# Priority Areas Evaluation for Green Hydrogen Production Implementation in Bahia

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**This study aims to assess different priority scenarios for developing Green Hydrogen (GH2) projects in Bahia, considering different input conditions in a mathematical model. This analysis supports the decision-making process regarding implementing GH2 production units, especially those utilizing the water electrolysis technique and electricity from renewable sources. Using the Analytic Hierarchy Process (AHP) method, eight hypothetical scenarios were modeled, considering the use of on-grid and off-grid renewable energy, production intended to meet local or external demands, and water availability for the electrolysis process. Due to the abundance of water resources and renewable energy sources, the Bacia do Rio Grande region emerged as the most suitable for the implementation of GH2 projects in the majority of the analyzed scenarios. However, the Metropolitano de Salvador region is the top option when factors such as development, infrastructure, and GH2 demand (internal and external) are more significant.**

**Keywords: Green Hydrogen. Scenarios. Priority Areas.**

## Introduction

The energy transition involves decarbonizing the energy matrix by replacing fossil fuel sources with clean energy alternatives. Brazil takes center stage in this discourse, given that its national energy matrix is predominantly composed of renewable sources, holding immense potential for mitigating Greenhouse Gas (GHG) emissions. Due to its unique geographic characteristics, the State of Bahia presents excellent potential for generating a clean and renewable energy source, such as green hydrogen (GH2).

Bahia is the fifth-largest Brazilian state in land area, with the longest coastline in the country (extension of 1,183 km) [1]. The geographical, environmental, historical, social, cultural, and economic diversity throughout the Bahian territory brings challenges, advantages, disadvantages, restrictions, and opportunities [2] for developing the GH2 production chain in the different state regions.

Then, evaluating the potential location for constructing renewable hydrogen production plants is essential. AHP is a multi-criteria decision-making method applied to determine the weights of criteria and priorities of alternatives in a structured and hierarchical manner based on comparing pairs [3] and can be used for this purpose.

This work aims to evaluate different scenarios for priority areas for the development of the GH2 projects in Bahia using a mathematical model to help in the decision-making process. In this study, we assumed that GH2 is produced from water electrolysis using electricity generated by renewable sources.

## Materials and Methods

The present study used the Analytic Hierarchy Process (AHP) method to design the mathematical model. To build the AHP Model, 28 indicators (sub-criteria) were defined at different hierarchical levels and grouped into four criteria: social and economic development, availability of infrastructure, environmental aspects, and availability of resources. Most of the data used in the calculation of the indicators and, consequently, in the construction of

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the AHP Model, are in the public domain, accessed from government repositories, or provided directly by the Environment Secretariat - SEMA (data related to the state's Protected Areas), Infrastructure Secretariat - SEINFRA (data related to the state's Electric System, Transmission and Distribution Lines) and the Economic Development Secretariat of Bahia - SDE (socioeconomic data of the state [2].

The AHP model was weighted based on the degree of influence exerted by the criteria and sub-criteria among themselves, based on the comparative analysis of the relevance of these indicators in the GH2 production chain. The method adopted to carry out the dynamics with the experts was Quantity, Quality, and Systematic Management (QQS), from which paired comparisons were conducted at the same hierarchical level. This methodology is detailed in GH2 Bahia Atlas [2].

Eight different hypothetical scenarios were proposed from the combination of three specific conditions, as described below:

**Condition 1.** Off-Grid or On-Grid Renewable Energy

Off-grid: GH2 production plant operates directly linked to a renewable energy generation system.

On-grid:GH2 production plant is connected to the national electricity grid (National Interconnected System - SIN). It uses renewable energy certificates to ensure that the hydrogen produced is classified as green.

**Condition 2.** Consumption of Local or External GH2

Local: GH2 consumption is local, occurring in the surroundings of the production unit.

External: GH2 consumption requires long-range transportation and depends on the existing transportation logistics infrastructure.

**Condition 3.** Water Resources Availability

Relevant: water availability can be a limiting resource for GH2 production in specific regions and, therefore, has significant relevance in the analysis.

Irrelevant: water is an abundant resource in the state and does not represent a limiting factor for GH2 production, making it of little relevance to the analysis.

Table 1 shows the combination of three specific conditions. These hypothetical scenarios allow specific analysis within a broad spectrum of possibilities for developing the green hydrogen economy in Bahia State.

Based on these scenarios, values were calculated for the 27 Territories of Identity of Bahia State, posteriorly ranked according to their suitability for GH2 production.

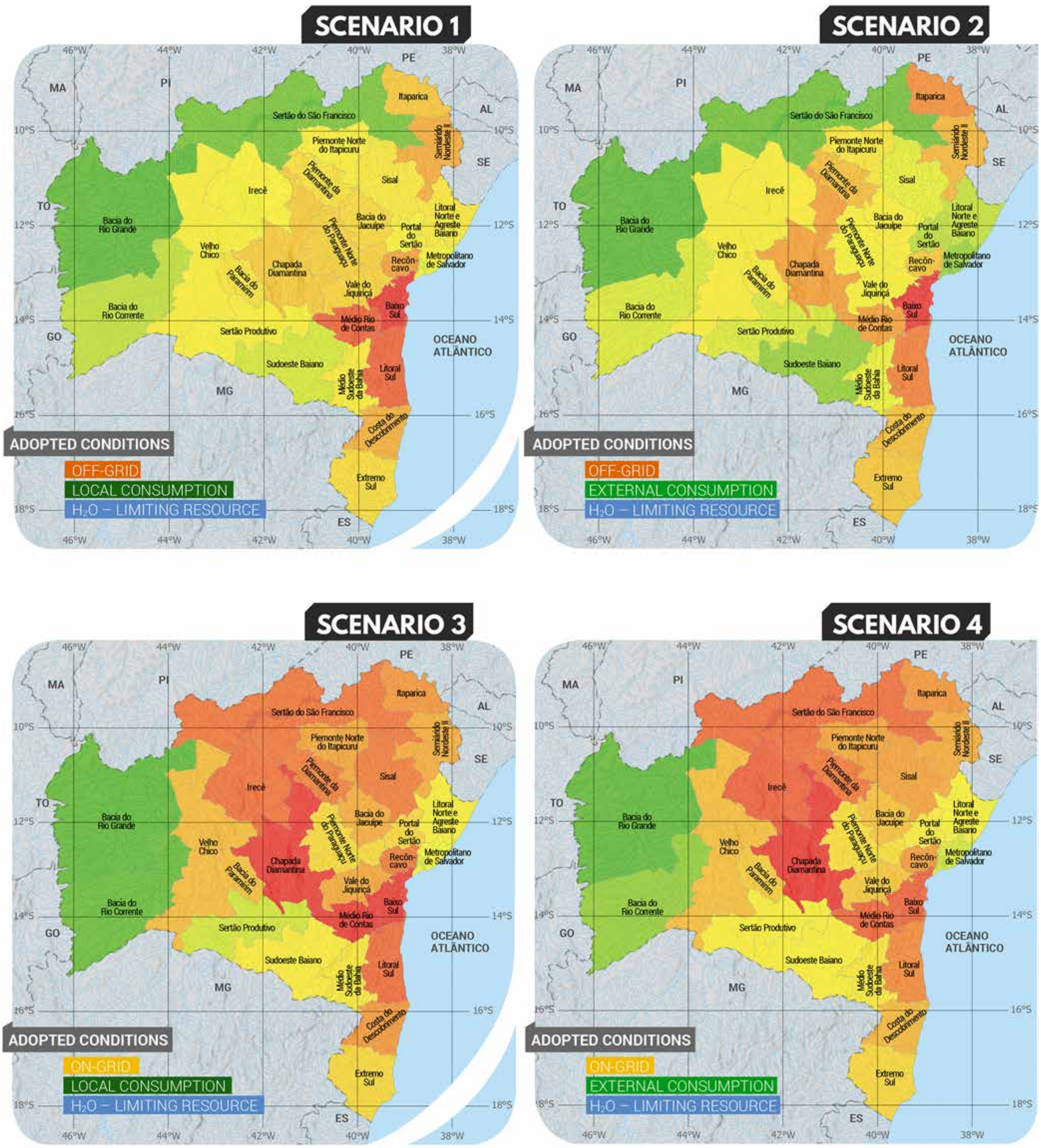
**Table 1.** Hypothetical scenarios.

| Scenario | Condition 1 | Condition 2 | Condition 3 |
|---|---|---|---|
| 1 | Off-grid | Local Consumption | $H_2O$ - Limiting Resource |
| 2 | Off-grid | External Consumption | $H_2O$ - Limiting Resource |
| 3 | On-grid | Local Consumption | $H_2O$ - Limiting Resource |
| 4 | On-grid | External Consumption | $H_2O$ - Limiting Resource |
| 5 | Off-grid | Local Consumption | $H_2O$ - Abundant Resource |
| 6 | Off-grid | External Consumption | $H_2O$ - Abundant Resource |
| 7 | On-grid | Local Consumption | $H_2O$ - Abundant Resource |
| 8 | On-grid | External Consumption | $H_2O$ - Abundant Resource |

## Results and Discussion

The heterogeneity of Bahian territory allows different approaches to developing the GH2 economy in Bahia, especially adapted to the particularities of each region. In this context, Figure 1 displays the eight hypothetical scenarios that indicate the suitability for GH2 production based on the combination of specific conditions representing different possible strategies for developing the GH2

**Figure 1.** Maps of priority areas for hypothetical scenarios.



economy in Bahia. Table 2 presents the numerical values that detail the ranking of each of the Identity Territories in the eight evaluated scenarios.

The rank of priority areas changes significantly if the GH2 production plant operates directly linked to a renewable energy generation system (off-grid) or if it is connected to the national electricity grid (National Interconnected System - SIN) and uses renewable energy certificates to ensure that the hydrogen produced is classified as green (on-

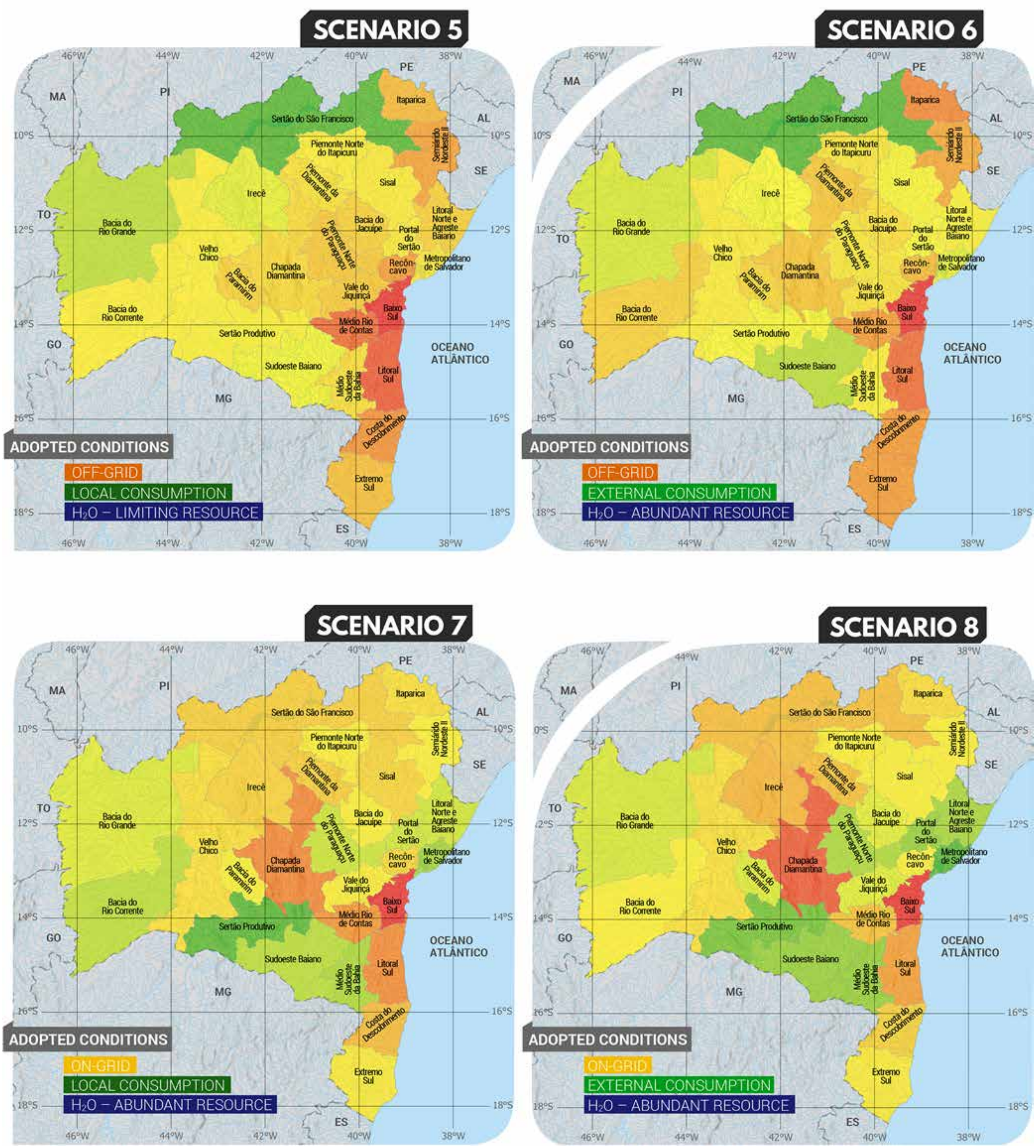


**Table 2.** Numerical ranking values for the different Identity Territories generated through the AHP Model.

| | Territory of Identity | Hypothetical scenarios | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SC1 | SC2 | SC3 | SC4 | SC5 | SC6 | SC7 | SC8 |
| 1 | Irecê | 5.10 | 4.52 | 0.97 | 0.65 | 5.69 | 5.25 | 3.17 | 2.37 |
| 2 | Velho Chico | 4.65 | 4.61 | 2.48 | 2.56 | 4.35 | 4.15 | 3.59 | 3.59 |
| 3 | Chapada Diamantina | 2.95 | 1.96 | 0.05 | 0.00 | 3.48 | 2.79 | 1.49 | 0.67 |
| 4 | Sisal | 4.01 | 5.62 | 1.24 | 1.98 | 4.10 | 5.11 | 3.35 | 4.55 |
| 5 | Litoral Sul | 0.73 | 1.33 | 0.89 | 1.48 | 0.65 | 1.02 | 1.59 | 1.92 |
| 6 | Baixo Sul | 0.00 | 0.00 | 0.04 | 0.72 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | Extremo Sul | 3.51 | 2.83 | 3.43 | 3.44 | 2.58 | 1.87 | 4.10 | 4.10 |
| 8 | Médio Sudoeste da Bahia | 4.16 | 5.48 | 4.04 | 4.00 | 3.64 | 4.35 | 7.25 | 8.25 |
| 9 | Vale do Jiquiriçá | 3.25 | 4.80 | 2.08 | 2.83 | 2.89 | 3.81 | 4.23 | 5.73 |
| 10 | Sertão do São Francisco | 9.20 | 9.37 | 1.09 | 0.93 | 10.00 | 10.00 | 3.09 | 2.56 |
| 11 | Bacia do Rio Grande | 10.00 | 10.00 | 10.00 | 10.00 | 6.70 | 5.90 | 5.82 | 5.98 |
| 12 | Bacia do Paramirim | 3.83 | 4.21 | 2.60 | 2.98 | 3.28 | 3.35 | 4.81 | 5.78 |
| 13 | Sertão Produtivo | 4.87 | 5.84 | 6.02 | 4.58 | 4.71 | 5.22 | 10.00 | 9.26 |
| 14 | Piemonte do Paraguaçu | 3.19 | 5.02 | 3.48 | 3.64 | 2.85 | 3.96 | 6.20 | 7.21 |
| 15 | Bacia do Jacuípe | 3.46 | 4.34 | 2.14 | 2.64 | 3.12 | 3.58 | 4.57 | 5.71 |
| 16 | Piemonte da Diamantina | 3.70 | 2.54 | 1.28 | 1.15 | 3.73 | 2.84 | 3.07 | 2.60 |
| 17 | Semiárido Nordeste II | 2.15 | 2.40 | 2.17 | 2.17 | 2.01 | 2.11 | 4.34 | 4.46 |
| 18 | Litoral Norte e Agreste Baiano | 4.05 | 6.42 | 4.60 | 5.07 | 3.12 | 4.49 | 6.06 | 7.53 |
| 19 | Portal do Sertão | 4.65 | 6.82 | 3.33 | 4.12 | 3.97 | 5.22 | 6.12 | 8.29 |
| 20 | Sudoeste Baiano | 5.95 | 8.30 | 4.20 | 4.49 | 5.44 | 6.81 | 6.81 | 8.24 |
| 21 | Recôncavo | 1.97 | 2.88 | 1.24 | 1.83 | 1.90 | 2.45 | 3.42 | 4.37 |
| 22 | Médio Rio de Contas | 0.70 | 1.95 | 0.00 | 0.82 | 0.99 | 1.88 | 1.77 | 2.66 |
| 23 | Bacia do Rio Corrente | 6.71 | 5.88 | 9.76 | 8.51 | 4.27 | 3.13 | 6.78 | 4.99 |
| 24 | Itaparica | 2.79 | 1.59 | 1.71 | 1.73 | 2.44 | 1.48 | 3.57 | 3.51 |
| 25 | Piemonte Norte do Itapicuru | 4.44 | 3.98 | 2.04 | 2.00 | 4.29 | 3.84 | 4.21 | 4.25 |
| 26 | Metropolitano de Salvador | 5.07 | 8.06 | 5.33 | 5.94 | 3.89 | 5.62 | 7.73 | 10.00 |
| 27 | Costa do Descobrimento | 2.22 | 2.63 | 1.75 | 2.41 | 1.71 | 1.85 | 2.51 | 3.23 |

grid). The classification also varies depending on local or external consumption, which requires transportation over long distances and depends on the existing transportation logistics infrastructure. The water and renewable energy resource availability analysis highlights the mesoregions Vale São Francisco, north-central and south-central of the state, mainly driven by the sub-criteria Wind & Solar Complementarity. The Bacia do Rio Grande territory is the most suitable for green hydrogen projects in most evaluated scenarios due to water and of-grid renewable energy resources. However, when development aspects, infrastructure, and demand (internal and external) are more significant, the Metropolitan Region of Salvador is ranked first (Scenario 8 in Figure 1). Due to the specificities of Bahia state, there are no data to compare to the results obtained in this work. It is essential to emphasize that the results obtained in this study represent a macro analysis of highly complex factors interconnected to the production chain associated with GH2. These factors may change over time, requiring the consideration of new premises, criteria, and sub-criteria, as well as the adaptation of the approach based on new technologies (e.g., the use of biomass for GH2 production) and other factors relevant to the state of Bahia. Therefore, it is necessary to update the mathematical model from time to reflect the conditions of the local reality as accurately as possible.

## Conclusion

Considering the 27 Territories of Identity of the state, mapping the indicators inserted in the AHP Model pointed out the diversity of characteristics (geographical, environmental, historical, social, cultural, and economic) present throughout the Bahian territory. Water and renewable energy resources, infrastructure, and GH2 demand are essential to indicate priority areas for hydrogen production. By determining specific conditions (e.g., SC1: Off-grid, Local Consumption, $H_2O$ - Limiting Resource), we can identify the Bacia do Rio Grande region as a preferential area for GH2 production. Another defined condition (e.g., SC8: On-grid, External Consumption, $H_2O$ - Abundant Resource) may highlight the Metropolitano de Salvador region as the most prominent for GH2 production. In this regard, the business model and the set of prioritized conditions must be carefully analyzed when defining priority areas for GH2 production.

## Acknowledgments

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