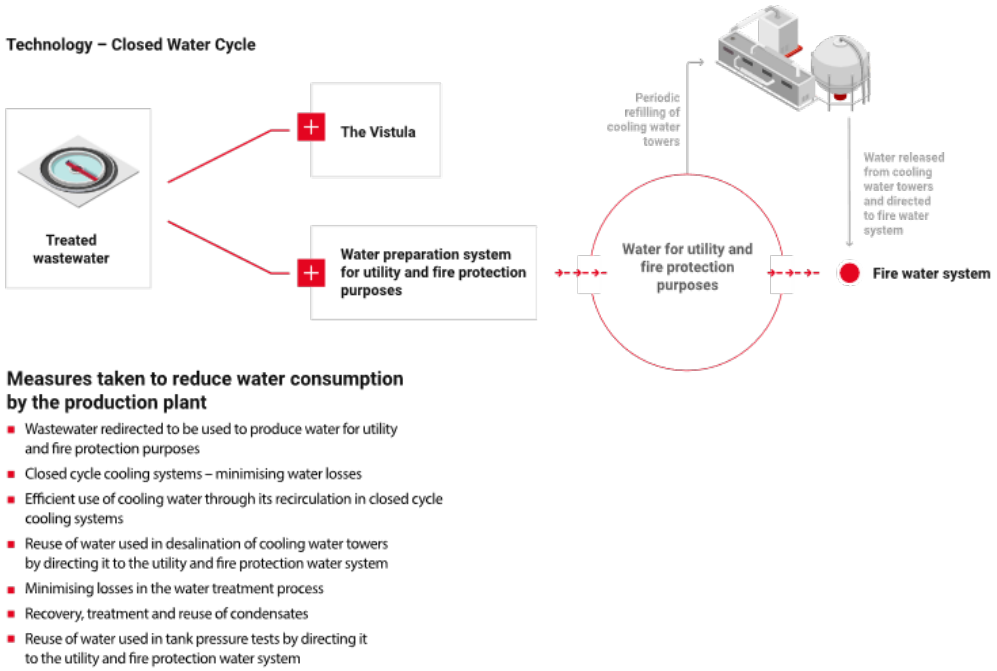

Figure 2. The measures taken to reduce water consumption by the ORLEN Group

Source: (ORLEN Group, 2021d)

It should be noted that the central wastewater treatment plant at the Plock Production Plant achieves treatment efficiency in excess of 90% in key parameters. As a result, the wastewater discharged by the plant is significantly cleaner than the required standards (Kamiński & Garstka, 2019).

ORLEN is also implementing the innovative 'Blue Bridge' project, which will enable a 25% reduction in water intake from the Vistula River to support industrial processes at the company's production plant in Płock (Perzyński, 2022; Polska Izba Paliw Płynnych, 2022; Więckowska, 2022). As a part of this process, PKN ORLEN has signed, together with its project partner Wodociągi Płockie, the local water utility company, a letter of intent with the State Water Management Agency PGW Wody Polskie in order to construct a recycling system for wastewater coming from the municipal treatment plant for reuse by PKN ORLEN (Derewenda, 2022; PolskieRadio24, 2022).

The Blue Bridge project involves treating municipal wastewater at the municipal wastewater treatment plant operated by Wodociągi Płockie and transporting the treated wastewater, e.g., through a pipeline along the Vistula River bed, approx. 5 km long (Centrum Informacji o Rynku Energii, 2022), to the water intake of the PKN ORLEN Production Plant in Płock. It will be transported and used in technological processes carried out by the Company. This will be a practical application of the Smart City concept with a resource-efficient economy in line with the idea of the European Green Deal and Circular Economy (Tygodnik Płocki, 2022; wGospodarce.pl, 2022; Zielona Gospodarka, 2022).

Currently, a programme and spatial concept for the project are being developed and tests are being carried out at a pilot station. The results will be used to design the entire wastewater treatment plant, while the entire treatment process will ensure that the water obtained in this way is transported to the company's intake (MarketScreener, 2022; Meissner, 2022). The project was initiated in 2019 (Wodociągowiec.pl, 2021). It will become operational in 2025 (ORLEN Group, 2022b; Portal Komunalny, 2022).

Another example of business activity aimed at fostering water management and reducing water intake by the ORLEN Group is the biological wastewater pretreatment plant implemented by Veolia Water Technologies on the site of the ORLEN Południe refinery at the Trzebinia plant, which treats wastewater from a newly constructed propylene glycol production facility (Bromboszcz, 2022; Nijhuis Saur Industries, 2023; ORLEN Południe, 2023; VEOLIA, 2022).

6.3.4 LOTOS

LOTOS was one of the most modern oil companies in Europe. It produced natural gas and oil in Poland, Norway, and Lithuania. It owns one of the world's most modern refineries located in Gdansk. As a retailer and wholesaler, LOTOS has supplied nearly one-third of the Polish market with fuel. It also held the position of the second-largest rail freight forwarder in the country. The company was also a leading producer of road bitumen, engine oils, and lubricants for cars, planes, trains, ships, and military vehicles.

As part of its strategy up to 2022, the company has aimed to become a leader in the area of new-generation fuels. Among other projects, LOTOS invested in hydrogen. The company signed letters of intent with local authorities: Gdynia, Tczew and Wejherowo, for the supply of hydrogen for city buses. Parallelly, LOTOS Group is implementing the Pure H2 project. It involves the construction of a hydrogen purification and distribution facility and 2 hydrogen refuelling sites.

Further modernisations are planned at the Gdansk refinery. A project related to the construction of an infrastructure for efficient refining called EFRA was completed in 2022 (LOTOS Group, 2022c).

The company is a subject of studies on the topic of circular economy that take into account measures related to water management (Czapicka-Kotas, 2020). In 2022, LOTOS was acquired by the ORLEN Group (LOTOS Group, 2022b).

The use of water resources by LOTOS is based on integrated water permits. As required, LOTOS continuously monitors the impact on water resources in relation to water intake and wastewater discharge, both in terms of quantity and quality. The company also ensures that as much water used in production processes as possible is reused. This ensures that the amount of water that is ultimately collected from the environment is reduced (LOTOS Group, 2021f, 2022e).

LOTOS was involved in the recovery of waste generated at the delayed coking plant and the production of domestic water from treated wastewater (LOTOS Group, 2021c, 2022d).

The main stakeholders related to water management in LOTOS are local communities, local authorities, national environmental regulators, and institutional and individual clients with expectations regarding water management.

Furthermore, companies of the LOTOS Group do not operate in water scarcity risk, according to the WWF Water Risk Filter (LOTOS Group, 2021f).

The total water abstraction (surface water, groundwater, seawater, produced water, water from another organisation) by LOTOS Group in 2021 totalled 7 324 megalitres (LOTOS Group, 2021f). Part of it (298 123 t) is used to produce demineralised water for steam production (LOTOS Group, 2021d).

The mechanisms of the LOTOS Group risk management model are embedded in existing business processes and consist of three lines of defence that are tailored to the specific nature of the business and the magnitude of the potential impact of the risks that may affect the Group's performance (LOTOS Group, 2021b). The main water-related risks identified are related to climate change (LOTOS Group, 2021a).

However, LOTOS uses many GRI indicators related to water, including Management of water and water consumption – GRI 303-2, Water intake GRI – 303-3 and Wastewater discharge – 303-4 (LOTOS Group, 2021e, 2022a).

One of the main procedures implemented in the LOTOS Group to ensure responsible environmental management is the monitoring of processes and activities that affect the environment, including wastewater emissions (LOTOS Group, 2021c). It includes CEMS (Continuous Emission Monitoring System). This system helps to analyse the refinery's performance when processing different grades of crude oil. This allows you to see how production affects the environment. Thanks to the CEMS system, staff have access to real-time information on the quality of wastewater flowing into the Dead Vistula. The condition of the liquid is monitored for chemical oxygen demand (a water and wastewater pollution indicator), total nitrogen, petroleum hydrocarbons, and total suspended solids (LOTOS Group, 2020).

The LOTOS Group Refinery has its own wastewater treatment plant, which receives wastewater from both the plant itself and from smaller companies, e.g. RCEkoenergia (RCEkoenergia, 2023), operating on the site (kierunekchemia.pl, 2014; Promostal, 2023). In addition to wastewater generated in production processes (so-called process wastewater), the plant treats drainage water, clean rainwater (from roads and yards), oily wastewater (from production areas), and sanitary wastewater. It is important because the quality of water collected from the Vistula River is not always acceptable and treatment is necessary before the water is used (Szmyd, 2016; Waara et al., 2014).

Internal technological standards are in place to ensure the appropriate process for the production of cooling water, demi-water (for steam production), and process water from treated wastewater. The plant has implemented wastewater monitoring instructions to stabilise the operation of the treatment lines and protect the activated sludge chambers. Measures are being taken to close water circuits with reference to BAT conclusions for the refining industry use of acidic water after stripper, recovery of domestic water, and recovery of steam condensates. (LOTOS Group, 2021f).

A pioneering water purification method introduced by LOTOS is the use of pressed barley straw in the retention tank of the Gdansk refinery. Phytoplankton blooms,

especially blue-green algae, are a problem industrial plants also have to deal with in the summer, as they have problems with water treatment. LOTOS Group has found a way to combat blue-green algae and has sunk bales of compressed barley straw in the retention tank of its Gdansk refinery. It was the first Polish industry to introduce this method.

On the surface of the reservoir, 17 strips of barley straw bales in openwork bags were placed between the edges of the reservoir, connected by steel cables. Eight tonnes of straw were used. After a few weeks, aerobic mineralisation of the straw with aquatic fungi and bacteria began, and organic substances (polyphenols) were released into the water, which, even in low concentrations, blocked the cell division of algae and cyanobacteria (Chemia i Biznes, 2014; laboratoria.net, 2014).

This installation also resulted in a decrease in water treatment costs for the refinery. The total volume of water intake from the environment was reduced by 6% compared to the previous year despite an increase in oil throughput. The improved water quality has significantly reduced water losses and the amount and cost of chemicals used in the water pretreatment plant. This has had an impact on the efficiency of subsequent installations, mainly water demineralisation, which has reduced the plant's water production costs by around 4% (LOTOS Group, 2014).

LOTOS also introduced a rainwater recovery system that reduces process water consumption at one of the petrol stations in Warsaw (Teraz Środowisko, 2019; TVP Info, 2019; wGospodarce.pl, 2019).

Other business activities related to water management include an innovative method to treat the water required for production processes. As a result, plant water production costs have decreased by 4% (wnp.pl, 2014).

6.3.5 PGE POLSKA GRUPA ENERGETYCZNA S.A.

PGE Capital Group is the largest company in Poland's energy sector in terms of revenue and profit generated. Through the use of its own fuel and power generation resources and its ownership of distribution networks, it provides a secure and stable electricity supply to more than five million clients (PGE, 2023). Among other major energy companies in Poland (including TAURON Polska Energia S.A., Enea S.A., and Energa S.A.), it is a subject of studies related to corporate social responsibility, including reducing the use of water (Cader et al., 2022).

PGE declares an open policy for reporting activities in the area of sustainable development (Witkowska, 2022). The PGE ESG Risk Rating calculated by Sustainalytics is 49, which is described as 'Severe Risk' (Sustainalytics, 2022). CSRHub also ranks PGE in the 48% percentile among all ranked in terms of conducting ESG activities, more than the average in the Electric & Gas Utilities industry (CSRHub, 2023).

PGE monitors the quantity and quality of water intake and wastewater discharge according to administrative decisions granted in this respect. Processes related to water and wastewater management in PGE Group installations are conducted primarily on the basis of the Water Law Act and other executive acts dedicated to water and wastewater management (PGE, 2017, 2018, 2020b, 2021a). In its Environmental Statement, PGE declares that it would minimize the negative environmental impacts and make economical use of resources (PGE, 2020a).

An example of rational water use is the system of power plants owned by PGE GiEK, including the Belchatow Power Plant, which operates in a closed water cycle (PGE GiEK, 2022). In the Bechatów and Turów lignite mines belonging to PGE, the exploitation of lignite deposits using the open-pit method requires prior dewatering of the rock mass, which has a significant impact on hydrogeological conditions and results in changes in hydrodynamic relations. The water management of lignite mines is related to both deep dewatering and surface dewatering of open pits. The water

from the pits is discharged to field settling ponds for final water treatment by natural sedimentation of suspended solids, aided by a plant filter or dedicated treatment plants. Each of PGE's open-pit lignite mines carries out planned water conservation activities. Dewatering facilities are being expanded and upgraded (PGE, 2021a; PGE GiEK, 2021).

Furthermore, increasing prices of energy resources result in energy companies, as PGE is either maintaining its water power plants, e.g. Solina-Myczkowce Water Power Plant, or developing them, e.g. Witka Water Power Plant (Frączyk, 2019) or Gubin Water Power Plant (Stachura, 2022).

There is no evidence that water management is a priority for PGE suppliers. Hence, with regard to water management, the following PGE stakeholders can be distinguished: local communities, local authorities, national environmental regulators, and clients with expectations regarding water management.

PGE reports water management information to CDP Disclosure Insight Action (PGE, 2021a). The CDP data are not publicly available, but their score given to PGE for their Water Security Programme in 2022 is C, the same as in 2021. It should be noted, however, that the change between scores given by CDP to PGE for their Climate Change Programme increased from F in 2020 to C in 2022. It indicates actions taken by PGE in the area of environmental management (CDP, 2023).

In 2019, the total volume of wastewater discharged by PGE was 35,821,490 m3, which is more than 200% of the volume in 2017. However, at the same time (2019), the total volume of water used by PGE in cooling systems was 1,248,615,376 m3, which is more than 35 times the total volume of wastewater discharged (PGE, 2019).

The water cycle in the processes of electricity and heat production in the PGE Group is visualised in Figure 1.

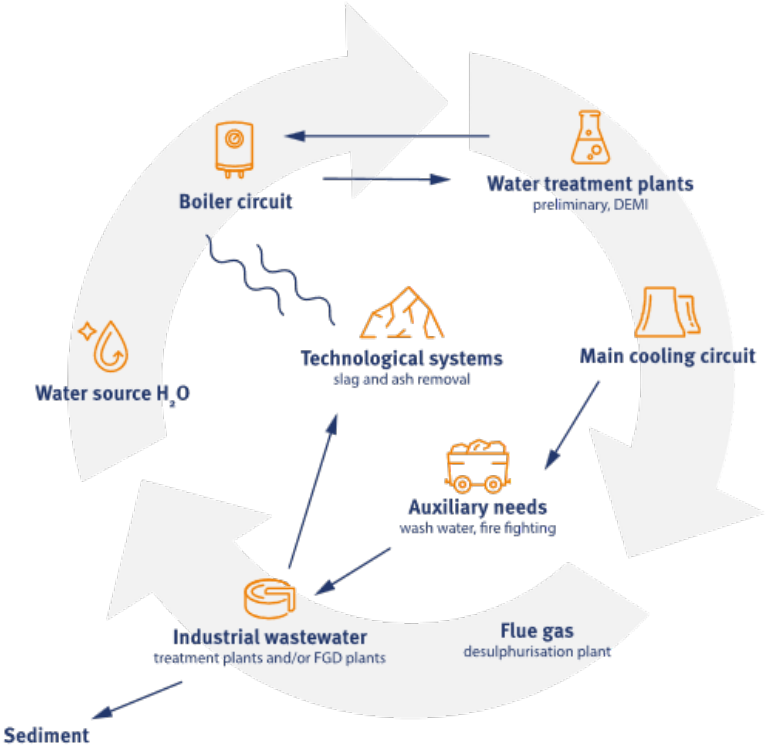

Figure 1. The water cycle in the processes of electricity and heat production in the PGE Group
Source: PGE, 2020.

Depending on technological requirements, water is directed to the collection points after different stages of preparation. In each stage of water preparation, particular attention is paid to its rational use. Many of the wastewater streams generated during water preparation are returned to the reuse process for reuse (PGE GiEK, 2022). Wastewater generated in other installations, if its composition allows it, is also returned to the process. Examples of water recovery processes are the following (PGE, 2020c, 2021a):

- the return of the so-called hot wastewater as a source for the water preparation process,
- the frequent use of rainwater or drainage water for water production,
- returning treated wastewater from the desulphurisation process to the desulphurisation process, as far as its composition directly depends on the quality of the coal combusted allows,

- using part of domestic wastewater, after its treatment, as a source of water for closed make-up,
- ongoing work on the cooling system at the Krakow CHP Plant to use treated wastewater from the municipal treatment plant as a source of process water,
- use of wastewater as a source of water for domestic water systems or to supplement ash removal and slagging systems.

It should be noted that PGE (along with other major energy companies in Poland) does not always disclose levels of water usage and wastewater withdrawal (Majchrzak & Nadolna, 2020).

Also, PGE uses both closed and open-water cooling systems (Elżbieciak, 2021; Rapacka, 2020). During the last decade, the wastewater volume discharge of PGE decreased between 2013 and 2015 (Woźniak & Pactwa, 2017).

In PGE energy plants, the water from surface water intakes is used for technological purposes, which is then subjected to purification and treatment processes. Closed circuits are used to reduce the amount of raw water consumption, and the used process water and wastewater are fed into other production processes. Wastewater resulting from the production activities of the power plant is subjected to a treatment process, including multistage treatment, and is then discharged to surface water or transferred to municipal enterprises.

Depending on environmental conditions, the units have the appropriate water and wastewater treatment technologies to ensure that all environmental requirements are met. Adapting to the requirements of the BAT Conclusions at PGE Mining and Conventional Power Generation also means reducing pollutants in the water from flue gas cleaning installations generated in the electricity generation process. In this regard, the modernisation and expansion of the wastewater treatment plant are being carried out (PGE, 2021a).

In PGE Heat Energy, mainly surface water or, in places, groundwater is used to produce process water. In Elektrociepłownia Szczecin, the internal sea waters are abstracted. All groundwater intakes in operation have established direct water protection zones. Several plants also use water from municipal water supply systems. Depending on the size of the plant, the source and the composition of the raw water, different water preparation techniques are used, such as lime decarbonisation, filtration, ion exchange, ultrafiltration, reverse osmosis, and electrodeionisation. In each case, the complete water preparation sequence consists of a combination of several of the above-mentioned techniques (PGE, 2021a).

Among the stringent requirements of the BAT conclusions for the removal of nitrogen and sulphur oxides, requirements have been introduced for the effluent parameters from wet flue gas desulphurisation plants. One of the key parameters is the concentration of metals and metalloids in the wastewater. As part of the adjustment programme to the BAT conclusions, a number of projects were implemented, including, in the field of water and wastewater management, a project derived from an R&D project, i.e. implementation of the InnUPS heavy metal capture technology (Cybulska, 2021) and other projects aiming at reducing the use of coal in heat production (PGE, 2021b). Between 2013 and 2016, a technology for the treatment of wastewater from the wet flue gas desulphurisation plant was developed at PGE Energia Ciepła. The developed technology is based on a column system containing ion exchange resins dedicated to the removal of metals and metalloids (PGE, 2021a).

The premise for introducing more business activities related to water management in PGE might be established by PGE, the Centre for Research and Development of the Circular Economy. This institution aims to develop and implement solutions to optimise the use of industrial waste from the energy industry and recover valuable raw materials from decommissioned RES (Renewable Energy Sources) facilities (wGospodarce.pl, 2022).

6.3.6 SUMMARY & REFERENCES

The Polish oil, gas and mining sector relies extensively on water for a variety of processes, including waste treatment, exploration, and production. In this sector, water is consumed mostly in the technological processes, mostly mining and processing. For these reasons, water management is an essential component of their operations. Businesses use a range of strategies to manage water, such as water conservation, water treatment, and water reusing.

Sustainable water management practices are becoming increasingly important in Poland's oil, gas and mining sector. To protect water resources, companies are embracing modern technologies and business activities, implementing more intense water usage limitations, and collaborating with environmental organisations. The actions of companies are not limited to Poland but are also present in the countries of operations of these enterprises.

It should be noted that these activities are mainly related to the core business of the focal companies. Their efforts aiming at reducing the use of water not related to technological processes are limited.

The main recommendation for the oil, gas and mining sector is to map the water flows in order to monitor precisely both water intake and discharge. It might allow the management staff to determine whether the water in specific technological or nontechnological processes might be reused or if its use might be reduced. Another recommendation is to extend reporting related to water management. Information on that area disclosed in published reports is scarce. Including extensive information on water management in integrated reports or ESG reports might allow advanced analysis and further development of recommendations for the company and for the entire sector.

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6.4 WATER AND WASTEWATER SECTOR

6.4.1 INTRODUCTION

The water and wastewater sector is considered crucial not only for the functioning of the economy but also for meeting the basic needs of the country's population. It is also an important element in protecting the environment and the health and safety of the population. Therefore, it is crucial to understand and apply water reuse techniques as part of water conservation (Rathi and Kumar, 2021). In addition to water efficiency solutions, the reuse of treated wastewater in a safe and cost-effective manner is a valuable way to increase water resources. Such activities are part of the „circular economy" (CE) model (Kacprzak and Kupich, 2023). The CE model framework in the water and wastewater sector includes the six following actions: (i) reduction - prevention of wastewater generation by reducing water usage and pollution reduction at the source; (ii) reclamation (removal) - application of effective technologies for the removal of pollutants from water and wastewater; (iii) reuse - reuse of wastewater as an alternative source of water supply (non-potable usage); (iv) recycling—recovery of water from wastewater for potable usage; (v) recovery - recovery of resources such as nutrients and energy from water-based waste; and (vi) rethink - reconsidering how to use resources to create a sustainable economy, which is free of waste and emissions (Smol et al. 2020).

This awareness in the wider context of CE, as a need to seek innovation, is a new challenge for companies in the water and wastewater industry. On the other hand, water and wastewater companies are increasingly aware that the consequences of climate change and the increase in energy prices will require big changes and a responsible approach to water resource management, as well as taking steps towards recovering water from wastewater to save natural drinking water resources. Despite many difficulties in implementing such solutions (e.g. sociological, legal, and economic barriers), innovative solutions are now being developed in Poland. An increasing number of companies in the water and wastewater sector assume

that instead of taking on the responsibility of discharging wastewater, it can be recovered and reused, which is now recognised as a smart business practice that is beneficial to the profitability and efficiency of companies. Examples of such good practices are, described in this chapter, MPWiK in Wrocław and ZWiK Dziwnów. A framework for organisational decision-making processes for companies and utilities to facilitate the uptake of water reuse practices in their operations

6.4.2 MPWiK in WROCŁAW

Miejskie Przedsiębiorstwo Wodociągów i Kanalizacji Sp. z o.o. (MPWiK), with its registered office in Wrocław, is an entrepreneur within the meaning of Article 4(1) of the Act on Competition and Consumer Protection (i.e. Journal of Laws 2005, No. 244, item 2080, as amended) conducting business activity in the form of a single-member limited liability company. The entrepreneur's object of activity was defined, among other things, as "service activity in the field of water distribution" and "sewage disposal and treatment." The company is active in the above-mentioned areas in the Wroclaw Municipality. MPWiK is the only water supplier (100% market share) for the area. Under its current name, MPWiK, it has been operating since 1952. The company is growing dynamically and responds to the growing needs of the city and its residents by building new networks in areas with new residential and commercial developments.

It is one of the largest water supply companies in the country, open to innovative solutions applied in water and wastewater technology, including the use of modern IT tools.

MPWiK's water supply network is extremely extensive. It is 2035 kilometres long. The water that MPWiK supplies comes primarily from the mountains. It is drawn from the Oława River, which in turn is fed by the Nysa Klodzka River. The sources of the latter are located in the Sudeten Mountains. Mountain water accounts for 99% of the raw material used by MPWiK. The remaining 1% is water from a deep-water intake in Lesnica, which is supplied to residents of that neighbourhood.

The length of Wrocław's sewerage network, managed by MPWiK, is more than 1,418 km. After passing through the sewer system, wastewater goes to the Wroclaw Janówek Wastewater Treatment Plant. This is a mechanical-biological treatment plant with full sludge management.

Water in the water supply and sewage company plays a major role, especially in the water treatment plant, which enables the provision of drinking water of appropriate quality to the inhabitants. In the treatment process, it is used not only as a raw material for production but also as a factor enabling the maintenance of equipment (e.g. water for rinsing filters, maintaining the cleanliness of the facility, dilution and preparation of dosed reagents).

In wastewater treatment plants, where closed technological water loops are not available, tap water is used for the maintenance of the facility. In the elements of the technological line, where water used to maintain cleanliness or proper functioning of devices does not have direct contact with humans, and therefore, there is no microbiological risk, it is possible to use treated sewage.

MPWiK Wrocław currently supplies water to about one million two hundred people from Wrocław and the surrounding area (at the highest peaks, i.e. including tourists, students and, starting in 2022, a group of about 100,000 refugees from Ukraine). The Janówek wastewater treatment plant treats about 140 thousand m3 of wastewater per day.

One of the diagnosed risks is weather risk due to lack of water at intakes due to drought or increased concentrations of contaminant parameters in water during flood periods. This may result in a threat to the continuity of services and deterioration of water quality in the water supply network. To this aim, MPWiK plans to realise investments in the field of water intakes in order to maintain the quantitative and qualitative level of water supply for the urban agglomeration and to increase the

efficiency of the existing hydraulic systems. The most important investment activities in this field include the modernization of water intakes and the modernization of the water transmission pipe. The program to intensify infiltration processes in water-bearing areas is also being continued. As part of these activities, further reconstruction of irrigation ponds is planned. In terms of improving water quality, investments are planned to improve the technological processes of water production plants.

There is also a possible weather risk caused by heavy rain, i.e. uncontrolled overflows in the pipes, overloading of the treatment plants with rainwater, which may result in flooding of properties, uncontrolled overflows into surface waters and violations of environmental regulations.

To this purpose, MPWiK intends to build retention reservoirs on the combined sewer network, construct an alternative pumping system and build and reconstruct the sewer network within the city and in the suburbs of Wrocław (for newly developed areas). There is also a risk of late action in the case of water losses due to uncontrolled leaks from the water supply network.

MPWiK has been 'fighting' against hidden leaks since 2009 when water losses reached a level of 24 per cent. In 2016, a modern IT system was implemented to supervise the water distribution process and detect some of the most difficult to locate failures, the so-called hidden leaks. The innovative system (SmartFlow) uses Internet of Things (IoT) solutions and provides a tool for managing the water supply network. Implemented by MPWiK S.A., the solution has reduced water losses by almost 10 per cent. The implementation of the application has resulted in a much faster response time to irregularities, thanks to which the municipal company saved nearly half a billion litres of water per year.

The company is aware of the consequences of climate change and unpredictable weather phenomena, i.e. droughts or floods, which put pressure on water resources. This results in the need to implement technologies to ensure rational water

management. For these reasons, the company is investing in projects reusing treated wastewater, in line with the idea of a circular economy. One such solution is the use of closed cycles of process water in combination with wastewater treatment techniques. This solution has been applied at the "Janówek" Wastewater Treatment Plant (WOŚ) in Wroclaw.

The wastewater/process water reuse plant was expanded in 2010 - 2012 when the modernization and expansion of the Wroclaw wastewater treatment plant (Janówek) was carried out. Process water is used in the wastewater section for washing gratings from screenings, diluting polyelectrolyte concentrate and flocculant, cooling the sludge drying installation and condensate reception, for periodic rinsing of pipelines, excessive sludge thickeners, dosing antifoam agents, periodic cleaning of pilaster overflows and troughs in primary and secondary settling tanks, breaking up dross in secondary settling tanks, periodic rinsing of pumps and macerators in the biogas section on digesters.

There are also specially marked hydrants with process water spaced pointwise between facilities at the treatment plant. In the event of any fire at the treatment plant, process water is used for firefighting (e.g., if there is a failure on the water mains and a fire at that point).

In 2021, the technological water used for its own purposes was 2,900,508 m3, which accounted for 5.28% of the total volume of treated wastewater discharged into the Oder River. This value is increasing year by year.

In 2022, four retention tanks with a total capacity of more than 60,000 m3 were completed in Wrocław. The cost of the investment is PLN 80 million. They are designed to protect Wrocław during heavy rainfall and relieve the Oder River from overflows. Thanks to the investment, excess rainwater will be intercepted and transferred via the sewer network to the new retention tanks. The collected rainwater will only reach the Wrocław Sewage Treatment Plant (Janówek) when it is under less hydraulic load.

Identification of stakeholders:

External stakeholders

- State and local administration (State Water Holding Polish Waters, City Hall, County Office, Municipal Office);
- Neighbouring communes;
- Cooperating Institutions (universities, scientific institutes, laboratories);
- Control institutions (sanitary-epidemiological station, Environmental Protection Inspectorate, Regional Water Management Authority);
- Clients (individual, institutional);
- Companies and trade unions (Polish Waterworks Chamber of Commerce);
- Non-governmental organizations;
- Suppliers;
- Local society.

Internal stakeholders

- Employees (including management staff).

In January 2021, the City Council accepted the Long-Term Plan for Development and Modernization of Water Supply and Sewerage Facilities in Wroclaw for 2021-2025. The total value of MPWiK's planned investments is PLN 761.3 million. The plan includes investments related to the processes of water intake, water production and distribution, wastewater collection and treatment, as well as investment tasks related to supporting core activities, which include the development of digital systems to support the automation of technological processes, the area of ensuring the security of business continuity including cyber security, and purchases of specialized equipment. Projected expenditures for the purpose are summarized in Table 1.

Table. The annual expenditures in million PLN

Sphere of MPWiK processes	2021	2022	2023	2024	2025	Total	Total %
Raw water intake	0,9	7,7	11,1	9,0	11,5	40,1	5,3
Water production	7,2	20,0	23,2	10,0	2,0	62,4	8,2
Water distribution	13,2	9,1	7,0	4,7	4,2	38,3	5,0
Wastewater collection	92,1	63,6	52,9	37,9	32,9	279,5	36,7
Wastewater treatment	4,9	14,9	34,7	97,5	120,8	272,7	35,8
Support primary activities	24,2	13,4	10,8	13,9	6,1	68,3	9,0
TOTAL	**142,6**	**128,7**	**139,6**	**173,0**	**177,7**	**761,3**	**100**

Source: Long-term Plan for Development and Modernization of Water Supply and Sewerage Facilities for 2021-2025, 2021.

Implementation of the plan to the extent envisaged will be possible under the following assumptions. The company:

- will obtain approval of the tariff rate at the planned level,
- will obtain an investment loan for the implementation of part of the planned tasks,
- will receive financing in accordance with the assumptions of the financial plan.

The implementation of investments will also be financed by European Union aid funds. The assumed total share of aid funds in the total investment outlay in 2021-2025 will be 27.5%.

6.4.3 ZWiK DZIWNÓW

Water and sewage companies belong to the water and sewage management sector and are responsible for water collection, treatment and supply as well as wastewater disposal and treatment.

The condition of land, surface water and groundwater determines the quality of water intended for human consumption. The approach to water supply and sewage disposal, as well as rainwater management, has changed and evolved over the centuries depending on the needs of society and the stage of economic development. Initially, the most important thing was to provide the right amount of water. With time, attention was paid to its quality and the need to treat wastewater discharged into the environment (water or ground). Taking into account the water cycle in nature, the fact that water resources can be limited, and the fact that the quality of water is of great importance for people using it, has become the basis of sustainable development. Currently, an important aspect of the functioning of the sector is adaptation to climate change, especially with regard to water supply during periods of drought and rainwater management, but also with regard to the protection of critical infrastructure (against floods, storms, etc.). At the same time, the intensive development of various branches of industry, which has been observed since the end of the 17th century, has contributed to the pollution of the earth's surface, as well as to a reduction in the quality of surface waters (to which sewage is most often discharged, and partly also used to supply the population) and groundwater (used to supply the population). In addition, intensive farming contributes to soil and water pollution. Today, many areas require reclamation and this also affects the quality of groundwater.

The water and sewage management sector should be regarded as crucial not only from the point of view of the functioning of the economy but also from the point of view of meeting the basic needs of the country's inhabitants. Water and sewage management is a particularly important element of environmental protection as well as the human health and safety of society. Water supply belongs to the critical

infrastructure systems, playing a "key role in the functioning of the state [1] and the lives of its citizens"[2], and "protection of critical infrastructure is one of the priorities" of the state [3].

Collective water supply and collective wastewater collection are the tasks of the local government and are usually carried out by municipal companies. The sector is open to privatisation, although the share of private companies is still low (below 5%). Also, knowledge in the field of public-private partnerships is still low.

The functioning of enterprises in the sector is limited territorially (a commune or an agreement of communes) and financially (tariffs approved by the central regulator at the level available to the consumer). The development of enterprises is strictly dependent on the development of the municipalities served and the form of cooperation (operator contract, municipal company, budgetary establishment, etc.).

Barriers to the development of the water and sewage management and reclamation sector are also:

- limitations in running an integrated water and sewage management system based on economic and ecological efficiency,
- deteriorating water quality, new pollutants (micropollutants of industrial and agricultural origin),
- capital intensity, investment needs exceeding tariffs,
- lack of qualified employees in the labour market in terms of the needs of the sector.

From a business point of view, municipal water and sewerage companies are public organisations, which means that they are not typical profit-oriented corporate enterprises.

The Water and Sewerage Plant in Dziwnów performs the tasks of the commune in the collection, treatment and supply of water intended for consumption, as well as the collection, treatment and discharge to the sewage receiver.

It is a tourist commune in the coastal area, permanently inhabited by 4,000 inhabitants. In the summer season, the number of people using the commune's infrastructure increases to 40,000. The use of water resources in the summer season, due to the ten times greater number of inhabitants, generates problems with uneven water intake and the ability to supply water in the right amount, of the right quality and under the right pressure to all recipients.

There are constant water shortages. Intakes are more and more often contaminated with chlorides - in the season, the intakes are exploited so much that seawater may be drawn in.

Water cuts during the season or during long weekends (e.g. in May) exceed the capacity of water intake from sources. Water intakes are located in the commune of Wolin and other neighbouring communes, and not in Dziwnów, therefore, efforts are being made to find a solution to water shortages that could make the commune of Dziwnów independent in terms of water resources.Thanks to the use of the system for the reuse of backwash water in the water treatment process, up to 130 m3 of water can be saved.

Water in the water supply and sewage company plays a major role, especially in the water treatment plant, which enables the provision of drinking water of appropriate quality to the inhabitants. In the treatment process, it is used not only as a raw material for production but also as a factor enabling the maintenance of equipment (e.g. water for rinsing filters, maintaining the cleanliness of the facility, dilution and preparation of dosed reagents).

In wastewater treatment plants, where closed technological water loops are not available, tap water is used for the maintenance of the facility. In the elements of the technological line, where water used to maintain cleanliness or proper functioning of devices does not have direct contact with humans, and therefore, there is no microbiological risk, it is possible to use treated sewage.

ZWiK sells 500,000 m3 of water a year, and the annual sewage discharge to the receiver is 800,000 m3. The increase in the amount of sewage in comparison to the water collected results from the existence of a combined sewage system. Wastewater from the sewage treatment plant is directed to Struga Lewieńska, where the water flowing before discharge is of worse quality than after being diluted with inflowing sewage. In Dziwnów, there are constant water shortages.

Intakes are more and more often contaminated with chlorides - in the season, the intakes are exploited so much that seawater may be drawn in. Water consumption during the season or during long weekends (e.g. in May) exceeds the capacity of water intake from sources.

Identification of stakeholders:

External stakeholders

- State and local administration (State Water Holding Polish Waters, City Hall, County Office, Municipal Office),
- Neighburing communes,
- Cooperating Institutions (universities, scientific institutes, laboratories),
- Control institutions (sanitary-epidemiological station, Environmental Protection Inspectorate, Regional Water Management Authority),
- Clients (individual, institutional, tourists),
- Companies and trade unions (Polish Waterworks Chamber of Commerce),
- Non-governmental organisations,
- Suppliers,
- Local society.

Internal stakeholders

• Employees (including management staff).

Currently, the Water and Sewage Plant in Dziwnów has introduced the process of recycling water after filtering it back into circulation, which saves up to 130 m3 of water from intakes. The company's goal is to introduce treated sewage into the receiver and then at the lower point - water intake and re-purification and treatment.

The use of treated sewage to supply the watercourse, the water of which can be a source of water intended for consumption, would make it possible to close the water consumption loop. Such a solution would make it possible to avoid the over-exploitation of groundwater resources, which currently have a significant increase in salinity due to their enrichment with seawater.

Unfortunately, with the current legal status in Poland, the use of wastewater as a source of water for treatment (even to a small extent) is not possible. Legal barriers are the basic barriers preventing the introduction of new solutions in the field of closing water circuits. They largely result from social prejudices. In the minds of citizens, sewage functions as waste, not a water resource that can be used to reduce shortages.

6.4.4 SUMMARY & REFERENCES

Water supply and sewage companies, including water treatment plants and sewage treatment plants, are considered businesses in the environmental context. Their main aims are mainly environmental services related to water extraction and water supply as well as the collection and treatment of wastewater.

Unfortunately, in the era of climate change, population growth, and predicted increase in water demand (even 30%), the protection of resources and searching for new/alternative water sources are becoming crucial challenges for many institutions.

Many of them are already facing the problem of insufficient coverage of the water needs of their recipients. Therefore, water and sewage companies, due to the volume of water extraction and the amount of wastewater treated and discharged into the environment, face the real possibility of implementing a circular economy business model. In the case of sewage treatment plants, elements of circular economy, i.e. water recovery/wastewater reuse for the needs of plants, are becoming common practice. Unfortunately, water treatment plants still operate based on the linear economy model.

Treated municipal sewage might be a source of water (it can supply the region's water resources) and might be directed to purifying processes, as in the case of a classically operating water treatment plant. This is a known and used method around the world. Such an approach and a change in the economic model in Poland will require the introduction of appropriate legal regulations, the implementation of advanced purification methods and technologies, and the initiation of broad educational activities not only for the community but also for politicians and local decision-makers.

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Long-term Plan for Development and Modernization of Water Supply and Sewerage Facilities for 2021-2025, Wrocław 2021 (available at https://www.wroclaw.pl/dla-mieszkanca/przyjeto-plan-rozwoju-sieci-wodociagowej-i-kanalizacyjnej-na-lata-2021-2025, accessed 11.01.2024.

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Extended interview conducted by the project team with MPWiK employees on 21/12/2022.

7. NATIONAL CONTEXT IN POLAND - SUMMARY

Stable economic development in Poland in the last 30 years enabled water management activities and strategies in Polish companies. Introducing CSRD (Corporate Sustainability Reporting Directive, 2022) has also been fostering disclosing actions focusing on limiting negative environmental impacts, including water management.
Taking into account the case studies of Polish organisations described, the following recommendations are outlined:

1. Monitor water flows in the organisation in order to identify the possibilities of limiting the use of water or closing the water loop cycle.
2. Introduce water efficiency practices.
3. Implement rainwater and snowwater collection.
4. Close the water loop cycle (related to both core and support processes) whenever feasible. It might involve not only processing water recycling but also other water recovery activities, such as closing the cooling water cycle,
5. Introduce water policy and/or water management strategy in order to support meeting goals related to water management.

Following the above recommendations might be included in integrated or environmental reporting in order to improve the organisation's image.

REFERENCES

Long-term Plan for Development and Modernization of Water Supply and Sewerage Facilities for 2021-2025, Wrocław 2021 (available at https://www.wroclaw.pl/dla-mieszkanca/przyjeto-plan-rozwoju-sieci-wodociagowej-i-kanalizacyjnej-na-lata-2021-2025, accessed 11.01.2024.

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Extended interview conducted by the project team with MPWiK employees on 21/12/2022.

8. REPORT SUMMARY

This report showcased 19 different case studies of water-intensive companies in Germany and Poland. Each case study was evaluated based on data from the company's reports and literature, supplemented with interviews if needed. Overall, the chemical sector has a significant presence in terms of water consumption in both countries, characterized by diversity in water abstraction sources and proactiveness in closing the loop. Specifically, the strong impact of the companies in on-site local environments promotes efforts to reduce water consumption and treat wastewater, allowing for re-purposing and reusing, particularly in cooling systems. The same is evident in the oil, gas, and mining sector, while less quality data is available for the paper and packaging sectors. Throughout the case studies, the effect of climate change on the smooth and sustainable operation of the companies is highlighted in industries such as food and beverage and paper and packaging, where extreme weather phenomena could influence the availability and continuity of water supply and quality.

A significant challenge to water reuse uptake is also the managerial attitude towards water management and sustainability. For this reason, the report emphasises the importance of monitoring tools in the company, such as water intensity indicators, impact assessment on local water bodies or mapping water flows. Additionally, the establishment of robust and formalised guidelines for water management in the company can create opportunities to reduce water consumption and increase recycling possibilities. Communication and collaboration with other stakeholders and industries in the local area are key to sustainable water management, which can be better achieved through a clear company water management system.

However, the analysis of this report finds that internal reformation of corporate sustainability management cannot be addressed in isolation. Legal measures, such as quality and quantity requirements and monitoring, are essential in creating external incentives for the company to adopt water reuse practices. Furthermore, technological advancements are crucial in the efficiency of water reuse rates, and thus, promoting advanced water purification and treatment technologies could make water reuse both accessible and feasible.

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