

# Sustainability in brewing - What are the most effective strategies for reducing water usage in large-scale brewing?

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## Abstract

Water is a key ingredient and raw material in beer production. On average, large-scale breweries consume between 4 and 6 litres of water for the production of every litre of beer. Nowadays, sustainability is becoming increasingly important worldwide in this industry. As manufacturers strive to meet new demands from customers and communities, in line with the sixth Sustainable Development Goal, which aims to ensure access to water and sanitation for all, reducing water usage has become a key focus for environmental and operational efficiency. This study investigates the most effective strategies for minimising water consumption in large-scale brewing operations. Through a combination of literature review, case studies, and industry data analysis, the research identifies best practices across several stages of the brewing process, such as water recovery and reuse, clean-in-place optimisation, real-time monitoring technologies, and dry-cleaning methods for equipment. Case studies from global leaders such as Anheuser-Busch InBev SA/NV and Heineken N.V. illustrate how innovations in water recycling and brewery processes contribute to substantial water savings. The findings suggest that while technology plays a critical role, organisational culture and strategic investment are also key to achieving long-term reductions. In this research, I would like to look at domestic trends as well as those of the major international manufacturers.

**Keywords:** sustainability, brewing industry, water conservation, SDG 6, clean-in-place

**JEL Classification:** Q25, Q01, L66

## Introduction

Nowadays, sustainability has become a key topic for the global food and beverage industry, including beer production, due to growing environmental pressures, resource shortages, and increasingly demanding consumer expectations. Among the most important questions, water consumption is particularly critical in brewing, where global production reached 1.88 billion hectolitres (hl) in 2023, led by China, the United States, and Brazil (Statista, 2025). Since water is not only used as a raw material in the production of these products, but also for the cleaning, washing and packaging processes, this type of production highlights the water-intensive nature of beer production. Thanks to these, large-scale breweries play a prominent role in both production and resource use. World's largest brewing conglomerates such as Anheuser-Busch InBev SA/NV (AB InBev), Heineken N.V. (Heineken), Carlsberg A/S (Carlsberg), Molson Coors Beverage Company (Molson Coors), China Resources Snow Breweries Ltd. (CR Snow), and Tsingtao Brewery Co., Ltd. (Tsingtao) operate hundreds of breweries around the world, often in water-stressed regions. Considering these circumstances, increasing and improving the efficiency of water use is an important aspect for these companies, and would be an important condition for our long-term successful operation, in addition to their environmental responsibility.

This research will focus exclusively on large-scale, commercial brewing companies, which typically have higher absolute water consumption and greater access to water-saving

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technologies than small craft beer producers. The selected large-scale companies account for nearly 60% of global beer production, so their practices are highly significant. AB InBev leads the list with an annual beer output of 506 million hl, followed by Heineken with 243 million hl, Carlsberg with 101 million hl, Molson Coors with 84 million hl, CR Snow with 112 million hl and Tsingtao with 74 million hl (Figure 1, Statista, 2024).



**Figure 1:** Beer output of the world’s largest brewing conglomerates (million hl)

**Source:** <https://www.statista.com/chart/25485/the-worlds-largest-beer-brewing-companies/>

“The brewery industry is among the most water-intensive sectors, typically consuming 4–6 L of water for every litre of beer produced, necessitating a strong focus on water sustainability.” (Diro, Angassa, Gebremeskel, Abewaa, & Mengistu, 2024, p. 1) This value may vary depending on the facility design, location, manufacturing technology used and local regulations. However, the majority of this amount is used not for product production but for clean-in-place (CIP) systems, boiler feedwater, packaging, and wastewater treatment. The potential inefficiency of these processes contributes to higher water consumption, which is especially important in production units that are already located in water-scarce areas. To reduce this, these conglomerates are paying closer attention to reducing water use during product manufacturing.

The aim of the research is to identify and examine the most efficient water use strategies applied in the sector. With the evaluation of the practices from the six major breweries, the study aims to:

- Compare their current water efficiency metrics.
- Examine the strategies and technologies that they use.
- Practical challenges in implementation.

**Literature review**

During the keyword search in the Scopus database, the research used the following criteria (Table 1) for the period between 2005 and 2025:

## Search terms and keywords

beer  
brew\*

water use\*  
water cons\*  
water eff\*  
wastewater

**Table 1:** *Scopus search terms and keywords*

**Source:** *Author's own compilation for Scopus database search of the research topic (2005–2025)*

This resulted in 3881 documents, mainly technical papers on brewery wastewater treatment and CIP system optimisation (for example: Fillaudeau et al., 2006; Olajire, 2020); however, the number of comprehensive comparative assessments is low. In addition, companies are constantly working to improve this area by introducing new technical solutions and processes to reduce their water consumption.

Water conservation has become a pressing sustainability issue in the brewing industry as global demand for beer continues to grow while water scarcity worsens. Brewing is inherently water-intensive; studies estimate that an average of 3 to 7 litres of water is required to produce one litre of beer, depending on the operational efficiency of the producer and the plant design or technologies (Olajire, 2020). An important metric in water conservation within the brewing sector is the water-to-beer ratio (litres of water/litre of beer, L/L) – the volume of water used per litre of beer produced. This ratio varies across companies and geographies. Another important metric is water footprint. In the context of brewing, the water footprint refers to the total volume of freshwater used directly and indirectly in the production of beer. This includes direct water use within the brewery – such as for brewing, cleaning, and cooling – as well as indirect water use associated with raw material cultivation (e.g., barley and hops), packaging production, distribution and logistics. A comprehensive understanding of the water footprint helps breweries identify opportunities for water conservation across the entire supply chain, not just at the production site (Hoekstra et al., 2011).

Literature review and company reports suggest that more standardised benchmarking and comparative data are needed across firms and regions to enable better performance comparisons within the industry, due to different reporting solutions (companies use partly different measurement solutions, and the results may differ significantly between regions) and local regulatory requirements. Existing literature presents various strategies to reduce water consumption, for example, CIP (Clean-in-Place) optimisation, membrane bioreactor systems (MBRs) for wastewater treatment and reuse, dry conveyor lubrication, and real-time monitoring with IoT sensors (Olajire, 2020). In addition to the Scopus search, the research also included a review of the annual sustainability reports of the 6 selected companies, which I accessed on the companies' websites. In the case of AB InBev, Heineken, Carlsberg, CR Snow, and Tsingtao, their 2024 annual sustainability reports were already available during the research preparation phase, but for Molson Coors, only the 2023 annual report was available. The objective of this research is to identify and evaluate the most effective and innovative water-reduction strategies from these companies. In addition to the companies' self-reported data, this study also incorporates insights from independent research and international organisations to enhance objectivity. Global assessments from the World Bank (2021), Organisation for Economic Co-operation and Development (OECD, 2018), and World Wide Fund for Nature (WWF, 2024) highlight water scarcity challenges and industry benchmarks beyond company disclosures. These external perspectives provide a valuable counterbalance to corporate self-reporting.

## Conceptual framework

This research paper adopts the Triple Bottom Line framework (Elkington, 1998), which emphasises the interdependence of environmental, economic, and social dimensions in evaluating sustainability. In this approach, environmental objectives are addressed from the perspective of the planet, social goals from the perspective of people, and economic goals from the perspective of profit.

The water conservation strategies employed by large-scale beer producers reflect these three dimensions. Environmentally, they reduce ecological impact by lowering water consumption, reducing wastewater discharge, and improving resource efficiency. Economically, such strategies can lower operational costs, reduce compliance risks, and enhance long-term resilience in water-scarce regions. Socially, initiatives such as community water replenishment, stakeholder engagement, and alignment with SDG 6 (Clean Water and Sanitation) contribute to community well-being and the social license to operate. By framing water-use reduction within the Triple Bottom Line framework, this study can evaluate not only technical efficiency but also broader implications for sustainable development. This framework provides a useful structure for comparing the efforts of different firms and understanding their alignment with global sustainability goals, particularly in water-stressed areas. Moreover, the integration of the Triple Bottom Line framework with empirical performance metrics – such as water-to-beer ratio, reuse rates, and watershed engagement – offers a balanced approach to analysing sustainability practices in the brewing industry.

## Methodology

### *Research Design*

This research uses a comparative case study approach to evaluate the effectiveness of water-reduction strategies among the global leaders of the brewing industry: AB InBev, Heineken, Carlsberg, Molson Coors, CR Snow (China Resources Snow Breweries), and Tsingtao Brewery. The study uses the companies' annual sustainability and ESG reports as the basis for comparison, supported by relevant academic literature. The goal is to systematically compare each company's performance and practices, identify best-in-class strategies, and evaluate their potential for broader industry adoption.

### *Data Sources*

Primary data is the company's official sustainability or annual ESG reports for: according to the following:

- AB InBEV – 2024 Annual Report,
- Heineken – Annual Report 2024,
- Carlsberg – Annual Report 2024,
- Molson Coors – 2024 Our Imprint Report (2023 progress),
- CR Snow – 2024 Environmental, Social and Governance report,
- Tsingtao – 2024 Environmental, Social and Governance report.

These reports were selected because they represent each company's most recent and comprehensive self-disclosure on environmental performance, water use, and sustainability initiatives. This study also considered verification data to validate company reports. Sources such as the Global Reporting Initiative (GRI, 2023) and Aqueduct Water Risk Atlas (WRI, 2023) were reviewed to provide reliability to the figures disclosed by companies.

As secondary data, the research uses Peer-reviewed academic literature on water usage in brewing (e.g., Olajire, 2020; Fillaudeau et al., 2006) and international frameworks:

- The Water Footprint Assessment Manual by Hoekstra et al. (2011),
- United Nations Sustainable Development Goals (specifically SDG 6: Clean Water and Sanitation).

### ***Data collection***

The following document review method was used to analyse and interpret data from the reports. The process included the identification and recording of reported water-to-beer ratios such as hectolitre/hectolitre (hl/hl), or equivalent water use metrics such as cubic meter/kilolitre (e.g., m<sup>3</sup>/kL), extracting descriptions of water reduction strategies, including technological innovations (e.g., dry lubrication, membrane bioreactors), management systems (e.g., real-time monitoring), and community projects (e.g., watershed restoration), and recording regional or site-specific water initiatives (particularly in water-stressed areas). Performance metrics (e.g., water-to-beer ratio) were compared across companies.

### ***Limitations***

This study is based on self-reported company disclosures, which may vary in detail, format, and verification standards. Differences in reporting methods — such as the use of different measurement units (e.g., hl/hl vs. m<sup>3</sup>/kL) — complicate direct comparisons across firms. In addition, water footprint assessments are not applied or reported uniformly, which means some data are only approximately comparable. The analysis primarily focuses on operational water consumption — that is, water used within the brewery facilities for production, cleaning, and packaging processes. However, indirect water consumption, including water used in the cultivation of raw materials like barley and hops, or in the production of packaging materials, also contributes significantly to a brewery's total water footprint. These upstream and downstream impacts are not fully captured in this study. To address this gap, future research should incorporate Lifecycle Assessment (LCA) methodologies to account for water use across the full value chain. This would enable a more comprehensive evaluation of sustainability performance and provide a better understanding of each company's overall water impact. Moreover, future analyses should extend beyond operational water use to systematically include supply chain impacts, particularly in raw material cultivation (e.g., barley, hops), packaging production, and logistics activities. Studies show that indirect, supply chain-related water consumption can far exceed direct operational water use, often accounting for over 70% of the total water footprint of brewing (Hoekstra & Mekonnen, 2012; Ridoutt & Pfister, 2010).

### **Strategies and results for water reduction**

Major global brewers have adopted a range of strategies to improve water efficiency, reduce consumption, and mitigate water stress in their supply chains. A central metric for assessing operational sustainability in brewing is the water-to-beer ratio, typically measured in hectolitres of water per hectolitre of beer (hl/hl) or litres of water per litre of beer (l/l). This indicator is an accepted tool for comparing efficiency across the entire sector, so the performance of different production plants within conglomerates is also compared using it. The 2024 reports reveal notable variations across the six companies:

#### ***AB InBev***

AB InBev has prioritised water stewardship, especially in high-stress areas. In 2024, the company reported a 20% improvement in water-use efficiency compared to its 2017 baseline, reaching 2.47 hectolitres of water per hectolitre of beer (hl/hl), which means a 2.47:1 ratio.

Moreover, 89% of AB InBev's sites targeted for its 2025 goals were showing measurable improvements in watershed health (AB InBev, 2024).

### ***Heineken***

Heineken operates under its "Brew a Better World 2030" framework and achieved an average water usage of 3.1 hl/hl globally in 2024 (3.1:1 ratio), with 3.0 hl/hl in water-stressed areas (3.0:1 ratio). It is on track to meet its 2030 targets of 2.9 hl/hl globally (2.9:1 ratio) and 2.6 hl/hl in water-stressed regions (2.6:1 ratio). The company's approach includes brewery-level water optimisation programmes and community water balancing efforts across 36 sites (Heineken, 2024).

### ***Carlsberg***

Carlsberg has made substantial improvements in water efficiency through its "Together Towards ZERO and Beyond" (TTZAB) strategy. The group reported usage rates of 2.5 hl/hl globally (2.5:1 ratio) and 2.2 hl/hl in high-risk areas (2.2:1 ratio), representing 31% and 44% improvements, respectively, compared to its 2015 baselines. It also initiated off-site water replenishment projects in China and Laos to enhance local water resilience (Carlsberg Group, 2024).

### ***Molson Coors***

Molson Coors reported a global water-to-product ratio of 3.41 hl/hl in 2023 (3.4:1 ratio). Its best-performing site in Trenton, Ohio, achieved a water usage rate of 2.56 hl/hl (2.56:1 ratio). The company attributes these results to automated clean-in-place (CIP) systems, local watershed investments, and performance monitoring tailored to regional risk profiles (Molson Coors, 2024).

### ***CR Snow***

CR Snow, operating under the China Resources Beer group, implemented an extensive efficiency program through its Green Factory Plan. Its national average water consumption was 2.88 cubic meters per kilolitre of beer (m<sup>3</sup>/kL), surpassing many Western competitors (2.88:1 ratio). CR Snow's measures include water recycling, advanced bottle washing systems, and government-aligned environmental audits (China Resources Beer, 2024).

### ***Tsingtao***

Tsingtao Brewery aims to reduce water use per unit of beer by 23% by 2025 (compared with 2019 levels). Initiatives include internal water recycling, rainwater harvesting, and process upgrades across 57 operational facilities. The brewery incorporates water risk into its broader ESG framework and has received third-party assurance for its disclosures (Tsingtao Brewery, 2024).

### ***Companies' comparison table and key strategic themes***

Companies like Heineken use MBR to filter and treat wastewater to a level which is suitable for non-production activities. AB InBev and Carlsberg implemented dry lubrication systems that eliminate the use of water-based lubricants on bottling lines. CIP systems, which account for a large share of water consumption, are being upgraded with automation and rinse-water reuse, reducing total cycles and improving efficiency. Molson Coors and AB InBev have adopted AI-based monitoring tools to refine CIP schedules further and detect inefficiencies (AB InBev 2024, Molson Coors 2024).

**Table 2:** Comparison table for water-to-beer ratio and goal/target based on reports  
**Source:** Author's compilation based on company sustainability/ESG reports (AB InBev, 2024; Heineken, 2024; Carlsberg Group, 2024; Molson Coors, 2024; China Resources Beer, 2024; Tsingtao Brewery, 2024)

Company	Water-to-beer ratio (2024)	Goal/Target
AB InBev	2.47 hl/hl (global average)	2.0 hl/hl in water-stressed areas by 2025
Heineken	3.1 hl/hl (global), 3.0 hl/hl (stressed)	2.9 hl/hl globally by 2030
Carlsberg	2.5 hl/hl (global), 2.2 hl/hl (high-risk)	1.7 hl/hl in high-risk areas by 2030
Molson Coors	3.41 hl/hl (global); 2.56 hl/hl (best site)	2.8 hl/hl by 2030
CR Snow	2.88 m <sup>3</sup> /kL (~2.88 hl/hl)	Improve factory-level standards annually
Tsingtao	Not disclosed; -23% by 2025 vs 2019	Targeted reduction in per-unit usage

This data (Table 2) shows that Carlsberg and AB InBev lead in overall efficiency, while Molson Coors and Heineken remain above the global best-practice threshold of 3.0 hl/hl. CR Snow's reported figure is highly competitive given its operational scale in China.

Key Strategic Themes Identified:

- Clean-in-place (CIP) optimisation: all companies deploy automated CIP systems that reduce rinse cycles and recycle final rinse water
- Water reuse and internal recycling: internal recycling systems to collect lightly used process water for reuse in cleaning, cooling, or utilities
- Digitalisation and real-time monitoring: all companies emphasise the use of IoT meters, sensors, and AI analytics
- Watershed and community engagement: leaders like AB InBev and Carlsberg engage in watershed replenishment projects in high-risk areas
- Policy-Driven Efficiency (CR Snow and Tsingtao): Chinese brewers operate under strict national water quotas and align with state environmental strategies

### ***Stakeholder engagement***

In addition to the efficient operation of companies, the appropriate level of stakeholder involvement and commitment in water management is key. Companies like AB InBev and Carlsberg have already initiated watershed projects in partnership with local communities and various non-governmental organisations (NGOs) to help restore natural water cycles and strengthen their connections with local communities. These initiatives show that sustainable beer production is not just a technical challenge, but also a social responsibility.

### **Findings**

This research revealed that, while all six brewing companies have committed to reducing water usage, their strategies vary significantly across geographical differences, regulatory environments, technological maturity, and operational scale (Table 3). The results measured and achieved by companies differ from one another. Carlsberg achieved the lowest average water-to-beer ratio (2.5 hl/hl globally, 2.2 hl/hl in high-risk areas), closely followed by AB InBev at 2.47 hl/hl, and leads in watershed-based community engagement. Molson Coors lags slightly with a global average of 3.41 hl/hl but demonstrates the best regional practices (2.56 hl/hl at its Trenton facility). CR Snow and Tsingtao, despite less international exposure, report

competitive efficiency levels (~2.88 hl/hl and a 23% reduction target, respectively), heavily influenced by China’s national environmental policies.

**Table 3: Effective strategies identified**

**Source:** Author’s synthesis based on company reports (AB InBev, 2024; Heineken, 2024; Carlsberg Group, 2024; Molson Coors, 2024; China Resources Beer, 2024; Tsingtao Brewery, 2024) and academic literature (Fillaudeau et al., 2006; Olajire, 2020)

Strategy	Observed Effectiveness	Company Examples
Clean-in-Place (CIP) Optimisation	Reduced water use by 10–30% in cleaning operations	AB InBev, Carlsberg, Molson Coors
Water Reuse and Recycling	Up to 25–40% reuse in cleaning and cooling	All companies
Real-time Monitoring & IoT	Enabled leak detection and process improvements	Heineken, Tsingtao, AB InBev
Watershed Stewardship	Local water improvements beyond brewery gates	AB InBev, Carlsberg
Government Compliance & Factory Auditing	Improved performance via structured policy alignment	CR Snow, Tsingtao

As part of their technical leadership, Carlsberg’s Fredericia pilot brewery achieved 1.4 hl/hl through full recycling and AI-led optimisation. AB InBev implemented a 7-step watershed assessment tool and extended the tool to 89% of its high-risk facilities. CR Snow deployed innovative mechanical solutions, such as intermittent spray washers. Chinese companies (CR Snow, Tsingtao) benefit from strong regulatory mandates under China’s Green Factory certification system. European and U.S. firms (Carlsberg, Heineken, Molson Coors) generally provide more detailed and assured disclosures, while Chinese brewers report progress but with less consistent metrics or third-party verification. Geographic context plays a significant role in shaping corporate water strategies. Breweries in high-stress areas, such as parts of China and sub-Saharan Africa, are often subject to stricter regulatory oversight or community pressure. Companies like CR Snow benefit from China’s top-down Green Factory certification, while European brewers face robust disclosure expectations from ESG frameworks. These factors contribute to the strategic diversity observed across firms.

## Conclusion

This research concludes that no single strategy alone is sufficient to reduce water usage in large-scale brewing significantly. Instead, the most effective companies adopt a multi-tiered approach that combines operational efficiency, technological innovation, and external water stewardship. Carlsberg emerges as a best-practice leader due to its low water-to-beer ratios, ambitious targets, and implementation of circular water reuse systems. AB InBev excels in community-focused watershed programs and strong alignment with local water regulations. CR Snow and Tsingtao show that regulatory compliance and localised innovation can rival global sustainability standards. Heineken and Molson Coors have made steady progress but could benefit from more ambitious reuse strategies and deeper engagement in water-stressed regions. Lower-performing firms should prioritise site-specific benchmarking, accelerate the adoption of advanced technologies (e.g., AI-driven monitoring), and pursue cross-sector collaboration to improve water-use efficiency. Learning from industry leaders and adapting their successful practices will be essential for continued progress. To support this, the development of a comprehensive benchmarking tool is recommended. Such a tool should standardise performance metrics (e.g., hl/hl or m<sup>3</sup>/kL), integrate data from reliable external sources (such

as regional water stress indicators), and allow comparison across company sites. This would enable regulators, companies, and stakeholders to identify top-performing facilities and promote the dissemination of best practices across the industry. A potential contribution of future research would be to pilot such a standardised benchmarking tool. This could integrate both company reports and independently verified data (e.g., GRI, WRI) and apply consistent metrics across firms. Piloting the tool in selected breweries or regions would allow for practical testing, refinement, and wider adoption across the industry (BIER, 2023).

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## Abbreviations

The following abbreviations are used in this manuscript:

CIP	Clean-in-Place
GRI	Global Reporting Initiative
hl	Hectolitre
hl/hl	Hectolitre/hectolitre
kL	Kilolitre
LCA	Lifecycle Assessment
L/L	Litre/litre
MBRs	Membrane Bioreactor Systems
m <sup>3</sup>	Cubic meter
m <sup>3</sup> /kL	Cubic meters per kilolitre
OECD	Organisation for Economic Co-operation and Development
SDG	Sustainable Development Goals
SDG 6	Sustainable Development Goals, Clean Water and Sanitation
WWF	World Wide Fund for Nature

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