Rio de Janeiro, Brazil

The German Chamber Network

Policy Paper Green Hydrogen and Fuel Cells in Brazil:

Context Overview and Outlook

Prepared by The German Chamber of Industry and Commerce Rio de Janeiro

for German-Brazilian Energy Partnership

November 21st, 2019

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26

Table of contents

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26

List of abbreviations

ABH2	Associação Brasileira do Hidrogênio *Brazilian Hydrogen Association*
ABNT	Associação Brasileira de Normas Técnicas *Brazilian Association of Technical Standards*
AHK	Câmara de Comércio e Indústria Brasil-Alemanha *German-Brazilian Chamber of Commerce and Industry*
BNDES	Banco Nacional de Desenvolvimento Econômico e Social *Brazilian National Bank for Economic and Social Development*
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMBF	Bundesministerium für Bildung und Forschung *Federal Ministry of Education and Research*
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur *Federal Ministry of Transport and Digital Infrastructure*
BMWi	Bundesministeriums für Wirtschaft und Energie *Federal Ministry of Economic Affairs and Energy*
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung *Federal Ministry for Economic Cooperation and Development*
CENEH	Centro Nacional de Referência em Energia do Hidrogênio *The Brazilian Reference Center for Hydrogen Energy*
CGEE	Centro de Gestão e Estudos Estratégicos *Center for Management and Strategic Studies*
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico *National Council for Scientific and Technological Development*
CO2	Carbon dioxide
COPPE/UFRJ	Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia da Universidade Federal do Rio de Janeiro *Alberto Luiz Coimbra Institute for Graduate Studies and Engineering Research of Federal University of Rio de Janeiro*
ECA	Export Credit Agency
EEG	Erneuerbare-Energien-Gesetz *German Renewable Energy Sources Act*
EMTU/SP	Empresa Metropolitana de Transportes Urbanos de São Paulo *Metropolitan Company of Urban Transport of São Paulo*
EP	German-Brazilian Energy Partnership
EPE	Empresa Brasileira de Pesquisa Energética

	Energy Research Office
Faperj	Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro *Research Support Foundation of the State of Rio de Janeiro*
Fetranspor	Federação das Empresas de Transportes de Passageiros do Estado do Rio de Janeiro *Federation of Passenger Transport Companies of the State of Rio de Janeiro*
Finep	Financiadora de Inovação e Pesquisa *Brazilian Financier of Studies and Projects*
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH *German Society for International Cooperation*
GW	Gigawatt
HFC	Hydrogen and Fuel Cells
IEC	International Electrotechnical Commission
Inmetro	Instituto Nacional de Metrologia, Qualidade e Tecnologia *National Institute of Metrology Standardization and Industrial Quality*
IPHE	International Partnership for the Hydrogen Economy
ISO	International Organization for Standardization
Itamaraty	Ministério das Relações Exteriores *Ministry of Foreign Affairs*
KfW	Kreditanstalt für Wiederaufbau *Credit Institute for Reconstruction*
LABH2	Laboratório de hidrogênio da COPPE/UFRJ *Hydrogen Laboratory of COPPE/UFRJ*
MW/h	Megawatt hours
MME	Ministério de Minas e Energia *Ministry of Mines and Energy*
MW	Megawatt
NIP	Bundesförderung Wasserstoff und Brennstoffzelle *National Innovation Program Hydrogen and Fuel Cell Technology*
NOW	Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie *National Organization for Hydrogen and Fuel Cell Technology*
PEMFC	Proton-exchange membrane fuel cell
PROCaC	Programa Brasileiro Sistemas Célula a Combustível *Brazilian program for hydrogen and fuel cell systems*
ProH2	Programa de Ciência, Tecnologia e Inovação para a Economia do Hidrogênio *Science, Technology and Innovation Program for the Hydrogen Economy*

RD&I	Research, Development and Innovation
SOFC	Solid oxide fuel cells
TW/h	Terawatt hours
UFRJ	Universidade Federal do Rio de Janeiro *University of Rio de Janeiro*
UNDP	United Nations Development Program
UNICAMP	Universidade Estadual de Campinas *University of Campinas*
WHEC	World Hydrogen Conference

1. Context

Since 2008, the Brazilian and German governments have collaborated in an energy partnership led by the German Federal Ministry of Economic Affairs and Energy (BMWi), the Brazilian Ministry of Mines and Energy (MME) and the Brazilian Ministry of Foreign Affairs (Itamaraty). The "Brazil-Germany Energy Partnership" was signed through the "Agreement on Cooperation in the Energy Sector" in May 2008, approved by the National Congress in the following year and ratified by the President of the Brazilian Republic in March 2012. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was appointed as the Energy Partnership Secretariat (EP). In addition to the EP between Germany and Brazil there are similar partnerships with other countries on a global level, all of which are supported by a support and coordination structure in Berlin called the "Global Bilateral Energy Partnership Program", which also takes responsibility for maintaining a close association with the BMWi.

The purpose of the EP is to strengthen bilateral dialogue and cooperation between Brazil and Germany in the energy sector, in particular renewable energy and energy efficiency. It is based on support for the already successful cooperation between the two countries.

The main objectives of the EP are the promotion of exchange of experiences between the two countries and the dissemination of the use of clean energy sources in Brazil. The intention is to improve the energy systems in both countries, especially by increasing the use of renewable energy and energy efficiency technologies and resources.

Other partnership purposes are:

- To facilitate a government dialogue on effective and efficient strategies for a safe, green and economic energy supply system;
- To provide an overview of the bilateral activities of the Brazilian-German cooperation;
- To involve private and civil stakeholders from Brazil and Germany in the variety of forms of dialogue that can provide technical solutions and expertise for the energy supply systems.

In this context, the relevance of the production of specific studies and projects for different sources, solutions and technologies in the field of renewable energies is particularly striking in order to contribute to the promotion of the performance of the "Brazil-Germany Energy Partnership".

The use of "green" hydrogen generated by electrolysis from renewable energy sources can contribute significantly to the decarbonization of industrial processes and the transport sector.

Furthermore, the high availability of renewable energy in Brazil allows the country to build new business opportunities by exporting green hydrogen and contribute to the CO_2 reduction goals of other countries in Europe and Asia which less access to renewable resources

In this context, the following strategy paper should contribute to the further development of the green hydrogen technology and market, analyzing the technology status in Brazil, the political and social environment, as well as the opportunities and challenges for the implementation of this new and promising technology.

It is worth mentioning that this document was prepared based on the impressions gathered from the Green Hydrogen Lab project, which brought together several stakeholders from the hydrogen and fuel cell sector (entrepreneurs, universities and governments) in São Paulo on 4th and 5th November 2019. It discussed the challenges and opportunities in the (green) hydrogen sector in Brazil, projects to promote the hydrogen economy in Brazil and proposals to reduce bureaucratic obstacles. Furthermore, a number of studies and articles on the hydrogen market in Brazil were consulted to support the preparation of this paper. In particular the study " Hydrogen Energy in Brazil: Subsidies for Competitiveness Policy,2010-2025; Critical and Sensitive Technologies in Priority Sectors", prepared in 2009 by the Center for Management and Strategic Studies (CGEE), a social organization composed of the most important scientists of the sector in Brazil and supervised by the Ministry of Science and Technology.

2. Use of hydrogen and market potential for green hydrogen in Brazil

Worldwide, in 2019 around 70 million tons of hydrogen are used, mostly for oil refining and chemical production, almost entirely supplied from fossil fuels, with 6% of global natural gas and 2% of global coal going to hydrogen production.

Therefore, the production of hydrogen is responsible for CO2 emissions of around 830 million tons of carbon dioxide per year, equivalent to the CO2 emissions of the United Kingdom and Indonesia combined.

Nowadays, nearly 100% of hydrogen has been used in chemical and transformational processes. Application in transportation or energy sector are still in pilot phases and need more investment and initiatives to be transformed in a competing alternative to currently existing and fossil-based fuels. In this chapter it will be highlighted where hydrogen is currently being used and can substitute fossil sources to contribute to the overall reduction of CO2 in the atmosphere.

Hydrogen today is mainly used as an industrial input in several chemical and transformational processes. Introducing hydrogen based on renewable energy sources (green hydrogen) can be seen as a first step to reduce overall carbon load for these kinds of demand. Technology for application don't need to be changed, only the source of supply.

2.1 Chemical application

Globally, the top four single uses of hydrogen are oil refining (33%), ammonia production (27%), methanol production (11%) and steel production via the direct reduction of iron ore (3%)[1].
In Brazil, the market approaches 920 thousand tons per year. The main sectors responsible for this growth are the oil refineries (production and improvement of fuels) and fertilizer industry (production of ammonia), followed by food and beverage industry (production of hydrogenated fats), steel plants, the semiconductor industry and others, whereby 95% of this hydrogen is obtained from fossil sources.

In oil refining, the hydrogen is used mainly to remove impurities from crude oil and upgrade heavier crude. In the chemical production, it is an important input for the ammonia production (fertilizer) and methanol production. It is expected that there will be a future increase in the consumption due to economic and population growth. In the iron and steel production hydrogen is required in the Direct Reduced Iron (DRI). As steel production is one of the major CO2 emitter,

[1] https://webstore.iea.org/login?ReturnUrl=%2fdownload%2fdirect%2f2803

a couple of research activities are under way to also use hydrogen in production process, e.g. to substitute natural gas as reduction component.

Obviously, costs are the major driver or inhibitor for the substitution. In oil refining, hydrogen costs strongly influence refining margins, same as in other before mentioned industry applications. In order to stimulate the substitution, an increase of the conventional H2 prices is needed which is being done in developed countries by introducing carbon load taxes. Unfortunately, due to the current economic crisis there, no actions are foreseen in Brazil in this direction which makes the introduction of green hydrogen as process inputs difficult.

2.2 Transportation application

Another application is the introduction of hydrogen as a new source of energy to be used for example in land-based transportation like cars and trucks, but also as fuel for aviation and maritime application.

Using hydrogen instead of fossil fuels in energy end uses could reduce local air pollution, improving environmental and health outcomes. Urban air pollution concerns and its related health impacts and global warming are now major drivers of energy policy decisions, and governments are keenly interested in ways of reducing not only the overall CO2 emissions. But as well air pollution and improving air quality in the cities. When used in vehicles, hydrogen does not produce particulates or Sulphur oxides or raise ground-level ozone (Stephens-Romero et al., 2009). When used in a fuel cell, hydrogen does not produce nitrogen oxides.

Use hydrogen in transportation vehicles like cars and trucks is already worldwide a well-known and approved technology but a missing consistent and stable refueling distribution chain is hindering its further expansion and raising overall fuel costs for this kind of new technology. Nevertheless, some pilot projects for hydrogen busses in Brazil were already executed in São Paulo and Rio de Janeiro (more details in Chapter 5 of this report) but are threatened to be stopped due to missing further investment and political support.

To mitigate the missing refuel stations and continue to use current vehicles, a big effort is currently done globally and also in Brazil to produce synthetic fuels based on green hydrogen and biomass as carbon carrier. In Brazil, automakers and their suppliers are working on some sustainable, low-carbon emitting solutions like “Hydrotreated Vegetable Oil” (HVO), using biomass and hydrogen to produce biodiesel. These kinds of projects are partially financed and supported by the federal program “Rota 2030” which uses tax reductions to stimulate investment in research & development with the objective of energy efficiency. HVO is also being a bet for German companies like Bosch, BASF, Mahle and Mercedes looking for the big truck and bus market in Brazil.

2.3 Energy generation and storage

Despite the large quantity produced, only a small portion of the hydrogen generated as a by-product of chemical processes is used for energy purposes, mainly for heat production in local applications. For this reason, it can be stated that currently the market for hydrogen energy is imminent. This is mainly because hydrogen cannot compete economically with other long-established energy options in the market[2].

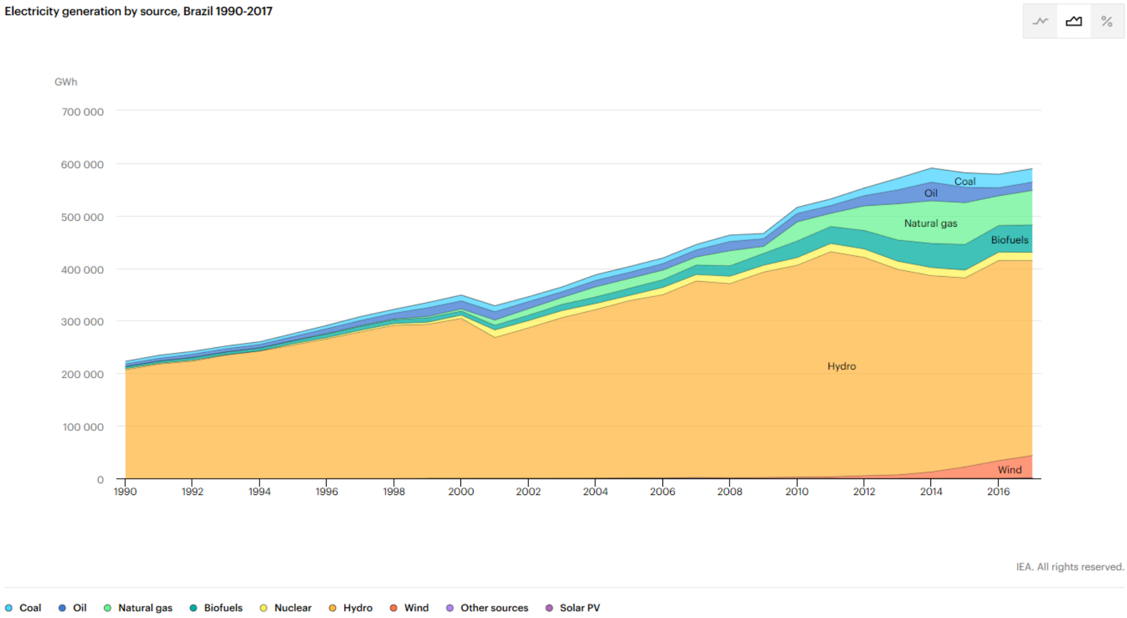
An interesting aspect about hydrogen is, that it is not an energy source but an energy carrier, which means that its potential role has similarities with that of electricity. Both, hydrogen and electricity can be produced by various energy sources and technologies. Both are versatile, they can be used in many applications and are free of greenhouse gas emissions, particulates, Sulphur oxides or ground level ozone.

The crucial difference between hydrogen and electricity is that hydrogen is a chemical energy carrier, composed of molecules and not only electrons. Chemical energy is attractive because it can be stored and transported stably, as it is done today with oil, coal, biomass and natural gas. The great advantage of the molecular effect and its storage facility is that it is a perfect partner to leverage generation and demand in flow-based energy systems. Energy generation exceeding the current demand can be by-passed to an electrolyzer, generating hydrogen, stored and injected back with nearly no losses when demand exceed current capacity, contributing significantly to energy system resilience showing an interesting tactical element for hydropower and wind energy plants.

Brazil's energy policy is well positioned against the world's most urgent energy challenges. Total primary energy demand has doubled in Brazil since 1990, led by strong growth in electricity consumption and in demand for transport fuels on the back of robust economic growth. Brazil's energy mixture with a high amount of hydropower plants make the country one of the least carbon-intensive in the world.

Large hydropower plants account for around 80% of domestic electricity generation, giving the electricity system a great deal of operational flexibility. Reliance on other sources for power generation is growing, notably natural gas, wind and bioenergy. It is expected that especially natural gas will gain more space in the upcoming years due to still unexplored gas-fields in the deep-water area "pre-salt".

[2] http://www.abh2.org.br/congresso/images/Coluna_Opiniao_Dezembro_-_Energia_do_Hidrogenio_2-compactado.pdf



Source: Electricity generation mix Brazil 1990 – 2017 in https://www.iea.org/countries/brazil#analysis

The positive effect of hydrogen storage cannot be used only for major hydropower plants or wind energy parks, but also in lesser extent, using residential photovoltaic installation. The current most common and financially interesting distributed generation using net metering model to transfer surplus power onto the public-utility power grid is under threat. The latest discussion around the Resolution 482 from ANEEL has shown that the current financial payback received will be reduced significantly. With this new scenario a fully independent PV installation can be more attractive, using hydrogen as an energy storage solution.
Generally said, market conditions for the implementation of green hydrogen solutions are getting more attractive, although the current economic situation requires other priorities than CO_2 reduction and public investment in alternative and more sustainable energy solutions.

3. Sources of hydrogen and the Brazilian energy matrix

In 2018, 83.3% of the electric energy supply in Brazil has been generated from renewable sources, which 66.6% comes from hydropower. In many hydroelectric plants, while water inflows are greater than demand, part of this water that could be used to generate energy is spilled by the dam gates and literally wasted. This wasted hydroelectric potential could be used to generate green hydrogen through water electrolysis[3]. According to Panik *et al.* (2017), the virtual energy available for this application may be estimated taking for example Itaipu's power plant, where around 3,8% of the poured energy is not used for consumption corresponded to an average of 4,0 TWh in 2016. If all hydraulic, non-explored potential, were at stream course and had the same utilization level as Itaipu, more than 28 TWh/year could be used for producing hydrogen. Furthermore, wind and solar energy are experiencing significant growth in the country and represent an additional potential which can be used for electrolysis applications.

Only from January to August 2019, wind power generation in the country grew 14.7% reaching 5,501.52 MW. This growth is due to the large expansion of projects carried out in this area. In addition, 1.2GW of photovoltaic solar energy was installed in Brazil in 2018, a growth of 50% in that year alone, totaling 2.4 GW of installed capacity[4]. Fortunately, the drought period in winter, which affects the availability of hydropower, coincides with higher wind availability and the sugar cane harvest, which provides large quantities of biomass. Considering the importance of agriculture in the country, there is a remarkable availability of biomass as well as a great potential for solar energy in the country as it has a considerable number of solar irradiation (number of sun hours) over 3000 hours per year. These facts enable Brazil to produce Hydrogen for various purposes and also to use it as an energy generator and storage.

According to Mr. Paulo Emílio V. de Miranda, one of the leading hydrogen experts in Brazil, "The transition to the hydrogen energy era is considered inexorable and will be made with a strong participation of renewable energies. Hydrogen is an energy carrier. It is a versatile, clean and safe energy carrier that can be used to produce electricity, heat, power and still finds application as raw material in the industry"[5].

The Clean Energy Partnership project, sponsored by the German Federal Ministry of Transport and Digital Infrastructure (BMVI) and conducted by the National Organization Hydrogen and Fuel Cell Technology (NOW), defines green hydrogen as the one produced exclusively from 100% renewable energy sources. Thereby, renewable energy sources are defined as renewable

3 https://repositorio.ufsm.br/bitstream/handle/1/8486/CARNIELETTO%2c%20RENATA.pdf?sequence=1&isAllowed=y

4 http://www.absolar.org.br/infografico-absolar-.html

5 http://www.abh2.org.br/congresso/images/Coluna_Opiniao_Dezembro_-_Energia_do_Hidrogenio_2-compactado.pdf

according to the German Renewable Energy Sources Act (EEG), which include hydroelectric power, wind power, solar radiation energy, geothermal energy, biomass, landfill gas, sewage gas and methane. However, the production of hydrogen from biomass has to be carried out in a certified green thermochemical or biological conversion process and the reduction of CO2 in processes for the production of hydrogen from biomass has to be demonstrated compared to the process for the production of hydrogen from natural gas reforming[6].

Given the large participation of renewable energy sources in the Brazilian energy matrix, the enormous potential for the production and use of green hydrogen in Brazil is obvious. In this regard, the main sources with great potential for such production are: solar, wind, biomass, water and biogas.

As pointed out in the study "Hydrogen energy in Brazil: subsidies for competitiveness policies, 2010-2025, the great advantages of using hydrogen as an alternative energy source to the other existing ones would be:

- Reduction of environmental impacts in the generation and use of energy;
- Increased energy security;
- Improving the use of natural resources;
- Regional development;
- Development of a competitive industrial parks;
- Generation of job opportunities;

Nevertheless, the recent discoveries of large natural gas fields offer a threat to the expansion of green hydrogen in the Brazilian energy matrix.
After the discovery of these gas sources, mainly in the pre-salt area and the full implementation of the gas Brasil-Bolivian gas pipeline in 2010 and the pipeline Urucu-Coari-Manaus in 2009, the consumption has grown significantly and its story is still not at an end.
Due to the facility in energy generation and an existing infrastructure, NG is for Brazil seen as the energy source of the future.

The government is supporting this tendency by deregulating the gas market – upstream and downstream – to attract foreign companies to invest in exploration and distribution. Strategically, it is very attractive to use national NG to have a self-sustained energy matrix. Whereas hydropower plants are coming to their limit of social and environmental acceptance, in the near future the increasing demand of energy – for electricity and transportation – will certainly be covered with natural gas.

6 https://cleanenergypartnership.de/fileadmin/Assets/user_upload/Definition_von_Gru__nem_Wasserstoff.pdf

As we have seen above, stable technology for generation, storage and distribution for green hydrogen still need to be developed and requires further public incentives. As the government is still focusing on fossil fuels, green hydrogen implementation only has a chance to create a stable market representation when receiving incentive and support from developed countries who are looking for future use and application of this technology.

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26

4. Brazilian market environment and socio-economic landscape

4.1 Political Environment

In 1999, the Ministry of Science and Technology included the ethanol reform agenda for hydrogen production in the Brazilian science agenda for the first time. This interest was either focused on environmental, as such economic aspects, and one of the main goals was to satisfy the demand from Brazil and other Latin American countries.

However, such an initiative that had not been formalized until 2002, when the Brazilian Program for Hydrogen and Fuel Cell Systems (PROCaC) was formally established. The aim of this program was to establish research networks focusing on hydrogen and fuel cell technologies. The studies carried out under this program show that there is a concentration of research efforts in the areas of: i) Proton-exchange membrane fuel cell (PEMFC); ii) solid oxide fuel cells (SOFC); and iii) catalysts and systems for ethanol reform.

In November 2003, the International Partnership for the Hydrogen Economy (IPHE) was established. This partnership is an international effort with the purpose of organizing and effectively implementing international research, development, commercial use and demonstration activities related to hydrogen and fuel cell technology. Furthermore, the IPHE has been designed to be a forum for advanced policies, standards and common technical standards that can accelerate the cost-effective transition to a hydrogen economy and educate and inform stakeholders and the public of the benefits and challenges of integrating hydrogen-related technologies into the market. Sixteen partners originally formed the IPHE, including Brazil, Germany, Australia, Canada, China, the European Commission, the Russian Federation, the United States, France, India, Iceland, Italy, Japan, Norway, the Republic of Korea, and the United Kingdom. Subsequently, New Zealand and, more recently, South Africa joined the partnership.

As a complementary program to the Brazilian program for hydrogen and fuel cell systems (PROCaC), the Program for Science, Technology and Innovation for the Hydrogen Economy (ProH2) was established in 2002. This complementary program was set up with the aim of developing international partnerships in the field of applied research and development of hydrogen, increasing the investment volume for research, making the use of available financial resources more efficient and better coordinating the activities of the participating research groups, in particular in organizing the results achieved and the continuance of work, in finding solutions to the technological bottlenecks.

As regards the formalization and commitment of the government to the development of a hydrogen economy policy in the country, it was only in 2005 that the Ministry of Mines and

Energy (MME) adopted the document "Road map for the Structuring of the Hydrogen Economy" (*Roteiro para a Estruturação da Economia do Hidrogênio no Brasil*) published. This document until today has been presented as the most important government document on this subject, in which concrete targets are introduced to the development of hydrogen as an alternative energy source compared to other renewable energies in Brazil and in which the following premises should serve as a guideline for the creation of a market development model for hydrogen:

• Diversification of the Brazilian energy matrix with growing participation of renewable fuels;
• Reduction of environmental impacts, especially those arising from air pollution in large urban areas;
• Reducing external dependence on fossil fuels;
• Production of hydrogen from natural gas in the next ten years;
• hydrogen production from renewable energy sources, with an increased focus on the use of ethanol;
• Development of a technological base to provide reliability to consumers, and;
• planning the involvement of the national goods and services industry in the development of the new economy.

Based on the above-mentioned premises, the Ministry of Mines and Energy highlights the necessity of increasing gradually the importance of hydrogen in the Brazilian energy matrix. In this sense, it is intended to start with the production of hydrogen from fossil fuels in the next ten years up to the production of green hydrogen from renewable energy sources with a focus on ethanol reform and biomass. Biomass is more or less abundant in all major regions of the country and currently accounts for 8,4% of the Brazilian energy matrix, due to the enormous expressivity of the agricultural industry in the economy. Thus, the use of ethanol and biomass for hydrogen production in Brazil is justified by the high availability of such resources.

Finally, it is also worth mentioning that for green hydrogen there is still no specific target in terms of deadline set in the document "Road map for the Structuring of the Hydrogen Economy".

Both documents, Road Map for the Structuring of the Hydrogen Economy in Brazil and the Science, Technology and Innovation Program for the Hydrogen Economy (ProH2) highlight that in the Brazilian scenario, with high benefit from renewable sources, hydrogen production should, primarily, be undertaken by:

- Ethanol reform
- Biomass gasification
- Water electrolysis using renewable sources of electricity generation

The Road map for Structuring the Hydrogen Economy in Brazil highlights that water electrolysis, ethanol reform and processes based on biomass are the key priorities for hydrogen production.

The production of hydrogen, through the electrolysis of water, will play a major role in countries that have great potential for renewable energy production, as in the case of Brazil.

Even though the conventional water electrolysis process is dominated abroad, there is not many suppliers offering this technology in Brazil. One of the well-known suppliers is the company Hytron[7], a spin off established 2013 at the campus of the Brazilian University of Campinas (UNICAMP).

Besides obtaining hydrogen from electrolysis with water, there are other processes that could be used such as ethanol reform or biomass gasification. The ethanol reform process is currently in the pre-industrial development phase, but still requires progress in basic research on catalysts, reactor technology, purification processes and plant balance. The Hydrogen production processes from biomass derivatives such as glycerin and bio-oils enable the use of by-products with low added value and diversify the hydrogen sources. Although these technologies are promising, they still represent many technological bottlenecks.

Nevertheless, in the short term, hydrogen production of chemical raw materials is an expanding market and represents an existing potential. The use of hydrogen based on renewable energies as a chemical energy carrier can reduce the environmental impact of production facilities.

Furthermore, some tax incentives for fostering the hydrogen economy are already in place in Brazil. On a national level the import taxes for electrical and fuel cell cars has been eliminated since 2015 (Resolução Camex Nr. 97/2015, updated thereafter by Resolução Camex Nr. 82/2015). In the state of São Paulo, the regulation “Portaria 063/2015” reduced by 50% the state tax for electrical, hydrogen and hybrid vehicles. Similar project is already ongoing at the state senate of Alagoas, and there is a trend that also other states join this tax incentives.

4.2 Social Environment

After the initial steps from the Brazilian government in the early years of 2000, the further development of the hydrogen technology is mostly based on research institutes in universities and some isolated initiatives. In the last years some social society organizations as universities, other institutes and enthusiastic entrepreneurs are working on developing a hydrogen ecosystem to promote the technology and join forces for development. Here are a few examples to demonstrate this development.

[7] https://www.hytron.com.br/

4.2.1 The Brazilian Hydrogen Association (ABH2)

The Brazilian Hydrogen Association (ABH2) is a non-profit association founded in April 2017 dedicated to hydrogen research in Brazil. As an obligation, the organization has made it its business to promote cooperation between individuals, companies and research groups with the aim of advancing the development of the hydrogen sector and to promote cooperation with domestic and foreign actors. Thus, the ABH2 promotes among other things the development of scientific, technological and innovative studies and research work, as well as training programs in the fields of hydrogen and hydrogen energy as well as the development of cooperative activities between research groups and institutions, development agencies and companies in the sector in order to increase the degree of interaction and cooperation between academic, scientific and technological communities, public authorities, financial institutions.

Recently ABH2 organized the first national congress to discuss the main challenges and opportunities in Brazil. The congress was held in the campus of COPPE/UFRJ on the November 7th and 8th with the goal of encouraging scientific and technological research in the areas of hydrogen energy and to promoting actions of cooperation between scientific institutions, development agencies and companies in the area. It was considered very successful for its first edition and gathered the most relevant players of the hydrogen sector in Brazil, such as universities (COPPE/UFRJ), gas producers and distributers (Oxiteno), hydrogen consumers (Toyota), technology providers (Hytron), regulation agencies (Inmetro) and energy supply (Furnas Centrais Elétricas S.A.)[8].

4.2.2 Research Laboratory

Hydrogen Laboratory (LABH2), COPPE - Federal University of Rio de Janeiro
The hydrogen laboratory of COPPE/UFRJ (LabH2 - COPPE/UFRJ) in the university campus of the Federal University of Rio de Janeiro, was founded 35 years ago by Professor Paulo Emílio de Miranda with the aim of expanding research in the field of hydrogen in materials. With the development of hydrogen-related technologies over the years, the laboratory began to focus primarily on hydrogen energy. Current developments include solid oxide fuel cells and heavy-weight electro-powered vehicles as well as on-board power generation with a fuel cell.

-Website: LABH2: http://www.labh2.coppe.ufrj.br/index.php/pt/sobre-o-labh2/o-laboratorio

[8] http://www.abh2.org.br/congresso/index.php/pt/programacao

5. Implemented Hydrogen Projects in Brazil

Although there are concrete manifestations about the intention of promoting and developing a hydrogen economy in Brazil, it is important to highlight that until now there has not been a large volume of projects carried out in this field. Two of the main projects in the field of mobility will be presented below:

Project 1 - Hydrogen Bus Project in São Paulo

According to the Brazilian public company Financier of Studies and Projects (Finep), Brazil was the first country in Latin America to have a fleet of buses powered by hydrogen cells. The Brazilian Hydrogen Bus Project, which represents the starting point for the development of a cleaner solution for the urban public transport, was coordinated by the Metropolitan Company of Urban Transport of São Paulo (EMTU/SP) and directed by the Brazilian Ministry of Mines and Energy (MME). The initiative had two main sources of resources: R$ 8.4 million from Finep and US$ 12.3 million from the Global Environment Facility (GEF), applied through the United Nations Development Program (UNDP).

The design and manufacture of the buses were developed by a consortium formed by eight national and international companies: AES Eletropaulo, Ballard Power Systems, Epri, Hydrogenics, Marcopolo, Nucellsys, Petrobras Distribuidora and Tutto Trasporti. In June 2015, three buses were delivered to the state of São Paulo and integrated into the inter-municipal bus fleet managed by EMTU/SP. Work began on the 287P Piraporinha to Santo André Line, a route that is in great demand by users.

The propulsion technology used is completely free of pollutant emissions. Instead of carbon dioxide and other emissions from ordinary cars, only water vapor is eliminated by the exhaust from those buses.[8]

Project 2 - Hydrogen Bus Project in Rio de Janeiro

Brazil's first hydrogen bus with 100% national technology was launched in 2010. The vehicle, developed by The Alberto Luiz Coimbra Institute for Graduate Studies and Engineering Research (COPPE), a unit of the Federal University of Rio de Janeiro (UFRJ) - Coppe/UFRJ in partnership with the Federation of Passenger Transport Companies of the State of Rio de Janeiro (Fetranspor) and the municipal and state transportation secretariats, is considered the evolution of urban transportation. The bus is financed by Finep, Petrobras, National Council for Scientific and Technological Development (CNPq) and Research Support Foundation of the State of Rio de Janeiro (Faperj). This vehicle circulates in the UFRJ, transporting teachers, students and employees.

With the same size and appearance as a conventional urban bus, the vehicle has a low-level entrance, air conditioning, space for the boarding of disabled people and autonomy to run up to

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26

300 kilometers. The electric energy obtained from an outlet connected to the electric grid is moved and complemented with energy produced on board by a fuel cell fed with hydrogen. This means a silent vehicle, with much greater energy efficiency than conventional diesel buses and with zero emission of pollutants. What comes out of its discharge pipe is just water vapor, so clean that if condensed, it would result in drinking water.

Its pioneering spirit lies in the fact that all the important technological equipment and subsystems for this application have been developed in Brazil. The electric traction system offers smooth starts and displacements and allows to optimize its performance in function of the running-cycle. The buses developed at Coppe have the same kinetic energy recovery system used by Formula 1 cars. The difference is that in Formula 1 this system is aimed at speed gain and Coppe buses to increase energy efficiency and save fuel.

The buses from both pilot projects are quiet, non-polluting, with a high rate of availability for use, comfortable for the driver and passengers, provide mass transportation and have the advantage of performing centralized refueling in the garage, which simplifies the required infrastructure. This may be an important factor for combating urban pollution in large Brazilian cities, where its use is intense. About 18,000 buses run in the Metropolitan Region of Rio de Janeiro. The fact that Brazil is a major bus producer, with national factories makes this attack easier. This fact does not occur in the field of automobiles, since the broad spectrum of factories installed here is made up of foreign companies. Brazil today has an advantage over other countries because it was the only country in the world to have already made a large-scale and successful transition of automotive fuel, but its vehicle manufacturers with flex fuel engines are transnational and may themselves migrate to another technology not dominated in the country. Corporate fleet vehicles, such as light commercial vehicles and buses, represent current niches in the application of electric mobility with hydrogen, due to the decreasing financial difference with conventional ones, the facilities in terms of infrastructure required for refueling and maintenance and, mainly, due to the immense environmental advantages. In some cities, such as Stuttgart, Germany, the population decided to sue the municipality for not providing a clean urban environment[9].

6. Main Challenges in the Development and Use of HFC in Brazil

Research, Regulation and Investments

A very important milestone in the assessment of the main challenges in the development of a hydrogen economy in Brazil was the publication in August 2010 of the document Hydrogen energy in Brazil "Critical and sensitive technologies in priority sectors. Subsidies for

[9] http://www.finep.gov.br/a-finep-externo/aqui-tem-finep/onibus-a-hidrogenio

competitiveness policies: 2010-2025" *(Hidrogênio energético no Brasil. Tecnologias críticas e sensíveis em setores prioritários. Subsídios para políticas de competitividade: 2010-2025)*.
This extensive document, prepared by the Center for Management and Strategic Studies (CGEE), a Social Organization formed by the main scholars of the sector in Brazil and supervised by the Ministry of Science and Technology, points out the main challenges for the development of hydrogen economy in Brazil and presents several proposals for diminishing these barriers. Thus, for a better comprehension of these main challenges the most relevant points of this document will be presented below.

Regarding to research and development, Brazil started very enthusiastic in the beginning of this century, mainly driven by the public initiatives a described above. Unfortunately, due to the economic crisis in the last years and reductions on public financial support, the research and number of publications in the field of green hydrogen went down in the last years.
Brazilian investments, of public and private origin, in hydrogen technologies, between 1999 and 2007, totaled approximately R$ 134 million, which corresponds to 25% to 35% of the individual investments made by Russia, India, China or South Korea, and only 3% to 5% of the investments made by Japan, the European Union or the USA[10]. There are currently no confirmed numbers of investment made in research in recent years.
In addition to the significantly lower financial volume, bureaucratic difficulties prevent the efficient use of the resources.

Furthermore, although there is great synergy between the areas, there are no joint programs on the use of alternative renewable sources of electricity generation (solar photovoltaic, wind, biomass gasification) and the use of hydrogen and fuel cells. In Brazil, expect the two projects presented on Chapter 5, there are practically no demonstration projects on hydrogen technologies, either with fuel cells, with hybrid systems or in the segment of production and storage of hydro-genie. Such projects are fundamental to give visibility to the technologies considered and also enable the evaluation of systems and their components in real situations and in long-term tests. Thus, there is little or no public dissemination of information about hydrogen technology, its positive and negative points and impacts, affecting the social receptivity about these technologies.
The demonstration of the projects can improve the interaction between RD&I groups and companies in the area of hydrogen technologies, encouraging the displacement of basic research towards applied research of RD&I activities developed in Brazil, besides contributing to the increase of durability (life time) and to reduce the production costs of materials, devices, components and systems.

[10] Hidrogênio energético no Brasil: subsídios para políticas de competitividade, 2010-2025. P. 17.

In addition to the presented points, four other factors are considered by the Brazilian Center for Management and Strategic Studies (CGEE) as critical for the development of hydrogen generation and use in Brazil. The first refers to the absence of a production scale for equipment developed in Brazil, which is essential for them to become competitive.
On the other hand, the international competition factor pointed out by CGEE as the second factor, is solved only with intense government investment and commitment in encouraging the development of a national and internationally competitive (green) hydrogen production chain.
As a third factor, the norms and standards are pointed out. There is an insufficient volume of national norms and standards related to the energy use of hydrogen. The existing standards are translations of International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) standards, which have few effective contributions from Brazil, although today the Brazilian Association of Technical Standards (ABNT) is a voting member of the ISO Hydrogen Technical Committee and an observer of IEC.
There are still no laboratories or national research institutions capable of certifying all equipment and processes developed in the industry or offering certified training in operation and safety.
Finally, the CGEE points out the research institutes, companies and researchers linked to the development of hydrogen technologies that do not have an official representative body of their interests. This latter critical factor has been solved with the creation of the a Brazilian Hydrogen Association (ABH2) in April 2017.

7. Opportunities for cooperation between Brazil and Germany

There are currently several possibilities for a cooperation between Germany and Brazil in the hydrogen sector, it is presumed that with the scale up of the investments in the hydrogen economy, the possibilities, and variety of cooperation should even increase. Some possible cooperation partners so as some project opportunities are listed below.

7.1 Institutional Level

7.1.1 ABH2

As already presented in Section 4, the organization is committed to establishing cooperation between individuals, companies and research groups and the government at national and international level to advance research in the field of hydrogen.

Among an information network, publications and other issues the organization plans and organizes scientific events for researchers e private companies in the HFC field with the aim of keeping abreast of all aspects of scientific research and technological innovation. The holding of the World Hydrogen Conference (WHEC) in Brazil is considered to be particularly important in this context. In this sense, the 22nd edition of the WHEC, which took place from June 17th to 22nd 2018 reunited after 26 years of the United Nations Conference on Environment and Development ECO 92 world leaders in Rio de Janeiro to discuss the most promising technologies towards sustainability for a hydrogen economy.
Furthermore, ABH2 organized this year the 1st Brazilian Congress of the Brazilian Hydrogen Association, which took place in November 2019.
Website: http://www.abh2.org.br/congresso/index.php/pt/

7.1.2 GIZ

In March 2018, the National Organization for Hydrogen and Fuel Cell Technology (NOW) and GIZ signed a cooperation agreement within the framework of the "Export Initiative Environmental Technologies" of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

As part of this export initiative, the partners intend to jointly establish a network in emerging and developing countries in order to advance projects for the climate-friendly use of hydrogen and fuel cell technologies.

7.1.3 AHK

The German-Brazilian chamber of commerce (Auslandshandelskammer - AHK Rio de Janeiro) has been promoting business relations between Brazil and Germany through comprehensive projects and services since 1916. The focus is on technology transfer, export and import, the search for new business partners and investments as well as the provision of relevant market information.

Under the service brand DEinternational, AHK network offers interested companies worldwide professional advice and support for the successful establishment and expansion of their business activities abroad. Including services such as market studies and support in business partner mediation in various areas.

7.2 Concrete Projects Opportunities

The Green Hydrogen Lab, organized by AHK with the support of GIZ, German-Brazilian Energy Partnership and the Impact Hub on November 4th and 5th 2019 in São Paulo, gathered several stakeholders from the hydrogen sector in Brazil such as entrepreneurs, government organizations, development institutions, startups and enthusiasts of the theme. After two days of discussions of the topic guided by the design thinking methodology, six project proposals for the development of a green hydrogen economy in Brazil were developed. These projects differ in size, complexity and areas of action and will be briefly presented below.
It is imported to highlight that these projects are proposals and still in the study stage. Therefore, a business case for each project still needs to be developed in order to verify the viability including definition of the main indicators such as return of investment, opportunity costs, breakeven, premises and requisites.

7.2.1 Use of photovoltaic systems on roofs and open areas for green hydrogen generation

- **Problem statement**: Companies are using fossil HFC as inputs in their production process. The consumption is low (20-30m²/day), but it represents a double load of CO2 emission during generation and transportation.
- **Solution**: Creation of local HFC plants using roofs and other free areas for install of PV panels in order to use the electrical energy generated in the electrolysis and store the HFC in the form of gas.

- **Value proposition**: The proposed solution helps to replace in a small-scale basis hydrogen generated from fossil fuel with green hydrogen, decarbonizing the usage and eliminating transportation bringing savings to the user company.
- **Overview**: As a pilot project it is aimed to select thermoelectric plants that use hydrogen as cooling for steam turbines. The estimated daily consumption is estimated around between 20-30 m3 of HFC, currently purchased from fossil sources.

7.2.2 Green hydrogen in the mobility for transport of goods and people

- **Problem statement**: Brazil is using renewable sources like biomass ethanol for automotive fuels. But trucks and busses are depending on diesel fuel due to missing knowledge of green hydrogen fuel.
- **Solution**: Demonstration of the applicability and feasibility of green HFC in the transport of loads and people.
- **Value proposition**: Hydrogen production with national technology to fuel vehicles in real application and analyze the feasibility of replicable and sustainable business models.
- **Overview**: Demonstrate hydrogen production with national technology to fuel vehicles in real application and analyze the feasibility of replicable and sustainable business models, as a pilot project hydrogen powered buses will circulate in the University of Campinas.

7.2.3 Web Map for Hydrogen in Brazil

- **Problem statement:** Missing knowledge and alignment of public and private decision makers about hydrogen incentives programs.
- **Solution**: Create a Hydrogen WebMap to visualize the current and potential demand (volume and prices) in a georeferenced way.
- **Value proposition**: Enable and encourage decision makers to create a convergent vision of a hydrogen economy that complements the existing matrix and adds maximum value to the users and in Brazil
- **Overview**: Using the already available WebMap platform from Energy Research Office (EPE), which currently provides information regarding all the existing and planned energy infrastructure in Brazil, a feature regarding hydrogen will be created, pointing out the existing industrial demand and for potential future markets.

7.2.4 Production of green hydrogen on site at industrial hubs

- **Problem statement**: Consumption of hydrogen is currently far away from the generation plants, causing additional CO2 emissions for transporting with trucks.
- **Solution**: Production of "in loco" green hydrogen on site.
- **Value proposition**: The project helps reduce the emission of CO2, and other polluting gases, by replacing hydrogen distributed by trucks with on-site production.
- **Overview**: To map hydrogen consumers that are more than 300 km from the production source, select sites that have available / favorable resources for on-site production of green hydrogen. Thereafter, the project aims to enable a technical / economic solution with partners that allows the adoption of the new model, carrying out the installation of the HFC plant through the partner that has the most appropriate solution for the end customer.

7.2.5 Hydrogen House Project

- **Problem statement**: Absence of hydrogen use for small-scale generation, e.g. residential use.
- **Solution**: *Hydro-House Project*: Development of a pilot project to implement a green hydrogen storage system for small-scale power generation applicable to residences.
- **Value proposition**: On-site generation of energy from solar sources with replacement of conventional batteries by a hydrogen production and storage kit, collaborating to drive the spread of green hydrogen culture and creating a new solution for sustainable enterprises.
- **Overview**: Movement of decentralization in various sectors and distributed generation of energy are strong tendencies for the future. The project aims to explore the possibility of using green hydrogen for power generation and peak storage for decarbonization of residential energy supply.

7.2.6 Green Hydrogen Valley Rio de Janeiro - São Paulo

- **Problem statement**: The BR116, road connecting Rio de Janeiro and São Paulo is a zone with great environmental impact caused by the urbanization and accelerated industrialization along the approx. 600 km.
- **Solution**: Development of a vision of a green hydrogen valley along the BR116 between Rio de Janeiro and São Paulo with the objective to promote green hydrogen solutions in different sectors.
- **Value proposition**: This project aims to consolidate different activities of green hydrogen generation and usage along the axis between Rio de Janeiro and São

Paulo in order to promote the generation of Green Hydrogen and the interconnection and use in the industrial, residential and transportation sectors.

- **Overview**: Production of green hydrogen through renewable sources available in the region like biomass, agro-industrial waste, solar, small hydroelectric plants. Furthermore, the project aims a green hydrogen storage and distribution in fuel cell trucks for industry, vehicle service stations, and residential and commercial condominiums.

8. Funding Sources

8.1 Funding Sources in Brazil

Brazil has few sources of direct financing. The existing financing options are FINEP or edicts from large companies such as BNDES and Petrobras. Another possibility is private companies, which invests massively in RD&I.

8.1.1 The Brazilian Financier of Studies and Projects (Finep)

Finep is a Brazilian public company that promotes science, technology and innovation in companies, universities, technological institutes and other public or private institutions.
There are two forms of financing available: reimbursable and non-reimbursable, which cover several areas of scientific and technological development. Basic or applied research, innovation and development of products, services and processes, among other projects such as the implementation of technology parks and innovations in established companies, meetings, seminars, congresses and technology fairs.

Finep also acts in an increasingly intense way in supporting technology-based companies. Since 2000, from the Innovate Project, which involved a wide, structured and transparent set of actions to stimulate new companies. Through a range of instruments, it provides risk capital, indirectly via venture capital funds and directly via the proprietary fund (FIP Inova Empresa).

8.2 Funding Sources and development of HFC market in Germany

Germany promotes the development and market introduction of hydrogen and fuel cells via various instruments and institutions.

8.2.1 Funding Instruments

The central instrument of the German Federal Government is the National Innovation Program Hydrogen and Fuel Cell Technology (NIP). Since 2007, the NIP has included R&D funding as a cross-departmental program. The Federal Ministry of Transport and Digital Infrastructure (BMVI) made a significant contribution of 500 million EUR in the period from 2007 to 2016.
The aim of NIP has been to prepare the market for HFC technologies under existing Research, Development and Innovation (RD&I) Directives. The long-term ten-year program thus contributed to the emergence of an internationally competitive industry based on stable framework conditions and funding opportunities in Germany.

With the launch of fuel cell products in the early stages and the development of a hydrogen infrastructure for transport, it is now time to realign the NIP in its second phase. The aim is to make hydrogen and fuel cell technology competitive in the transport sector and in the energy market by the middle of the next decade. This can only be achieved with a continued joint effort of all actors.

The cornerstones of this were the joint "Government Program Hydrogen and Fuel Cell Technology 2016-2026 - from Market Preparation to Competitive Products" of the Federal Ministries of Transport and Digital Infrastructure (BMVI), Economic Affairs and Energy (BMWi), Education and Research (BMBF) and for Environment, Nature Conservation and Nuclear Safety (BMU).

8.2.2 National Organization of Hydrogen and Fuel Cells (NOW)

In order to coordinate and develop the national funding programs for HFC the aforementioned Federal Ministries established the National Organization of Hydrogen and Fuel Cells (NOW) in 2008.

The NOW is fully owned and funded by the German federal government, but stakeholders from other tiers of government, private sector and science are actively involved via an advisory council.

Most notably the NOW are funded by the German government on a long-standing basis, to ensure operational certainty and guarantee long-term strategic and sustainable operations. NOW receives 3 Mio. EUR annually over a period of 10 years. The budget covers the operational costs and 17 staff members (1,5 Mio. €), small strategy studies and dissemination (1.5 Mio. €).

8.2.3 Export Credit Agency (“ECA”) Funding

An export credit agency or investment insurance agency is a private or quasi-governmental institution that acts as an intermediary between national governments and exporters to issue export financing.

The financing can take the form of credits (financial support) or credit insurance and guarantees (pure cover) or both, depending on the mandate the ECA has been given by its government. Application of HFC technology will depend on imported equipment and services and as such could qualify for ECA support. It will have the effect of reducing the cost of bank debt funding that will form part of the sources of funding for the commercial development of the technology. For example, if the ECA support is provided by Euler Hermes, the German ECA, then the Brazilian banks will regard that amount covered by commercial risk insurance guarantee as German Government risk and not technology or sponsor/developer risk. This will have the effect of reducing the Bank’s overall cost of funding and accordingly the cost of funding available by a significant margin of between 2-3% over the Bank’s cost of funds.

8.2.4 Exportinitiative Energie

The Federal Government also supports companies in the development of foreign markets with the program "Exportinitiative Energie". The Export Initiative Energy of the Federal Ministry for Economic Affairs and Energy (BMWi) supports suppliers of climate-friendly energy solutions in entering foreign markets. New technologies such as power-to-gas or fuel cells are also moving into focus. The strategic selection of promotional offers and target markets is carried out in coordination with the German industry and taking into account the need for energy solutions abroad.

8.2.5 DeveloPPP

DeveloPPP.de was set up by the German Federal Ministry for Economic Cooperation and Development (BMZ) over 20 years ago to foster the involvement of the private sector in areas where business opportunities and development policy initiatives overlap. To this end, BMZ offers financial and technical support for companies that want to do business or have already begun operating in developing and emerging-market countries. The company is responsible for covering at least half of the overall costs. The program was recently extended to also support local countries in their innovative projects as long as they offer long-term benefits for the local population and do not simply constitute an investment in their actual core business.
Funding are available between EUR 100,000 and EUR 2 million* on top of company's own contribution (≥ 50%). The criteria for granting are:

- Minimum annual turnover: EUR 800,000
- Minimum number of employees: 8
- At least two years of audited financial statements

8.2.6 KfW DEG / IPEX

IPEX stands for "International project and export finance" and is a branch of the German KfW Bank, responsible for international project and export finance for companies within the KfW Group offering medium and long-term financing solutions tailored to the specific needs of the companies who generally range from internationally oriented large companies to medium-sized enterprises.
The KfW-IPEX Bank has a subsidiary in São Paulo to support German and European customer for their market entry and expansion in the Brazilian market.

8.2.7 ExperTS

The objective of the ExperTS Program is to promote sustainable business practices around the world and to create better conditions under which companies can become involved in development policy activities in partner countries.

The ExperTS advise German, European and local companies in around 30 developing and emerging economies on development policy issues. They work at the intersection between development cooperation and foreign trade promotion. As local contacts, ExperTS support small and medium-sized companies in particular in tapping into new markets and setting up innovative cooperation arrangements, as well as ensuring that their involvement brings benefits for all sides. In this way, they create the basis for local sustainable economic development.
In Brazil ExperTS are located in the German Chamber of Commerce (AHK) in Rio de Janeiro and São Paulo.

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26

9. SWOT Analysis

As a summary of the chapters discussed above it is now presented a SWOT Analysis of the hydrogen economy in Brazil. This analysis, as a technique for assessing the four aspects of a business (strengths, weaknesses, opportunities and threats) will also support the readers of this paper in understanding and categorizing the main issues and chances of the hydrogen economy in Brazil.

Strength	**Weaknesses**
-Abundance of renewable sources for green and/or blue hydrogen: solar, wind, biomass -Ongoing tax incentives on federal and state level -Political interest and first initiatives (e.g. PROH2) -International Commitment from Brazilian government (IPHE) -Sector representation (ABH2) -Growing environmental awareness -Civil Society mobilization (private companies hydrogen supply and consumer chain + universities) - Good coordination and cooperation between stakeholders, isolated / fragmented activities -Two big projects successfully implemented (Buses)	-Absence of joint programs: hydrogen and renewable sources (photovoltaic, wind and biomass) -Lack of certification of products and processes - insufficient volume of national norms and standards for hydrogen -Small volume of investments /Few ongoing projects -Absence of a production scale for national equipment (electrolyzers amongst others) - (Still) high cost of HFC technology, availability and cost of hydrogen - Need to build new infrastructure for hydrogen (storage and distribution), limited natural gas related infrastructure - International competition more advanced and limited business linkages - Limited skill pool - Slow pace in technology adoption (from lab to market)
Opportunities	**Threats**
- Rising cost of energy enhances attractiveness of HFC technology - Interest from Brazilian industry – chance to leverage private sector investments -the use of green hydrogen as a buffer by	-Custo Brasil[11]: regulation, corruption and lack of infrastructure - Weak growth of the Brazilian economy - Lack of funds for market development programs - International competitors advancing at a faster pace (closing window of opportunity) - Advancement of battery technology / energy storage

[11] A term used to describe the high cost of business in Brazil. Custo Brasil comes at least in part from corruption, regulation, and lack of infrastructure. The term itself is Portuguese for "Brazil cost."

renewable energies (water and solar) -Use of the photovoltaic boom in Brazil to develop green hydrogen and boost distributed generation in the country. - Numerous potential applications: e.g. production of green hydrogen and green fuels, electrification, mobility - Sector coupling: HFC can benefit existing, key industrial sectors (mining, chemical, steel) - International collaboration - Transition to low-carbon economy: less dependence on oil imports and increased energy security	technologies and battery electric vehicles

10. Conclusion and Recommendation

Hydrogen is a central pillar of the energy transformation required to decarbonize industrial and transportation energy use and limit global warming to two degrees Celsius. Furthermore, HFC can enable large scale renewable energy integration and power generation.

The main conclusions that can be taken out of this research are stated below:

1. Brazil has an energy matrix based on nearly 80% renewable energy sources, which can be used to generate green hydrogen, mainly in time slot, when the demand is lower than generation potential.
2. For substitution of chemical application of fossil-based hydrogen, the generation of green hydrogen needs to be proven economically viable. Here external investments could help to foster this substitution.
3. On transportation application some pilot projects on busses were already started but with difficulties to continue due to missing investment. Nevertheless, this is a very promising area, as most of the technology is coming from national suppliers.
4. Hydrogen as energy storage can also be used in smaller scale for a better decentralization of energy production. Energy transmission losses could be prevented.
5. Due to the current economic crisis, the public acceptance to invest in hydrogen technology is low. Preferences are done to further exploration of natural gas as large sources are available in the near shore area of Brazil.

Overall, Brazil has very promising base factors to pioneer a successful green hydrogen industry and with this becoming a leader in the worldwide decarbonization strategy. Nevertheless, political incentives and strong leadership to develop and pilot technology for generation, storage and distribution are decisive factors.

Based on the Global IEA Report 2019 for hydrogen, some recommendations also can be adapted to the Brazilian market:

- **Targets and/or long-term policy signals.** A clear statement and commitment of the government to the CO2 reduction goals of Paris and COP 25. Together with this a timely development of clear road maps would decrease obstacles to grid conversion and help potential hydrogen suppliers estimate future market size. Timelines for the first large-scale projects might act as critical milestones in long-term plans.
- **Demand creation.** At current cost levels, even low levels of hydrogen blending require policy support to stimulate demand from gas suppliers and to encourage hydrogen equipment production and infrastructure use. Similar to quotas of alcohol blended in

gasoline green hydrogen injection in natural gas blending could be fostered by setting quotas, emission targets or blend levels for low-carbon gases.

- **Investment risk mitigation.** Governments could reduce the risks associated with investment in new hydrogen supplies by clarifying market and technical conditions. (Mulder, Perey and Moraga, 2019). The issues that need clarifying include conditions relating to third-party access, regulated returns for system operators, and consumer protection.
  Governments and system operators could further help investors to manage risks by taking steps to ensure that existing and future equipment on the grid is able to operate with blended hydrogen, including gas storage, compressors, turbines and home appliances.
- **R&D, strategic demonstration projects and knowledge sharing**. There is a rationale for public-sector involvement in improving technologies associated with hydrogen production. Public co-funding could also accelerate the development of appliances that use 100% hydrogen, especially if the future size of their markets is uncertain.
- **Harmonizing standards, removing barriers.** As hydrogen in the gas grid, whether blended or 100% hydrogen, will be used in people's homes, ensuring safety is of paramount importance. Public safety concerns or adverse events could seriously impair the speed of deployment or prevent it altogether. Technical standards need to be created will also be important for new appliances and equipment. It is preferable that these standards need to be in line with international standards to lower the barrier for international supplier to enter in the Brazilian market.

It is now up to the promotion of joint initiatives from private sector, third sector and government to promote the development of this promising source, in a way to complement the growing energy demand in different sectors as well to contribute to the decarbonization of the global economy.

11. References

Balanço Energético Nacional. Empresa de Pesquisa Energética, Ministério de Minas e Energia, 2018.
Available at: http://epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2018.

The future of Hydrogen - Report prepared by the IEA for the G20, Japan, June 2019
Available at:
https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf

BRASIL. **Resolução Camex 97/2015 - Altera a Lista Brasileira de Exceções à Tarifa Externa Comum do MERCOSUL.** Brasília, Presidência da República/CONSELHO DE GOVERNO/CÂMARA DE COMÉRCIO EXTERIOR, 2015.

Clean Energy Partnership. **Definition von Grünem Wasserstoff in der CEP.** Bundesministerium für Verkehr, Bau und Stadtentwicklung. Available at: https://cleanenergypartnership.de/fileadmin/Assets/user_upload/Definition_von_Gru__nem_Wasserstoff.pdf

Deutscher Wasserstoff und Brennstoff Verband. https://www.dwv-info.de/

Energia Solar Fotovoltaica no Brasil – Infográfico. ABSOLAR, 2019.
Available at: http://www.absolar.org.br/infografico-absolar-.html

Hidrogênio energético no Brasil: subsídios para políticas de competitividade, 2010-2025; Tecnologias críticas e sensíveis em setores prioritários – Brasília: Centro de Gestão e Estudos Estratégicos, 2010.

Hydrogen Council: https://hydrogencouncil.com/en/seizing-the-opportunities-of-hydrogen/

Hydrogen Scaling Up: A sustainable pathway for the global energy transtition. Hydrogen Council, Nov. 2017.

PANIK, S. M.; PANIK, F.; SOBRINHO, S. G. O.. **Hydrogen Fuel Cell Buses for Urban Transportation in Brazil results**. EVS30 Symposium, Stuttgart, 2017.

Roteiro para a Estruturação da Economia do Hidrogênio no Brasil. Ministério de Minas e Energia, 2005.

SÃO PAULO. **Portaria nº 63/2015 - Carros Elétricos, Hidrogênio e Híbridos.** São Paulo, Secretário Municipal do Verde e do Meio Ambiente, 2015.

AHK MERCOSUL

DEinternational ist eine Marke der
Deutsch-Brasilianischen Industrie- und Handelskammer
Avenida Graça Aranha 1 | 20030-002 Rio de Janeiro-RJ | Brasilien
Tel. / Fax. +55 21 2224 2123
Email loana@ahk.com.br | www.ahkrio.com.br

CNPJ 33.752.767/0001-26