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Hydrogen fact sheet – Argentina

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[1] IEA Hydrogen Project Database
[2] IEA Hydrogen Project Database
[3] Own calculations based on EWI (2020): potential-weighted average production costs for basic cost case and low temperature electrolysis.
[4] https://www.iea.org/countries/argentina

RES share in electricity generation[5] [%]	26% (9% without hydro)	20% (excluding large hydro)
CO_2 intensity of electricity generation [gCO_2/kWh, 2019]	428[6]	Not available
Largest fossil fuel in electricity generation (share in total generation)]	Gas (60%) Oil (5%)	Not available
GHG emissions per capita	3.4 t CO_2 / capita	Not available
GHG intensity per GDP	0.3 kg CO_2 / 2015 USD	Not available
Decarbonization goals	2030: 483 Mt CO2eq / 369 Mt CO2eq with international support 2050: net-zero	

Opportunities for trade with EU and its Member States

Strengths	Weaknesses
Large, low-cost potentials to produce renewable electricity	No hydrogen strategy published
First hydrogen projects in operation and MoU for future projects concluded	Long shipping distance to Europe and other future demand centres for hydrogen which increases hydrogen landing costs
Experience with deployment and use of wind power and the associated support schemes	High cost of capital and limited access to capital for large scale projects
Existing gas terminals and associated know how in gas transport and handeling	Insufficient investments into electricity grid which could be relevant for grid integrated electrolysers
Know-how in hydrogen production in chemical industry	

Convergence	Divergence
High economic interest in exporting fuels and gases (however, currently focussed on unconventional gas)	Strong focus on unconventional gas resources to cover increasing domestic demand and to increasingly export fuels and gases
Ambitious RES-E target for 2025 and net-zero climate target for 2050	Unclear political strategy for further uptake of RES-E and the decarbonisation of the economy
	MoU with Japan on development of hydrogen as clean fuel, with potentially lower standards for hydrogen compared to the EU

[5] IRENA (2020): Renewable Energy Statistics
[6] http://datos.minem.gob.ar/dataset/calculo-del-factor-de-emision-de-co2-de-la-red-argentina-de-energia-electrica

Executive Summary

Argentina offers some of the largest potentials for low costs hydrogen based on renewable electricity in the world. This is due to high average wind speeds and in addition high solar irradiation throughout large areas of the country. However, transport distances to major offtake regions such as Europe or Asia are large, and this will increase the landing costs for hydrogen. As shipping of pure hydrogen will lead to significant (distance depending) energy losses, it can be expected that Argentina will rather export derivatives such as ammonia, methanol or e-fuels in the future. Concerning green hydrogen, Argentina started to deploy increasing capacities of onshore wind and could built on this expertise. While goals for the RES-E share are ambitious, the current support for RES-E deployment has been reduced, so that the continuance of its expansion is unclear.

However, the political activities in the field of the hydrogen economy are scarce. A hydrogen strategy is non-existent[7] and there are no specific support mechanisms in place. Some initiatives are in place that deal with specific production technologies for hydrogen. On the other hand, there is an existing hydrogen production facility based on electrolysis in operation that delivers valuable knowhow in this area to the country. Furthermore, the chemical industry produces grey hydrogen for domestic use already which indicates knowhow in dealing with hydrogen in general.

Since 2018 the previously dominant role of fossil gas in energy carriers has experienced a further push due to potentials expected from producing unconventional gas. Argentina expects to export high volumes of unconventional gas in the future. This strategy might also lead towards a pathway of producing and exporting blue hydrogen. However, blue hydrogen is not mentioned in official statements which might also be a result of missing sites, knowhow and technologies for capturing and storing the CO_2. Increasing global demand for green hydrogen might lead to a reorientation of the export strategy and the foundation for aiming economic growth towards a more renewable based system.

One major drawback for renewable as well as blue hydrogen in Argentina is that cost of capital is high and access to capital low. High cost of capital will increase the cost of hydrogen significantly and could cause a significant regional disadvantage compared other exporting countries.

Altogether, besides substantial potentials for low-cost wind and solar power, Argentina is well-equipped with know-how relevant for the production, transport and storage of hydrogen, e.g. through its existing petrochemical industry. If managed well, expanding hydrogen production could help promote industrial development within the ‘hydrogen-lithium ecosystem’. However, economic instability could be a substantial challenge to attracting investors. In a nutshell it could be summarised that vast potentials and sufficient knowhow exists in Argentina, but economical difficulties must be solved so that the potentials can be made available.

1 Political System, governance & economy

Argentina is a presidential democracy. The current president President Alberto Fernández holds office since 2019. He is a member of the center-left Partido Justicialista. Argentina is divided into 23 provinces and the autonomous district of Buenos Aires. These federal states have their own constitution and respective government bodies.

Argentina has a population of roughly 45 million. In 2019, GDP amounted to a little under US$ 10.000 per capita[8]. The country’s economy has been plagued by repeated financial crises, economic instability and high levels of inequality (more than 10% of the population live in extreme poverty). Economic activity has been seriously affected by Covid-19. Despite a rebound in 2021, GDP was

[7] The Argentinian Government under the Secretariat of strategic Issues announced to work on a road map for hydrogen in 2022.

[8] https://www.focus-economics.com/countries/argentina

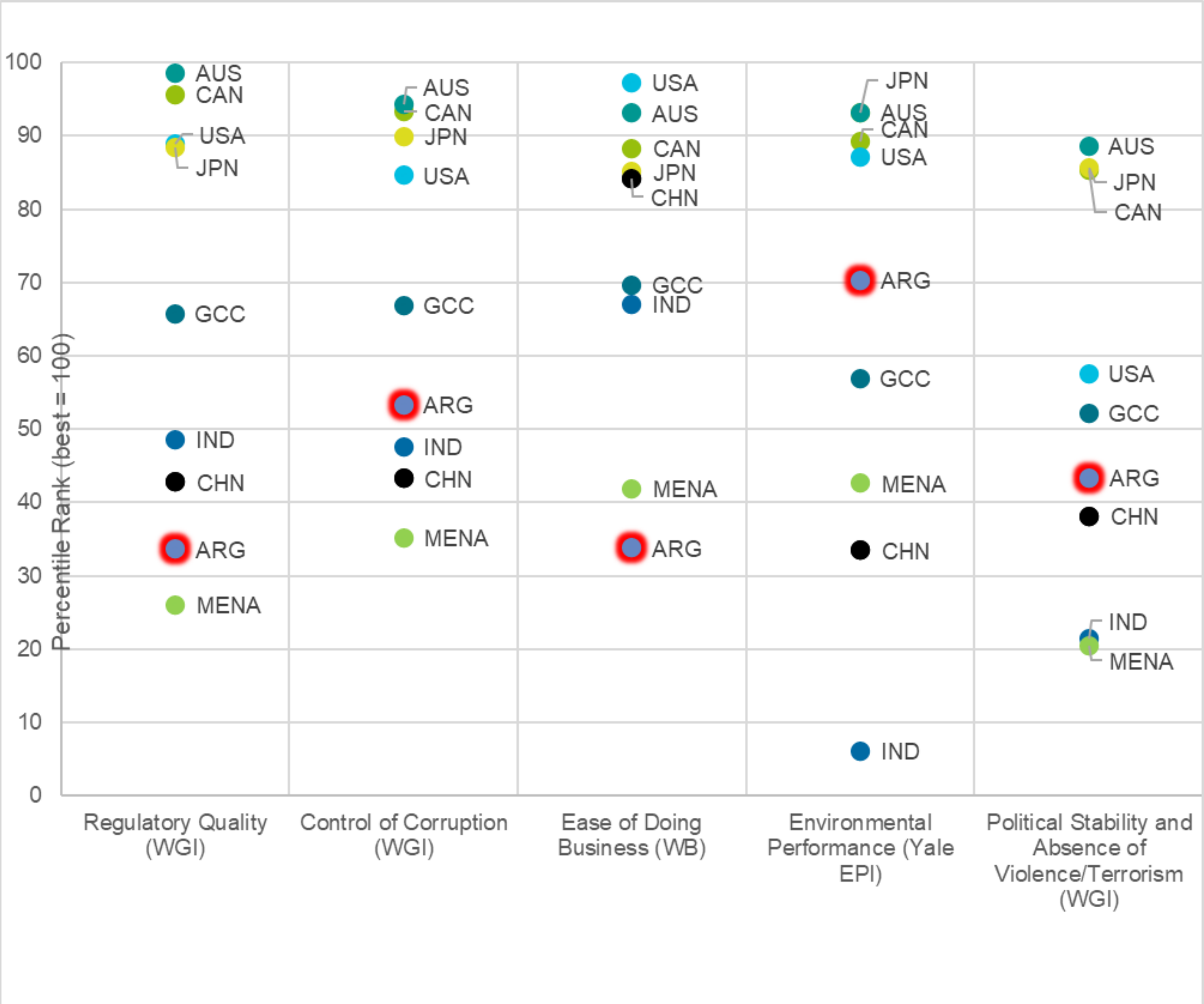
still below its pre-pandemic level. Inflation, which in 2020 exceeded 50%, is a further important economic problem in Argentina[9]. Extractive industries, most importantly oil, and to some lesser extent fossil gas, account for about 4% of GDP[10]. Petroleum products make up about 5% of Argentine exports (which are dominated by agricultural products). The main export partners are Brazil, China and the US[11].

Argentina has persistently high public debt. In August 2020, the government concluded an agreement to restructure, i.e. partially default, debt with private creditors. At the time of writing, the Argentine government is negotiating a stand-by agreement with the IMF to be able to serve its payment on the remaining debt of more than $40 billion[12]. Default risk has raised the costs of public debt and might contribute to increase financing costs for renewable energy projects. Credit rating agency S&P attributes a rating of CCC+ to Argentina[13], on par with countries such as Angola, the Congo, Ethiopia and Mozambique (by contrast, Chile, which, has received a rating of A).

As Figure 1 shows, Argentina occupies an intermediate position in terms of institutional quality indicators. In all categories considered, Argentina is ranked substantially lower than industrialized countries (Australia, Canada, Japan and the US). For the World Governance Indicators (WGI) “Control of Corruption” and “Political Stability” and Yale’s “Environmental Performance Index”, Argentina is ranked above China, India and the MENA countries. For “Regulatory Quality” (also WGI), however, Argentina ranks at the lower end of the spectrum considered. No data on capital costs for renewable energy projects in Argentina are available. However, data for other countries suggest that capital costs for renewables can be more than 10% above the risk-free interest rate (Steffen 2020), which constitutes a significant barrier for the development of clean energy sources.

[9] https://www.worldbank.org/en/country/argentina/overview#1
[10] http://www.mecon.gov.ar/download/infoeco/actividad_ied.xlsx
[11] https://oec.world/en/profile/country/arg/
[12] https://www.reuters.com/business/no-imf-thousands-protest-argentina-against-debt-deal-2022-02-09/
[13] https://tradingeconomics.com/argentina/rating

Figure 1: Business, sustainability and Governance Indicators



Source: Own illustration based on Kaufmann & Kraay (2020); Yale Center for Environmental Law & Policy (2020); World Bank (2021a). MENA: Algeria, Morocco, Egypt, Tunisia, and Mauretania. GCC: Saudi Arabia, UAE, Qatar, Oman, Kuwait, and Bahrein.

2 Energy and Electricity

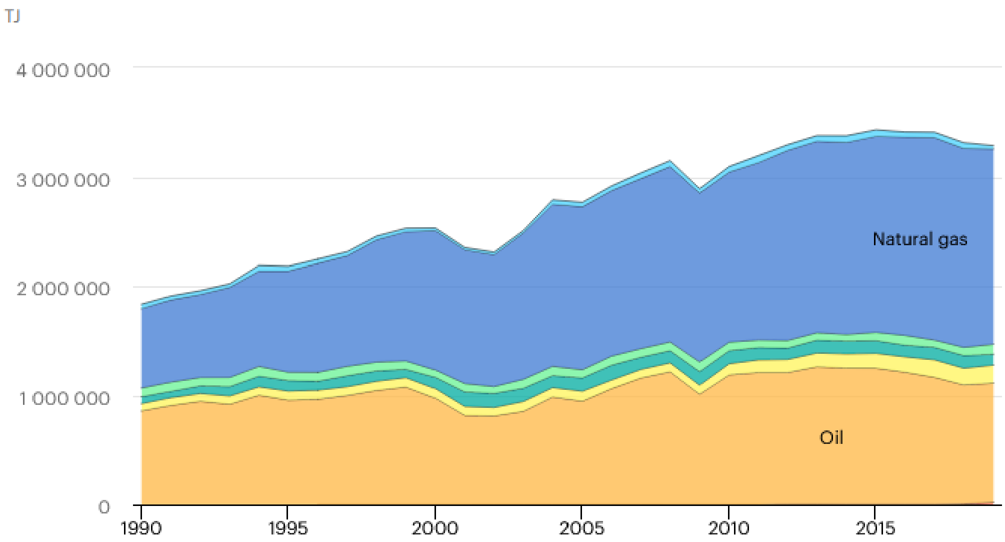
2.1 Production and demand

Argentina was the 23rd largest gas producer in 2015 and the 26th largest oil producer in 2016 (last available data)[14]. Approximately 20% of its gas consumption had to be imported from other countries. For oil the domestic production and consumption were almost on the same level.

Both Argentina's primary energy consumption (cf. Figure 2) and its electricity generation (cf. Figure 3) showed an increasing trend between 1990 and appr. 2014 and stayed on a more or less constant level over the last years. Approximately 90% of the primary energy consumption are allocated to gas (54%) and oil (33%). With an increasing trend for gas and a decreasing trend for oil (2010: 50% gas and 38% oil).

[14] https://www.worldometers.info/oil/argentina-oil/
https://www.worldometers.info/gas/argentina-natural-gas/

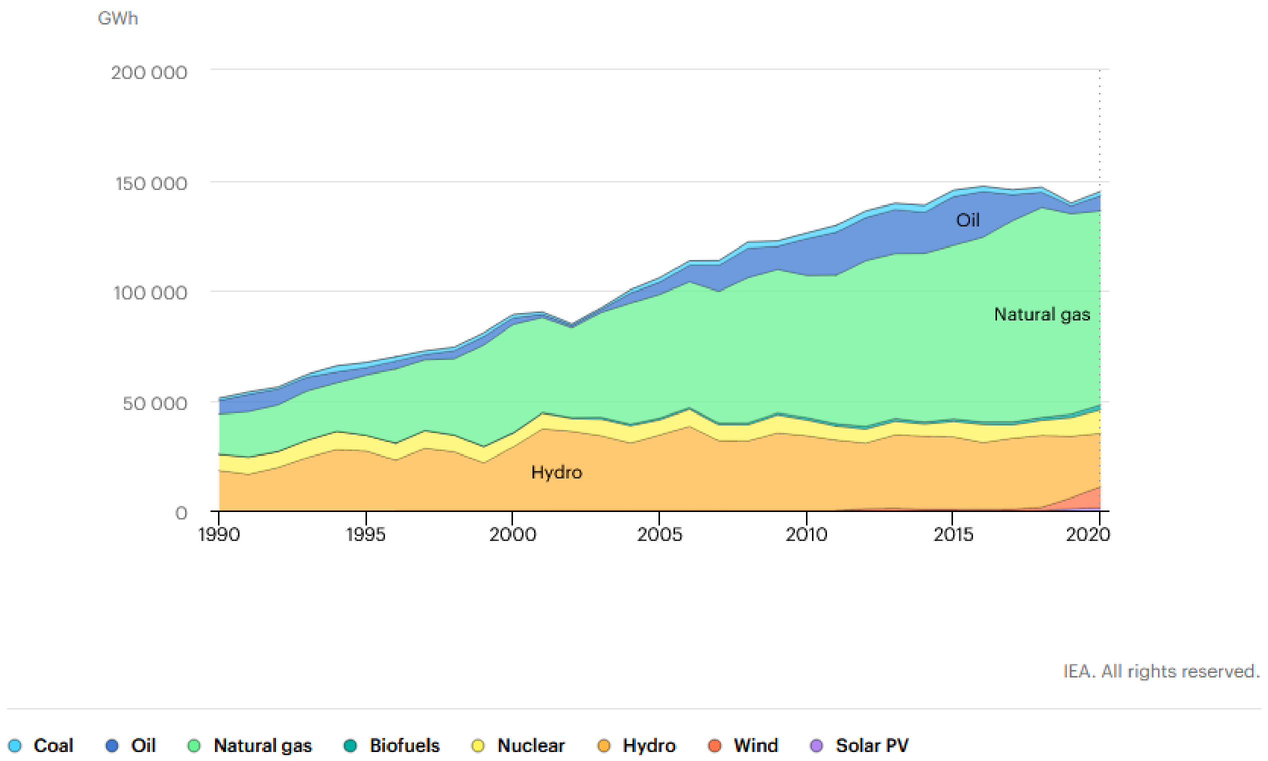
Figure 2: Primary energy consumption of Argentina, 1990-2019[15]



The electricity generation is mainly based on fossil gas (appr. 60% in 2020). Gas was the energy carrier that covered the strong increase of Argentina's electricity demand over the last 30 years, while most of the other energy sources stood mainly constant, beside a temporary increase of oil-based electricity generation between 2005 and 2015. The share of nuclear power accounts for 7%. Argentina is running three nuclear reactors and one small reactor (25 MWe) is currently under construction.[16] Over the last five years wind power started to play an increasing role in Argentina's electricity supply and accounts now for a share of 6% in the electricity generation. For the time being only onshore but no offshore plants have been built. Hydro power is still the second main source (17% in 2020) but stayed on a constant level for the last 15 years. The total RES-E share was 26% in 2020. Solar power expansion just started and accounted for 4% of the RES-E production and 1% of the total share in 2020. This leads to a decreasing emission factor over the last years, so that it was in the year 2019 with 0.428 t CO_2/MWh 20% lower than ten years before.[17]

15 https://www.iea.org/countries/argentina
16 https://world-nuclear.org/information-library/country-profiles/countries-a-f/argentina.aspx
17 http://datos.minem.gob.ar/dataset/calculo-del-factor-de-emision-de-co2-de-la-red-argentina-de-energia-electrica

Figure 3: Argentina's power mix, 1990-2020[18]



2.2 Import and export

Argentina is a net-importer of fossil gas; its gas imports are approx. 100 times higher than its exports.[19] Argentina's only import country for fossil gas in gaseous state is Bolivia and the main export country is Chile (90%)[20]. Details on LNG imports can be found in chapter 7. The trade with crude oil only plays a minor role as only 2% of consumption are imported and only 7% of production are exported.

Argentina is also a net-importer of electricity. Imports increased over the last years and accounted for 11 TWh in 2019.[21] 85% of the imports are received from Paraguay and 15% from Uruguay while all exports are going to Brazil.[22] This is because Argentina shares with Paraguay the binational hydro power plant Yacyreta. According to the treaty 50% of the energy generated corresponds to each country but as Paraguay so far does not need this electricity, Argentina demands almost all the energy from this power plant of (Total capacity of 3.100 MW/20.000 GWh annual generation). In the case of Uruguay, these imports correspond to the other binational hydroelectric power plant Salto Grande.

2.3 Forecasts

The renewable energy law sets a target of 20% RES-E share by the year 2025.[23] For this target big hydropower is excluded (> 50 MW). If hydro power and demand remain on the current level the total

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18 https://www.iea.org/countries/argentina
19 https://www.worldometers.info/gas/argentina-natural-gas/
20 https://oec.world/en/profile/bilateral-product/natural-gas-in-gaseous-state/reporter/arg
21 https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances
22 https://oec.world/en/profile/bilateral-product/electricity/reporter/arg
23 http://www.energia.gob.ar/contenidos/archivos/Reorganizacion/renovables/legislacion/ARGENTINA_-_Renewable_Energy_Law_Act_27191_(English_version).pdf

RES-E share target could be estimated to 37% for 2025. After the renewable energy law was implemented in Both

The RES schemes RenovAR and Mercado a Término de Energía Eléctrica deFuente Renovable (MATER) showed significant impact on a rapid scale up of wind and solar capacity since 2015. But despite large and cheap potential for wind and solar power it is unclear whether this development will continue in the next years and if the 2025 target could be achieved as there are seen several challenges. New Climate Institute pointed out four main areas with challenges for the renewable expansion in their report published on September 2020. [24] (1) The macro-economic situation is critical due to successive economic crises and increasing cost of capital. This situation reduced the attractiveness of RES projects while the RenovAr scheme could not achieve a robust and sustainable renewable market. (2) Focusing on the exploration of domestic gas resources was meant to ensure economic growth and security of supply but turned into economically vulnerable projects with the potentially need for subsidies. These could lead to a shift of subsidies from renewable to fossil sources. (3) Argentina's transmission grid infrastructure is too weak for the current and the upcoming expansion of renewable which results in several power outages. On the one hand side investments in grid infrastructure were not sufficient for the growth of renewables. On the other side there are several geographical challenges for a stable and Pan-Argentina transmission grid as it is a large country (3,700 km from North to South) with a population and thus also the electricity demand concentrated in a few arears with larger cities. (4) Clear political signals to continue the support of renewables (and not focusing on fossil gas) from the current government is missed while the unit responsible for renewable energy was downgraded from a Sub-Secretariat to a Directorate.

3 Decarbonization and RES policies

Argentina is among the group of countries that have announced plans to become net-zero by 2050. Argentina's Nationally Determined Contribution (NDC), submitted in 2016, states that the country's emissions will be limited to 483 Mt CO2eq by the year 2030[25], which would constitute an increase of roughly one third (in 2016, Argentina's total emissions amounted to about 364 Mt CO2eq.[26]). With international support, a conditional target of 369 Mt CO2eq is envisaged, according to the INDC. Relative to business-as-usual projections included in the NDC, the unconditional and conditional pledges correspond to 18% rand 37% reductions, respectively.

On the national level, in late 2019 minimum budgets for actions related to adaptation to and mitigation of climate change (such as a national system for monitoring emissions) have been decided (Law 27.520). The respective law also establishes a National Climate Cabinet of Climate Change to coordinate different areas of government and monitor their progress and calls for the elaboration of specific strategies, measures, policies, and instruments as part of the 'National Plan for Adaptation and Mitigation of Climate Change'. These have been developed in the form of specific plans for energy, transport, agriculture, industry and forestry.

In January 2018, Argentina implemented a carbon tax of 10 USD/tCO2e for most liquid fuels sold in Argentina (Law 27.430). In 2019, the tax decreased to 5 USD/tCO2e, but extended to other fossil fuels (fuel oil, petroleum coke and coal)[27]. Fuel oil, mineral coal, and petroleum coke, started with at 10% of the full tax rate, to be increased by 10 percentage points per year (to reaching the full rate in

[24] https://newclimate.org/wp-content/uploads/2020/12/Impact-of-Cost-Progressions-on-Argentinas-NDC-Governance-Report.pdf

[25] https://www4.unfccc.int/sites/NDCStaging/pages/Party.aspx?party=ARG

[26] https://unfccc.int/documents/201965

[27] However, the tax was not directly decreased to 5 USD/tCO2 by the government. Indirectly it decreased (in USD) since the tax values in 2017 were fixed in pesos ARG and are subject to a trimestral update depending on inflation/IPC. Inflation increased at a different speed than exchange rates, which results in the indirect tax decrease in USD.

2028). The tax, which covers about 20% of national GHG emissions, neither includes fossil gas nor international aviation and shipping[28].

Several laws are in place to foster the use of renewable energy. The law on renewable energy (Law 271.91)[29] requires 16% of all electricity consumed nationally must be generated from renewable sources by the end of 2021. This target will be increased to 18% by 2023 and 20% by 2025. The Fund for the Development of Renewable Energies is established to provide financial support for RE, inter alia by means of feed-in tariffs.

Other climate-relevant laws include a mandate that all gasoline produced and consumed in Argentina must be composed of at least 5% biofuels (Law 26.093) and a sales ban for incandescent light bulbs (Law 26.473). Finally, a Presidential Decree (140/2007) declared in 2007 decree declares rational and efficient energy use a national priority and calls for, inter alia, information campaigns, labeling schemes for appliances, energy certification for newly constructed residences and improved management of public transport.

However, in parallel to the expansion of renewable energy sources, Argentina also plans to massively increase its production of fossil fuels, in particular fossil gas. For instance, the national energy plan aims to create up to double the production of fossil gas by 2023 by further developing Vaca Muerta[30], the second largest known non-conventional gas reserves in the world. To combat the economic consequences of the Covid pandemic, the Argentina government has increased subsidies for fossil fuel industries. This support has – alongside the deterioration of the overall macro-economic situation, high capital costs, bottlenecks of transmission infrastructure and lack of political commitment to climate policy – slowed down the roll-out of renewable energy sources in recent years (New Climate 2020).

4 Hydrogen sector in Argentina

Argentina currently uses about 330,000 tons of grey hydrogen per year[31]. The largest part, more than 300,000 tons are used in the petrochemical industry for refineries to lower the sulfur content of diesel fuels. The chemical industry makes up the largest share of the remainder with more than 25,000 tons per year.

The hydrogen employed is almost entirely self-produced by these industries, only 2% of produced hydrogen is marketed. A small share of 0.3% is used for power generation. Some relatively small-scale projects produce green hydrogen. For instance, Hychico[32] has been running a wind-powered hydrogen plant in Comodoro Rivadavia City, in Chubut Province, since 2008. The Hychico plants is also used to test possibilities for transport and storage of hydrogen. It includes a pipeline of roughly 15 kilometers towards depleted gas wells as test sites for storage.

Other small-scale pilot plants are undertaken by the Institute for Hydrogen Technology and Sustainable Energies related to producing hydrogen from biomass, and by the Institute for Energy and Sustainable Development focusing on blending hydrogen with compressed fossil gas for public and freight transport. (The Oxford Institute for Energy Studies 2021)

28 https://climateactiontracker.org/countries/argentina/policies-action/
29 https://climate-laws.org/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBaDhJIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--60f7eef4bcbe53d7ecb81be2309e2adf5c01e2f3/f
30 https://www.argentina.gob.ar/economia/energia/vaca-muerta
31 https://y-tec.com.ar/wp-content/uploads/2020/08/H2AR-Presentaci%C3%B3n-lanzamiento_INGL%C3%89S.pdf
32 http://www.hychico.com.ar/eng/hydrogen-plant.html

5 Hydrogen strategies & support schemes

A law to declare hydrogen a national interest and promote its use and technological development had already been passed in 2006, but never entered into force (Law 26.123).

In late 2021, shortly after COP26, the Argentine government signed a Memorandum of Understanding with the Australian energy company Fortalesco regarding the development of hydrogen production capacity in Rio Negro, Patagonia. In a pilot project, US$ 1.2 bn shall be invested until 2024. By 2030, total investment of US$ 4.8 bn for 3 large-scale wind farms with a potential of 2.000 MW shall produce 2.2 mio tons of green hydrogen per year. Fortelesco allegedly seeks support from the government for this project by means of tax breaks and a free zone. In a similar vein, the state-owned energy conglomerate IEASA has signed an agreement with Fraunhofer Institute[33] to start developing a wind-powered green hydrogen hub on an area of about 200 hectares in the Bahía Blanca area.

The Consejo Ecónomico y Social (Economic and Social Council) has tendered three major studies, to be released in 2022, to prepare the country's hydrogen strategy. This roadmap aims to create 15,000 direct jobs related to green hydrogen, and 40,000 to 50,000 indirect ones, by 2030. It also mentions the potential for international cooperation with countries that might become major hydrogen importers, such as Germany and Japan.

The growing importance of hydrogen in Argentina is also underlined by the emergence of networks to align the activities of key actors. These networks include the H2ar Consortium[34], which comprises more than 60 companies (such as utilities, oil refiners, gas distributors and automotive) and the PlataformaH2 Argentina (which promotes dialogue between academia, civil society and industry associations).

6 Potentials for hydrogen production

6.1 Green hydrogen

Argentina's electricity system is based mainly on thermal power plants fueled by oil or fossil gas (see section 2). Smaller shares are contributed by nuclear energy and renewable energy (mainly hydro power). According to the high share of electricity generation based on fossil fuels, the specific CO_2 emissions for the electricity grid mix is as high as 428 gCO_2/kWh[35] (compared to EU average in 2017 was 303 gCO_2/kWh). Grid integrated production of hydrogen using electrolysis would therefore account for high GHG emissions associated with the hydrogen and exceed the RED II threshold of a reduction of 70% related to the fossil comparator.

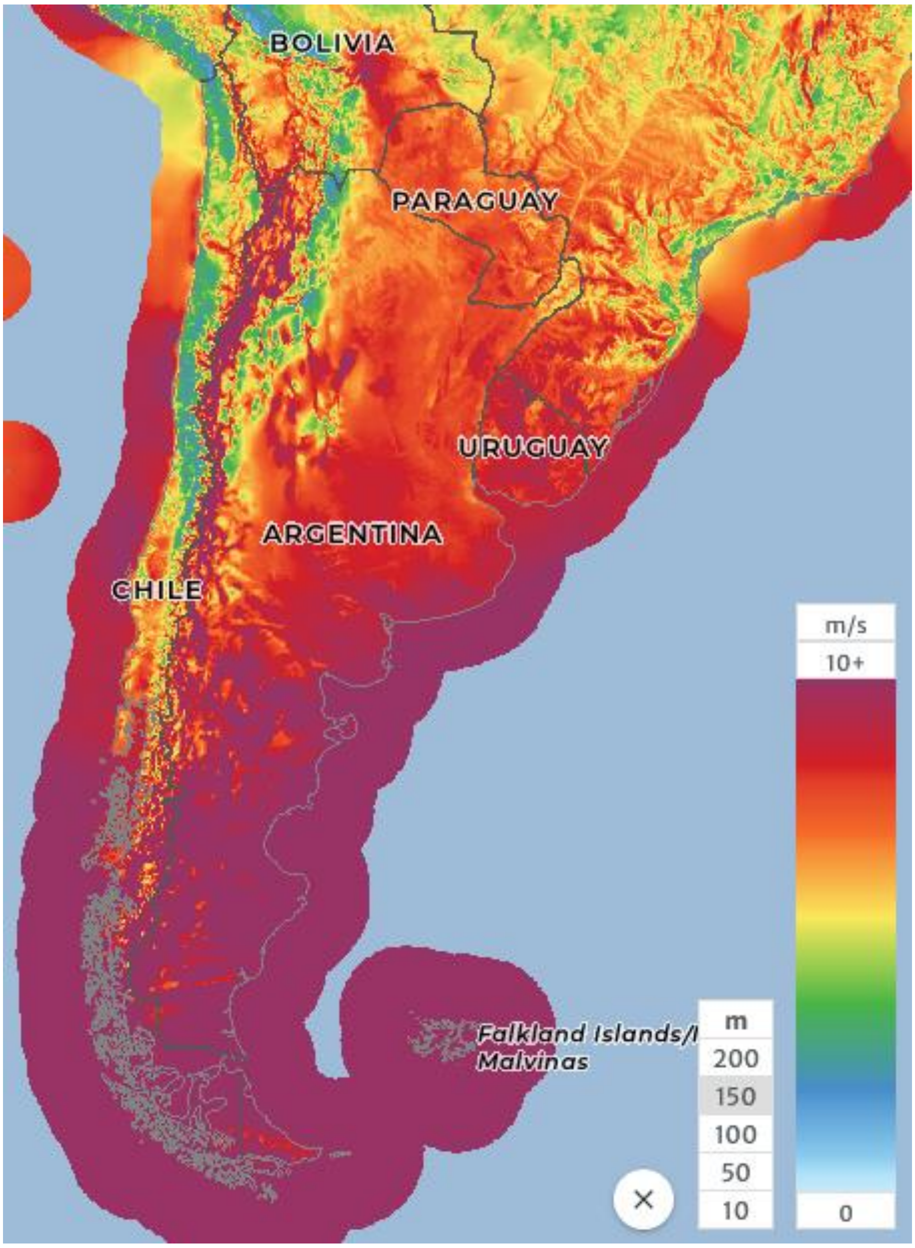
However, looking into the potentials for production of hydrogen based on renewable electricity, Argentina has vast potentials. Sigal et al. (2014) estimate that Argentina could produce almost 1 billion tons of hydrogen per year from solar, wind and biomass, a potential close to that of the) US.

Especially volumetric potentials of renewable electricity based on wind and solar are large and production costs low due to high capacity-utilization levels. Large areas in Argentina have wind speeds of almost 10m/s at a hight of 150 meters above ground. This compares to the coast lines of the northern sea in Europe. The wind speeds increase from northern regions with, in average 7.5

[33] https://www.ieasa.com.ar/index.php/ieasa-firma-un-acuerdo-con-el-instituto-fraunhofer-para-el-desarrollo-del-primer-proyecto-de-hidrogeno-verde-a-gran-escala-en-la-republica-argentina/
[34] https://y-tec.com.ar/en/h2ar-consortium/
[35] http://datos.minem.gob.ar/dataset/calculo-del-factor-de-emision-de-co2-de-la-red-argentina-de-energia-electrica

m/s up to 11 m/s in the most southern parts of Argentina (compare to Figure 4). Offshore wind speeds reach values of up to 12 m/s in large areas.

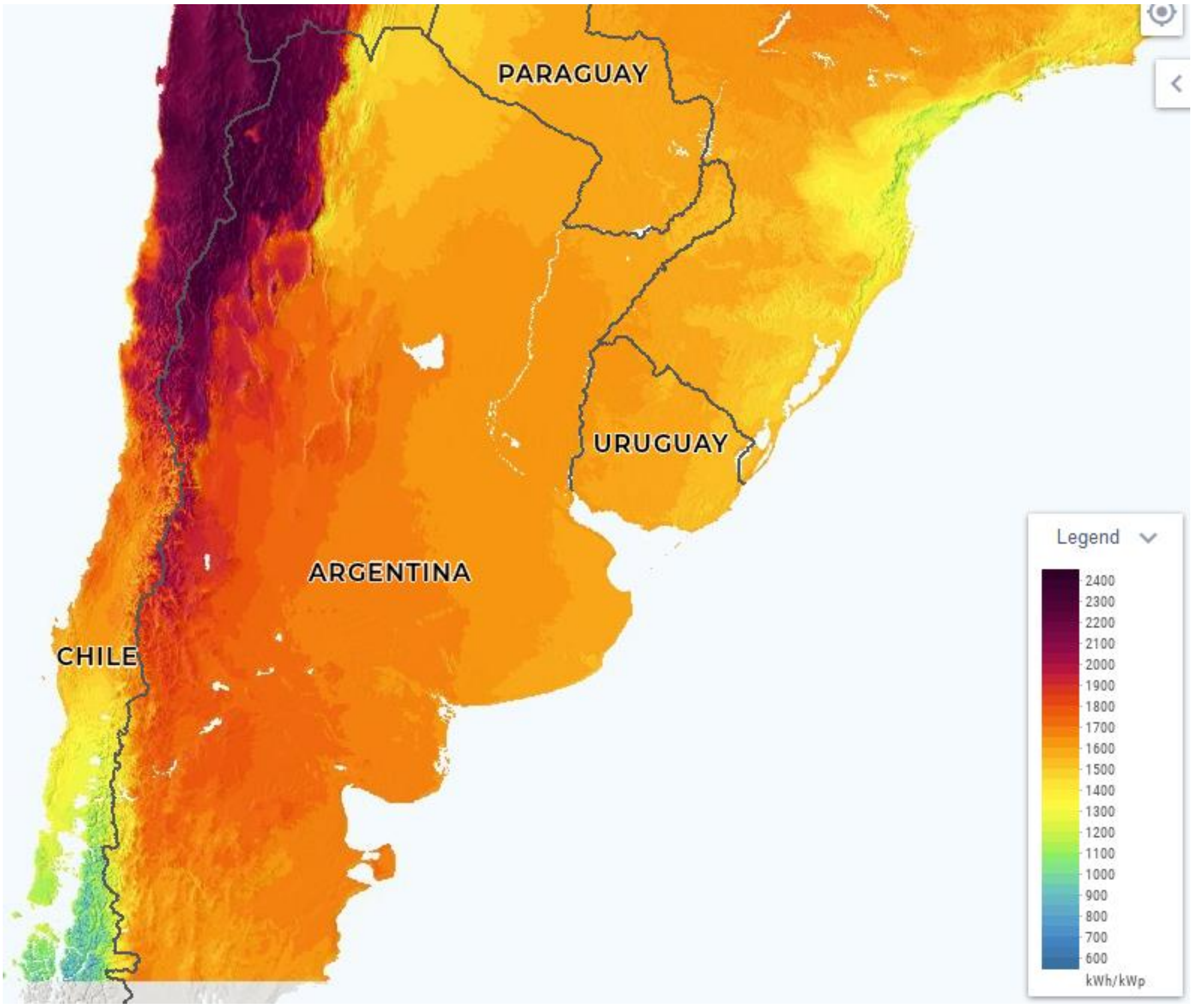
Figure 4: Average Windspeeds in Argentina



Source: https://globalwindatlas.info/ under the Creative Commons Attribution 4.0 International license

For solar power, Argentina has very large areas with solar capacity usage values of more than 1,700 kWh/kWp. Those numbers are comparable to Spain or Italy. Even in southern regions of Argentina the values are still high with about 1,500 kWh/kWp. Compared to other countries, solar irradiation in Argentina does not show major local variation (compare Figure 5).

Figure 5: Capacity utilisation of solar power in Argentina



Source: https://globalsolaratlas.info under the Creative Commons Attribution 4.0 International license

The PtX Atlas of Fraunhofer IEE[36] expects production potentials for green hydrogen (that take into account availability of water and considers only suitable areas for electricity production) of about 14,000 TWh. This potential compares to about 600 TWh for Morocco or 2,500 TWh for Saudi-Arabia. Based on this data and the vast RES-E potentials within the country it can be expected that large potentials for exporting hydrogen and derivatives are available.

6.2 Blue hydrogen

Argentina has domestic conventional gas reserves and produces fossil gas. Most of the energy consumption in the country is based on fossil gas. World Bank data shows that Argentina exports petroleum gas but also imports petroleum gas. Compared to other export goods, petroleum gas is not a significant export good (only 1,2% of export value).

The domestic conventional gas reserves are not large compared to the domestic demand (reserves can cover demand for 8 years) however, there is a large potential for unconventional shale gas. According to wintershall-DEA[37], Argentina unconventional gas resources (shale gas) rank second in

[36] https://maps.iee.fraunhofer.de/ptx-atlas/
[37] https://wintershalldea.com/en/where-we-are/argentina

the world. These resources are mainly untapped until now. The Secretaria de Gobierno de Energiá published in its “Argentina Energy Plan” numbers of strongly increasing production of unconventional gas[38]. One of the main six objectives within this strategy is to double fossil gas production in five years from 2018 onwards. This strategy includes exporting unconventional gas into the world.

Argentina produces grey hydrogen already and is experienced in steam methane reforming. However, there are no current CCS projects[39] in operation. The climate tracker states that there is also no regulatory framework or strategy for the application of CCS in place. The Secretaria de Gobierno de Energiá published in its “Argentina Energy Plan” no detailed information if blue hydrogen based on unconventional gas is expected to be achievable.

One major obstacle for blue hydrogen addressed in The Oxford Institute for Energy Studies (2021) is the reduced access to funding and high costs which is very relevant for large industry projects such as CCS projects. High cost of capital and lack of investments are mainly due to weak governance and high uncertainties for investors.

The gas pipeline network is developed and connects the major fossil gas sources and the demand centers. This infrastructure could be used to transport fossil gas to SMR facilities and produce blue hydrogen.

6.3 Other forms of hydrogen production

Coal production and **coal gasification** is not a major hydrogen production route to be expected for Argentina. However, in 2013 to 2015 a project aiming at underground coal gasification has been developed[40]. To date it is not clear what the status of this project is.

Argentina has three nuclear power plants which could be used to produce **pink hydrogen**. However, no current projects are public, that consider this form of hydrogen production. The Institute for Energy and Sustainably Development of the National Nuclear Energy Commission (CENA) do partly focus their work on pink hydrogen, however.

Biogas and biomethane is a relevant source of energy in Argentina. However, biomethane is currently blended with fossil gas. Projects looking into hydrogen production from biomass are not known of.

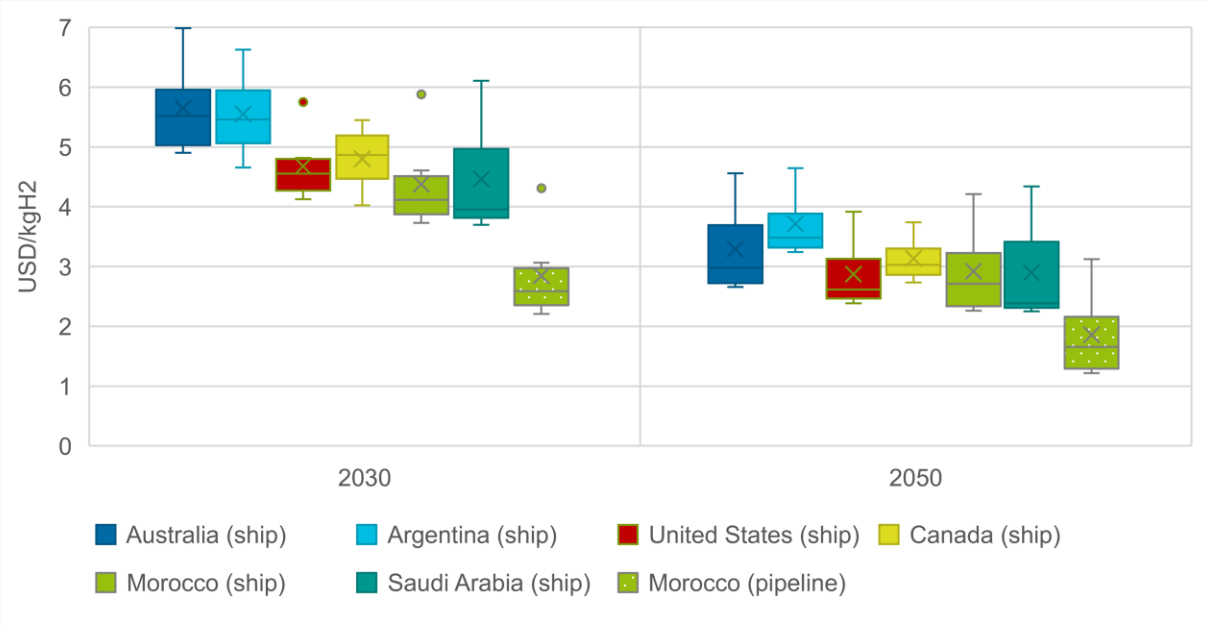
6.4 Hydrogen production costs

Due to large potentials to generate renewable power at low costs, a recent study suggests that green hydrogen in Patagonia could be produced at costs of around USD 2 /kgH_2 (Armijo und Philibert 2020). The same study also points to the advantages of producing green ammonia at costs close to those of conventional ammonia from fossil fuels. This trend can also be derived from the data published by EWI (2020) as displayed in the following table and diagram. Especially due to high transport costs the overall landing costs of hydrogen from Argentina will be relatively high. This might lead to a focus on other molecules and substances such as ammonia, methanol or e-fuels. This strategy is for example considered by other south American countries such as Chile.

[38] http://www.energia.gob.ar/contenidos/archivos/Reorganizacion/planeamiento/argentina-energy-plan_.pdf
[39] https://co2re.co/FacilityData
[40] https://delmogroup.com/claromeco-basin-ucg

Tabelle 1: Landing costs of hydrogen

Origin – Destination, Distance, (Mode)	Costs (USD/kgH_2)	2030	2040	2050
Morocco – Spain	Total supply:	2.2 – 4.3	1.7 – 3.6	1.2 – 3.1
750 km	LCOH:	2.0 – 4.1	1.5 – 3.4	1.0 – 2.9
(low cost new pipeline)	Transport:	0.2	0.2	0.2
Morocco - Spain	Total supply:	3.7 – 5.8	3.0 – 5.0	2.2 – 4.2
39 km	LCOH:	2.0 – 4.1	1.5 – 3.4	1.0 – 2.9
(ship)	Transport:	1.7	1.5 – 1.6	1.2 - 1.3
Saudi Arabia – Italy	Total supply:	3.7 – 6.1	3.0 – 5.2	2.2 – 4.3
3042 km	LCOH:	1.9 – 4.2	1.4 – 3.5	1.0 – 3.0
(ship)	Transport:	1.8 – 1.9	1.6 – 1.7	1.3
USA – Netherlands	Total supply:	4.1 – 5.8	3.2 – 4.8	2.4 – 3.9
8050 km	LCOH:	2.2 – 3.7	1.6 – 3.1	1.1 – 2.6
(ship)	Transport:	2.0	1.6 - 1.7	1.3
Canada – Netherlands	Total supply:	4.0 – 5.4	3.3 – 4.5	2.7 – 3.7
5148 km	LCOH:	2.2 – 3.6	1.8 – 2.9	1.5 – 2.5
(ship)	Transport:	1.8 – 1.9	1.5 - 1.6	1.2 – 1.3
Argentina – Netherlands	Total supply:	4.7 – 6.6	4.0 – 5.6	3.2 – 4.6
13,751 km	LCOH:	2.3 – 4.2	1.9 – 3.4	1.6 – 2.9
(ship)	Transport:	2.3 – 2.4	2.1	1.6 – 1.7



Source: own compilation based on data from EWI (2020) Note: X in the Boxplots marks the average supply cost value.

7 Hydrogen transport to the EU

Green hydrogen produced in Argentina would need to be transported to the EU by ship. Even though Argentina exports fossil gas to neighboring countries via pipelines, it does not export liquefied fossil gas (LNG). YPF, the country's biggest fossil gas producer, is conducting preliminary studies to build up terminals for LNG exports[41]. However, according to industry experts Argentina is unlikely to become a major LNG exporter before 2030[42].

Argentina has two terminals that are used to import natural gas (gas is being re-gasified from LNG on ships located in the port) during times of peak demand in winter. These are the Escobar Terminal at the Paraná River[43], about 30 miles outside Buenos Aires, and the Exemplar floating storage and regasification unit at Bahía Blanca. Additional LNG imports can be handled via the terminal in Montevideo, Uruguay, and a third domestic terminal to import LNG from Quatar is currently under consideration[44].

These terminals have direct access to Argentina's fossil gas grid, which might be repurposed to transport green hydrogen. Most important in this regard is the Gasoducto Methanex[45], which runs through Patagonia, which is destined to be a prime location to produce renewable electricity, to Tierra del Fuego. Electrolysers to produce green hydrogen could then be located close to this pipeline and be supplied with power from nearby solar and wind farms[46]. Alternatively, electrolysers could also be located close to export terminals and run with power from the national grid without the need to use a pipeline.

41 https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/121021-argentinas-ypf-studying-lng-export-for-growing-vaca-muerta-gas-production
42 https://www.naturalgasintel.com/argentina-lng-export-ambitions-said-unlikely-to-materialize-before-2030/
43 https://www.hydrocarbons-technology.com/projects/escobar-terminal/
44 https://www.reuters.com/article/argentina-lng-idUKN2319264820110323
45 https://excelerateenergy.com/projects/gnl-escobar/ https://www.gem.wiki/Bahia_Blanca_LNG_Terminal

46 https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/121021-argentinas-ypf-studying-lng-export-for-growing-vaca-muerta-gas-production

Maritime transport of green hydrogen would entail substantial costs of about USD 2 / kg H_2 for final consumers. Depending on the specific assumptions with regard to the costs of producing green hydrogen in Argentina, transport costs amount to between about 50% and 100% of production costs. Whether green hydrogen produced in Argentina will be competitive on the EU market depends to a large extent on whether there is sufficient pipeline capacity to transport green hydrogen from other countries, in particular northern Africa, to the EU. As transport by pipeline is associated with substantially lower costs, producers with access to a pipeline could offer green hydrogen at lower prices than Argentina, even if their production costs are higher. Transport costs by ship would hence render Argentina's advantage in producing renewable power at low costs insufficient to gain a foothold in the EU market.

For exports of methanol and ammonia, which are produced using hydrogen, transport costs are a lesser concern. However, it should be noted that Argentina imports about 60% of fertilizer used for the country's large agricultural sector. In both 2019 and 2020, fertilizer imports amounted to more than 3 million tons, at costs of more than USD 1 billion per year[47]. Ensuring that fertilizer produced with domestic green hydrogen is used to substitute for imports would yield more effective benefits for the climate than exporting ammonia from green hydrogen from Argentina to the EU while at the same time maintaining imports of carbon-intensive fertilizer to Argentina.

8 Sustainability issues

As envisaged in the report of the Economic and Social Council, green hydrogen would not only be produced for exports and the domestic petrochemical industry, but also to decarbonize transport and as a buffer to stabilize the power grid. Hence, hydrogen could play an important role for the energy transition in Argentina itself. In view of the large potential of cheap RE, it seems unlikely that hydrogen production will delay the phase-out of fossil fuels from Argentina's power grid. However, the lack of political signals and commitments increases uncertainty for investors (New Climate 2020).

A potential sustainability issue arises from the fact that Argentina also considers the production of 'blue' hydrogen from fossil gas in combination with Carbon Capture and Storage (CCS). Even if the use of blue hydrogen as a 'bridge technology' could help build up the hydrogen market, it entails the danger of prolonging the political influence of vested interests associated to fossil gas, thus exacerbating existing lock-ins in fossil fuels. Moreover, if storing carbon entails the risk of leakage, blue hydrogen could have a highly negative effect on the climate.

The hydrogen project proposed by Fortalesco will likely rely on desalination of sea water – thus it will not put pressure on local water resources. Nevertheless, desalination requires additional energy, and it needs to be ensured that the resulting brine will be treated and not cause local environmental problems.

A crucial question is whether production of green hydrogen in Argentina can yield broader benefits for economic development. Besides substantial potentials for low-cost wind and solar power, Argentina is well-equipped with know-how relevant for the production, transport and storage of hydrogen, e.g. through its existing petrochemical industry. If managed well, expanding hydrogen production could help promote industrial development within the 'hydrogen-lithium ecosystem'. However, economic instability could be a substantial challenge to attracting investors.

[47] https://www.world-today-news.com/what-are-the-four-main-fertilizer-factories-in-argentina/

9 Appendix

Datasets by Brändle et. al. (2020) (Institute of Energy Economics at the University of Cologne, EWI) and Fraunhofer IEE (2021) as part of their PtX-Atlas project were used in this study to show and compare green hydrogen production and -supply potentials between different countries.

Brändle et. al. (2020) modelled the total green hydrogen supply costs from multiple countries based on solar and wind energy for electricity generation and liquid hydrogen transport by pipeline or ship to other countries, assuming it will be the cheapest in long-term. They estimated the theoretical hydrogen production potentials of the countries solely based on solar and wind resources, and suitable land areas. They did not consider other constraints like access to water and do not account for technological, socio-economic or ecological factors, as are partly considered in the PtX-Atlas analysis. Furthermore, the authors only considered hydrogen production sites either based on solar or wind energy, but not both together as hybrid systems, assuming that in most countries suitable wind and PV resource areas do not overlap. Also, only standalone systems without connection to the grid were considered, assuming that excess renewable electricity is thrown away, if it cannot be used for hydrogen production. These assumptions, amongst others, can lead to an overestimation of future hydrogen production costs.

Fraunhofer IEE (2021) as part of their PtX-Atlas modelled which countries have the potential to produce green hydrogen and -derivates beyond their own needs based on RES, and can therefore become a relevant hydrogen exporter for the global market by 2050. Their modelling is not only based on RES potentials (from PV, onshore wind, hybrid sites), suitable land areas, but also on socio-economic conditions for the development of a PtX infrastructure. Not considered for the hydrogen production are, inter alia, areas with a population density of > 50 inhabitants/km², nature reserves, and potentially critical habitats, areas with electricity generation costs of more than 4 ct/kWh for wind and 3 ct/kWh for PV (based on the Global Wind Atlas and Global Solar Atlas), and - most importantly - areas with more than low water stress levels (based on WRI's Water Risk Atlas). These restrictions lead to significantly lower hydrogen production potentials than in the modelling of Brändle et. al. (2020).

Following the more rigorous restrictions and conservative assumptions considered by Fraunhofer IEE (2020), their PtX-Atlas generally shows significantly higher green hydrogen production and - supply costs to Europe than the modelling by Brändle et. al. (2020).

In this factsheet, we only showed the result of Brändle et. al. (2020)'s so-called "optimistic scenario" for green hydrogen supply costs to Europe because the assumptions under Brändle et. al. (2020)'s "baseline scenario" and Fraunhofer's PtX-Atlas regarding the future development of electrolyzer CAPEX and RE costs are further away from the findings of other recent studies than in Brändle et. al. (2020)'s optimistic scenario. Regarding the CAPEX for low-temperature electrolyser systems by 2050, Fraunhofer IEE (2021) expects only cost reductions to 470 – 550 EUR/kW and Brändle et. al. (2020) assume 450 USD/kW under their baseline scenario. However, other recent studies by the IEA (2019) and IRENA (2019) forecast the electrolyzer CAPEX to fall to approx. 200 $/kW in 2050, which is the same expectation as under Brändle et. al. (2020)'s optimistic scenario. Regarding the LCOE expectations, Table C.9 in the study by Brändle et. al. (2020) shows that also here the optimistic scenario estimations are closer to the findings of other studies than the baseline scenario assumption.

The conservative assumptions by Brändle et. al. (2020)'s baseline scenario and Fraunhofer's PtX-Atlas can lead to an overestimation of future green hydrogen production cost and -supply costs. However, on the other hand, both studies in all scenarios assume a uniform weighted average cost of capital (WACC) of r = 8%, which is likely too optimistic for many developing and emerging countries and can thus lead to an underestimation of hydrogen production costs in those countries.

10 Sources

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