south pole

Methodology for Water Risk Assessments of Equity Portfolios

Technical report

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Acronyms and abbreviations

AuM	Assets under Management
AWS	Alliance for Water Stewardship
BaU	Business as Usual
CDP	Carbon Disclosure Project
CPS	Current Policies Scenario
ETP	Energy Transition Pathways
FOEN	Swiss Federal Office for the Environment
GCM	Global Climate Models
GDP	Gross Domestic Product
GICS	Global Industry Classification Standard
ICCR	Interfaith Centre on Corporate Responsibility
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KPI	Key Performance Indicator
MSCI	Modern Index Strategy Indexes
NCFA	Natural Capital Finance Alliance
NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
S&P	Standards & Poors
SDG	Sustainable Development Goals
SDS	Sustainable Development Scenario
SASB	Sustainability Accounting Standards Board
SMI	Swiss Market Index
SNB	Schweizerische Nationalbank
SPI	Swiss Performance Index
SSP	Shared Socioeconomic Pathways
TCFD	Task Force on Climate-related Financial Disclosure
UN	United Nations
UNPRI	United Nations Principles for Responsible Investment
VA	Value Added
WEF	World Economic Forum
WEO	World Energy Outlook
WFaS	Water Future and Solutions Initiative
WFN	Water Footprint Network
WRF	Water Risk Filter
WRI	World Resource Institute
WRM	Water Risk Monetizer
WWF	World Wildlife Fund

Executive summary

This study examines how investors can analyse and understand the water risks in their equity portfolios with the aim to align portfolios to global water targets and goals such as the UN's Human Right to Water or the Sustainable Development Goal 6 - Clean water and sanitation. To that end, the study 1) describes a newly developed water risk methodology for equity portfolios and applies it to a sample portfolio, 2) describes a water risk analysis for individual stocks and applies it to three Swiss companies from different industries associated with diverse water risk profiles and 3) analyses and gives recommendations for the development of water scenarios based on existing climate scenarios.

Water risks are not only material for the real economy but they also lead to implications in the financial system due to decreased revenues and increased costs within invested companies, and interdependency of affected financial institutions. The interaction between water risks and the financial system is a topic that has been gaining traction due to the important milestones such as the development of the Investor Water Toolkit by Ceres and the recommendations given by the Task Force on Climate-related Financial Disclosures (TCFD). Therefore, this study aims to develop the basis for equity investors to analyse water risks holistically on industry or individual stock level. The information from the application of the developed methodologies should ultimately provide the relevant information in the research and development of investment strategies that align investment portfolios to global water treaties.

For the first time, equity portfolios are linked to water risks with a geographical component. The portfolio water risk methodology allows investors to analyse and understand the water risks of industries associated with their equity portfolio in terms of their geographical distribution. This is the first step into water risk analysis and helps investors to prioritise the companies in the portfolio based on their water risks profiles. To effectively manage and better understand companies associated with high water risks, investors need to consider more granular data and should, therefore, analyse water risks on individual stock level. For that purpose, South Pole developed a methodology to assess water risks of individual stocks. Through the development of these two methodologies, South Pole was able to build on the expertise of Ceres and SASB, explore the data availability for water risk analysis and give recommendations on how to further develop existing methodologies. The analysis showed that different methodologies serve different needs and it ultimately depends on what an investor wants to achieve with the water risk assessment. The needs of an investor have to be balanced with the time and data available to an investor.

The suggested approach can be seen in Figure 1.

Figure 1: 3-Step approach for engaging with portfolio companies on water risks

While the methodologies represent an important step in the development of water risk analysis, both have a few shortcomings. The currently available data and methodologies are not well suited for investors to align their portfolio to global water targets. While there is a growing number of data, the different data sets are not consistent, comparable or reliable. Further, there is a persisting lack of aggregated geographic data on company level. Very few companies report the locations of their offices, manufacturing sites or their supply chain. Further, South Pole welcomes the development of the presented methodologies which could then be applied to a large number of equity stocks while increasing the level of granularity and accuracy of the water risk analysis of individual stocks. Such a methodology would be required to align equity portfolio to global water goals such as the SDGs.

The number of water-specific scenarios is still very limited and the existing ones are missing important features. All water scenarios are currently focusing on physical risks, while neglecting transitional risks and financial impacts. Developing a water scenario is a very complex and challenging matter which would require one universally recognised scientific body developing a water scenario in a collaborative effort, such as the Intergovernmental Panel on Climate Change (IPCC) has done in the climate community. For this reason, South Pole recommends the Swiss Federal Office for the Environment to engage with the Water Futures 2050 scenario in collaboration with the World Resources Institute and the International Institute for Applied Systems Analysis.

1. Background and goal

1.1 Background

Our global economy relies very heavily on water resources. A steady and timely supply of freshwater is essential for nearly all industries, from agriculture to industrials. The compounding impacts of decreasing availability and declining quality could have dramatic impacts on a company's ability to operate, grow and generate revenue. Across industries, between 50-90% of companies disclosing to CDP are exposed to substantive water risks in their direct operations or value chain (CDP, 2018). The World Bank estimates that water scarcity could cost some geographic regions up to 6% of GDP by 2050 (World Bank Group, 2016). The risk of having a water supply crisis has been recognised as one of the top five global risks in terms of impact from the World Economic Forum (WEF) since 2012 and as one of the top five global risks in terms of likelihood in 2012 and 2013 (WEF, 2019).

Water risks are not only felt in the real economy but also lead to implications in the financial system due to decreased revenues and increased costs within invested companies, and interdependency of affected financial institutions. We can distinguish between physical, regulatory and reputational water risks. These can have ripple down effects to individual securities and portfolios across all asset classes. However, the challenge is to understand materiality and timing of water impacts on specific asset classes, sectors and industries. In comparison to greenhouse gas (GHG) emissions, water conditions can strongly vary over time and location. A first analysis of market indices such as the S&P 500, Russell 3000, MSCI World and MSCI Emerging Markets by Ceres demonstrated that a large share of publicly traded companies are exposed to medium or high water risks (Ceres, 2015). If our economy continues with business as usual, high costs to limit damages will arise and will make investments in a transition to a resilient and resource-efficient economy more expensive. The financial sector plays a crucial role in accelerating this transition due to its steering function. A systematic integration of environmental risks and opportunities by financial players could direct financial flows into this transition and at the same time avoid investments in non-sustainable companies. The recommendations of the Task Force on Climate-related Financial Disclosure (TCFD) are clear: companies and investors alike should consider climate-related scenario analyses in their long-term strategy, growth and cost considerations (TCFD, 2017). First attempts to provide investors with methodological approaches to quantify water risks, such as the Investor Water Toolkit by Ceres, exist.

With water risks becoming more prevalent for the global economy and thus the financial sector, it is important to further develop the data and tools to adequately quantify them. The Federal Office for the Environment (FOEN) supports the methodological development of tools and metrics to enable financial institutions to accelerate the transition to a resource efficient economy nationally and internationally, including the management of water resources. The first study conducted by South Pole provided an overview of the available tools, databases and methods to assess water risks for the real economy and the financial market (South Pole, 2018). In addition to the risk perspective, the study explored alignment strategies which aim at contributing to international water goals through investments. The study found that the existing tools often emphasise physical water related risks, such as focusing on baseline-water stress, while the equally important reputational and regulatory risks are neglected. Further, the available tools are not yet sufficiently suited to engage the private sector in aligning with public water policy goals.

With this study, the FOEN seeks to fill this gap by contributing to the development of a holistic water risk methodology for investors. The focus of this report is on the **development of a methodology to quantitatively assess water risks in an equity portfolio.**

In an ideal scenario, an investor would use granular data, on a company and river basin-level, to make a risk-based investment decision, such as to buy, sell or hold. Creditors and investors request risk information that is consistent, comparable, reliable and clear. However, the challenges that investors face in assessing water-risks in their portfolios, are manifold.

- Quantitative water data has been very scarce, poorly reported and not externally verified on all levels (company and basin). According to TCFD, all climate-related information should be comparable among companies within a sector, industry or portfolio. There is, however, no homogeneous and reliable raw data with regards to water accounting of companies (water withdrawal, use or discharge) or their risk management approaches.

- Geographic information about companies' operations and their supply chain is rarely available or arduous to identify and analyse. Geographic data is crucial because water risks are local and should be assessed on a basin-level.

- Asset managers and analysts have limited amount of resources available to analyse a great number of companies in a portfolio and need to optimise their investment portfolios along a wide range of fund specific criteria.

- A perceived lack of an effective framework for conceptualising water risks. (Ceres, 2015)

1.2 Goals and structure of the study

This report seeks to address these challenges by creating a simple, easy-to-apply methodology based on industry-level data to adequately assess water risks on the portfolio level to enable informed financial decision-making. **The water risk analysis of equity portfolios enables investors to assess the exposure of their equity portfolios and equity stocks to regional water risks**. The insights provided by the methodology inform investors whether and where portfolio companies analysed according to industries and regions may be exposed to high, middle and low water risks. Investors are advised to, in a second step, take a closer look at the water risks of industries that are exposed to high water risks by applying the water risk analysis of individual equity stocks. This methodology gives investors more accurate and in-depth information on the water risks of a specific company. The methodology does not cover how these risks might materialise in a portfolio or company's financial statement or affect the performance of an investor's portfolio. It only highlights water risks and, therefore, potential downsides for investors and companies alike. It builds the basis for more informed decision-making towards investment and operational strategies that are water aligned or, in other words, aligned with international water treaties. The methodology is applied to water risks in equity stocks and portfolios but could potentially be applied to other asset classes as well. The goals of the report are to

- improve existing databases and methodologies for analysing water risks through quantitative data for equity;
- understand the availability and reliability of publicly available water data; and
- contribute to the development of water scenarios.

The report is structured in four main chapters as described below:

1. **Water risk analysis of equity portfolios**: Chapter 2 and 3 describe the development and application of a high-level quantitative methodology to analyse water risks on industry level. The aim is to build on existing methodologies (Ceres) by adding additional water risks types and geographical dimensions.
2. **Water risk analysis of individual equity stocks**: Chapter 4 and 5 provide an in-depth quantitative analysis of water risks. This methodology represents the ideal scenario of consulting granular company data to understand geographic water risks.
3. **Preliminary conclusions** on the water risk analysis of both portfolio and individual stock level are drawn and detailed in Chapter 6.
4. **Water scenario analysis**: Chapter 7 identifies and assesses current water scenarios, and discuss potential future developments of these.

1.3 Overview of water risks

In the context of this study, water risks are understood as water-related risks that companies are exposed to. Those risks consist of a combination of a company's **operational water risks**, **basin water risks** as well as the **water management** of a company. Operational water risks are inherent to the nature of a business and relate to the dependency on water such as water intensive production processes. Basin water risks include physical, reputational and regulatory risks (as described in Figure 2), and relate to the hydrological context of where companies operate in addition to which other water users tap into the same water resources. Water management refers to how corporate management chooses to mitigate water risks (Ceres, 2015). Analysing a company's management response towards water risks is crucial to obtain a holistic understanding of the company's overall water risk. A company with high water risks might mitigate these risks thanks to an in-depth analysis and a correct response through management, lowering the overall risk rating. Hence, water management can also be seen as a measure of resilience.

In order to fully grasp a company's water risks, an investor should include all these factors as they can significantly decrease or increase the water risks, lead to changes in the bottom line and as a result affect financial performance in investors' portfolios.

	Physical Risk	Regulatory Risk	Reputational Risk
Operational Water Risk	**Water quantity** and **water quality issues** related to the performance of the company and its supply chain.	The potential risk of changes in pricing, supply, rights, standards and license to operate.	Negative response and brand image due to poor communication on actions related to water use.
Basin-related Risk	These stem from **water quantity** (including scarcity, flooding, and droughts) and **water quality** (pollution) of water within the river basin available to the company.	Strength and enforcement of water regulations and the consequences of restrictions. Felt by regulatory actions or from neglect, blockage or failure.	Public perceptions around a company's water use/pollution and its behavior with relevant stakeholder that may have negative impacts on the company brand or influence purchasing decisions.

Figure 2: Type of water risk

2. Analysis of water risks of equity portfolios

The assessment of water risks of an equity portfolio helps investors to understand the aggregated water-related risks of a portfolio and serves as a guideline to evaluate where closer analysis on individual stock level is required. The methodology can be applied to both, private and public equity, even though a more in-depth analysis is recommended for private equity as data availability might be more limited than for public equity. The methodology is a top-down approach and aims at high coverage while at the same time taking into account local factors as far as possible. This is crucial as water issues and risks vary across the world depending on factors such as: climate, geography, geology, population density, the level of industrial and agricultural development, and the maturity of water governance and regulation. Given the limited time and research resource portfolio managers have at hand, the methodology has to be easily applicable to different kinds of portfolios, independently of their size or geographic scope. Investors should also be able to identify the water risks for all types of companies, including those that report their data poorly. Therefore, the methodology has been developed based on industry data. Ceres advocates for such an approach by stating that "water risk exposure may be clearest at the portfolio level. Conducting security level water-risk analysis alone will not uncover high portfolio exposure to geographic or industry water-risk hotspots - but conducting portfolio risk analysis will" (Ceres, 2015), which further underpins the need for portfolio-level assessment of water risks.

The following figure (Figure 3) shows which indicators, data sources and tools were applied for the portfolio water risk analysis. In this chapter, the data and methodology are described and differences with respect to the methodology developed to assess the water risks of individual stocks are highlighted. The results from the application of the methodology to a sample portfolio as well as the most important insights and some considerations for further development are then presented and discussed in chapter 3.

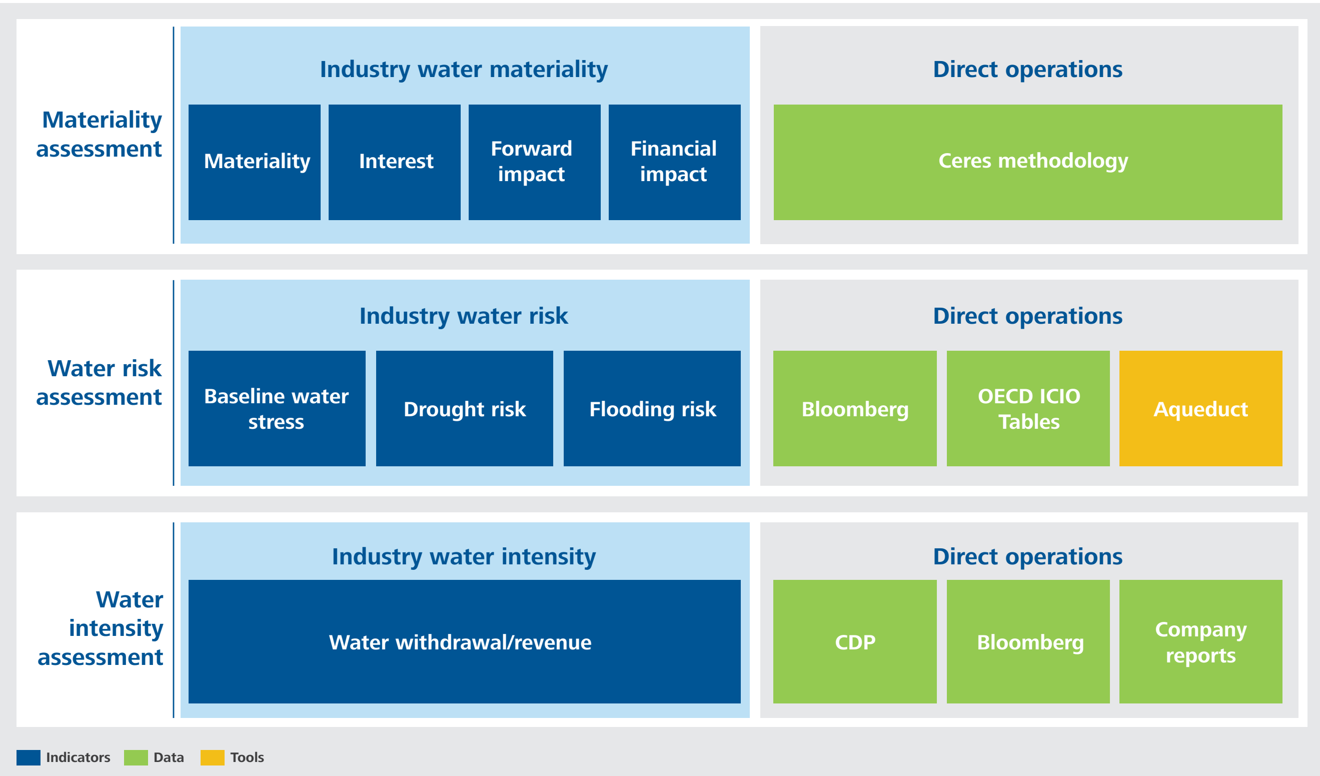

Figure 3: Portfolio water risk analysis methodology

2.1 Equity portfolio water risk methodology

Industry-level data and benchmarks are required to reduce time and resource burden of portfolio managers and keep the data requirements of the methodology simple but meaningful. The final risk result of the portfolio water risk analysis is a score for water intensity and a score for water risks (baseline water stress, drought risk and flood risk) on industry level. This helps investors to grasp a company's exposure by linking the titles of an equity portfolio to the industries and its associated water risks. Furthermore, the portfolio's geographical exposure to water risks can be analysed and combined with other risk types to create a comprehensive risk analysis. The equity portfolio water risk methodology currently only considers the water risks in direct operations, whereas water risks in the supply chain as well as management's response to dealing with water risks are neglected. Scoring the management response and supply chain risks as part of this methodology is challenging because no meaningful industry averages and benchmarks have been developed yet.

2.1.1 Industry water materiality according to SASB

Not all industries are prone to water risks and water risks themselves are variable. For investors it is important to understand the overall risks associated with their portfolio and, therefore, the information should be as targeted as possible. In order to follow this line of thought, the methodology presented in this section follows a step-wise approach, which focuses only on those industries where water risks are deemed financially material. This initial risk assessment and first step of the methodology is based on the in-depth industry research of the Sustainability Accounting Standards Board (SASB) and considers all industries with "**high**" water and wastewater risks in their direct operations in more detail. For all these industries four factors were considered in the SASB analysis: materiality, interest, forward impact and financial impact. Under **materiality**, the industry working groups (IWGs) examine if an issue is financially material for an industry. Under **evidence of interest**, SASB evaluates several factors: the relative importance of a certain issue based on the frequency of relevant keywords in documents that are available on the Bloomberg Terminal; the percentage of Industry Working Group participants that find an issue to be material as well as the appearance of this sustainability issue in shareholder resolutions, corporate sustainability reports, financial analysis, regulation and academic studies. To evaluate whether a sustainability issue has a **financial impact** on an industry, SASB checks whether there has been any evidence of impact on the revenue or costs, the assets or liabilities or on the cost of capital. Both indicators are assessed subjectively based on quantitative and qualitative findings. Evidence of **forward-looking** impact assesses if there is a probability that it will have an impact in the future, if that impact is of a certain magnitude and the timing. For each industry, an in-depth industry analysis briefly described the identified sustainability issues and provided supporting evidence (SASB; 2013).

2.1.2 Country water risk

For industries which were classified with "high" water and wastewater risks in their direct operations by SASB, country water risks, which is the water risk exposure of an industry's **geographic locations**, were considered. Industry averages need to be considered when analysing geographic locations for all individual titles of a portfolio, which is arduous and time consuming. For that purpose, the geographic locations of the largest companies of a given industry (**making up at least 50% of an industry by market capitalization**) were analysed. The overall geographical distribution of the industries was calculated through several steps. These are illustrated in chapter 2.1.4. The geographic information was gathered from the following sources:

1. If available, **asset locations**[1] of the companies as defined and indicated through the Bloomberg Terminal were considered.
2. If that data was not available, data on **employees per country** of the company using the Bloomberg Terminal was considered.

Finally, if none of the two mentioned data points were available, Value Added (VA) based on industry average data from "**inter-country Input-Output**" **tables from the OECD** was used. VA denotes the actual economic creation of value and can therefore be used to calculate the contribution of each industry to the country's overall GDP. Using this information, the contribution of each country's industry to the global value creation of that industry was calculated. This was done by first calculating the global VA of one single industry by summing up the global VA over all countries in the database. Second, the share of each country in the global VA of the industry under consideration was calculated. Finally, the respective shares serve as a proxy for the geographical distribution of one single industry.

2.1.3 Industry water risk score

Water risks have a strong local characteristic and should, therefore and if possible, be considered at the basin level. Due to time and resource constraints to realize this methodology as well as data availability constraints, the methodology does not consider water risks at the basin level but on the country level. This already gives a good first indication whether and where an industry faces a certain type of water risk. In order to determine how exposed one country is to one type of water risk, the Aqueduct country water risk database needs to be considered (see box).

[1] Asset location is defined as where the assets of a company are located. It includes all assets, tangible and intangible and does not allow the user to infer what type of operations a company has in a specific location.

Aqueduct country water risk database

The database from Aqueduct indicates five water risk indicators: flood risk, drought risk, baseline water stress, seasonal variability and interannual variability for all countries, the 100 most populous river basins and the 100 largest river basins by area. The scores vary depending on the sector (agricultural, domestic, and industrial) (Reig et al., 2013). The methodology works with the industrial scores for all industries except for the beverages and food products industry. For this methodology seasonal and interannual variability was not applied.

The database scores each country on the three water risks detailed below from 0 to 5. The scores need to be analysed with caution as the metric is based on historical data. The risk scores for flood risks, drought risks and baseline water stress are only expected to increase due to climate change.

- **Flood risk** is the number of floods recorded from 1985 to 2011. Scores above 3.25 were classified as high, representing an average flood occurrence in the reference period of approximately every two years.

- **Baseline water stress** measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water. An industry is considered as having high baseline water stress when above 30% of the available blue water is withdrawn from municipalities, industry or agriculture. Higher values indicate more competition among users (Reig et al., 2013). Scores above 2.5, indicating a value of more than 30%, are considered high.

- **Drought risk** measures the average length of drought times and the dryness of the droughts from 1901 to 2008. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in months and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Scores above 2.5 are classified as high indicating a value of more than 35 (length x dryness). It was chosen, as drought risk is considered in combination with the water intensity of an industry (see below). The combination of high water intensity and high drought risks can pose a threat for a geography and the industry active in said region.

To provide investors with a comprehensive overview of their water risk, the different water risk categories are condensed into one score which ranges from 1 to 5 representing low to extremely high risk (Figure 4). The final risk score is a combination of the SASB rating and the industry specific risk score which is based on the highest share of one type of country related water risk (drought, flood or baseline water stress). The steps to arrive to this score including example calculation is in chapter 2.1.4.

2.1.4 Example calculation of the industry water risk

As described in chapter 2.1.2, the three data sources used to connect water risks to country risks are asset locations, employees per country and the inter-country input output tables from the OECD. The following chapter will demonstrate the steps that were taken in order to obtain the geographic distribution of the different industries.

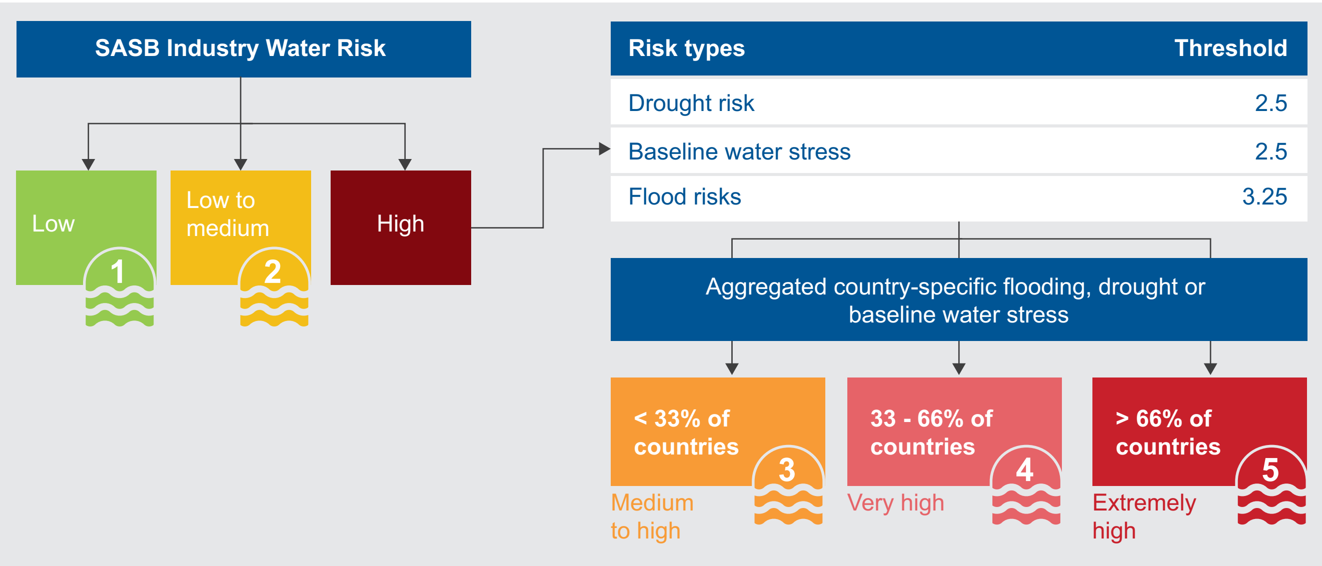

Figure 4: Scoring method for industry water risk

Table 1 provides an example of how country data was collected and compiled for companies of one industry depending on data availability. In a second step, the data on country shares per industry was linearly extrapolated to the entire industry, representing a value of 100%.

- Company 1 makes up 25.11% of the industry's market capitalization and has data on asset locations. Company 1's assets are distributed across three countries (USA: 40%, Canada: 35% and Finland: 25%).
- Company 2 makes up 14.56% of the industry's market capitalization and has no data on asset locations is available. Therefore, data on employee location is used which indicates the countries of operation of the given company (China: 60% and USA: 40%).
- Company 3 contributes with 12.01% to the industry's market capitalization and has neither data on asset nor employee location. Therefore, OECD industry average data is required.

Table 1: Example collection of geographic data

Company	Share of Industry market cap.	Scaled share of industry market cap.	Data on asset locations	Data on employee location	OECD industry average data needed
Company 1	25.11%	48.59%	USA: 40% Canada: 35% Finland: 25%	Not needed	Not needed
Company 2	14.56%	28.17%	Not available	60% China 40% USA	Not needed
Company 3	12.01%	23.24%	Not available	Not available	Industry average data considered (e.g. USA 10%, Canada 0.3%, China 12% and Finland 3.4%)
Sum of data sources used	51.58%	100%	25.11%	14.56%	12.01%

The data on Value Added from the inter-country input output tables consider all 63 countries in the OECD database (see Annex for full list of countries). The three companies account for 51.58% of the industry's total market capitalization and, therefore, no additional company is considered in this case. The market capitalization of the three companies is scaled to 100%, now representing the entire industry for simplicity and further calculation purposes. For the industries considered in the methodology development, between 3 to 25 companies accounted for 50% or more of an industry's market capitalization. The global coverage of the Value Added data lies between 87.3 – 98.8% depending on the industry, which provides a good coverage of an industry's global distribution.

Following the country data collection as shown in Table 1, if linearly extrapolated to the entire industry, this results in the overall country shares as found in Table 2. The table breaks down the data gathered on company level (see Table 1) to country level. For that purpose, the share of one specific country of every company is weighted by its scaled share of market capitalization and summed up. In the case of USA, all three example companies contribute to the total country share from the three different data sources.

- Company 1 has 40% of its assets located in the USA and weighted (multiplied) by its scaled share of industry market capitalization of 48.59% this results in 19.44% that Company 1 is contributing to the total country share of the industry.
- Similarly, Company 2 has 40% of its employees located in the USA leading to a contribution 11.27% to the total country share of the industry after a weighting with its scaled share of industry market capitalization.
- Finally, Company 3 contributes 2.32% to the total country share of the industry. This as a result of weighting the Value Added data for the USA (10%) with the scaled market capitalization of Company 3.

Table 2: Example calculation of geographic distribution per industry

Country	Country share per company	Total country share
USA	Company 1: 19.44% Company 2: 11.27% Company 3: 2.32%	**33.03%**
Canada	Company 1: 17.01% Company 2: 0% Company 3: 0.07%	**17.08%**
China	Company 1: 0% Company 2: 16.90% Company 3: 2.79%	**19.69%**
Finland	Company 1: 12.15% Company 2: 0% Company 3: 0.79%	**12.94%**
Remaining 59 countries from OECD database (except the four above)	Company 1: 0% Company 2: 0% Company 3: 17.27%	**17.27%**
Sum	**100%**	**100%**

Summing up these three country shares leads to the total country share of 33.03% of the considered industry. In other words, 33.03% of the industry is located in the USA, linked through three different data points as previously detailed. This calculation is repeated for each country and results in a geographical distribution of an industry.

As shown, the combination of the two datasets allows to break the industries down to a country level and the values can now be **combined with the Aqueduct country water risk database**. This includes the consideration of flood risk, drought risk and baseline water stress.

Table 3 shows how country shares per industry were connected with water risk indicators from Aqueduct based on the illustrative example elaborated in the two previous tables.

In a next step, an overall risk score is defined based on the share of high-risk countries (Table 4). An industry specific risk score is related to the highest share of one specific water risk to an industry. Based on the illustrative example in Table 3, the industry is exposed to **52.71% flooding risks** (USA and China

Table 3: Example of combination of geographic industry distribution and country risk indicator

Country	Industry share	Aqueduct Industrial Risk Indicator
USA	33.03%	**Flood: 3.33** Drought: 1.4 Baseline water stress: 2.47
Canada	17.08%	Flood: 1.86 Drought: 1.65 Baseline water stress: 1.16
China	19.69%	**Flood: 3.45** Drought: 1.95 **Baseline water stress: 2.94**
Finland	12.94%	Flood: 0.22 **Drought: 2.51** Baseline water stress: 0.9

are contributing with a threshold of > 3.25), **12.94% drought risks** (Finland is the only contributor with a threshold of > 2.5) and to **19.69% risks of baseline water stress** (China is the only contributor with a threshold of > 2.5). The industry would in this case be associated with **very high flooding risks** and has, therefore, a **specific risk score of 4**. The overall scoring process in Table 4 below.

Table 4: Example calculation of industry water risk score

Share of aggregated "high" country- specific flooding, drought or baseline water stress risk	Industry specific risk score (based on South Pole methodology)	Industry specific risk
< 33%	3	Medium to high
33%-66%	4	Very high
> 66%	5	Extremely high

If the share of countries exposed to any of the above detailed risks contributing to an industry is less than one third, the industry was categorised with ***medium to high risk***, between one third and two thirds with ***very high risk*** and above two thirds with ***extremely high risk***. An industry is allocated an industry specific risk based on the highest risk it is exposed to across baseline water stress, flood or drought risk.

2.1.5 Industry water intensity

As indicated in the two previous chapters, industry data is needed in order to keep the complexity of the methodology low and to ensure the comparability with other industry-level data (e.g. industry water risk score). Water intensity is an indicator for a company's operational water risks. It is calculated by dividing a company's yearly average water withdrawal with its yearly revenue. Water withdrawal refers to the net water withdrawn for a company's operational processes (including consumed and discharged water). CDP defines water withdrawal as "the sum of all water drawn into the boundaries of the organization (or facility) from all sources for any use over the course of the reporting period" (CDP, 2019). For that purpose, the data of 720 companies across 67 industries disclosing water withdrawal data and revenue from 2017, through company reports, CDP questionnaires and the Bloomberg Terminal were considered and used to calculate water intensities of the companies upon which the industry water intensity can be defined. The **Industry water intensity** corresponds to the median of the company water intensities that are part of the respective industry and are scored from low to extremely high (see graph below).

Applying a logarithmic scale to the water intensity of the 67 analysed industries, suggests an almost linear distribution. Clusters were, therefore, formed along the industry water intensity values to the power of 10 as shown in Figure 5 below. This means that industries with water intensities between 10 and 100 where classified as **Low**, between 100 and 1,000 as **Low to Medium**, between 1,000 and 10,000 as **Medium to High**, between 10,000 and 100,000 as **Very High** and above 100,000 as **Extremely High**.

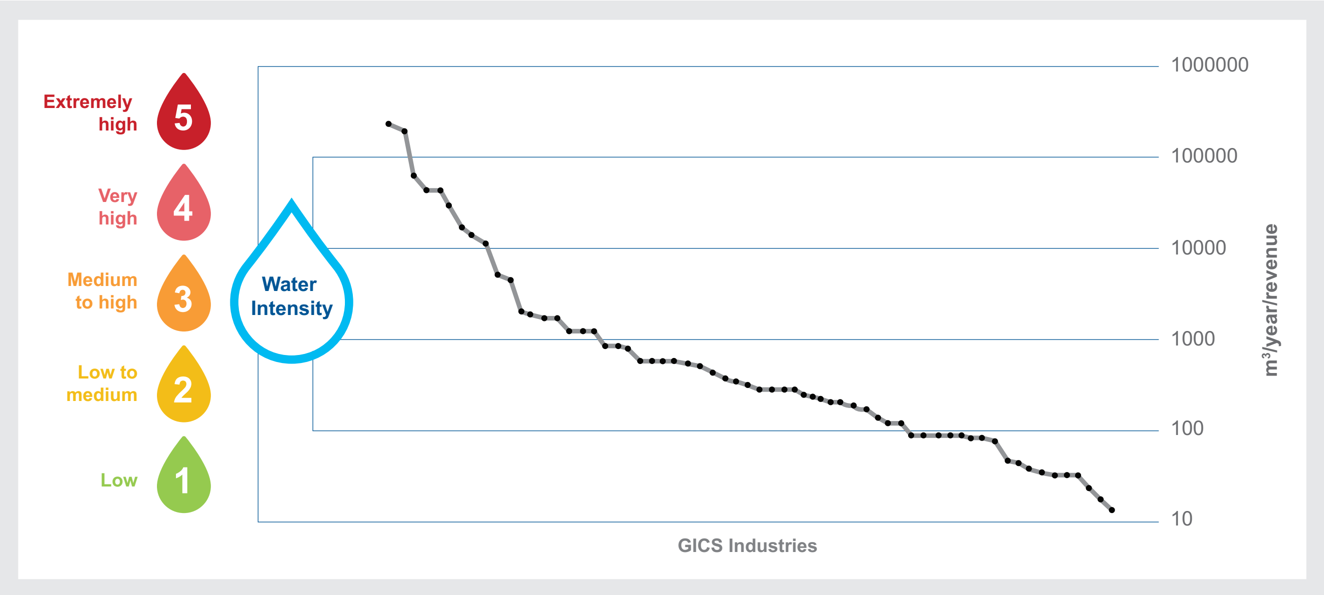

Figure 5: Scoring for water intensity for all 67 GICS industries

3. Results of the sample portfolio analysis

A sample portfolio, encompassing 26 different industries was compiled in order to test the methodological development of the equity portfolio water risk analysis (sample portfolio compilation in the Annex). Industries from different countries with different risk profiles (high, medium and low) were included in the sample portfolio. Figure 6 shows the water intensity and water risk of the different industries in the portfolio. The following two subsections discuss the results in terms of water intensity and water risk in more detail.

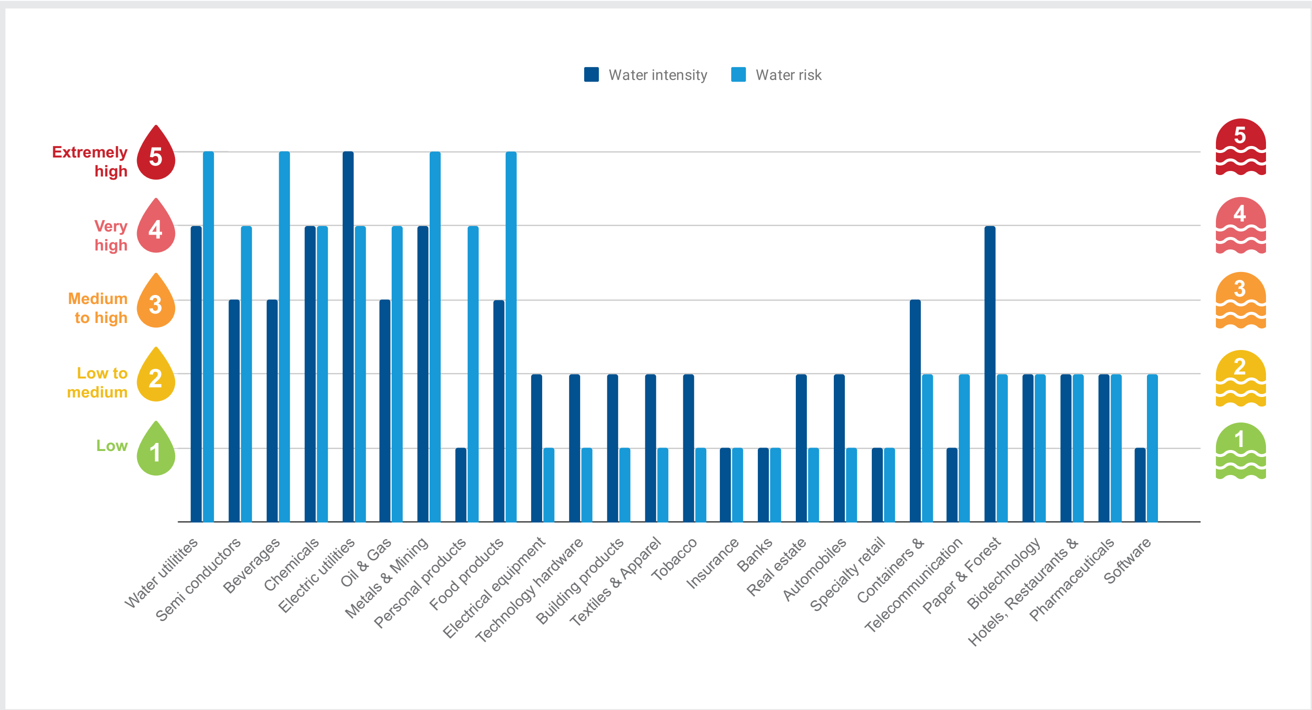

Figure 6: Water risk and water intensity score per industry

3.1.1 Water intensity

The results show that the industry water intensity is relatively aligned with the materiality assessment of the industries according to SASB. The industries that are categorised as having "material" water and wastewater risks were found to have the highest water intensity. This indicates that the methodology with which SASB deduced their materiality assessment is quite robust. Further, it also adds additional information which cannot be covered when only considering the water intensity. The only GICS industry with material water risks and low water intensity is Personal Products. Most of the industries that were categorised as being industries where water risks are not material do also have low or low to medium water intensities. Two industries have a *low to medium* risk score despite having *medium to high* or *very high* water intensity. This is the case for Pulp & Paper and Containers & Packaging.

3.1.2 Water risk

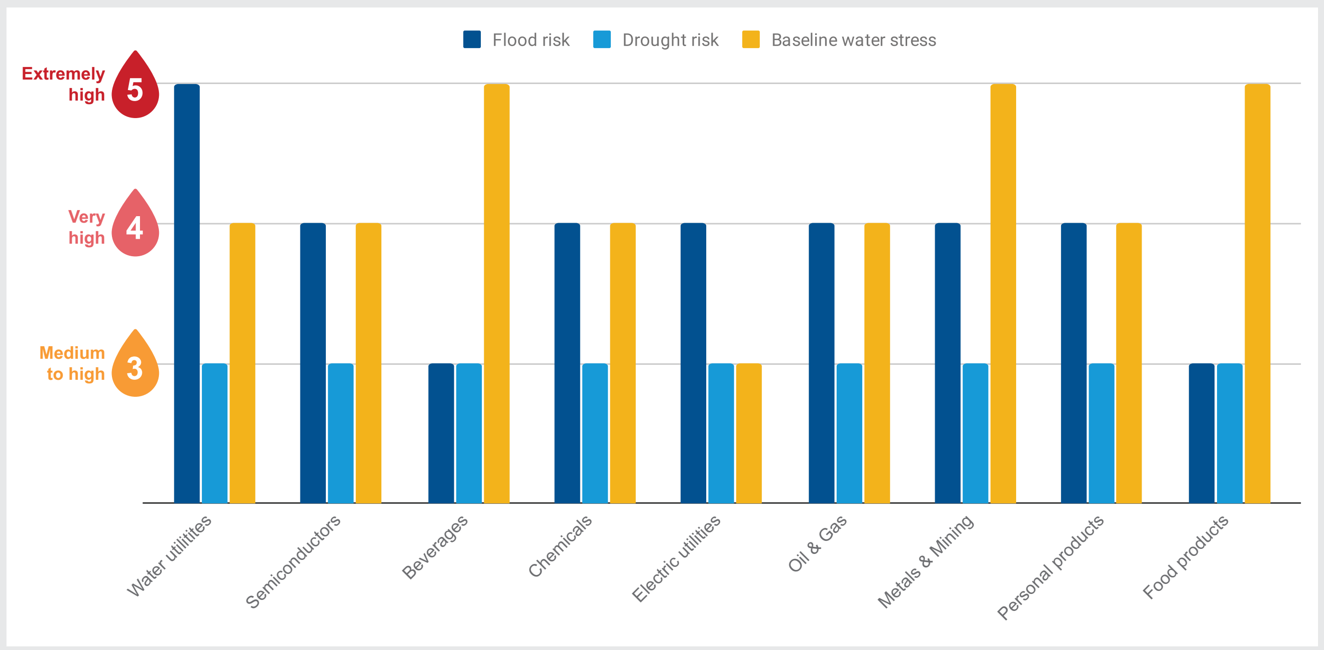

Figure 7: Water risk types per industry

Figure 7 shows the three water risk types (baseline water stress, flood and drought risk) for each industry with *medium to high*, *very high* or *extremely high* water risks in the sample portfolio. The industries that are exposed to extremely high water risks are water utilities, beverages, metals and mining and food products. A number of conclusions can be drawn from the correlations depicted in this figure:

- **Baseline water stress**: baseline water stress is a very important indicator to understand when evaluating water risks. Three industries, beverages, food products and metals & mining are exposed to *extremely high* baseline water stress. According to Aqueduct's water scenarios climate change is anticipated to increase in large parts of the world. When analysing water stress, an investor should also look at an industry's water intensity. Industries with high water intensity are inherently more prone to water risks. All three industries with extremely high baseline water stress have at least a *medium to high* water intensity because they are heavily reliant on water as a key input to value creation and are therefore highly vulnerable to baseline water stress.

- **Medium to high drought risk in every industry**: droughts can be very harmful to a company's operations if the company relies heavily on water. The developed methodology only finds small overall drought risks because according to the Aqueduct country water risk database, drought risks are generally low. The countries with high drought risks, mostly located in Africa or in the Middle East, barely contribute to the geographic distribution of the industries. Between 0.44% (Electric utilities) and 3.45% (Metals & Mining) of countries are exposed to high drought risks (risk score of above 2.5).

- **Significant exposure to flood risks**: from the 13 analysed industries, one is exposed to *extremely high* flood risks and nine to *very high* flood risks. Regions that are exposed to high flood risks corresponds to having experienced a flood approximately every two years between 1985 and 2011. Floods are amongst the most common, wide-reaching natural disasters in the world (OECD, 2016). This is also reflected in the risk scores of the Aqueduct country water risk database. With the impacts of climate change, the number of floods and their impacts are likely to increase. Therefore, flood management and insurance are necessary to protect businesses from financial losses. Flood risks can be extremely expensive and while they are insurable, on a global level a significant financial gap remains. Out of all uninsured losses, flood losses accounted for 23% between 2005 and 2018 (OECD, 2016).

3.2 Interpretation of the results

Figure 8 illustrates how the industries represented in the portfolio score on industry water risk (y-axis) and the water intensity (x-axis) of their direct operations.

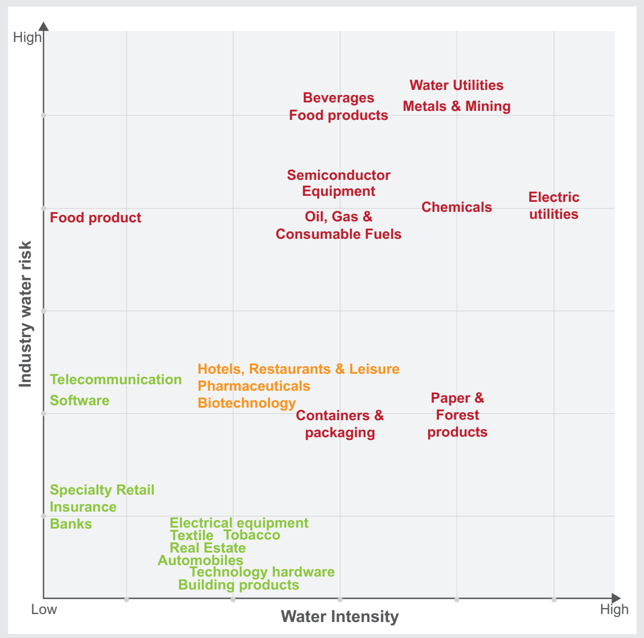

Figure 8: Risk distribution within sample portfolio

The results from Figure 8 can be interpreted in the following way:

- **Bottom left quadrant**: these industries face *low water risks* and have a *low water intensity* and are therefore currently not forced to act.

- **Top left quadrant**: industries face *high water risks* but *low water intensity*. This indicates that companies and investors alike need to continuously monitor the risks they are exposed to and ensure that their water intensity stays low in order to mitigate the risks from e.g. high baseline water stress.

- **Bottom right quadrant**: industries have *high water intensities* and *low water risks*. Similarly, to the industries in the top left quadrant, investors and companies alike need to carefully monitor the water risks that they're exposed to as e.g. baseline water stress might increase over time. Also, they should aim at reducing their water intensity in order to be more resilient should water risks increase in the future.

- **Top right quadrant**: industries face *high water risks* and have *high water intensities*. These industries are highly exposed to water risks and need a comprehensive water management strategy in order to minimize water risks that they're exposed to. The industries in the top-right quadrant of Figure 7 need to be analysed in more detail in order to understand the underlying water risks on e.g. basin-level.

This portfolio water risk methodology supports investors in identifying where their key priorities should be in terms of managing water risks. Investors are encouraged to dig deeper into the industries and the according titles that are exposed to high water risks and water intensities located in the top-right quadrant of Figure 8 in order to identify where these are geographically located and how they can engage with the companies to mitigate these risks. This will be part of the Analysis of water risks of individual stocks.

Industries with high water intensity are inherently more prone to water risks, which is why it is important to analyse the water intensity in combination with water risks. As the analysis of water intensity has shown, the water intensity can vary quite significantly between companies within an industry. For deeper analysis, an investor could identify the company specific water intensity, through company reports, CDP or the Bloomberg Terminal. The company specific water intensity can also show an investor that this company is not managing its water resources sufficiently. If a company has a higher water intensity than the median of its industry, it might indicate that there is a lack of water management.

The country-water risk can show an investor, on average, in which countries an industry is active and how high the water risks in the respective countries are. This data set can be used in different ways. The country risk data could, for example, be used as exclusion criteria. An investor could exclude those industries that are exposed to the highest geographical water risks (e.g. those that are exposed to baseline water stress in more than 30% of their assets). Investors might also find that despite being in an industry with high water risks, the company in the portfolio is aware of these risks and is working to mitigate them. In order to look at more details, an investor could start by looking at the company's CDP score. Doing so shows that American Water has not participated, while Apple and ExxonMobil have declined to participate for example (CDP, 2017b). Most companies that lead in terms of water risks also report to CDP. If a company does not disclose to the CDP, the company reports and other publicly available material need to be checked.

3.3 Limitations and further development of the methodology

Data availability on geographic distribution of industries. Reported data of companies is collected by different data providers, for example, Bloomberg or Factset. The respective tools of these providers may show the facilities on a map as it is possible with the Bloomberg maps (BMAP) function in the Bloomberg Terminal. This data, however, often cannot be downloaded and brought into a suitable format for subsequent analysis. Only asset location data can be downloaded, and many companies do not disclose the locations of their assets or only disclose it on a continental level. Additionally, “assets” includes all assets, tangible and intangible, and does not allow the user to infer what type of operations a company has in a specific location (e.g. whether it’s relevant for water risks or not). Due to this lack of data, the geographic distribution of the industries relies, depending on the data availability more or less heavily, on the OECD ICIO Tables. This information is useful when other asset location data is lacking but combining the ICIO Tables with the asset data from Bloomberg has a few limitations. First of all, the ICIO Tables do not use GICS industry classification. This means that some industries, e.g. the power sector, is combined to one industry under OECD, while it represents three different industries in the GICS classification. Another factor is that the ICIO Tables include all economic activity of a specific country and does not differentiate between private or publicly listed companies. Increasing the data availability or creating one centralised database on company asset locations would greatly benefit the methodology and the water risk assessment of portfolios. This information could be included in an already existing reporting framework (e.g. CDP).

Building on industry-level data. The methodology has allowed the introduction of geographical risks on an industry level. By covering 50% of the industry's market cap, the methodology covers a significant part of the considered industries. Working on an industry level carries risks. The geographic information for each company is based on average geographic distribution from the respective industry. The data that was used for the analysis is relevant, but never fully correlated with actual company-specific data. To illustrate, a Swiss company that does not have business operations in the US will be categorised as having high water risks because a large part of the industry is based in the US. The methodology gives an indication of which industries need to be analysed further. Therefore, it is important to perform the water risk analysis of individual stocks for the industries that are exposed to high water risks.

Aggregated country-level data. The methodology uses the Aqueduct Country Risk database. Summarising a country’s hydrological indicator in a single number has inherent limitations. Using country-level data does provide valuable information where basin-level data is not available but in an ideal scenario, basin-level data should be used for the analysis because each basin carries different water risks. Therefore, it is recommended to conduct the basin-level analysis for individual stocks and is further detailed in the next chapter.

Using backward-looking data. The analysis clearly shows the drawbacks of using backward looking data. In the case of flood risks, Aqueduct ranks as high flood risks countries that have been exposed to 10-27 floods in from 1985 to 2011. The Aqueduct country risk database will be updated in June 2019, but there is still a clear need to incorporate forward-looking scenario data as the aim of the methodology is to prepare investors for the climate risks associated with climate change and hence change in water risks. Chapter 7 will provide an overview of currently existing water scenarios.

Supply chain risks should be taken into account where possible. Water risks in the supply chain are significant for certain industries, especially industries with agricultural supply chain, but little is known about their materiality for investors (UNPRI; 2018b). WWF and PwC have identified 25 crops that are exposed to the highest water risks. The results from the analysis were, however, not made publicly available (United Nations Principles for Responsible Investment (UNPRI), 2018a). More research needs to go into the materiality of supply chain risks for investors. As a further extension to the methodology, the water risks in the supply chain of different industries could be analysed on the basis of macroeconomic models. Such models allow to track international supply and demand chains on an industry level. The water risks analysis of individual stocks will attempt to calculate the water risks in the supply chain through a similar methodology, based on the most relevant commodities for a given company.

Including a water management score. A water management score is currently missing in this portfolio water risk analysis. The methodology for water risk analysis for individual stocks introduces a water management assessment methodology for individual companies. This method requires company-level data. As mentioned above, another way of assessing the water management of a company could be comparing the company water intensity with the industry water intensity as an indicator for a company’s water management. Further, if available, the CDP score is a great indicator for a company’s water management. In the report published by CDP in March 2019, the organisation provides a great overview over how industries perform on water disclosure (CDP, 2019). These percentages could be combined to an additional score to include the water management on industry level in the methodology.

Including regulatory and reputational risks. Depending on the business, regulation and reputation can be a substantive risk for businesses. While physical risks can interrupt a company’s operations in a certain area, regulation and reputation may influence a company’s license to operate in the long term. The developed portfolio water risk analysis methodology does not include regulatory and reputational water risks in the analysis as there is a lack of freely available data on these types of risks.

3.4 Key findings and conclusions from the methodology "water risk analysis of equity portfolios"

The main goal of this methodology is to combine industry level data with geographical data which enables the consideration of the Aqueduct country water risk data. By choosing this approach it is now possible to assess an equity portfolio's geographical water risk distribution. This is, to our knowledge, the first time that such an approach has been successfully developed and tested.

The developed methodology strongly builds on the work by Ceres and SASB. The work conducted by the industry working groups of SASB is highly valuable and gives a good first indication on industries that are more prone to water risks than others. As the aim of this methodology is to indicate where the largest water risks occur (in terms of industries as well as geographies) to investors, the methodology described in this study builds on industries which were categorised with facing material water risk. Except for the work of Ceres and SASB, industry-level data is largely lacking.

As described in the previous chapter, there are some limitations to the current methodology that considers water risks on portfolio level of equities. But, nevertheless, the current methodology serves the purpose to identify hot spots of water risks of an equity portfolio and, therefore, where to further detail the analysis on individual stock level. This analysis is described in the next chapter and also serves as verification of the developed methodology on portfolio level.

The methodology developed for the analysis of individual stocks in chapter 4 will demonstrate how to dig deeper into the water risks of a given company. This is especially relevant for companies that face high water risks and have a high water intensity. The methodology introduces more precise geographical and management information on company-level as well as regulatory, reputational and supply chain risks.

4. Analysis of water risks of individual stocks

After conducting the portfolio water risk analysis and prioritising the high water risk companies, investors need to dig deeper on those companies that are exposed to high water risks in their equity portfolios. The aim of the analysis of water risks of individual stocks, therefore, is to really understand where the water risks are the highest and provide the basis to adopt suitable water-aligned investment strategies or engage with those companies for them to start addressing and mitigating these risks. For this reason, the methodology does not aim to come up with a final risk score, but rather provide the investor with a depth of information on what type of risks a company is exposed to and how it is prepared to mitigate them. With this aim, an in-depth water risk methodology was developed on the basis of three multinational companies from the portfolio water risk analysis with different water risk profiles. In a first step, the sample, the methodology and the data sets are presented and explained. Then, the results from the application of the methodology to the three companies' direct operations and supply chain are presented. Finally, the most important insights and key take-aways are described.

4.1 Sample

Three companies from the sample portfolio from three distinctive industries were selected in order to highlight the different water risks that industries can be exposed to. Included in the analysis is one company in the electric equipment industry (Company 1), one in the food industry (Company 2) and one in the pharmaceutical industry (Company 3). The analysis in chapter 3 resulted in three different risk profiles for said industries and companies. The electric equipment industry was associated with low water risks and water intensity (bottom-left quadrant of Figure 8), the food industry with high water risks and water intensity (top-right quadrant of Figure 8) and the pharmaceutical industry with low to medium water risks and water intensity (between the bottom-left and top-left quadrant in Figure 8). All three companies are constituents of the Swiss Market Index (SMI) and the Swiss Performance Index (SPI) from Six Swiss Stock Exchange (SIX). The reason for this selection lies also in the need to analyse the data availability of companies headquartered in Switzerland.

4.2 Methodology

Figure 9 explains in more detail which indicators, data sources and tools were applied and evaluated for operational water risk, basin water risk and management response which are described in more detail in the following sections. The three risk categories are not combined to a final score as it would dilute the obtained information. The following sections on the different risk categories show, that information is partly quantitative, partly qualitative and that several different risk drivers are analysed. Generating one score would lead to a loss of granularity and depth. Each risk category will be interpreted on a stand-alone basis as well as in combination with the remaining risk categories. The results from the analysis can be found in Table 7 and Table 8.

4.2.1 Operational water risk

Operational water risk refers to the water risk at company level or even facility level. Company water intensity is an indicator for a company's operational water risks in direct operations. Whereas the portfolio water risk methodology used company (individual stocks) water intensities of an industry to identify an industry's median water intensity, the analysis of water intensity of specific individual stocks uses company data and can now be related to the industry's median (see Chapter 2.1.5 for more details). The company water intensity is defined as the total water withdrawal (in thousands of cubic meters) divided by the revenue in US Dollars. Water withdrawal refers to the net water withdrawn for a company's operational processes (including consumed and discharged water), which is defined as the sum of all water drawn into the boundaries of the organization (or facility) from all sources for any use over the course of the reporting period (CDP, 2019).

Commodity water intensity is used as a second indicator for a company's operational water risks in their supply chain. The analysis of individual stocks calculates the water intensity of the three most relevant commodities per company. These are defined as the commodities that contribute the most to a company's revenue. If this metric is not available, the commodity that contributes the most to a company's products by weight (kg of total kg purchased), should be identified. The three most relevant commodities are identified through desk-based research. The commodity water intensity refers to the average litres of water usage per kilogram of said commodity (l/kg). That metric was identified by using the Ecoinvent database. The commodity water intensity is compared qualitatively because the small data sample does not allow to score the water intensity from low to high. It does, however, give an indication of how dependent on water the company is in its supply chain.

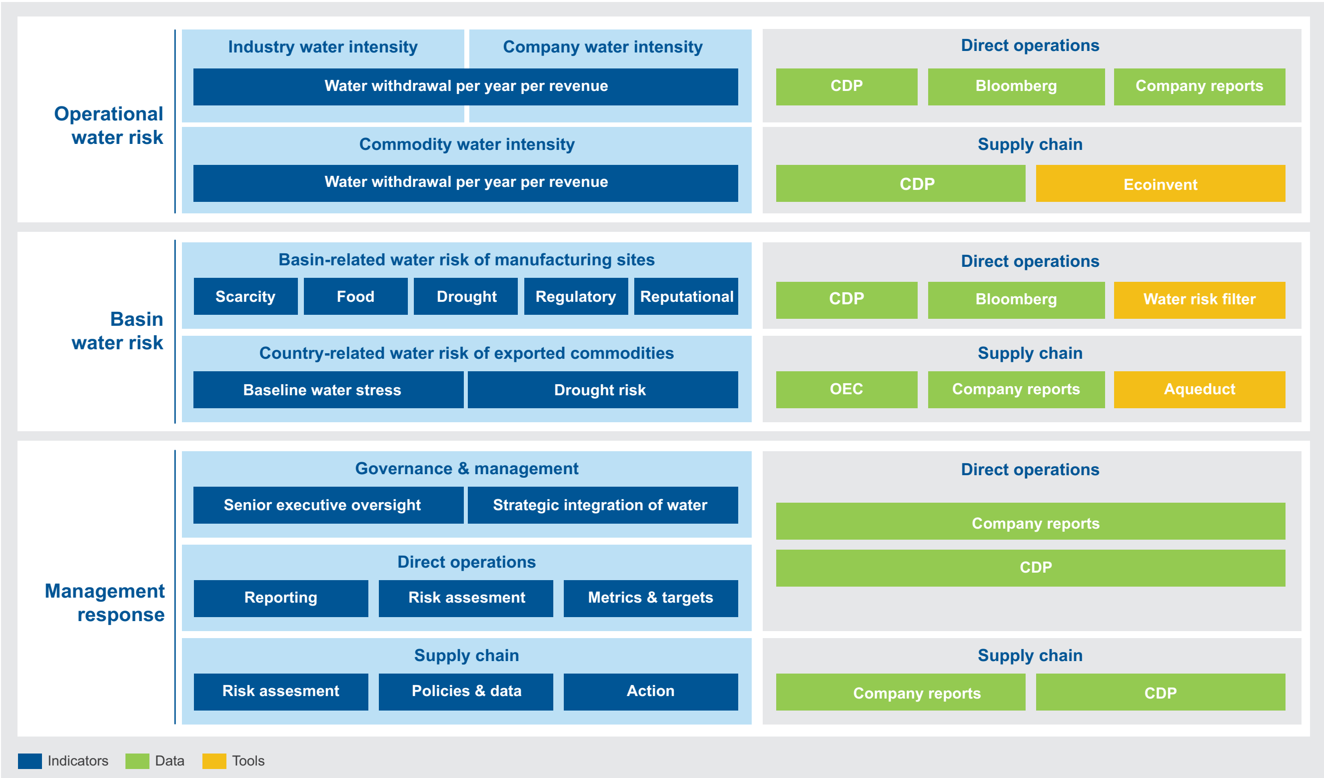

Figure 9: Methodology for the water risk analysis of individual stocks

4.2.2 Basin water risk

Basin water risk refers to the geographical water risk in which a company is operating. In order to assess the basin water risks in direct operations, the basin water risks of the manufacturing facilities for each company can be assessed through the Water Risk Filter. For that purpose, the manufacturing facilities of Company 1 (174 facilities), Company 2 (367 facilities) and Company 3 (242 facilities) were identified through the Bloomberg Terminal. The water risk scores per facility were identified using the Water Risk Filter (WRF).

Water Risk Filter

The Water Risk Filter allows the user to analyse the physical, reputational and regulatory risks of the manufacturing facilities. The tool scores each basin on physical, regulatory and reputational risk between 0 and 5 and computes an overall risk score by applying corresponding industry weightings. WRF has developed weightings for 25 industries, comparing the importance of each risk metric per industry. For the analysis, the percentage of facilities that are exposed to high water risks were identified in order to compare the different companies. The WRF classifies 3.5 as a threshold for "high" basin water risk.

Table 5: Individual risk scores aggregating into a final risk score

Overall water risk types	Sub-risk types
Basin physical risk	• Quantity scarcity • Quantity flooding • Quality • Ecosystem service status
Basin regulatory risk	• Enabling environment (policy & laws) • Institutions and governance • Management instruments • Infrastructure & finance
Basin reputational risk	• Cultural importance • Biodiversity importance • Media scrutiny • Trust & conflict

As described in chapter 3.3, the water risks analysis of individual stocks allows to go beyond the physical water risks (flood, drought and baseline water stress) and also look at the reputational and regulatory risks. Table 5 shows the different risk scores that go into the three overarching final risk scores; physical risk, regulatory risk and reputational risk. As the methodology is meant to give insights into where the water risks of a specific company lie, the physical risks are individually listed in the final results for each company. This gives investors insight into what types of physical risks a company is exposed to.

To assess the water risks in the supply chain, the commodities and their respective origin countries need to be considered in more detail through the following approach:

1. Determine the most relevant commodities per company. These are defined as the commodities that contribute the most to a company's revenue. If this metric is not available, the commodity that contributes the most to a company's products by weight (kg of total kg purchased), should be identified.
2. Determine the countries which export the relevant commodities based on the data of the Observatory for Economic Complexity (OEC). For the commodities considered in this analysis, the countries that were identified through the OEC data covered between 60 and 80% of the total exports per commodity, depending on how fragmented the distribution is.
3. Determine the baseline water stress, drought and flood risk per country of commodity origin through the Aqueduct country risk database.
4. Based on these scores, the percentage of export countries that are exposed to high water risks were determined. For baseline water stress and drought risks a threshold of 2.5 and for flood risks a threshold 3.25 was applied.

4.2.3 Water management

As a last step, the water management is assessed. Table 6 demonstrates which indicators were analysed and how the water management was scored. The categories and indicators are based on the methodology developed by Ceres for the 'Feeding Ourselves Thirsty' report (Ceres, 2018). A company either fulfils or doesn't fulfil an indicator. For Governance & Management two indicators, for direct operations three and for the supply chain also three indicators are defined. The data is retrieved from company and CDP reports.

Table 6: Scoring of water management

Topic	Category	Indicator/Proxies
Governance & Management	**1. Governance**	Board and/or senior executive oversight over water issues
	2. Strategy	Integration of water into the business strategy and planning, translation of water risks into financial terms, policy to guide procurement function
Direct Operations	**3. Reporting**	Reporting on water withdrawals, water consumption, water discharge
	4. Risk assessment	Analysis of watershed conditions, analysis of facility impacts analysis of future conditions
	5. Targets	Targets to reduce water use, wastewater discharge standards, watershed protection plan
Supply Chain	**6. Risk assessment**	Analysis of water use in the supply chain, analysis of watershed conditions, analysis of supplier performance, analysis of future conditions
	7. Policies & Data	Supplier policy, data collection from manufacturing suppliers, water management program, watershed protection plan
	8. Action	Educational support, direct financial incentives or indirect financial incentives for suppliers

Table 7: Key outcomes from water risks in direct operations

		Company 1 Electrical Equipment	Company 2 Food products	Company 3 Pharmaceuticals
Operational risk	Company water intensity [m^3/year/revenue] (industry median in brackets)	**278.02** (277.2)	**1456.82** (1692.5)	**1539.31** (430.7)
	Classification of water intensity (according to figure 3)	**Low to medium**	**Medium to high**	**Medium to high**
Basin water risk	% of facilities exposed to "high" water scarcity risks	7%	11%	9%
	% of facilities exposed to "high" flooding risks	**33%**	**31%**	**43%**
	% of facilities exposed to "high" water quality risks	**74%**	**66%**	**73%**
	% of facilities exposed to "high" regulatory risks	6%	13%	4%
	% of facilities exposed to "high" reputational risks	**41%**	**50%**	**21%**
	% of facilities exposed to high overall basin risk	7%	10%	9%
Management response	Board-level oversight over water issues	Yes	Yes	Yes
	Integration of water into the business strategy	Yes	Yes	Yes
	Reporting on water use	Yes	Yes	Yes
	Assessing water risks in direct operations	Yes	Yes	Yes
	Setting water-related targets	Yes	Yes	Yes

Legend: The final basin risk share is calculated by WRF and corresponds to the aggregated risk scores with applied WRF weightings.

Table 8: Key outcomes from water risks in the supply chain

		Company 1 Electrical Equipment			Company 2 Food products			Company 3 Pharmaceuticals
		Copper	Aluminium	Steel	Milk	Coffee	Cereal	
Commodity Water intensity	1st raw material	160 l/kg	80 l/kg	9 l/kg	60 l/l	500 l/kg	N/A	No information
Country-related water risk	% of global production exposed to "high" baseline water stress	**65%**	**19.6%**	**56.2%**	9.6%	3.44%	**34%**	No information
	% of global production exposed to "high" drought risk	**49%**	8.9%	0%	0%	3.7%	**23%**	No information
	% of global production exposed to "high" flood risk	0%	0%	0%	7.8%	**37.3%**	0%	No information
Management response	Analysis of the water conditions in the supply chain	**No**			Yes			Yes
	Policies that include water in the supply chain	**No**			Yes			Yes
	Incentives or support to suppliers on water management	**No**			Yes			**No**

5. Results of the water risks in direct operations and the supply chain of individual stocks

The tables above demonstrate the depth of information that can result from the analysis of individual stocks. Because the main goal of the analysis is to provide insights on where the water risks lie the three risk categories, operational risk, basin water risk and water management, are not combined to a final score, but should rather be analysed individually. Water intensity is important to take into account in combination with the other risk scores. Rather than being a risk in and of itself, a high water intensity will expose a company to a higher extent to its physical, regulatory and reputational water risks.

The basin water risk scores, especially for flooding, quality and reputational risks, are relatively similar across all three companies despite different geographic distributions and industries. This is because, overall, the risk scores for water quality are relatively high whereas they are relatively low for water scarcity and regulatory water risks. The final basin water risk score is calculated by WRF by applying its developed industry-specific weightings. From this score, an investor can infer that despite all three companies having relatively high-water quality risks, the overall basin water risks are low. All three companies have good corporate water management practices in place for their direct operations.

Considering their supply chain, the management practices vary. Company 2 addresses all listed indicators whereas Company 1 doesn't. To obtain an even better understanding of a company's water management the next step in analysing water management and resilience strategies would be to understand whether the companies invest in basin protection and collective action in the facilities at risk.

Electrical equipment company

Company 1's water intensity score corresponds to its industry median and is therefore not of immediate concern. Companies in the electric equipment industry are reliant on high quality water and Company 1 is exposed to high water quality risks in 74% of its facilities. This could point towards a concrete threat to its operations. Despite that, with only 7% of facilities exposed to high basin water risks and a good water management score, the company is not exposed to very significant water risks in its direct operations. The supply chain shows a high water intensity due to the large amounts of copper that is sourced. With copper being mined in countries that are facing high water stress and drought risks and the company not addressing these issues properly, it can be concluded that the risks in the supply chain are substantial.

Food industry company

Company 2: Company 2 has a water intensity that is slightly below the industry's median. Because the overall water intensity of the industry is high, the 11% of facilities exposed to high water scarcity risks need to be monitored. Further, the company needs to be aware that 50% of the facilities are exposed to high reputational risks and 66% to high water quality risks. As the company manages its water risk thoroughly, the concerns are limited. In the supply chain, coffee beans are an extremely water-intensive crop. According to the analysis, the main coffee growing areas are not highly exposed to water stress or drought risk, but mainly to flood risks. These flood risks could be very damaging for the company's operations, as coffee contributes largely to its revenue. Looking at the water management score, it seems that the company collaborates with suppliers to mitigate these risks.

Pharmaceutical company

Company 3: The water intensity of Company 3 is significantly higher than the industry's median. This could indicate that the company does not manage its water resources well, but in the overall water management the company scores the full number of points. The company is highly exposed (73%) to quality risks which are material for the pharmaceutical industry. Further, 43% of facilities exposed to flooding risks also represents a risk for the company. These risks need to be mitigated and with 5 out of 5 points in water management, it seems that the company does manage its water risks well. As a pharmaceutical company uses many different raw materials its main raw materials are not disclosed. According to Ceres, water risks in the supply chain are not material for the pharmaceutical industry (Ceres, Toolkit Sector and Industry Water Risk Database).

5.1 Comparison industry water risk analysis and analysis of individual stocks

The results from the water risk analysis of equity portfolios and water risk analysis of individual stocks differ in terms of outcomes that each water risk analysis provides. The portfolio water risk analysis provides high-level data, whereas the water risk analysis of individual stocks is much more detailed and also provides information on supply chain risks, reputational and regulatory risks as well as water management. However, some factors, such as baseline water stress, drought risk and flood risk, are outcomes of both methodologies. The aim of this section is to compare the results from both methodologies.

The geographic data inputs vary quite significantly between the portfolio water risk analysis and the water risk analysis of individual stocks. While the water risk analysis of individual stocks locates the precise geolocation of the manufacturing sites of a company, the portfolio water risk analysis is based on average industry data on country level. The difference between the geographic data can be seen in the figures below. Figure 11 demonstrates the 373 locations identified with Bloomberg of Company 2. The colours of the dots represent the overall water risk from the Water Risk Filter (from blue = low to dark red = high). Figure 10 shows the geographic distribution of the industry based on industry average data that Company 2 is part of Figure 11.

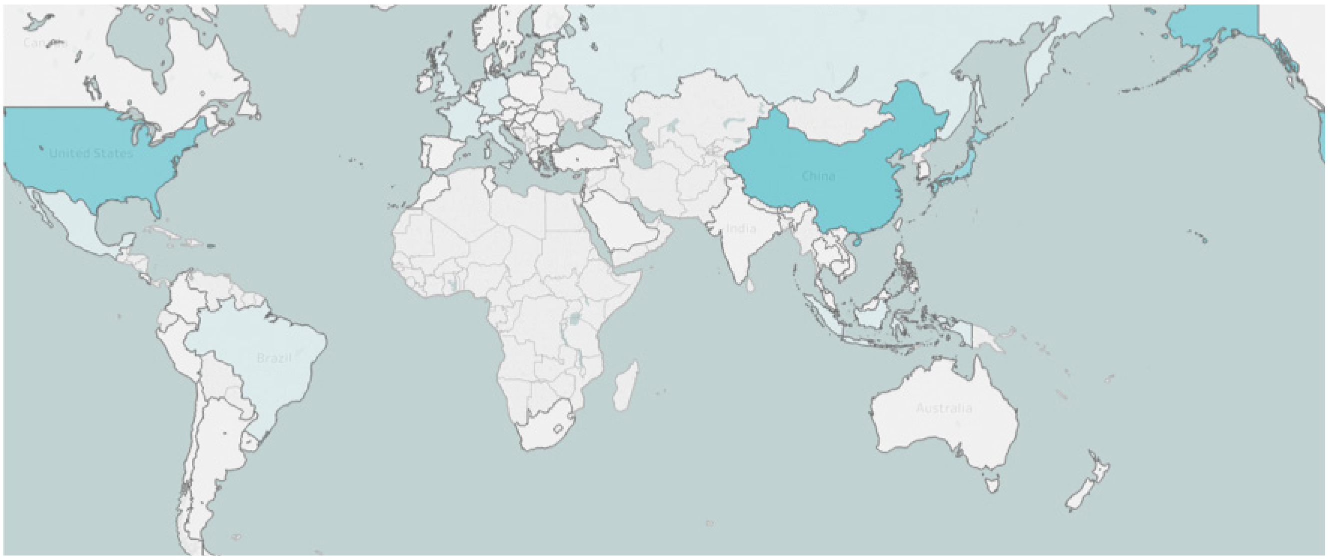

Figure 10: Geographic distribution of Company 2 based on industry average

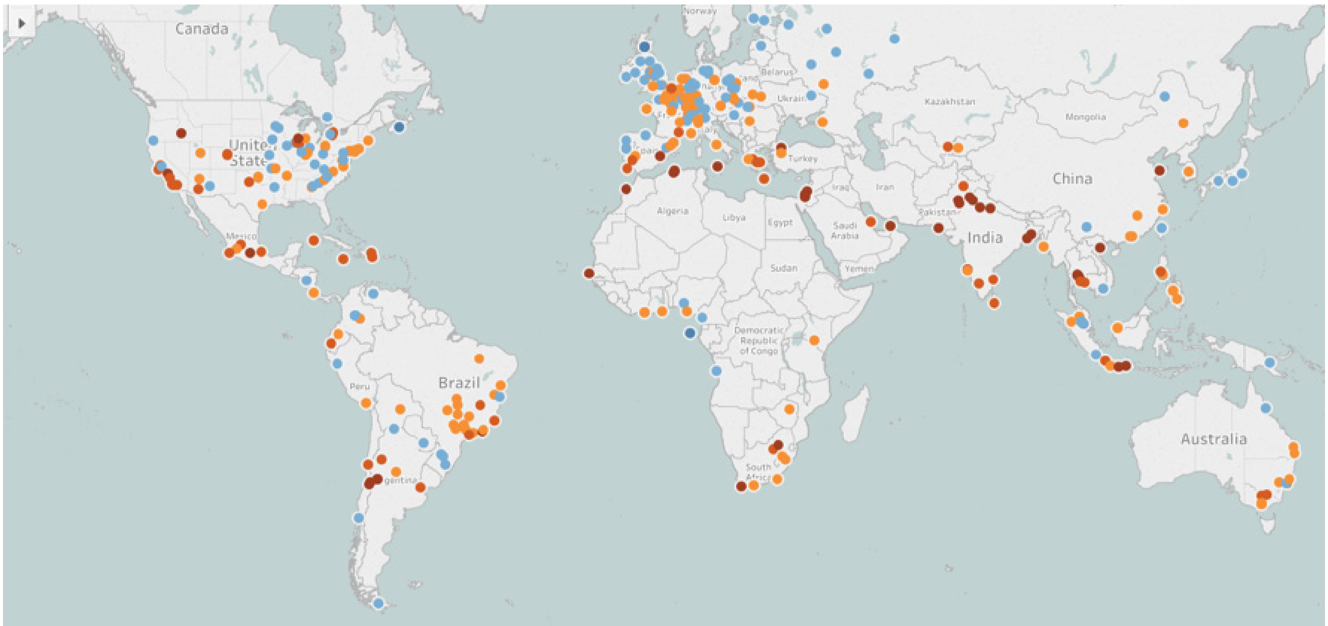

Figure 11: Manufacturing sites of Company 2 based on water risk analysis of individual stocks

From these two figures it is clear that the data from the water risk analysis of individual stocks is much more granular and precise. For example, while China is an important country for the food industry globally, Company 2 does not have that many facilities in China. It does, however, have quite a few in Latin America, South East Asia and India and these countries are not as important based on the industry average data from the portfolio water risk analysis. The in-depth analysis has shown that Company 1 counts 242 facilities located in 36 different countries while for Company 2 370 facilities are located in 70 different countries and the 173 facilities of Company 3 is located in 32 different countries.

As a next step, the results for the different types of water risk exposure from both methodologies will be compared. Table 9 shows how the 3 example companies performed on flood, drought and baseline water stress from the portfolio water risk analysis and the water risk analysis of individual stocks. The indicated percentages are the percentages of the company (based on the industry average for the portfolio analysis and the location of manufacturing sites for the analysis of individual stocks) that is exposed to "high" flood risk, drought risk or baseline water stress.

Table 9: Comparison of results for baseline water stress, flood and drought risk

Company	Methodology	Flood Risk	Drought Risk	Baseline Water Stress
Company 1	Portfolio analysis	46.67%	1.01%	53.38%
	Individual analysis	33%	3%	17%
Company 2	Portfolio analysis	27.98	0.44%	66.89%
	Individual analysis	31%	3%	20%
Company 3	Portfolio analysis	50.60%	1.62%	45.19%
	Individual analysis	43%	2%	20%

Table 9 shows some differences in the results between the portfolio and individual analysis. This is not a cause for concern, as averages of data sets lose the granularity of information that is provided through individual analysis. Nevertheless, the percentages are in the same range for drought and flood risks. Drought risks are consistently low over all companies and both methodologies and flood risks are between 30-50%. This is due to the fact that drought risk are generally fairly low and not many basins nor countries have a high drought risk score. Baseline water stress varies the most between the portfolio water risk analysis and the water risk analysis of individual stocks. Table 10 compares the final scores for water intensity and water risks of both methodologies. Water intensity is aligned in company 1 and 2, but not in company 3. All companies face extremely high or very high quality and reputational water risks, which are both not included in the portfolio water risk analysis.

Table 10: Comparison of final risk scores for portfolio and individual stocks water risk analysis

Company	Results from portfolio water risk analysis	Results from individual stocks water risk analysis
Company 1	• low to medium water intensity score • low water risks	• low to medium water intensity score • extremely high water quality risks and very high reputational risks
Company 2	• medium to high water intensity • extremely high water risks	• medium to high water intensity • extremely high water quality risks and very high reputational risks
Company 3	• low to medium water intensity • low to medium water risk	• medium to high water intensity • extremely high water quality risks, very high reputational risks and flooding risks

5.2 Key findings and conclusions from the methodology "water risk analysis of individual stocks"

The water risk analysis of individual stocks has provided a detailed overview over the water risks and water management practices of three companies in three different industries exposed to different levels of water risks. The main goal of this methodology is to develop a deeper understanding for the water risks of a given company. It provides the basis for investors to either engage with the company or develop investment strategies that are aligned with water risks or international water treaties.

Table 11 demonstrates the key findings from the water risk analysis of individual stocks related to the methodological framework and granularity level, the data availability and some important considerations for the different categories of water risks.

As the process of gathering the company-related data is very arduous, one way of further developing the water risk analysis of individual stocks may be to integrate country-level information rather than exact geolocation data. Country-location data is easier to find on company level. This information is sometimes

Table 11: Key findings and conclusions from the analysis of individual stocks

Category	Description
Methodological framework and granularity	• **Granular data provides important information for engaging with companies**. The information resulting from this analysis is ideal for investors for engaging with the companies. It provides a comprehensive overview on how a company performs on the three risk drivers. • **Granularity level not suited for high-level risk assessments**: for investors that are only interested in mitigating and adjusting their risks in their large portfolio, the water risk analysis of individual stocks is not well-suited. • **Water risks are local**. Therefore, geographical information is crucial. Without geographic data, actual water risks cannot be identified.
Data availability	• **Data availability and comparability remains very low**. While the identification of relevant quantitative datasets is possible to some extent (water withdrawal, supply chain risks etc.) these are often not accessible (as they are subject to a fee) and not comparable (as they need to be combined from various sources). This is very time-consuming and makes it very challenging to combine the information to a comprehensive water risk score. • **Geographic data is barely available**. The data sets that exist are subject to a fee and not necessarily in a directly suitable format. • **Abundance of water management data**. Various sources for assessing a company's water management exist (company reports, CDP data). If none is available, this can be seen as a low water management score. • **Possibility of including forward-looking data**: when geolocation data is available from companies, the Aqueduct tool can be used, and forward-looking scenario-data can be applied to the risk scores.
Important considerations for the different categories of water risks	• **Water intensity is important but not informative in itself**. It needs to be analysed in relation to reduced water availability (e.g. caused by baseline water stress or drought). • **Water management score**: A company can have a big impact on its water risks through a comprehensive water management strategy. This does not only decrease the reputational risks of a company, but also enables them to know where their risks are and plan ahead accordingly. • **Regulatory and reputational risks**: the analysis has shown that these risks can be very high and should therefore definitively be taken into account. • **Supply chain risks are material for certain industries**, especially industries with agricultural supply chain (UNPRI; 2018b). If an in-depth analysis of the supply chain risks is conducted, the identification of raw materials should be executed on a company level. This was also done by WWF and PwC that have identified 25 crops that are exposed to the highest water risks. The results from the analysis, however, were not made publicly available. (UNPRI, 2018b).

available for the supply chain as well. However, the challenge is that, when using the Aqueduct country water risk database, no regulatory, reputational and quality risks are included. For the reputational risks, rather than calculating reputational risks on a basin-level, databases such as RepRisk provide reputational risk scores on a corporate level. According to the WWF (2009), well-known brands that are highly water dependent are exposed to the highest reputational challenges. Therefore, a way of integrating reputational risks could be to score companies or industries according to the notoriety. Many reports targeting specific industries have been published. This could be used as an indication of how notorious the water risks of a specific industry are. In order to include regulatory risks, the regulatory framework on country level could be assessed. Up to today, no database assessing the regulatory risk score on country level could be identified. In combination with a company's headquarters this could give an indication of how heavily regulated a specific company is. This assessment could potentially also be done on industry level. The chemicals industry is, for example, one of the industries that is heavily regulated due to its toxic substances that are released in the production. It could potentially serve as benchmark for all the companies in said industry.

6. Preliminary conclusion on analysis of water risks of individual stocks and portfolios

The past four chapters have illustrated the two water risk methodologies that have been developed by South Pole and its results based on a sample analysis: the water risk analysis of equity portfolios and the water risk analysis of individual stocks. These two methodologies differ strongly in terms of the approach and the results. They can be applied individually or complimentary. The approach developed in this report has the aim of providing the basis for investors to either engage with companies on individual water risks or aligning their investment portfolios with global water targets and goals. The suggested approach can be seen in Figure 12 and is described in detail below.

- **Step 1: Water risk analysis of equity portfolios**
  South Pole has developed the first methodology which is able to connect geographical water risks information with equity portfolios. The portfolio water risk analysis combines top-down industry-based analysis starting from the SASB materiality analysis with bottom up geographical risk information and makes an important contribution to converge both approaches. Nevertheless, it is not yet able to integrate more granular data due to issues of data availability and the disclosure of individual companies. This methodology does, however, give investors a first overview on where, in terms of individual stocks and geographies, water risks should be analysed more closely.

- **Step 2: Water risk analysis of individual stocks**
  Through the analysis of water risks of individual stocks, a great depth of information is made available to an investor. The analysis provides an investor with a comprehensive risk assessment by combining the risks that a company is exposed to, due to its operations and its location, with its water management strategy. While achieving this granularity is time-consuming, this information is highly relevant in order to understand how a specific company performs on all three risk drivers and can be used by investors as a basis for engagement. The methodology further also highlights supply chain water risks, even though this analysis has proven to be even more challenging in terms of data availability.

- **Step 3: Engagement with portfolio companies**
  The results from the water risks analysis of individual stocks builds the basis for an investor to form investment decisions on holistic and comprehensive data. Due to the depth of information, this methodology can also be applied to develop water-aligned strategies

The development of these methodologies has shown that there is no right or wrong in water risk assessments. Different methodologies serve different needs and it ultimately depends on

Figure 12: 3-Step approach for engaging with portfolio companies on water risks

what an investor wants to achieve with the water risk assessment. The needs of an investor have to be balanced with the time and data available to an investor. It does not make sense to aim for value-at-risk if data availability is scarce. Precisely quantifying the water risks does not have to be the ultimate goal. Having an indication of where an investor needs to do more detailed analysis can already be highly useful.

Investors need to put pressure on companies and demonstrate a demand for corporate water disclosure, and data to perform better water risk assessments. Nevertheless, many tools are already available, and investors have access to large amounts of data sets which support them in their water risk assessments. With this data, high level conclusions on water risks can be drawn.

6.1 Application of the methodology to lending portfolios

This chapter assesses how the methodology developed by South Pole for public equity could be applied to lending portfolios. So far, research has mainly focused on assessing the physical climate risks of equity portfolios, while the risk of credit and lending portfolios held by banks and other financial institutions received much less attention (Connell, Firth, Baglee, Haworth, Steeves, et al., 2018). Water risks can, however, affect the financial health of borrowers and the credit risks in banks' loan portfolio in a variety of ways. Therefore, there is an urgent need for more research into the linkages between water and credit risk. Lending activities are not only highly relevant in terms of risks. It is through lending activities that banks can play the most influential and impactful role in achieving SDG 6 on clean water and sanitation.

Two tools, the Drought Stress Testing Tool and the Corporate Bonds Water Credit Risk tool, have already been developed to assess the impact of water risks on loan portfolios. The Drought Stress Testing Tool, developed by a multi-stakeholder group, enables lenders to assess the risk of default, as a consequence of drought, on a company and portfolio level based on different drought scenarios. The study has shown that, even when exposed to less extreme drought scenarios, companies across all industries see their credit ratings downgraded (Colas, Khaykin, Pyanet, Westheim, 2018). The Corporate Bonds Water Credit Risk Tool assesses how a future shadow water price would impact a company's Net Debt/EBITDA and hence its credit rating in three sectors - mining, power utilities and beverages. The results from the study show that companies from both the mining and the power sector might see their credit ratings decrease.

The beverage sector is less affected by increasing water prices because most of the water use of the beverage companies is in the supply chain, which has not been included in the assessment (Ridley & Boland, 2015). Both of these examples show how important it is to include water-related risk analysis into the credit risk scoring system.

The challenges of assessing water risks are similar for both asset classes, equity and debt. In order to understand how water risks might affect lending portfolios it is important to consider that lending portfolios can potentially include corporate loans, bonds and mortgages. However, these financial instruments vary significantly in terms of time horizon. While individual stocks can be sold at almost any time, corporate loans are often underwritten for 1-2 years and mortgages can even last up to 20 years or more. But similarly to equity portfolios there is limited geographical information available on company or industry level to assess how water risks might impact the creditworthiness of specific borrowers and industries. In the case of mortgages, however, the advantage is that the geographic data inputs such as property locations are available for calculating geographic water risks. This is not the case across all types of mortgages. Retail mortgages, for example, face data restrictions because of very strict privacy rules.

The developed water risk analysis enables investors to assess the exposure of their portfolios to regional water risks. In chapter 1 through 6, the methodology was applied to water risks in equity stocks and portfolios. It evaluates the vulnerability to water risks impact across industries (water risk analysis of equity portfolios) and companies (water risk analysis of individual stocks). Whether analysing equity or debt, the water risks on a company level are identical. Industry-level information is, however, only relevant in the case of corporate loans and cannot be applied to mortgages. The water risk analysis of equity portfolios can therefore also be applied to corporate loan portfolios (analogous to water risk analysis of equity portfolios the methodology could be called water risk analysis of loans). The water risks of mortgages do not depend on the industry but require using geographical data on the location of the asset through the bottom-up water risk analysis.

The first step to assess the water risks of corporate loans would be for financial institutions to analyse which loans in the loan portfolio are exposed to high water risks with the water risk analysis of loan portfolios. This high-level and easily applicable methodology gives investors a first overview on which companies should be prioritised and where, in terms of individual loans and geographies, water risks should be analysed more closely.

For all loans that are in an industry that is exposed to very high or extremely high water risks, a creditor should analyse the specific company more closely and conduct a water risk analysis of the individual corporate loan to see if the water risks are indeed as high as predicted by the water risk analysis for the corporate loan portfolio. Through this analysis, a great depth of information is made available to a lender. While obtaining this level of data-granularity is time-consuming, this information is highly relevant in order to understand how a specific company performs on all three risk drivers and can be used by lenders as a basis for engagement or adjustment of the credit risk. The water risk analysis of individual loans could also be applied when determining if a borrower's loan application is an acceptable risk. The recommended approach for lenders is to analyse water risks before underwriting. Financial institutions could adapt their data requirements at the point of underwriting making it mandatory for the borrowers to disclose geographic company data.

Where the process of analysing water risks differs between equity and lending portfolios is the impact that those water risks have on the investor or creditor. The Corporate Bonds Water Credit Risk Tool demonstrates that using a significant amount of water and being exposed to high water stress would result in having a relatively high weighted average shadow water price which could deteriorate their credit rating (Ridley & Boland, 2015). The methodology developed by South Pole does not evaluate how the water risks affect the financial performance of a company or its ability to repay the loan. Both existing tools, the Drought Stress Testing Tool and the Corporate Bonds Water Credit Risk tool, assess how credit ratings would be affected by water risks. In the case of mortgages, water risks may affect the value of the property and hence impact the loan-to-value ratios, while in the case of loans water risks would affect the revenue and cost component, potentially having an impact on the probability of default (Connell et al., 2018). In order to understand how these indicators may be affected by water risks, different calculations and assessment methods are required.

In order to improve the tools and methodologies to assess water risks of lending portfolios, there is a need to access location-based client data and improve the quality and consistency of water-related datasets and further research into the macroeconomic impacts of physical climate change on water (Connell et al., 2018). Therefore, collaboration between all types of creditors and other stakeholder groups is absolutely necessary. Ultimately, transparency and collaboration will enhance decision-making for all.

7. Scenario-based analysis

As chapter 2 and 3 of this report have shown, assessing the current day water risks from an investor's perspective is a substantial task in itself. The developed methodologies address this issue through a water risk analysis of individual stocks and a portfolio water risk analysis. The methodologies are based on current day data despite the fact that water risks will not stay constant overtime. It is therefore of great interest to also analyse future water risks taking into account future developments in terms of technological shifts, water supply (climate change) and water demand (population growth) to only list a few. The Task Force on Climate Related Disclosure (TCFD) recommends companies and financial institutions to perform scenario based-analysis to deal with this type of uncertainties (TCFD 2017). Although the TCFD was developed for the analysis of climate risks, the model invites to analyse, disclose and handle all environmental risks in this form. Therefore, future water risks should also be included in scenario analysis. To perform such a scenario analysis specific water scenario are needed. This chapter will show how a scenario can be defined and how it can be used in general. Then, a summary of existing water scenarios and their characteristics will be provided. Overall the scenario describing future greenhouse gas (GHG) emissions and concentrations tends to be more advanced. Therefore, the most common GHG or climate scenarios will also be analysed. This analysis will allow to compare climate with water scenarios and find analogies helpful for the future developments of water scenarios. In the last part recommendations on how to improve and build the next generation of water scenarios will be provided.

7.1 Scenarios in general

Analysing future developments of complex systems, such as the global water system, comes with many challenges and uncertainties. Due to the long time scales, a precise forecast becomes impossible due to several reasons: (i) the lack of understanding of some processes within the system; (ii) unknown future human decisions; and (iii) the inherent unpredictability of chaotic systems themselves. To address all these issues, scenario-based analysis has been developed (Wada et al. 2016). A scenario is a set of narratives of a possible future which provides boundary data to simulate the implications of these futures. It aims at better understanding uncertainties in order to reach decisions that are robust under a wide range of possible futures (Moss et al. 2011). Scenarios are not forecasts, but projections of a possible future, hence it is recommended to explore different scenarios for the same time horizon.

It is important to notice that even though scenarios are supposed to be neutral and are not supposed to represent forecasts of the future, they can influence it. This is why they are seen by some as a very political objects and can include more conservative or progressive assumptions depending on the institution that develops them. For instance, the International Energy Agency's (IEAs) World Energy Outlook has been repeatedly criticised for failing to integrate renewable energy in its scenarios (Oil Change International, 2018). It has also been accused of promoting carbon lock-in through self-fulfilling prophecies (i.e. governments using scenarios to back their fossil fuels investments choices as has been the case for Australia which used the 450 scenarios to promote coal investments (Geoscience Australia and ABARE, 2010). This is one of the reasons why it is recommended to use several scenarios with a wide range of underlying assumptions. In financial modelling, for example, typically three scenarios (a best case, a base case and a worst-case scenario) (Corporate Finance Institute, 2015-2019) are used to describe potential futures. They allow to study sensitivity in valuations and prices. In the climate change community, the business-as-usual (BaU) scenario (carbon emissions growth following recent trends) became the norm for describing the worst-case scenario. The worst-case scenario which would describe an exacerbation of current trends is rarely explored. The best-case scenario is assumed to be a strong mitigation scenario decreasing current emission trends to limit global warming to below 2°C.

Scenarios are generally developed in three steps (Gallopin, 2012):

1. The current situation is analysed and central characteristics are identified. These characteristics are the central dimensions along which a future scenario will be developed to provide a complete picture of the future. Examples of possible dimensions are economic growth, social progress, environmental quality, etc.
2. The most important driving forces are identified, these driving forces are processes, stakeholders, etc. that decisively influence the future development of the system. There are two types of drivers: (i) invariant drivers that do not differ between the scenarios; and (ii) critical drivers whose change will significantly affect the future of the scenario.
3. Optional: models are used to correctly represent and simulate the interdependencies of different variables within a scenario allowing to build a quantitative scenario. In general, and especially for quantification of financial impacts, quantitative data tends to be preferred over qualitative one because it allows for higher comparability.

A powerful approach used for building a scenario, and going through the three steps, is to use the story and simulation (SAS) approach. "An approach to (environmental) scenario analysis that combines qualitative and quantitative information based on two main elements: a narrative (story) and results from model calculations (simulation)." (EEA, 2017)

Model vs. Scenario

In the public debate as well as in public literature the two terms, models and scenarios, are often used interchangeably although there are important differences between the two. As introduced, a scenario represents a certain picture of the future. Whereas a model in general is an abstract representation of the "reality". It can take many forms such as computer models, statistical models, conceptual models etc. A model can be used to develop a consistent set of scenario variables. Take the example of the impact of climate change on an onshore windfarm's profitability in Germany. A climate model can be used to provide a consistent set of average and variability in future wind velocities at this location that can be used to calculate the expected power production. The scenario in this case is a certain assumption about future climate change greenhouse gas (GHG) concentrations for example and the climate model is used to provide the quantitative boundaries for the economic model.

7.2 Introduction on water scenarios

As water is closely linked with climate it is no surprise that it is included as a climate risk in the recommendations of the TCFD (TCFD, 2017). The recommendations of the TCFD separate between physical and transitional risks were physical risk are

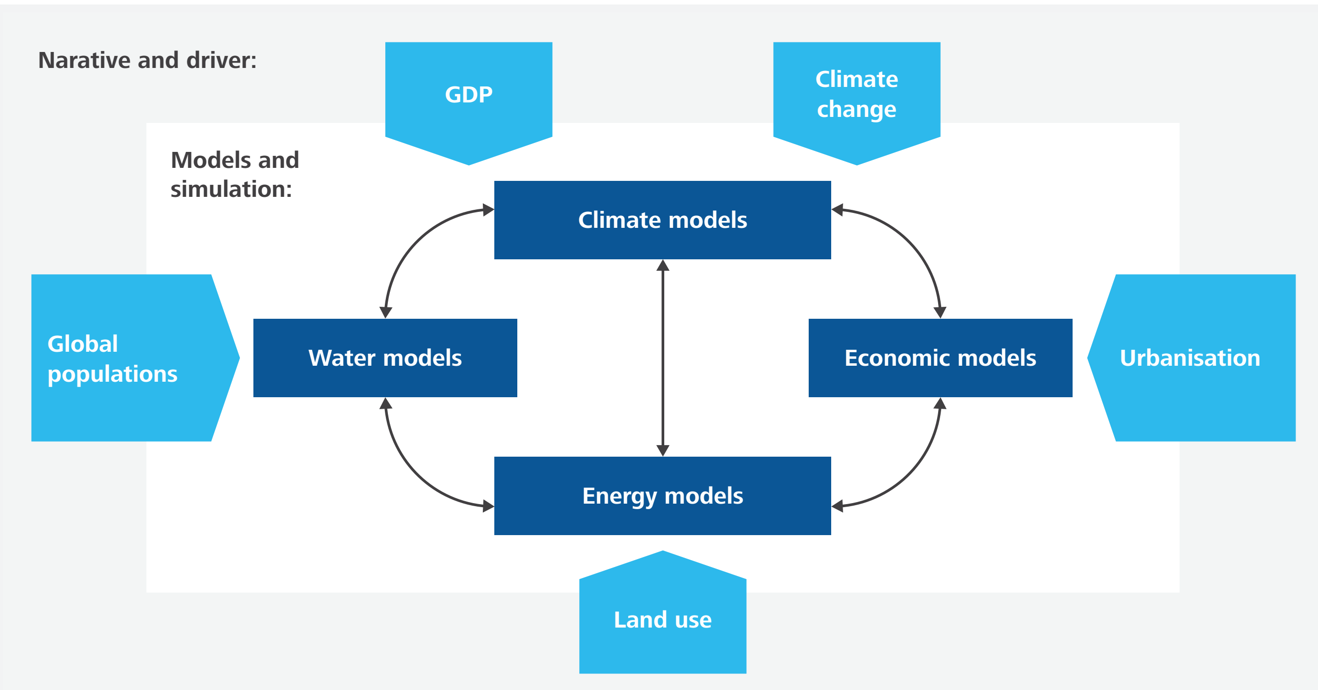

Figure 13: Overview of scenario design process

caused by climate change effects (adaption) and transition risks are caused by the transition to a low carbon economy (mitigation).

- Transition risks: includes policy and legal risk (e.g. 'greater water efficiency measures') as well as market risk (e.g. 'increased production costs due to changing input prices of water and output requirements').

- Physical risks: includes specific water-related risks such as cyclones, hurricanes, floods (acute risks) and sea-level rise (chronic risk). Water availability is mentioned as a potential risk to financial performance because it could lead to higher operating costs (e.g. inadequate water supply for hydroelectric plants or for cooling nuclear plants).

This clearly shows that there is a great need for water scenarios for companies and investors alike. In this chapter we will summarise the existing scenario based on their key features and present the most advanced scenario in more detail. Here it is important to notice that we are not focusing on individual water risk assessment tools, as was done in the report by South Pole from 2018, but that we are explicitly addressing the underlying scenarios which in principle can then be used by different tools. The "overview water and climate scenarios" as presented in a separate PDF provides an overview of current water scenarios. We selected the key criteria based on the general scenario characteristics introduced in chapter 7 and some water specific criteria. More details on the respective criteria, their general meaning, pro and cons as well as examples are provided in the Table 12 below.

Table 12: Key components and characteristics of scenarios

Models	Atmospheric or climate models	Represent the physical laws governing the behaviour of the climate system earth.
	Water models	Based on physical laws which govern the flow and distribution of water. Most of these models focus on land (including surface and groundwater).
	Economic models	Mostly supply and demand models. Energy models are also summarised under this category.
	Multi-model	As all models include inherent uncertainties, due to limited understanding of the represented process or limits in the resolution, it is best practice to use a multi model approach to assess the so-called model uncertainty.
Methodology	Qualitative	Have a logical, high level storyline. • Pro: can be easily communicated between different stakeholders and can include non-quantifiable parameters. • Contra: impacts can't be quantified, no concrete metrics.
	Quantitative	Based on models and numerical simulations • Pro: actionable metrics and outputs, comparability, transparency. • Contra: building and running comprehensive model is difficult and time consuming, often expert knowledge is needed to understand the outputs.
Drivers	Physical	• Climate change (greenhouse gas concentrations, precipitation, temperature) • Land use (area used for forest, agriculture, rainfed vs irrigated) • Geological (river morphology, etc.) • Ecology (spread of species, etc.)
	Socio-economic	• Demographic (population, age distribution) • Economic (water price, GDP) • Technological (water efficiency, desalination technology) • Social (poverty, trends in water usage etc.) • Energy (energy consumption, electricity production, the share of renewable energy) • Governance (stability, type of government, global cooperation)
Outputs	Water availability	Representing the supply side mostly due to precipitation and river flows.
	Water use	Representing the demand side for example industrial and agriculture water used.
	Water stress	Can be deduced from water availability and water use.
	Water quality	Chemicals, ecological etc.
	Extreme events	Variability in the supply side can lead to certain moments in time where too much or too little water is present (floods, droughts).
	Resolution	The usefulness of the respective scenario will be determined by the final outputs and the spatial resolution of the data.

7.3 Overview of current water scenarios

7.3.1 Water Future and Solutions Initiative

Introduction and background

This flagship programme of the International Institute for Applied Systems Analysis (IIASA) was launched in 2013. It originates from the World Water Vision prepared in 2000 under the aegis of the World Water Council as well as from the initial phase of the UNESCO's World Water Scenarios project (Wada et al. 2016). It includes quantitative and qualitative multi-model assessments using new generations of socio-economic and hydrological models. IIASA follows an iterative process to build the scenario in which it engages with scenario experts, stakeholders, data experts, modellers and decision-makers.

Main characteristics

The main drivers of the Water Future and Solutions Initiative (WFaS) are based on the Shared Socioeconomic Pathways (SSP) and Representative Concentration Pathways (RCPs) (see chapter 7.3.1), and include Population growth, GDP, urbanisations, land use changes, etc. The WFaS 'fast-track' analysis seeks to use available ongoing research to develop a set of preliminary quantitative water projections. It uses a multi-model approach using three global water models (HO8, PCR GLOBWB, WaterGAP) which differentiate between all the major water usages: domestic, industrial (energy/manufacturing), and agricultural (livestock/irrigation).

Table 13: Strengths and weaknesses of the Water Futures and Solutions Initiative

Strengths	• Small but multi-model approach • Large number of drivers • Builds upon the SSP scenarios, and can therefore be aligned with the most popular climate scenarios using the SSP as underlying story • Specific Water models are used
Weaknesses	• Complex to use • Not specifically designed for the financial sector • A lot of actors involved in the process, risk of reduced flexibility and agility

7.3.2 Aqueduct Water Stress Projections Data

Introduction and background

The Aqueduct risk tool focusing on current day risks was launched in 2013 by the World Resource Institute (WRI) and included 12 global indicators grouped in quantitative physical risks, qualitative physical risk and regulatory and reputational risk. The 'Aqueduct Water Stress Projections Data', related scenarios that were launched two years later were focusing on future risks but included less indicators. The data has been aggregated at country level (Luo et al., 2015). These scenarios were produced for "decadal-scale planning, adaptation and investment [...] over the next three decades" (Luck et al., 2015).

Main characteristics

The Water Stress Projections Data includes two main indicators and two derived indicators (water stress and seasonal variability) (Gassert et al., 2013), these are listed below.

1. **Water supply** was computed from an ensemble of six global climate models (GCMs) from the CMIP5 ensemble. The six models were chosen based on the availability of required data for the RCP4.5 and 8.5 scenarios and their ability to reproduce the mean and standard deviation of historical runoff. Nevertheless, the data needed to be bias-corrected and resampled to match hydrological catchments. Two types of water supply were computed: total blue water (Bt), which is flow-accumulated runoff, and available blue water (Ba), which accounts for upstream consumptive use. The final indicator of water supply used by Aqueduct was total blue water (renewable surface water).

2. **Water demand** (water withdrawal and consumptive use) was modelled projecting size, wealth and other characteristics of countries for the three following sectors as defined by the FAO (agriculture, industry and domestic). The variables used in the projections are area equipped for irrigation, agricultural land area, irrigation efficiency, industrial water withdrawals, domestic water withdrawals, GDP per capita, urbanisation, baseline water stress, population density and world population. The final indicator of water demand was measured as water withdrawals.

The projections data are based on three scenarios: SSP2-RCP4.5 (optimistic), SSP2-RCP8.5 (business as usual) and SSP3-RCP8.5 (pessimistic). The scenarios are based on the RCPs and the SSP developed by the IPCC for climate scenarios analysis. The quantitative data is taken from global climate models (GCMs) and mixed-effects regression models based on projected socioeconomic variables from the SSP. The SSPs are presented with more details in a dedicated chapter of this report. All indicators were resampled to a sub-basin scale to facilitate hydrological routing.

Table 14: Strengths and weaknesses of the Aqueduct Water Stress Projections Data

Strengths	• Specifically designed for the financial sector • Quantitative and multi-model output
Weaknesses	• No specific water models used, • No economic numbers, • Number of scenario indicators much smaller than current day indicators

Table 15: Strengths and weaknesses of the World Water Future 2050

Strengths	• Multitude of drivers and their interdependencies are considered • Large support of stakeholders and external experts • Next Phase of scenarios will be quantitative
Weaknesses	• Qualitative scenarios • No clear output • No decision support • Still a long lead time until the next scenario come out

7.3.3 World Water Future 2050

Introduction and background

In 2000, the UNESCO World Water Assessment Programme (UNESCO WWAP) developed one of the first holistic global water scenarios, the "World Water Visions". In recent years the process to develop new global water scenarios called "World Water Futures 2050" as part of the Word Water Development Reports (WWDR) has been initiated. The World Water Futures 2050 should develop a set of alternative futures of the world's water and provide guidance on how to apply these in current day decision making. Even though the project is still ongoing, the first phase of the project (Driver selection, review and analysis) was concluded with a report on the main drivers as well as a first set of so called "stylized" scenarios. In this chapter, the first stylized scenarios will be analysed as they are a great example of qualitative scenarios.

Main characteristics

In the "stylized" scenario, 10 main drivers are identified: Agriculture, Climate change and variability, Demography, Economy and Security, Ethics, Society and Culture (includes questions of equity), Governance and Institutions (including the right to water), Infrastructure, Politics, Technology, Water resources, including Groundwater and Ecosystems, and their interdependencies are quantified. Based on these main drivers and their connections, five qualitative scenarios are developed. They use the 10 drivers and present a logical storyline on how these 10 drivers will develop in the future in a qualitative way. For example, in scenario 1 "the Conventional World" it is assumed that the 10 drivers will develop similarly to the last 40 years and "based on what could be expected according to widespread conventional expectations about the future, including an exacerbation of current trends". The five scenarios presented are a conventional world, a conflict-world, a techno-world, a global consciousness and a conventional world gone sour.

7.4 Conclusion on current water scenarios

The "overview water and climate scenarios" as presented in a separate PDF shows that there is only a limited number of water scenarios available today. Overall the scenarios start to include more and more features in terms of drivers and outputs, the two most advanced scenarios, the Aqueduct and Water Future and Solution Initiative (WFaS) even provided quantitative model out. Nevertheless, all scenarios are missing financial impacts as well as risk measure beside physical risks (regulatory and reputation risk for example). It is interesting to notice that only the WFaS scenario takes the effort to run individual global water models. The Aqueduct scenario data is relying purely on the output of the global climate models for example.

7.5 Existing climate scenarios

7.5.1 Introduction on climate scenarios

Since the influence of GHG on the global climate was recognised late in the 1970, the United Nation (UN) put a framework in place to organise the research on this topic: The IPCC. In 2015, the 'Fifth Assessment Report' (AR5) by the IPCC was already published (Stocker et al., 2013). One major tool used by the IPCC is scenario analysis. The respective scenarios are used to describe the future emissions and concentrations of GHG by looking at the major drivers. Over the recent years, additional entities beside the IPCC, such as IEA, have developed their own climate scenarios. In this chapter, the most prominent of these scenarios will be evaluated according to the question if there are things to learn for the development of water scenarios. A SWOT matrix for each of the scenarios will be created.

Climate change scenarios focus on two things:

1. the development of future GHG concentrations depending on different socioeconomic drivers like global population, urbanisation land use and energy production systems; and

2. the development of the climate depending on future GHG concentrations.

The most common scenarios, the so-called transition scenarios, are developed to study how dangerous climate change effects can be prevented and how to transition towards a zero-carbon economy. These can be of quantitative and qualitative nature. The second type of scenarios deal with the future climate, based on future GHG concentrations, these are mostly quantitative and supported by the use of climate models. The first type of scenarios have to take a lot of different drivers into account ranging from political to economic and environmental drivers. Because this report focuses on water scenarios, we will not present the results of our research in detail. Instead, we will provide a summary of the strengths and weaknesses of the most common climate scenarios. The detailed description of these scenarios can be found in the Annex.

7.6 Transition scenarios

Transition scenarios provide future socio-economics data (e.g. energy use) to describe a world going towards a certain global temperature target. They make plausible assumptions about the development of climate policies and the deployment of "climate-friendly" technologies to limit GHG emissions. They draw conclusions, often based on modelling, about how policy and technology regarding energy supply and GHG emissions interact with economic activity, energy consumption, and GDP amongst other key factors. Different sorts of institutions have developed their own or contributed to the development of scenarios: NGOs (e.g. Greenpeace's Energy [Re]volution (Greenpeace, 2015), academic institutions (e.g. International Institute for Applied Systems Analysis contributing to the SSP (IIASA, 2019)), intergovernmental organisations (e.g. International Energy Agency's World Energy Outlook), corporates (British Petroleum's Energy Outlook (BP, 2019)). The strength and weakness of the most commonly used scenarios: the World Energy Outlook and Energy Transition Pathways developed by the IEA and the SSP developed by the scientific community around the IPCC will be presented.

7.6.1 World Energy Outlook and Energy Transition Pathways

The IEA is a autonomous intergovernmental organisation based in France, founded in 1974 in the wake of the 1973 oil crisis. So far it has published a minimum of 14 different scenarios divided into two groups: World Energy Outlook (WEO) and Energy Transition Pathways (ETP). These scenarios are often used as transition risk scenarios[2] although they focus mostly on the energy transition and exclude other important drivers.

Table 16: Strengths and weaknesses of the World Energy Outlook and Energy Transition Pathways

Strengths	• Qualitative model based on energy and economy models • wide variety of scenarios available
Weaknesses	• Ignores important drivers beside the energy sector • IEA is not transparent about the underly-ing assumptions • Only based on a single model

7.6.2 Shared Socioeconomic Pathways

The SSP scenarios were developed to support the work of the IPCC on climate change, they were developed in a community effort using large expert teams that designed the storylines and ensured their internal consistency (Riahi et al., 2017). The three main drivers of the SSP are GDP, Urbanisation and Population (O'Neill et al., 2016). Further the SSP narratives were supported by results of integrated assessment models (IAMs), which provided quantitative analysis for a wide range of outputs. One key element of the SSP was their co-development with the so-called RCP scenarios used in the climate modelling community ensuring a close alignment between the two scenarios.

Table 16: Strengths and weaknesses of the World Energy Outlook and Energy Transition Pathways

Strengths	• Includes several primary as well as secondary drivers • Combines quantitative modelling with qualitative narratives • Quantitative output for additional variables can be produced in combination with the integrated assessment models • Multi-model approach
Weaknesses	• Expert knowledge is needed to apply the scenarios • Modelling results of the IAM's are not well organised • Feedback between the IAMs and the RCPs are missing

[2] For example, the Paris Agreement Capital Transition Assessment (PACTA)-tool developed by the 2 degree investment initiative is using several of the IEA scenarios.

7.7 Physical scenarios

Physical scenarios provide climate related data (GHG concentration, etc.). Global climate models are used to show the response to GHG concentrations, such as the (RCPs). Model results are frequently “downscaled” to derive potential local-level changes in climate, which are then used to generate boundary data for regional or local scale impact studies of climate change (first order impacts such as flooding or drought, second order impacts such as loss of crop production, and third order impacts such as famine). Due to the large resources needed to run and maintain global climate models only a few physical climate change scenarios are available, all being developed by the IPCC. Below you will find a summary of the most recent scenario “the representative concentration pathways”.

7.7.1 Representative Concentration Pathways

The RCPs were developed by a community effort of the climate science community to support the work of the IPCC and were used in the ‘Fifth Assessment Report’ (AR5) (AR5 WG1 (Stocker et al., 2013)). RCPs are a set of scenarios that consider different possible future atmospheric GHG and aerosol concentration, air pollutant emissions and land use pathways (Moss et al., 2010). Overall four RCPs are developed which are named after the radiative forcing reached in 2100 (2.6, 4.5, 6.0, and 8.5W/m2). They deliberately do not include any assumptions about the underlying socio-economic developments as these are developed in the related SSPs (see above). The latest ensemble of global climate models using the RCPs is the Climate Model Intercomparison Project 5 (CMIP5) (Taylor et al., 2012).

Table 18: Strengths and weaknesses of the Representative Concentration Pathways

Strengths	• Most up-to-date physical climate change scenarios • Allows to study future physical climate change impacts with CMIP5 • Less political and combinable with a variety of socio-economic scenarios, because no underlying socio-economic developments are assumed • Quantitative outputs • Multi-model approach
Weaknesses	• Low number of scenarios • Scenarios don’t allow extreme assumptions

7.8 Conclusions on current climate scenarios

Based on the analysis shown above, four main areas in which future water scenarios could get inspirations from the current climate scenarios were identified, these are listed below.

1. Climate scenarios have a unifying topic, all are concerned with reducing GHG emissions and restrict global climate change below 2°C. Hence it helps to have a main narrative for the scenarios as well as a key metric, which are GHG emissions and GHG concentrations. Water scenarios are missing, for example, a unifying narrative (some looking at freshwater reserves, others at drinking water etc.)

2. Quantitative socio-economic data exists: based on the unifying narrative for climate scenarios, socio-economic scenarios have been developed that also apply models (energy system modes, economic equilibrium models) to provide quantitative analysis of the so called “transition risks” like changes in prices (energy, oil, gas, electricity), the share of renewable energy, etc., Similarly, quantitative analysis is missing on the water scenario side.

3. Strong institutional entity driving the scenario-development: with the IPCC the climate community had a strong driver that was able to integrate a lot of different stakeholders and scientific communities towards one goal. This type of entity is missing on the water site despite efforts from the UN water project and the ‘New Water Future 2050 scenario’ project. Buy-in from the private sector and the large public is mainly missing. This could be a sign of that there is still a lack of political will to tackle the problem on a global level.

4. Modelling efforts from the climate community exists: the ability to produce quantitative scenarios will in the end be key for the water scenarios to be useful for investors as well as for the private and public sector in general. To achieve this goal a huge modelling effort is needed. The climate community has the so-called model intercomparison projects (for example CMIP5) to which different model developers from around the world are contributing. A similar effort is missing for the water community, partly because water modelling was often done on much smaller regional scales and not aiming to simulate the global water circle. A first step was done by the new water scenarios from IASA (see chapter 7.3.1) .LOPÖ which is integrating three different models, however, a more dedicated effort to bring together the modelling communities would be very beneficial.

7.9 Future development of existing scenarios

Chapter 7.3 has demonstrated that the number of water specific scenarios is still very limited and that the existing ones are missing important features. In this chapter we will discuss the identified gaps and missing data. We will then make suggestions on how to approach scenario analysis given the current constraints and lastly, give an outlook on how future scenarios could be developed and which institutions could be involved. Depending on the use case, different caveats will be more important than others. We will first focus on the needs from the perspective of an investor and then address more general caveats.

7.9.1 Investor specific caveats

We identified two main caveats in the existing scenarios which are: (i) missing financial output Key Performance Indicators (KPIs); and (ii) a low sectoral resolution. Even the most advanced scenarios, the WFaS and the aqueduct water scenario projections, provide no indication of the financial implications of the respective scenarios. This makes it almost impossible to transfer the provided outputs directly into the financial numbers meaningful for individual asset managers or the financial system in general. This problem is not only encountered in scenario analysis but it is also still unsolved for current day water risks as can be seen from the portfolio water risk analysis.

The current scenarios only separate between domestic, industrial and agricultural water use this limited sector partitioning is an even more fundamental caveat. It only allows a very limited analysis, even if financial numbers would be provided, considering that already the highest GICS classification includes 10 different sectors. For the portfolio water risk analysis presented in chapter 2, a classification based on 68 different industries is used. This makes it clear that future water scenarios will need to break down their output KPIs on a more detailed level, separating, for example, between water used for energy production and industrial use.

7.9.2 How scenarios could be applied

Although there are major constraints on the usage of current day water scenarios, one example of how an investor can already address water risks using scenario analysis will be provided. In chapter 2.1.2 we presented a way to identify the geographical distribution of certain high-risk sectors and how this could be combined with the aqueduct country water risk database to address current day flood and drought risks. Based on this geographical distribution the aqueduct tool could also be used to assess future water stress based on projections of future water demand and water supply for different combinations of SSP and RCP scenarios. This would, however, require developing scenario data on country level. Combining the presented portfolio-screening methodology with the aqueduct scenario projections would allow an investor to see future shifts in water stress in the respective portfolio due to climate change and increasing water demand. The last problem preventing such an analysis is a mismatch in the spatial scale of the information. The aqueduct scenario data is provided on basin level whereas the screening method needs country averages as input data. If WRI would solve this issue and extend its water projections and also provide flood and drought projections, then it would already allow for a comprehensive view of physical related water risks.

7.9.3 Future scenario development

First of all, it is important to notice that due to the complexity of the topic almost no institution has the resources to develop a quantitative water scenario completely independently. Instead, this needs to be a collaborative effort. Overall, we see two ways how new water scenarios could be developed: i) completely independent water scenarios which build around a common vision of water. This would mean developing narratives focused on water in comparison to the SSP for example which focus on GHG as well as building up completely new model chains of climate and water models; ii) align and adapt to the current and future climate change scenarios by using the existing SSP as well as the existing climate projections databases.

The way taken to develop new water scenarios will depend on the purpose behind the new scenarios and who the users will be. For this reason, no final recommendations can be given.

Nevertheless, having the financial sector in mind, we would strongly recommend following the second path. This is because of the two main reasons listed below.

1. Climate change will continue to be one of the dominating topics for the years to come and investors will help generate the political will to solve the issues around it. This includes the future of water availability globally.

2. Future estimates of physical water risk and opportunities (supply, variability etc.) are strongly coupled with climate change. Due to the ongoing efforts of the IPCC, the climate science community produced an extensive and well tested database on future climate projections which can already be used as input variables for water modelling. The only constraint of these projections is the underlying RCP scenarios are built to explore the uncertainties around GHG which may not be the same for water issues. Nevertheless, it is highly unrealistic (looking at the amount of time and resources that have been used) that a similar extensive and well test database of simulations will be done for specific water scenarios. Without this extensive database, no adequate quantitative estimates of water supply and variability will be available.

The Aqueduct water projection and the WFaS scenarios are two initiatives that are going this way. The Aqueduct water projections are directly integrating the SSP and RCP scenarios into their water scenarios. The WFaS is going on step further, by also using the CMIP5 database (and therefore the RCP scenarios) while adopting the SSP scenarios to take more water specific assumptions into account. As described in Chapter 7.3.1 the SSPs are mostly focusing on the socio-economic aspects related to GHG emissions.

In order to further advance the existing scenarios to address the most important caveats of scenarios for investors, the main drivers behind these scenarios, the World Research Institute (WRI) and the International Institute for Applied Systems Analysis (IIASA), need to be engaged. This would include addressing the financial impacts as well as focusing on specific sectors and geographies. The portfolio water risk analysis presented in this report could be used to identify on which sectors and geographies to focus first. One very interesting project is the so called Inter-Sectoral Impact Model Intercomparison Project (ISIMIP see "overview water and climate scenarios, separate PDF) which is funded by the German Federal Ministry of Education and Research and builds up a database on climate change impacts. One focus sector of this database is water on the regional and global level. This extensive dataset should be explored, and ways defined to integrate it into a easily accessible tool which could be the Aqueduct tool or a completely new tool.

Whichever path is taken, it is crucial to align future scenarios with the tools used by the private sector to address current day water risks and build the scenarios in such a way that their output can be directly integrated into these tools. This will ensure the usability of the respective scenarios and the fast uptake within the private sector. South Pole recommends that governments get involved with the Water Futures 2050 scenario developed by UN water beside the institutions named in the paragraph above.

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Annex

Countries included in the inter-country input-output tables from the OECD

List of countries included in the OECD database	
Argentina	Lithuania
Australia	Luxemburg
Austria	Malta
Belgium	Malaysia
Bulgaria	Mexico
Brazil	Morocco
Brunei	Netherlands
Cambodia	New Zealand
Canada	Norway
Chile	Peru
China	Philippines
Colombia	Poland
Costa Rica	Portugal
Croatia	Romania
Cyprus	Russia
Czech Republic	Saudia Arabia
Denmark	Singapore
Estonia	Slovakia
Finland	Slovenia
France	South Africa
Germany	South Korea
Greece	Spain
Hong Kong	Sweden
Hungary	Switzerland
Indonesia	Thailand
India	Tunisia
Ireland	Turkey
Iceland	Taiwan
Israel	United Kingdom
Italy	United States
Japan	Vietnam
Latvia	

World Energy Outlook and Energy Transition Pathways

Introduction and background: the International Energy Agency (IEA) is an autonomous intergovernmental organisation that is based in France and founded in 1974 in the wake of the 1973 oil crisis. So far IEA has published a minimum of 14 different scenarios divided into two groups: World Energy Outlook (WEO) and Energy Transition Pathways (ETP). These scenarios are often used as transition risk scenarios although they focus mostly on the energy transition and exclude other important drivers. The World Energy Model (WEM) is the principal tool used to generate detailed sector-by-sector and region-by-region quantitative projections for the WEO. In order to derive insights into other aspects of possible future energy sector developments, the WEM can also be coupled to other model types. The drivers and outputs include final energy consumption, energy transformation, energy supply, energy flows by fuel, investment needs and costs, carbon dioxide (CO2) and other energy-related GHG emissions. In addition to end-user prices, as well as policies (database of 3000+ regulations worldwide). The ETP has a lower spectrum of drivers and mainly provides scenario analysis of lower carbon technology development and deployment in various sectors.

Main characteristics: we will look at the main scenarios included under the WEO and ETP groups. The WEO also includes six other scenarios that will not be looked at in detail: 450 scenario, Faster transition scenario, Low Oil Price Case, Energy For All, Clean Air Scenario, Bridge Scenario.

World Energy Outlook (WEO, 2018)

- **New Policies Scenario (NPS)**: considered as the central scenario of the WEO, it reflects both currently adopted measures and, to a degree, declared policy intentions. This is why it is often – wrongly – considered a forecast. It incorporates the Nationally Determined Contributions (NDCs).
- **Sustainable Development Scenario (SDS)**: is a new scenario examining what it would take to reach the energy related Sustainable Development Goals (SDGs) in 2030 (to achieve universal energy access, take urgent action to combat climate change; to dramatically reduce the air pollutant).
- Current Policies Scenario (CPS): a BaU scenario.
- **Future is electric scenario**: assumes that electric technologies will be widely taken up in this sector as soon as they become cost-competitive, because policymakers remove noneconomic barriers.

Energy Transition Pathways (ETP)

- **Beyond 2°C (B2DS)**: explores how far deployment of technologies that are already available or in the innovation pipeline could take us beyond the 2DS (1.75°C by 2100).
- **2 °C (2DS)**: represents energy system pathway and CO2 emissions trajectory consistent with a 2°C world by 2100 (>50% chance). The 2DS continues to be the ETP's central climate mitigation scenario.

Reference Technology Scenario (RTS): takes into account today's commitments by countries to limit emissions and improve energy efficiency, including the NDC (2.7°C by 2100).

Shared Socioeconomic Pathways

Introduction and background: the SSP scenarios were developed to support the work of the IPCC on climate change. They were developed to replace the old Special Report on Emissions Scenarios (SRES) from 2000. The SSP narratives were supported by results of integrated assessment models (IAMs) which provided quantitative analysis for a wide range of outputs. The SSP are built in a framework around a matrix that combines climate forcing on one axis (as represented by the Representative Concentration Pathways) and socio-economic conditions on the other. Together, these two axes describe situations in which mitigation, adaptation and residual climate damage can be evaluated.

Main characteristics: the narratives of the SSPs (Riahi et al. 2017) were developed in a community effort using large expert teams that designed the storylines and ensured their internal consistency. Similarly, different interdisciplinary groups of experts (5–10 people) participated in the development of the model input tables, ensuring sufficient discussion on the interpretation of the different elements. The three main drivers of the SSP are GDP, Urbanization and Population (O'Neill et al. 2016). One key element of the SSP was their co-development with the so-called RCP scenarios used in the climate modelling community ensuring a close alignment between these two scenarios.

The five scenarios developed within the SSP are (O'Neill et al. 2016):

- **SSP1 Sustainability**: good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency;
- **SSP2 Middle of the road**: trends typical of recent decades continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency. It is generally considered as a BaU scenario;
- **SSP3 Fragmented world**: separation into regions characterised by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population. It is therefore a "pessimistic" scenario;
- **SSP4 Inequality**: highly unequal world both within and across countries. A relatively small, rich global elite is

responsible for much of the emissions, while a larger, poorer group contributes little to emissions and is vulnerable to impacts of climate change, in industrialized as well as in developing countries;

- **SSP5 Conventional development**: conventional development oriented toward economic growth as the solution to social and economic problems, leading to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation.

The five scenarios have been modelled using six different Integrated Assessment Models (IAMs) (i.e. AIM-CGE, GCAM4, IMAGE, MESSAGE-GLOBIOM, REMIND-MagPie, WITCH-GLOBIOM).

Representative Concentration Pathways

Introduction and background: the RCPs were developed by a community effort of the climate science community to support the work of the IPCC and were used in the fifth Assessment Report (AR5) (Stocker et al., 2013). RCPs are a set of scenarios that consider different possible future atmospheric GHG and aerosol concentration, air pollutant emissions and land use pathways (Moss et al. 2010).

Main characteristics: overall four RCPs are developed which are named after the radiative forcing reached in 2100 (2.6, 4.5, 6.0 and 8.5W/m2). They deliberately don't include any assumptions about the underlying socio-economic developments as they are developed in the related SSPs (see above). Global climate models are used to translate future GHG concentrations into climate change projections. The latest ensemble of global climate models is the Climate Model Intercomparison Project 5 (CMIP5) which provided the underlying data for the 5th assessment report of the IPCC (AR5 WG1 (Stocker et al., 2013)).

- RCP2.6: "optimistic", a very high mitigation scenario where temperatures increase 0.3-1.7°C by 2100.
- RCP4.5: "cautiously optimistic" with medium-high mitigation scenario where temperatures increase 1.1-2.6°C by 2100.
- RCP6.0: medium mitigation where temperatures increase by 1.4-3.1°C by 2100
- RCP8.5: is a "business-as-usual" scenario of relatively unconstrained emissions were temperatures increase by 2.6-4.8°C by 2100.

	General Information	
	Overview	Scenario funder / commissioner / publisher
Water scenarios		
The water futures and solutions (WFuS) scenarios	This flagship scenario of the IIASA was developed in 2013 and is leveraging the previous work from the World Water Council and the UNESCO. It aims at developing global water scenarios at the interesection of scientific research and policy making.	Initative led by IIASA; Partners: International Water Association, UNESCO, Ministry of Land, Infrastructure and Transport (MOLIT), Republic of Korea, World Water Council, World Water Assessment Programme
World Water Vision (also called Long Term Vision for Water, Life, and Environment in the 21st Century)	The 'World Water Vision' was introduced during the WWC's first World Water Forum in Marrakech in 1997. The 'World Water Vision - Making Water Everybody's business"" is the culmination of the Vision development exercise."	World Water Council
World Water Future 2050	Still under development. The process is structured into 4 Phases. Phase 1 is finished and provids an overview over the driver which should be included into the new water scenarios. The five stylized scenarios are a first attemt to biuld qualitative scenarios out of the indentified drivers.	UNESCO, World Water Council, UN Water
Five stylized scenarios	Since the present exercise is intended only as a first approximation, the alternative futures discussed are referred to as ‘stylized scenarios’. The purpose is to open the discussion on the universe of possible trajectories of the world water system.	UNESCO, World Water Council, UN Water
The dynamics of Global Water futures driving forces 2011-2050	Report on the findings of Phase One of the UNESCO-WWAP Water Scenarios Project to 2050	United Nations
Aqueduct Water Stress Projection Data	The Aqueduct tool is an very advanced scenario for risk assessment and includes quantitative physical risks (water stress, inter-annual variability, etc.), qualitative physical risk (return flow ratio, upstream protected land) and regulatory and reputational risk (media coverage, access to water, threatened amphibian.	World Research Institute
Inter-sectoral impact model intercomparison project (ISImip)	A framework which allows to buildup a database of climate change impacts. Its specific contribution to water will be explored here.	Supporter: Potsdam Institute for Climate Impact Research (PIK) and International Institute for Applied Systems Analysis Funding: German Federal Ministry of Education and Research
Scenarios of global municipal water-use demand projections over the 21st century	A global municipal water demand projections until 2100 are presented using a model based on global water-use statistics at the country scale.	Mohamad Hejazi, James Edmonds, Vaibhav Chaturvedi, Evan Davies & Jiyong Eom (2013) Scenarios of global municipal water-use demand projections over the 21st century, Hydrological Sciences Journal, 58:3, 519-538, DOI: 10.1080/02626667.2013.772301
Climate scenarios		
Representative concentration pathways (RCPs)	The RCPs were developed by a community effort of the climate science community to support the work of the IPCC and were used in the fifth Assessment Report (AR5) (IPCC AR5 WG1 (2013)). RCPs are a set of scenarios that consider different possible future atmospheric GHG and aerosol concentration, air pollutant emissions and land use pathways (Moss et al. 2010).	IPCC
Shared socio-economic pathways (SSP)	The SSP scenarios were developed to support the work of the IPCC on climate change, they were developed in a community effort using large expert teams that designed the storylines and ensured their internal consistency (Riahi et al. 2017).	IPCC (IIASA, PIK etc)
World Energy Outlook (WEO)	The IEA produced its first energy outlook, the World Energy Outlook (WEO) in 1977 to help understand how different policies would impact the future of oil and energy demand. The World Energy Model (WEM) is the principal tool used to generate detailed sector-by-sector and region-by-region projections for the WEO.	IEA
Energy Transition Pathways (ETP)	The ETP provides scenario analysis of lower carbon technology development and deployment in various sectors with a focus on energy sector	IEA

	Methodology				
Latest update	Qualitative	Quantitative			
		Multi-model (Yes/no)	Atmospheric/ climate model / water suply	Water model / Land water / Land Use / Irrigation	Economic model / Water prices
2015	In 2014 the 5 SSP storylines (SSP1 Sustainability, SP2 Middle of the road, SSP3 Fragmented world, SSP4 Inequality, SSP5 Conventional Development) were extended with stories and qualitative assumptions on the implications of the SSPs for water availability and demand.	Yes	Based on CMIP5 IPCC	"Yes (H08 (Hanasaki et al. 2013), WaterGAP (Flörke et al. 2013, Schmied et al. 2014), and PCR-GLOBWB)"	No
2000	Three scenarios are explored: business as usual (extrapolation of current trends), technology economics and private sector (private initiatives leaving poor countries behind), values and lifestyle (sustainable development).	No	No	No	No
2018	Propably using five storylines introduced in the report five stylized scenarios: Conventional World, Conflict-world, Techno-world, Global Consciousness,Conventional World Gone Sour	Under development	Under development	Under development	Under development
2012	Using 5 storylines: Conventional World, Conflict-world, Techno-world, Global Consciousness,Conventional World Gone Sour	No	No	No	No
2012	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
2013	Based on SSP storylines without special adjustments. Only SSP2 and SSP3 are considered	Yes (based on 6 CMIP5 global climate models)	Yes (downscaled and biases correced CMIP5 data)	No	No
2019	Yes often based on the SSP scenarios	Yes (Multi-model water projections)	Yes (downscaled and biases correced CMIP5 data as well as regional model data EURO-CORDEX)	Yes	Yes (damge functions)
2013	"Yes, three narratives: business-as usual (BAU) low technological improvement (Low Tech) high technological improvement (High Tech)"	No	No	Yes	Yes
2013	The RCP feature not underlying storyline and are meant as purly quantitative scenarios	Yes (using the global climate model ensemble to translate GHG concentrations into climate projections)	Yes	Yes (some climate models are coupled to land-surface models etc)	No
2017	SSP1 Sustainability: SSP2 Middle of the road: SSP3 Fragmented world: SSP4 Inequality: SSP5 Conventional development:	Yes (unsing the intergrated assessment models to inlclude further driver than the original three)	No	Yes (some IAM include water models)	Yes (some IAM include economic models)
2018	Includes 4 different narratives: New Policies Scenario (NPS) Sustainable Development Scenario (SDS) Current Policies Scenario (CPS) Future is electric scenario	No	No	No	Yes (World Energy Model WEM)
2018	Includes 3 different narratives: Beyond 2 degree scenarios (B2DS) 2 degree scenario (2DS) Reference Technology Scenario (RTS)	No	No	No	No

	Geographical focus	Sectoral focus	Time horizon	Driver		
				Physical		
				Climate change	Land use	River morphology
Water scenarios						
The water futures and solutions (WFuS) scenarios	Global, gridded dataset but presented at country level	All sectors devided into agriculture, industrial, domestic	2050	Yes (based on RCP scenarios)	Yes (based on SSP scenarios)	No
World Water Vision (also called Long Term Vision for Water, Life, and Environment in the 21st Century)	Global	Qualitative all sectors	2025	No	Yes (based on the three qualitative story lines)	No
World Water Future 2050	Under development	Under development	2050	Yes (based on own storyline)	Yes (based on own storyline)	No
Five stylized scenarios	Global		2050	Yes (based on own storyline)	Yes (based on own storyline)	No
The dynamics of Global Water futures driving forces 2011-2050	Not applicable	Not applicable	2011-2050	Yes (based on own storyline)	Yes (based on own storyline)	No
Aqueduct Water Stress Projection Data	World wide	All sectors devided into agriculture, industrial, domestic	2020 2030 2040	Yes (based on RCP scenarios, Downscaled and biase corrected CMIP5 data)	Yes (regression based on SSP and historical data)	Partly, Upstream dependency was taken into account
Inter-sectoral impact model intercomparison project (ISImip)	World wide with a global modelling and regional modelling stream	Mostly water some intersections to general economy and energy sector	until 2100	Yes	Yes	Yes
Scenarios of global municipal water-use demand projections over the 21st century	Word wide but focusing on specific regions	Water demand by municipality	2100	No	No	No
Climate scenarios						
Representative concentration pathways (RCPs)	Global	No	2020-2100	Yes	Yes	No
Shared socio-economic pathways (SSP)	Global	No	2020-2100	Yes (through the RCPs)	Yes	No
World Energy Outlook (WEO)	Global	Energy, transportation, buildings	until 2100	No	No	No
Energy Transition Pathways (ETP)	Global	Energy, transportation, buildings	until 2100	No	No	No

		Socio-economic				
Ecology	Demographic	Economic	Technological	Social	Energy	Governance
No	No	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenariosw)
Yes (based on the three qualitative story lines)	No	Yes (based on the three qualitative story lines)	Yes (based on the three qualitative story lines)	Yes (based on the three qualitative story lines)	No	Yes (based on the three qualitative story lines)
Yes (based on own storyline)	Under development	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)
Yes (based on own storyline)	No	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)
Yes (based on own storyline)	Not applicable	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)	Yes (based on own storyline)
No	No	Yes (based on SSP scenarios)	No	No	No	No
Yes	Yes (damge functions)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)	Yes (based on SSP scenarios)
No	Yes	Yes	No	No	No	No
No	No	No	No	No	No	No
Yes	Yes (some IAM include economic models)	Yes	Yes	Yes	Yes	Yes
No	Yes (World Energy Model WEM)	Yes	Yes	No	Yes	No
No	No	Yes	Yes	No	Yes	No

	Hazard types	Output KPI'S			
		Quantitative			Qualitative
		Water availability	Frequency of extreme events (floods, droughts)	Water use	Ecological condition (chemistry, pesticide, temperature)
Water scenarios					
The water futures and solutions (WFuS) scenarios	Global water scenario	Yes	No	Yes	No
World Water Vision (also called Long Term Vision for Water, Life, and Environment in the 21st Century)	No quantitative outputs	No	No	No	No
World Water Future 2050	Under development	Under development	Under development	Under development	Under development
Five stylized scenarios	Global water scenario	Yes	No	Yes	Yes
The dynamics of Global Water futures driving forces 2011-2050	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Aqueduct Water Stress Projection Data	Water demand, water supply, Baseline water stress, seasonal variability,	Yes (Water supply)	Party (seasonal variability as proxy)	No	No
Inter-sectoral impact model intercomparison project (ISImip)	Floods, droughts,	Yes (Water supply)	Yes	Yes	Yes
Scenarios of global municipal water-use demand projections over the 21st century	No	Yes	No	No	No
Climate scenarios					
Representative concentration pathways (RCPs)	All atmospheric hazards: heatwaves, heavy precipitatoin, storms, etc	No	Yes	No	No
Shared socio-economic pathways (SSP)	No direct simulation but using RCP Input	Yes	Yes	No	No
World Energy Outlook (WEO)	No	No	No	No	No
Energy Transition Pathways (ETP)	No	No	No	No	No

		Link
Resolution	Materiality	
Grided data? which resolution has the grid	Financial impact measure	Demographic
0.5x0.5 grided data	No	http://www.iiasa.ac.at/web/ScenariosSummaryDocument_final.pdf http://www.iiasa.ac.at/web/home/research/wfas/water-futures.html
No	No	http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/world-water-scenarios/
Under development	No	http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/world-water-scenarios/phase-1/
Qualitative description	No	http://wedocs.unep.org/bitstream/handle/20.500.11822/18829/Global_Water_Futures_2050.pdf?sequence=1&isAllowed=y
Not applicable	Not applicable	http://wedocs.unep.org/bitstream/handle/20.500.11822/18829/Global_Water_Futures_2050.pdf?sequence=1&isAllowed=y
Variable, based on river basin	No	https://www.wri.org/our-work/project/aqueduct https://www.wri.org/resources/presentations/wris-aqueduct-global-water-risk-mapping-data-methodology http://www.wri.org/publication/aqueduct-metadata-global. http://www.fao.org/nr/water/aquastat/water_use/aqueduct_metadata_global.pdf
Yes	Some	https://www.isimip.org/
No grid, country scale data	Yes	https://www.isimip.org/
Depding in the global climate model	No	http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html
Depending on the IAM and output KPI	No	https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about
No	No	https://www.iea.org/weo/
No	No	https://www.iea.org/etp/

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