SUMMARY WATER FOOTPRINT REPORT

Our Corporate Footprint

CELSIA's total water footprint in 2012 is 204 million m^3/year, of which 99% is associated with the water footprint at EPSA's hydroelectric power plants. Meanwhile, the water footprint for 2013 is 202.2 million m^3/year, with the EPSA accounting for the same percentage share.

Our Corporate Water Footprint	
Blue and Gray Footprint	**Thermal: ZFC, Meriléctrica Hydroelectric power plant: EPSA reservoir Hydroelectric power plant: SHPPs - EPSA and Celsia**
Of CELSIA's total water footprint, 99.8% is blue, corresponding to evaporation from reservoirs and in thermal processes. The remaining 0.2% of Celsia's water footprint is gray, associated with the volume of water required to dilute contaminants.	The business that contributes most the most to Celsia's water footprint is EPSA, through its Hidroprado and Calima power plants, which account for 62% and 32%, respectively.

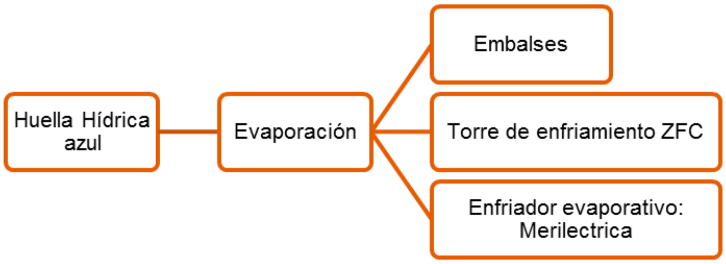
4.1. THE WATER FOOTPRINT CONCEPT

Blue Water Footprint

The blue water footprint is an indicator of consumptive water use, which can apply to any of the following cases:

- Evaporated water
- Water incorporated into a product
- Water that is not returned to the same basin, but to, for example, a different basin or the sea.
- Water that is not returned in the same period; for instance, water removed during a period of scarcity and returned during a rainy period.

In this study, to account for the Blue Water Footprint, an attempt is made to quantify consumptive water use through the records kept across the power plants.



The Blue Water Footprint was accounted for through a combination of direct measurement and water balance for processes at thermal power plants; and daily reservoir evaporation in the case of hydroelectric power plants.

Zona Franca Celsia

For the Celsia thermal power plant, there is a water balance and designated containers for stages of the water cooling process. Though there are not containers present at all points, mass balances are employed to determine the volume of evaporated water.

$WF_{direct, blue}$= Intake – Discharge.
$WF_{direct, blue}$= Blue Water Footprint for the process over the year. (m^3/year)
Intake = Water harnessed by the power plant over the year (m^3/year).
D = Water discharged by the Company over the year (m^3/year).

Meriléctrica

The water balance for determining the volume of water evaporated is calculated by taking the power plant's total water intake, minus the total water discharge. The difference corresponds to water lost through evaporation.

EPSA

For EPSA's reservoirs, daily evaporation is calculated by applying the Penman-Monteith method, as it takes a combined, complete approach involving transfer of the mass and energy balance, as well as factoring in heat storage.

Gray Water Footprint

The water volume required to dilute the contaminants in process discharges that could affect the quality of water in a receiving body.

The gray water footprint is calculated by dividing the contaminated load (L in mass/time) by the difference between the quality standard for the contaminant (maximum acceptable concentration, c_{max}, in mass/volume) and the natural concentration of the contaminant in the receiving water body that would exist without human intervention (c_{nat}, in mass/volume)

This latter method was employed for the calculations included in this study.

SUMMARY OF RESULTS

The direct water footprint at each power plant corresponds to their respective operations, divided by the blue and gray footprints. This is calculated based on data from the records at each of Celsia's power plants in Colombia; that is, from primary information.

The quantification of the water footprint at the following power plants is set out below:

- Zona Franca Celsia
- Merilectrica.
- EPSA.
- Rio Piedras.
- Hidromontañitas

A summary of Celsia's direct blue and gray water footprint in 2012 and 2013 is set out in Table 1 and Table 2.

Table 1. Summary of direct blue and gray water footprint for Celsia - 2012.

Instalación	HH Azul (m^3/año)	HH Gris (m^3/año)	HH Total (m^3/año)	HH Total (%)
Zona Franca	2.254.264	8.223.327	10.477.591	4,9%
Merilectrica	3.690	73	3.763	0,002%
EPSA	201.400.000	340.147	201.740.147	95,1%
Rio Piedras	-		-	0,0%
Hidromontañitas	-		-	0,0%
Total	**203.657.954**	**8.563.547**	**212.221.501**	**100,0%**
	96,0%	**4,0%**	**100,0%**	

Table 2. Summary of direct blue and gray water footprint for Celsia - 2013.

Instalación	HH Azul (m^3/año)	HH Gris (m^3/año)	HH Total (m^3/año)	HH Total (%)
Zona Franca	3.060.301	20.749.711	23.810.012	10,5%
Merilectrica	2.901	3,6	2.905	0,001%
EPSA	201.400.000	827.529	202.227.529	89,5%
Rio Piedras	-		-	0,0%
Hidromontañitas	-		-	0,0%
Total	**204.463.202**	**21.577.244**	**226.040.446**	**100,0%**
	90,5%	**9,5%**	**100,0%**	

The different is negligible from one year to the next, as EPSA's percentage share of the water footprint accounts for 99% of the total due to evaporation of water from the reservoirs.

Moreover, the specific water footprint for generation capacity and actual generation in 2012 and 2013 is of interest for comparison with other power plants, and can be seen in Table 3 and Table 4.

Table 3. Specific Water Footprint for Celsia - 2012.

Instalación	Capacidad Instalada (MW)	Generación (MWh)	HH Específica Capacidad (m^3/MW)	HH Específica Generación (L/MWh)	HH Azul Específica Generación (L/MWh)	HH Específica Generación (m^3/GJ)
Zona Franca	610	1.544.054	17.176	6.786	1.460	1,88
Merilectrica	167	118.054	23	32	31	0,01
EPSA	969,9	3.190.439	208.001	63.233	63.126	17,56
Rio Piedras						
Hidromontañitas						
Total	**1.747**	**4.852.547**	**225.200**	**70.050**	**64.617**	**19,46**

Table 4. Specific Water Footprint for Celsia - 2013.

Instalación	Capacidad Instalada (MW)	Generación (MWh)	HH Específica Capacidad (m^3/MW)	HH Específica Generación (L/MWh)	HH Azul Específica Generación (L/MWh)	HH Específica Generación (m^3/GJ)
Zona Franca	610	2.475.070	39.033	9.620	1.236	2,67
Merilectrica	167	118.054	17	25	25	0,01
EPSA	969,9	3.190.439	208.503	63.385	63.126	17,61
Rio Piedras						
Hidromontañitas						
Total	**1.747**	**5.783.563**	**247.554**	**73.030**	**64.387**	**20,29**

Analysis for thermal power plants

Making a comparison with other studies conducted, Delgado[1], with respect to the water footprint for thermal generation, finds that 85% to 95% of water is required for cooling; some of the power plants cited by Delgado in his thesis are set out in Table 5. These power plants are operated by the South African company, Eskon. South Africa is a country subject to water shortages, and as such the company has always been committed to efficient usage. Eskom is a pioneer of hybrid and dry cooling. Eskom's power plants are coal-fired; six of these employ wet cooling towers, two indirect drying, and one hybrid. The data enables a comparison of water use values across the different thermal power plants, and also includes the number of concentration cycles (**ncc**) and the Heat Rate for each one.

Table 5. Water use in thermal coal generation for Eskom power plants, South Africa.

Power plant	Type of cooling system	Heat Rate (KJ/KWh)	Water consumption (L/MWh)
Arnot	Wet cooling tower (ncc=20)	11,030	2,074
Duvha	Wet cooling tower (ncc=20)	10,686	2,005
Hendrina	Wet cooling tower (ncc=20)	11,747	2,327
Matla	Wet cooling tower (ncc=14)	10,265	1,994
Lethabo	Wet cooling tower (ncc=39)	10,308	1,819
Tutuka	Wet cooling tower (ncc=39)	10,230	1,915
Matimba	Indirect drying	10,670	106
Kendal	Indirect drying	11,002	136

On comparing the specific blue water footprint results for generation at ZFC, set out in Table 4, it can be seen that this is less than the thermal power plants cited by Delgado in his thesis: ZFC's blue water footprint is 1,236 L/MWh, versus Lethabo, at 1,819 L/MWh.

Merilectrica has a footprint of just 14 L/MWh, because it is a simple cycle power plant.

In the case of EPSA, a comparison is made with the Water Footprint Network's (WFN) Report 51[2], in which the average of the specific blue water footprints is 68 m^3/GJ. According to this, Hidroprado and Calima exceed these values, standing at 184 and 110 m^3/GJ, respectively. However, the maximum is attained at Akosombo-Kpong, with 846 m^3/GJ. EPSA stands at 11.04 m^3/GJ, which is a low value.

[1] Delgado, A. *Water Footprint of electric power generation: modeling its use and analyzing options for water-scarce future.* United States, Massachusetts. 2012, page 24.

[2] Mekonnen & Hoekstra. The water footprint of electricity from hydropower. WFN. Report 51

4.1.1.1. Summary - Direct Water footprint for EPSA, 2012 - 2013

Table 6 and Table 7 provide a summary of EPSA's direct water footprint in 2012 and 2013, respectively.

Table 6. Direct Water Footprint - EPSA, 2012

Power Plant	Blue Water Footprint (m^3/year)	Gray Water Footprint (m^3/year)	Total Water Footprint (m^3/year)
Alto Anchicayá	4,000,000	49,785	4,049,785
Alto Tulua	0	93,860	93,860
Amaime	0	18,613	18,613
Bajo Anchicayá	500,000	36,393	536,393
Calima	64,400,000	8,265	64,408,265
Hidroprado	125,400,000	27,499	125,427,499
Nima	0	11,364	11,364
Río Cali	0	3,706	3,706
Riofrío I	0	72,301	72,301
Ríofrio II	0	10,641	10,641
Rumor	0	3,501	3,501
Salvajina	7,100,000	4,220	7,104,220
Total	**201,400,000**	**340,147**	**201,740,147**

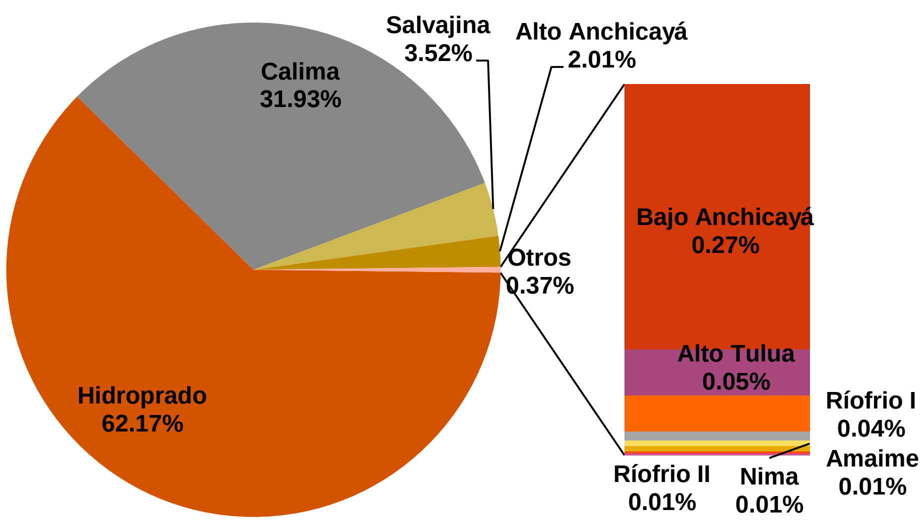


Figure 1. Direct Water Footprint - EPSA, 2012

Table 7. Direct Water Footprint - EPSA, 2013

Power Plant	Blue Water Footprint (m^3/year)	Gray Water Footprint (m^3/year)	Total Water Footprint (m^3/year)
Alto Anchicayá	4,000,000	116,499	4,116,499
Alto Tulua	0	93,860	93,860

Amaime	0	97,959	97,959
Bajo Anchicayá	500,000	25,891	525,891
Calima	64,400,000	37,052	64,437,052
Hidroprado	125,400,000	21,964	125,421,964
Nima	0	185,963	185,963
Río Cali	0	123,955	123,955
Riofrío I	0	72,301	72,301
Ríofrio II	0	10,641	10,641
Rumor	0	3,501	3,501
Salvajina	7,100,000	37,942	7,137,942
Total	**201,400,000**	**827,529**	**202,227,529**

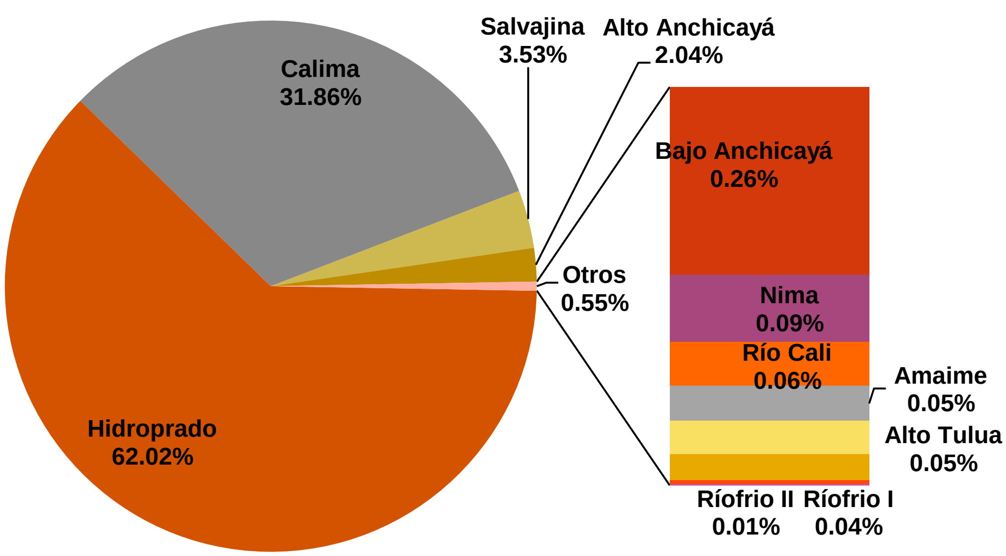


Figure 2. Direct Water Footprint - EPSA, 2013

In the case of EPSA, a comparison is made with the Water Footprint Network's (WFN) Report 51[3], which posts values between 0.3 m^3/GJ and 846 m^3/GJ. EPSA stands at 279.6 m^3/GJ and 330.6 m^3/GJ for 2012 and 2013, respectively, which are intermediate values.

[3] Mekonnen & Hoekstra. The water footprint of electricity from hydropower. WFN. Report 51

1. WATER RISK ESTIMATIONS AT THE BASINS OF INFLUENCE OF EPSA

the basins with sufficient hydro-climatic information resulting from a total of six basins (Amaime, Alto Anchicayá, Bajo Anchicayá, Calima, Río Cali I, and Río Cali II), were selected; a hydrological model was implemented to these basins that allowed a reconstruction of the flows at the exit so as to calculate the environmental flow, additionally allowing for a simulation of different scenarios for assessing the sensitivity of the territories to changes in land use.

We define the water risk as the susceptibility of the basin's water regulation to vary due to changes in land use. Because there is only one known form of land use per basin, the Open Hydrological Simulation model (Simulación HIdrológica Abierta - SHIA) has been adjusted to each of the basins and subsequently the variation in the basin's water response is analyzed as the percentage of forest cover varies, given that this land cover type plays an important role in the regulation processes in both high and low flows.

The following methodology seeks to estimate the environmental flows and the water risk posed by changes in land use in the basins of interest. To achieve this objective, a procedure based on hydrological modeling has been proposed to allow representation of the water processes in the basin; thereafter, a simulation of scenarios was run to enable assessment of changes in the flow associated with changes in land use. The following methods are outlined below:

- Map digitalization: Secondary information was employed to draft land use maps for each of the basins.

- Hydrological Modeling: The SHIA model was calibrated at each of the basins in order to represent the water processes under current land use conditions.

- Environmental flow estimation: The hydrological model was employed to reconstruct the basin outflows, and the environmental flow was estimated at 25% of the lowest multi-annual average monthly flow.

- Simulation of scenarios and water risk estimation: Hydrological simulations were run based on land-use change scenarios in order to assess the effects on the flow; the water risk was estimated using a flow sensitivity analysis given these scenarios.

- Stochastic flow duration curves were constructed based on the multiple land-cover change scenarios. The susceptibility of water regulation for each flow was obtained by analyzing the differences in the exceedance flows of 3%, 50%, and 90% of the duration curves. Thresholds of change were established for each exceedance flow level (3%, 50%, and 90%) to determine whether the risk is low, medium, or high.

A detailed account of the different steps taken as part of the methodology is provided below, while the most important results are given.

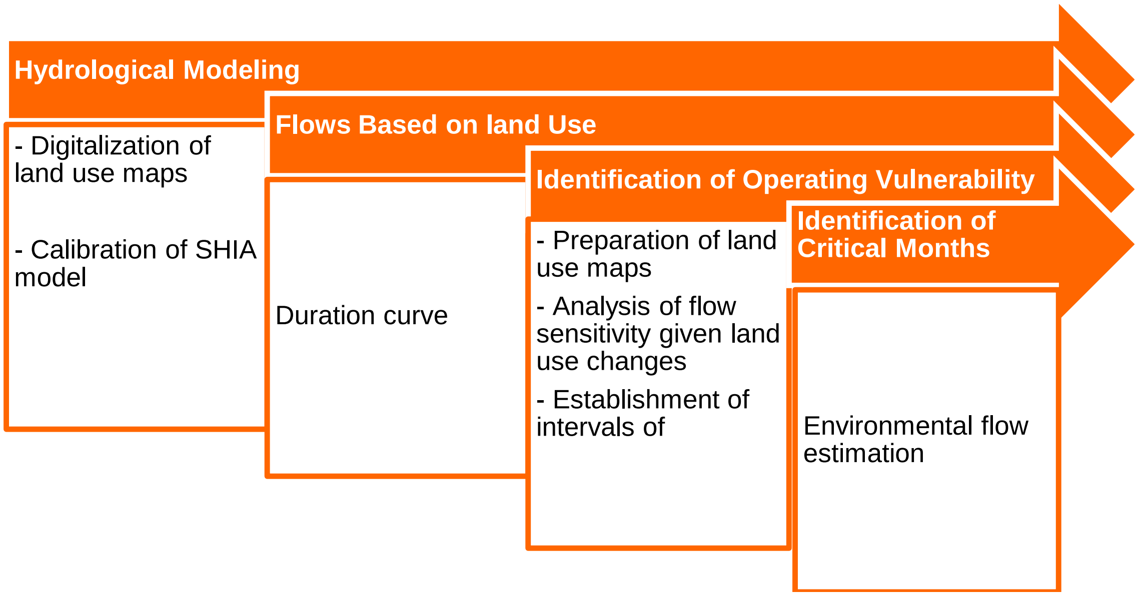


Figure 3. susceptibility analysis methodology

According to the Figure 3 system, using the calibration of the previously determined model, the annual flow cycle at the outflow of each of the basins was reconstructed. Based on this information, the environmental flow was estimated at 25% of the minimum monthly multi-annual flow (IDEAM, 2000). In the different cases analyzed, the estimated environmental flow is lower than the minimum flow, minus the deviation in the corresponding month. This is because of the low deviation values corresponding to dry months and the weighting applied due to the 25%. <u>The environmental flow was calculated in order to identify the lowest admissible flows at each of the main slopes analyzed</u>. However, these are not subject to land use change, and are more closely related to water use inside the basin.

7.1. SUMMARY OF RESULTS

The Table 8 provides an overview of the water risk estimation results for the basins studied. For the basins analyzed, the greatest risk is concentrated at high sensitivities associated with the exceedance flows of 50% and 90%, as the former is statistically close to the medium draft and is thus the flow with the greatest likelihood of occurrence, while the latter represents the minimum flows, which are fundamental during periods of low rainfall.

Table 8. Water risk categories in the basins studied

Basin	Risk category		
	High flows - 3% exceedance	**Medium flows - 50% exceedance**	**Low flows - 90% exceedance**
Amaime	Low	Medium	Medium
Alto Anchicayá	Medium	Medium	Low

Bajo Anchicayá	Medium	Medium	Medium
Calima	Medium	Low	Low
Río Cali 1	Medium	High	Medium
Río Cali 2	Medium	High	High

The areas of greatest sensitivity are the basins of the Cali 1 Cali 2 rivers, which are those with the lowest drainage areas and the lowest flows.

Overall, it is seen that the maximum flows (3% exceedance) are less susceptible; however, it should be kept in mind that flows of this kind are associated with torrential floods and sudden increases, whose consequences can be human and economic losses.

The Figure 4 shows the water risk variation with the drainage area for the three flow regimes analyzed. Also shown are the high risk classification thresholds for the flow regimes in question.

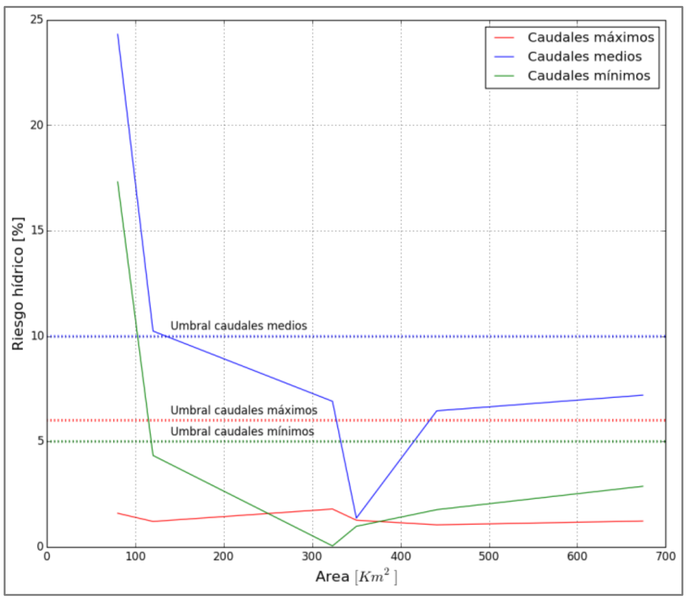


Figure 4. Water Risk Variation with Drainage Area.

Based on Figure 4, it can be seen that, as stated above, the flows do not present high risks associated with the maximum flows, as this flow regime does not exceed its corresponding threshold in any case. On the other hand, the medium and minimum flows exceed the high risk threshold when the basins are less than 120 Km^2, while in the case of larger basins, there are no high risks for these two flow regimes.

These results suggest, then, that the water risk associated with changes in land use is strongly related to the basin area, so that the sensitivity of the basin reduces as the drainage area is increased.

It should be clarified that the results have been obtained through use of a composite hydrological model, as the lack of information has hindered implementation of a distributed model. However, it can be appreciated that natural forest coverage in all cases is more conducive to basin regulation , such that increases thereof suggest minimum flows with values greater than those obtained through the original scenario. Conversely, when forests are replaced with pasture (in this case there are no urban areas), the basin loses its regulatory capacity and thus results in lower minimum flows.

It should be understood that the replacement of forests with pasture is commonplace in these areas, in which natural forests are felled or burnt to give way to crop or cattle farming. With this in mind, it is important that EPSA, in conjunction with the environmental authority, proposes methods to control and mitigate such changes in land cover.

2. CONCLUSIONS

The water footprint for hydroelectric energy generation is much bigger than that for thermal power generation, and is associated with evaporation from the reservoir water mirrors, which is an external variable that cannot be controlled.

The water footprint in thermal power generation is primarily associated with water evaporation from cooling towers and evaporative coolers (blue footprint), because the gray footprint for these facilities is very low or null on account of an external situation; namely, the water quality in the catchment basin. If this factor were to be changed the gray footprint would increase, so this is identified as a critical point of action in any case.

For the specific case of Celsia's operations in the Valle del Cauca, the resource management strategies are oriented toward water source protection. EPSA has a specific agreement with UNICAUCA for the reforestation of strategic conservation and water source areas, backed up by a strategic reforestation plan in order to ascertain the challenges related to water and drainage in the communities.

An analysis has been conducted of the water risk associated with six basins of interest to EPSA as part of the study. Because the analysis of the Salvajina and Prado basins remains outstanding and there is no available information, these have both been excluded, but will be factored in once at least one rainfall station and one flow station are assigned to each.