Green Hydrogen

A new
way for
Rio Grande
do Sul.

2023

GOV RS
NOVAS FAÇANHAS

Rio Grande do Sul, the global hub of Green Hydrogen

EDUARDO LEITE

Governor of Rio Grande do Sul

It is the government's duty to promote the development, which means going beyond supporting traditional sectors of the economy. It requires, to the same extent, an attentive and strategic look at new businesses, that can not only be added to the existing ones but can also enhance them. It is in this context, that the policy of setting up a Green Hydrogen production hub in Rio Grande do Sul fits in.

Among the priorities of the new administration, we list the incentive to a sustainable economic growth. We believe that by generating wealth and income, improving competitiveness, we will even consolidate a new moment for the public management in Rio Grande do Sul. It does not mean growing in any direction, but growing based on a strategic guideline. Therefore, our commitment is more than growing only, it is growing with innovation, energy transition and sustainability.

The Green Hydrogen project addresses the three guidelines simultaneously. At the same time, the Green Hydrogen puts Rio Grande do Sul on the global map of an innovative and promising product, reinforces our commitments with the energy transition and deepens the idea that we seek to reconcile development and sustainability. In a certain way, we can say that the project is a perfect symbol of what we are thinking for our state.

This booklet aims to present the state's advantages to become a competitive hub for Green Hydrogen. We have abundant water and sources (sun and wind) for the production of renewable energies. We also have one of the largest ports in Brazil (Rio Grande), that can be converted into a production distribution point for any place in the world. Besides exporting the produced hydrogen, we can also use it to produce ammonia, an essential fertilizer for the agricultural production in Rio Grande do Sul, with obvious productivity gains.

We want to show to Brazil and to the world that we have all the logistical and competitive conditions to establish ourselves as a reference in this field. For this purpose, we are adopting legal measures, studying the market deeply and technically and strengthening contacts with international investors and manufacturers. With the seen perspectives, we are facing a revolution, that will certainly be a milestone for the future of our state.

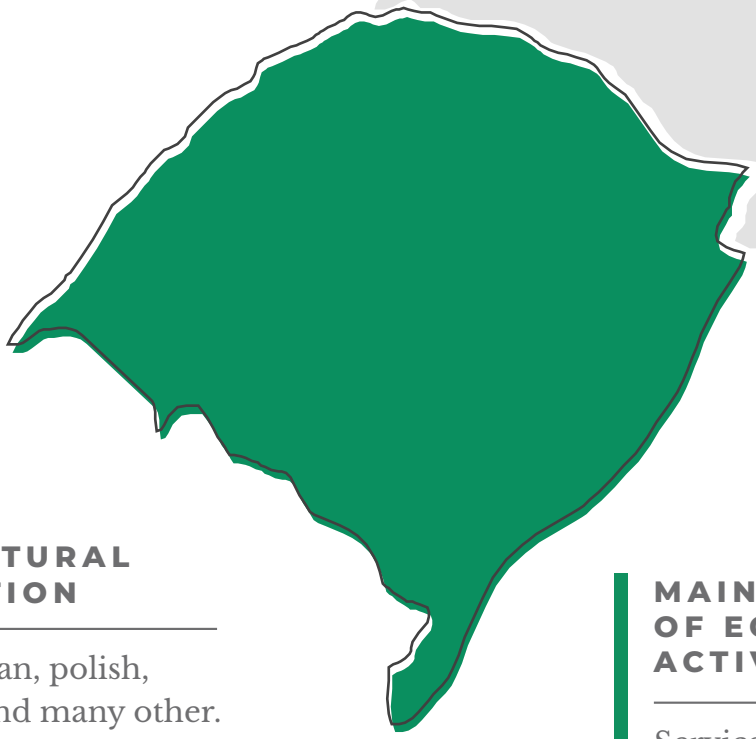
Rio Grande do Sul

11,4 MILLION INHABITANTS

More than 5% of the Brazilian population.

CAPITAL PORTO ALEGRE

Almost 4 million inhabitants, including the Metropolitan Region.



MULTICULTURAL IMMIGRATION

German, italian, polish, portuguese and many other.

MAIN SECTORS OF ECONOMIC ACTIVITY IN RS

Services – 67,3%
Industry – 23,4%
Agribusiness – 9,3%

GDP Brazil	BRL 8,7 tri
GDP per capita Brazil	BRL 40.688,00
GDP RS	BRL 582,6 bi
GDP per capita RS	BRL 50.840,40

STRATEGIC LOCATION

70% of South America's GDP and 150 million inhabitants within a radius of 1,500 km

In the centre of the main markets in South America

Integration with Mercosur through roadways, railways, waterways and international flights

Economic sectors highlights

Diversified Industry

1st industrial park in the country for:

- Biodiesel
- Tractors, agricultural machinery and equipment
- Road implements and bus bodies
- Leather and footwear
- Wines
- Tobacco

2ND INDUSTRIAL PARK IN THE COUNTRY FOR:

- Automation
- Computer programming
- Metallurgical products
- Machines and equipment
- Furniture
- Animal and vegetable fats and oils

3RD INDUSTRIAL PARK IN THE COUNTRY FOR:

- Plastic and rubber products

4TH INDUSTRIAL PARK IN THE COUNTRY FOR:

- Wind power generation
- Light vehicles
- Chemicals
- Vessels, aircrafts, military vehicles and other transport equipment

Internationalized economy

2nd
State in exports of manufactured products

3rd
Most promising state in Brazil for investments

4th
State in exports

U$ 8,7 billion

-

U$ 16,5 billion
8.95% of all exports from Brazil

Environmental pioneering

Average time for analysis of environmental licenses **reduced by 50%**

2018	256 days on average
2022	128 days on average

AS A RESULT OF

- People management intelligence
- System improvements
- Acquisition of equipment
- Update of the environmental law (Law 15.434), that authorized new forms of licensing
- Implementation of the Environmental License by Commitment for 49 activities with lower polluting potential

RS and climate actions

COP 26

Commitment to neutralize CO_2 emissions by 2050.

COP 27

Cooperation Agreement between RS and CDP (Carbon Disclosure Project). Protocol of Intentions of Codesur member states.

JOINING TO RACE TO ZERO AND RACE TO RESILIENCE

Neutralizing greenhouse gas emissions by 2050 and the climate resilience.

JOINING TO UNDER2COALITION

Coalition of subnational governments to achieve the mitigation of greenhouse gas (GHG) emissions.

Main sources of H_2

Low Carbon H_2

	GRAY H_2	BLUE H_2	TURQUOISE H_2	GREEN H_2
Feedstock	Natural gas	Natural gas	Biomass or biofuels	Water
Production Process	Split natural gas[1] into H_2 and CO_2	Similar to Gray, but with CO_2 sequestration and/or storage	Catalytic reforming[2], gasification[3] or anaerobic digestion[4] with or without CCUS (Carbon Capture, Use and Storage)	Splitting water into H_2 and O_2 in an electrolyser powered by renewable energy
CO_2 emissions CO_2 Kg/H_2 Kg produced	~10	~1-3 (most CO_2 stored)	n.a.	~0 (Assuming a mix of green electricity, typically solar and wind)

Focus of discussion

1. Process: Sulfur Removal, Syngas Production via Steam Methane Reforming (SMR) or Automatic Thermal Reforming (ATR), CO Shift Reaction, Purification. The latter is expected to offer greater efficiency in combination with CCS. Furthermore, gray hydrogen can also be produced from coal gasification;
2. Also called hydrogen reforming or catalytic oxidation, it is a method of producing hydrogen from hydrocarbons;
3. Processes that transform solid or liquid fuels into a fuel mixture of gases generating CO and H_2;
4. Degradation of organic compounds without simpler substances (eg: CH4 and CO_2), using anaerobic microorganisms;

Source: EPE

What is GH_2

Green Hydrogen (GH_2) consists of hydrogen generated by renewable energy, being an energy source of wide applicability with significantly lower carbon emissions than gray H_2 or other fossil fuels.

Study guide for the elaboration of the GH_2 development plan in RS

Step 1	Preparatory activities	Step 2	Understanding the starting point and potential for Green Hydrogen in RS	Step 3	Design of potential action by the government of RS

10 weeks

4 weeks | 6 weeks | 4 weeks

- 0.1 Understanding and evaluating available research and data.
- 0.2 Relevant data collection.
- 0.3 Outline and launch of complementary research.
- 0.4 Definition of main companies and stakeholders to be interviewed.
- 0.5 Interviews with executives and market experts.
- 1 Kick-off presentation that summarizes the scope, methodology and preliminary results of the preparatory steps (0.1 to 0.5).
- 2 Report detailing the Government's aspirations and boundary conditions for the Green H_2 market.
- 3 Market research report with objectives and challenges of the main stakeholders of the GH_2 chain in RS.
- 4 Benchmark of public policies, characterization of the distinctive aspects of the State of RS in relation to GH_2 and identification of socioeconomic and technological challenges.
- 5 Mapping of the starting point and potential perspective of renewable energy and gas markets in the State of RS.
- 6 Estimate of production cost and assessment of competitiveness of GH_2 in RS in 2022 and 2040.
- 7 Estimate of the internal demand for GH_2, considering possibilities for substituting energy sources.
- 8 Estimate of future external GH_2 demand in the State of RS, including landed cost analysis.
- 9 Based on government input, preparation of a detailed Plan for the economic development of the GH_2 sector in RS, including the structuring of guidelines and also the definition of the main insights for the most characteristic companies and sectors of the State for the advancement of H (focus on key sectors, such as the transformation industry, metal-mechanics, agriculture, utilities, transport and logistics).
- 10 Assessment of the economic impact, through the impact on GDP and job generation.
- 11 Assessment of the environmental impact of the emission of greenhouse gases and other qualitative benefits resulting from the development of the sector.
- 12 Implementation roadmap, including results to be achieved, macro activities to be carried out and deadlines.
- 13 Final report of the sectoral development plan of the Green Hydrogen market in RS, grouping and synthesizing the methodology and the main results of products 1 to 12.

Applicability of GH_2 in Brazil

FEEDSTOCK FOR THE INDUSTRY

- H_2 for steel
- H_2 for refinery
- Ammonia for fertilizers and chemicals

TRANSPORT

- H_2 for passenger cars
- Road freight (medium weight and heavy duty trucks)
- H_2 for long distance rail freight
- Mining trucks
- Ammonia or methanol for bulk carriers /container ships

HEATING AND ENERGY FOR THE INDUSTRY

- H_2 for medium and high grade heating
- H_2 for H_2 gas mixture
- H_2 for combined cycleturbine

GH_2 Context in Brazil

1

- The global moment of decarbonization provides a favorable scenario for Hydrogen, with a potential application growth of more than 10 times
- GH_2 in Brazil can be competitive in ecosystems due to the country's characteristics

2

- The GH_2 chain should become a sector with revenues between USD 15 billion and USD 20 billion in 2040 in Brazil, with approximately 70% of the volume destined for the domestic market

3

- Several projects were announced in Brazil, especially with an initial focus on exports
- States have significant potential as producers and/or consumers of GH_2

GH_2 Context in RS

The H_2V opportunity in RS dialogues with the global moment and the commitment to decarbonization and the development potential of the local chains

1

- The aspiration of government representatives is to become a leader in the country in GH_2, given the high potential of renewable energies and the need for a sustainable agenda in the state

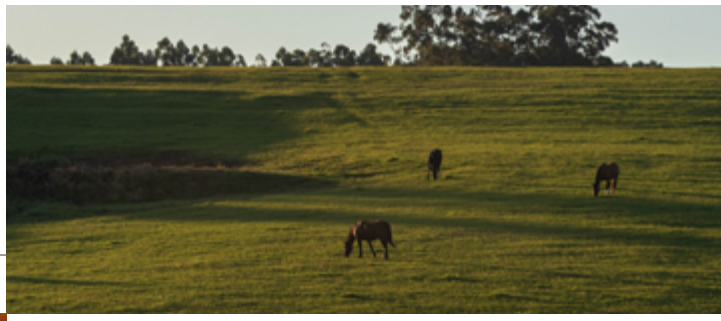
2

- The global moment of decarbonization provides a favorable scenario for the Hydrogen, with a potential application growth of more than 10 times and support for the 1.5°C target
- The GH_2 supports the ambition to decarbonize the economy, which was assumed by Rio Grande do Sul when committing to the Race to Zero

3

- Rio Grande do Sul has a potential as a producer (solar and wind potential), as a consumer (due to manufacturing industries and consumption of fertilizers1) and has a logistic infrastructure
- Given the high wind and solar capacity factors, estimated GH_2 costs in RS are competitive with other regions of the country, ranging from 2.1 to 3.4 USD/kg

Opportunities for the southern region



DECARBONIZATION AS A GOAL

IMPROVEMENT OF THE USE OF NATURAL RESOURCES

DECREASE OF THE ENVIRONMENTAL IMPACTS ON ENERGY GENERATION AND USE

GENERATION OF JOBS, INCOME AND IMPROVEMENT IN THE QUALITY OF LIFE

INCREASE IN ENERGY SECURITY

REGIONAL INTEGRATED DEVELOPMENT

Use of GH_2 for decarbonization in RS

DEMAND-SIDE MEASURES AND CIRCULARITY

Reduce the demand for primary resources by increasing the circularity of products, e.g. reuse, recycle

ENERGY EFFICIENCY

Decrease the energy intensity of equipments or infrastructures, e.g. building insulation or heat recovery improvements

ELECTRIFICATION AND CARBON-NEUTRAL ENERGY

Replacing fossil fuel with renewable electricity, e.g. from wind and solar farms

C-NEUTRAL HYDROGEN AS FUEL OR FEEDSTOCK

Replace carbon-intensive feedstock or fuel with carbon-neutral H_2, e.g. in ammonia production

BIOMASS AS FUEL OR FEEDSTOCK

Replacing feedstock or fuel with sustainably produced biomass or biogas, e.g. bio-based feedstock in the chemical production

CAPTURE AND STORAGE OR CARBON USE (CCS/U)

Using technology to capture the CO_2 emitted in chemical processes

OTHER INNOVATIONS

Applying GH_2 in innovative processes, e.g. electrochemical production processes

Switching to non-fossil fuel feedstock, e.g. cement industry

LAND USE OR CHANGES IN AGRICULTURAL PRACTICES

Altering land use or agricultural practices to reduce net emissions, e.g. through reforestation (for negative emissions) or changing livestock feed

What RS offers

NATURAL RESOURCES

- Natural resources in abundance (energy generation – carbon free)
- Sea coast and lagoons
- 82% of the electric energy matrix is renewable

INFRASTRUCTURE

- Logistic and production base
- Transmission lines
- Port structure
- Waterways
- Roadways
- Railways
- Universities and science and technology centers

MARKET

- Internal consumption
- External market
- Added value in the local productive sector
- Tax incentive (Fundopem/RS)

Potentialities and structure

Type of Plant	Installed Power[1]		Energy Generated[2]	
	MW	%	GWh	%
Hydroeletric plants	**4.632**	**44**	**11.701**	**49.7**
UHE	3.865	36,7		
PCH	665	6,3	11.701	49.7
CGH	102	1,0		
Thermoeletric plants	**2.211**	**21**	**3.870**	**16,4**
Biomass	380	3,6	3.870	0,2
Fossil[1]	1.831	17,4	3.834	16,3
Nuclear	-	-	-	-
Wind	**1.836**	**17,4**	**5.424**	**23,7**
Photovoltaic[3]	**1.859**	**17,6**	**2.562**	**10,9**
Total	10.538	100	23.557	100

INSTALLED

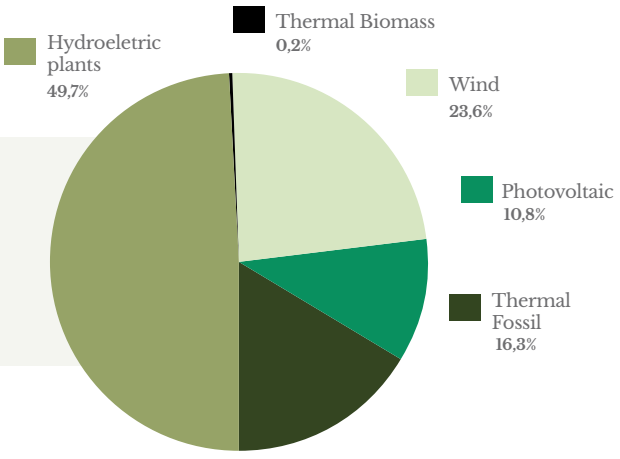
82,6%

Renewable

PRODUCED

83,7%

Renewable



Raw data source: ANEEL on 10-01-2022 and ONS.

Note: CGH up to 5MW; PCH between 5 and 30MW; UHE greater than 30MW

1. Considers half of the border plants on the Pelotas and Uruguay rivers;
2. Considers the generation given by the ONS from 10/01/2021 to 09/30/2022;
3. Considers 1,577MW from GD, on 06/22 plus 9.64MW registered with ANEEL;

Average Annual Import of Electricity, by RS, from the National Interconnected System (SIN) 2015-2020: 30%

BRL 6,5 bi
in recent investments

3.200 km
of lines

8,8 GVA
capacity

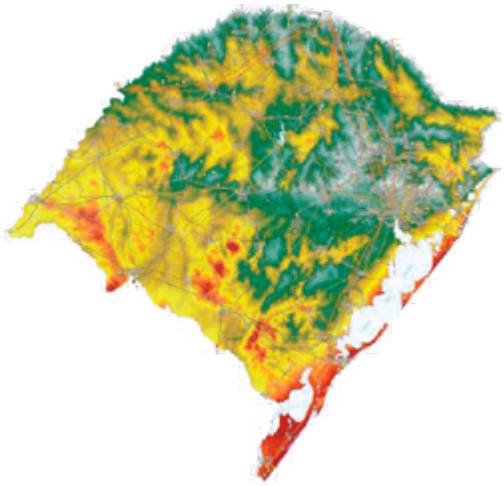
The expansion of the transmission system makes it possible to install GH_2 projects in regions with greater wind and solar potential.

Potential for wind and solar generation favors GH_2 projects in RS

ANNUAL ON-SHORE WIND POTENTIAL

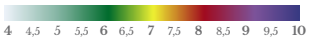
Wind speed ≥ to 7 m/s

Theoretical total installable capacity of approximately 103 GW with 17% already in operation or planned



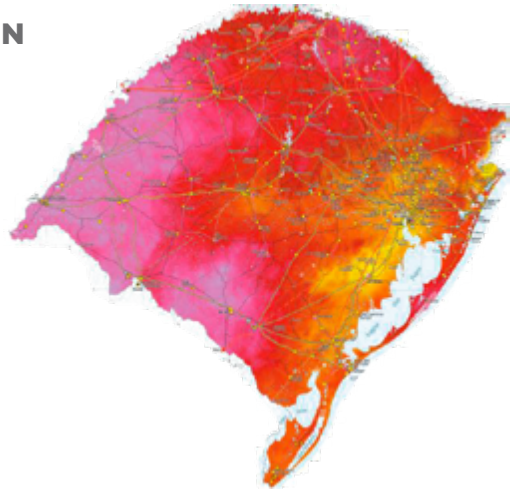
Capacity factor (%): 47

Wind speed (m/s)



ANNUAL TOTAL IRRADIATION ON THE INCLINED PLANE AT 20°

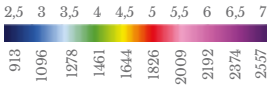
The RS has a theoretical total solar installable capacity of approximately 100 GW



Capacity factor (%): 15-17

Average total irradiation

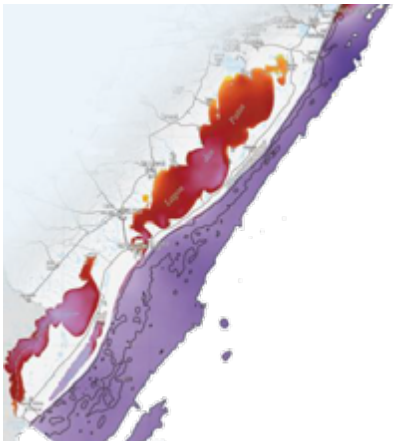
Sum of the day - kWh/m2/day



Sum of the year - kWh/m2/year

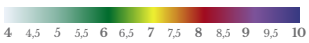
AVERAGE THEORETICAL OFF-SHORE WIND CAPACITY FACTOR BY REGION IN RS

The offshore wind potential in the Patos, Mirim and Mangueira lagoons and on the coast of the state is approximately 114 GW



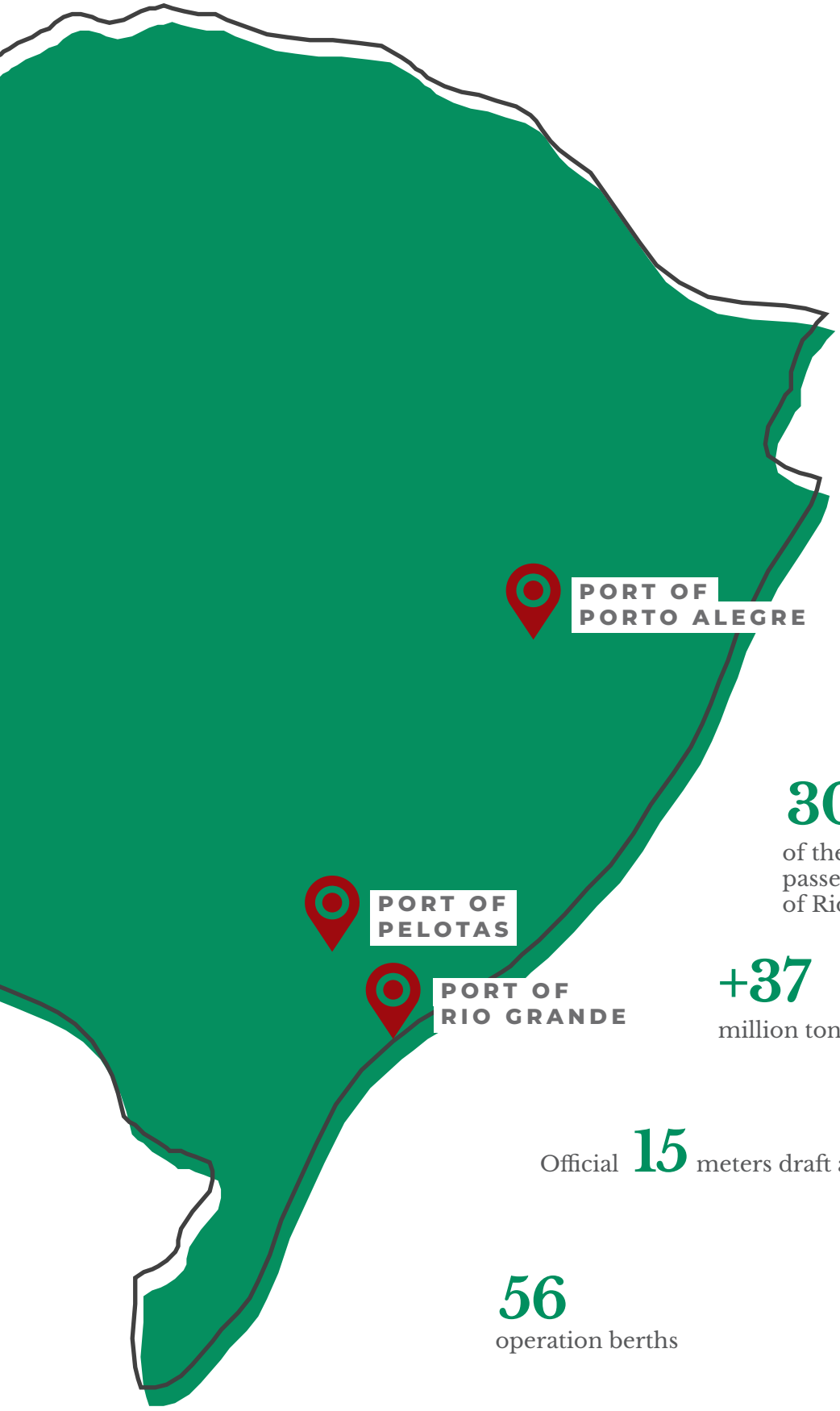
Capacity factor (%): 43-53

Wind speed (m/s)



Source: Wind Atlas of Rio Grande do Sul (Government of Rio Grande do Sul, 2014)

Port Systems in RS



30%
of the state's economy passes through the ports of Rio Grande do Sul

+37
million tons handled in 2022

Official **15** meters draft at the Superport

56
operation berths

A port for the GH_2

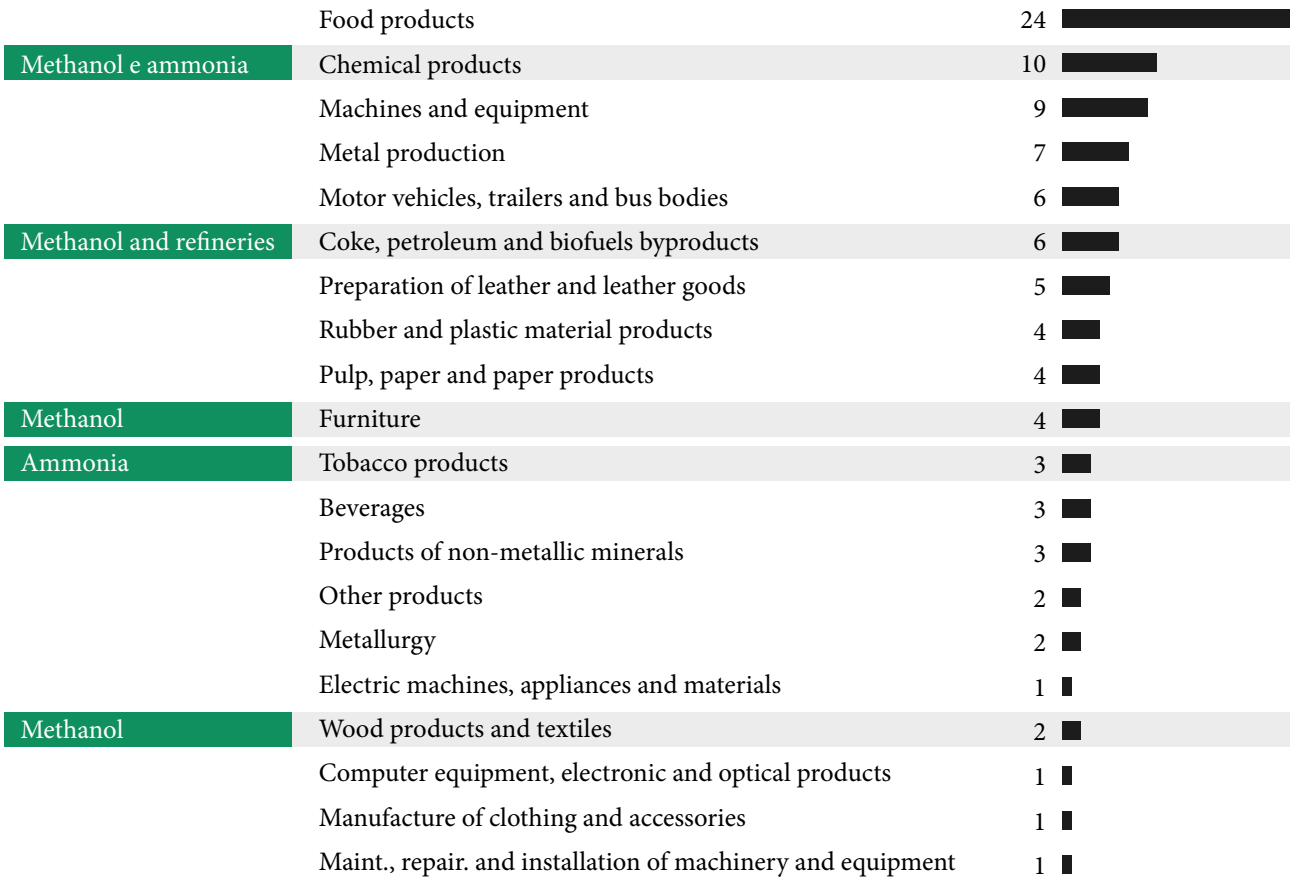
LOCAL ADVANTAGES

Rio Grande (industry-port)

- Largest industrial district in RS
  - 2,580 hectares of total area
- Back areas available
- Strategic and privileged position
- Synergy with production chains
- Logistic advantages
  - Production flow
  - Receipt of raw materials
- Handling more than 37 million tons in 2022

GH_2 potential in economic sectors in RS

COMP. OF THE INDUSTRIAL TRANSFORMATION VALUE OF RS, 2020 (%)



Source: Annual Industrial Survey (PIA-IBGE). Document intended to provide insights based on available information and not advice, opinions or recommendations on public policy.

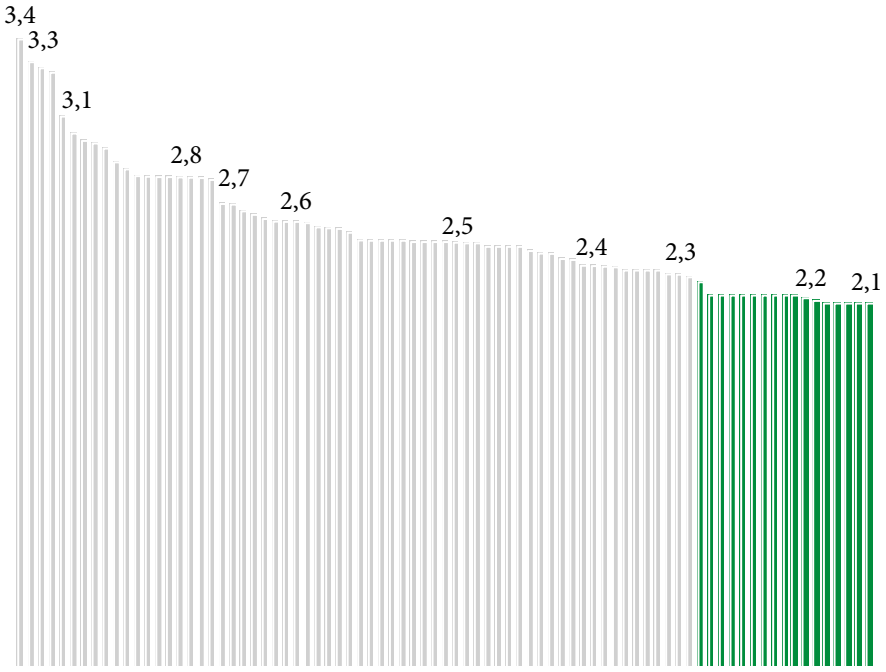
KEY INDUSTRY APPLICATION

Some GH_2 applications can benefit important sectors of the RS economy, including:

- Petroleum products, mostly produced in refineries, and biodiesel, with the need to use methanol, represent 6% of the VTI.
- The production of chemical products, that represents 10% of the VTI, can be impacted both by the production of ammonia for fertilizers (which also has industrial uses) and methanol (with the production of formaldehyde). Ammonia for fertilizers still impacts the tobacco industry (3% of VTI) and methanol impacts the wood products and furniture industry (6% of VTI).
- Other conventional, direct replacement uses of H_2 – similar to refining – include the hydrogenated vegetable oil (food), paper and cellulose (hydrogen peroxide) and glass industry, but the demand is limited.

GH_2 production cost in RS

LEVELIZED COST OF HYDROGEN (LCOH+S) IN 2030
ALL SETTINGS ANALYZED FOR RS, USD/K



MINIMUM LCOH+S FOR EACH CLUSTER BY PRODUCTION SCENARIOS, USD/KG

CLUSTER	ON-GRID	OFF-GRID	MIXED-GRID
01 São Francisco de Assis*	2,26	2,24	
02 Uruguaiana*	2,22	2,22	
03 Giruá*	2,22	2,24	
04 Vila Nova do Sul*	2,26	2,26	
05 Mostardas*	2,50	2,21	
06 Santa Vitória do Palmar*	2,17	2,15	
07 Cambará do Sul**	2,37	2,54	
07.1 Arroio do Sal**	2,19	2,56	
08 Dom Pedrito*	2,49	2,20	
09 Rio Grande**	2,49	2,18	2,09
10 Porto Alegre**	2,58	2,34	2,21

**: Cluster with Capacity Factor in the first quadrant*
***: Cluster with Capacity Factor between the second and fourth quadrant*

Most relevant GH_2 applications for RS

INDUSTRY FEEDSTOCK

Conventional routes

Refineries

Refap's Hydrogen Generating Unit has the capacity to produce 60 KTA of Gray H_2. Petroleum derivatives represent 5% of VTI.

Low carbon routes

Ammonia for fertilizers

Nitrogen fertilizer imports totaled 620 kT in 2021 (exc. Urea). The value of imports corresponds to 0.8% of VTI.

Methanol

Methanol imports from RS amounted to 20 KT in 2021. Methanol is used in the biodiesel industry, representing 0.6% of VTI.

Steel

Although the steel industry accounts for 1% of the VTI, the non-integrated route in RS reduces the possibilities of H_2 application.

ENERGY CARRIER

Transport

H_2 for passenger cars

RS has 8% of the car fleet. Road energy consumption represents 45% of the state's total consumption.

Long distance rail freight

Rails could be decarbonised using hydrogen or electricity as a diesel substitute.

Air transport

Air energy consumption representsless than 1% of consumption in the air transport. RS does not have a national/ international air hub.

Road transport

Focus on trucks (85% of the heavy duty fleet). RS has 8% of the truck fleet. Road energy consumption represents 45% of the State's total consumption.

Sea transport

Porto de Rio Grande is the 5th busiest port in Brazil.

Heat for industry and services

Medium and high degree heating

Natural gas, mineral coal and diesel for energy purposes add up to 800,000 TOE in the industry, representing 6% of state consumption.

Combined cycleturbine

Mineral coal and natural gas consumption add up to 1.7 MTOE in the energy transformation process. Restriction of natural gas prevents the complete use of thermoelectric plants.

Mix of H_2 gas

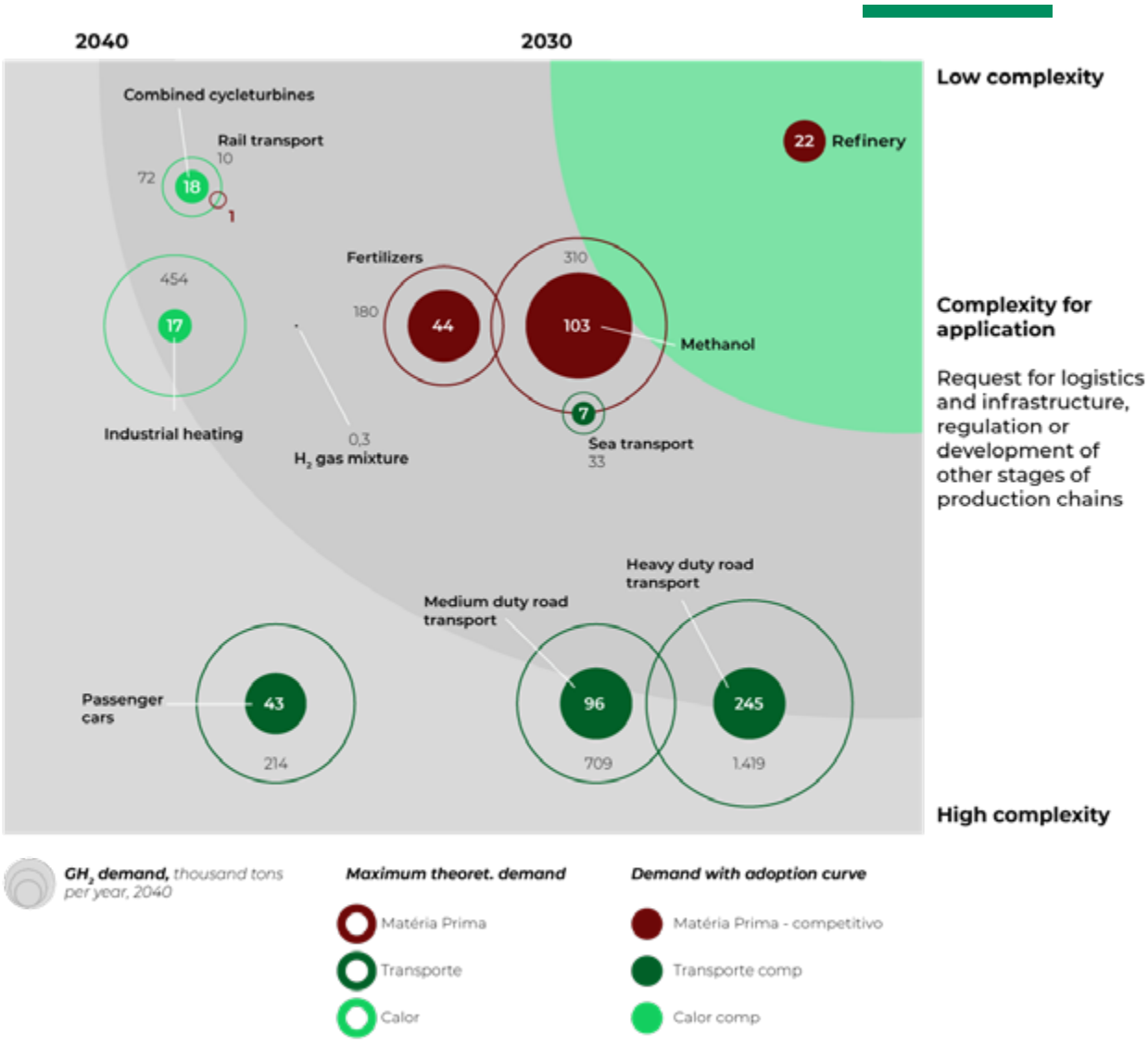
Hydrogen can be added to the natural gas network, increasing the overall supply and enabling a better supply-demand balance.

Demand and production potential in RS until 2040

Theoretical potential of 2.8 million tons of GH_2 distributed in several applications with dispersed complexity and competitiveness

GH_2 APPLICATION FEASIBILITY MATRIX

GH_2 solution cost breakeven year compared to traditional and low-carbon alternatives



The maximum demand for GH_2 could reach 2.8 million tons of GH_2 in 2040. However, the actual demand for GH_2 depends on the adoption rate and the dynamics of each market, projected to 0.8 million in 2040.

Two types of application can act as keys to the development of the GH_2 chain in the state:

- Applications with high volume, but more difficult to apply in the short term, such as road transport and industrial heating
- Niche applications with small volume but easy to use such as in refineries

Investments in downstream production chains and GH_2 logistics can reduce challenges and bottlenecks

Maximum potential (100% adoption)
Potential with adoption curve

Application	Demand in RS, KTA, 2040	Complexity for GH_2 adoption
Refinery	22	-
Fertilizers	180	Need for additional CAPEX investment for ammonia plant and nitrogen fertilizers. To reach the maximum potential, it is necessary to be competitive in other states of the centre-south
Methanol	313	Need for additional CAPEX investment for methanol plant. To reach the maximum potential, it is necessary to be competitive in other states of Brazil
Road transport	341 / 1.247 / 1.588	Competition with BEV, especially for medium trucks. Logisticl challenge of implementation in a distributed chain.
Passenger cars	43 / 171 / 214	Competition with BEV. Distributed chain implementation logistic challenge.
Rail transport	9 / 1 / 10	-
Sea transport	19 / 7 / 33	-
Industrial heating	17 / 437 / 454	Low competitiveness of GH_2 compared to mineral coal and biogas
Combined cycleturbines	54 / 18 / 72	-
Mixture of H_2 gas	0	Low energy consumption of natural gas in homes and businesses

Benefits of GH_2 in RS

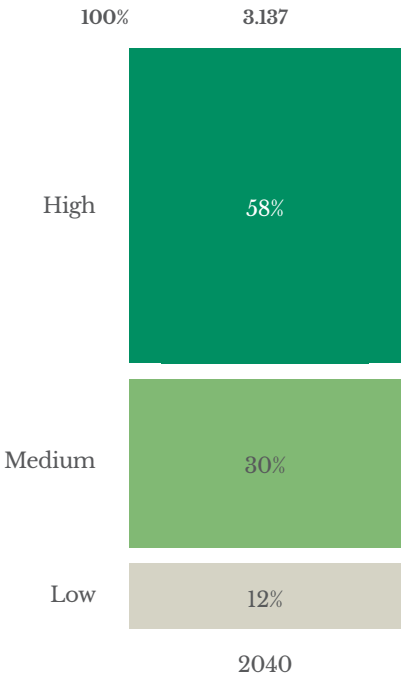
Scenario	Adoption of low complexity applications	Adoption of low and medium complexity applications	Adoption of low, medium and high complexity applications
Applications adopted in the scenario	Use in refineries, rail transport and cycleturbines	» Use in refineries, road transport and cycleturbines » Use in fertilizers, methanol, industrial heating, sea transport, gas mixtures	» Use in refineries, road transport and cycleturbines » Use in fertilizers, methanol, industrial heating, sea transport, gas mixtures » Use in road transport and passenger cars
Cumulative estimates up to 2040 GDP	~R$ 3,7 bi (1% of the RS annual GDP of 2021)	~R$ 33,6 bi (6% of the RS annual GDP of 2021)	~R$ 62 bi (11% of the RS annual GDP of 2021)
Jobs	~2 M	~25 mil	~41 M

Note: Amounts at 2022 prices in reais without discount rate, considering average exchange rate for 2022 according to IPEA of USD/BRL of 5.1. Given the existence of factors linked to the dollar, exchange rate volatility can affect the size of long-term values

Source: FIPE/DEE, OECD input/output tables, IBGE/SIDRA, CAGED

Expected demand for GH_2 in RS

ACCUMULATED DEMAND UNTIL 2040 BY ADOPTION COMPLEXITY (KTA, 2040)



APPLICATION	2025	2030	2040	FOSSIL SOLUTION PARITY YEAR	COMPLEXITY
Refinery	0	22	22	2026	Low
Methanol	0	0	103	2028	Med.
Road transport	0	21	341	2028	High
Passenger cars	0	5	43	2030	High
Sea transport	0	0	14	2034	Med.
Fertilizers	0	0	26	2035	Med.
Rail transport	0	0	1	2036	Low
Combined cycleturbines	0	6	18	2038	Low
Industrial heating	0	0	17	2038	Med.
H_2 gas mixture	0	0	0,3	2038	Med.

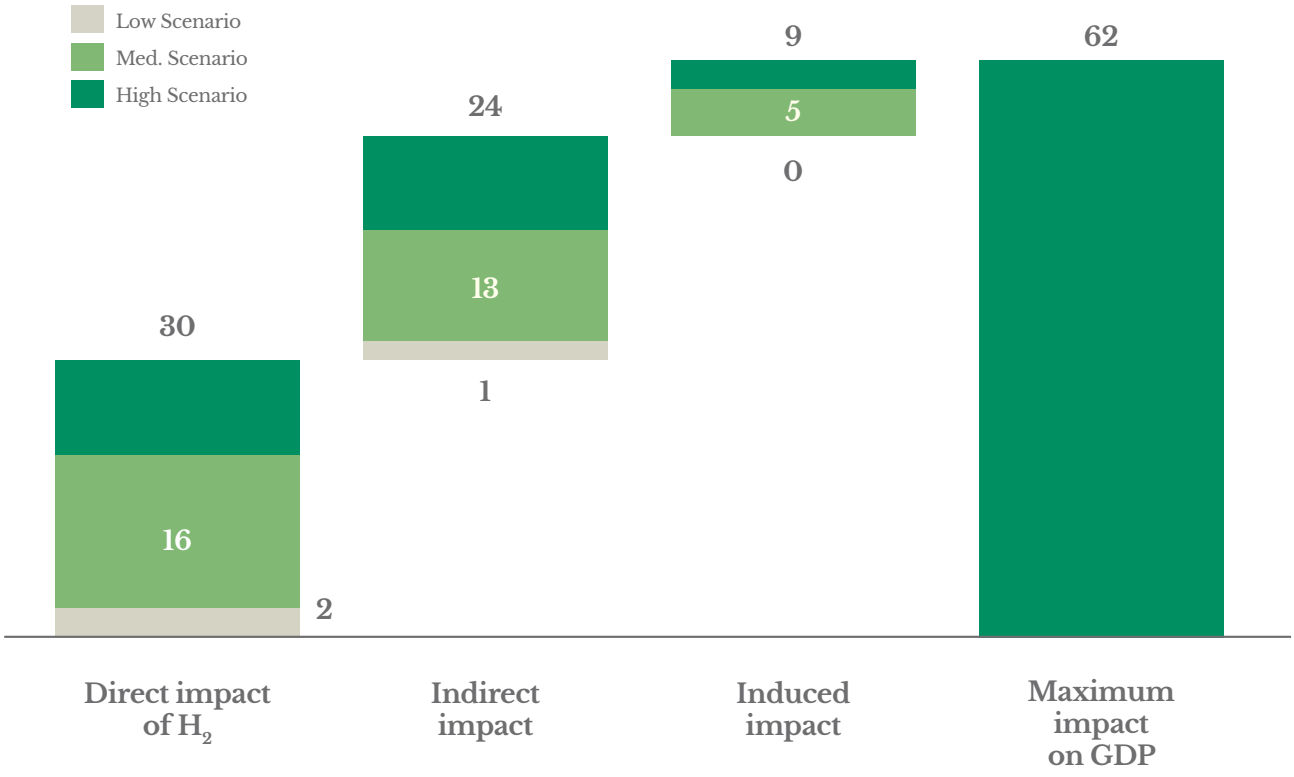
IN ADDITION TO THE ABOVE INTERNAL DEMAND ITEMS, THERE IS A POTENTIAL EXTERNAL DEMAND CAPTURE OF 0.5 – 0.9 MTA BY 2040

Benefits of GH_2 in RS

The maximum impact of GH_2 on GDP in RS by 2040 is BRL 62 billion

MAXIMUM CUMULATIVE IMPACT ON RS GDP UNTIL 2040

(in BRL billion with 2022 values)



Note: Amounts at 2022 prices in reais without discount rate, considering average exchange rate in 2022 according to IPea of USD/BRL of 5.1. Given the existence of factors linked to the dollar, exchange rate volatility can affect the size of long-term values

DIRECT IMPACT OF H_2

Direct impacts are the cost of Construction (e.g., investment in construction and equipment) and the expected change in revenue from expanded operations that add value to the economy. Initial costs with the import of equipment1 with inputs were removed from this amount.

INDIRECT IMPACT

Indirect contributions measure impacts on different supply chains from direct impacts. This impact reflects the effect on the supply chain of other production chains not directly involved with GH_2.

INDUCED IMPACT

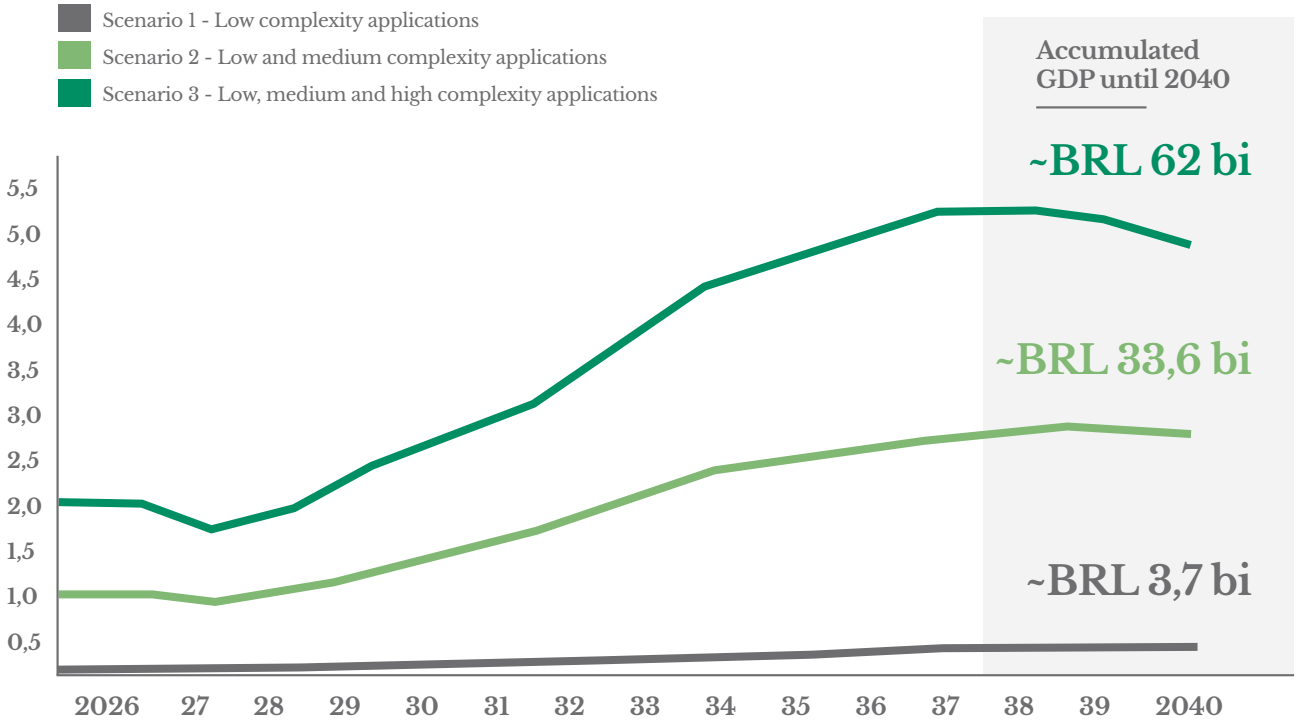
Economic impact caused by employees who from the chain spend their salaries on the economy, providing more income and creating more jobs. This impact is the most subject to variation in the long term given the incipience of the H_2 chain.

To calculate these impacts, the substitution and location effects were also considered, in which the first takes into account the increase in the contributions of H_2 and removes the added value of the fossil equivalents that H_2 replaced and the second adds a possible effect on the economy to produce locally and no longer import fertilizers and methanol,

Increase in annual GDP according to GH_2 adoption scenarios in RS

5-year moving average, BRL billion.

MAXIMUM CUMULATIVE IMPACT ON RS GDP UNTIL 2040
(in BRL billion at 2022)



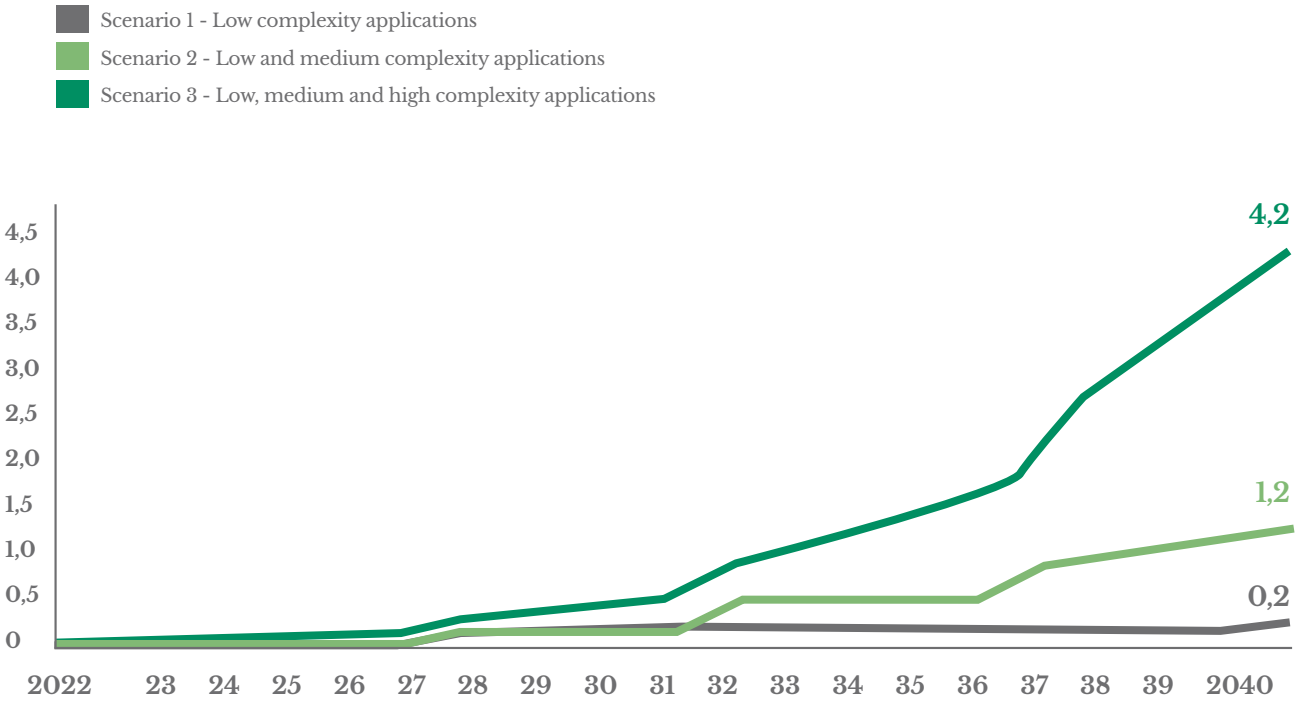
Note: Amounts at 2022 prices in reais without discount rate, considering average exchange rate for 2022 according to IPEA of USD/BRL of 5.1. Given the existence of factors linked to the dollar, exchange rate volatility can affect the size of long-term values. It was assumed that the H_2 projects would be built in 2026, 2029, 2030, 2033 and 2034 with 2 years of construction and the ammonia, methanol fertilizer plants would take 4 years and start construction in 2026, 2035, 2030.

Source: FIPE/DEE, OECD input/output tables, IBGE.

By 2040, RS could avoid 0.2-4.2 Mt of CO_2 per year, considering the three scenarios for the adoption of GH_2

CO_2E EMISSIONS AVOIDED ACCORDING TO EACH GREEN HYDROGEN ADOPTION SCENARIO IN RS

$MtCO_2e$/year



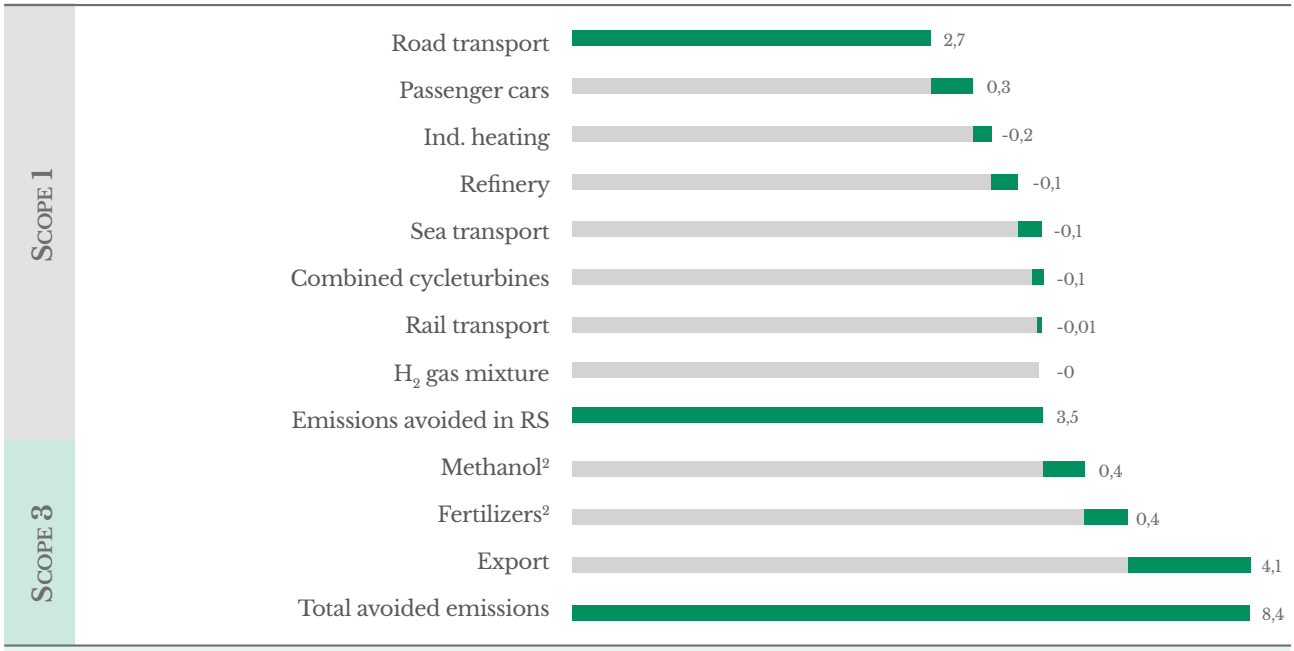
Includes scope 3 (indirect emissions, which occur outside the state and would be replaced by local production) for fertilizers and methanol consumed in the state, does not consider exports.

Source: Climate Observatory

How can GH_2 help to reduce carbon emissions in RS by 2040

Reduction of emissions in RS by application[1] – scenario[3]

2040, $MtCO_2e$/year



~3,5 a 8,4

$MtCO_2e$/year

in reducing emissions scope 1[1] and 3[1], by 2040

~4%[2] a 9%[3]

of total current scope 1[1] emissions from the state of RS[3]

~17%[4] a 38%[5]

of current Scope 1[1] emissions from sectors in RS where GH_2 is applicable[6]

1. Scope 1: emissions released as a direct result of operations within the state; Scope 3: indirect emissions that occur in the state's value chain;
2. Potential emission reduction of 3.5 $MtCO_2e$ in 2040 vs. total emissions of 84.3 $MtCO_2e$ RS in 2020 (according to the Climate Observatory using the GWP-AR5 methodology);
3. Considering RS contribution to total emission reductions (8.4 $MtCO_2e$ in scope 1 and 3) vs. the state's total emissions (84.3 $MtCO_2$ in scope 1);
4. Emission reduction potential of 3.5 and 8.4 $MtCO_2e$ in 2040 vs. emissions of 20.2 $MtCO_2e$ in sectors of RS where GH_2 is applicable;
5. Considering RS contribution to total emission reductions (8.4 $MtCO_2e$ in scope 1 and 3) vs. emissions where GH_2 is applicable in the state (20.2 $MtCO_2$);
6. Applicable sectors include synthetic fertilizers in agriculture, burning fuel in road, air, rail and water transport, fuel production in refineries, industrial heating, use of fuel in agriculture, fuel consumption for industrial processes of cement, pig iron and steel

Source: Climate Observatory

Action plan

The main initiatives raised make up a macro action plan divided into three main moments

	HORIZON 1 (2022-2026)		HORIZON 2 AND 3 (2027 +)
Lever	Next year	Short term	Medium and long term
Strategy and planning	» Establish GH_2 state management governance » Create state GH_2 policy with detailed strategic goals	» Establish the ongoing review of the strategy and governance processes associated with GH_2, including communication	
Stakeholder coordination	» Establish tools and forums that connect producers and demanders	» Establish bilateral agreements	» Monitor results and review planning and actions between supply and demand
Infrastructure and R&D	» Map infrastructure projects and gaps for renewable energy and GH_2 production » Develop a GH_2 scientific and technological cooperation program with national and international reference centers	» Design an infrastructure program for the production and use of GH_2 » Create GH_2 programs and research lines and seek support to make them financially viable	» Support and monitor the development and installation of infrastructure projects » Evolve innovation and research programs in line with the needs of the chain
Regulation	» Propose systems and processes applicable to environmental licensing and tax treatment related to GH_2 » Analyze and propose GH_2 certification models that adhere to the RS strategy at national and international level	» Adapt and communicate regulations and structures for licensing the chain	» Licensing and monitoring the performance of the GH_2 chain in relation to certification and licensing of new GH_2 businesses
Financial and tax incentives	» Define and approve local incentive mechanisms, based on economic and legal impact studies	» Offer, implement and communicate the approved incentives » Collaborate for the creation of mechanisms at the federal level	» Monitor the impact of incentives and adapt as the chain evolves
Human capital	» Prepare a map of needs and a training plan for professionals demanded by the GH_2 chain	» Execute training plan with support from the S system and technical schools	» Evolve professional training programs

Note: The actions mentioned here are a consolidation of the work plans prepared by the government's technical groups, presented in a summarized text format for high-level communication purposes. The "from-to" that allows tracking the consolidation of initiatives is available in the Annex to Product 12 of this study. Detailed action plans for each lever are included in Output 9 of the study and retain the original wording developed by the technical groups.

Designed governance structure

Level	Structure	Objectives	Participants
Estrategic	Directive committee	Establish and monitor the evolution of strategic objectives in the development of the GH_2 chain Define priority areas in the medium and long term Plan how the government will act to achieve the established objectives Delimit the scope of action and reporting structure	Representatives of the State Departments Leader of the GH_2 Working Group
Tactical	GH_2 Working Group	Establish and monitor the evolution of measurable goals for the strategic objectives Establish and monitor short and medium term programs to achieve the goals Define roles and responsibilities for program execution, reporting and coordination	Leader of the GH_2 Working Group Initiative delivery manager
Operational	Implementation teams of the levers	Prioritize and manage specific projects and specific actions within the enabling program to achieve economic development objectives Hold forums for decision-making regarding projects and operational actions Monitor the execution and delivery of projects and program actions	Lever implementation leaders Owners of government initiatives

Final considerations

RS has great wind and solar potential for the development of GH_2 projects

Current economy, infrastructure and strategic position for GH_2 projects

Current and projected internal and external demands are adequate for scaled-up developments

GH_2 plays a central role in helping the world achieve carbon neutrality by 2050 and limiting global warming to 1.5°C

GH_2 is key to enabling a decarbonized energy system

Competitive GH_2 production costs in the national and international scenario

More information about GH_2 in Rio Grande do Sul:

STATE DEPARTMENT FOR ENVIRONMENT AND INFRASTRUCTURE

h2v@sema.rs.gov.br

GOV RS

NOVAS FAÇANHAS

estado.rs.gov.br