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Quantifying Progress Made in Achieving Sustainable Development Goal 6 in Chile: A Holistic and Local Approach

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Abstract: The implementation of Sustainable Development Goal 6 (SDG 6) in Chile, a middle-income country, has only been partially measured, mainly due to the lack of the data required to quantify all indicators related to this goal. Quantifying the progress made in achieving SDG 6 is particularly relevant in countries such as Chile, which is currently facing major drought and water management issues. This research aims to quantify all indicators in SDG 6 based on a holistic and local approach. In doing so, a three-step process is proposed: a critical analysis of SDG 6 indicators using the specific, measurable, achievable, realistic, time-bound (SMART) indicators framework, a new definition proposal for indicators when necessary, and lastly, a composite index capable of reflecting the progress made toward achieving SDG 6. The results show that none of the targets in SDG 6 have been achieved in Chile. The main challenges the country faces are related to integrated water resource management, transboundary arrangements, and community participation in water management. Conversely, Chile's performance in water supply and sanitation services is closer to the target. This research contributes a group of specific indicators for Chile, which provide an inexpensive and pragmatic way to measure the progress made in achieving SDG 6.

Keywords: SDG 6; composite index; goal programming synthetic indicator; SMART indicators

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1. Introduction

The Sustainable Development Goals (SDG) were adopted in 2015 by the United Nations (UN) members as a way to end poverty, protect the planet and guarantee sustainable development by 2030 [1]. Each SDG comprises targets whose fulfillment is measured through indicators. SDG 6 is commonly known as the water and sanitation SDG, but also includes targets that aim to measure the social, environmental, and economic role of water. This SDG comprises eight targets which comprise 11 indicators altogether, as shown in Figure 1 and Table 1.

When considering the SDG 6 indicators individually, some of them (e.g., 6.1.1, 6.2.1) only capture the social dimension of water, while others allude only to the economic dimension (i.e., 6.4.1) and others focus only in the ecosystemic dimension of water (i.e., 6.6.1). On the contrary, some indicators capture more than one dimension of sustainability given the interactions between human activity and the environment (e.g., 6.3.1, 6.3.2). For this reason, SDG 6 needs to be measured comprehensively, so that the result of aggregating the individual indicators reflects all the dimensions of water. If not, the results can be misleading and ignore the fact that countries might face trade-offs between the achievement of socioeconomic and environmental goals [2].

Furthermore, when taking into consideration the trade-offs mentioned previously [2], sustainable development cannot be analyzed separately from the local context. It is fundamental to study national particularities when defining an action course and policies, since each human group inhabits a determined geospatial territory wherein unique social and economic relations take place [3].

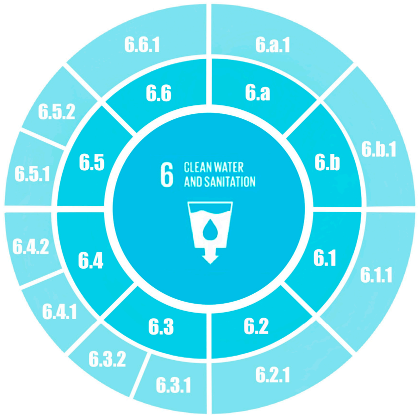

Figure 1. Targets and indicators of Sustainable Development Goal 6.

SDG 6 is especially important in a country such as Chile which faces severe water-related issues. The Consejo Nacional de Implementación de la Agenda 2030, henceforth Consejo, is responsible for the coordination of the implementation and monitoring of the 17 SDGs in Chile. However, it has only reported on 6 of the 11 indicators of SDG 6, since not all the information is available. In addition, the reported indicators have not been updated, and the values correspond to the period between 2015 and 2017.

Previous studies on the monitoring of the implementation of the 2030 Agenda in Chile focused on quantifying the progress made in achieving the 17 SDGs through composite indexes. The first study, conducted by the Centro de los Objetivos de Desarrollo Sostenible para América Latina y el Caribe in 2020 (CODS) [4], assessed the performance of 24 countries belonging to Latin America and the Caribbean. They used four indicators to measure three of the eight targets in SDG 6. Second, Sachs et al. [5] quantified progress among UN members. For SDG 6, the authors used seven indicators to measure four of the eight targets. A third study by Pereira and Marques [6] measured the progress made in achieving SDG 6 in low- and middle-income countries, among them, Chile, and used four indicators to quantify four of the eight targets. Despite the contributions of these studies, none of them contemplated all eight targets of SDG 6, and so this SDG was not holistically quantified. Therefore, the results are not enlightening regarding the implementation state of this goal. Moreover, they focused on assessing the aggregated results to compare countries in near periods. In addition, some of the studies use redundant indicators. Sachs et al. [5] and CODS [4] used two indicators to represent indicator 6.4.1, while Sachs et al. [5] used two indicators based on different standards to refer to indicators 6.1.1 and 6.2.1. Finally, Sachs et al. [5] used different indicators for measuring SDG 6 progress in different countries. For instance, in Brazil and Ecuador, the authors used five indicators, while in Chile, they used seven.

Figure 2a–c illustrate that none of the previous studies included all of the targets proposed by the UN. As a matter of fact, none of them quantified targets 6.5, 6.6, or 6.b. Target 6.a.1 was only measured by Pereira and Marques [6]. In addition, as said before, the Consejo has only reported six indicators that partially allow for the measurement of five targets, as shown in Figure 2d. Therefore, it is illustrated that none of the previous studies on this topic holistically and locally assessed the progress made in achieving SDG 6 in Chile or other countries, which could lead to countries not knowing their situation in deep terms, but rather only their rank compared to other countries. This approach is essential to systematically monitoring the progress made in the achievement of SDG 6 and adopting specific policies to implement the 2030 Agenda.

To overcome the limitations mentioned above, this research aims to holistically quantify the progress made toward achieving SDG 6 in Chile by providing a methodology that takes into account the local context and could be applied to other middle-income countries in order to report on the implementation of the 2030 Agenda.

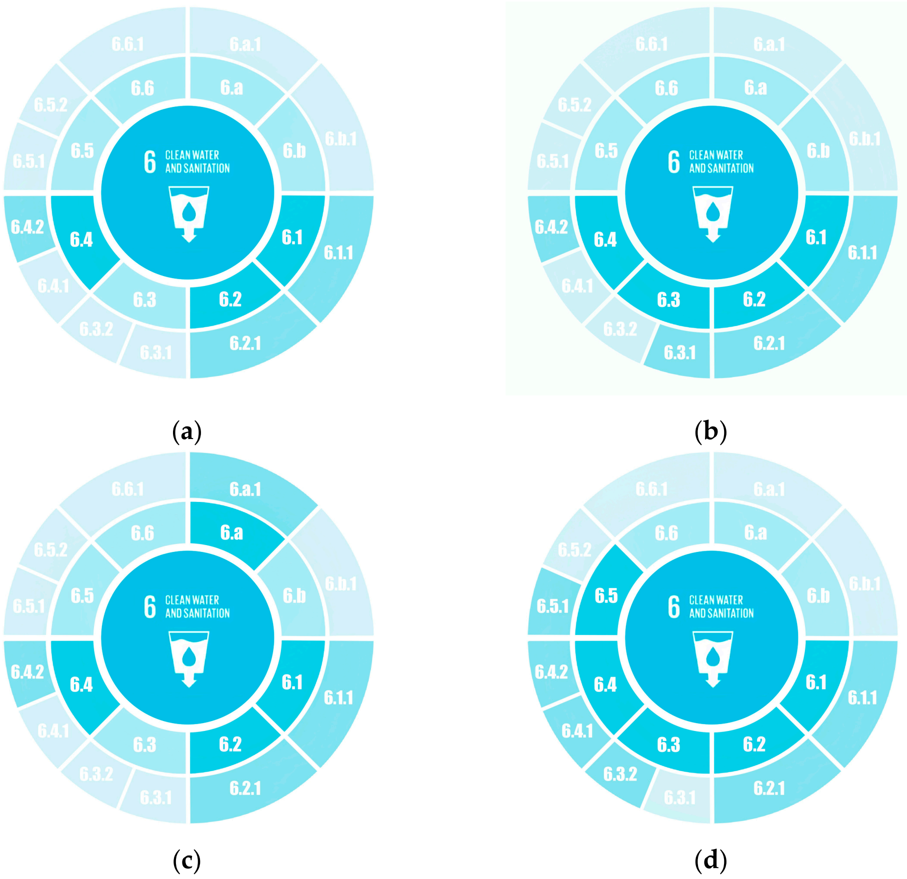

Figure 2. Targets and indicators measured in studies conducted by (and prepared on the basis of) (**a**) CODS in 2020 [4], (**b**) Sachs et al. in 2022 [5], (**c**) Pereira and Marques in 2021 [6] and (**d**) Consejo Nacional de Implementación de la Agenda 2030. For the outer circle, darker blue represents those indicators reported by the studies, while lighter blue represents those indicators that remained not reported. For the inner circle, darker blue represents those targets being partially measured (at least one of the two indicators is reported) or measured, while lighter blue represents those targets for which none of its indicators were reported.

Table 1. SDG 6 targets and indicators according to [1].

Target ID	Target	Indicator ID	Indicator
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1	Proportion of population using safely managed drinking water services
6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1	Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1	Proportion of domestic and industrial wastewater flows safely treated
		6.3.2	Proportion of bodies of water with good ambient water quality

Table 1. *Cont.*

Target ID	Target	Indicator ID	Indicator
6.4	By 2030, substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1	Change in water use efficiency over time
		6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1	Degree of integrated water resources management
		6.5.2	Proportion of transboundary basin area with an operational arrangement for water cooperation
6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1	Change in the extent of water-related ecosystems over time
6.a	By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan
6.b	Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management

2. Case Study

The Chilean territory is compounded by 101 river basins, all centrally managed by the Dirección General de Aguas (DGA), which is the main organization responsible for the management, preservation, and monitoring of water quality and resources. Currently, there is no local authority for basins or communities with authority to make decisions related to water resources. Regarding sanitation and drinking water services, the Superintendencia de Servicios Sanitarios (SISS) is responsible for ensuring access to sanitation and drinking water services and wastewater treatment plant compliance in concessioned urban areas. The Superintendencia del Medio Ambiente (SMA) is responsible for the control of liquid waste emissions into water bodies. The drinking water supply in rural areas in Chile is managed through rural drinking water committees, which are community organizations.

Chile is currently facing major issues related to water resources. A severe drought with annual rainfall deficits ranging from 25 to 45% has been reported since 2010 and has lasted over a decade. It has mostly affected central Chile, but it has extended farther south than previous events. Because of its longevity and large extent, it has been called a megadrought and is expected to become a recurring phenomenon in the future due to climate change [7,8].

In addition to the lack of available water, management problems have been reported. In fact, only 17% of the water crisis can be explained by climate change (rainfall deficit and temperature increase mainly). The remaining 83% of the reasons behind water issues in river basins are related to water management and governance, environmental degradation, increased demand, and water pollution. Governance issues are reflected in aspects such as a lack of coordination of institutions at the basin level, lack of transparency of the water market, lack of knowledge and insufficient control of illegal water abstraction, and others [9].

Water issues have translated into a lack of access to drinking water and sanitation services for over 1.4 million people in Chile [10]. They have been addressed with reactive measures such as water scarcity decrees and drinking water being supplied continuously by cistern trucks [11].

3. Materials and Methods

The methodology consisted of three interdependent phases, as shown in Figure 3. First, indicators proposed by the UN to appraise SDG targets were critically analyzed using the SMART framework. Secondly, indicators were quantified and new indicators were proposed and quantified when needed. Lastly, indicators were aggregated in a composite index.

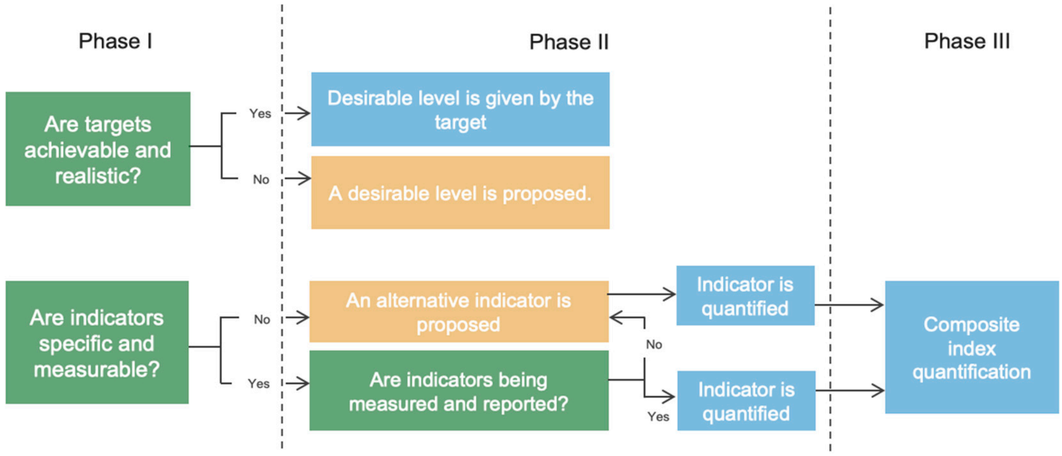

Figure 3. Methodological approach for holistically quantifying progress toward achieving SDG 6.

3.1. Step 1: Critical Analysis of SDG 6 Indicators

SMART indicators refer to those indicators designed to be specific, attainable or achievable, realistic or relevant, and time-bound or time-sensitive. The SMART framework has been extensively used as a tool to set goals. For instance, Shahin and Mahbob [12] used the SMART framework to set criteria for use in the analytic hierarchy process (AHP), Wood [13] used it to assess marine protection goals critically and Ishak et al. [14] used it to determine the relevance of different key performance indicators in an organizational context.

Despite there not being a consensus on the meaning of each letter in the SMART acronym, the definitions tend to be similar throughout the consulted literature [12–14]. Table 2 shows the definitions used in this research, which are based on Wood [13], because of the similarities between her research and the application in this study. The criteria defined below were used to assess each indicator in SDG 6 and verify that they comply with being SMART.

Table 2. Definition of SMART targets or indicators. Prepared on the basis of Wood [13].

	A Target Is . . .
S	specific when it is clear, easy to understand, and helps guide stakeholders' decisions to a limited amount of outcomes. In this research, an indicator and the associated target are deemed specific if they are presented in an unambiguous manner.
M	measurable if it is possible to quantify in order to assess the evolution of an indicator. In this research, an indicator is deemed measurable if it is clear on how it should be quantified
A	attainable when oriented to action and those responsible of implementing them have the required knowledge and skills to achieve the target. In this research, an indicator is deemed attainable if its target explicitly points an aspiration level to be achieved.
R	realistic when the change required to achieve the aspiration level is in itself attainable. A target must be ambitious enough to mobilize efforts but not so high that it might cause frustration.
T	time-sensitive when a deadline is established.

3.2. Step 2: Proposal and Quantification of Indicators

In this phase, there were two paths. If the pair indicator target proposed by the UN met the criteria to be deemed as SMART and data were available, then the indicator was quantified. If not, an alternative indicator was proposed and quantified using a proxy variable when needed. Moreover, a specific aspiration level was proposed for Chile for all indicators for which there is not a clear target (i.e., is not attainable), as suggested by Germann and Langergraber [15] and according to the three 2030 Agenda principles, using the underlying principles of the proposed indicator or a benchmark approach if necessary.

The three principles guiding the 2030 Agenda are (i) universality, (ii) leaving no one behind, and (iii) integration. Universality means that targets are relevant for all governments and actors, without implying uniformity, but instead implying differentiation in responsibilities. Leaving no one behind means that no target is fulfilled until everyone achieves it. Finally, integration stands for an equilibrium between economic growth, environmental protection, and social development [16].

3.3. Step 3: Selection and Quantification of a Composite Index

Composite indexes are mathematical combinations of a set of indicators that do not share a common unit of measurement, and there is no obvious way of weighting their value when aggregating [17]. Composite indexes' main advantage is their ability to summarize complex phenomena in a single dimensionless value. Additionally, they are easy to interpret when compared to a set of indicators, and thus make it simpler to analyze data [18]. On the contrary, their main disadvantage is that they miscommunicate information if not properly interpreted or built. Additionally, the construction of a composite index requires subjective judgments, hence transparency in the process is of the utmost importance. Lastly, composite index construction must be completed using widely available and frequently updated data [19].

Composite indexes must demonstrate the following properties: existence and determinacy, completeness, monotonicity, uniqueness, invariance, homogeneity, and transitivity [20]. In addition, depending on the aggregation method, an index may be compensatory or non-compensatory. If it is compensatory, the aggregation method allows for an offset between indicators [21]. If it is non-compensatory, the indicators do not neutralize each other. This approach is convenient when the existence of high values could hide low values and vice versa [22]. In this research, the non-compensatory property is needed, since the 2030 Agenda is based on the integration principle, which stands for an equilibrium between the sustainable development pillars. Therefore, if there are two competing values in the selected system, the progress of one is not masked by the decline in the other. For that reason, the weight designated for each indicator is equal.

There are five steps in building a composite index: (1) defining the phenomenon to be measured, (2) the selection of the set of indicators, (3) the normalization of indicators, (4) the aggregation of indicators, and (5) validation [18]. The phenomenon to be measured here is the progress made in the implementation of SDG 6 in Chile, and the indicators are those defined in phase 1. Normalization and aggregation depend on the chosen index, which in this research is the Goal Programming Synthetic Indicator (GPSI) developed by Blancas et al. [23].

The GPSI is suitable according to the main objective of this research, based on the non-compensatory nature of the vectorial GPSI which is denoted as $GPSI^V$. This methodological approach allows for us to express both the weaknesses and strengths presented by the evaluated unit without them being offset by each other. Moreover, the building process of the GPSI requires the determination of an aspiration level for each indicator encompassed in the index, which allows for the aspiration levels determined in phase 2 to be used, in contrast to other composite indexes, which require comparison with other units (e.g., countries) to assess unit performance.

The GPSI is constructed by a set of individual indicators I_j, where subindex $j \in J$ represents the set of indicators used to assess the unit or phenomenon. In this case, set J

represents the 11 indicators comprising SDG 6. Individual indicators can be positive (I_j^+) or negative (I_j^-), where the former means that an increase in the value of indicators signifies an improvement in the analyzed unit, and the latter means that a higher value of indicators shows the deterioration of the unit. The process requires an aspiration level $\overline{I_J^+}$ and $\overline{I_J^-}$ to be achieved by positive and negative indicators, respectively. Then, deviation variables n or p are calculated according to the following equations.

If the indicator I_j is positive, then

$$I_j^+ + n_j^+ - p_j^+ = \overline{I_J^+} \text{ with } n_j^+, p_j^+ \geq 0,\ n_j^+ \cdot p_j^+ = 0 \tag{1}$$

where p_j^+ is the desirable deviation variable, since it signifies that the value achieved by indicator I_j surpasses the aspiration level, and n_j^+ is the undesirable deviation variable.

If the indicator I_j is negative, then

$$I_j^- + n_j^- - p_j^- = \overline{I_J^-} \text{ with } n_j^-, p_j^- \geq 0,\ n_j^- \cdot p_j^- = 0 \tag{2}$$

where n_j^- is the desirable deviation variable, since it signifies that the value achieved by indicator I_j is below the aspiration level.

Then, a weight w_j is assigned to each deviation variable and aggregated as indicated in the following equations. Note that the normalization step is included in the equation using a technique denominated distance to the target, as the normalized value could be interpreted as a fraction of the target value [24]. $GPSI^+$ and $GPSI^-$ are the vector components of $GPSI^V$.

$$GPSI^+ = \sum_{j \in J} \frac{w_j p_j^+}{\overline{I_J^+}} + \frac{w_j n_j^-}{\overline{I_J^-}} \tag{3}$$

$$GPSI^- = \sum_{j \in J} \frac{w_j n_j^+}{\overline{I_J^+}} + \frac{w_j p_j^-}{\overline{I_J^-}} \tag{4}$$

$$GPSI^V = \left(GPSI^+,\ GPSI^-\right) \tag{5}$$

Despite the advantages of the GPSI, its non-compensatory character does not always provide an order to the evaluated units. The unit U_i only presents a "better" performance than U_k if one of the following relations can be established. The same is valid comparing the same unit throughout time.

$$U_i \succ U_k \Leftrightarrow \begin{cases} GPSI_i^+ > GPSI_k^+ \ and\ GPSI_i^- < GPSI_k^- \\ GPSI_i^+ > GPSI_k^+ \ and\ GPSI_i^- = GPSI_k^- \\ GPSI_i^+ = GPSI_k^- \ and\ GPSI_i^- < GPSI_k^- \end{cases} \tag{6}$$

When comparability is needed, the net GPSI, denoted as $GPSI^N$, can be used.

$$GPSI^N = GPSI^+ - GPSI^- \tag{7}$$

In this case, the following relationship is enough for the unit U_i to be "better" than U_k.

$$U_i \succ U_k \Leftrightarrow GPSI_i^N > GPSI_k^N \tag{8}$$

4. Results

4.1. Critical Analysis of SDG 6 Indicators Based on SMART Framework

Table 3 shows the results of the critical analysis of SDG 6 indicators, which is the outcome of Phase 1. Note that when an indicator includes the concepts "safely managed", "safely treated" or "good", it is not considered to be specific (S), since the meaning of those concepts is not clear, and further explanation is required. The precise definition of indicators 6.1.1, 6.2.1, 6.3.1, and 6.5.1 is provided in the UN documentation methodology for each one [25–29]. The measurable character (M) was only met by the indicators tht establish a clear way of being quantified, such as "proportion of" or "change in". In the case of indicator 6.4.1, despite including the concept "change in", this indicator is not considered measurable because the water-efficiency concept is unclear. The attainable (A) characteristic was only met by those indicators presenting a situation or level to be achieved. For instance, target 6.1 urges the achievement of "universal access", which allows for the assumption that the drinking water supply should cover all of the population; hence, indicator 6.1.1 must be equal to 100%. Regarding the realistic (R) character, an indicator is considered realistic if it is attainable because in order to assess the realism of an indicator, it is necessary to know which level must be achieved. It is worth noting that all indicators deemed attainable were also realistic. Finally, regarding the time-sensitive (T) character, 90% of the indicators are to be fulfilled by 2030, except for indicator 6.6.1 whose associated target (6.6) indicates 2020 as the deadline year. Target 6.b does not indicate a deadline, so indicator 6.b.1 is not considered time-sensitive.

Table 3. Indicators meeting SMART criteria.

Indicator ID	UN Definition	S	M	A	R	T
6.1.1	Proportion of population using safely managed drinking water services.		✓	✓	✓	✓
6.2.1	Proportion of population using (a) safely managed sanitation services and (b) a handwashing facility with soap and water		✓			✓
6.3.1	Proportion of domestic and industrial wastewater flow safely treated		✓	✓	✓	✓
6.3.2	Proportion of bodies of water with good ambient water quality.		✓			✓
6.4.1	Change in water use efficiency over time					✓
6.4.2	Freshwater withdrawal in percentage of available freshwater resources.	✓	✓			✓
6.5.1	Degree of integrated water resources management (0–100)			✓	✓	✓
6.5.2	Proportion of transboundary area with an operational agreement for water cooperation.	✓	✓			✓
6.6.1	Change in extent of water-related ecosystems over time	✓	✓			✓
6.a.1	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	✓	✓			✓
6.b.1	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management.	✓	✓			

4.2. Proposed Indicators to Evaluate SDG 6

The proposed indicators used to monitor the progress of the SDG 6 are shown in Table 4. Indicators 6.1.1 and 6.2.1 changed to reflect the variables that can be measured with the information available and show that they are not exactly the same as the methodology proposed for each one [25–27]. For instance, for indicator 6.1.1, it was not possible to determine the absence of primary chemical contamination, and for indicator 6.2.1, it was not possible to determine access to handwashing with soap. Instead, the available data only show access to handwashing facilities within one's dwelling. Similarly, indicators 6.3.1.a and 6.3.1.b were measured using databases that are the result of both auditing processes by the corresponding Chilean authority (SISS or SMA) and sample records reported by wastewater treatment plants for concessioned areas for industries for indicator 6.3.1.a and indicator 6.3.1.b, respectively. This information, despite not being perfect, is the most similar to what is needed according to the methodology proposed for indicator 6.3.1 [28]. The aspiration level for indicators 6.1.1, 6.3.1.a and 6.3.1.b was proposed based on the wording of the associated targets, i.e., 6.1 and 6.3, while for indicator 6.2.1, it was determined by the "leaving no one behind" principle (see Appendix A for further explanation).

Table 4. Definition used for each indicator, latest value, and aspiration level for 2026 and 2030.

Indicator ID	Used Definition	Latest Value	Aspiration Value for 2026	Aspiration Value for 2030
6.1.1	Proportion of population using drinking water services supplied through public network or cistern truck.	92.6 ± 0.1%	100%	100%
6.2.1	Proportion of population whose house has a toilet connected to the sewerage system or a pit latrine and a handwashing facility located within the dwelling	89.0 ± 0.1%	76.0%	100%
6.3.1.a	Proportion of domestic wastewater produced in concessioned areas treated in compliance with Chilean quality standards	89.7 ± 8.9%	92.3%	94.9 ± 8.9%
6.3.1.b	Proportion of industrial wastewater discharged in water bodies in compliance with Chilean quality standards	96.3 ± 0.4%	97.2%	98.1 ± 0.4%
6.3.2	Proportion of hydrographic basins in compliance with Chilean quality standards	76%	100%	100%
6.4.1	Weighted average of the aggregate value of water per cubic meter withdrawn.	5.0 USD/m^3	5.9 USD/m^3	6.9 USD/m^3
6.4.2 *	Proportion of the municipalities surface area with a water scarcity decree in force during the period studied.	27.1% (72.9%)	13.6% (86.5%)	0% (100%)
6.5.1	Degree of integrated water resources management (0–100).	32	86	100
6.5.2	Proportion of transboundary area with an operational agreement for water cooperation.	0%	58%	100%
6.6.1	Proportion of surface area of water bodies protected by a Chilean legal figure.	54.4 ± 0.1%	57%	59.1 ± 0.1%
6.b.1	Proportion of municipalities that have a water office or similar.	6.1%	53%	100%

* Indicator adapted to have a non-zero aspiration value, so Equation (4) can be determined. The new definition is the proportion of the municipalities surface area without a water scarcity decree in force during the period studied. The values for the modified indicators are shown in parenthesis.

Indicator 6.3.2 is the result of a study conducted by the Centro de Desarrollo Urbano Sustentable (CEDEUS) and DGA [30], following the guidelines proposed for this indicator [31]. Although the authors followed the methodology proposed by the UN, its definition was modified to show that the unit of measurement is a basin and not a body of water, and that "good ambient quality" means compliance with Chilean quality standards. As the value of this indicator is legally bound to Chilean regulations, its aspiration value was 100%.

Indicator 6.4.1 was quantified using the UN-Water database [32] and local information [33]. The UN-Water database was used to retrieve water efficiency by economic sector, while local information [33] was used to obtain the proportion of water used by sector. Despite the final value of indicator 6.4.1 being available in the UN-Water database, it was not possible to know what proportion of water was used to compute the indicator. Therefore, we decided to use local information. The definition of this indicator was modified so that its wording would explain how it was computed according to UN guidelines [34]. The aspiration level for indicator 6.4.1 was determined by a benchmarking exercise using the UN-Water database.

In order to measure indicator 6.4.2, information about the water balance in the country is needed. This information is only available for five river basins in Chile [35]. Then, a proxy variable and definition were proposed: the proportion of surface area with a water scarcity decree in force during the study period. Since a scarcity decree can be issued for a territory as small as a commune, this was the unit of measure chosen to determine the surface. The reason for choosing this variable is its relation to the original definition, which is the ratio between the total freshwater withdrawn by all major sectors and the total renewable freshwater resources after considering the environmental flow requirements [36]. The aspiration level is 0% because of the practical meaning of a scarcity decree.

The definitions of indicators 6.5.1 and 6.5.2 are the same as those proposed by UN, because it is possible to measure them with information available for Chile according to the methodology proposed by the corresponding UN division [29,37]. Their aspiration values were determined to be a score of 100 and a proportion of 100%, respectively, based on the indicators themselves and the "leaving no one behind" principle of the 2030 Agenda.

Indicator 6.6.1 was redefined in order to make it simpler to assess and quantify. One of the main issues in its original definition is that there is no direction or magnitude of percentage change in the extent of the ecosystem surface that could be universally "good" or "bad"; hence, each aquatic ecosystem should be individually assessed [38]. For that reason, a new definition capturing ecosystem protection and conservancy authorities' intentions was proposed. The new definition is based on Chilean legal schemes that aim to protect and guarantee actions for ecosystem conservancy. Legal schemes include laws for protection and conservancy and quality standards designed to preserve and protect nature. In Chile, the latter are called secondary environmental quality standards (NSCA by its Spanish acronym). The aspiration level proposed is based on the diagnosis of water bodies in need of protection.

Indicator 6.a.1 was not quantified because Chile is no longer eligible for Official Development Assistance (ODA), as of 2018. Chile was removed from the list of ODA recipients because the country exceeded the high-income threshold for three consecutive years [39]. Finally, indicator 6.b.1 was not possible to measure according to UN guidelines [38], because Chilean local authorities do not participate in decision-making processes related to water issues, and all related decisions are to be made by the DGA. However, in an attempt to capture the first steps toward community participation, a proxy variable was proposed: the proportion of municipalities that have a water affairs office or similar. Despite these offices not having a formal and operational mechanism to assure community participation, they constitute the first attempt at coordinating public and private stakeholders related to water management and use. The aspiration value for indicator 6.b.1's new definition is 100% based on the "leaving no one behind" principle.

Aspiration values for 2026 were also proposed and are shown in Table 5. The criteria used to define the aspiration levels for 2026 depend on the availability of data for comparison and the applicability of this value to the Chilean context. For indicators 6.1.1, 6.2.1, 6.3.2, and 6.5.1, the 90th percentile of the values in the countries included in the UN-Water database in 2020 was proposed as the aspiration value for 2026, since the definition proposed for these indicators is similar to the original. For indicator 6.5.2, despite keeping the original definition, the 90th percentile is equal to the aspiration value for 2030, and then the mean value for 2020 was proposed as the aspiration value for 2026. For indicators 6.4.1, 6.4.2, 6.6.1, and 6.b.1, because the definition proposed here is different from the original, the proposed aspiration value for 2026 is the midpoint between the latest value and the aspiration level in 2030, i.e., the average of those two values. In the case of indicators 6.3.1.a and 6.3.1.b, the 90th percentile is higher than the 2030 aspiration level; hence, the mean was used again.

Figure 4 shows the level achieved by the indicators as a proportion of the aspiration level. Indicator 6.4.2 was inverted so that aspiration level was 100% and not 0%. Note that indicators from 6.1.1 to 6.3.2 and 6.6.1 are beyond a 75% level of achievement.

Table 5. Corresponding period for latest value, criteria used to determine aspiration values and data sourced used to determine latest value. All data sources are public, available online or upon request to Chilean institutions.

Indicator ID	Corresponding Period for Latest Value	Criteria Used to Determine 2030 Aspiration Value	Data Source	Criteria Used to Determine 2026 Aspiration Value
6.1.1	2020	Target	[40]	90th percentile (2020)
6.2.1	2020	Leaving no one behind	[40]	90th percentile (2020)
6.3.1.a	2021	Target	[41,42]	Average
6.3.1.b	2021	Target	[43]	Average
6.3.2	2018	Legally bound	[30]	90th percentile (2020)
6.4.1	2019	Benchmark	[32,33]	Average
6.4.2	2021	Nature of the indicator	[44,45]	Average
6.5.1	2020	Nature of the indicator	[46]	90th percentile (2020)
6.5.2	2017	Leaving no one behind	[47]	Average (2020)
6.6.1	2022	Nature of the indicator	[48]	Average
6.b.1	2022	Leaving no one behind	[49]	Average

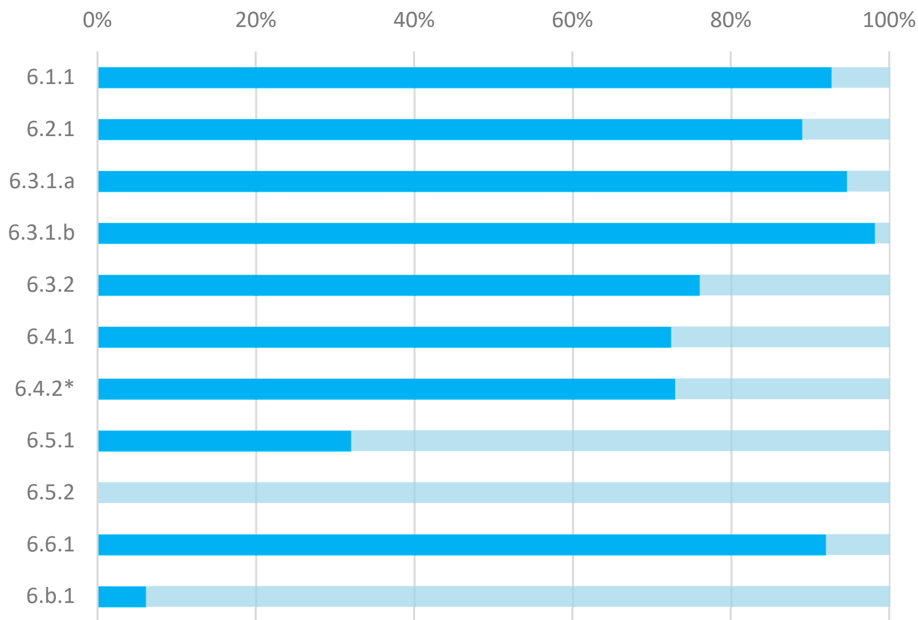

Figure 4. Level achieved in Chile by indicator as a proportion of the aspiration level for 2030. * Indicator adapted to have a non-zero aspiration value, so Equation (4) can be determined. The new definition is the proportion of the municipalities surface area without a water scarcity decree in force during the period studied.

4.3. Holistic Assessment of the SDG 6 through a Composite Index

The composite index used to assess the achievement of the SDG 6 targets from a holistic perspective was computed for different scenarios. First, it was computed considering the estimated values of each indicator and their upper and lower limits of the confidence interval, compared to the aspiration values determined for 2030 and 2026. The results are shown in Table 6. Secondly, for comparative purposes, the GPSI was computed using the sets of individual indicators proposed by Sachs et al. [5] and CODS [4] to quantify progress toward achieving SDG 6. The results are shown in Table 7, and the sets of indicators proposed by Sachs et al. [5] and CODS [4] are shown in Tables A1 and A2, respectively, in Appendix B.

Table 6. GPSI for 2030 and 2026 aspiration values.

	$(GPSI^{+}; GPSI^{-})$	$GPSI^{N}$
$GPSI^{V}_{2030,upper}$	(0.0020; 0.3673)	−0.3653
$GPSI^{V}_{2030}$	(0.0000; 0.3708)	−0.3708
$GPSI_{2030,lower}$	(0.0000: 0.3760)	−0.3760
$GPSI^{V}_{2026,upper}$	(0.0212; 0.3181)	−0.2969
$GPSI^{V}_{2026}$	(0.0176; 0.3201)	−0.3025
$GPSI^{V}_{2026,lower}$	(0.0174; 0.3253)	−0.3078

Table 7. GPSI for the three different sets of indicators compare to their corresponding aspiration or optimal values. $GPSI^{V}_{2030}$ is computed using indicators proposed in this research, $GPSI^{V}_{Sachs}$ is computed using indicators by Sachs et al. [5], and $GPSI^{V}_{CODS}$ is computed using indicators by CODS [4].

	$(GPSI^{+}; GPSI^{-})$	$GPSI^{N}$
$GPSI^{V}_{2030}$	(0.0000; 0.3708)	−0.3708
$GPSI^{V}_{Sachs}$	(0.0000; 1.6663)	−1.6663
$GPSI^{V}_{CODS}$	(0.0000; 140.5943)	−140.5943

It is worth recalling that the weight assigned to each indicator was $w_j = \frac{1}{10}$ for all indicators except for indicators 6.3.1.a and 6.3.1.b, for which the assigned weight is equal to $\frac{1}{20}$.

The six quantified scenarios show negative values for the $GPSI^{N}$, which indicates that Chile has more weaknesses than strengths in the achievement of the SDG 6 targets. Notwithstanding this, for the three scenarios related to 2026, it is observed that Chile presents some strengths, i.e., it achieved the targets established for that year for one or more indicators. However, in the cases of $GPSI^{V}_{2030}$ and $GPSI^{V}_{2030,lower}$, it is possible to observe that Chile does not present strengths, only weaknesses, in relation to the goals to be achieved by 2030. This implies that, under these two scenarios, Chile is not achieving any of the SDG 6 targets. Furthermore, when comparing the current situation with 2030, only strengths are shown in $GPSI^{V}_{2030,upper}$. This strength comes from the upper limit of the confidence interval of indicator 6.3.1.a, with a value of 98.6%, which is higher for the 2030 aspiration value. This highlights the relevance of estimating the SDG 6 indicators as precisely as possible, since considering the errors results in a composite indicator that goes from having no strengths to having them.

Strengths shown in $GPSI^{V}_{2026}$ come from indicator 6.2.1, for which the target value is 75.63% and whose current value is 88.95%. For $GPSI^{V}_{2026,upper}$, the strengths come from indicators 6.2.1 and 6.3.1, with a value of 89.09% and 98.63%, respectively, which are both higher than the aspiration value determined for 2026. The strengths in $GPSI^{V}_{2026,lower}$ come from indicator 6.2.1, with a value of 88.81%. That is to say, even when using the lower limit of the confidence interval for this indicator, its value surpasses what is desirable for the year 2026.

In order to compare the results of this research with those obtained by Sachs et al. [5] and CODS [4], the same methodology used for the calculation of the composite index was applied, but based on the individual indicators reported by each study (see Tables A1 and A2). It is worth mentioning that, in both cases, the values of the indicators reported by the authors were the latest available in the databases consulted at the time the studies were conducted. The optimal values were defined on the basis of three criteria by the authors of both studies: the average of the five best performers at the global level, the principle of leaving no one behind and the technical optimum. Note that the values of some indicators are not consistent with those reported in this study. This can be seen, for example, in the indicator "population with access to basic drinking water services", for which Sachs et al. [5] reported a value of 100%. This same limitation is observed for the data reported by CODS [4], in which the mentioned indicator had an associated value of 99.0%. The weight assigned in each case is $w_j = \frac{1}{|J|}$, i.e., $\frac{1}{7}$ y $\frac{1}{4}$, respectively. The results are shown in Table 7.

In Table 7, it is possible to observe that the resulting GPSIs markedly differ from each other, despite referring to the same assessed unit: the progress made in achieving SDG 6 in Chile in close time periods. Notwithstanding the difference between the three GPSIs, they all indicate that Chile only has weaknesses in relation to SDG 6 progress. The $GPSI^V_{Sachs}$ and $GPSI^V_{CODS}$ illustrate a worse situation than that evidenced by the $GPSI^V_{2030}$. This could be explained by the indicators associated with water scarcity in both CODS [4] and Sachs et al. [5], given the difference in magnitudes between the most current value and the optimal value determined by the authors of each study, resulting in a normalized indicator that was one to two orders of magnitude higher than the rest of the indicators. Secondly, the differences between the three GPSIs are due to the fact that, in this research, the rest of the SDG 6 indicators were incorporated and, in some of them, Chile shows a similar performance to the proposed target.

This shows that the methodology significantly influences the monitoring of SDG 6 progress. As mentioned above, the indices calculated for both studies, $GPSI^V_{Sachs}$ and $GPSI^V_{CODS}$, reflect a pessimistic situation with respect to $GPSI^V_{2030}$, despite the fact that, in the common indicators included in the three indices (e.g., 6.1.1 and 6.2.1), the first two show much closer values to the optimum than the indicator calculated here.

5. Discussion

The studies previously conducted to measure the progress of countries in achieving the 2030 Agenda do not consider all indicators and targets of SDG 6. Furthermore, the results reported for each indicator are different from each other, even though, in some cases, they are for the same period of time. This evidences a lack of rigor in the definition of the indicators and the databases used to calculate them. Additionally, in some cases, the values reported by the studies do not coincide with the value reported by the countries themselves. For example, in the case of Sachs et al. [5], the authors report a value of 100% for Chile for the indicator "population with access to basic drinking water services", which is not consistent with locally reported statistics [10].

Therefore, in this research, a set of indicators is proposed to measure all SDG 6 targets using local databases and proxy indicators if necessary. The results obtained for both the individual indicators of SDG 6 and the composite index show that Chile has not achieved the targets proposed in this research, which are realistic targets, when adapted to the national scenario. However, Chile presents indicators with both high values (6.1.1 to 6.3.2 and 6.6.1 above 75% of progress) and low values (6.5.1, 6.5.2 and 6.b.1) compared to the target for each indicator, meaning that some aspects of SDG 6 need more attention than others. The results show that the largest gaps between the level achieved and the proposed target are presented in the indicators associated with stakeholder coordination and integrated water resources management (IWRM). These indicators are 6.5.1, 6.5.2 and 6.b.1.

Indicator 6.5.1 measures the state of implementation of IWRM in the countries, understanding that the tools it provides are part of the solution to manage the growing water demand of the different requirements of human activity. Therefore, the fact that Chile has one of the largest gaps in this indicator is evidence of insufficient management in relation to the use of its water resources. Indicator 6.b.1, referring to community participation in decision making and water resource management, is the second worst-performing indicator, which reflects the lack of representation of communities and regional and local governments in decision making. To make progress in the achievement of indicators 6.5.1 and 6.b.1, it is recommended to accelerate the formalization of the basin councils, organizations framed in the strategy, such as Transición Hídrica Justa, which are configured as the base organizations for water governance at the basin level and which are expected to be promoted together with regional and local governments [50]. Improving water governance in Chile has been identified as a central element for a water transition, needed in the context of climate change.

Indicator 6.5.2 is related to transboundary water agreements between Chile and neighboring countries, with this being the indicator with the worst performance among the 11 estimated indicators. In practice, this is reflected, for example, in the case of the Silala River, a body of water shared with Bolivia, which has been a source of conflict between the two countries to date. It is necessary to take action regarding Chile's foreign relations on water issues. In the first place, Chile needs to take an inventory of the water resources shared with other countries, whether surface or groundwater, so as to act on those that pose a potential conflict.

On the other hand, the indicators that show a better performance are those associated with access to drinking water, the treatment of domestic wastewater (in urban concessioned areas) and industrial wastewater, and the protection of aquatic ecosystems. These indicators are 6.1.1, 6.3.1.a, 6.3.1.b, and 6.6.1. This shows that efforts made by the country have focused on the social and ecosystemic role of water, and not on its integrated and participatory management. Even with this, Chile must continue to make efforts in this area, as it has yet to reach the goals set for 2030.

The database used to quantify indicators 6.1.1 and 6.2.1 is not ideal in terms of the sample design of the survey, since it is designed to be representative of the income poverty rate and not of the drinking water supply or sanitation services. Similarly, indicator 6.3.1.a was only calculated for urban concessioned areas, since the SISS is only in charge of managing water treatment services in these areas. This is not the case for rural areas, for which there is no reliable information regarding the treatment and management of rural domestic wastewater. This shows how important it is that the definition of the indicator is transparent.

Indicators 6.3.1.a and 6.3.1.b could be overestimated, as the source of the data is the report that each audited unit (emitting industry or water treatment plants, as appropriate) submits to the SISS or the SMA. For the reliability of this indicator to be increased, the source data would need to be the result of periodic audits by competent Chilean institutions.

In the case of indicator 6.6.1, this research offers a practical and economical alternative for monitoring its progress compared to the methodology proposed by the UN, which requires site-specific analysis of each ecosystem to obtain a diagnosis. Meanwhile, the methodology proposed here only requires updating vector layers that are already available, as and when water bodies are added or subtracted from the country's protection systems. For this same reason, although this indicator is useful for obtaining a general diagnosis, it does not imply that a given water body presents the optimal health conditions of the aquatic ecosystem it supports, especially those protected by an NSCA. However, it does imply that efforts have been made for the protection and conservation of the ecosystems included in the protection schemes, and that, in the long term, it is expected that these efforts will result in ecosystemic conditions closer to the optimum.

For indicator 6.b.1, previously not quantified by the Consejo, a new methodology is proposed. This captures the first steps in the inclusion of local authorities in water resource management decisions at the country level. Although none of the municipalities formally establish mechanisms through which the participation of the communities is possible, municipal authorities are seeking involvement in these decisions and aim to coordinate with the competent bodies in this area. Hence, this approach is considered to be in line with the UN definitions for this indicator, since municipalities are the official authorities closest to the problems that afflict communities and are important in the delivery of water through water trucks, in the promotion of rural drinking water committees, and in sanitation initiatives in non-concessioned areas.

Chile needs to improve its systems for collecting the information needed to quantify progress made in achieving SDG 6, especially in those indicators that fail to capture the rural population, which continues to be a blind spot in the area of domestic water treatment, and in those indicators that result from self-reported units. Finally, regardless of the technique used to summarize SDG 6 in a composite index, it is important that it is at least non-compensatory, so that it highlights trade-offs and does not hide them.

6. Conclusions

SDG 6 encompasses different aspects of the role of water in sustainable development: the social, economic and ecosystemic. The quantification of the progress made in achieving this SDG is particularly important in countries facing water challenges, such as Chile, which faces a long-lasting drought and water scarcity throughout its territory, which could translate into trade-offs between the different dimensions of the role of water. Thus, the quantification of the progress of SDG 6 provides a diagnosis of the water challenges within the sustainability framework proposed by the 2030 Agenda.

The studies developed to date do not consider all the SDG 6 targets, so they do not holistically report progress on this goal. In addition, the indicators commonly used to monitor this goal are not SMART and are not transparently defined. This makes it difficult to interpret the results while also making some of the dimensions of water invisible, which could lead to incorrect conclusions about the progress of SDG 6 in the evaluated countries. A SMART approach may help authorities to identify urgent issues when criteria and targets are clearly defined and measured. Nevertheless, the indicators by themselves will not solve the country's water problems and major changes in water governance are required.

In the particular case of Chile, the Consejo has not recently updated the value of the indicators according to UN guidelines. Therefore, this research proposes a set of practical and inexpensive indicators, for which there are updated data with a maximum frequency of 3 years that preserve the original meaning of the targets and indicators of SDG 6. It also proposes a composite index capable of reflecting the strengths and weaknesses of Chile in relation to SDG 6. Specifically, this research contributes a practical and novel proposal for the quantification of indicators 6.3.1, 6.6.1 and 6.b.1, which were not previously reported by the Consejo. Likewise, indicator 6.5.2, whose value had not been reported before, is quantified according to the methodology proposed by the UN.

The need for a pragmatic methodology that does not require the collection of additional data arises from the fact that there are only eight years left to implement the 2030 Agenda and that, to date, Chile does not have an official comprehensive diagnosis of the progress made in achieving SDG 6. However, the methodologies used for the quantification of individual indicators, although practical, can still be improved, especially for those indicators that require geographic and demographic disaggregation to be reported correctly.

These results reflect that the country is still on its way to achieving the SDG targets and that its greatest weakness is integrated water resource management at both the national and community management levels, and in the international relations that Chile maintains with neighboring countries with which it shares watersheds. The country is in an advanced stage of meeting the goals of providing drinking water and sanitation services in urban areas to which most of its population belong.

Therefore, the most urgent actions to be taken are for the country to establish international agreements with neighboring countries to coordinate the management of shared water resources and for all actions taken to be configured within IWRM. Additionally, it is necessary for Chile to make efforts in the disaggregated reporting of its indicators so that it is possible to detect inequalities in the progress of the indicators and develop a more specific approach to the problem posed by a particular indicator.

Finally, it is necessary for the institution in charge of monitoring and reporting progress made in achieving the 2030 Agenda, in this case the Consejo, to keep the calculation of the indicators up to date and explore alternative indicators in the event that it is not possible to measure them according to UN definitions. As mentioned above, this would contribute to the diagnosis of the challenges faced by the country in relation to all SDGs. Other technical institutions already implemented in Chile, such as the Statistics National Institute or the Sustainability and Climate Change Agency, could develop specific methodologies for defining specific, critical indicators to implement the 2030 Agenda in Chile.

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Appendix A. Definition of the Aspiration Levels

The aspiration level for indicator 6.1.1 is proposed on the basis of the wording of the target 6.1, which mentions that "universal access" is to be achieved. Hence, the aspiration level is 100%. Similarly, aspiration levels for indicators 6.3.1.a and 6.3.1.b are based on the wording of target 6.3, which says that water quality is to be improved by "halving the proportion of untreated wastewater", in which case the "halving" period is from now to 2030.

The aspiration level for indicator 6.4.1 was determined by a benchmark exercise using UN-Water databases in order to determine the change possible in an 8-year time period (from now to 2030). Then, based on the percentage increase possible, an aspiration value was computed as an increase from the current value in terms of USD/m^3.

Regarding indicator 6.4.2, since scarcity decrees in Chile allow communities to use water beyond the environmental flow requirements, it is possible to say that if there is one in force, then the value of indicator 6.4.2, in its original definition, would be higher than 100%. For this reason, 0% would be the aspiration value for the proposed definition of indicator 6.4.2, meaning that in none of the communities, the original 6.4.2 would be higher than 100%.

Regarding indicator 6.6.1, despite it being based on the legal protection figures of Chile, it does not bind each water body to a protection figure. Instead, it responds to a diagnosis in which the water body was considered sufficiently important or in need of protection (for conservancy or other purposes). For that reason, the aspiration level proposed for this indicator is a dynamic value which changes every period, and it takes into consideration those water bodies or basins that have been already diagnosed to need (or to be suitable for) certain protection by law, and that have not yet been approved by lawmakers in Chile.

Appendix B

Table A1. Indicators used by Sachs et al. [5].

j	Indicator	Polarity	Latest Value	Optimum Value
1	Population using at least basic drinking water services	Positive	100%	100%
2	Population using at least basic sanitation services	Positive	100%	100%
3	Freshwater withdrawal (% of available water resources)	Negative	21.6%	12.5%
4	Anthropogenic wastewater that receives treatment	Positive	71.9%	100%
5	Scarce water consumption embodied in imports	Negative	1142.9 m^3 H_2O eq/capita	100 m^3 H_2O eq/capita
6	Population using at least safely managed water services	Positive	98.8%	100%
7	Population using safely managed sanitation services	Positive	78.6%	100%

Table A2. Indicators used by CODS [4].

j	Indicator	Polarity	Latest Value	Optimum Value
1	Population using basic drinking water services	Positive	99.0%	100%
2	Population using basic sanitation services	Positive	99.0%	100%
3	Freshwater withdrawals as a percentage of total available water resources	Negative	5.5%	0.01%
4	Groundwater depletion in importing	Negative	2.01 m^3/year/capita	0.14 m^3/year/capita

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