INTERNATIONAL PARTNERSHIP FOR
HYDROGEN AND FUEL CELLS IN THE ECONOMY

IPHE Country Update November 2018: Brazil

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1. New Initiatives, Programs, and Policies on Hydrogen and Fuel Cells

On October 31st 2018, the Ministry of Science, Technology, Innovation and Communications (MCTIC) launched a National Program entitled "Science, Technology and Innovation Plan for Renewables and Biofuels" to run from 2018 until 2022. An access link for the text published in Portuguese is available at the following URL address: http://www.mctic.gov.br/mctic/export/sites/institucional/publicacao/arquivos/Plano-de-Ciencia-Tecnologia-e-Inovacao-Para-Energias-Renovaveis-e-Biocombustiveis.pdf).

This Program aims to foster research, technological development and innovation within the energy production chains, with an emphasis on renewable energies, including hydrogen energy, and biofuels. Its objective is to diversify the country's energy matrix with a focus on energy security and energy efficiency.

Among the themes covered, MCTIC intends to support actions, development of projects and conception of policies to foster:

i) hydrogen production from water electrolysis using excess electrical energy from renewable intermittent sources, based on the important use of renewable energies in Brazil;
ii) research and deployment of technologies to use hydrogen for:
   a. energy storage;
   b. sustainable mobility;
   c. the distributed cogeneration of electrical energy and heat;
   d. the production of syngas to facilitate alternative routes for the synthesis of renewable fuels, and, based on the existing infrastructure, to improve access to renewable fuels in remote regions with positive impacts on social, economic, and environmental developments;
iii) research and deployment of technologies for the production and use of renewable fuels such as biogas, bio-methane and bio-ethanol and bio-diesel from improved production methods;
iv) research and deployment of technologies for the production and use of bio-kerosene and renewable hydrocarbons for aviation;
v) research and deployment of technologies for hydrogen energy use; and,
vi) the formation of human resources and consolidation of R&D&I networks focused on hydrogen energy.

2. Hydrogen and Fuel Cell R&D Update

- The Brazilian Hydrogen Association has made a compilation of the research centers from universities and industry presently active in research developments on hydrogen and fuel cells, and a selection of companies that co-finance such developments. The following charts present the results. Figure 1 presents the main topics of interest, with emphasis on hydrogen production. Figure 2 shows that the research and development activities are mainly distributed across the Southeastern, Northeastern and Southern regions of the

country. Figure 3 shows that most of the companies co-financing H&FC research and development are from the utility sector, mainly generating and distributing electrical energy and most of them are from the public sector, as shown in Figure 4.

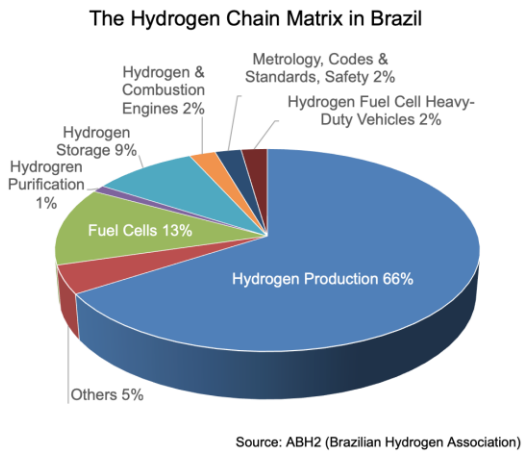

Fig. 1 – Main topics under research development in Brazil presently.

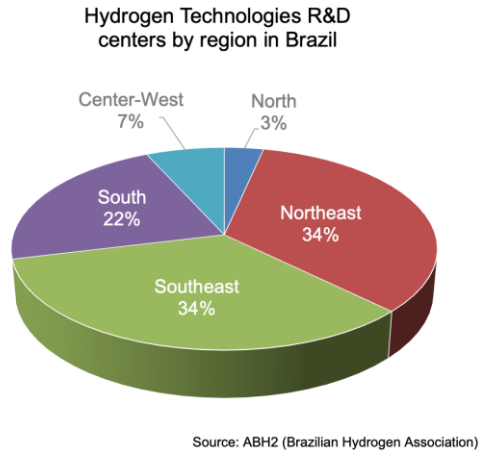

Fig. 2 – Distribution of R&D centers working on H&FC themes across the country's regions.

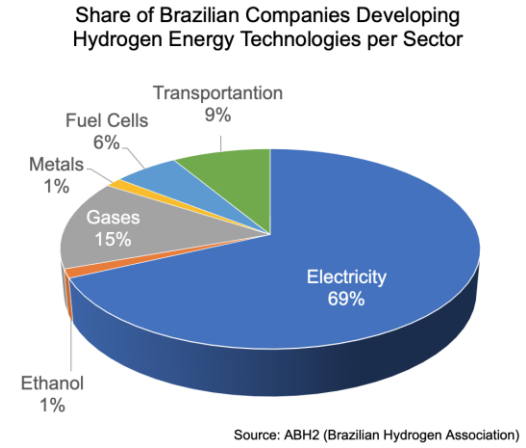

Fig. 3 – Main activities of the companies developing hydrogen energy technologies in Brazil presently.

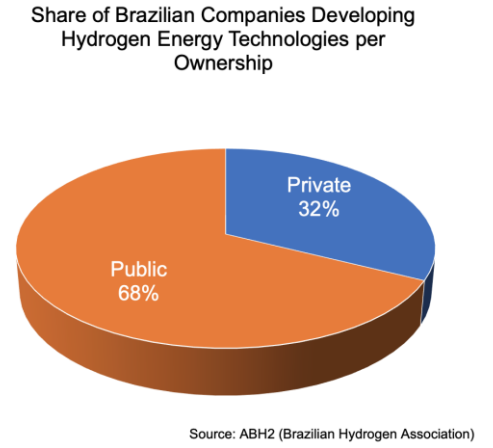

Fig. 4 – Type of ownership of the Brazilian companies developing hydrogen energy technologies presently.

Annex 1 below presents a listing of the institutions selected to generate the data for Figures 1 and 2 and Annex 2 shows a listing of the companies selected to produce the data presented in Figures 3 and 4.

3. Demonstration, Deployments, and Workforce Developments Update

- Science-based technological developments are presently being made by the following companies:
  - Electrocell (http://www.electrocell.com.br): is delivering to INT – National Institute of Technology (http://www.cnpq.br) in December 2018 a 5 kW PEM fuel cell made in Brazil.

- Tracel (www.tracel.com.br/produtos/): made the following demonstrations during the WHEC2018:
  - An uninterrupted energy generation system using a solar power plant of up to 50 kW_p integrated with an electrical energy storage system based on lithium-ion batteries and a hydrogen-fueled power plant generation using a 10 kW PEM fuel cell;
  - The last version of their proprietary equipment for the power train and the auxiliary and control systems of a hybrid electric-hydrogen fuel cell city bus.
- Hytron (www.hytron.com.br): demonstrated during the WHEC2018 a methane reformer for the production of purified hydrogen from biogas or natural gas.
- Itaipu Hydroelectric Power Plant (www.itaipu.com.br): demonstrated the production of hydrogen by water electrolysis using energy that would otherwise be spilled and is taking actions in association with Eletrobras (the Public Holding Co. of the electric sector, www.eletrobras.com.br) to expand this initiative to other Brazilian hydropower plants.

- A new book on hydrogen energy was published November 2018, with the following reference:
  P.E.V. de Miranda, Editor, "Science and Engineering of Hydrogen-Based Energy Technologies", 438 p, Elsevier, Nov. 2018.
  The book presents the following chapters:
  - Chapter 1: P.E.V. de Miranda, "Hydrogen Energy: Sustainable and Perennial".
  - Chapter 2: A. Coralli, B.J.M. Sarruf, P.E.V. de Miranda, L. Osmieri, S. Specchia, N.Q. Minh, "Fuel Cells".
  - Chapter 3: V. Singh, D. Das, "Potential of Hydrogen Production from Biomass".
  - Chapter 4: M. Carmo, D. Stolten, "Energy Storage Using Hydrogen Produced from Excess Renewable Electricity: Power to Hydrogen".
  - Chapter 5: H. Uchida, M.R. Harada, "Hydrogen Energy Engineering Applications and Products".
  - Chapter 6: A.V. Tchouvelev, S.P. Oliveira, N.P. Neves Jr., "Regulatory Framework, Safety Aspects, and Social Acceptance of Hydrogen Energy Technologies".
  - Chapter 7: David Hart, "Roadmapping".
  - Chapter 8: R. Steinberger-Wilckens, B. Sampson, "Market, Commercialization, and Deployment – Toward Appreciating Total Owner Cost of Hydrogen Energy Technologies".

4. Events and Solicitations

- The World Hydrogen Energy Conference 2018, WHEC2018 (http://www.whec2018.com), was held in Rio de Janeiro (June 17th to June 22nd 2018), hosted by the Hydrogen Laboratory at the Engineering Graduate Research Institute Alberto Luiz Coimbra (COPPE), at the Federal University of Rio de Janeiro (UFRJ). It is the most important world event on Hydrogen Energy. In its 22nd edition, 784 representatives from 51 countries attended, with the conference having 485 presentations, 23 Plenary Sessions, 35 Keynotes, 295 Orals and 132 Posters. In addition, the World Bioenergy Symposium was held, as well as, 6 Workshops, 3 Round tables, a Trade Fair with 35 exhibitors, 4 technical tours and a pleasant "Brazilian Night" party. Presentations and articles covered regulations, codes and

standards, products, research developments and innovation towards a Hydrogen Society. The Ministry of Science, Technology, Innovation and Communication (MCTIC) was the main governmental supporter of the conference that was hosted and sponsored by the institutions and companies depicted in Figure 5.

Figure 5 – Institutions and companies that hosted and sponsored the WHEC2018.

- The XIV HYdrogen - Power THeoretical and Engineering Solutions International Symposium – HYPOTHESYS2019, will be held in Foz do Iguaçu, at Itaipu, from April 24th to 26th, 2019. Additional information is available at: http://www.hypothesis.ws/index.php/overview/committees-xiv

5. Investments: Government and Collaborative Hydrogen and Fuel Cell Funding

Nothing to report in this period.

6. Regulations, Codes & Standards, and Safety Update

- The Brazilian Association of Technical Standards, ABNT, (http://www.abnt.org.br) issued on June 2018 the technical standard **ABNT IEC/TS 62282-1:2018**, entitled **"Fuel cell technologies Part 1: Terminology"**. It was prepared by the Hydrogen Technologies Technical Committee, CEE-67, which is also a mirror of *ISO TC-197 Hydrogen Technologies* and keeps a close connection with *IEC TC-105 Fuel Cells*. For the year 2019, CEE-67 has planned:
  - to apply to become an ISO TC-197 P-member;
  - to develop the necessary work to issue in Portuguese in Brazil in the near future the following new standards:
    - ISO/TC 197/WG 05 Gaseous hydrogen land vehicle refuelling connection devices;
    - ISO/TC 197/WG 15 Gaseous hydrogen - Cylinders and tubes for stationary storage
    - ISO/TC 197/WG 18 Gaseous hydrogen land vehicle fuel tanks and TPRDs
    - ISO/TC 197/WG 19 Gaseous hydrogen fuelling station dispensers
    - ISO/TC 197/WG 20 Gaseous hydrogen fuelling station valves
    - ISO/TC 197/WG 23 Gaseous hydrogen fuelling station fittings
    - ISO/TC 197/WG 24 Gaseous hydrogen fuelling stations – General requirements
    - ISO/TC 197/WG 25 Hydrogen absorbed in reversible metal hydride
    - ISO/TC 197/WG 26 Hydrogen generators using water electrolysis
    - ISO/TC 197/WG 27 Hydrogen fuel quality
    - ISO/TC 197/WG 28 Hydrogen quality control.

Annex 1: Listing of Institutions selected to generate the data in Figures 1 and 2

1	Comissão Nacional de Energia Nuclear	http://www.cnen.gov.br/
2	Instituto Federal da Bahia	http://portal.ifba.edu.br/
3	Instituto Federal de Alagoas - Matriz	https://www2.ifal.edu.br/
4	Instituto Federal de Educação, Ciência e Tecnologia da Paraíba	http://www.ifpb.edu.br/
5	Instituto Federal do Ceará - Reitoria	https://ifce.edu.br/
6	Instituto Nacional de Metrologia, Qualidade e Tecnologia	http://www.inmetro.gov.br/
7	Instituto Nacional de Tecnologia	http://www.int.gov.br/
8	Pontifícia Universidade Católica de Minas Gerais	https://www.pucminas.br
9	Pontifícia Universidade Católica do Rio Grande do Sul	http://www.pucrs.br/
10	Universidade de Brasília	www.unb.br
11	Universidade de Caxias do Sul	https://www.ucs.br
12	Universidade de Guarulhos	http://www.ung.br/tags/universidade-guarulhos
13	Universidade de Pernambuco	www.upe.br
14	Universidade de São Paulo	https://www5.usp.br
15	Universidade do Estado da Bahia	www.uneb.br
16	Universidade do Estado de Santa Catarina	https://www.udesc.br
17	Universidade do Estado do Amazonas	www.uea.edu.br
18	Universidade Estadual de Campinas	www.unicamp.br
19	Universidade Estadual de Maringá	www.uem.br
20	Universidade Estadual do Ceará	www.uece.br
21	Universidade Estadual do Centro-Oeste	https://www3.unicentro.br
22	Universidade Estadual Paulista Júlio de Mesquita Filho	https://www.unesp.br
23	Universidade Federal da Bahia	https://www.ufba.br
24	Universidade Federal da Grande Dourados	https://www.ufgd.edu.br
25	Universidade Federal da Integração Latino-Americana	https://www.unila.edu.br
26	Universidade Federal de Alagoas	https://ufal.br
27	Universidade Federal de Campina Grande	www.ufcg.edu.br
28	Universidade Federal de Goiás	https://www.ufg.br
29	Universidade Federal de Itajubá	https://unifei.edu.br
30	Universidade Federal de Juiz de Fora	https://www2.ufjf.br
31	Universidade Federal de Minas Gerais	https://ufmg.br
32	Universidade Federal de Pernambuco	https://www.ufpe.br
33	Universidade Federal de Santa Catarina	https://ufsc.br
34	Universidade Federal de São Carlos	https://www2.ufscar.br
35	Universidade Federal de São Paulo	www.unifesp.br
36	Universidade Federal de Uberlândia	www.ufu.br

37	Universidade Federal do ABC	www.ufabc.edu.br
38	Universidade Federal do Amazonas	https://ufam.edu.br
39	Universidade Federal do Ceará	www.ufc.br
40	Universidade Federal do Espírito Santo	www.ufes.br
41	Universidade Federal do Oeste da Bahia	https://www.ufob.edu.br
42	Universidade Federal do Paraná	www.ufpr.br
43	Universidade Federal do Piauí	www.ufpi.br/
44	Universidade Federal do Recôncavo da Bahia	https://ufrb.edu.br
45	Universidade Federal do Rio de Janeiro	https://ufrj.br/
46	Universidade Federal do Rio Grande	https://www.furg.br
47	Universidade Federal do Rio Grande do Norte	https://www.ufrn.br
48	Universidade Federal do Rio Grande do Sul	www.ufrgs.br/ufrgs/inicial
49	Universidade Federal do Sul da Bahia	https://www.ufsb.edu.br/
50	Universidade Federal dos Vales do Jequitinhonha e Mucuri - Campus JK	www.ufvjm.edu.br/
51	Universidade Federal Fluminense	www.uff.br/
52	Universidade Federal Rural de Pernambuco	www.ufrpe.br/
53	Universidade Federal Rural do Rio de Janeiro	http://portal.ufrrj.br/
54	Universidade Salvador	https://www.unifacs.br
55	Universidade Tecnológica Federal do Paraná	http://portal.utfpr.edu.br/
56	Universidade Tiradentes	https://www.unit.br/

Annex 2: Listing of Companies selected to produce the data in Figures 3 and 4

1	3M DO BRASIL LTDA	www.3m.com.br
2	AES ELETROPAULO	www.aeseletropaulo.com.br
3	AES TIETÊ	www.aestiete.com.br
4	AIR LIQUIDE BRASIL LTDA	www.airliquide.com/brazil
5	ANOD-ARC	www.anod-arc.com.br/
6	BRASILH2	www.brasilh2.com.br/brh2-info.html
7	CEA	www.cea.portal.ap.gov.br
8	CEB	www.ceb.com.br
9	CEEE	www.ceee.com.br
10	CEELBIO	www.gust.com/companies/ceelbio_tecnologia_em_cermicas
11	CELESC	www.celesc.com.br
12	CELPA	www.celpa.com.br
13	CELPE	www.servicos.celpe.com.br
14	CEMAR	www.cemar116.com.br
15	CEMIG	www.cemig.com.br
16	CENTRO DE TECNOLOGIA CANAVIEIRA	www.new.ctc.com.br
17	CEPEL - ELETROBRAS	www.cepel.br
18	CER	www.cer-energia.com.br
19	CESP	www.cesp.com.br
20	CHESF	www.chesf.gov.br
21	CHESP	www.chesp.com.br
22	COCEL	www.cocel.com.br
23	COELBA	www.coelba.com.br
24	COOPERALIANCA	www.cooperalianca.com.br
25	COPEL	www.copel.com
26	COSERN	www.cosern.com.br
27	CPFL	www.cpfl.com.br
28	CTEEP	www.isacteep.com.br
29	DME	www.dmedsa.com.br
30	EDP BRASIL	www.edpbr.com.br
31	EFLUL	www.eflul.com.br
32	ELECTROCELL	www.electrocell.com.br/
33	ELEKTRO	www.elektro.com.br
34	ELETROCAR	www.eletrocar.com.br
35	ELFSM	www.portal.elfsm.com.br
36	EMBRAER	www.embraer.com/br/pt
37	ENEL	www.eneldistribuicao.com.br

38	Energética Barra Grande S/A	www.baesa.com.br/baesa/
39	EnergiaH	www.energiah.com.br
40	ENERGISA	www.energisa.com.br
41	ENEVA	www.eneva.com.br
42	ENGIE	www.engieenergia.com.br
43	EQUINOR	www.equinor.com.br
44	FURNAS	www.furnas.com.br
45	GEAM	www.machadinho.com.br
46	HIDROGENIO GLOBAL	www.hidrogenioglobal.com/
47	HIDROPAN	www.hidropan.com.br
48	HYSTER YALES	www.hyster.com/brasil/pt-br
49	HYTRON	www.hytron.com.br
50	IGUAÇU ENERGIA	www.ienergia.com.br
51	ITAIPU	www.itaipu.gov.br
52	LIGHT	www.light.com.br
53	LINDE GAS BRASIL	www.linde-gas.com.br
54	MUXENERGIA	www.muxenergia.com.br
55	NEOENERGIA	www.neoenergia.com
56	NISSAN	www.nissan.com.br/
57	NOVOCELL	www.novocell.ind.br
58	OXITENO	www.oxiteno.com
59	PETROBRAS	www.petrobras.com.br
60	PETRONAS LUBRIFICANTES BRASIL S.A	www.pli-petronas.com/br
61	POTENCIAL BIODIESEL LTDA	www.potencialbiodiesel.com.br
62	QUIMICA AMPARO LTDA	www.ype.ind.br/a-ype
63	RGE	www.rge-rs.com.br
64	STILL	www.still.com.br
65	SULGIPE	www.sulgipe.com.br/
66	SYNGENTA PROTEÇÃO DE CULTIVOS LTDA	www.syngenta.com.br
67	TRACEL LTDA.	www.tracel.com.br/produtos/
68	Tractebel Energia S/A	www.tractebelenergia.com.br/wps/portal/internet
69	Usina Xavantes S.A.	www.utexavantes.com.br

Summary Country Update November 2018: Brazil

Transportation	Target Number	Current Status	Partnerships, Strategic Approach	Support Mechanism
Fuel Cell Vehicles[1]	No target.			
FC Bus	No target.	4 HFC buses and 1 hybrid HFC bus		
Fuel Cell Trucks[2]	No target.			
Forklifts	No target.			
H_2 Refueling Stations	**Target Number**	**Current Status**	**Partnerships, Strategic Approach**	**Support Mechanism**
70 MPa On-Site Production	No target.			
70 MPa Delivered	No target.			
35 MPa On-Site Production	No target.	1 hydrogen production and refuelling station. Another refuelling station is under construction.		

[1] Includes Fuel Cell Electric Vehicles with Range Extenders

[2] As above

35 MPa Delivered	No target.			
Stationary	**Target Number[3]**	**Current Status**	**Partnerships, Strategic Approach**	**Support Mechanism**
Small[4]	No target.			
Medium[5]	No target.	5 kW FC under development	IPEN and INT.	Brazilian financing agencies: Finep and CNPq (both from MCTIC) and Fapesp (São Paulo State financing agency)
Large[6]	No target.			
District Grid[7]	No target.			
Regional Grid[8]	No target.			
Telecom backup	No target.			
H_2 Production	**Target[9]**	**Current Status**	**Partnerships, Strategic Approach**	**Support Mechanism**
Fossil Fuels[10]	No target.	2 fuel processors under construction (one using		

[3] Targets can be units installed and/or total installed capacity in the size range indicated
[4] <5 kW (e.g., Residential Use)
[5] 5kW – 400 kW (e.g., Distributed Residential Use)
[6] 0.3MW – 10 MW (e.g., Industrial Use)
[7] 1MW – 30 MW (e.g., Grid Stability, Ancillary Services)
[8] 30MW plus (e.g., Grid Storage and Systems Management)
[9] Target can be by quantity (Nm^3, kg, t) and by percentage of total production; also, reference to efficiency capabilities can be a target
[10] Hydrogen produced by reforming processes

		ethanol and another one using natural gas).		
Water Electrolysis[11] (PEM, Alkaline, SOEC)	No target.	1 hydrogen production (water electrolysis) and refueling station.		
By-product H_2	No target.			
Energy Storage from Renewables	**Target[12]**	**Current Status**	**Partnership, Strategic Approach**	**Support Mechanism**
Power to Power[13] Capacity	No target.			
Power to Gas[14] Capacity	No target.			

[11] Please indicate if targets relate to a specific technology (PEM, Alkaline, SOEC)
[12] Can be expressed in MW of Installed Capacity to use the electricity from renewable energy generation, and Annual MWh of stored energy capacity
[13] Operator has an obligation to return the electricity stored through the use of hydrogen back to electricity
[14] Operator has the opportunity to provide the stored energy in the form of hydrogen back to the energy system through multiple channels (e.g., merchant product, enriched natural gas, synthetic methane for transportation, heating, electricity)