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Water Use and Efficiencies in Refineries

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Water Use and Efficiencies in Refineries

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ABSTRACT

This report has been prepared by ERM for Concawe with the aim of describing current water use in EU refineries, establishing the refining water footprint, and examining alternatives practices which may help to reduce future stress on local freshwater resources. Water uses in refineries fall into three categories; 1) process water (for distillation, stripping, cracking and boilers), 2) cooling water, and 3) other non-process water (firefighting, cleaning, etc.). This review is in preparation for the upcoming updates to Best Available Techniques (BAT) Conclusions relevant to the fuel manufacturing industry. The objective was to better understand the industry water efficiencies measures, their applicability and their drivers for implementation. A combination of desk-based literature reviews, data visualization techniques, member interviews, and digital surveys have been used to describe trends in water stress and scarcity across Europe up to 2030, evaluate available water stress tools, identify and define common water metrics, review Concawe member water data (2019), and collate information about members experience with water use, water efficiency techniques, and other related topics.

It was concluded that water stress varies by region across Europe with southern Europe experiencing the greatest impact of water stress, northern regions being heavily populated which impacts (fresh) water availability, and eastern and western regions being largely affected by seasonality resulting in droughts and floods. The greatest challenges regarding the implementation of upcoming changes to the REF BREF are likely to include; a lack of baseline monitoring on which to base ‘reduction’ efforts, difficulty implementing new techniques into existing facilities due to economic or spatial challenges, varying degrees and types of water stress, and the impact of increased reuse on treatment and discharge of wastewater (concentration of contaminants) alongside other cross media effects. Finally, there is a need to have clear definitions for the terms water use, water withdrawal and water consumption in order to derive meaningful metrics that could be used for deriving BAT Conclusions on water use.

KEYWORDS

Water; wastewater; freshwater; water use; water efficiency; water stress; techniques

INTERNET

This report is available as an Adobe pdf file on the Concawe website (www.concawe.eu).

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SUMMARY

Under the Industrial Emissions Directive (IED) (2010/75/EU), the European Commission (the Commission) is required to undertake a process of drawing up and reviewing Best Available Techniques (BAT) for relevant industry sectors. The Refineries sector BAT conclusions were last reviewed and adopted in 2014 under Commission Implementing Decision establishing BAT on industrial emissions for the refining of mineral oil and gas in October 2014 (2014/738/EU). It is expected that the Commission will commence the next review of Refinery sector BAT in due course. The process of exchanging information and preparing draft and final versions of the BAT conclusions and associated Reference document (BREF) normally takes 5-8 years (according to the newly revised IED, the duration of the exchange of information shall not exceed four years for each individual BAT reference document from now onwards, with then a 4-year period for existing industry to comply). For the purposes of this report references to the review of the Refinery (REF) BREF should be taken to mean the process of review and adoption of BAT conclusions for the Refinery Sector.

ERM has undertaken this report at the request of Concawe in preparation for the process of review of the REF BREF, with the aim of describing current water use in EU refineries, establishing the refining water footprint, and examining alternatives practices which may help to reduce current and future stress on freshwater resources. Water uses in refineries fall into three categories; 1) process water (for distillation, stripping, cracking and boilers), 2) cooling water, and 3) other non-process water (firefighting, cleaning, etc.).

ERM conducted a desk-based literature review of the current thinking and planning within Europe to summarise the current and projected types of water stresses in Europe, magnitude of water stresses in Europe, and the geographical distribution of different types of water stresses. An assessment of projected water use in Europe (Medarac et al, 2018) suggests that overall water demand in the oil refining industry has declined since 2015 and will continue to decline by nearly 10% in 2050 compared to 2015. The same report suggests there will be an overall decline in water use in the energy transformation by 2050.Given the early stage of this transformation however there are few specific studies available. There is e.g. no data on water intensity for 'full scale' hydrogen production – furthermore, there is little agreement on standard methods for calculating water intensity and as such, compiling robust data sets for meaningful comparisons with traditional refining is very challenging.

The European Environment Agency (EEA) report that one third of European countries or associated river basins have a relatively low availability of water. Among all uses, industry use remains to be the use with largest [] withdrawal (water withdrawn from a water body)of water in Europe, with agriculture being the largest consumer (water withdrawn minus the water returned to a water body of same type). Industry use include the energy sector activities such as electricity production, primary energy production and oil refineries, and within which electricity production represents more than 90% of water withdrawal in the energy sector in EU-27 and UK. It is expected that precipitation will continue to change in future years, with an increase in mean annual precipitation in northern Europe and a decrease in southern Europe, along with prolonged periods of drought and episodes of more intense rainfall. It is expected that there will be significant changes in the seasonality of river flows across Europe with summer flows expected to decrease for most of Europe.

Concurrently, ERM also carried out a high-level evaluation of the strengths and weaknesses of the various water scarcity tools used in Europe and relevant global tools. This considered the scale of assessment, the range of stresses measured by the tools, the selection of inputs, and at a high level, the algorithms or calculations used to derive the assessment.

A matrix of definitions was created and cross-checked with members during the interviews and via the digital survey. It was found that while Concawe members often broadly follow the same definitions of water terminology, with many subscribing to the IPIECA definition of 'freshwater , there are variations which are often dependant on the local environment and requirements. For many other water-related terms, members have no official internal definitions, and no industry wide standard exists.

The Concawe Water Use/ Effluent Quality Survey for the reporting year 2019 showed that 21% of all water reported was withdrawn from freshwater sources including surface water, groundwater, purchased fresh water and rainwater. The other 79% was brackish/ salt water.

ERM conducted interviews with 6 Concawe members to discuss their experience with current, planned and considered, water reduction/efficiency practices and techniques, reasoning for adoption or not of efficiency techniques, water metric terminologies, water metric targets and other reporting indices (e.g. intensity of water use), experience at operations with water stress, both existing and anticipated in the future, and key operational sensitivities regarding water use and stress. A digital survey was also produced, the results of which largely supported the finding of the interviews and provided more technical detail where requested.

The key industry challenges identified were:

- No standardised definition of freshwater or other water-related terms.
- A general lack of baseline monitoring makes reduction difficult to plan for or achieve.
- Different challenges in different environments, simply reducing freshwater withdrawal may not always be the best solution for example, in locations where water quality is a greater concern than water quantity or where water availability is not a primary concern.
- Improvement likely to be a better objective to focus on, however, this still requires baseline monitoring.
- Water Framework Directive is all about context and improvement so this approach would be aligned.
- Reductions in discharge volumes causing increased concentrations of contaminants in smaller volumes of wastewater. Concentration based limits may then be exceeded although the mass output of pollutants remains unchanged. Therefore, in order to encourage and enable economically viable water reclamation and reuse, it is important that this be accompanied by legislative flexibility that allows the establishment of discharge limits that, in addition to protecting the receiving environment, are compatible with the reclamation and reuse of discharge water as a substitute for freshwater. It is worth nothing that such flexibility does exist in the IED (article 15(3)b) but local implementation may vary.
- Modifications to existing (older) installations/ facilities may not be possibly or economically feasible to achieve required improvements.

Through discussions with operators, it is clear that the energy production process is undergoing significant evolution and that new products and techniques are going to have an impact on sourcing of water at refineries. This includes, but is not limited to, generation of blue and green hydrogen and the adoption of CCS techniques. These aspects are out of scope in terms of current considerations of the potential water demand.

1. BACKGROUND

The Commission Implementing Decision on industrial emissions, for the refining of mineral oil and gas, the Best Available Techniques (BAT) Conclusions, 2014 is likely to be revised in the coming years and more focus is likely to be given to preservation of freshwater resources in the revised document. The additional focus on freshwater resources is on the context of increased pressure on water resources linked to population and industry growth along with climate and environmental factors.

In preparation for a revision of BAT Conclusions, Concawe and its members have undertaken a data gathering project to "describe which type and how water is used within European[1] refineries in order to get a clear picture about our refining footprint and evaluate alternatives to reduce water consumption and reduce stress on freshwater".

The project involved desktop studies to:

- Describe trends in water scarcity and stress in Europe up to 2030 and available tools used to determine water stress;
- Identify a standard and common suite of water metrics currently used by members; and
- Summarise, using Concawe member data from 2019, a baseline of water metrics.

Additionally, a data-gathering questionnaire was sent to selected sites and several corporate member staff were interviewed to collate their experience of the type of water use, water efficiency mechanisms and costs, and environmental effects of water use.

The information in this report is intended to provide Concawe and its members with an information set which highlights the direction of travel around water management in refineries alongside some of the potential technical and procedural challenges that an update to the REF BREF may present the industry.

1.1. STRUCTURE OF THE REPORT

The four parts (**Figure 1**) to this project are strongly interlinked:

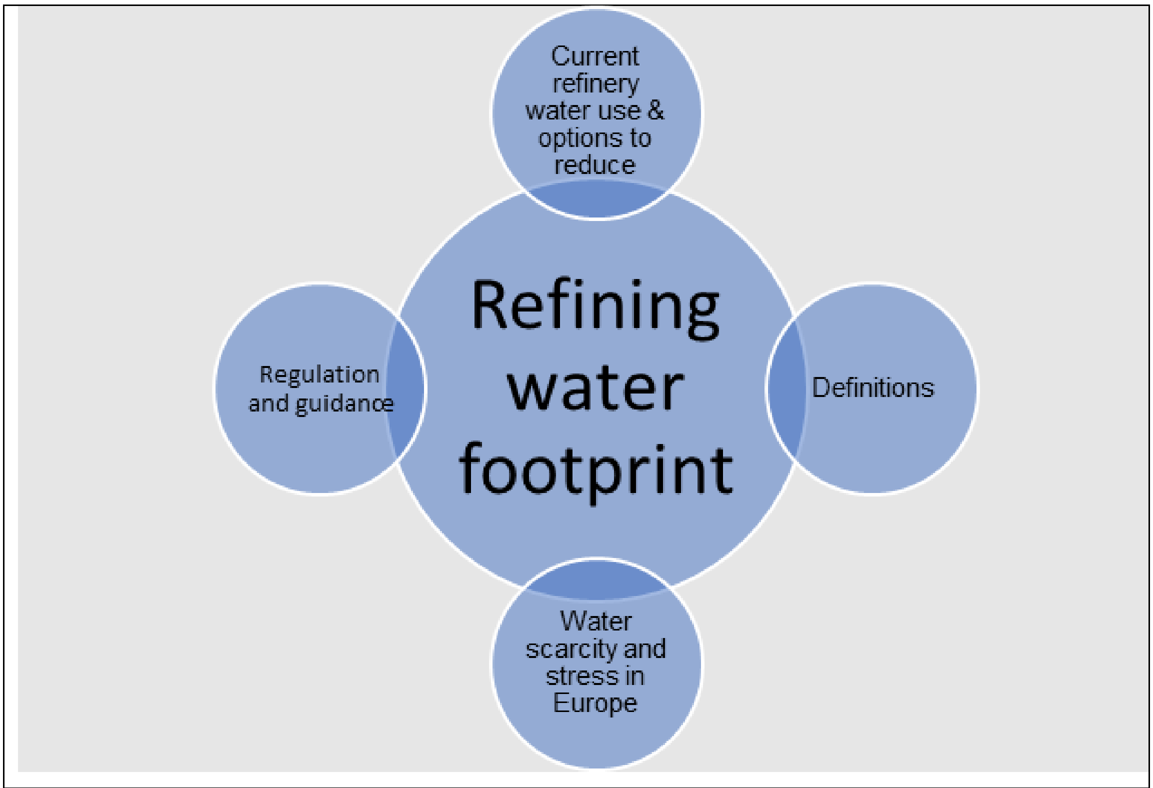
- The focus of this study is availability and use of water, specifically freshwater;
- The current uses and opportunities for water savings indicate where water of a certain quality is absolutely required and where substitutes may be made;
- The context of EU regulation is critical due to the anticipated changes; and
- Definitions are important in terms of understanding and communicating targets and compliance whilst remaining operational.

[1] Note that the scope of this report covers refineries within the UK as well as the EEA. Several of the reports referred to are EU documents which include data from the UK and Norway, exceptions are identified. It is not currently clear whether or how the UK will adopt the changes in the IED. For the purposes of this report, it is assumed that they will apply equally to refineries in the UK. The term 'Europe' is used in this document to include the UK.

All these aspects are interdependent and hence there is no single logical order to describe the findings of this project. The report is structured as follows but could be read in different orders, depending on the focus and interest of the reader:

- Section 2 lists key definitions regarding water use in refineries and proposes common terms to be used across all Concawe member organisations for clarity and consistency. This will also enable the impact of terminology introduced in the REF BEF update to be considered promptly and to enable engagement by Concawe and its members through any consultation phase.
- Section 3 describes water use and efficiency measures at refineries (globally) from professional experience, literature reviews, and data from Concawe member interviews and questionnaires.
- Section 4 summarizes the current understanding of water scarcity and stress in Europe up to 2030 based on literature reviews. The use, advantages and disadvantages of commonly used water scarcity mapping tools are also listed.
- Section 5 presents graphical summaries of the refinery water balance data provided by members in the 2019 survey and questionnaires/interviews for this project.
- Section 6 presents the list of references consulted.

Figure 1 Interlinkages of the important influences on a refinery water footprint



2. DEFINITIONS

2.1. INTRODUCTION

Europe's waters and wetlands are under pressure from water pollution, over abstraction of water and physical changes and climate change is expected to exacerbate many of these pressures (EEA, 2019). As such, revisions to EU legislation, such as the Industrial Emissions Directive (IED) and the linked Refineries sector Best Available Technique Conclusions (REF BATC) are likely to give more consideration to preservation of freshwater resources. With that in mind, Concawe members have set out to understand and quantify their current water uses. In order to do this, a common set of definitions for key terms is required as there are often no consistent definitions for many of the terms used in an industrial context and in water literature.

In the following sections, suggested definitions for freshwater and water stressed areas are presented, along with a summary of terminology for water use. Additional definitions are presented in the tables below. There is no available industry standard definition for 'water intensity', this term is typically locally defined by individual companies or regulating bodies.

Definitions are taken directly from the sources cited within the table and are not created or adapted by ERM, these are intended as reference of available definitions only. The following list is not exhaustive but should be inclusive of key industry definitions.

Freshwater

Company / Organisation	Freshwater Definition
GEMI Local Water Tool	The constituent content of freshwater should be defined by local regulations. In the absence of local regulations, [companies] should determine best definition for a site based on company policies and global guidelines. A limit of 1,000 mg/L of total dissolved solids (TDS) (the limit set by the World Health Organisation) should be used in absence of company policies.
International Petroleum Industry Environmental Conservation Association (IPIECA)	The definition varies in accordance with local statutes and regulations. Where it is not defined by local regulations, fresh water is defined for reporting purposes as non-brackish water and may include drinking water, potable water, water used in agriculture, etc. The total dissolved solids (TDS) concentration of this water type is up to 2000 mg/l.
CDP	Fresh surface water, including rainwater, water from wetlands, rivers and lakes: water that is naturally occurring water on the Earth's surface in ice sheets, ice caps, glaciers, icebergs, bogs, ponds, lakes, rivers and streams, and has a low concentration of dissolved solids.
Equinor	Naturally occurring water with a low concentration of salts, or generally accepted as suitable for abstraction and treatment to produce potable water. Includes water from public installations, wells (including groundwater reservoirs), lakes, streams, rivers and purchased freshwater. Freshwater produced from salt water on facilities/installations is not included
Global Reporting Standards, OMV Group, PKN Orlen, Saras & Valero	Water with concentration of total dissolved solids (TDS) equal to or below 1,000 mg/l.
BP	Water with concentration of total dissolved solids (TDS) equal to or below 2,000 mg/l.

Company / Organisation	Freshwater Definition
Phillips 66	Defined as water that has low salinity - usually less than 0.1% (local legal definition vary). The reported value includes freshwater used as once-through cooling water.
Shell	From public utilities (such as municipal water supplies), surface water (such as rivers and lakes) and groundwater.

Groundwater

Company / Organisation	Groundwater Definition
Alliance for Water Stewardship (AWS)	Water below the surface of the Earth stored in pore spaces and fractures within rock or layers of sand and gravel (aquifers). In water resources management the term more specifically applies to water that can be extracted at a viable rate, quantity and quality for human use (with or without treatment). Saline water or water contained in rocks of very low permeability is not conventionally considered groundwater.
CDP	Groundwater - renewable: water which is being held in, and can be recovered from, an underground formation. Renewable groundwater sources can be replenished within 50 years and are usually located at shallow depths. Groundwater - non-renewable: water which is being held in, and can be recovered from, an underground formation. Non-renewable groundwater has a negligible rate of natural recharge on the human timescale (more than 50 years) and is generally located at deeper depths than renewable groundwater. This is sometimes referred as "fossil" water. As part of groundwater withdrawal volumes (be it from renewable or non-renewable sources), organizations should include all withdrawals from aquifers (other than the formation being exploited). These withdrawals may be intended for any use in the organization, including injection to maintain well pressure or as part of the fracture fluids.
GEMI Local Water Tool	Subsurface water occupying the saturated zone.
International Petroleum Industry Environmental Conservation Association (IPECA)	Groundwater (wells) > suspended solids, dissolved solids (metals), dissolved organics.
European Environment Agency	Groundwater abstraction is the process of taking water from a ground source, either temporarily or permanently. Most water is used for irrigation or treatment to produce drinking water.

Surface water

Company / Organisation	Surface Water Definition
GEMI Local Water Tool	Water that flows over or is stored on the ground surface.
European Environmental Agency	All waters on the surface of the Earth found in rivers, streams, ponds, lakes, marshes, wetlands, as ice and snow, and transitional, coastal and marine waters.

River Water

Company / Organisation	River Water Definition
National Geographic	A river is a natural flowing watercourse, usually freshwater, flowing as a result of gravity, towards an ocean, sea, lake or another river.
European Environmental Agency	A river is a body of inland water flowing for the most part on the surface of land, but which may flow underground for part of its course.
USGS	Water from a natural stream of water of considerable volume, larger than a brook or creek.

Rainwater/Precipitation

Company / Organisation	Rainwater Definition
International Petroleum Industry Environmental Conservation Association (IPIECA)	Rain that falls within the refinery battery limits is usually treated before discharge.
European Environment Agency	In meteorology, precipitation (also known as hydrometeor) is any product of the condensation of atmospheric water vapour that is deposited on the earth's surface. It occurs when the atmosphere (being a large gaseous solution) becomes saturated with water vapours and the water condenses and falls out of solution (i.e., precipitates) Air becomes saturated via two processes, Cooling and Adding Moisture. Precipitation that reaches the surface of the earth can occur in many different forms, including rain, freezing rain, snow, sleet, and hail.
GEMI Local Water Tool	Liquid or solid products of the condensation of water vapour from clouds or deposited from air on the ground. (If it falls onsite and is not used, then it does not need to be counted in the GEMI LWT.)

Reused Wastewater Effluent

Company / Organisation	Reused Wastewater Effluent Definition
International Petroleum Industry Environmental Conservation Association (IPIECA)	Water that has been used more than once in a process or used in other processes, with treatment as appropriate, to reduce freshwater withdrawal. Note that the terms reused and recycled are similar and not differentiated for this indicator. If reused/recycled water is reported quantitatively, the reported volume should equal the reduction in the volume of freshwater withdrawn that resulted from the reuse/recycling.
GEMI Local Water Tool	Recycled Water: The amount of used water/wastewater employed through another cycle back in the same process or in a higher use in the process cycle before discharge for final treatment and/or discharge to the environment. Reused Water: The amount of used water/wastewater employed in another function in a lower use in the process cycle before discharge for final treatment and/or discharge to the environment. Reuse includes wastewater used for irrigation within a facility boundary. Reuse includes harvesting of rainwater within a facility boundary.
Alliance for Water Stewardship (AWS)	Wastewater: Used water of reduced quality discharged from a site. It is usually contaminated in its raw state, but should be treated, either on site, or delivered (by pipe or truck) to an authorised wastewater treatment facility. Treated wastewater should be legally compliant and of a high enough quality to present no risk to the receiving water body (or land where applicable). Safe or treated wastewater may be re-used on site, or by other users to reduce original water demand and/or wastewater discharge volumes. Examples of re-use include irrigation of gardens or crops, washing vehicles and other uses not demanding high quality water.

Sea Water

Company / Organisation	Sea Water Definition
CDP	Saline surface water/seawater: surface water in which the concentrations of salts is high and far exceeds normally acceptable standards for municipal, domestic or irrigation use (at least higher than 10,000 mg/l TDS). Seawater has a typical concentration of salts above 35,000 mg/l TDS.

Company / Organisation	Sea Water Definition
International Petroleum Industry Environmental Conservation Association (IPIECA)	Sea water source > suspended solids, dissolved solids (metals, chlorides).

Abstraction

Company / Organisation	Abstraction Definition
European Environmental Agency	Water removed from groundwater and surface water. Surface water contains water abstraction from rivers, reservoirs and lakes.
USGS	Water removed from a ground- or surface-water source for use.

Withdrawal

Company / Organisation	Withdrawal Definition
AQUASTAT Database United Nations	Agricultural water withdrawals consist of water used for irrigation, livestock watering and cleaning, and aquaculture. Water for processing agricultural products is included under industrial or municipal water withdrawals. In rural areas, agricultural water withdrawals frequently include water for domestic purposes. Industrial water withdrawals consist of water used by self-supplied industries not connected to a public distribution network for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; water incorporated into a product; or water used for sanitation needs within the manufacturing facility. Municipal withdrawals are a broad category that includes water for domestic uses, as well as water provided by a municipality or other public supplier for commercial, industrial, and institutional purposes.
GEMI Local Water Tool	The sum of all water drawn into the boundaries of the reporting organisation from external sources.
CDP	The sum of all water drawn into the boundaries of the organisation (or facility) from all sources for any use over the course of the reporting period. In the oil & gas sector, the reporting of water withdrawals volumes typically does not include produced water (part of the connate water that is brought to the surface during the production of hydrocarbons including formation water, flow-back water and condensation water). To enable comparability, CDP requires all companies to include produced water volumes in their withdrawal's disclosure, in order to have an accurate water balance.
BP	The volume of freshwater received by the site or operational facility from the catchment and/or a third-party supplier.
World Resources Institute (WRI)	Withdrawal consists of two components: Consumptive withdrawal and non-consumptive withdrawal. Gross withdrawal refers to consumptive plus non-consumptive withdrawal. Net withdrawal refers to only the consumptive withdrawal. The non-consumptive withdrawal will return to the water body, usually downstream and is also referred to as return flow. Withdrawal is from water resources (e.g., river, aquifer, lake, and ocean).

Use

Company / Organisation	Use Definition
World Resources Institute (WRI)	Water use describes the total amount of water withdrawn from its source to be used. Withdrawal is from water resources (e.g., river, aquifer, lake, and ocean).

Company / Organisation	Use Definition
USGS	Water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface- and groundwater sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.

Consumption

Company / Organisation	Consumption Definition
World Resources Institute (WRI)	Water consumption is the portion of water use that is not returned to the original water source after being withdrawn. Consumption occurs when water is lost into the atmosphere through evaporation or incorporated into a product or plant and is no longer available for reuse.
International Petroleum Industry Environmental Conservation Association (IPIECA)	The difference between water withdrawal and the water discharge to the same source or a different source with the same catchment / watershed).
GEMI Local Water Tool	The difference between water withdrawal and water discharge. Consumption removes water from a system and makes it unavailable for further use.
BP	The volume of freshwater used by the site and not returned to the catchment or a third party.
OMV Group	Water consumption is calculated as water withdrawal minus water discharge.

The specific definitions relating to consumption appear simple but can become complex – particularly where water is withdrawn from one source at one location and potentially discharged (rather than being technically consumed) and placed into a different water body. When considering consumption and discharges consideration should be given to differences in the withdrawing and discharging environments to characterise water that is consumed appropriately.

Efficiency

Company / Organisation	Efficiency Definition
Alliance for Water Stewardship (AWS)	Water efficiency is the concept of using less net water for an equivalent purpose or volume of production. For example, using less water to produce the same weight of final product (measured in l/kg or m3/kg produced). It may not result in using less total water if the volume of product is increasing. Methods to improve water efficiency include technology (e.g. drip irrigation), leakage reduction, re-use and recycling of wastewater.

Scarcity

Company / Organisation	Scarcity Definition
CEO Water Mandate	The volumetric abundance, or lack thereof, of freshwater resources. “Scarcity” is human driven; it is a function of the volume of human water consumption relative to the volume of water resources in a given area.

Stress

Company / Organisation	Stress Definition
European Environmental Agency	Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of freshwater resources in terms of quality (aquifer over exploitation, dry rivers etc.).
CEO Water Mandate	The ability, or lack thereof, to meet human and ecological demand for fresh water. Compared to scarcity, "water stress" is a more inclusive and broader concept. It considers several physical aspects related to water resources, including water availability, water quality, and the accessibility of water (i.e., whether people are able to make use of physically available water supplies
IPIECA	Water stress/scarcity: when reporting qualitative and quantitative water stress and scarcity information, the definition or indicator of stress and scarcity should be defined by the company. There is no one measure of stress and scarcity that is universally accepted. Many tools and models have been developed that map stress and scarcity. IPIECA has looked at a range of these tools in the 2014 publication "Review of Water Risk Tools" and does not make any specific recommendation to companies on which one to use.
GEMI Local Water Tool	The tension resulting from the imbalance of insufficient supply and strong demand. External stress severity level describes the current conditions of a specific water source. It is a result of natural physical conditions and cumulative anthropogenic (human, industry, agriculture) impacts.
CDP	Water stress is based on subjective elements and is assessed differently depending on societal values, such as the suitability of water for drinking or the requirements to be afforded to ecosystems. However, CDP's reporting guidance suggests some publicly available and credible tools for identifying water stressed areas. Companies may complement the results from these tools with their own assessments to provide more granular local-level data. As good practice, a water stressed area should be at the catchment level as a minimum,
WRI	The World Resources Institute's Aqueduct® tool is used to determine baseline water stress, which is the ratio of total annual water withdrawal from a catchment to average annual available water to the same catchment. The Aqueduct® tool classifies stress into five levels, low, low-medium, medium-high, high and extremely high.
Galp	Water stress is an indicator of competition for water resources and is defined informally as the ratio of demand for water by human society divided by available water.
OMV Group	Water-stressed areas are areas where the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. In such areas, water stress causes deterioration of freshwater resources in terms of quantity (aquifer overexploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.).

The following definitions have been selected from the matrix using ERM's experience and judgment in the area of water resources assessment to present a set of usable working definitions that are best practice in water resources assessment and will be recognisable from an external stakeholder perspective.

2.2. FRESHWATER

Proposed definition: *Where it is not defined by local regulations, freshwater is naturally occurring, non-brackish water having a concentration of total dissolved solids (TDS) equal to or below 2,000 mg/l.*

It should be noted that certain elements (or compounds) may be present in the water source at concentrations above drinking water standards (e.g. boron or other metals, coliforms from sewage or other man-made chemicals) without affecting the status as a fresh water source.

This definition is aligned with IPIECA[2] and widely adopted by Concawe members (Section 5). Note that Concawe have previously defined freshwater according to the ISO definition as '*naturally occurring water on the Earth's surface (in ice, lakes, rivers, and streams) and underground as groundwater in aquifers containing low concentrations of dissolved solids (ISO 16075-1 2015)*' (Concawe, 2022). The added detail of TDS removes potential ambiguity in what is considered 'low concentrations'.

The WFD does not contain a specific definition of freshwater. Key objectives of the WFD at a European level are 'general protection of the aquatic ecology, specific protection of unique and valuable habitats, protection of drinking water resources, and protection of bathing water3. All these objectives must be integrated for each river basin. Special habitats, drinking water areas and bathing water apply only to specific bodies of water (those supporting special wetlands; those identified for drinking water abstraction; those generally used as bathing areas). In contrast, ecological protection should apply to all waters.'

The IED has no definition for freshwater, however it seeks to reduce pollution of water (including groundwater) from industrial emissions. There is reference made to water bodies (i.e. in relation to direct or indirect emissions), however other than defining groundwater, the Directive appears to take a holistic view of water.

Based on discussions with Concawe members and experience across other industry types it is also common practice to exclude precipitation and runoff at an operation from the volumes of water reported as freshwater. This is often because it is difficult/impractical to segregate this water from drainage systems and it becomes 'contact' water as soon as it lands on the operation.

For the survey, the following definitions were used for freshwater and brackish/salt water.

The following definition was used for 'freshwater';

"Water with a total dissolved solids (TDS) concentration below 2,000 mg/L as defined by IPIECA or defined as fresh water by local statutes and regulations. Where it is not defined by local regulations, fresh water is defined for reporting purposes as non-brackish or sea water and may include drinking water, potable water, water used in agriculture, etc."

[2] "Where no regulation exists, freshwater is defined for reporting purposes as non-brackish water and may include drinking water, potable water and water used in agriculture. The total dissolved solids (TDS) concentration of this type of water is up to 2,000 mg/l" IPIECA, 2020
[3] Note that this includes sea water

The following definition was used to differentiate between 'brackish and saltwater, with 'brackish' water defined as;

"Water with a total dissolved solids (TDS) concentration between 2,000 and 35,000 mg/L."

Sea or saline water has higher TDS than brackish water.

2.3. WATER STRESS

Water can be scarce for many reasons: demand for water may be exceeding supply, water infrastructure may be inadequate, or institutions may be failing to balance everyone's needs. A common working definition used by most practitioners in water resources and in evaluating water risk, is to use the term **water stress** – which better reflects the pressure of the different factors which can affect scarcity. Water stress can also be the results of many pressures within a catchment. The EEA uses the term water stress defined by the CEO Water Mandate as '*the ability, or lack thereof, to meet the human and ecological demand for water. Compared with scarcity and shortage, water stress is a more inclusive and broader concept. As well as water scarcity, it also considers water quality, ecological flows and the accessibility of water*' (The Global Compact, 2014). Moreover, **baseline water stress** can be used within an assessment to represent water stress. Proposed definition: *Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users.* (WRI, 2019).

The subject of water stress has been addressed in a lot of studies all over the world (Liu et al., 2017) and a wide range of different methodologies have been used to measure water stress during the last four decades (Wang et al., 2021). A screening of water stress assessment methodologies by Wang et al. (2021) showed that water stress involves not only physical terms to meet all demand, such as quantity (Kummu et al., 2016; Aquastat) or quality (CEO, 2014; European Environment Agency), but also social, economic, and political aspects. Moreover, particularly related to physical water stress factors, there is not a widely accepted definition of water stress (Wang et al., 2021; Liu et al., 2017). Concawe members do not currently have a uniform way to define whether a site is within a water stressed area or not. Further, the WFD does not define water stressed areas but does assess water stresses at a catchment level which is relevant to understanding water stress.

For the Oil and Gas sector in particular, IPIECA has concluded that a local approach is necessary to understand water risks effectively (IPIECA, 2014; IPIECA 2020). Using a local approach, i.e., not using a single global definition, is also supported by the 2018 review paper *Physical water scarcity metrics for monitoring progress towards SDG target 6.4: An evaluation of indicator 6.4.2 "Level of water stress"* (Vanham et al., 2018) with the European Commission (EC) Joint Research Centre (JRC) as first author. The publication is a critical review of the concepts included by the UN in the definition of the Sustainable Development Goal (SDG) number 6, which includes Water Stress as an indicator for Water Scarcity. It is concluded that seven essential elements are recommended to be accounted for in the development of local Water Stress Indicators. Although SDG 6 definition was already in agreement with the seven elements proposed, additional recommendations are made, aiming to the implementation of these principles in Water Stress indicators. Summarising the main concerns raised by Vanham et al (2018), Water Stress indicator(s) should include:

- Gross and net water abstraction used in parallel;
- Consider specific Environmental Flow (EF) Requirements (Water availability = Total renewable water resources-EF);
- Use local indicators to account for spatial variability in water availability and use. Recommendation of 5 arc-minute (0.0833° or about 10 km at the equator);
- Use local indicators to account for temporal variability in water availability and use. Take both, annual and monthly water stress indicators;
- Renewable water availability should be considered (separately from non-renewable) and it should include surface and groundwater. Also, include artificial surface water and groundwater storage. Modelling and remote sensing data may be used to complete national statistics. Quantifications for different levels are not directly comparable due to different boundary conditions and specifications;
- Account for fossil groundwater and water for desalination. As an example, Wada et al. (2011) accounted in their Water Stress assessment for fossil groundwater and desalination by subtracting the volume of desalinated water and abstracted non-renewable groundwater from the water demand prior to the calculation of water stress;
- Account for constructed reservoirs. Consider evaporation from reservoirs as water use. Evaluate recycling or reuse of Water Account for managed aquifer recharge.

Attending to the seven principles that Vanham et al (2018) dictates to be accounted for in Water Stress assessment, **the appropriate methodology to evaluate water stress indicators shall be site-specific** in order to understand the situation on a site/local level**.** Also, the outcome of this water risk assessment at local level is expected to lead to ad-hoc mitigation action plans, which will be specific and potentially different in every location (IPIECA, 2014).

2.4. WATER TERMINOLOGY

Water use terms in refineries are explained in section 3 below. For reference, the following are explained also here:

- **Water Use**: - Water use describes the total amount of water withdrawn from its source to be used. Withdrawal is from water resources (e.g., river, aquifer, lake, and ocean).
- **Withdrawals** – Also termed abstractions - Water removed from a ground- or surface-water source for use.
- **Discharges** – Water which is returned to the environment (original water source or other source) after use.
- **Consumption** - Water consumption is the portion of water use that is not returned to the original water source after being withdrawn. Consumption occurs when water is lost into the atmosphere through evaporation or incorporated into a product or plant and is no longer available for reuse.

  Fresh Water consumption (as differentiated between water consumption above) is the difference between freshwater withdrawn and freshwater returned. WRI (World Resources Institute) consider that water is consumed when it is not returned into the same source (or even downstream within the same source) within the same catchment. This strict definition is adopted by most external stakeholders and observers, and it is because returning water downstream of the original source can affect environmental flows, water quality and water availability for other water users. Losses to the atmosphere, leakages, and water in final products are also examples of water volumes consumed.

Most Concawe members adopt the IPIECA definition of Water consumption which states that it is "The difference between water withdrawal and water discharge to/from the same source or catch basin /watershed)").

- **Efficiency** - Water efficiency is the concept of using less net water for an equivalent purpose or volume of production. For example, using less water to produce the same weight of final product.

3. WATER USE AND WATER EFFICIENCY MEASURES IN REFINERIES

Water management is an essential component of industrial operations. While the global amount of water consumed by the oil and gas industry is considerably lower than in the agriculture, food and drink, power and other sectors (see Section 4.2), the use of water is essential for oil and gas operations.

Petroleum refineries are large and complex industrial sites that involve many different processing units and auxiliary facilities such as utility units and storage tanks. Each refinery has its own unique arrangement and combination of refining processes and water management, largely determined by the refinery location, raw materials to be refined, desired products, and economic considerations. The complexity of individual operations will also affect the specifics around water sourcing, use, and efficiency.

This section summarises the main uses and sources of water in refineries, and established methods of calculating water efficiency. The information presented here draws on literature and professional experience. Information specific to member organisations gathered through this project are presented anonymously in Section 5 and **Appendix A**.

Water reuse, recycling and reclamation was the subject of another recent Concawe report (Concawe, 2022). This report does not attempt to replicate that, simply to present a summary for the context of water use and efficiencies which may be useful to understand the baseline situation and potential challenges under a revised BREF.

3.1. WATER USE IN REFINERIES

Refining uses water in three broad areas:

- Process water for distillation, stripping, cracking and for boilers
- Cooling water
- Other non-process water (firefighting, cleaning, etc.)

Cooling systems require by far the largest volumes of water (see Sections 3.2.2.1 and 5.2.2 below) and may comprise closed, open recirculating, or once-through systems. Although water quality is not the primary concern for cooling water, issues with scaling and fouling must be planned for in the design, taking into account water quality. Equally, discharged cooling water can sometimes be discharged without treatment whereas discharged process water must undergo treatment before discharge. Any discharged water must meet quality requirements, including those set by license requirements and legislation.

Water consumption in refineries surveyed by the JRC's European IPPC Bureau, indicated that in European refineries consumption ranges between 0.2 m^3/t and 25 m^3/t of feedstock refined, more than 50% of the water being consumed through cooling (Medarac et al., 2018). Water uses in refineries are summarized below in **Table 1** and described in more detail in Concawe (2022).

Understanding the water balance for a refinery is a key step towards optimizing water usage, enhancing the reuse and recycling of water as well as optimizing performance of water and wastewater treatment systems.

Figure 2 illustrates a generic refinery water balance and Section 5 presents a summary of the water balances developed at member sites.

Figure 2 Generic water balance for a refinery

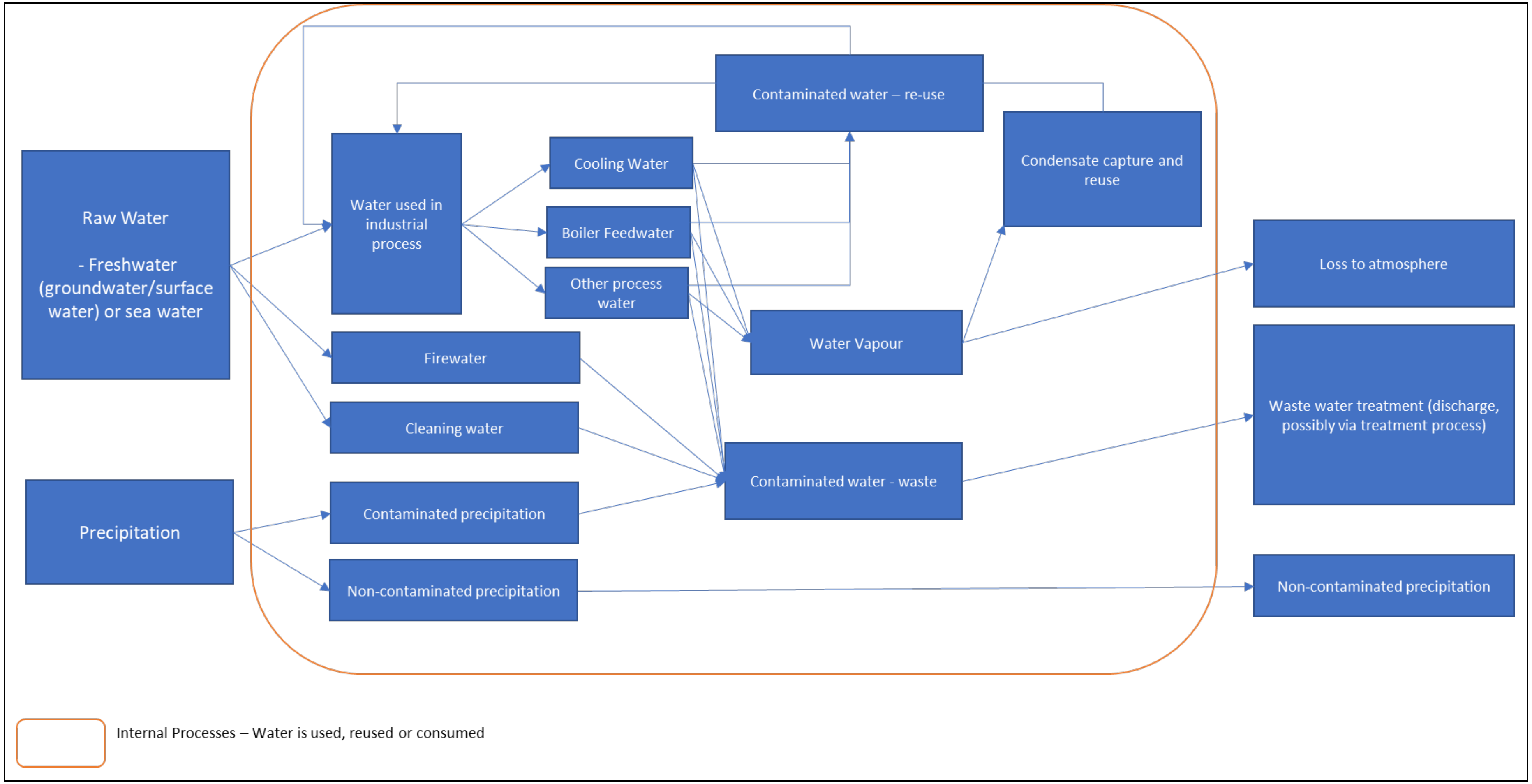


Table 1 Examples of Refining Processes and Water Use

Process	Description	Water In	Water Out
Crude-Oil Desalting	Removes chloride salts from crude to avoid corrosion in the overheads of the crude and vacuum distillation units. Typically, desalter water rates are 5% of crude rate.	Make-up needs to be low-salt water. Hydrocarbons in make-up water OK. Stripped Sour Water (SSW) is often a good candidate	Desalter wash water is contaminated with free oil, solids and dissolved hydrocarbons (HCs). Not a good candidate for re-use
Crude Unit Distillation (sometimes called atmospheric column but operates well above atmospheric pressure) (including base oil and bitumen production)	Along with Vacuum Distillation, this process separates the incoming crude into its many fractions for further processing. May use stripping steam in the column.	Steam	Condensed steam becomes sour water, usually dilute sour water. Re-use directly in desalter often possible
Vacuum Distillation	Further distils the heavy oil from the Crude Unit. Vacuum Distillation is performed at a pressure well below atmospheric pressure. Usually the vacuum is produced with steam-driven ejectors. Vacuum Distillation often also utilizes stripping steam in the column itself	Steam	Condensed steam becomes sour water, usually dilute sour water. Re-use directly in desalter often possible
Hydrogen Production	Converts natural gas into hydrogen for the hydrotreaters/hydrocrackers via steam reforming and water-gas shift. Consumes 2 moles of water per moles of CH_4	Steam	No water out
Hydrotreatment/Hydrocracking	Uses hydrogen, catalyst and high pressure to treat or crack hydrocarbon streams depending on severity. Many units utilize water injection to remove ammonium salts from reactor effluent coolers.	Relatively pure water. Stripped Sour Water may be a good candidate if it does not have chlorides.	Sour Water, not re-usable without first being stripped
Alkylation	Converts isobutane and butylene into alky late using a liquid acid catalyst (H_2SO_4 or HF). Reactor effluent needs water washing for acid by-product removal	Typically, freshwater is used for make-up	Effluent water contains some HCs, sulphates or fluorides, LPG. Needs degassing prior to sending to effluent system

Process	Description	Water In	Water Out
Amine System	This system removes H_2S from various gas and LPG streams using one of several different types of regenerable amines such as MEA, DEA or MDEA	High-purity water as needed to make-up for losses	Main water out is the amine regenerator(s) purge stream, which goes to sour water
Fluid catalytic cracking (FCC) including catalytic reforming	Upgrades the heavier, higher-boiling fractions from the crude oil distillation by converting them into lighter and lower boiling, more valuable products using a fluid catalyst and heat. Significant user of direct-contact steam	Direct-contact steam in the reactor riser and main fractionator	Sour water, with significant organic contamination such as phenol
Delayed coking	Converts very heavy residual oils mostly into solid petroleum coke as well as some thermally cracked, lighter fractions. After the coking reaction is complete, the coke is cut out of the drums with high-pressure water jets.	Cutting water, high purity not required, good option for re-used stream	Cutting water along with coke
Sour water stripping	Uses steam directly or indirectly to remove hydrogen sulphide and ammonia from various sour water streams.	Sour water	Stripped Sour Water, a significant stream for re-use consideration. Indirect heating is more water efficient
Sulphur plants/tail gas treatment	Sulphur plants convert hydrogen sulphide gas into elemental sulphur and water vapour. Tail-gas plants treat the gas from the sulphur plants, removing residual H_2S or SO_2 depending on design. Tail-gas plants usually include a quench to lower the gas temperature, which condenses most of the water vapour from the sulphur plants and creates a significant purge stream	No water consumption	Dilute sour water purge, often with low levels of contamination, suitable for re-use in some applications.

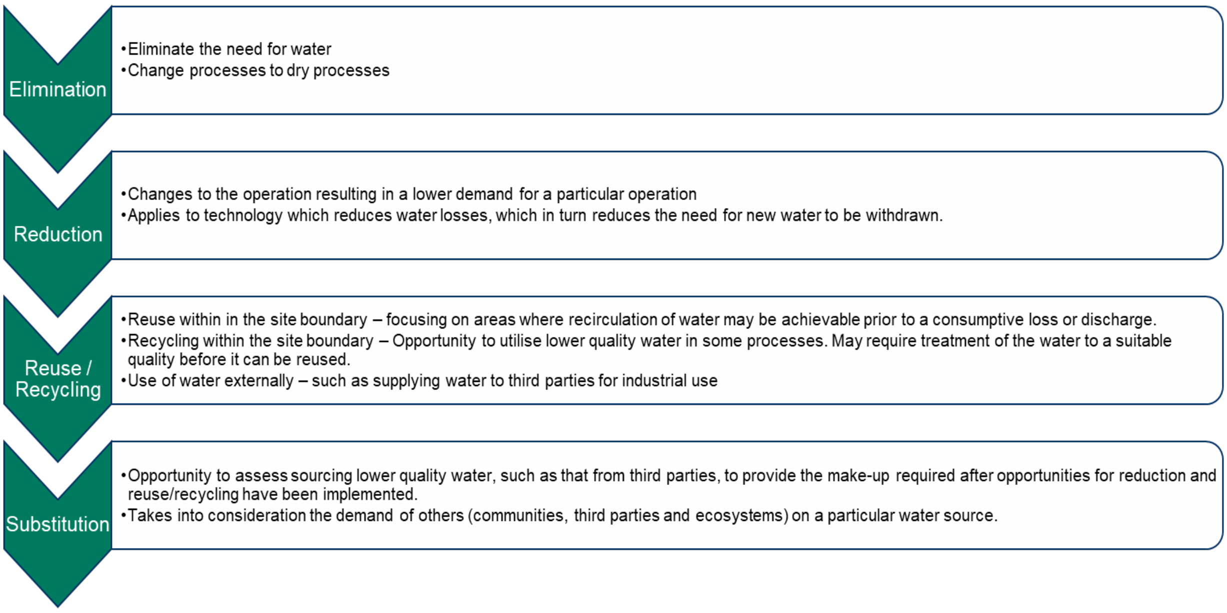
Process	Description	Water In	Water Out
Recirculating Cooling Water System	Recirculating cooling water system utilising cooling towers for rejecting heat, mostly via water evaporation. Avoids excessive salt build-up via blowdown with system cycles ranging from up to 10, depending on make-up quality. Often the largest water consumer in the refinery.	Freshwater - alternatives may include reclaimed municipal wastewater and filtered site stormwater. However, water must be treated to prevent scaling, and combat risk of legionella, and corrosion protection	Cooling tower blowdown, at same salt concentration as recirculating system. Significant losses to evaporation.
Once-thru Cooling Water	Some locations use high flow rates of sea, river, or lake water on a once thru basis instead of a recirculating system to utilise the cooler temperatures of the incoming water.	Seawater or fresh surface water	Returned to same body of water, just warmer
Boiler Feed water System/Steam Generators	Depending on the purity needed for the BFW and technology preference, filtration followed by RO, softening, demineralization are options. Boiler feed water is then converted to steam in boilers.	Freshwater. Alternate sources can be considered, like for cooling water, but purity is more important, particularly for steam generators.	Filtration reject, RO reject stream or demineralizer regeneration stream
Refinery Firewater System	Used for firefighting.	Freshwater. Lower purity alternatives for system make-up usually acceptable.	Purges via fire-fighting tests, system leaks
Wastewater collection and treatment	API separators, dissolved air flotation (DAF) units and some type of further treatment (such as an activated sludge biotreater) to make the wastewaters suitable for reuse or for disposal.	Wastewater	Discharged effluent, a candidate for re-use for low purity users

Footnote - The above table covers many of the traditional refining operations as referenced by the REF BREF. Through discussions with operators it is clear that the energy production process is undergoing significant evolution and that new products and techniques are going to have an impact on sourcing of water at refineries. This includes, but is not limited to, generation of blue and green hydrogen and the adoption of CCS techniques. These aspects are out of scope in terms of the potential water demand as it is not clear how the future REF BREF may address these issues.

3.2. EFFICIENCY MEASURES

The following subsections summarise possible efficiency measures applicable to refineries. The overarching principles applied to efficiency of reduce-reuse-substitute are summarised in **Figure 3**. These follow that the best approach is to reduce overall demand by eliminating the need for water in processes. The next best approach is to reduce the demand by changing techniques on site to reduce total water required or reuse water already abstracted from the environment (or provided by third parties, for example, reused municipal wastewater). Finally, if the above cannot be achieved or increased, substitution of higher quality or higher demand water (for example river water which may be used as a potable source and/or provide ecosystem support services) for lower quality or demand water (generally this means using treated wastewater from municipal systems or substituting in sea water for freshwater).

Figure 3 Hierarchy of water efficiency measures



3.2.1. Reduction Measures in Refineries

The following are some of the available options for reducing water consumption at refineries:

- Improving operational and monitoring practices via leak detection systems, flow monitoring, etc. to reduce overall water losses.
- Develop and maintain a cooling tower monitoring program to ensure cycles of concentrations are maintained within operating envelope.
- Develop and maintain a vigorous steam trap inspection and replacement program. If not closely monitored, the system-wide losses of failed steam traps can result in a significant waste of steam and thus water.
- Trend the fraction of recovered condensate per boiler feed water (BFW) production as a critical system variable. Identify non-recoverable sources of BFW (such as steam to flares, stripping steam in columns, steam for H2 production, etc.) and identify a site-specific theoretical maximum for the fraction of recoverable condensate noting that this may require a dedicated treatment process.

- Identify and frame projects for steam condensate which is not recovered currently due to system difficulties in capturing and returning condensate to the BFW system.
- In sour water stripping, utilize steam reboilers rather than live steam injection.
- If ultrafiltration and reverse osmosis are used to produce BFW, ensure reject streams are minimized within the limits of system reliability and regulatory permits.
- When building new projects, consider using fin-fan cooling instead of cooling water exchangers, selecting Membrane Bioreactors (MBRs), and subsequent wastewater reuse.
- Establish cross-functional teams with accountabilities to identify and reduce water use across operations.
- Improve ion exchange resins operational efficiency for demineralised water, by optimising regeneration and waste stream production.

3.2.2. Reuse Measures in Refineries

Where practical and economically feasible, in addition to reduction, water can be reused by the following methods:

- Re-use stripped sour water for desalter water make-up.
- Segregate various sources of sour water to enable re-use of those least contaminated, such as sour water from tail-gas treating.
- Use the BFW RO reject stream, which is a relatively high-quality water stream (no hydrocarbons) if TDS appropriate), for alternate uses rather than being sent to drain.
- If lower quality of water is available, providing there is no adverse chemistries, this may be used in place of freshwater for caustic soda dilution.
- Consider water recovery from treated refinery final effluent or municipal effluent using a filtration system (sandfilter/ultrafiltration), RO-based system, or a thermal recovery system ideally using a waste heat source, noting there is no current known example of this in refining.

3.2.2.1. Cooling Systems

A sample of European refineries were analysed as part of the 2015 REF BREF. It was found that the largest use of water (on average >50% of total water use) was for evaporative cooling. Such systems evaporate large quantities of water but also have significant blowdown streams to manage the build-up of dissolved solids to avoid metallurgical concerns and fouling. The amount evaporated is a function of the heat duty and can't be minimized without reducing the head load to the cooling system. A key aspect of minimizing water use in such systems is to carefully monitor the qualities of the recirculating cooling water and run at as high cycles of concentration as possible while still maintaining reliable system operation. Often the monitoring of such systems is inadequate to allow minimization of blowdown. Investments in improved monitoring can achieve significant water savings.

Recirculating cooling water systems contain underground piping where there is potential for losses, these leaks may go undetected for years. Only careful monitoring of key system parameters will enable detection of such leaks. In some cases, the underground leaks become so significant that no controlled blowdown is required and it becomes impossible to optimize cycles of concentration. Careful monitoring is needed to detect such underground leakage and prompt maintenance is also required to address such leaks.

In some situations, it may be possible to use once-through cooling instead of recirculating evaporative cooling. If the once-through cooling water is seawater, then water is evaporated from a seawater source and freshwater is not consumed. If once-through cooling water is from a freshwater source, the net evaporation is the same as from using recirculating evaporative cooling and there is therefore no difference in the freshwater savings made by using once-through cooling. In some locations, the use of once-through cooling is being discouraged due to concerns of impacts to community of species living in the source water.

Substituting direct process cooling using air-cooled fin-fans is an option that should be considered in water-scarce areas. Such systems represent a significant difference in the overall design of the refinery process plant and are typically not economically practical as a retro-fit option. However, when new refinery projects are considered and designed, preference should be given to fin-fan cooling to avoid evaporative water consumption where feasible and considering local climate and land availability.

In some relatively rare cases, closed-loop water systems can be used. Such systems circulate water through conventional cooling water heat exchangers but then remove the acquired heat from the circulating water stream via banks of air-cooled fin-fans instead of evaporative cooling. Such systems may be a more practical retro-fit option than conversion of an existing refinery process plant from a cooling water system to a fin-fan air-cooled system.

As discussed in the next section, reclaimed water can often be used in cooling water systems instead of using freshwater. Such use of reclaimed water often results in lower cycles of operation in the cooling towers since reclaimed water is typically higher in dissolved solids than freshwater. Despite the lower cycles of concentration, the net impact on freshwater sources can be very beneficial since by using reclaimed water one is avoiding the use of freshwater. The use of reclaimed water in cooling water systems is already common in many refineries.

3.2.3. Replacement Measures in Refineries

Finally, the following are some replacement sources of water which may be available:

- Use of reclaimed municipal wastewater or other wastewater sources.
- Capture stormwater, treat as needed and utilise as cooling tower make-up.
- Utilize any recovered groundwater, treating as necessary, e.g. to be used as cooling tower make-up.
- Consider pressurizing the firewater system with treated refinery wastewater.
- Introduce segregated ballast tankers to reduce the volume of ballast water (often high volumes and salt content contaminated with oil) which require treatment.
- Consider using waste heat sources to drive energy-efficient thermal desalination facilities to make freshwater from seawater or other higher-salt sources. Many research programmes are developing techniques to support the use of waste heat in desalination. One example is the desalination technology developed by Florida University to use waste heat from electrical power plants to serve as the primary source of energy - significantly reducing the cost of desalination.

- In the design phase, select air cooling instead of water cooling techniques for bulk heat removal.

3.2.3.1. Desalination Water Treatment

Desalination is a water treatment process that removes salts from water. This can be used in combination with other techniques to remove TSS, organics for industrial and commercial wastewaters within the petroleum industry for the production of high-purity boiler feed water and process water.

It can also be used for municipal desalting of brackish water, treatment of wastewater and other industrial and commercial wastewater.

Types of desalination water treatment include:

- Thermal technologies (e.g., multiple-stage flash distillation, multiple effect distillation and vapor compression),
- Membrane technologies (e.g., reverse osmosis and electrodialysis and electrodialysis reversal).

The electrical power requirements for desalination vary considerably depending on the total dissolved solids (TDS) of the feed, the desired percentage recovery, the membrane quality and other variables. This may present challenges for carbon footprint reduction – in particular for thermal desalination.

Industrial or municipal wastewaters would be considered brackish (typically TDS of 2,000- 5000 mg/l) compared to seawater (typically TDS of 35,000 mg/l). The percentage recovery is much higher with lower power requirements for brackish water compared to seawater (**Table 2**).

Table 2 Estimated benefits for using onsite desalination water treatment

	Power (kWh / m^3)	**Carbon Production (kg-eq CO_2 / m^3)***
For desalination of brackish water	0.5 – 2.0	0.1 - 1.5
For desalination of sea water	1.0 – 5.0**	0.1 – 4.0

* In addition to the carbon production the desalination process will also give rise to up to 1m^3 of brine per m3 of fresh water which will require disposal. The carbon production will be highly dependent on the source of energy for the desalination process (e.g. solar versus gas power/grid electricity from non-renewable sources)
** The power requirements for desalination of seawater are dependent on the method and could be as high as 20 kWh/m^3

The above figures are estimates based on running costs for purchased power. All figures used were appropriate at the time of use however, it is recognised that cost variability is a key factor and changes in global/local economy should be accounted for.

Costs for power range from €0.05 / kWh for in-house power generation via a cogeneration facility, to €0.1- €0.15 / kWh for purchased power (US Bureau of Reclamation, 2003). There is currently a high variability in the cost of electricity and the cost per kWh provided is only given as an indication of cost. Additional set up costs include those associated with pipelines, and construction.

Other benefits include:

- Reuse of water onsite, reducing water withdrawal.
- Ability to utilise lower quality, lower demand water which may not be otherwise utilised in the catchment, making higher quality water available for the catchment.
- Potential to work with other industries to utilise third-party wastewater.

Challenges:

- Changing seawater conditions and the effect of algal blooms on pre-treatment systems.
- Brine disposal and the potential negative impacts on receiving water bodies.
- Membrane fouling – This is typically overcome using an increase in pressure resulting in an increased energy demand at the facility.

3.2.3.2. FCCU Wash Water

There are additional benefits which relate to the treating and reuse of Fluid Catalytic Cracking Unit (FCCU) Wash Water – these include:

- Recycling of water from steam condensation within the same FCCU.
- Removing the need to strip the sour water as it is contained within the same unit. This also has the benefit of keeping contaminants from the sour water contained within the unit and prevents trace compounds entering other sour water streams.
- There is no need for the extraction of water for the FCCU, allowing more water to remain available for the catchment.

3.3. WASTEWATER AND DISCHARGES

Discharges are an important consideration in an effective site water balance, both as a potential source of recycled water and as a potential source of regulatory non-compliance and/or environmental contaminants (see Section 5 for member experience on the impact of reuse of water and increase in concentration of salts and contaminants in discharge water).

Discharge quality is likely to feature in updates to the BREF with anticipated tighter permit controls on water emissions.

Table 3 lists the main wastewater streams and methods to reduce the volume of wastewater produced.

Table 3 Wastewater Streams

Wastewater Stream	How wastewater stream is produced	Reducing the amount of wastewater produced
Process Wastewater	Generated from steam injection and/or washing hydrocarbon fractions	
Maintenance Wastewater	Steam and/or water used to clean hydrocarbons from equipment. Typically, an intermittent process that can generate a large quantity of wastewater in a short period of time.	Using a dedicated hydrocarbon recovery sewer.
Utility Wastewater	Cooling water, steam and boiler feed water. Water may be clean but can contain hydrocarbons or other contamination.	Cooling water: ▪ Once-through cooling water can be discharged to source and does not typically require treatment. ▪ Recirculated cooling water runs multiple cycles with a small fraction of total discharge (blowdown) generated as wastewater. ▪ Cooling water blowdown volume and quality depends on the cycles of concentration, composition and quality of water used, quality and composition of any corrosion inhibitors or biocides added to the cooling system. ▪ Contamination of cooling water can occur due to leaks within the system from exchangers, corrosion or failed gaskets. Based on analysis of hydrocarbons, eventually and only after the manifestation of a significant leak, one can detect process leaks of this nature and initiate a procedure to safely stop the unit in order to transfer on leak repair.

Wastewater Stream	How wastewater stream is produced	Reducing the amount of wastewater produced
Stormwater	From precipitation falling within the refinery boundary.	▪ Reducing the volume of contaminated or potentially contaminated Stormwater. ▪ Separate drainage systems for contaminated and non-contaminated water, including containment and treatment for contaminated water.

Implementation of the discussed techniques will need to take into consideration economic costs, staff training required, area required, and integration with the existing facilities. Due to these limitations, not all techniques will be applicable to all facilities and would need to be assessed on a case-by-case basis.

3.4. CROSS-MEDIA EFFECTS

3.4.1. Introduction

Cross media effects are a consideration in the adoption of Best Available Techniques (BAT) IED article 3(10): BAT means most effective and advanced stage in the development of activities and their methods of operation **"to reduce emissions and the impact on the environment as a whole" and** 'best' means most effective in achieving a high general level of protection of the **environment as a whole**.

Three further articles are also relevant:

- IED Article 5 (2): Member States shall guarantee an effective integrated approach by all authorities competent for the granting of permits.
- IED Article 13(2)(b): Information exchange on BAT shall inter alia address cross-media effects.
- IED Article 17(1): Member States shall ensure an integrated approach, and a high level of environmental protection when adopting general binding rules.

These specific articles will need careful consideration when considering implications of refinements to the REF BREF where these have an implication on reducing/changing water source or as a consequence of changes in the emissions profile of a site which may result from adoption of BAT. Ultimately whilst the REF BREF indicates that cross-media effects of BAT are usually minor and not often mentioned in BAT conclusions, the result of cross media analysis could render a BAT recommendation having applicability restrictions and/or a technique not being BAT.

This means that implementation of water savings techniques must also consider the emissions or impacts associated with these techniques, and their emissions must be also taken into account.

An example of where cross-media effects are a consideration in the applicability of BAT is outlined in **Figure 4**:

Figure 4 Example of Cross media effects for consideration

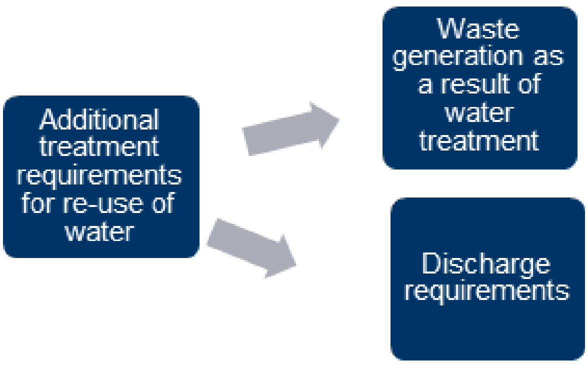
Technique	Description	Applicability
Zero liquid discharge (ZLD)	Precipitation, softening, crystallisation, evaporation	Applicable only to plants discharging to very sensitive receiving waters, where techniques (a) and (b) do not enable meeting the environmental quality Standards

Potentially significant cross-media effects of water reduction and reuse techniques may be through:

- Increased waste generation (e.g. through the use of desalination processes introduced to avoid the use of fresh water sources);
- Increased energy use (e.g. through increased treatment requirements for grey water or other non-fresh sources of water which may be identified);
- Changing emissions to water and air (where the processes of reuse/recycling result in concentration of contaminants in effluent discharges or the use of energy to treat water results in increased emissions to air from the power source being used to run the treatment process), and
- Permitting & legislation changes (as a result of a need to explain and get authorization for higher concentrations of contaminants in effluent even though the actual total mass released may be the same or less).

Many of the above issues are cross cutting and may arise as several different situations. The most common situations have been identified as illustrated in **Figure 5**.

Figure 5 Most common water-related situations



3.4.2. Additional treatment requirements

As work progresses towards water reduction, there will be a move towards reuse and recycling of water streams within the process, and the identification of other wastewater streams from off-site which could potentially be used for a water source. Different sources of water will typically require greater levels of pretreatment before use which will have a negative impact on the energy requirements and potentially increase the emission of greenhouse gases. For example, reuse of wastewater can involve filtration and reverse osmosis which are energy intensive processes. Green energy would be one way to balance this. A careful balance and calculation would be required to better understand the overall impact and benefit of treatment on the operations. This should consider not only the direct cost of treatment/energy but also the benefits through potential for reduced lost time and stabilized production capacity – particularly in areas where drought may affect the operability of the refinery.

In water scarce areas, there may be the opportunity to work with other industrial facilities and combine requirements – for example wastewater from communities could be swapped with freshwater requirements. There are many examples of this outside of the Oil & Gas industry where catchment requirements have fostered this type of arrangement – where the benefit to all in the catchment may outweigh local or isolated considerations.

Treating more water before reuse also has a potential effect with waste generation from the treatment techniques. Waste generation in general is discussed further below.

3.4.3. Waste Generation

Treatment of water generates waste products which are often sent offsite for disposal incurring additional costs and potentially impacting other operational metrics. Where sludges are generated, these can require incineration, which will incur increased energy use and cost as the volumes of sludges and waste products incinerated rises. Where facilities exist locally for this, this may be an option. Where no infrastructure or facilities exist for this type of disposal then wider discussions on investment in local industry, and work in partnerships may be applicable.

3.4.4. Emissions

Additional emissions could be generated by water reduction and re-use techniques. Air emissions could be generated from treatment plants for example from energy production including NOx and SOx. Increased emissions to water in discharges are covered below.

3.4.5. Discharge requirements

As water is reused, the level (either concentration or total mass depending on parameter) of contamination will typically increase. Rather than being suitable for disposal by discharge, the waste waters will no longer meet permit requirements and will need to be treated as a waste stream.

This was a concern identified by a number of the members during the interview process, who proposed that reduction in the volume of discharge water will increase concentrations of contaminants, thus exceeding discharge limits although the mass loading remains the same. Again, this will require further treatment and generation of waste as above.

This will affect discharge permits in some jurisdictions and local consideration will need to be made of limits as the industry moves away from dilution. Discharge streams may require further treatments.

In scenarios where the total mass of contaminants remaining in the wastewater may be the same, a smaller discharge volume will result in an increase in concentration. This means there could be a perceived (and possibly real) impact on the receiving water environment. This is especially the case for waters such as cooling waters, where the impact of climate change may also reduce the capacity of the environment to receive discharge water, either by reducing streamflow as a consequence of changing rainfall and runoff, or by the increasing temperatures within surface water bodies due to increasing temperatures.

Cross cutting and competing BREF requirements in European jurisdictions will also play out as complex in this area. The desire to reduce impacts and discharge less water overall is currently based around contaminant concentrations not mass constituent load, whereas the increase in recycling of water will potentially increase concentrations in each discharge increase the mixing zone area and thus increase the environmental impact.

3.4.6. Supporting Guidance

The above information captures some of the key challenges and themes which need to be considered when determining whether cross-media effects are relevant when implementing BAT. The challenge for industry will become the demonstration of whether BAT is or is not achievable. The purpose of this document is not to exhaustively assess specific refinery water technologies and analyse where the specific BAT challenges may lie, however, the European Commission (EC, 2006) has produced a reference document on Economics and Cross-Media Effects as related to Integrated Pollution Prevention and Control. This document provides a wealth of information and suggested approaches – most of which are relevant for water related technology implementation. This document is a specific cross-reference document for use by BAT across industries.

In addition to background information on cross media effects the document provides a set of cross-media guidelines to use in order to try and determine which technology approach is likely to provide the highest level of environmental protection

3.4.7. Conclusion

The decisions to make improvements around water volumes and quality at a refinery will need to carefully balance a range of factors influenced by the prevailing legislation and stakeholder expectations. The role of Water Stewardship will also have to come into play here, as the needs of the catchment will have to be considered. This will however potentially offer opportunities, as the cross-cutting themes, impacts and opportunities can be discussed and agreed in a multistakeholder environment. Opportunities exist for refineries to work with local regulators and stakeholders to overcome the local water challenges experienced by communities, ecosystems, and the refineries themselves. In terms of water stress, variability in market and regional and catchment differences means that options will have to be looked at on case-by-case basis. Furthermore, any targets set around water reduction and recycling will have to reflect not only the broad aspirations of the companies, but the needs and requirements of those living and working in the operating catchments.

4. WATER STRESS IN EUROPE UP TO 2030

4.1. INTRODUCTION

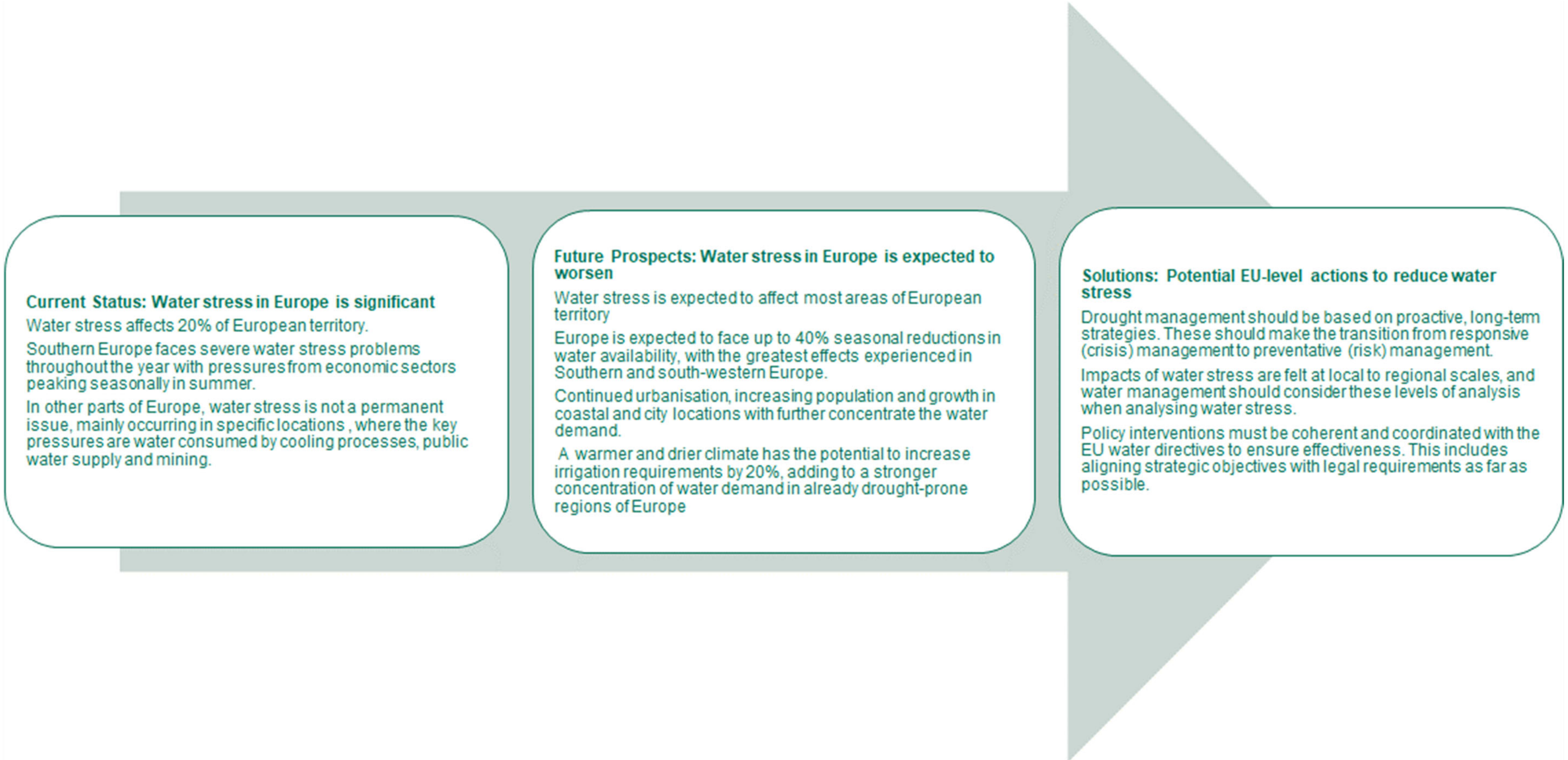
According to a report by the European Environment Agency (EEA) in 2021, approximately 20% of the European territory and 30% of Europeans are affected by water stress during an average year with an economic cost of the damage from droughts estimated at €2-9 billion annually (EEA, 2021b). This cost estimate does not include the unquantified damage to ecosystems and their services. Climate change is expected to make the problem worse, as droughts are increasing in frequency, magnitude, and impact (EEA, 2021b). The current EEA approach to water stress is outlined in **Figure 6**.

According to the EEA (2021b), economic growth shows an overall trend towards absolute decoupling from water consumption in Europe. Water use efficiency has increased in agriculture, electricity production, industry, mining, and public water supply, that is consumption decreased while production increased. The same report estimates that approximately 0.7% decrease in water demand from industry, agriculture and electricity production can be achieved in the coming years. Note that this is reduction in demand and is not expected to offset the climate change impacts or local agriculture and potable water demand (EEA, 2021b).

Water stress including drought and water scarcity are the focus of this section of the report, however, river and coastal flooding are also projected to increase with climate change effects (Dottori et al, 2020). Hence refineries located in potential flood zones, or potentially impacted by disrupted transport links or personnel caught up in flooded towns, need to be prepared for as well as the potential for water restrictions.

With respect to water, the revisions of the IED are directed towards water emissions (quality) and withdrawals (efficiency and reuse). Water impacts from flooding will not be covered in any detail in this report.

Figure 6 Water Stress in Europe



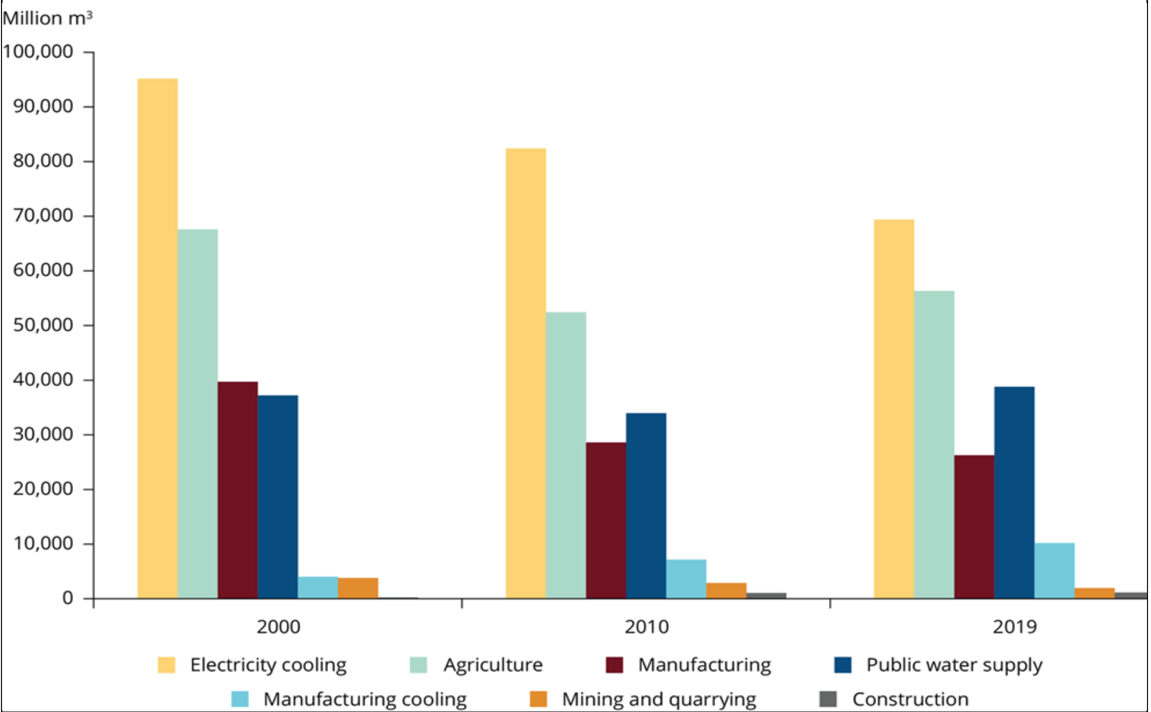
Source: European Environment Agency, 2021b.

4.2. WATER USE AND DEMAND IN EUROPE

Freshwater demand in the EU-27 is met mainly by abstraction from surface waters (rivers, reservoirs and lakes) and groundwater. Based on the European Environment Agency's estimations, total water abstraction and water use in the EU-27 have decreased by 15% from 2000 to 2019. The proportion of groundwater abstractions has increased from 19% to 23%, largely due to the increase in demand in the public water supply and agriculture sectors which are increasingly switching to groundwater to supplement less reliable surface water resources in the spring and summer months (EEA, 2022).

Figure 7 plots freshwater abstraction by economic sector for the EU-27 in 2000, 2010, and 2019. Abstractions for electricity cooling are the greatest volumes, however they have declined by 27%, due to a number of factors - upgrades of existing power plants; relocation of power plants near coasts, where seawater is used for cooling; and increases in the shares of the least water-intensive renewable energy sources (EEA, 2021b). Other sectors have increased water abstraction, e.g. cooling water abstraction in manufacturing has almost tripled, while abstraction for public water supply increased by 4%. Abstraction for manufacturing has decreased reflecting policy measures implemented under the WFD. Water abstraction for agriculture decreased overall between 2000 and 2019. However, since 2010 it has increased by 8%, mainly because of the increasing demand for irrigation in southern Europe (EEA, 2021b). While industry is the largest abstractor of freshwater, primarily for electrical cooling, it should be noted that according to the EEA, agriculture remains the largest consumer.

Figure 7 Freshwater abstraction by economic sector in the 27 EU Member States, 2000-2019



Source: European Environment Agency, 2022

An assessment of projected overall water use, both consumption and abstraction, in Europe (Medarac et al, 2018) suggests that overall water demand in the oil refining industry has declined since 2015 which is thought to be due to an overall decrease in oil refining capacity in EU and will continue to decline. However, the forecast by Medarac et al (2018) which anticipates a reduction of 10% in water use in fuel refining activities, was not including the impact of the EU Green Deal, around usage of liquid fuels (specially for transportation) coming from fossil sources, might propel the drastic reduction of fuel refining activities. It is expected that many fuel refining sites will subject to rationalization, therefore reducing sharply, and significantly more than 10% water consumption by this activity by 2050 (Concawe, 2021).

4.3. WFD STATUS OF SURFACE WATERS IN EUROPE

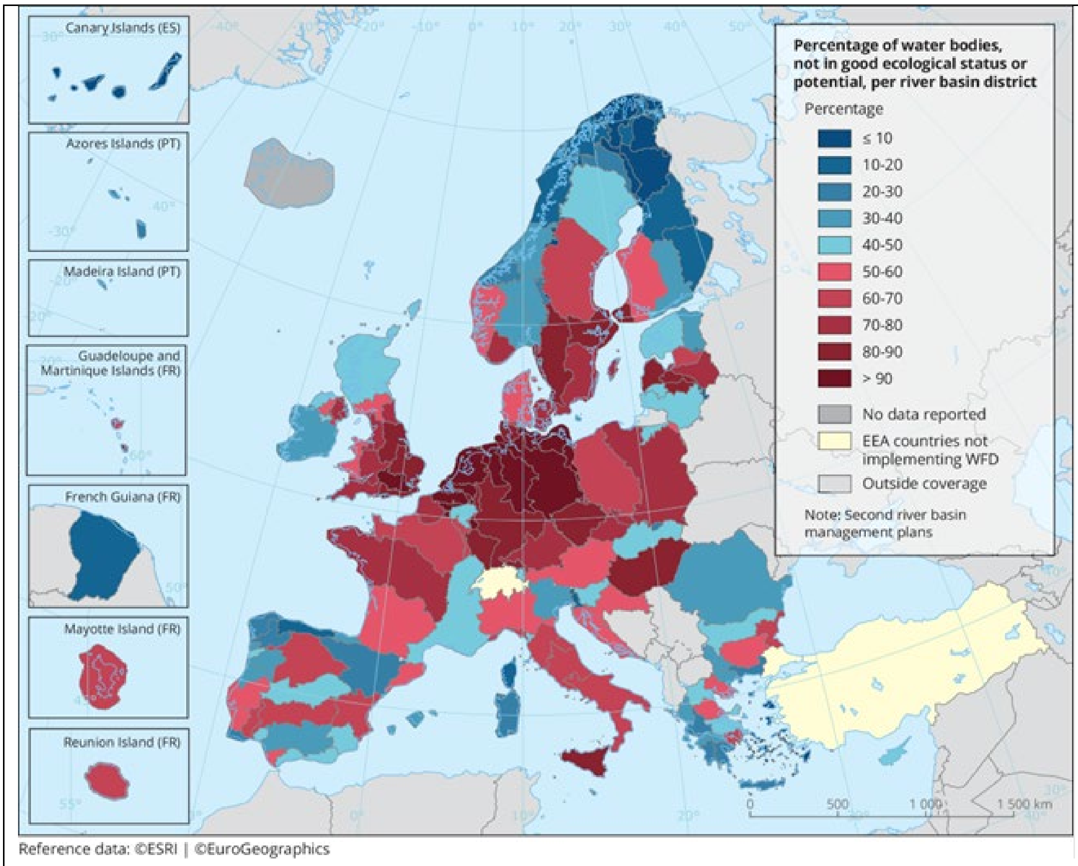
The Water Framework Directive (WFD) stipulates that EU Member States should aim to achieve good status for all surface water and groundwater bodies. This is an important aspect for the BREF to consider when it identifies BAT for reducing the volumes of water being withdrawn by refineries and the implications on increasing discharge concentrations as a result of more efficient operations. There is therefore the potential for conflict between adoption of BAT and the approach to regulating discharges from refineries which is biased towards concentrations rather than mass loading.

Since its implementation in 2019, good or better (high) ecological status has been achieved for only around 40% of surface water (rivers, lakes, and transitional and coastal waters) (**Figure 8**). Europe is not on track to achieve overall good ecological status (EEA, 2021a). Continued progress is expected as the implementation of the Water Framework Directive continues.

The main pressures on surface water bodies are identified as pollution from point (e.g., wastewater) and diffuse (e.g., agriculture) sources, and various hydromorphological pressures such as barriers (dams), and low-flow or channelised rivers.

Main impacts are identified as nutrient enrichment, chemical pollution, and habitat alterations due to morphological changes.

Figure 8 Percentage of water bodies not in good ecological status (2010-2015)



Source: EEA, 2021a

4.4. GEOGRAPHICAL DISTRIBUTION OF WATER STRESSES

One third of European countries have a relatively low availability of water, less than 5,000 m^3 of water per head per year.

Water demand is generally increasing, especially with increased demand from agriculture. Industry use remains the largest abstractor of water in Europe, with agriculture being the largest consumer. The average return ratio of cooling water from industrial and electricity production is around 80% of total water abstraction, while agriculture returns around 30%, and hydropower almost 100% (EEA, 2021b).

The average intensity of water use (the percentage of abstraction of water resources available from within the country and from transboundary rivers) varies with an average of 15% for Europe.

Two thirds of European countries rely on groundwater for drinking and other water needs. 60% of large (> 100,000 inhabitants) European cities have people living in or near areas of groundwater over-exploitation (EEA, 2020).

Water quality is largely impacted by contaminants from agriculture and industry. Recorded data shows rising concentrations of nitrates in both surface water and groundwater from agriculture, high levels of phosphorus and organic matter from municipal wastewater treatment plants and agriculture. Transboundary rivers (those where the aquifers and lake and river basins are shared by two or more countries) are an issue in Europe. Transboundary basins and aquifers create a nexus of hydrological, economic and social links between communities living in border areas, and beyond. Since actions in one country have consequences in another, this cooperation is essential especially in areas vulnerable to the impacts of climate change and where water is already scarce. Transboundary rivers can lead to downstream countries being vulnerable to water shortages and droughts, where there is no water management mechanism agreed between the two or more states.

Northern Europe:

- Heavily populated northern Europe countries with moderate rainfall, such as Denmark and UK have a relatively low availability of water.

Eastern Europe:

- Vulnerable to floods with the highest costs related to flood damage as a percentage of GDP. Transboundary rivers, which are rivers shared by two or more countries, are vulnerable to a high risk of flooding upstream and are vulnerable downstream to water shortages and droughts (OECD., 2012).
- Transboundary water issues are particularly prevalent in Hungary, as large parts of the catchment area are outside national borders and exposed to other countries management systems (OECD., 2020).

Southern Europe:

- Southern Europe is highly vulnerable to water stress and drought, with a relatively low availability of water per year. Southern Europe is experiencing the largest increase in the demand for water, compared to the rest of Europe.
- High water abstractions upstream cause water shortages downstream and could also lead to a deterioration of groundwater aquifers as a result of reduced river discharges and saltwater intrusions. It is expected that freshwater resources will suffer in the future from climate change impacts (OECD., 2012).
- Southern European countries are also vulnerable to flash floods.

Western Europe:

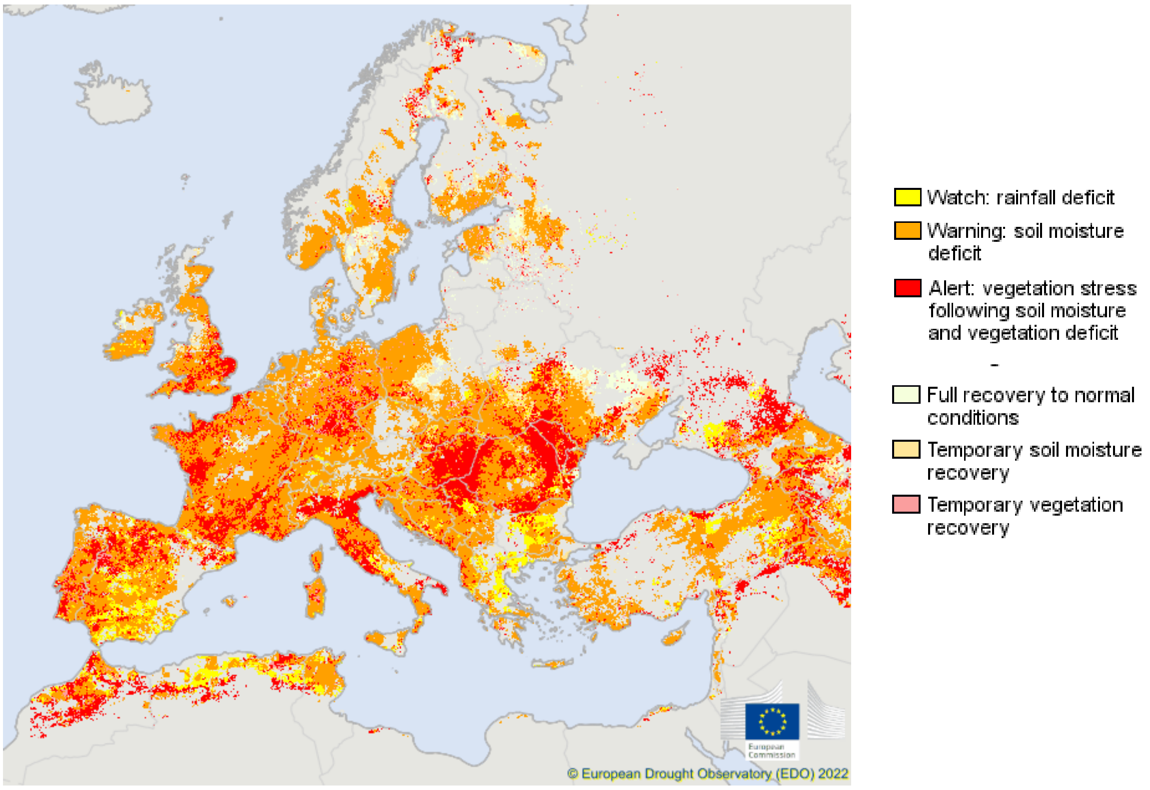
- Western Europe is vulnerable to seasonal water variability including drought and floods.
- Some western European countries rely on transboundary rivers for their water resources with Netherlands and Luxembourg relying on over 75% of their water resources on transboundary rivers, thereby depending on the upstream countries. Transboundary rivers have a high risk of flooding upstream, with downstream countries being vulnerable to water shortages and droughts.

4.4.1. Observed changes and trends

Spatially variable trends in precipitation across Europe, with annual precipitation in northern Europe increasing by 10-40% and decreasing up to 20% in some parts of southern Europe during the 20th century (Goliński et al., 2018).

There is a general increasing trend in annual river flows in parts of northern Europe, with the increases mainly occurring in winter due to seasonality. There is a slightly decreasing trend in annual river flows in parts of southern Europe and an increase in flooding and heavy rain events in recent years. Several significant periods of drought in recent decades, such as those in 2003 in central parts of Europe, 2005 drought in the Iberian Peninsula and current drought experienced in 2022. **Figure 9** shows the extent of the 2022 drought in Europe.

Figure 9 Map of Drought in Europe for 1st ten-day period in August 2022



Source: European Drought Observatory, 2022

4.4.2. Predicted changes and trends

It is expected that precipitation will continue to change in future years, with an increase in mean annual precipitation in northern Europe and a decrease in southern Europe. There has been an increase in flooding and heavy rain events in recent years. The frequency and intensity of floods is also expected to increase in parts of Europe, in particular flash and urban floods. Flood hazards are also likely to increase during wetter and warmer winters.

It is expected that there will be significant changes in the seasonality of river flows across Europe with summer flows expected to decrease for most of Europe (EEA, 2021c). This is expected to increase annual river flows in northern Europe and decrease annual river flows in southern Europe. Europe has also seen an increase in the frequency and severity of droughts due to river flows in southern and south-eastern Europe, the UK, France, and western parts of Germany.

4.4.3. Water Stress in relation to the EU refining sector

According to the abovementioned current and predicted trends of Water Stress, it is one of the key aspects to consider when defining water management strategies. To deal with this subject in the near future, it is a good practice for European Refineries to monitor the Water Stress impacting their activities.

As mentioned in Section 2.3, the Water Stress has been addressed in a lot of studies all over the world (Liu et al., 2017) and a wide range of different methodologies have been used to measure water stress (Wang et al., 2021). The previous chapter of this report includes a review of the most popular techniques to assess water stress.

To inform the range of water stresses that may be experienced by the EU refining sector, the World Resources Institute's (WRI) Aqueduct Water Risk Atlas software (Kuzma et al., 2023) was used for a first pass assessment for current and future water stress (WRI Aqueduct future water stress based on a business-as-usual scenario for 2030). Aqueduct WRI version 4.0 provides the choice of different sectors, whose water risk may be evaluated: Chemical industry, Oil and gas, Food and Beverages, Agriculture, Electric Power and Textile, among others. Also, the weight of the three factors that average for the Overall Water risk can be customized.

Aqueduct considers in total 13 water risk indicators (Kuzma et al., 2023):

- Physical risk on Quantity considers water stress, water depletion, interannual variability, seasonal variability, groundwater table decline, riverine and coastal flood risk and drought risk.
- Physical risk on quality includes untreated connected wastewater and coastal eutrophication potential.
- Regulatory and reputational risk includes no drinking water, no sanitation and country ESG risk index.
- The relative weight of every parameter can be adapted, so that the simulation can be made as site-specific.

It shall be noted that Aqueduct 4.0 can provide Water Risk images on a global basis. The pictures provided by the non-customized application allow European Industries to understand how they are seen in a world context. For this purpose, simulations (using default settings) have been run to assess the Overall Water risk, the Physical Risks on Quantity and Quality, and Regulatory/Reputational risks.

The results of the tool show that:

- The south of Europe has extremely high baseline water stress, and a high overall water risk.
- Some areas of northern Europe show a medium-high baseline water stress, including north of France, south of UK, parts of Germany, Denmark and west of Sweden.
- However, most of the western, northern, and eastern Europe show low and low-medium overall water risk (based on wider factors).

The tool shows an increased baseline water stress in 2030:

- The south of Europe continues to have extremely high baseline water stress, and a high overall water risk.
- Some areas of northern Europe also show extremely high or high baseline water stress.
- Two thirds of location show an increase in water stress.

However, to confirm water stress risk in a local area, it is necessary a deeper understanding of the challenges being faced at local scale. Therefore, it is necessary to zoom inside the European perspective, by first, highlighting the parameters that best meet water risks in Europe; second, developing criteria on how to implement them on a water risk estimation tool; and third, generating local, site-specific data. The work done by the Vanhem et al. (2018) is a starting point in this regard. Concawe's current dataset is not comprehensive enough to make specific assessments for each Membership site.

4.5. LONG-TERM EFFECTS OF CLIMATE CHANGE

Climate change is expected to increase global mean sea levels, thereby changing the run-off patterns of water courses, increasing the frequency of flooding and droughts and lowering the soil water storage capacity in southern Europe.

This change in climate is predicted to create a wetter climate in northern Europe and a drier climate in southern Europe (EEA, 2015).

Climate change and population growth are expected to increase water stress.

S&P Global Trucost (2021) carried out an analysis on 10 countries for water stress. These found that Greece, Italy, Spain, and Belgium are the most exposed to water stress between now and 2050, followed by Germany, France, Hungary and the UK, Russia and Sweden. The analysis considered a moderate scenario for projected temperature increase for 2020-2050 and the combination of reduced water availability and increased water demand (population, industrial and agricultural use).

The increasing frequency of extreme weather conditions is having large economic impacts on European countries. Sweden and Germany suffered large economic losses because of droughts in 2018 and 2019.

Increased variability in weather patterns is also increasing the frequency and/or magnitude of such extreme weather events in existing hotspots (e.g., southern Europe). Extreme weather events and higher water temperatures (expected to increase by 1°C to 5.5°C by end of the century) will impact or is projected to impact water quality and exacerbate existing pollution problems.

Water stress is predicted to increase with a decreasing quantity of fresh groundwater resources, especially in coastal areas and southern Europe, as a result of over withdrawal or use of non-renewable sources.

4.6. WATER RISK TOOLS

Tables 4-7 evaluate the strengths and weaknesses of the various water stress tools available in Europe. The tools were evaluated by ERM based on the intended use of the tool, the range of physical and social stresses measured. The tools are then compared for strengths, limitations, data transparency and level of user understanding required. They are an important consideration under potential future regulatory changes as some requirements may be linked to the level of water stress experienced with a catchment.

Table 4 Summary of Available Water Stress Tools and the Intended Use of the Tool

Available Tools	Scale	Intended Use of the Tool
WRI	Regional to Global	Measure, map and aid the mitigation of water risks around the world.
WWF	Regional to Global	Aid companies and organisations in screening for water-related risks.
GEMI Local Water Tool	Regional to Global	To identify the external impacts, business risks, opportunities and management plans related to water use and discharge at a specific site or operation. Note that this tool was last updated in 2016 and whilst still available to download/use it does not appear to have been updated recently.
Climate Central: Portfolio Analysis Tool	Regional to Global	Estimates future coastal flood events at a large number of coastal locations.
Fathom Global 2.0	Local to Global	Screening for river (fluvial) and flash flood (pluvial) flood risk, offering quantification and mitigation of flood risk and improved portfolio management.
GFDRR: Think Hazard!	Regional to Global	Hazard screening tool which enables users to screen project locations for multiple natural hazards globally.
Ecolab Water Tool	Local to Regional	Aids in setting corporate water targets and reducing water use through improved water management.
WEAP: Water Evaluation and Planning	Site to Regional	Operates on the basic principle of a water balance which can be applied to municipal and agricultural systems, a single watershed or complex river basin systems.
Munich Re's: Location Risk Intelligence	Regional to Global	Screening for natural hazard and climate change risks.
Swiss Re: CatNet	Regional to Global	Natural catastrophe risk assessment and event impact analysis for insurers. Detects potential hazards for the benefits of the insurance industry and its clients.
Verisk Maplecroft: Global Risk Dashboard (GRiD)	Local to Regional	Screening for political, human rights and environmental risks. Allows the simplifying of complex global risk assessments and map the entire range of issues affecting international operations, extended supply chains and investments.

Table 5 Comparing Water Stress Tools for Range of Physical Stresses Measured

Tool	Water Quantity	Water Quality	Water Stress	Water Depletion	Flood Risk	Drought Risk	Seasonal and Interannual Variability	Climate Change and Future Risk
WRI	✓	✓	✓	✓	✓	✓	✓	✓
WWF	✓	✓	✓	✓	✓	✓		✓
GEMI Local Water Tool		✓	✓			✓		✓
Climate Central: Portfolio Analysis Tool			✓		✓			✓
Fathom Global 2.0					✓			✓
GFDRR: Think Hazard!			✓		✓			
Ecolab Water Tool	✓	✓						
WEAP: Water Evaluation and Planning	✓	✓				✓		
Munich Re's: Location Risk Intelligence					✓	✓		✓
Swiss Re: CatNet					✓			
Verisk Maplecroft: Global Risk Dashboard (GRiD)					✓	✓		✓

Table 6 Comparing Water Stress Tools for Range of Social Stresses Measured

Tool	Local Reputation	Social Activism	Availability for Human Needs	Availability for Local Food Supply	Agricultural and Livestock Demand	Water and Treatment Costs	Unimproved / No Drinking Water	Unimproved / No Sanitation
WRI	✓	✓				✓	✓	✓
WWF	✓	✓					✓	✓
GEMI Local Water Tool	✓	✓	✓	✓	✓			
Climate Central: Portfolio Analysis Tool								
Fathom Global 2.0								
GFDRR: Think Hazard!								
Ecolab Water Tool								
WEAP: Water Evaluation and Planning								
Munich Re's: Location Risk Intelligence								
Swiss Re: CatNet								
Verisk Maplecroft: Global Risk Dashboard (GRiD)								

Table 7 Comparing the Strengths and Weaknesses of the Water Stress Tools[1]

Tool	Strengths	Limitations	Data Transparency	Last Updated	Level of User Understanding	Format
WRI Aqueduct	Ability to compare large geographical regions with each other to identify areas of higher risk. Hierarchy of risk indicators to provided weighted overall risk. Weighting of each risk factor can be adjusted by selected the industry. Risk indicators selected based on review of literature, potential data source evaluation and consultation with industry, public sector and academic water experts.	Useful mostly as a prioritisation tool and should be supported by local and regional investigations. Risk indicators selected based on being actionable in the context of private and public sector decision-making, which may exclude risk indicators which are not actionable but may still be relevant such as biodiversity importance or future changes to legislation.	Relies on hydrological modelling, remotely sensed data and published data accessible online. Published files on the water risk indicators and model framework including sources, calculations and limitations.	2019	Designed for easy use with basic understanding with guidance provided.	Online Tool
WWF Water Risk Filter	Ability to compare large geographical regions with each other to identify areas of higher risk. Hierarchy of risk indicators for three broad types of corporate risks, allows for the comparison of basin vs. operational risks. Weighting of each risk category can be adjusted by selecting the industry based on stakeholder	Designed as a corporate and portfolio-level screening and prioritisation tool. Looks at typical conditions with a weighted bias to more recent risk conditions and level of future risk. This does not account for real-time or local level water risk conditions. Does not provide local scale data	Based predominantly on freely available external, peer-reviewed datasets which are reviewed and updated annually. Integrates current datasets and future projections of water risks.	2021	Designed for easy use with basic understanding with step-by-step guidance provided.	Online Tool

[1] The seven principles that Vanham et al (2018) dictates to be accounted for in Water Stress assessment shall be considered for the appropriate methodology to evaluate water stress indicators at a site-specific level.

Tool	Strengths	Limitations	Data Transparency	Last Updated	Level of User Understanding	Format
	consultations and peer reviews with water experts.	which would be necessary to integrate to provide a more informative assessment of risk. WWF only uses region or country datasets to assess a company where all sites are located entirely within a specific region or country.				
GEMI Local Water Tool	Site specific water stress and risks identified from user inputs on water uses and impacts and business risks to identify opportunities and strategic water challenge. Takes into account the site-specific characteristics and risks, allowing users to list or change risk based on local knowledge.	Requires a higher level of user input that WRI and WWF. Not useful for portfolio-level screening without a lot of user input. Requires a higher level of understanding of water balance and risks at the sites to ensure all characteristics and challenges the site faces are captured.	Requires a large amount of data input from user including water sources, withdrawals, use on site, water quality, water discharge etc.	2015	Requires a good understanding of the water balance at site (or ability to collect the data required).	Excel File
WEAP: Water Evaluation and Planning	Site specific water balance model (water use, loss and reuse, demand management, water quality, cost and priority) based on user inputs. Designed to integrate water supply, water quality, ecosystem and planning and policy in one model. Flexible display of model outputs and map results.	Requires a high level of user input and understanding of the tool to utilise the model. Requires a license and understanding of GIS based systems.	Requires a large amount of data input from user including water sources, withdrawals, use on site, water quality, water discharge etc.		Requires an understanding of GIS based systems and water balance.	Licensed tool utilising GIS based systems.

Tool	Strengths	Limitations	Data Transparency	Last Updated	Level of User Understanding	Format
	Ability to change to site specific or business specific requirements of key assumptions and indicators by being able to change data variables.					
Ecolab Water Tool	Evaluates water management plan based on input from the user to identify focus areas for water management.	Information is based inputs by the user on their water management plans and targets.	Requires data input from user, to evaluate against a water management maturity curve.	2020	Designed for easy use with guidance provided.	Online Tool
GFDRR: Think Hazard!	Online tool to assess multiple hazards for physical risk based on probabilistic data evaluating hazard severity and frequency. Aggregated to show the highest hazards level of the selected area. Provides recommendations on understanding and mitigating the hazard risk.	Only shows risk from country to national level. Each level only shows the aggregated highest hazard level. The risk displayed does not consider the specific sites exposure and vulnerability to the hazard.	Open-source code linked to different data sources, not all data sources are publicly available due to their licensing restrictions.	2020	Designed for easy use with basic understanding with guidance provided.	Online Tool
Climate Central: Portfolio Analysis Tool	Tool to understand the flood risk to specific locations and to aid informed decision making and resilience planning.	No information publicly available on the algorithm or risk ranking criteria. No information publicly available on the sources of data used in the model. Focuses just on risk from floods and sea level rise. Subscription or one-off costs.	Paid for service with limited transparency on data algorithms.	Based on 2012 studies.	Designed for easy use with basic understanding with guidance provided.	Web Service

Tool	Strengths	Limitations	Data Transparency	Last Updated	Level of User Understanding	Format
Fathom Global 2.0	Comprehensive global flood hazard dataset including modelling of flood defences for defended and undefended areas. Uses high resolution terrain dataset to show river channels and predict event footprints. Utilises the latest climate data and the impacts from real world events.	No information publicly available on the algorithm or risk ranking criteria. No information publicly available on the sources of data used in the model. Focuses just on risk from floods and sea level rise. Not available for all global regions. Subscription or one-off costs.	Paid for service with limited transparency on data algorithms.	unknown	Designed for easy use with basic understanding with guidance and support provided.	Licenced software
Munich Re's: Location Risk Intelligence	Combines different assessment models to generate detailed assessments on past, current and future events to model climate change scenarios and risks from natural hazards.	No information publicly available on the algorithm or risk ranking criteria. No information publicly available on the sources of data used in the model. Subscription or one-off costs.	Paid for service with limited transparency on data algorithms.	unknown	Designed for easy use with basic understanding with guidance and support provided.	Software
Swiss Re: CatNet	Screens for natural hazards and risks including global flood zones, official flood zones, global storm surge zones and global pluvial flood zones.	Does not consider nonenvironmental risks on water or drought. No information publicly available on the algorithm or risk ranking criteria. Basic free online service with paid for premium service.	Basic free online service with paid for premium service.	unknown	Designed for easy use with basic understanding with guidance provided.	Online tool and licenced software

Tool	Strengths	Limitations	Data Transparency	Last Updated	Level of User Understanding	Format
Verisk Maplecroft: Global Risk Dashboard (GRID)	Screens for political, human rights and environmental risks including drought hazard, coastal flood hazards and riverine flood hazards.	No information publicly available on the algorithm or risk ranking criteria. No information publicly available on the sources of data used in the model. Subscription or one-off costs.	Paid for service with limited transparency on data algorithms.	unknown	Designed custom for use with guidance and support provided.	Online tool

Using multiple water stress tools can help to increase the understanding of water stress factors applicable to a site, when used with local site and stakeholder information.

While WRI Aqueduct and WWF are useful for an initial country level analysis into water stress, the WEAP and GEMI water tools allow the user to add their own local or site-specific information to calculate a local based stress. Ecolab Water Tool allows users to create or manage site specific water management plans and assess various water risks. This tool is almost entirely dependent on local information and user inputs to calculate water risk specific to a single site.

Whilst tools are a useful starting point, any analysis of water stress or challenges within a catchment should include dialogue with local water users to understand the local challenges within a catchment. Analysis should also include local water data that is specific to the catchment.

5. CONCAWE MEMBERS DATA

5.1. INTRODUCTION

This section summarizes the main findings from interviews with members and data questionnaires sent out under this project alongside the results of the Concawe 2019 water use survey. It also includes an analysis of water stress carried out on the Concawe members facility location to give context to the water use data.

5.2. 2019 WATER USE SURVEY

Data from the Concawe members' internal survey was provided for 2019. All water data in this section of the report is presented in thousands of cubic metres or decameters cubed (SI unit dam^3)[5]. The dataset also includes data from the 2016- and 2012-members' internal survey which has not been analysed as part of the Power BI dashboard data review. The 2016 and 2012 data are included within the PowerBI dashboard and can be accessed by the dropdowns on each page. The 2019 data was reviewed by ERM. ERM has not verified the data, although data limitations have been identified through our review

The 2019 dataset includes survey responses from 111 sites across Europe. Not all sites reported water usage data and not all water use is accounted for. The difference between water used on site and effluent is not clear and may be due to a lack of reporting for some onsite water use processes. The difference between effluent and output may be due to losses as a result of transfer and treatment.

As part of the data review, the intake salt and freshwater categories were reviewed and reassigned to three categories: fresh, salt and remediated/reused. Virtual intakes, where they are recycled/reused streams (e.g., treated water that is used by the refinery instead of being directly discharged or sour water that is used for desalting the crude) are included in the intake's spreadsheet as a 'coding consideration'. Sour water was classified as fresh in the original data set. These have been reassigned as part of the data review of the intake sources as remediated/reused.

Water intakes are categorised as:

- Groundwater
- Surface Water
- Remediation/Hydraulic Control
- Tank Bottom Draws
- Purchased Raw Water (unknown original source)
- Purchased Steam
- Purchased Potable Water
- Purchased Demineralised Water
- Purchased Recycled Water

[5] The SI unit for water is m^3. The SI unit for 1000 m^3 is the decameter cubic (dam^3) which is 1,000 m^3 In water resources terms this is also commonly termed either Ml (megalitres) or TCM (thousand cubic metres). This report uses dam^3.

- Rainwater (all rainwater, not separated to consider harvested rainwater independently)
- Sour Water

Water uses are categorised as:

- Crude Desalting
- Direct to Discharge and/or Treatment (Intake water not used on site. This could include, for example, water pumped for remediation or hydraulic control as well as Rain/storm water that is not used for site purposes.)
- Exported to Third Party – Use or Treatment
- Flue Gas Scrubber
- Once-Through Cooling Water
- Recirculated Cooling Water (Water used as makeup water for recirculating cooling systems)
- Steam/Boiler – Demineralised Water Plant (Water used to supply a demineralised water plant or used in a steam/boiler unit without first going through an on-site demineralised water facility)
- Other Process Use (Water used for processes not listed above, e.g. coking, wash water, etc)
- Other Non-Process Use (Water used for non-processes, e.g. domestic use (e.g. drinking water, kitchen utility water, shower), firefighting water, etc)
- Undefined Use

Output receiving environment types categorised as:

- Freshwater
- Saltwater
- Transfer (Interpreted as water being given to another industrial user or for treatment external to the site)

Water use was recorded in the survey using the following terms.

- Intakes – total volume of water withdrawan (including volume, source and intake type).
- Water Used Onsite - the volume of water used onsite, reported as use per water use category. This water is then treated as effluent.
- Effluent – the wastewater (treated where necessary) generated by the refinery.
- Output – the water discharged from the refinery (including volume, water qualtiy parameters and destination environment).

Consumption has been calculated using water outputs and intakes.

The data provided was insufficient to provide an overall water balance.

5.2.1. Water Intakes

The 2019 Concawe members' survey reported intakes as fresh, salt/brackish and 'virtual intakes'. Virtual intakes are recycled or reused streams from the refinery that are reused within the refinery boundary. Virtual intakes have been renamed as recycled/remediated and have been removed from the intake analysis.

For 2019, the total intake volume for all refineries was 2,178,736 dam^3 (**Figure 10**). Of this, 464,479 dam^3 was freshwater and 1,714,257 dam^3 was salt/brackish water. The intake volumes were analysed for source type (**Figure 11**). The majority of fresh water was extracted from surface water (31.8%). Other fresh water sources include purchased raw water (unknown original source), groundwater, purchase potable (source unknown), remediation/hydraulic control, rainwater, purchase recycled water, purchased mineralised water, and purchased steam.

Figure 10 Intake Volume by Source and Type

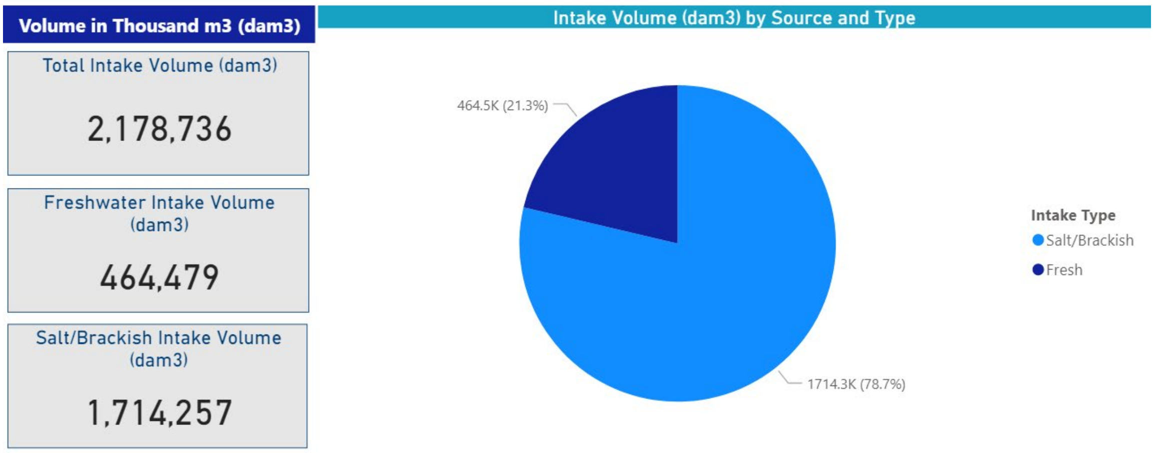
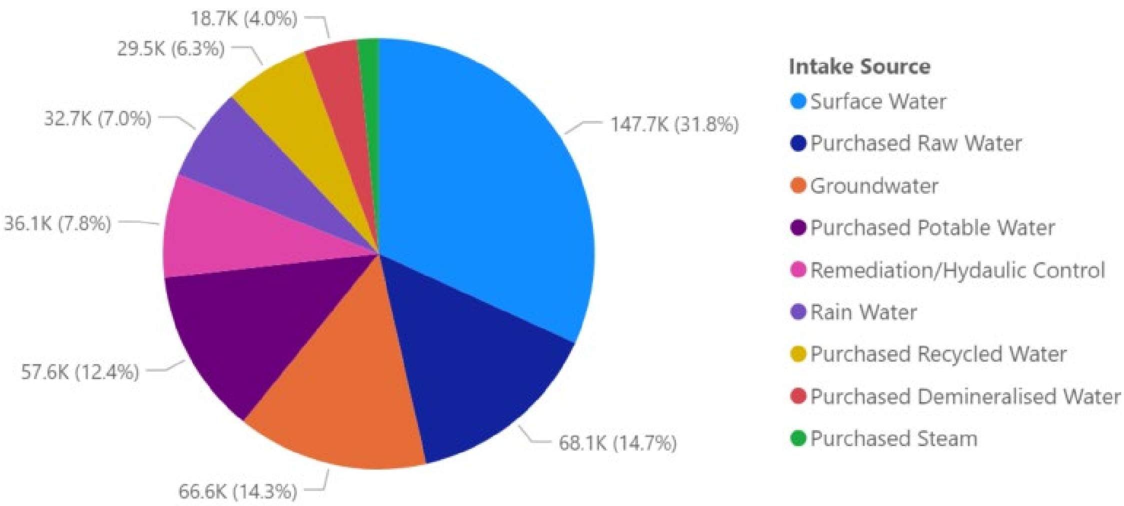


Figure 11 Intake Volume by Source and Type of Freshwater



The proportion of freshwater and salt/brackish water doesn't show any clear relation to the water stress of the location -i.e. sites located in water stress areas do not appear to use any higher proportion of salt/brackish water when compared to sites located in low stress areas.

The proportion of salt/brackish water shows a correlation to site location with the majority of sites in areas of low, high and extremely high water stress being located closer to the coast. Sites located in areas of extremely high water stress use a lower proportion of salt/brackish water than sites located in areas of high water stress.

5.2.2. Main Uses

For the 2019 Concawe members' survey data, Once-Through Cooling Water is the highest use of water (64%) (**Figure 12** and **13**). Three sites used once-through cooling water from a freshwater source, equating to 23% of all water used for once-through cooling water. Of these three sites, only one is landlocked (not bordered by coastline). The data does not provide enough information to identify how much water was consumed by the various refinery processes.

Figure 12 Proportions of All Water Used

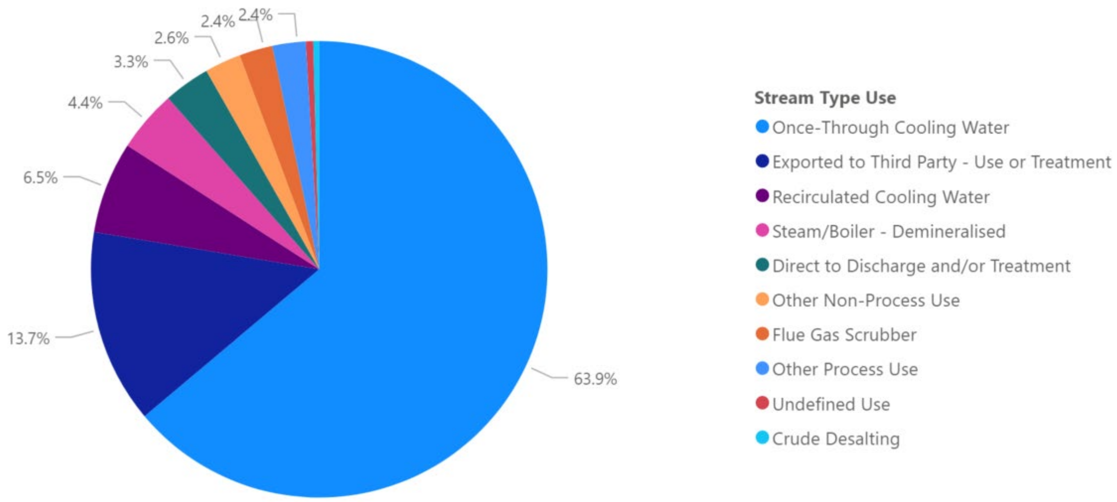
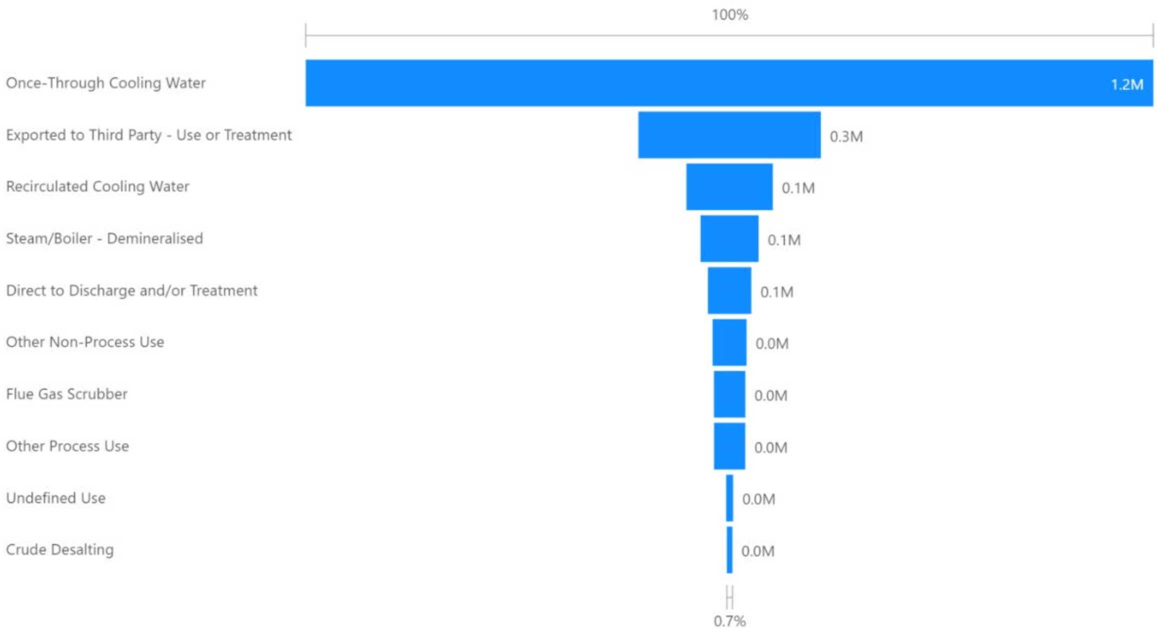


Figure 13 Water Use by Volume (dam^3)

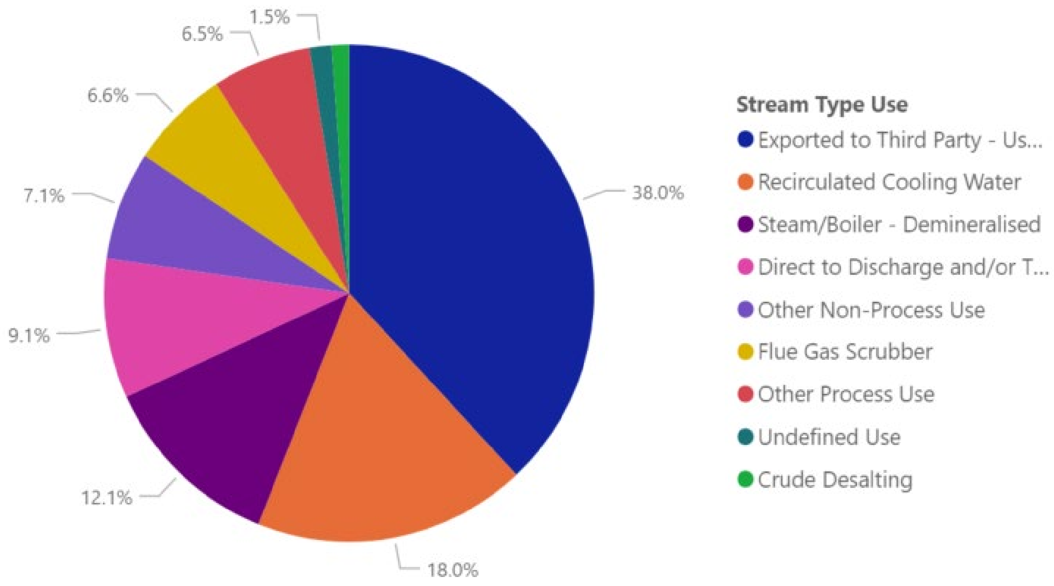


Exported to third party – use or treatment accounts for the second highest use of water. Excluding Once-Through Cooling Water from the analysis provides a clearer illustration of the other water uses (**Figure 14**). Four sites reported exporting of water to third parties It is not clear from the data provided if the refineries are acting as a water utility company by providing water to other users or exporting water for treatment by a third party offsite.

Recirculated cooling water accounts for 7% of water use, all reported recirculated cooling water is from a freshwater source, or an internally recycled/remediated source. Half of the sites that reported use of water as recirculated cooling water are located on, or near the coast. Water use in cooling processes is the highest water use with 1,325,308 dam^3 of water used for both once-through cooling water and recirculated cooling. 268,558 dam^3 of water is reported to be reused before discharge. This is mainly reused as recirculated cooling water.

There is no clear relationship between the proportion of water use and the baseline water stress. I.e., sites in extremely high-water stress areas have similar proportions of once through cooling water as sites in low stress areas.

Figure 14 Proportions of Water Used Excluding Once-Through Cooling Water

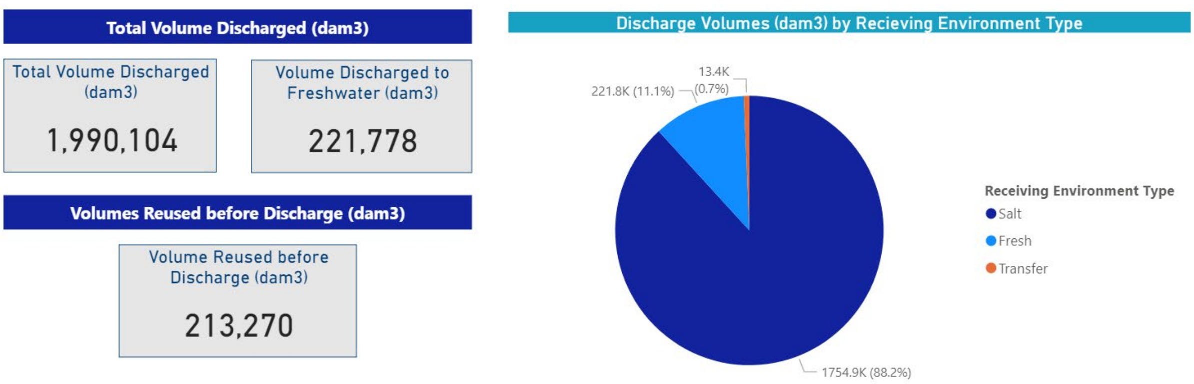


5.2.3. Discharges

The 2019 Concawe members' survey reported discharges to fresh and saltwater environment types. Discharges to other sites, such as third-party use or offsite wastewater treatment plants are recorded as transfers.

For 2019, the total discharge volume for all refineries was 1,990,104 dam^3 (**Figure 15**). Of the total discharge volume, 221,778 dam^3 was discharged to freshwater environments and 1,754,899 dam^3 was discharged to saltwater environments. A total volume of 13,426 dam^3 was transferred off site to third parties. Excluding once through cooling water, total discharge volume for all refineries was 51,993 dam^3. Of this discharge volume, 9,229 dam^3 was discharged to freshwater environments and 37,386 dam^3 was discharged to saltwater environments. A total volume of 5,377 dam^3 was transferred off site to third parties.

Figure 15 Discharge Volumes by Receiving Environment Type



The discharge volumes for freshwater were analysed for receiving environment type (**Figure 16**). The majority of water was discharged into rivers (68.9%).

Sites located in areas of lower water stress appear to discharge more water to freshwater environments (**Table 8**). Sites located in areas of extremely high-water stress discharge more to salt/brackish environments, the majority of these sites are located on, or near the coast.

Figure 16 Discharge Volumes (dam^3) by Receiving Basin Type for Freshwater Discharges

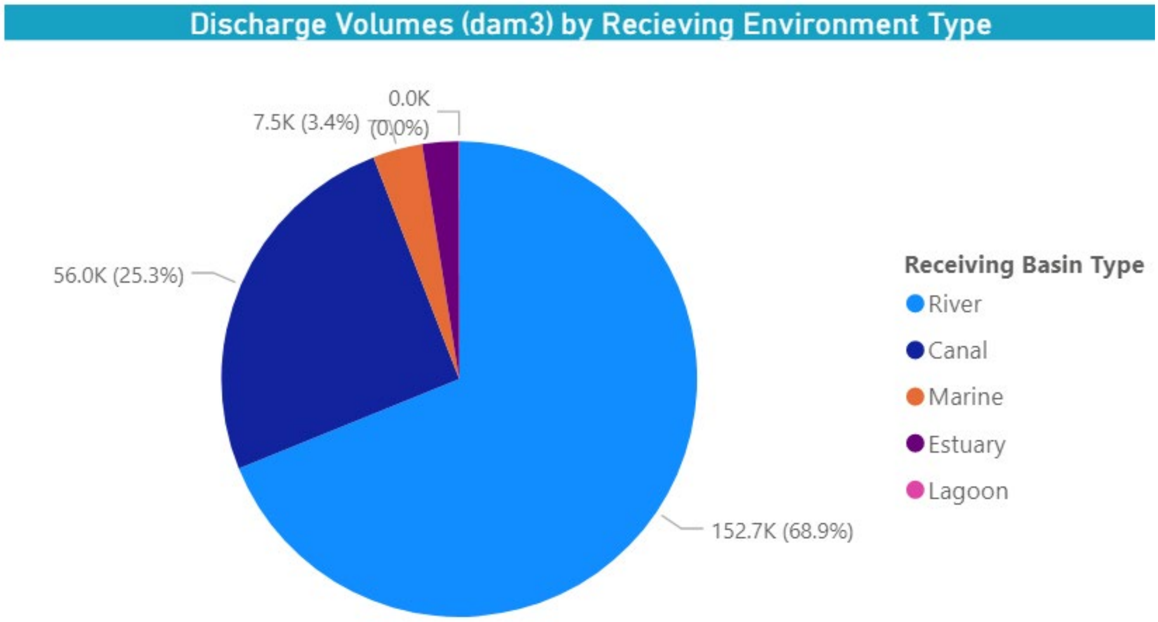


Table 8 Percentage of Water to Freshwater and Saltwater Environments by Water Stress Category

Water stress Category	Freshwater Environment Discharges (%)	Saltwater Environment Discharges (%)	Transfer (%)
Low (<10%)	90.578	8.880	0.002
Low - Medium (10-20%)	58.0	41.4	0.6
Medium - High (20-40%)	48.7	50.0	1.3
High (40-80%)	100.0	0.0	0.0
Extremely High (>80%)	12.4	84.0	3.6

Table 9 shows the percentage discharge of water to freshwater and saltwater environments by water stress category, excluding once-through cooling water. With the exception of sites located in areas of low water stress, the majority of water not used for once-through cooling is discharged to a freshwater environment. For sites in an extremely high-water stress areas, this water is transferred to a third party.

Table 9 Stress Category excluding OTCW

Water stress Category	Freshwater Environment Discharges (%)	Saltwater Environment Discharges (%)	Transfer (%)
Low (<10%)	1.2.	94.8	4.0
Low - Medium (10-20%)	98.3	1.7	0.0
Medium - High (20-40%)	70.6	29.4	0
High (40-80%)	100	0.0	0.0
Extremely High (>80%)	20.9	0.0	79.1

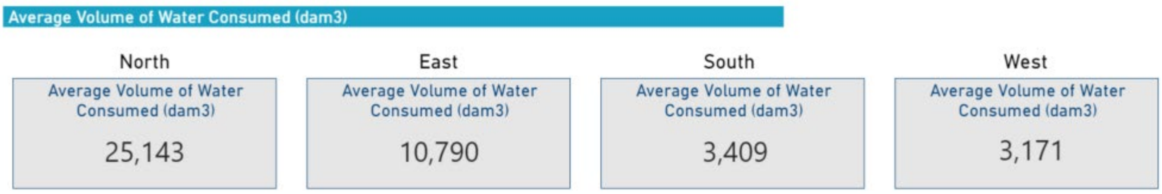
5.2.4. Consumption

Total consumption is calculated as total intakes minus total discharges.[6]

This total intake volume for all refineries is 2,178,736 dam^3. With a total discharge volume of 1,990,104 dam^3 the calculated total consumption is 188,632 dam^3, equating to 9% of all water abstracted.

The average total water consumption is highest for sites located in the north of Europe (**Figure 17**); these sites have the largest average water withdrawal volume of all regions.

Figure 17 Water Consumption by Region



5.2.5. Water Intensity

ERM compared water consumption per primary production capacity (Mt/a) as an indication of water intensity[7]. The volume of water consumed does not show any clear relationship to the primary production capacity.

[6] This does not take into consideration the source and discharge location of the water as this was not available in the original data (i.e. extraction and discharge locations not specified)

[7] Normally, production figures are used but these were not available. In this case, production capacity was used as a proxy.

The calculated average water intensity (consumption per production capacity) is 558 dam^3/Mt.

Sites that reported once through cooling water had much higher water consumption per production capacity generally. There is no clear variation in intensity between different regions with different water scarcity.

5.2.6. Discharges Water Quality

The discharge water quality BAT-13 parameters are presented below (**Table 10**). Sites local discharge requirements may differ from the BAT-13 parameters.

Table 10 BAT-13 Parameters

Analyte	Analytical Method / Standard	BAT-AEL (yearly average) Upper Limit	Unit
Benzene	Not specified	0.05	mg/l
Cadmium (Cd)	Not specified	0.01	mg/l
Chemical Oxygen Demand	Not specified	125	mg/l
Lead (Pb)	Not specified	0.03	mg/l
Mercury (Hg)	Not specified	0.0001	mg/l
Nickel (Ni)	Not specified	0.1	mg/l
Total Nitrogen	Not specified	25	mg/l
Total Petroleum Hydrocarbons (TPH) / Oil in Water (OiW) / Hydrocarbon Oil Index	EN 9377-2	2.5	mg/l
Total Suspended Solids	Not specified	25	mg/l

5.3. SUMMARY

- More than 20 sites are currently located in high or extremely high-water stress areas. There are a number of locations expected to have increased baseline water stress in 2030. The majority of these sites are located on or close to the coast.
- The proportion of salt/brackish water is correlated to site location with the majority of sites in areas of low, high and extremely high water stress being located closer to the coast. Sites located in areas of extremely high water stress use a lower proportion of salt/brackish water than sites located in areas of high water stress.
- The largest use of water is for once-through cooling water with the majority of sites using water from a salt/brackish source. Sites located in areas of high and extremely high-water stress do source water for once-through cooling water. The majority of these sites are located on or near the coast.
- 268,558 dam^3 of water is reported to be reused before discharge. This equates to 12% of all water withdrawn being reused within the refinery, which is reported to be reused as recirculated cooling water. 79.4% (213,270 dam^3) of reused water is first used for once-through cooling water.

- Sites located in areas of higher water stress appear to discharge more to salt/brackish environments although this is likely to also be related to the geography of the sites located closer to the coast.
- Surface water receiving environments include rivers (receiving 69% of freshwater discharge volumes), canals, estuaries, and lagoons.
- Total consumption is reported to be 188,632 dam^3, equating to 9% of all water abstracted. Total freshwater consumption appears to be at 242,701 dam^3, equating to 52.3% of all freshwater abstracted.
- Water consumed generally increases with primary capacity. The average water consumption per primary capacity is 6,439 dam^3/Mt. There is some variation from this, likely due to varying efficiency, water losses and local climate effects (i.e., greater evaporation in higher temperature climates).

5.4. MEMBER INTERVIEWS

ERM conducted freeform interviews with six Concawe company members to discuss the following topic areas:

- current, planned and considered, water reduction and efficiency practices and techniques;
- water metric terminologies;
- water metric targets and other reporting indices;
- their general experience at operations with water stress, both existing and anticipated in the future; and
- any key operational sensitivities regarding water use and stress.

The majority of members interviewed aligned to the IPIECA freshwater definition *"The total dissolved solids (TDS) concentration of this water type is up to 2000 mg/l"*. While some also considered the source of the water within the definition, for example, water originating from glaciers, lakes, reservoirs, ponds, rivers, streams, wetlands, or groundwater, this was not consistent by all members. No members considered stormwater within their freshwater intakes, and this was consistently reported to be sent directly to a wastewater treatment plant (WWTP). Rainwater and runoff at the refinery were also typically excluded as a source of freshwater.

Five out of the six members interviewed have some form of environment strategy or KPI's in place which strive to achieve some reduction in the withdrawals of freshwater and use within their refineries. These had various drivers, from European regulations, local requirements, or stakeholder and industry pressure to reduce their environmental impact.

When assessing water stress, all members interviewed made use of WRI Aqueduct as a high-level assessment tool. Most however, found that additional tools were required in order to assess the local conditions around individual site. It was also noted that often these tools are unable to account for manmade water infrastructure such as, reservoirs and dams, which can be a key source of intake water at many facilities.

High-level or broad water balances exist for many sites however, it was discussed that these are unlikely to be detailed enough to accurately calculate the efficiency of many internal processes. At sites where there was no significant water stress or older facilities where metering capabilities were limited, water balances often do not exist.

Whether or not sites have experienced water stress issues that affected production in recent years was variable. Some sites have already experienced reductions in water availability or in water quality due to reduced water levels during very hot summer periods, while other sites have observed no change at all. In general, most members interviewed are yet to experience significant impacts in water availability but foresee this as a likely occurrence in the future and have begun to plan for this. As a result of the differing current experiences, the conversations with the members uncovered a broad range of current attitudes towards the implementation or freshwater reduction and efficiency measures. While some members are beginning to view freshwater as a resource and explore options for future reuse and recycling, other members do not see water savings as a priority due to relatively low costs of water as a resource and no significant limitations on water availability. As interviews were conducted at a member level, it cannot be ascertained whether the sites that are less concerned with reducing savings are located within water stressed areas.

The most common direction of those members engaging in active water savings projects was substitution of freshwater intakes with municipal wastewater. There were several examples given where this has been successfully trialled at individual sites and multiple members stated that this is being explored as a future option. Some sites were also exploring the reuse of their own treated wastewater however, this presented more quality challenges than the use of external treated wastewater. Members found that internal wastewater required additional and more complex treatment to remove contaminants and get the water to a quality where it could be reused. Other reoccurring areas of improvement were based around addressing known losses to internal leaks and uncontrolled blowdown and the potential for segregation of certain wastewater streams to allow for reuse of cleaner discharges.

The main concerns about the future BREF and legislation changes surrounded the potential for discharge limits to be exceeded when discharge volumes are reduced by the reuse of water. Although the members discussed the challenges around the resultant changes in mass loading and discharge concentration that would result from increased reuse and recycling of water, it is noted that discharge requirements are set according to the receiving water contest as set out in the WFD.

Some of the key challenges identified were:

- The implementation of new water saving infrastructure in older facilities. For example, spatial challenges when adapting existing combined sewers into segregated systems for contaminated process water compared to known domestic water or clean stormwater runoff.
- Cost of facility improvements compared to the cost of water itself although this neglects the cost impact of reduced production if water availability is reduced).
- The lack of formal restrictions in some countries via regulators or legislation as a driver for change.

- Reductions in the volume of discharge water may cause the concentration of contaminants, thus exceeding discharge limits although the mass loading remains the same.
- Difficulties in pre-empting changes to the BREF and therefore, uncertainty around making changes now.
- Uncertainty surrounding the future of refining, for example, the increase in use of biofuels, and hydrogen, and how these will affect the current facility water requirements and how they will be considered in future legislation and BREF documents.
- Transboundary and cumulative effects for example, where the source of the water is in another country. It is unclear how various future documents and legislations will interact with one another when water bodies cross country boundaries, it may be difficult for downstream countries to take responsibility for overall water quality in water bodies that cross-cut but do not originate within their jurisdiction.

5.5. DIGITAL SURVEY

ERM created and distributed a digital survey to all members aimed at individual sites to gain insight into their specific experiences of the topics discussed in the member interviews (see Section 5.4). A total of 10 responses to the survey were received. The results of these are summarised in the following text with the full responses provided in Appendix A, all responses were anonymous.

5.5.1. Water Balance

All responders indicated that sites have water meters in place for inputs and outputs, with 80% indicating that they also monitor internal processes. 30% of responses stated that they had a system in place for tracking changes in water balances, either via software or the storage and review of historic data. 70% of sites reported to track condensate recovery with the greatest barrier to complete condensate recovery being leaks. Boiler feedwater systems and cooling water cycles are generally well monitored

The majority of sites listed rainwater as an unmeasured portion of their raw water make-up. Only 20% of sites reported having combined sewer systems for industrial and sanitary wastewater which is less than was suggested during the member interviews, however, 70% of sites reported that these wastewater streams are treated at the same treatment plant. 80% of sites stated that they did not have a thorough water balance for the various constituent wastewater streams that make up the total facility dry weather wastewater flow. Comments included *"flows are not well monitored"*, *"difficulties monitoring all the wastewater coming from activities"* and *"rainwater, service water, cooling of some pumps difficult to track"*.

The majority of sites do not report using 'fin-fan coolers' (air-fin coolers). Sources of firefighting water used at sites varied, some of the sources listed include; raw water, freshwater, potable municipal water, reused water, brackish water from rivers and canals, seawater, and rainwater, with many using a combination. Most of these systems require constant make-up. 70% of sites reported having no dust suppression or irrigation systems that use water at their sites, the 30% that did all stated this was unmetered.

The greatest limiting factors in water monitoring at refineries was reported as *"underground leaks"* or *"unmonitored water users"*. This is consistent with the findings of the member interviews.

5.5.2. Substitutions

During the member interviews, the most common suggested substitution for freshwater was the use of treated municipal wastewater. The results from the digital survey found that 60% of sites had knowledge of nearby sanitary water discharge from local community that could be used relatively reliably as reclaimed water (**Figure 18**). 20% of sites had not investigated this and 20% had investigated but found no nearby source. 40% of responses indicated that this water could be reclaimed and considered as a source for industrial processes (**Figure 19**).

All sites reported that stripped sour water was already in use as an alternative water source for various industrial processes. 20% of sites reported the use of extracted groundwater and/or rainwater from collection ponds, 50% of sites reported these resources as present but not used, and 20% had no access to collection ponds or extracted groundwater. 20% of sites reported they already utilise treated refinery effluent for firefighting water, 60% stated they do not currently use this but recognise there is potential.

Figure 18 Could that treated wastewater be reclaimed and considered as a water make-up source for your cooling towers or some other application?

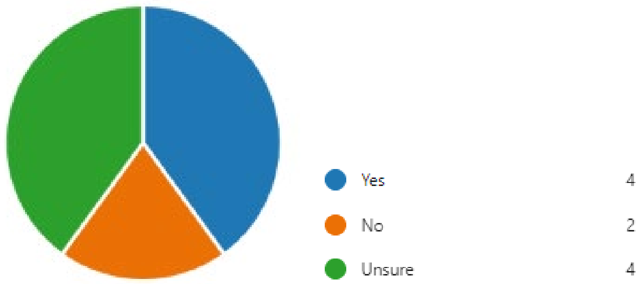
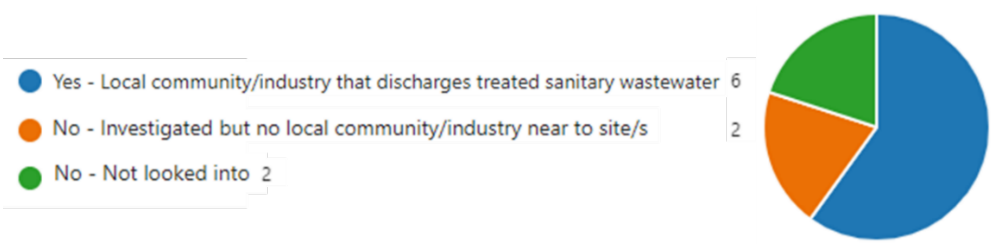


Figure 19 Is there nearby sanitary water discharge from local community that could be used as reclaimed water?



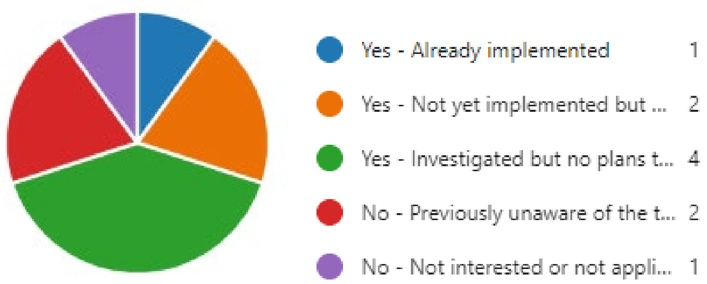
5.5.3. Water Efficiency Techniques

Water efficiency techniques covers all techniques that impact and improve the efficiency of overall water use, including all activities of elimination, reduction, reuse/recycling, and substitution.

When asked the question 'Have you studied the possibility of recovering high quality water for reuse from your treated wastewater (E.g. Ultrafiltration/Reverse Osmosis)?', the response was varied (**Figure 20**). 30% of sites indicated that they had already implemented or had plans to implement these techniques with the other responses indicating no plans, no interest, or no prior knowledge of the techniques.

All sites indicated that they either had no prior knowledge, no plans, or no interest in the implementation of waste heat to drive thermal desalination of seawater. Within the last 4 years, 50% of sites reported implementing new water efficiency techniques in their refineries. These included; ultrafiltration, reverse osmosis, sand filtration, the optimisation of cooling water cycles by optimising the chemical program, the collection of treated wastewater and rainwater for use in the cooling and firefighting systems, distillate hydrocracker effluent used as service water, reduction of uncontrolled blowdown, and the reuse of municipal wastewater.

Figure 20 Responses to Have you studied the possibility of recovering high quality water for reuse from your treated wastewater (E.g. Ultrafiltration/Reverse Osmosis)?



5.5.4. Industrial Regulation

100% of refineries that responded to the digital survey have undertaken a review of operations under the BAT Conclusions for Refineries adopted in October 2014. As a result of this most sites matched the BAT conclusions or implemented water efficiency techniques and modifications to improve the use and/or management of incoming water, water used in an industrial process, wastewater or stormwater.

As a result of this review, company-wide changes were made in 30% of cases, where KPI's were updated, widespread modifications were made, reduction targets were created, and task forces were created to identify potential water reduction initiatives. Where these changes were not company-wide, the review was often still used to identify gaps in monitoring or other changes required at individual sites.

5.5.5. Definitions

Sites were asked to provide details of the definitions of a series of water related terms including; freshwater, groundwater, precipitation, brackish water, seawater, reused wastewater effluent, withdrawal, use, consumption, abstraction, efficiency, scarcity, and stress. In general, most sites indicated they followed the IPIECA definition for freshwater or a similar definition with a lower salinity limit. This corresponds with the findings of the member interviews. For other definitions, where responses were provided, they were broadly consistent between sites. Many sites did not have internal definitions for these terms. The full responses provided by sites are available in Appendix A.

6. CONCLUSIONS

Industry use remains the largest abstractor of water in Europe, with agriculture being the largest consumer. It is expected that precipitation will continue to change in future years, with an increase in mean annual precipitation in northern Europe and a decrease in southern Europe, along with prolonged periods of drought and episodes of more intense rainfall. Whilst water scarcity tools are a useful starting point, any analysis of water stress or challenges within a catchment should include dialogue with local water users to understand the local challenges within a catchment. Analysis should also include local water data that is specific to the catchment.

For refineries, the decisions to make improvements around water volumes and quality will need to carefully balance a range of factors influenced by the prevailing legislation and stakeholder expectations. The role of Water Stewardship will also have to come into play here, as the needs of the catchment will have to be considered. This will however potentially offer opportunities, as the cross-cutting themes, impacts and opportunities can be discussed and agreed in a multistakeholder environment. Opportunities exist for refineries to work with local regulators and stakeholders to overcome the local water challenges experienced by communities, ecosystems, and the refineries themselves. In terms of water stress, variability in market and regional and catchment differences mean that options will have to be looked at on case-by-case basis. Furthermore, any targets set around water reduction and recycling will have to reflect not only the broad aspirations of the companies, but the needs and requirements of those living and working in the operating catchments.

It was found that while Concawe members often broadly follow the same definitions of water terminology, with many subscribing to the IPIECA definition of 'freshwater', there are variations which are often dependant on the local environment and requirements. For many other water-related terms, members have no official internal definitions, and no industry wide standard exists. The Concawe Water Use/ Effluent Quality Survey for the reporting year 2019 showed that 21% of all water reported to was abstracted from freshwater sources, including surface water, groundwater, purchased fresh water and rainwater. The other 79% was brackish/ salt water.

From interviews with 6 Concawe members the following key industry challenges were identified:

- No standardised definition of freshwater or other water-related terms.
- A general lack of baseline monitoring makes reduction difficult to plan for or achieve.
- Different challenges in different environments, simply reducing freshwater withdrawal may not always be the best solution for example, in locations where water quality is a greater concern than water quantity or where water availability is not a primary concern.
- Improvement likely to be a better objective to focus on, however, this still requires baseline monitoring. The Water Framework Directive is all about context and improvement so this approach would be aligned.

- Reductions in discharge volumes causing increased concentrations of contaminants in smaller volumes of wastewater. Concentration based limits may then be exceeded although the mass output of pollutants remains unchanged. Therefore, in order to encourage and enable economically viable water reclamation and reuse, it is important that this be accompanied by legislative flexibility that allows the establishment of discharge limits that, in addition to protecting the receiving environment, are compatible with the reclamation and reuse of discharge water as a substitute for freshwater. It is worth nothing that such flexibility does exist in the IED (article 15(3)b) but local implementation may vary.
- Modifications to existing (older) facilities/installations may not be possibly or economically feasible to achieve required improvements.

Through discussions with operators, it is clear that the energy production process is undergoing significant evolution and that new products and techniques are going to have an impact on sourcing of water at refineries.

Overall, deriving BAT conclusions requires more technical investigation and thoughtful thinking, due to the lack of clear definitions, limitations of reliable data and the local aspect being the critical factor.

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8. DEFINITIONS

"AQUASTAT Database United Nations"	Freshwater Scarcity | Annual Review of Environment and Resources (annualreviews.org)
AWS	AWS_Standard_2.0_2019_Final.pdf (a4ws.org)
BP	Microsoft Word - Glossary SD2 ESIA FINAL (bp.com) bp ESG datasheet 2022
CDP	CDP-technical-note-water-accounting-definitions.pdf
CEO Water Mandate	Glossary - CEO Water Mandate
Equinor	Glossary of terms - Equinor
European Environment Agency	Glossary — European Environment Agency (europa.eu)
Galp	WaterRisks_ScreeningReport_Galp_2021.pdf
GEMI Local Water Tool	GEMI
Global Reporting Standards	gri-303-water-and-effluents-2018.pdf (globalreporting.org)
IPIECA	identifying_and_assessing_water_sources_2014 (1).pdf
OMV Group	sustainability-report-2021.pdf (omv.com)
Phillips 66	2022 Sustainability Report by Phillips66Co - Issue
PKN Orlen	Orlen Raport Zintegrowany 2020 | Gospodarka wodno-ściekowa
Saras	saras_bilancio-di-sostenibilita-2021_eng_web.pdf
Shell	Sustainability Report 2021 (shell.com)
Valero	PowerPoint Presentation (valero.com)
WRI	World Resources Institute

Water Risk Tools

Aqueduct | World Resources Institute (wri.org)

CatNet® | Swiss Re

Fathom | Global Flood Hazard Mapping & Water Risk Intelligence

GEMI Local Water Tool (LWT)

Global Risk Dashboard | GRiD - Our Client Portal | Maplecroft

Location Risk Intelligence | Munich Re

Products | Climate Central

Smart Water Navigator - Guide Your Water Strategy with Smart Water Tools

Think Hazard

WEAP: Water Evaluation And Planning System (weap21.org)

WWF Water Risk Filter

APPENDIX A DIGITAL SURVEY (ANONYMOUS) RESPONSES

ID	1	2	3	4	5	6	7	8	9	10
Do you monitor your water volumes for inputs/ withdrawals and outputs/discharges?	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place
Do you currently monitor your water volumes at any of your onsite processes?	Yes - water meters in place	Yes - water meters in place	No - do not currently monitor specific process' inputs or outputs	Yes - water meters in place	Yes - based off production volumes/timings/recirculation calculations	Yes - water meters in place	Yes - water meters in place	Yes - water meters in place	No - do not currently monitor specific process' inputs or outputs	Yes - water meters in place
Do you have a system in place at your facility for tracking differences in water balance?	No	No	No	Yes	No	No	Yes	Yes	No	No
If yes, describe the system or process				Local software, developed with services provider (based on energy efficiency model). PowerBI dashboard to follow KPIs			Excel file which was monthly updated to follow water consumption	We keep track of the water balance. Historic data from metric volumes are stored digitally.		
Do you track the fraction of steam condensate recovery and compare that against a theoretical maximum fractional recovery for your facility?	Yes - Track the fraction of steam condensate recovery, but do not compare	Yes - Track the fraction of steam condensate recovery, but do not compare	No - Do not track or compare	Yes - Track the fraction of steam condensate recovery and compare against a theoretical maximum	Yes - Track the fraction of steam condensate recovery and compare against a theoretical maximum	No - Do not track or compare	Yes - Track the fraction of steam condensate recovery, but do not compare	Yes - Track the fraction of steam condensate recovery and compare against a theoretical maximum	No - Do not track or compare	Yes - Track the fraction of steam condensate recovery, but do not compare

ID	1	2	3	4	5	6	7	8	9	10
Are there any losses which prevent your system from achieving its maximum theoretical recovery fraction documented?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Please provide details	Leaks, no condensate header, pea traps	Maximum theoretical recovery not calculated. All the quantities of steam are not monitored. We don't have a global overview of condensates volumes: condensates that need to be treated are well monitored, condensate that are already at the quality to be reused are less followed.	questions 5 and 6 to be discussed with technical team	Condensate leaks that need to be repaired: losses during the reparation of the line.	Blowdown leaks	Some losses are known to exist but not quantified	Leaks on systems. A specific procedure is in place to track leaks on steam and condensate systems.	Leakage under ground	No collection system in some units, some losses. Also contaminated condensate cannot be recycled because there is no specific treatment	Condensates too hot to be recovered
Do you monitor the cycles of concentration of your cooling water systems?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes

ID	1	2	3	4	5	6	7	8	9	10
If no, why not?								The cooling water system is a closed loop, so there is no evaporation.		
Do you measure the cooling water make-up rate and blowdown rate?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
If no, why not?2							One is measured (make-up), one is calculated by evaporation (blowdown).		It is measured for some cooling systems but not for all. On some systems, an issue is uncontrolled blowdown	
Do you compare the ratio of dissolved compounds in the blowdown with the raw water make-up?	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
If no, why not?3			to be discussed with technical team					Measurement is only to detect leakage from closed loop.		
Do you have a good mass balance for your boiler feedwater system?	Yes - Have a mass balance in place but aware not all streams are tracked	Yes - Have a mass balance in place but aware not all streams are tracked	Yes - Have a mass balance in place but aware not all streams are tracked	Yes - Have a good mass balance in place	Yes - Have a good mass balance in place	Yes - Have a good mass balance in place	Yes - Have a good mass balance in place	Yes - Have a mass balance in place but aware not all streams are tracked	Yes - Have a mass balance in place but aware not all streams are tracked	Yes - Have a good mass balance in place

ID	1	2	3	4	5	6	7	8	9	10
Please provide details (optional)	N/A	For the majority of boilers we have the information of water inlet and the production of steams in PI informatic system. The blowdown of the boilers are not monitored. An important part of the water is coming from an external plant. The production is globally well monitored (water inlet in resins.), except for the regeneration of the resins		Just a doubt on calculation for return of condensates. Production of feedwater well monitored	Thanks to extremely detailed balance				not all condensate recycling is measured. Not a good balance around aerator	If we are only talking about the production of demin water, it is very well documented on site.
How much of the water fed to this system ultimately becomes boiler feedwater? (Compared to how much is rejected)	40-60%	80-100%	20-40%	60-80%	40-60%	80-100%	60-80%	60-80%	20-40%	80-100%
Is boiler feedwater used for hydrogen production?	No	No	No	No	No	Yes	No	No	No	Yes
And if so, how much is lost to that process?						0-20%				0-20%

ID	1	2	3	4	5	6	7	8	9	10
Please provide details (optional)2	N/A					Regarding question 12: The range depends on the water feed quality and the treatment system. Regarding question 15: In existing reforming plants for hydrogen production, it is understood that there are no losses.				
Are there sources of water that are not measured as part of the raw water make-up to your facility?	No - No additional sources	Yes	Yes	Yes	Yes	No - No additional sources	Yes	No - No additional sources	Yes	Yes
If yes, please list sources		Rainwater (calculated) ; brackish water, for open cooling (withdrawals and discharge are monitored, but high uncertainty of flow meters, and no possibility to track all the usages at the moment and the consumption))	water ingress from groundwater	Rainwater + ground water reaching surface, going to a pond and recirculated within cooling system.	Rainwater		Rainwater, going to a pond and recirculated within cooling system.		Rainwater, groundwater remediation	Rainwater in wastewater treatment

ID	1	2	3	4	5	6	7	8	9	10
Are there meters for those flows or can they be indirectly calculated?		Yes - Indirectly calculated	Yes - Indirectly calculated	Yes - Metered	Yes - Indirectly calculated		Yes - Indirectly calculated		Yes - Indirectly calculated	Yes - Indirectly calculated
Outside of production related water use, Does your facility have completely separate potable water/sanitary sewer systems or is there interconnection between industrial uses?	Yes - Separate systems and metered separately	No - Combined systems and metering	No - Combined systems and metering	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately	Yes - Separate systems and metered separately
Is sanitary wastewater treated along with the industrial wastewater for your site?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Please provide details (optional)3	Some sites treat the sanitary wastewater at our site WWTP	Network is interconnecte d (cooling water provided by public network). Sanitary water is treated in the WWTP of the refinery.	septic pit and overflow to sewers		Both are sent to the wastewater treatment plant				sanitary water goes through septic tanks. The water is in most drained.	
Do you have a good water balance for the various constituent wastewater streams that make up the total facility dry weather wastewater flow?	No	No	No	No	Yes	Yes	No	No	No	No

ID	1	2	3	4	5	6	7	8	9	10
Please provide details (optional)4	N/A	these flows are not well monitored.		Separation between rainwater sewer and wastewater from process. But difficulties to monitor all the wastewater coming from activities (service water, condensate not recovered). 20% of uncertainty for this part of water balance.					only for some specific pollutants such as COD we have a balance at the wastewater plant and for some high contributors at the processes	rainwater, service water, cooling of some pumps difficult to track
Does your facility sometimes use water sprays on fin-fan coolers for supplemental cooling in hot weather? If so, are these flows metered?	No - Fin-fan coolers not used	No - Fin-fan coolers not used	No - Fin-fan coolers not used	No - Fin-fan coolers not used	No - Fin-fan coolers not used	No - Fin-fan coolers not used	No - Fin-fan coolers not used	Yes - Metered fin-fan coolers used	Yes - Fin-fan coolers used but not metered	No - Fin-fan coolers not used
What water source does your facility use for its fire-fighting system?	Raw water	Brackish water.	well water	water from public network + mix between ground water and rainwater collected in a pond.	The refinery's water input is 100% potable municipal water. So is the same water source for all.	Reused and freshwater	Ground water ; rainwater mixed with treated wastewater	Industrial water (freshwater), and/or seawater	surface water, pre-treated by third party	brackish water or river (depending of the season)

ID	1	2	3	4	5	6	7	8	9	10
Does your fire-fighting system require constant make-up?	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Does your facility use water for irrigation and/or dust control? If so, is that use measured?	Yes - Not metered	No - No dust suppression or irrigation	No - No dust suppression or irrigation	No - No dust suppression or irrigation	Yes - Not metered	Yes - Not metered	No - No dust suppression or irrigation	No - No dust suppression or irrigation	No - No dust suppression or irrigation	No - No dust suppression or irrigation
Does your facility wastewater go to wastewater holding ponds after treatment prior to discharge? Are these ponds lined? Is the metered final discharge before or after these ponds?	No - No holding ponds present	No - No holding ponds present	Yes - Lined holding ponds with meter after	No - No holding ponds present	No - No holding ponds present	Yes - Lined holding ponds with meter after	Yes - Lined holding ponds with meter after	Yes - Lined holding ponds with meter after	No - No holding ponds present	No - No holding ponds present
Are there currently any significantly limiting factors affecting your ability to monitor water use in any part of your facility? (E.g. Equipment limitations, unmonitored water users, assumptions a...	Unmonitored water users and discharges	Part of leaks are difficult to identified (underground) . Some usages are difficult to monitored too with portable device (insulated pipe). Lots of data are already available in PI informatic system.	lack of monitoring (lack of flowmeters), leaks	Globally, for monitoring, it is mostly a question of means and priorities on site (lot of monitoring devices to be maintained on a lots of topics).	unmonitored water users	There are no limitations for the main uses, but there may be economic limitations to install meters in minority uses.	Underground leaks are difficult to identify. Difficulty scraping discharge pipes limiting flow rates. But globally, for monitoring, it is mostly a question of means and priorities on site.	Unmonitored water users	Yes. Not all users are monitored. There is not always a meter at each process units	
Is there nearby sanitary water discharge from local community that could be used as reclaimed water?	Yes - Local community/ industry that discharges treated sanitary wastewater	Yes - Local community/ industry that discharges treated sanitary wastewater	No - Not looked into	Yes - Local community/ industry that discharges treated sanitary wastewater	No - Investigated but no local community/ industry near to site/s	Yes - Local community/ industry that discharges treated sanitary wastewater	No - Not looked into	No - Investigated but no local community/ industry near to site/s	Yes - Local community/ industry that discharges treated sanitary wastewater	Yes - Local community/ industry that discharges treated sanitary wastewater

ID	1	2	3	4	5	6	7	8	9	10
Could that treated wastewater be reclaimed and considered as a water make-up source for your cooling towers or some other application?	Yes	Yes	Unsure	Unsure	Yes	Yes	No	No	Unsure	Unsure
If yes, please expand	the treated water would replace the current FW source so cooling tower make up would be one source	Project to use city's wastewater for cooling, service water and demin water (produced on site)			There are some things moving around so maybe that could be accomplished but on a very early stage .	The water is used or could be used with a regeneration pretreatment.				
Is there any extracted groundwater (not from a source well) and/or rainwater collection ponds that could be utilized as an additional water source?	Yes - Not currently used, but present	No - No collection pond or extracted groundwater present	Yes - Not currently used, but present	Yes - Already used	Yes - Not currently used, but present	No - No collection pond or extracted groundwater present	Yes - Already used	Yes - Not currently used, but present	Yes - Not currently used, but present	No - No collection pond or extracted groundwater present
Have you evaluated options for the re-use of stripped sour water as desalter make-up or as another water make-up source?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Please provide details2	Already use SWS in the desalter	Already used.	partial	already used with sour water from distillation process, improvement on going for sour water from FCC	Stripped sour water is used as desalter make-up	Yes, already implemented.	Stripped sour water reused as desalter make up.	We use stripped sour water as desalter make-up.	part of it, is used as desalter wash water but not the total	Already used.

ID	1	2	3	4	5	6	7	8	9	10
Have you considered using treated refinery effluent water as the make-up source water for the refinery fire-fighting system?	Yes - Not currently used, but potential for future implementatio n	Yes - Not currently used, but potential for future implementatio n	Yes - Not currently used, but potential for future implementatio n	Yes - Not currently used, but potential for future implementatio n	Yes - Not currently used, but potential for future implementatio n	Yes - Already used	Yes - Already used	No - Not currently used	Yes - Not currently used, but potential for future implementatio n	No - Not currently used
Are there future projects being considered at the refinery where fin-fan cooling could be considered instead of cooling water?	Yes	No.	not know	n	We are constantly evaluating ideas, including this one. But not considered as projects yet.	No	Not planned (CO2 footprint?)	N.A.	It may be considered during project	yes, looking to close some cooling loops (no more evaporation), but very theorical at the moment. Already exist cooling by air for distillation process.
Have you studied the possibility of recovering high quality water for reuse from your treated wastewater (E.g. Ultrafiltration/Reve rse Osmosis)	Yes - Investigated but no plans to implement	Yes - Investigated but no plans to implement	No - Not interested or not applicable to facility	Yes - Investigated but no plans to implement	Yes - Already implemented	Yes - Not yet implemented but have active plans to	Yes - Investigated but no plans to implement	No - Previously unaware of the technology but interested in future implementation	No - Previously unaware of the technology but interested in future implementation	Yes - Not yet implemented but have active plans to
Some locations of refinery waste heat can potentially be used to drive thermal desalination of seawater, is this something you were aware of or have implemented in your facility? Would you consider...	Yes - Aware of the technology but no plans to implement	Yes - Aware of the technology but no plans to implement	No - Not interested or not applicable to facility	Yes - Aware of the technology but no plans to implement	Yes - Aware of the technology but no plans to implement	Yes - Aware of the technology but no plans to implement	No - Not interested or not applicable to facility	No - Previously unaware of the technology but interested in future implementation	No - Not interested or not applicable to facility	Yes - Aware of the technology but no plans to implement

ID	1	2	3	4	5	6	7	8	9	10
Have you installed any new water efficiency technologies in your facility or made any process modifications in this area within the last 4 years?	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes
Please provide details3	N/A	Project for reuse of municipal wastewater.	NA	pump to recirculate rainwater from the pond within firefighting system	This year an Ultrafiltration +Reverse Osmosis system was installed in the wastewater treatment plant for 20% water reuse.	UF in one site and sand filtration in other site.	Treated wastewater was collected together with rainwater in a pond and recirculated within cooling and firefighting system. Plan to maintain the use of rainwater (but separated from treated wastewater in the future, which won't be reused)	Not prioritized.	optimizing cooling water cycles by optimising the chemical program	Distillate hydrocracker effluent used as service water. reduction of uncontrolled blowdown.
Are there any technologies/modifi cations you already have knowledge of that could be easily implemented in your facility?	We are looking into these opportunities now	Easily no/	no	easily : n	Nothing is easy, but there are efficiency modifications getting done. One that is worth mentioning, which could be relatively easy, is the installation of more	Easy ones are already implemented. Additional modifications are not easy to implement	maintain the use of rainwater (but separated from treated wastewater in the future, which won't be reused)	Extend water treatment.	expand the new chemical program to other cooling water system to allow higher cycle rates	not easily. work on recirculation of condensate.

ID	1	2	3	4	5	6	7	8	9	10
					ultrafiltration+ osmosis modules that will increase water reuse. But given the economics, it's probably not "easy"					
Has the Refinery undertaken a review of operations under the BAT Conclusions for Refineries adopted October 2014?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If so, were any measures identified for improvement relevant to the use and/or management of incoming water, water used in an industrial process, wastewater or stormwater? Please describe including...	Yes	all BAT conclusions were matched for water	-	BAT conclusions were matched	As said before, we had to install a UF+RO system so that we could reuse water. The system will be operational in Q3 2023	Increased analytical plan and tertiary treatment modifications at some sites	no	N	no	BAT conclusions were matched.
If no, please explain why the Refinery has not had to participate in this review.										
Has the Company made any Company-wide changes following adoption and implementation of the BAT Conclusions for Refineries adopted October 2014.	No	No	No	No	Yes	Yes	No	Yes	No	No

ID	1	2	3	4	5	6	7	8	9	10
If so, were any measures identified for improvement relevant to the use and/or management of incoming water, water used in an industrial process, wastewater or stormwater? Please describe including...2					A task force was created in order to identify water reduction initiatives. Thanks to the work done, Cepsa now has a freshwater reduction target.	Increased analytical plan and tertiary treatment modifications at some sites		KPI's where updated and followed closely.		
If no, please explain why the review was not necessary.	Gap analysis indicated it was only necessary at one location	Only improvement on monitoring of wastewater for some sites	modifications prior 2014	review show that only adaptation of monitoring were required.			Gaps were only identified on monitoring requirements for water management.		No related to water. there is little BAT for water use.	Gaps were only identified on monitoring requirements for water management.
Please provide your currently used internal definitions (if available) for the following terms: 'Freshwater'	IPIECA definition TDS < 2000 mg/	salinity <2g/l	NA	salinity <2g/l	Water from any source which contains TSS<= 1,000 mg/L	Freshwater: water with a total concentration of dissolved solids equal to or less than 1000 mg/l.	Salinity <2g/l	From drinking water source	Follow IPIECA definitions Freshwater: Water where total dissolved solids (TDS) is less than or equal to 2,000 mg/l (ppm) (or in the absence of TDS data, where conductivity is less than or equal to approximately 2,800 microSiemens/ cm at 25°C) OR Water that is specifically considered '"fresh" by local regulation.	salinity <2g/l

ID	1	2	3	4	5	6	7	8	9	10
Please provide your currently used internal definitions (if available) for the following terms: 'Groundwater'	N/A	operated intakes in ground water and aquifer accompanying the rivers	NA	operated intakes in ground water and aquifer accompanying the rivers	Don't have an internal definition.	Water that is being held in, and that can be recovered from, an underground formation	operated intakes in ground water and aquifer accompanying the rivers	Rainwater in the ground	Groundwater - Water purposefully taken from a confined or unconfined aquifer that is not a by-product of another activity (e.g., not associated with an oil/gas formation). This typically will be from company operated water wells, but should also include water obtained from wells of individual landowners.	operated intakes in ground water and aquifer accompanying the rivers
Please provide your currently used internal definitions (if available) for the following terms: 'Precipitation'	N/A	rain water collected in sewers	NA	rain water collected in sewers	No internal definition.	Rainwater: Water collected in storage containers by drains or by direct precipitation into open ponds or storage tanks.	rainwater collected in sewers	NA	none for precipitation. but for Harvested Rainwater: Rainwater purposefully collected using runoff capture or other harvesting techniques for use on site.	rainwater collected in sewers

ID	1	2	3	4	5	6	7	8	9	10
Please provide your currently used internal definitions (if available) for the following terms: 'Brackish Water'	N/A	> 2 g/l salinity	NA	> 2 g/l salinity	No internal definition. GRI definition used	No definition	> 2 g/l salinity	NA	not specific one. but will not be freshwater - per IPIECA guidance	> 2 g/l salinity
Please provide your currently used internal definitions (if available) for the following terms: 'Sea Water'	N/A	no specific definition, reported together with brackish water.	NA	no specific definition, reported together with brackish water.	No internal definition, but water withdrawn from the sea	Water with a total concentration of dissolved solids greater than 1000 mg/l.	no specific definition, reported together with brackish water	Water from the sea	none	no specific definition, reported together with brackish water.
Please provide your currently used internal definitions (if available) for the following terms: 'Reused Wastewater Effluent'	N/A	effluent from wastewater treatment plant valorized as intake for new usages (after additional treatment or not)	NA		Water current used in processes after being treated in a wastewater treatment plant	Reclaimed water: Water withdrawn from a third-party or from other Company operational center (inter-center) that had one or several previous uses and will be reused, regardless of whether it has been treated externally before being used by the operational centre. Water reused internally: Water that has had one or various previous uses		NA	we speak about water reused/recycled: water that has been used more than once in a single process or used in other processes, with treatment as appropriate, to reduce freshwater withdrawal. Note that the terms reused and recycled are not differentiated for this indicator. This category is intended to record the ongoing water reduction	

ID	1	2	3	4	5	6	7	8	9	10
						on the operational center and has been treated internally, or not, before being used again on the same operational center and that therefore reduces the gross withdrawn water. This include, among others: • Recycled water from the water treatment plant. • Acid process water (desalination, washing, etc.). • Rejects from inverse osmosis that are recycled. • Mud sent to the coker plant. • Water to be used for soil compaction, dust control on roads, irrigation or supply to local communities.			benefits from projects.	

ID	1	2	3	4	5	6	7	8	9	10
Please provide your currently used internal definitions (if available) for the following terms: 'Withdrawal'	The volume of water removed from sources (including surface water, groundwater, harvested rainwater and municipal freshwater supplies) and taken into the boundaries of the reporting unit for use.	total water withdrawn on Environment or coming from external providers (rain water excluded)	NA		Water from any source which is used for any reason	Water withdrawn from each of the sources; Water withdrawn from surface water; Rainwater; seawater; Third party water; Water purchased from a private service supplier, for use at the operational site; reclaimed Water		NA	not exactly but we speak about freshwater withdrawn: Freshwater withdrawn: the volume of freshwater removed from sources (including surface water, groundwater, harvested rainwater and municipal water supplies) and taken into the operations of the reporting company for use	
Please provide your currently used internal definitions (if available) for the following terms: 'Water Use'	N/A	water inlet of each usage	NA	water inlet of each usage	No internal definition.	Not defined	water inlet of each usage	NA	none specific	water inlet of each usage
Please provide your currently used internal definitions (if available) for the following terms: 'Consumption'	The difference between water withdrawn and fresh water returned/discharged		NA	withdrawals + rainwater - discharge (except if freshwater intake and discharge to salty environment, in this case : consumption = withdrawals)	Withdrawal-Discharge	The total amount of water that was withdrawn and is not returned to surface water, groundwater or the ocean or sent to a third party.		NA	Freshwater consumption : the difference between freshwater withdrawn and freshwater returned (this is used in sustainability report per Sustainability	

ID	1	2	3	4	5	6	7	8	9	10
									reporting guidance for the oil and gas industry, 2020 per IPIECA/API/IOGP)	
Please provide your currently used internal definitions (if available) for the following terms: 'Abstraction'	N/A	no specific definition	NA	no specific definition	No internal Definition.	-	no specific definition	NA	none specific	no specific definition
Please provide your currently used internal definitions (if available) for the following terms: 'Efficiency'	N/A	no specific definition	NA	no specific definition. local KPI on Reverse Osmosis, return of condensate and stripped water recycled to desalting process	No internal definition.	-	no specific definition ; KPI under definition	NA	none specific	no specific definition (KPI to be defined)
Please provide your currently used internal definitions (if available) for the following terms: 'Scarcity'	Scarcity reflects the physical availability of fresh water rather than whether that water is suitable for use	no specific definition	NA	no specific definition, associated with drought crisis?	No internal definition.	-	: no specific definition, associated with drought crisis?	NA	Water scarcity/water stress: using the WRI Aqueduct tool. (reference https://ceowatermandate.org/terminology/)• Water scarcity - the volumetric abundance, or lack thereof, of freshwater resources	no specific definition, associated with drought crisis?

ID	1	2	3	4	5	6	7	8	9	10
Please provide your currently used internal definitions (if available) for the following terms: 'Stress'	Stress is a general term for water-related constraints, including water availability (e.g., droughts), water quality (e.g., pollution) and the accessibility of water (e.g., infrastructure constraints), that is arises routinely in an area	WRI aqueduct water stress baseline (balance between global needs and available resource > 40%)	Na	WRI aqueduct water stress baseline (balance between global needs and available resource > 40%)	We define water stressed areas with the WRF tool. Areas which result >3 in the scarcity indicator.	Measures the ability, or lack of ability, to satisfy the human and ecological need for water. It can refer to the availability, quality or accessibility of water.	WRI aqueduct water stress baseline (balance between global needs and available resource > 40%)	NA	Water stress - the ability, or lack thereof, to meet human and ecological demand for fresh water; compared to scarcity, "water stress" is a more inclusive and broader concept	WRI aqueduct water stress baseline (balance between global needs and available resource > 40%)
Is there anything else you would like to tell us about water use and efficiency in your refinery that has not been covered in this survey? (optional)	N/A			Local administration requires regular study to substitute drinking water from public network used in process by other sources. Requirements to reduce water withdrawals during drought period.		In order to promote reuse (reclaimed or regenerated water), it is essential to make the discharge parameters more flexible. Either by making the ELV more flexible and linking them to the existing recovery percentage, or by allowing discharge in mass load instead of in	new policy on water adopted in 2022 : updated water balances for all sites withdrawing more than 500 000 m3/year. freshwater withdrawals reduction target (-20%) for sites in water stress areas by 2030 (WRI Aqueduct)	NA		Administration requests to study freshwater withdrawals reduction by 20%. Company ambition to have updated water balance and action plan for freshwater withdrawals reduction

ID	1	2	3	4	5	6	7	8	9	10
						pollutant concentration. // In order to define water stress it is important to consider local sources of information to determine or complement the information available in global tools (such as aqueduct) which do not have sufficient granularity and do not include water infrastructures in the local environment. // We understand that several questions in this survey are very generic, so the results may not be comparable between members, as they will depend on the approach that each member has given to the answer.				

Environmental Science for European Fuel Manufacturing

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