

# Measuring the Cost of Corporate Water Usage

DG Park  
George Serafeim  
Rob T. Zochowski

Working Paper 21-036



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Harvard Business School

George Serafeim

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Funding for this research was provided in part by Harvard Business School. George Serafeim is a co-founder of both KKS Advisors and Richmond Global Services providing advisory and software solutions, which are using the authors' methodology. He has equity stakes in both firms.

## **Measuring the Cost of Corporate Water Usage**

DG Park, George Serafeim and T. Robert Zochowski \*

### **Abstract**

We develop a methodology that calculates the impact that organizations have on the environment through their water consumption relating to water stress risk. Using the methodology, we derive estimates for four companies that show how assumptions on the geographic location of the water withdrawal and use of different prices for water across geographies lead to variation in these estimates. We conclude with a framework guiding a user to understand the conditions under which a methodology might lead to over- or underestimation of water costs.

**Keywords:** water, environment, valuation, sustainability

\* DG Park is a research associate for the Impact-Weighted Accounts Project. George Serafeim is the Charles M. Williams Professor of Business Administration at Harvard Business School and the Faculty Chair of the Impact-Weighted Accounts Project. T. Robert Zochowski is the program director of the Impact-Weighted Accounts Project.

## 1. Introduction

Water is one of the most important resources in the world, supporting human life, the natural ecosystems of earth, and, in turn, the economy. Given that a significant amount of water is consumed by organizations, and that water stress risk is rising due to climate change-driven droughts and changes in rainfall patterns, as well as demographic patterns, in this paper, we focus on measuring the impact that organizations have through their water usage. Our methodology and insights could be useful to managers, investors, and policy makers around the world as they make resource allocation decisions or design new policies.

The methodology we derive relies on accurate data on the geographic location of water withdrawal and water discharge, and data on water cost in different geographies. Unfortunately, these data are not available for most organizations. Almost no organizations provide the geographic location of their water withdrawals and discharges. Therefore, we rely on a few organizations with available asset location data to proxy for the location of water usage. Similarly, to the best of our knowledge, no data exists on water cost that incorporates the production and delivery costs for all geographic locations. Therefore, we create a process to extrapolate water costs from locations with available estimates.

We apply our methodology to four organizations that have available data on asset geographic composition. Using these four cases, we derive a framework showing the conditions under which current measurements are likely to systematically under- or overestimate water costs.

## 2. Data Sources

### 2.1 Bloomberg & Thomson Reuters (Asset4) Databases

We acquire organization-level water consumption data from both Bloomberg and Thomson Reuters for the year 2017. Specifically, we collect data on two water usage variables, which are water withdrawal and water discharge.<sup>1</sup>

### 2.2 The AWARE Model

Water scarcity varies significantly among geographical locations based on resource availability, as well as agricultural, industrial, and human needs. Moreover, unlike other commodities with well-defined global markets, inter-regional transfers of water are logistically challenging and expensive. The Availability Water Remaining (AWARE) model provides supplemental water monetization factors, allowing us to account for the effect of local water scarcity.

As described in Freiberg et al (2020):

“Water consumption in one area has highly variable implications for human well-being. In order to incorporate the nuances of local water scarcity and availability based on various

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<sup>1</sup> Water withdrawal is the total amount of water diverted from any source for use by the organization. Water discharge refers to the total amount of liquid waste and process water discharged by the organization. We define net water consumed as water withdrawal minus water discharged. Exhibit 3 provides additional descriptive information for these variables.

human and ecosystem demands, while also enabling comparisons at a corporate level, a robust model for estimating true water usage costs is needed. EPS water monetization factors for monetizing various emissions types are on a global level and do not account for local scarcity. Therefore, we incorporate data from the AWARE model, which provides conversion factors for the absolute amount of available fresh water remaining in each country in terms of global-equivalent cubic meters (Lee et al., 2018). In other words, the AWARE factors represent the available water remaining per unit of surface in a given watershed relative to the world average after human and aquatic ecosystem demands have been met.<sup>2</sup> The underlying assumptions of this model are described in Exhibit 1. By integrating controls for local water scarcity, the AWARE model provides a more accurate comparison of water use across countries with different levels of water scarcity. The scaling provided by the model also allows for the use of a global price once the local water use is converted to a global equivalent value by multiplying it with the AWARE factor.”

### *2.3 Global Water Cost Indices from Waterfund*

A key challenge in identifying the price of water is that water is considered a basic human right, and thus is often heavily subsidized. As a result, at a country level around the world, there is little correlation between the actual price paid and its true value or availability. A global average water price used in this paper is sourced from Waterfund, which has developed a comprehensive measure of water costs for six countries globally. The Waterfund dataset provides two broad sub-categories, water production and delivery cost and wastewater treatment cost, each of which is composed of operating expenses, depreciation, and non-operating expenses. Therefore, the global water cost indices by Waterfund help to provide a key measure of the hidden “economic costs of water,” which are not properly incorporated into the price that organizations pay for water. However, “Waterfund’s data do not provide an estimate for the raw cost of extracting water, as water itself is viewed as a human right and research on this has been surprisingly sparse.<sup>3</sup> Even absent the raw cost of water, the Waterfund price represents a significantly more economically representative cost of water compared to the current prices in many countries (Freiberg et al., 2020).”

### *2.4 Unit Operational Cost Database*

We obtain unit operational costs of water and wastewater services for 134 countries from the International Benchmarking Network for Water and Sanitation Utilities (IBNET)’s public database.<sup>4</sup> Here, the term *unit operational cost of water and wastewater services* is defined as the cost of providing water to customers. Mathematically, it is the total annual operational expenses

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<sup>2</sup> AWARE Factors- conversion factors for the absolute amount of available fresh water remaining in each country in terms of global-equivalent cubic meters, defined as the world average after human and aquatic ecosystem demands have been met.

<sup>3</sup> Turner et al. (2019) estimated the 2017 global price of groundwater to be on average \$0.096/m<sup>3</sup>, however, this does not include estimates for surface water cost or other high capital costs of the required infrastructure for abstracting, transferring, storing, and treating water. Moreover, the percentages of water sourced from groundwater versus surface water are neither consistent across different water utility agencies nor readily quantified by them.

<sup>4</sup> The International Benchmarking Network for Water and Sanitation Utilities (IBNET) is an initiative funded by the World Bank to drive water and sanitation utilities to be more transparent about their core cost and performance indicators. For more information about IBNET, visit: [ib-net.org](http://ib-net.org)

of water and sanitation utilities, in US dollars, divided by the total annual volume of water sold, in cubic meters. IBNET's definition of total annual operational expenses, however, excludes such costs as depreciation, interest, and debt service. Therefore, in order to ensure that we capture the comprehensive costs of water across countries, we rely centrally on Waterfund's water cost indices for six countries, and additionally utilize the unit operational cost database from IBNET to extrapolate water costs for the countries outside of those included in Waterfund's database. Our extrapolation methodology involves the use of multipliers, on which we elaborate in the methodology section.

### *2.5 S&P Capital IQ Database*

We acquire companies' country-level asset distribution data from S&P Capital IQ. We note that many companies do not disclose information about the geographic segments in which their assets are located. Furthermore, the majority of those whose geographical asset distribution data are available in Capital IQ do not reach the level of individual countries, and are instead limited to broader categories such as continental regions. Thus, as we explain in the methodology section, our sample of observations that passes this selective criterion is surprisingly small. In this paper, we utilize the percentages of corporate asset allocations on a country-level as a proxy for distribution of water usage across different countries for multinational corporations in order to more accurately estimate their true costs of water consumption.

## **3. Methodology**

### *3.1 Sample Selection & Cleanup*

First, we obtain the list of all companies whose water withdrawal and water discharge data were reported in Bloomberg and Thomson Reuters. We focus on the data for year 2017, as they are often the most recent data available for all variables of interest. Next, for all observations that have data in both Bloomberg and Thomson Reuters, we ensure a certain level of agreement by comparing the two values against each other. Specifically, we select our sample from the list of firms whose absolute differences between the Bloomberg and the Thomson Reuters values divided by the average of the two are smaller than 10%. We then further limit our sample to the firms whose assets, in 2017, were distributed in countries that are reasonably *similar* to the countries whose water cost indices are available in Waterfund's database. Here, we define similar countries strictly in terms of *similarity in geographic regions and GDP per capita*. This step in our sample selection is to ensure robustness in extrapolating water costs using Waterfund's data and the unit operational cost database. Furthermore, given that S&P Capital IQ database does not disclose country-level asset distribution percentages for the majority of the companies, and that only five countries' water costs data overlap between Waterfund's database and the unit operational cost database, the list of companies that satisfies the criteria above is very short. As such, we choose four companies in total. Our intent in this paper, thus, is not to assert that the four observations are representative of the overall population of multinational companies' water usage cost calculations. Rather, we suggest a framework for monetizing corporate level water use and illustrate the

application of different methodologies through few real-life examples that have implications for how best to approach the estimation of the total cost of corporate water use.

### 3.2 Multipliers

To extrapolate water costs for countries whose unit operational costs are available, yet whose total water costs are not available from Waterfund, we create and use multipliers that combine both the Waterfund's data and IBNET's unit operational costs. It is important to note that we apply multipliers only to countries with comparable GDP per capita and geographical proximity. This is a critical assumption that allows us to extrapolate the costs for countries where our sample observations' assets are allocated, outside of the six included in Waterfund's database.

As demonstrated by the equations below, we define *multiplier* as the ratio between a country's water cost subcomponent (i.e. Water Production & Delivery Cost or Wastewater Treatment Cost as defined by Waterfund) and its unit operational cost. Hence, the two multipliers for country  $j$  employed in this paper are:

$$(1) \text{ Water Production \& Delivery Cost Multiplier}_j = \frac{\text{Water Production \& Delivery Cost}_j}{\text{Unit Operational Cost}_j}$$

$$(2) \text{ Wastewater Treatment Cost Multiplier}_j = \frac{\text{Wastewater Treatment Cost}_j}{\text{Unit Operational Cost}_j}$$

We then apply these multipliers across other analogous countries. As such, we assume in this paper that similarity in geographic regions and GDP per capita is correlated with these multipliers, or in general, that the ratios between each water cost subcomponent and the total water cost in a country remain constant for other similarly developed countries within each region around the world. For instance, in the AES Corp's case, we apply Brazil's multiplier to other South and Central American countries in which its assets are located, including Dominican Republic and Argentina.

### 3.3 Three Models of Deriving Corporate Water Usage Costs

In this paper, we introduce three different approaches of calculating the total cost of corporate level water use. The first method is the one used in Freiberg et al (2020). Here, *net water consumed* is calculated as water withdrawal less water discharged. The environmental impact of water is calculated using Waterfund's global average water costs and AWARE factors. Equation 3 defines the environmental impact of water of firm  $i$  in year  $t$ .

$$(3) \text{ Environmental Impact of Water}_{i,t} = \text{Water Production \& Delivery Cost}_{i,t} + \text{Wastewater Treatment Cost}_{i,t}$$

Waterfund posits that the best representation of the global average price of water is the sum of all economic costs of supplying water. Therefore, the environmental impact of water is calculated as the sum of two costs: water production and delivery cost and wastewater treatment cost. Water production and delivery cost scales by the amount of water consumption and by the level of water scarcity. Waterfund defines the wastewater treatment cost as the sum of expenses incurred by water

utilities to both treat the byproduct of water production and provide specifically the recycled water to organizations. We thus conclude that this cost component intuitively does not depend on water scarcity, and therefore does not scale by the AWARE factor. In this regard, wastewater treatment cost only scales by the volume of water consumption.

$$(4) \text{ Environmental Impact of Water}_{i,t} = (\text{Net Water Consumed}_{i,t} * \text{AWARE Factor}_j * \text{Global Water Production \& Delivery Cost}) + (\text{Net Water Consumed}_{i,t} * \text{Global Wastewater Treatment Cost})$$

Equation 4 describes the breakdown of these two costs in the first model introduced by Freiberg et al (2020). Water production and delivery costs, for organization  $i$  in year  $t$ , are the product of net water consumed by organization  $i$  in year  $t$  and the two time-invariant factors, the AWARE factor and the global water production and delivery unit cost. The AWARE factor is a measure of water scarcity relative to a global average. Since the AWARE factor is measured at a country level, an important assumption of this first model is that all water consumed by the organization each year is withdrawn from an organization's country of domicile. Therefore, the AWARE factor in this equation is defined for country  $j$ , the domicile of the organization. Wastewater treatment costs, for organization  $i$  in year  $t$ , are the product of net water consumed and the global wastewater treatment cost.

However, considering that many companies have operations outside of their countries of domicile, this first model could be applying incorrect AWARE factors to net water consumption. Enhanced geographical granularity in water disclosure data would improve the accuracy of our model's calculations. Hence, in our second model, we utilize country-level asset allocation data of firms from S&P Capital IQ as a proxy for their water usage distribution across different countries. This allows us to assign multiple AWARE factors for multinational firms, while still using global water prices:

$$(5) \text{ Environmental Impact of Water}_{i,t} = \sum[(\text{Net Water Consumed}_{i,t} * \text{Asset Allocation Percentage}_{j,i,t} * \text{AWARE Factor}_j * \text{Global Water Production \& Delivery Cost}) + (\text{Net Water Consumed}_{i,t} * \text{Asset Allocation Percentage}_{j,i,t} * \text{Global Wastewater Treatment Cost})]$$

For each country  $j$ , among the list of countries in which firm  $i$ 's assets are distributed in year  $t$ , the water production and delivery cost is the product of firm  $i$ 's net water consumed in year  $t$ , the percentage of firm  $i$ 's asset allocation in country  $j$  in year  $t$ , country  $j$ 's AWARE factor, and the global average cost of water production and delivery. The wastewater treatment cost in country  $j$ , which doesn't scale by the AWARE factor, is simply the product of net water consumed, asset allocation percentage in the country, and the global average cost of wastewater treatment. The sum of the two water cost components for all countries where the company  $i$ 's assets are located is then the total cost of the firm's water usage in year  $t$ .

Finally, our third model advances one step further in geographic granularity and localization by additionally incorporating *country-level water prices* into the second model. Here, the country-level water prices refer to either the water costs in the six countries provided by Waterfund or the costs we extrapolate using both the Waterfund’s global cost indices and the IBNET’s country-level unit operational costs:

$$(6) \text{ Environmental Impact of Water}_{i,t} = \sum[(\text{Net Water Consumed}_{i,t} * \text{Asset Allocation Percentage}_{j,i,t} * \text{AWARE Factor}_j * \text{Water Production \& Delivery Cost}_j) + (\text{Net Water Consumed}_{i,t} * \text{Asset Allocation Percentage}_{j,i,t} * \text{Wastewater Treatment Cost}_j)]$$

As noted by the Equation 6 above, the only difference from Equation 5 that highlights our second model is that for each country *j*, *local* water costs are used instead of the global averages.

### 3.4 Assumptions

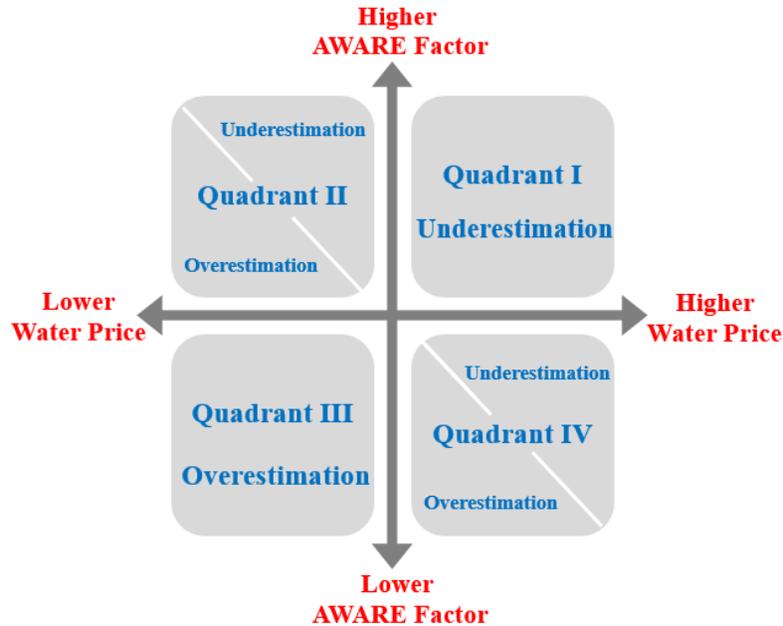
To summarize the key assumptions made in this paper, first, we posit that a firm’s country-level asset allocation data act as a proxy for its operation’s water usage distribution. Currently, there is a distinct lack of public disclosure of the specific locations at which organizations withdraw water and the amount withdrawn at each. Large differences in total water usage costs between the first and the second models would signify a clear need for disclosure of more geographically granular water withdrawal data at a corporate level. Next, regarding a handful of countries within our cases for which we have neither the unit operational cost data nor the Waterfund data to extrapolate water costs with robustness, we utilize global water prices and the world’s average AWARE factor. The same goes for the *Rest of the World* category, which organizations often report as an aggregate of many different countries in which their assets are distributed, presumably in less material amounts. Third, in order to extrapolate water costs for countries that are not included in the Waterfund data, we apply multipliers across countries with comparable GDP per capita in adjacent geographic regions, by assuming that such similarity is correlated with ratios between water cost subcomponents and the total water cost. This means also that we assume correlation between the unit operational costs of supplying water and the Water Cost Indices from Waterfund. Although it makes an intuitive sense that IBNET’s unit operational costs of water and wastewater services are calculated in similar logistical terms as the Waterfund’s methodology, it is admittedly difficult to prove correlation with only five countries whose data match between the two. We thus note that the correlation among the ten data points that are available equate to 0.954, although the sample size renders it trivial.

## **Framework**

**Figure 1** below illustrates how the estimate from our first model might differ from the corporate water usage estimated by our third model, which uses more granular information related to water withdrawal locations and localized water prices.

To clarify our framework, consider the four quadrants in **Figure 1** and examples of an organization that might occupy each:

**Figure 1: Estimation Result of Model 1**



*Quadrant I: Higher than home-country AWARE factor, higher country-level water price*

An organization whose water withdrawal largely occurs across countries with higher AWARE factors than its domicile and higher localized water prices than the global price would certainly experience an increase in water usage cost estimation in the third model. For instance, countries with higher than average AWARE factors and higher than average country-level water prices include Spain, Portugal, and Australia. As such, for those firms that withdraw large volumes of water in these countries or similar ones, we can safely expect that the first model will *underestimate* the true cost of water usage.

*Quadrant II: Higher than domicile AWARE factor, lower country-level water price*

As the cases we introduce in this paper demonstrate, an organization's water withdrawal can take place in countries with higher AWARE factors than its home country, yet the water prices in those countries may be lower than their global counterpart. In this scenario, whether the first model underestimates or overestimates the true cost of water usage depends on the *relative magnitude* of the increase in AWARE factor compared to the decrease in water price. If, as in the case of the AES Corp, the weighted average AWARE factor of the countries from which an organization withdraws water is 1.7 times the AWARE factor of its domicile, yet the weighted average country-level water price is about half that of the global water price, then the first model will still *overestimate* the third model's calculation of the total water usage cost. On the other hand, as

demonstrated by the cases of Golden Agri-Resources Limited and Ball Corporation, the magnitude of the decrease in water prices also may not sufficiently offset that of the increase in the weighted-average AWARE factor, resulting in the first model's *underestimation*. Therefore, for all organizations that belong to both Quadrant II and Quadrant IV, which is the direct opposite scenario of Quadrant II, understanding the relative magnitude of the increase or decrease in AWARE factor and water prices is the key to determining whether the first model underestimates or overestimates the third model's more in-depth estimate.

*Quadrant III: Lower than home-country AWARE factor, lower country-level water price*

An organization that withdraws water primarily from countries whose AWARE factors are below its domicile's and whose water prices are lower than the global water price will definitely see a decrease in its total water usage cost, once the third model's granularity is taken into account. An example of an organization that belongs to this quadrant is one whose majority of water withdrawal takes place across such South Asian countries as Philippines and Malaysia, or in some South American countries like Brazil and Panama, for which both the AWARE factors and the water prices are lower than average. As we introduce in this paper, Alpek is one such case, as its operations are spread out across few countries in South America among others.

*Quadrant IV: Lower than domicile AWARE factor, higher country-level water price*

This quadrant is the antithesis of Quadrant II, as an organization's weighted-average AWARE factor becomes lower in the third model, while its weighted-average country-level water price increases. Therefore, the explanation for Quadrant II is also applicable in this scenario: depending on the relative magnitude of the decrease in AWARE factor as opposed to the increase in water prices, an organization's true cost of water usage can be either underestimated or overestimated by Model 1. An organization whose water withdrawal operations are distributed across countries such as Denmark, Norway, Singapore, or the United Kingdom is likely to be placed in this quadrant, as these countries are marked by their lower than average AWARE factors and higher than average water prices. In sum, depending on which country the organization is domiciled in and how much of its water withdrawal takes place elsewhere, the first model's result and the third model's estimate could differ in either direction.

We note that the framework we introduce above is a simplified version, as wastewater treatment cost is another variable that modifies the total cost of water, albeit it does not scale by AWARE factor and its effect, therefore, is less material to the total cost of water usage. In addition, incorporating the wastewater treatment cost yields a similar analysis and result overall.

## 4. Results

**Table 1: Comparison of Results (Three Different Models of Estimating Water Usage Costs)**

Company	First Model (\$)	Second Model (\$)	Third Model (\$)
Ball Corporation	10,576,262	13,779,449	13,684,298
The AES Corp	11,317,169,085	18,080,335,543	7,870,068,171
ALPEK	98,251,352	92,411,725	27,974,216
GOLDEN AGRI-RESOURCES LIMITED	20,076,732	116,193,896	33,422,754

Table 1 illustrates the total corporate water usage costs using three different models. The column *First Model* refers to our first model described in the methodology section, which makes use of global water costs and domicile country's AWARE factor. The column *Second Model* indicates our second model that employs global water costs and country-level AWARE factors according to a firm's asset distribution. The column *Third Model* highlights our third model, which involves using both the localized water costs and the country-level AWARE factors. Country-level water costs are either directly taken from Waterfund's data or extrapolated using the *multipliers* method as explained in the methodology section.

### 4.1 Case 1: Ball Corporation

Our first model, which utilizes global water costs and assumes that all of Ball Corporation's water withdrawal occurs in its domicile country of United States, estimates that the total cost of water use in 2017 for the firm is \$10,576,262. In our second model, allocating water usage across three different countries, namely the United States, Brazil, and the United Kingdom, as well as the Rest of the World category, the weighted-average AWARE factor becomes about 1.3 times higher at 12.08, resulting in total water usage cost that also increases to \$13,779,449. In our third model, by additionally localizing water cost components at a country-level, the weighted-average local water production and delivery cost of Ball Corporation in 2017 is about 9% lower than its global counterpart. Moreover, the weighted-average local wastewater treatment cost decreases minimally by 1% from the global wastewater treatment cost, resulting in total water usage cost of \$13,684,298. Consequently, in Ball Corporation's case, the change in total water usage cost by utilizing the most granular and localized model is an increase of about 30% from the first model that uses global water prices and domicile country assumption.

### Case 2: The AES Corp

The cases that we introduce hereafter exhibit more dramatic results than that of the Ball Corporation for different reasons. First, assuming the home country of United States and employing global water costs, the total cost of water use in 2017 for the AES Corp is \$11,317,169,085. Applying the asset-based country level distribution, the AES Corp's water usage is distributed across 10 countries in total, mostly in South and Central America, as well as the Rest of the World category. The weighted-average AWARE factor changes to 15.0, or about 1.7 times higher than the United States' AWARE factor of 9.1. The total water usage cost, therefore, increases similarly to \$18,080,335,543. Incorporating country-level water costs, we note that the weighted-average local water production and delivery cost for the AES Corp is only 55% of its global counterpart, while the weighted-average local wastewater treatment cost decreases to about 70% of the global average cost. The total water usage cost in this case, as a result, decreases to

\$7,870,068,171, or roughly 30% lower than the original estimation of water cost using global water costs and the assumption of all water usage taking place in domicile country. Here, we illustrate that although the percentage difference between the first model's water cost calculation methodology and the third model's country-level localization methodology is similar at around 30% for both the Ball Corporation and the AES Corp, the actual cost differences in US dollars differ conspicuously based on the company's net water consumption volume. Therefore, we observe that accurate reporting and reflection of true water usage information and costs can result in a material difference within a firm's total environmental impact, especially for organizations whose net water consumption occurs at a high level.

#### *4.3 Case 3: Alpek*

In Alpek's case, its domicile country is Mexico, whose AWARE factor is relatively high at 14.5. Using global water costs, the total cost of water use in 2017 for Alpek is \$98,251,351. Allocating water withdrawal according to its country-level asset distribution, Alpek's water consumption takes place across three different South American countries, Mexico, and the United States, in addition to the Rest of the World category. Consequently, the weighted-average AWARE factor of all countries from which Alpek withdraws water decreases slightly to 13.54, resulting in a marginally lower water consumption cost of \$92,411,725. Once the local water costs are incorporated, however, Alpek's water usage cost in 2017 changes dramatically. The weighted-average country level water production and delivery cost for Alpek in 2017 is about 68% lower than its global counterpart, and the country-level wastewater treatment cost also decreases about 12%. As a result, the total water usage cost becomes much smaller at \$27,974,216, or only about 28% of the estimated cost using our first model. Alpek's case, thus, clearly demonstrates that for certain countries whose water costs are noticeably lower or higher than the global average water costs, incorporating localized, country-level water costs can elicit notable changes in the total cost of corporate water usage.

Furthermore, we note that the domicile country assumption in water consumption from our first model can result in conspicuous differences in total water usage cost based on where the firm's water usage actually takes place. For instance, as we discuss in our next case, 1) when the majority of a firm's water consumption takes place in countries other than the domicile, and/or 2) if the domicile country's AWARE factor is noticeably different (either higher or lower) from the weighted-average AWARE factor of all countries where the firm's water consumption takes place, the domicile country assumption should raise reasonable concerns.

#### *4.4 Case 4: Golden Agri-Resources Limited (GAR)*

Golden Agri-Resources Limited, although headquartered in Singapore, has only 3% of its assets located in the country. Moreover, given Singapore's very low AWARE factor of 0.9, this case is a prime example of companies whose total water usage cost changes materially once the true water usage distribution data and local water costs are accurately reflected. The original total cost of water consumption for GAR in 2017 is estimated at \$20,076,732 using global water prices and the AWARE factor of its domicile country, Singapore. As soon as the water usage is more accurately assigned based on its country-level asset distribution, however, Golden Agri-Resources

Limited's weighted-average AWARE factor surges to 9.22. Specifically, based on its assets, we allocate 93% of GAR's water usage in 2017 to two South Asian countries, namely India and Indonesia, as well as 4% to the Rest of the World Category. As a result, GAR's total water usage cost in 2017 using our second model soars to \$116,193,896. Further incorporating country-level water costs then makes another noticeable difference. For both India and Indonesia, we apply Philippines' multipliers of water production and delivery cost and wastewater treatment cost. The weighted-average of localized water production and delivery cost for GAR, thus, plunges about 67% from its global cost, and the weighted-average of localized wastewater treatment cost dives even further, at 83%, from the global average. In sum, combining the dramatic rise in AWARE factors with the similarly notable decrease in water costs, the total water usage cost for GAR in 2017 is estimated at \$33,422,754, or about 66% higher than the cost derived using our first estimation model.

## **5 Conclusion**

As demonstrated by Freiberg et al (2020), the water usage cost of an organization can occupy a significant portion of its total environmental impact from operations. Our paper seeks to propound a methodology through which companies, investors, or regulators can utilize readily available and publicly disclosed resources to estimate a total cost of yearly water consumption by an organization. Our findings in this paper highlight the potential for improvement in this space. Within this paper, we discuss three different models through which a company's total water consumption cost in a year can be estimated. Each model after the first incorporates just one additional granularity in data and methodological approach, thereby underlining how much added value it can provide in estimation. Our sample, although not extensive, offer important implications that are widely applicable to other multinational organizations.

Overall, our four cases illustrated in this paper suggest that an enhancement in both the disclosure of geographic granularity in corporate water usage and the localization of water costs would be a worthwhile addition to multinational companies. This is especially true for the firms with vast yearly water consumption volumes and for those whose locations of water withdrawal are highly decentralized. The three cases of the AES Corp, Alpek, and Golden Agri-Resources Limited all demonstrate that firms with a higher level of decentralized water withdrawal operations are subject to greater risks of under- or overestimating the true costs of total water consumption, primarily due to a significant variability in both the AWARE factors and the water costs across countries.

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## Appendix

### Exhibit 1. Details of AWARE Model

The AWARE Model represents the outcome of a 2+ year consensus building process by the Water Use in Life Cycle Assessment (WULCA), a working group of the UNEP-SETAC Life Cycle Initiative. The model is based on water remaining per unit of surface in a given watershed relative to the world average, after human and aquatic ecosystem demands have been met and provides scaling factors to express water use at the river basin or country level in terms of world-eq. Water availability and human water consumption is based on the WaterGap2 Model and ecosystem demands are modeled by environmental water requirements.

### Exhibit 2. Waterfund Contact Information

The Water Cost Index, produced by Waterfund LLC, is an ever-changing set of rates updated regularly at [www.worldwaterfund.com](http://www.worldwaterfund.com). Please contact Evan Olsen (Phone: +1 (415) 834-5640; Email: [evan.olsen@worldwaterfund.com](mailto:evan.olsen@worldwaterfund.com)) for current Water Cost Index information.