The Remaking of Africa's Future through Hydrogen

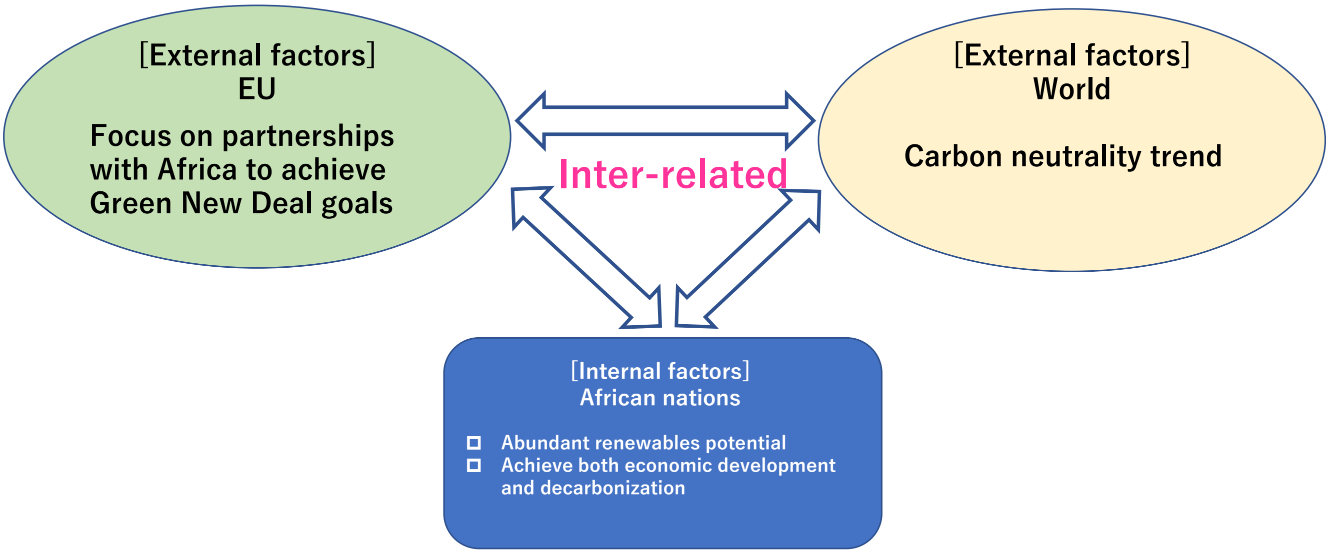
Masato Yoshida
New and Renewable Energy Group
Electric Power Industry & New and Renewable Energy Unit

Introduction

Recent years have seen governments around the world raise their hopes for the use of hydrogen as a trump card for achieving carbon neutrality by 2050. The European Commission has formulated the Green Recovery Plan and is working to revive the European economy post COVID-19 while seeking to be a world leader in the market for climate change mitigation technologies, an area in which it excels. Hydrogen will play a central role in this endeavor. Europe has already achieved a considerable measure of renewable energy usage, and with efforts to decarbonize in the industrial field, where electrification is problematic, it is no wonder that hydrogen adoption is set to gain momentum. "Hydrogen in Africa," on the other hand, is a phrase that no doubt many would have a hard time believing. Yet surprisingly, Africa is in fact attempting to transform itself with hydrogen as a driving force. This paper begins by examining the context for Africa's increasing interest in hydrogen and specific efforts being made. It then looks at issues that hydrogen-adopting countries in Africa will need to overcome, as well as the implications for Japanese companies.

1. Context for Africa's Growing Interest in Hydrogen — Internal and External Factors Driving Hydrogen

Hearing that hydrogen is currently attracting attention in Africa might make some doubtful, both with respect to the need for and feasibility of hydrogen power in the region. The truth is, many African nations are struggling financially and cannot afford to fund massive projects. They are devoid of major infrastructure such as electrical grids and power generation equipment, and have inadequate legal systems. They possess no advanced technologies and have a shortage of people with the necessary skill sets. Yet while these nations may lack a great many things, through a combination of internal and external factors that are key to realizing hydrogen power and that are working together organically, Africa's hydrogen industry is developing for entirely rational reasons (**Fig. 1-1**).

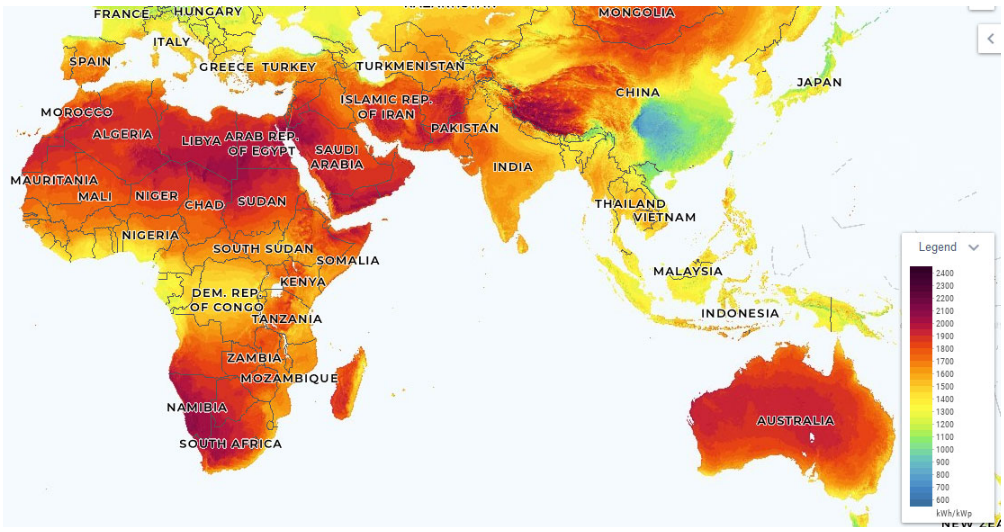


(Source) This author

Fig. 1-1 Relationship between internal and external factors driving Africa's hydrogen industry

[Internal factor 1] Advantaged renewable energy potential

One internal factor behind Africa's hydrogen industry's growth is the positively gigantic potential for renewables in the region. The map in figure 1-2 below shows solar energy resource quantities, with Africa in possession of **solar resources that exceed 2,200 kWh/m^2 across nearly the entire region**. The International Renewable Energy Agency (IRENA) estimates the **African continent to have a theoretical solar photovoltaic power (solar PV) potential of approximately 15 million TWh/year**.[1]

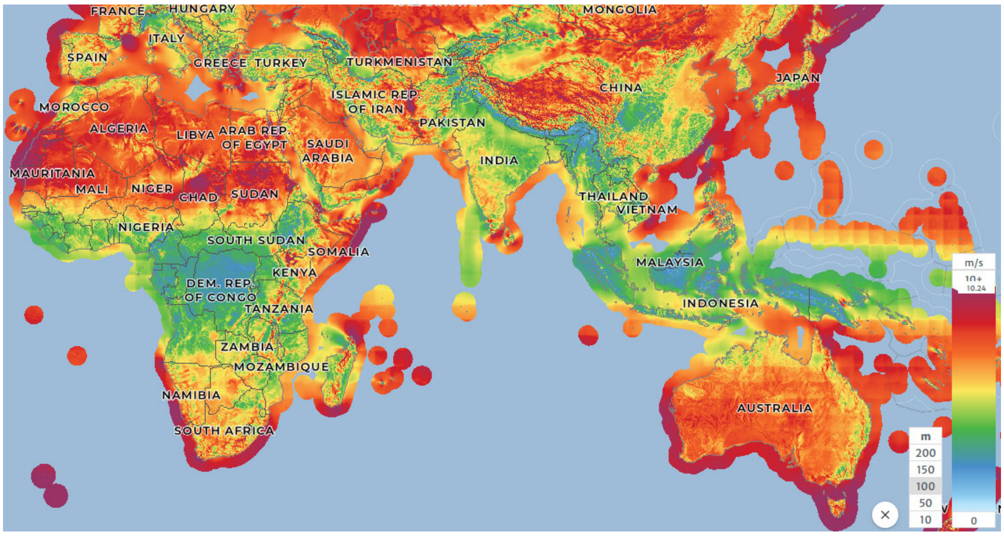


(Source) Global Solar Atlas, The World Bank Group, ESMAP, Solargis (2021)[2]

Fig. 1-2 Solar energy resources worldwide

1 IRENA (2021), *The Renewable Energy Transition in Africa*, Abu Dhabi: International Renewable Energy Agency, pp.37-38
2 World Bank Group (2021), https://globalsolaratlas.info/map?c=9.275622,23.642578,3

Africa's wind resource potential is also huge. Figure 1-3 presents global wind power resources and indicates that **coastal regions in North and South Africa enjoy wind speeds that exceed 7m/s**. IRENA estimates that the **continent of Africa has a theoretical wind power potential of about 1 million TWh/year**.[3] Some nations even have abundant offshore wind resources.

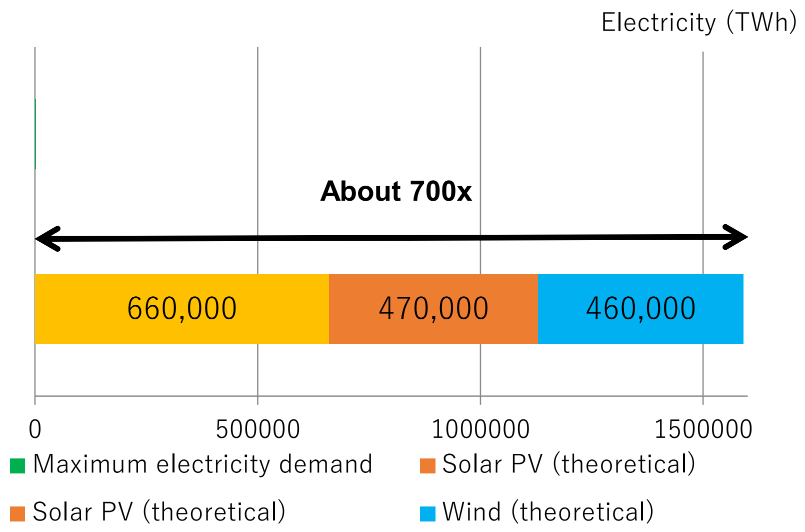


(出所) Global Wind Atlas, The World Bank Group, ESMAP, Vortex, DTU (2021)[4]

Fig. 1-3 Wind energy resources worldwide

The key point here is that **Africa's total renewable output potential greatly exceeds the region's electricity demand**. According to an estimate by the International Energy Agency (IEA), total electricity demand in Africa could grow from 700TWh in 2018 to 1,600−2,300TWh in 2040, a potentially three-fold increase.[5] IRENA also estimates a theoretical potential output of 660,000TWh, 470,000TWh and 460,000TWh for solar PV, concentrating solar power (CSP) and wind energy resources respectively, for all of Africa in 2040 (this paper defines energy from renewables as "clean energy"). While these are just theoretical numbers and much has yet to be determined, clean energy has the potential to satisfy the total electricity demand for all of Africa 700 times over in 2040, which is an order of magnitude more than the current level.

3 IRENA (2021), *Ibid*., pp.37-38
4 World Bank Group (2021), https://globalwindatlas.info/
5 Electricity demand is defined as "total gross electricity generation less own use generation, plus net trade (imports less exports), less transmissions and distribution losses," IEA (2019), Africa Energy Outlook 2019, France: International Energy Agency, pp.190-191



Source: Prepared based on data from IEA (2019), IRENA (2014)

Fig. 1-4 Comparison of electricity demand and renewables potential throughout Africa (theoretical figures, 2040)

[Internal factor 2] Hydrogen as a means to simultaneously drive economic development and solve energy poverty problems

Along with economic poverty, many African nations suffer from "energy poverty," whereby they lack access to electricity or harmless gas used for cooking. Unemployment remains high and the governments of these nations view it as a high-priority policy issue to develop the industry with the goal of creating more jobs. While the effects of COVID-19 have stalled economies in the short-term, these nations must skillfully get their economies back on track by making the most of a rapidly growing population and young workforce. Achieving a project that utilizes Africa's abundant renewable resources through hydrogen industry insourcing and external direct investment is an ideal undertaking for creating jobs and achieving economic development, while also attaining energy security.

[External factor 1] A partnership with Africa essential to realizing Europe's Green New Deal

Expressed differently, Africa's enormous renewable energy potential **lies in the enormous amount of importable hydrogen usable for renewable power generation (defined as "clean hydrogen").** This is because hydrogen is a means of transporting renewable energy (an energy carrier).

Europe, which is physically proximate to and shares historically tight relationships with African nations, will not be able to ignore the region's renewable energy resources as they will be a determining factor in whether European efforts to decarbonize succeed or fail. In December 2019, newly appointed European Commission President Ursula von der Leyen announced six commission priorities. One of these was the Green New Deal, which seeks to generate clean energy broadly and sustainably while furthering trade. This will involve building a hydrogen ecosystem mutually beneficial to Europe and Africa through collaboration between Eastern Europe (Ukraine) and North African nations (Morocco and Tunisia).[6] What has attracted investors' attention as a key action plan of the Green New Deal is the EU Hydrogen Strategy (**Fig. 1-5**).[7] This plan describes the building of and research and innovations into a hydrogen system mutually beneficial to Europe and Africa, as well as regulatory policies and collaboration on technology development to be implemented by Africa. It also details public-private support for boosting awareness for clean hydrogen through the Africa-Europe Energy Initiative, as well as a plan to consider potential projects using the European Fund for Sustainable Development.

			Phase 1 2020–2024	Phase 2 2025–2030	Phase 3 2030–2050
Qualitative targets			- Implement GW-level renewable power generation - Enlarge water electrolyzers (<100 MW) - Recommend CCS technologies - Establish regulations and institutions	- Liberalize EU's hydrogen market (around 2030) - Boost renewable hydrogen cost competitiveness - Increased hydrogen demand in the industrial sector (steel, etc.) - Provide flexibility by utilizing hydrogen in renewables-centered power systems - Develop Hydrogen Valley - Develop a hydrogen supply chain and systems throughout Europe	- Use 25% of renewable power generation for hydrogen production - Use hydrogen in sectors where decarbonization is problematic (Promote sector consolidation) - Use biogas as a natural gas alternative
			Build a hydrogen ecosystem beneficial for both Europe and Africa (Green New Deal) **Research, innovation, regulatory policy, physical interconnections, and cooperation on technological development**		
Quantitative targets	Water electrolyzers	Installed capacity	6GW	Europe: 40 GW **Non-Europe: 40 GW** **Northern Africa: About 30 GW (*)** Ukraine: About 10 GW	Become a mature market
		CAPEX	300–600 euros/kW	250–500 euros/kW	Under 200 euros/kW
	Renewable hydrogen	Costs	17-34 yen/Nm^3 (similar to the cost of fossil fuel-derived hydrogen using CCS)	11–23 yen/Nm^3 (Similar to the cost of fossil fuel-derived hydrogen using CCS)	8–17 yen/Nm^3
		Production volume	1 million tons	10 million tons	Large-scale deployment in all sectors
	Investment		Producers: 180–470 billion euros End users: 100–120 billion euros		

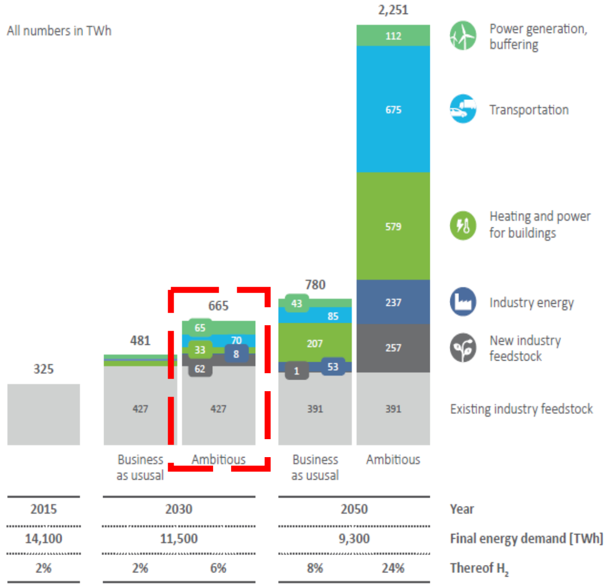
(Source) Prepared based on sources including "A Hydrogen Strategy for a Climate-Neutral Europe" (July 2020),"Green Hydrogen for a European Green New Deal A 2 x 40 GW Initiative" (March 2020)

Fig. 1-5 EU Hydrogen Strategy summary

To achieve its goal of becoming carbon neutral by 2050, the EU believes that taking concrete action over the next 10 years will be critical. The EU Hydrogen Strategy lays out specific quantitative targets concerning water electrolyzer installed capacity and CAPEX, and renewable hydrogen production costs and volume. The Strategy estimates that hydrogen demand as a proportion of final energy demand for Europe as a whole will be 17 million tons (665TWh) in 2030 (**Fig. 1-6**). Of the 17 million tons/year shown to the left, new demand will account for 6.1 million tons/year (238TWh). Roughly 70% of that, or 4.4 million tons/year, will be supplied via water electrolysis (40GW installed capacity. Own use in industry will account for 1 million tons while 3.4 million tons will go to hydrogen

[6] EC (December 11, 2019), *The European Green New Deal*, Belgium: European Commission, p.21
[7] EC (July 8, 2020), *A hydrogen strategy for a climate-neutral Europe*, Belgium: European Commission, p.20

production), with the goal of satisfying approximately 25% of the EU's total demand, which is 17 million tons/year. The water electrolyzer installed capacity needed to achieve this target is estimated to be 40GW for the EU region.



Electrolyser Capacity	2023	2024	2025	2026	2027	2028	2029	2030	Total 2030
Domestic Market [MW]									7,500
Ammonia North Africa	75	125	250	500	750	1,000	1,250	1,500	5,450
Ammonia Ukraine		50	100	200	250	300	400	500	1,800
Other (glass, steel, refineries)				10	20	30	40	50	150
Hydrogen refuelling stations					10	20	30	40	100
Export Market [MW]									32,500
Hydrogen North Africa (Hydrogen plants)		500	1,000	2,000	3,000	4,000	6,000	8,000	24,500
Hydrogen Ukraine (Hydrogen plants)			500	700	1,000	1,400	1,900	2,500	8,000
Total (MW)	75	675	1,850	3,410	5,030	6,750	9,620	12,590	40,000

(Source) Hydrogen Europe[8]

Fig. 1-6 Hydrogen demand projection for Europe (2030/2050) Fig. 1-7 Water electrolyzer installed capacity (neighboring cooperating countries)

Of particular interest is **how the European Commission is positioning the utilization of Africa's huge renewable energy potential as an essential component for achieving its 2050 carbon-neutral goal**. Specifically, along with the aforementioned hydrogen production volume within the European region (equivalent to 40GW using water electrolyzers), the European Commission is expecting **the deployment of 30GW of water electrolyzers in North Africa (realistically, Morocco), and the import of 2.3 million tons/year (24.5GW, 14% of Europe's total hydrogen demand of 17 million tons in 2030) outside of domestic demand (5.45GW equivalent, including for ammonia production)** (**Fig. 1-7**). African nations that utilize clean hydrogen will need state-of-the-art climate change mitigation technologies, an area where European companies have global dominance. Meanwhile, Europe also seems intent on deploying water electrolyzers and other such advanced technologies that are its forte by leveraging economic partnership agreements, while at the same time carrying out specific hydrogen production projects in North Africa and promoting decarbonization in the industrial sector by importing clean hydrogen produced through such projects.

[8] Hydrogen Europe (April 2020), *Green Hydrogen for a European Green Deal A 2 x 40GW Initiative*, Brussels: Hydrogen Europe, P.8 (Figure 4) & P.27 (Table 2)

[External factor 2]　Global trends surrounding carbon neutrality

The majority of African nations are poised for full-fledged economic development. It is no surprise, then, that decarbonization efforts have so far been put on the back burner. However, this situation appears to be changing in dramatic fashion.

As **Table 1-1** below shows, North African nations and South Africa have already established ambitious climate change mitigation targets. While these nations are naturally looking to join the ranks of developed nations, they seem to understand that showing their commitment to achieving a clean energy future will speed the inflow of foreign direct investment. This strategy shines light on these nations' aim to boost their energy self-sufficiency by developing hydrogen as an industrial cluster, while at the same time growing their economies and creating jobs.

Table 1-1　African nations' climate change mitigation targets

Country	Climate Change Mitigation Measures	Target Year
Morocco	52% share for renewables as a percentage of total power generation (solar PV 20%, wind 20%, hydro 12%) *10GW total new generation capacity: Solar PV 4.5GW, wind 4.2GW, hydro 1.3GW Reduce energy usage by 20% in the three largest energy consuming sectors (transport, housing and office buildings, and the manufacturing industry)	2030
Egypt	42% share for renewables as a percentage of total power generation	2035
Tunisia	41% reduction in greenhouse gas emissions compared to 2010 30% share for renewables as a percentage of total power supplied (3.8GW)	2030
South Africa	Large-scale deployment of solar PV and wind power generation facilities (6.8GW)	2022-2024
	0.5GW battery capacity deployment	By 2022 end
	Cessation of aging coal-fired power: Reduce share from 71.3% (as of 2018) to 42.6%	2030

(Source) Prepared based on data from announcements made by each nation, including Egypt Vision 2030 (Egypt) and Integrated Resource Plan 2019 (South Africa)

2.　Concrete Developments Concerning Hydrogen Industrialization in Africa

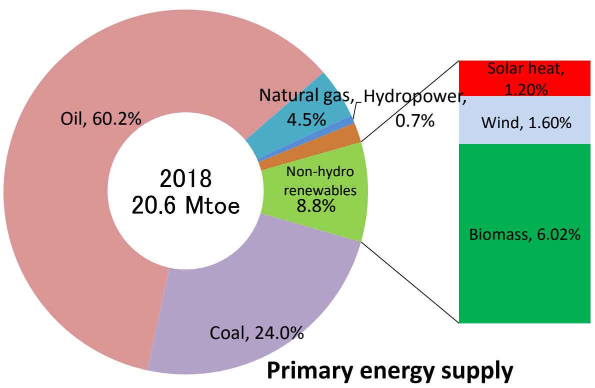
In the previous section, this paper looked at internal and external factors to provide a backdrop behind hydrogen industrialization in Africa based on the use of clean energy. This section will focus on North Africa (Morocco, in particular) and South Africa and look at specific efforts related to hydrogen industrialization.

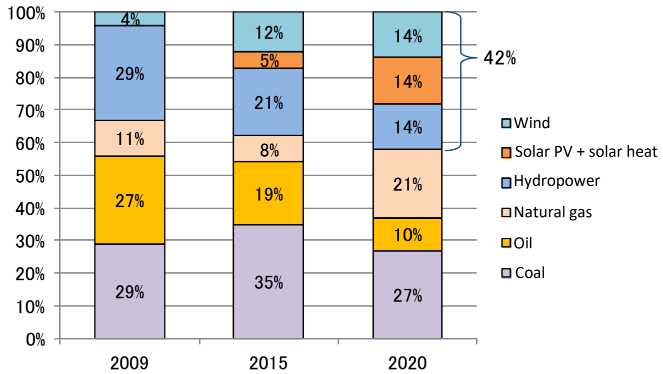
[Morocco]　A fossil fuel importer transforms into a major clean hydrogen exporter

Morocco is attempting to transform itself from an energy importer to an energy exporter by conducting clean hydrogen, Power-to-X (P2X) and other such clean synthetic fuel projects. Details are given below.

<u>Developing clean hydrogen and P2X through economic partnerships with Europe</u>

Morocco has set the most ambitious climate change mitigation targets of any North African nation. Despite fossil fuels accounting for a high 90% of the country's primary energy sources (as of 2018, see **Fig. 2-1**), it has an extremely low 10% energy self-sufficiency rate and imports almost all of its oil, coal, and natural gas. In the National Energy Strategy that Morocco released in 2009, the country aims to deploy 6GW of total generation capacity of solar PV, wind and hydro power (2GW each) and thereby increase the share of these capacities as a percentage of total installed capacity to 42% (14% each). In 2016, **<u>Morocco established new targets to increase renewables as a percentage of total installed capacity to 52% and newly deploy at least 10 GW of renewable power generation capacity</u> (4.5GW of solar PV, 4.2GW of wind, and 1.3GW of hydro) <u>by 2030</u>**. This has led to a sharp rise in the country's share of renewables in recent years. All renewables development is done through competitive bidding, and Morocco's political stability when compared to other North African nations has helped it attract foreign direct investment. This coupled with its potential for renewable energy development[9] is seeing successful progress being made on numerous projects without the need for incentives such as feed-in-tariffs. Additionally, in 2019 the country won a bid for an 850MW wind farm through one of the world's lowest tariffs: 0.028 euros/kWh, which is expected to fall to between 0.010 and 0.020 euros/kWh over the next 10 years.[10] Factors such as these make Morocco one of the most watched markets for renewables.





(Source) Prepared based on data from the IEA, World Energy Statistics and Balances 2020 (**Fig. 2-1**)

(Source) Prepared based on data from MEME, "La nouvelle stratégie énergétique nationale : bilan d'étape," Janvier 2013, p.33. (**Fig. 2-2**)

Fig. 2-1 Morocco's primary energy supply (2018) Fig. 2-2 Morocco's energy mix (2009−2020)

Along with improving the country's energy self-sufficiency rate, the Moroccan government is also promoting clean hydrogen production with a view to creating surplus export capacity. In 2019 the country established a hydrogen roadmap and put together the Hydrogen Commission, an organization spanning multiple ministries.[11] In terms of

---

9 The Sahara Desert in Morocco gets 3,000 to 3,600 hours of sunlight a year, among the highest levels in the world. Wind speeds reach 10 m/s on the country's 3,500 km coastline, which is estimated to provide wind power generation potential equivalent to 135 GW. Source: DLP Piper (February 2021),The Hydrogen Revolution in EMEA, p.27

10 *Ibid., p.27*

11 Morocco World News (January 21, 2021), https://www.moroccoworldnews.com/2021/01/332775/energy-minister-celebrates-moroccos-green-hydrogen-achievements, Ministry of

international collaboration, the Moroccan government, which is looking to take advantage of advanced technologies and funding from Europe, shares complementary objectives with the European Commission, which sees Morocco as an important nearby partner to which it can sell water electrolyzers and other technologies in which Europe excels, as well as a country from which it can import the hydrogen needed to achieve carbon neutrality for the whole of Europe by 2050. Specific projects are currently being discussed between the parties based on an economic cooperation agreement (**Table 2-1**).

Table 2-1 Morocco's collaborative relationships with and investments from other countries (renewables/hydrogen)

Field	FY	Country/Company	Details
Hydrogen	June 2020	Government of Germany (BMZ)	Signed a Memorandum of Cooperation for the development and use of clean hydrogen[12] ■ Conduct clean hydrogen and P2X projects proposed by the Moroccan government ■ Establish an R&D platform
	February 2021	Government of Portugal	Agreement to cooperate with regard to clean hydrogen[13]
	June 2021	IRENA (Abu Dhabi)	■ Jointly conduct technology and market forecast research for clean hydrogen, and promote public-private partnerships[14] ■ Jointly explore the construction of a hydrogen value chain for exporting clean carbon to global and regional markets
Renewables	October 2017	Siemens Gamesa (Spain)	Construct a wind turbine blade factory and training facility for markets in Morocco, Europe and Africa and directly and indirectly create 1,100 jobs[15]

While reducing generating costs will be key to reducing hydrogen production costs, Morocco is, as explained above, exceptionally competitive even globally when it comes to renewable generation costs. Hopes are therefore high for clean hydrogen produced in Morocco. Indeed, one estimate finds that **the cost of water electrolyzer**

Energy, Mines and Environment, https://www.observatoirenergie.ma/en/actualites/energies-renouvelables-creation-dune-commission-nationale-de-lhydrogene/

12 European council on foreign relations (January 2021), *Power surge: How the European Green Deal can succeed in Morocco and Tunisia*, United Kingdom: European council on foreign relations, pp.6-7

13 Kingdom of Morocco (February 2, 2020), “Morocco, Portugal Strengthen Cooperation on Green Hydrogen,” https://www.maroc.ma/en/news/morocco-portugal-strengthen-cooperation-green-hydrogen

14 S&P Global Platts (June 14, 2021), “Morocco eyes green hydrogen exports with IRENA renewables collaboration,” https://www.spglobal.com/platts/en/market-insights/latest-news/coal/061421-morocco-eyes-green-hydrogen-exports-with-irena-renewables-collaboration

15 Siemens Gamesa (October 11, 2017), “Siemens Gamesa inaugurates the first blade plant in Africa and the Middle East,” https://www.siemensgamesa.com/newsroom/2017/10/siemens-gamesa-inaugurates-the-first-blade-plant-in-africa-and-the-middle-east

<u>equipment will fall to around 300 euros/kW, which translates into 1 euro/kg-H_2 if 80% capacity utilization is achieved</u>.[16]

With regard to P2X, this assessment was jointly conducted by the Research Institute for Solar Energy and New Energies (IRESEN) and German Corporation for International Cooperation and the German Moroccan Energy Partnership (GIZ-PAREMA), which suggest that Morocco has the **<u>potential to capture 2-4% of the global P2X market by 2030</u>**.[17]

Currently, Morocco seems to be formulating a P2X roadmap for 2050.[18]

<u>Potential for a hydrogen-dedicated pipeline between North Africa and Europe</u>

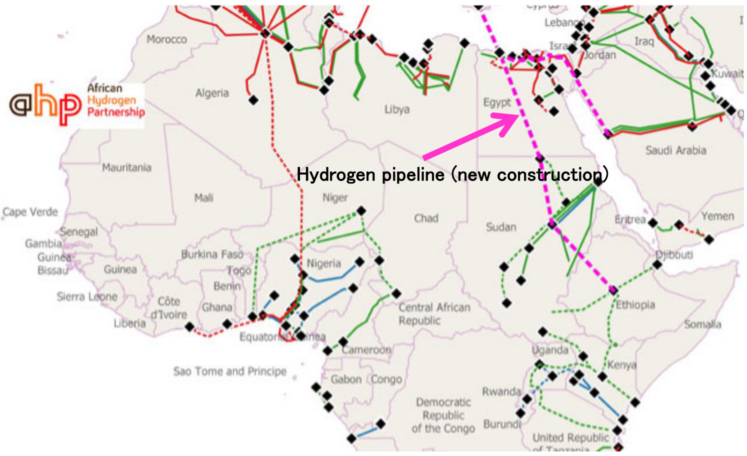
In the future, access to a pipeline exclusively for the transport of hydrogen and P2X products from North Africa to the European markets could see a dramatic decrease in transport costs compared to the use of liquid hydrogen transport vessels. According to Hydrogen Europe, the construction of a hydrogen pipeline extending from Egypt to Italy through Greece (indicated by the pink dotted line in **Fig. 2-3**, which will extend to Ethiopia and the Middle East in the future) is being mulled over that is estimated to levelize transport costs between Egypt and Italy to 0.2 euros/kg-H_2 (principal prerequisites are shown in **Table 2-2**).[19] Considering geographical advantages (there is a maritime distance of 36 miles between Morocco (Tangier) and UK territory Gibraltar, the closest point to Morocco on the European continent; this is 1/37 the length of the aforementioned Egypt-Spain pipeline), a hydrogen pipeline between Morocco and Spain could significantly reduce transport costs.

Table 2-2 Pipeline transport prerequisites and preliminary calculations

Route	Egypt --> Greece --> Italy
Total length	2,500km (1,350 miles)
Capacity	66GW (2 x 48 inch diameter)
Investment	16.5 billion euros
Availability	4,500 hours/year
Hydrogen transport volume	7.6 million tons/year
Cost	0.2 euros/kg-H_2

(Source) Prepared based on data from Van Wijk A. & Wouters (2019)

Fig. 2-3 Potential hydrogen transport infrastructure bridging the African continent with Europe



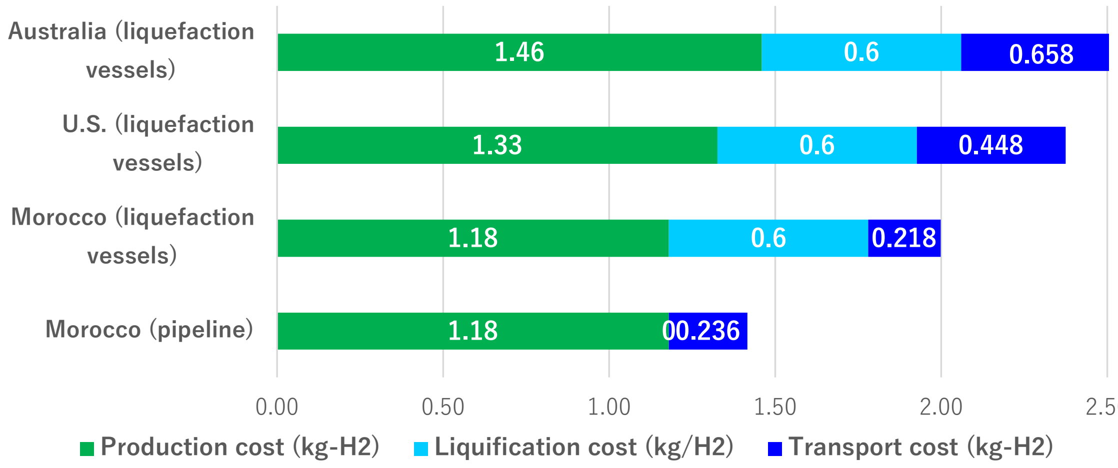
(Source) Hydrogen Europe (2020), p.17

Let us now examine the price competition advantages of clean hydrogen produced in Morocco. **Fig. 2-4** shows the price upon arrival in Spain for hydrogen produced in Morocco compared to hydrogen produced in the U.S. and

---

[16] DLP Piper (February 2021), *op.cit.*, p.28
[17] Infomineo (April 13, 2020), "Power to X: What role could Morocco play in this new paradigm?," https://infomineo.com/power-to-x/
[18] IRESEN (June 2020), *Power-To-X In Morocco Driver of Mediterranean Energy Market Integration*, Morocco: Research Institute for Solar Energy and New Energies, p.12
[19] Hydrogen Europe (June 2020), *op.cit.*, pp.15-17

Australia using a simple calculation. It assumes that Morocco will supply hydrogen via two methods, namely liquid hydrogen transport vessels and hydrogen pipelines, while the U.S. and Australia will use only liquid hydrogen transport vessels. No useful calculations exist for the Morocco-Spain pipeline cost. However, even though the distance differs, the conservative estimate of 0.2 euros/kg-H_2 shown in **Table 2-2** above is used. In light of Morocco's competitive renewable energy generation costs and geographical advantage in being close to the European continent, **clean hydrogen produced in Morocco is extremely competitive**.



Note: Clean hydrogen production costs: 2030 targets are assumed for Morocco (1 euro/kg-H_2) and Australia (2 AUD/kg-H_2)

Note: 0.6 USD/kg-H_2 is used as the provisional cost for liquefaction for all countries; Liquefied hydrogen transport vessel size: 11,000 tons-H_2

Note: No delivery costs are included in any case

Fig. 2-4 Comparison of clean hydrogen cost competitiveness with Morocco (comparison with the U.S. and Australia, 2030)

Possibilities for clean energy exports, an area of rapidly growing demand in Europe

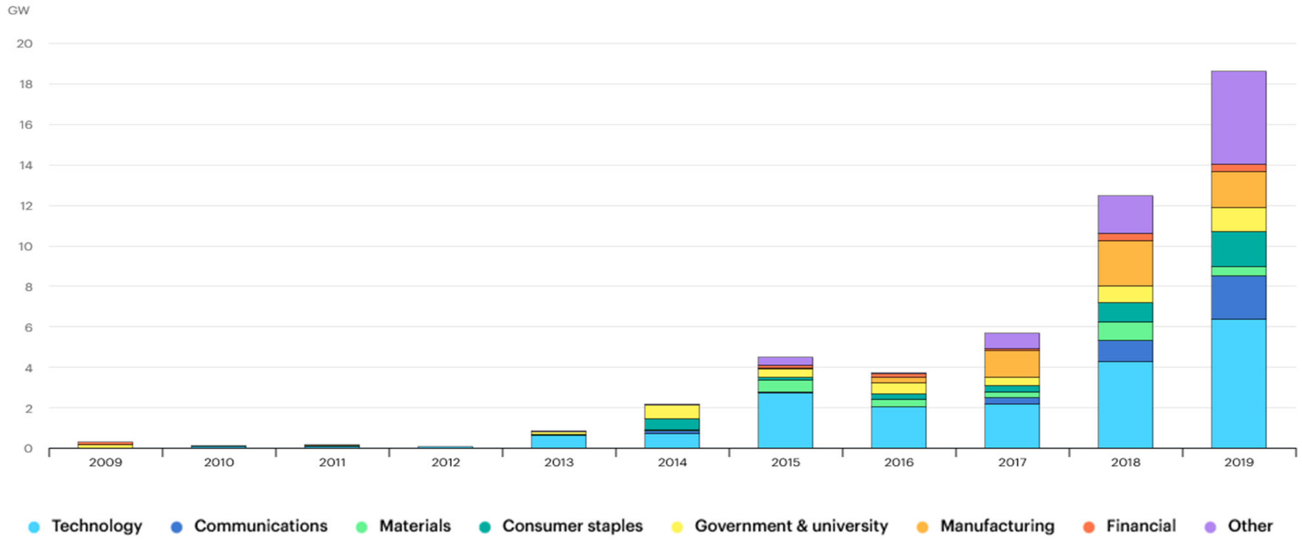
Renewables can also be exported as clean energy without being converted to hydrogen. There are currently two submarine power cables stretched between Spain and Morocco (1997: 0.7GW, 2016: 0.7GW, totaling 1.4GW). Spain once used to provide power to an electricity-impoverished Morocco, but the inverse occurred in 2019 and Morocco began sending power to Spain when its Safi coal-fired power plant went online (2 x 693MW).[20] Spain and Morocco have signed a memorandum[21] for the construction of a third submarine power cable (0.7GW), whose completion is projected to result in a total capacity of 2.1GW. Given the rapidly growing demand in Europe, the near future could see these power cables used to export clean energy from Morocco to Spain. This is due to a sharp uptick in demand for global data centers brought about by the explosive proliferation of data and digital services. The IEA predicts that total global Internet traffic will double between 2020 and 2022 to 4.2 zettabytes, one example that suggests demand for data and digital services will continue to grow at an exponential rate.[22] These factors put data center demand on

[20] Since the European Commission began considering the implementation of a carbon border adjustment mechanism, fossil fuel energy selling by Spain has been declining; European Council of Foreign Relations (January 2021), *op.cit.*,p.12

[21] *Ibid*., p.12

[22] IEA (June 2020),"Data centres and data transmission networks,"

an upward trajectory. In the energy sector, meanwhile, a key growth driver for decarbonization will be corporate PPA (**Fig. 2-5**).[23] Corporate PPA is seeing rapid growth among large IT companies such as GAFAM (Google, Amazon, Facebook, Apple and Microsoft) as a way to match 100% of their electricity consumption with purchases of renewable energy. In recent years, these companies are placing highly on offtaker rankings (**Fig. 2-6**). In Europe, business requests are already flooding in to power companies from customers in a development that is expected to see the scramble for clean energy only intensify. There are already numerous data centers online in Spain and southern France, with many plans being announced for the construction of new data centers in anticipation of future demand growth (**Fig. 2-7**). To achieve carbon neutrality for highly energy-consumptive data centers, hopes are expected to grow even further for clean energy in northern African nations.[24]



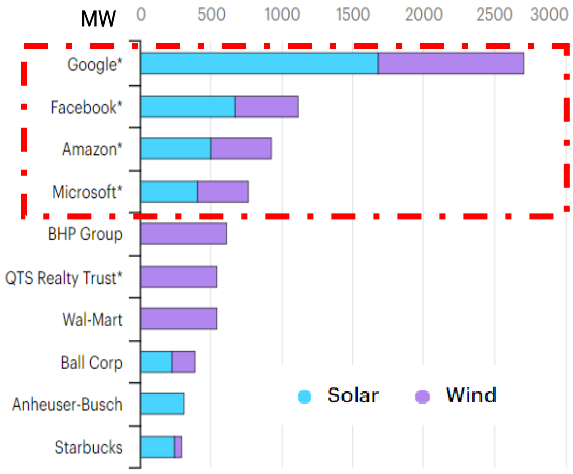
(Source) IEA (June 2020)

Fig. 2-5 Corporate PPAs around the world (by sector and capacity, 2009−2019)

https://www.iea.org/reports/data-centres-and-data-transmission-networks

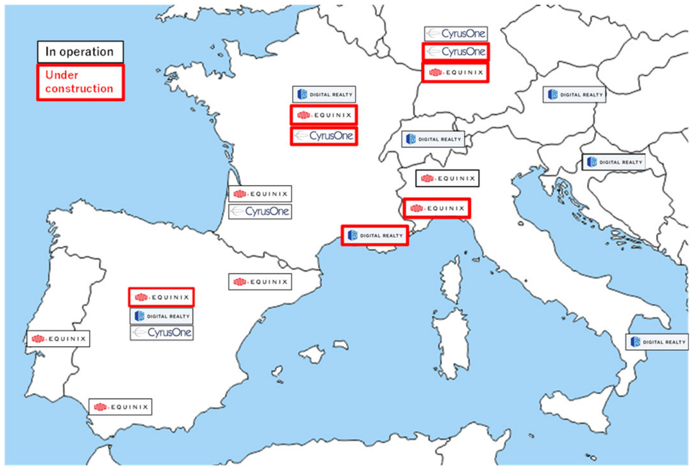
[23] Long-term contracts under which organizations such as corporations and local governments agree to purchase electricity from a renewable energy generator

[24] With support from the World Bank, a feasibility study was launched in May 2021 concerning a submarine power cable between Tunisia and Italy (0.6 GW, HVDC); MEED (August 5, 2021), “Team starts Italy-Tunisia power link study,” https://www.meed.com/team-starts-italy-tunisia-power-link-study



(Source) IEA (June 2020)

Fig. 2-6 Corporate PPA ranking (2019)



(Source) Prepared based on investor relations data from EQUINOX, Digital Reality and Cyrus One

Fig. 2-7 Southern Europe data center map (top 3 companies, 2019)

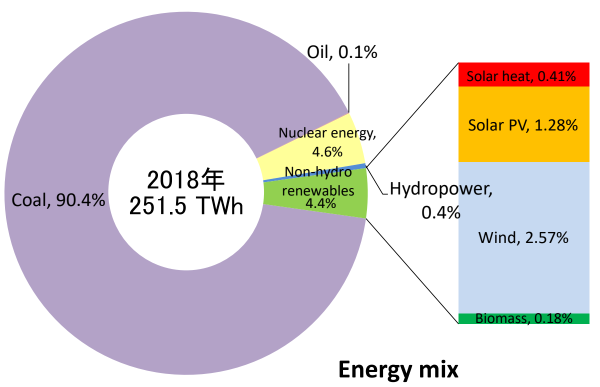
[South Africa] Focusing on creating a mega supply center for zero carbon fuel

Now let us look at efforts under way in South Africa concerning clean hydrogen. Because of geographical distance, South Africa is not a key partner for economic cooperation aimed at achieving carbon neutrality for Europe. However, South Africa is looking to achieve both economic development and carbon neutrality through a focus on producing and supplying clean hydrogen that leverages the region's rich renewables potential, as well as zero-emission vessel fuels that include synthetic fuels and clean ammonia.

As indicated in **Table 2-1** above, South Africa has set ambitious climate change mitigation targets that center on decommissioning aging coal-fired power plants and building large-scale solar PV and wind power generation facilities. As examples, the country is reducing its proportion of coal-fired power generation, which was 71% of its energy mix in 2018, to 43% by 2030 by decommissioning aging facilities, and will deploy 6.8GW of new solar PV and wind power facilities between 2022 and 2024 (**Figs. 2-8 and 2-9**). We will look at renewables potential next. With average sunshine of 2,500 hours a year and average amount of solar insolation of 4.5-6.5kWh/m^2 a year, South Africa is well-positioned for solar PV.[25] South Africa's Integrated Energy Plan 2016 (IRP 2016) calls for taking advantage of the abundant wind resources located on the country's southern coastline and coastal waters to deploy a minimum of 24GW of wind power generation facilities in base case scenario by FY 2050.[26][27] More than 100 renewable energy projects are currently being bid on internationally (solar PV 1.0GW, wind 1.6GW, totaling

[25] Department of Energy, "Renewable & Alternative Fuels," http://www.energy.gov.za/files/renewables_frame.html
[26] Department of Energy (November 2016), "Integrated Energy Plan," http://www.energy.gov.za/files/IEP/2016/Integrated-Energy-Plan-Report.pdf
[27] IRP2019 was updated into a plan calling for the deployment of 17.7 GW of wind power generation facilities by 2030

2.6GW).[28] IRENA and Sweden's Royal Institute of Technology estimate South Africa's theoretical solar PV and onshore wind power potential (facilities with availability factor of at least 20%) to be 83,000TWh/year.[29]



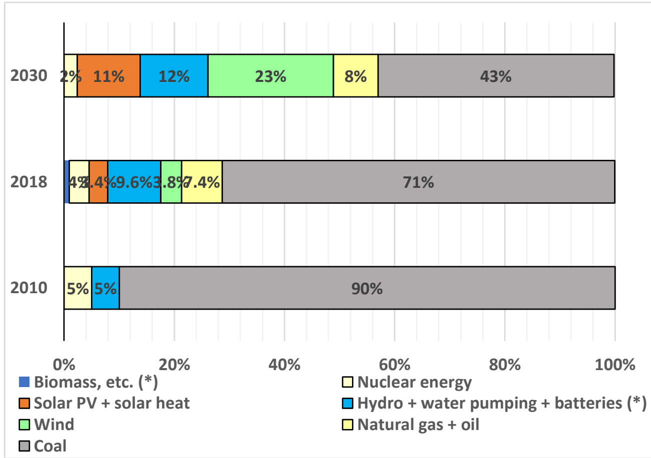


Fig. 2-8 South Africa's energy mix (2018) **Fig. 2-9 South Africa's historical energy mix (2010−2030)**

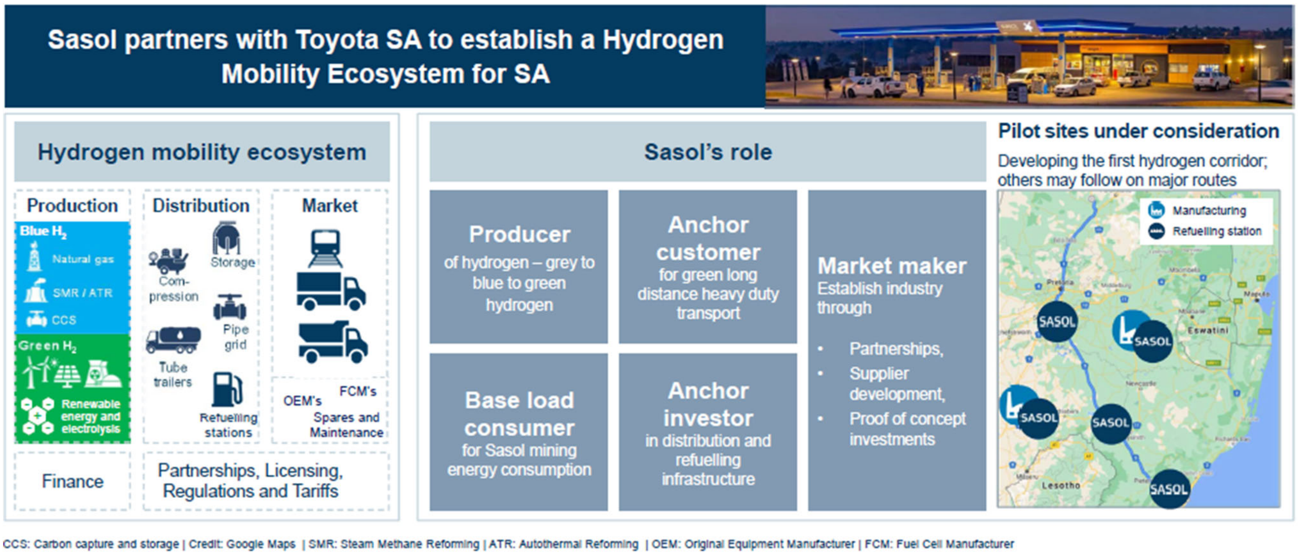
With regard to hydrogen, South Africa's Department of Science and Innovation is currently carrying out Hydrogen South Africa, otherwise known as HySA,[30] as part of the country's efforts in specific industries such as land transport, maritime transport and mining.

Approach for the land transport industry: SASOL to produce and use renewable hydrogen-based clean synthetic fuels

SASOL, a diversified energy and chemicals company of South Africa, is currently working towards decarbonization in the land transport industry. In April 2021, SASOL announced that it would be conducting a proof of concept for a clean hydrogen production, transport and utilization business together with Toyota South Africa.[31] The two companies will use heavy-duty, long-haul trucks powered by fuel cells on an arterial road running between Durban and Johannesburg. Toyota's headquarters in Japan will develop the fuel-cell trucks, while SASOL will make investments for the production of hydrogen-based clean synthetic fuels, as well as for fuel transport and supply equipment (**Fig. 2-10**). Having been involved in the development and commercialization of gas-to-liquid, coal-to-liquid, and other such synthetic fuel technologies, SASOL is now aiming to also become the market leader in synthetic fuel production and utilization.

---

28 PV Magazine (August 23, 2021), "Sixty-three PV projects to compete in South Africa's 2.6 GW renewables tender," https://www.pv-magazine.com/2021/08/23/sixty-three-pv-projects-to-compete-in-south-africas-2-6-gw-renewables-tender/
29 IRENA (2014), *Estimating the Renewable Energy Potential in Africa*, Abu Dhabi: International Renewable Energy Agency, p.36
30 Hydrogen South Africa, https://www.hysasystems.com/
31 SASOL (April 142021), "Sasol and Toyota South Africa Motors form green hydrogen mobility partnership, https://www.sasol.com/media-centre/media-releases/sasol-and-toyota-south-africa-motors-form-green-hydrogen-mobility



(Source) SASOL presentation materials[32]

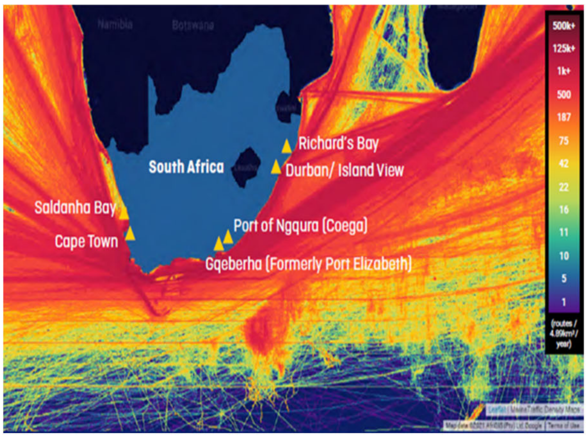
Fig. 2-10 Overview for mobility ecosystem using clean synthetic fuel-based hydrogen

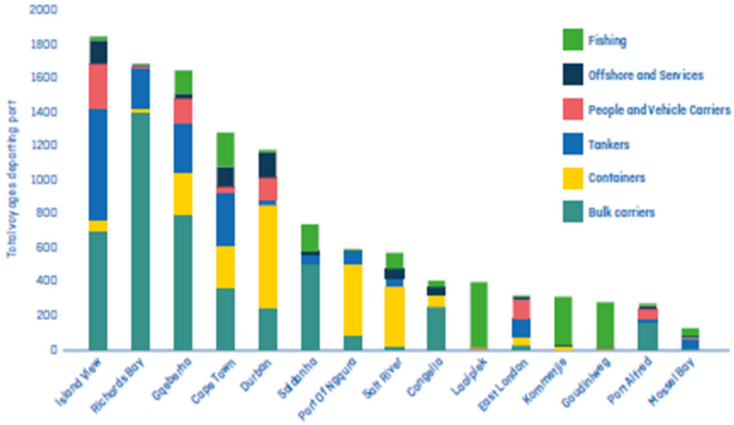
Approach for the marine transport industry: Developing a production and supply base for zero-emission vessel fuel

Decarbonizing the marine transport industry is another essential step toward achieving carbon neutrality globally. Along with a potential for renewables that far exceeds the degree needed to satisfy its own domestic demand, South Africa is located at a strategic point on maritime shipping routes, positioning it quite favorably among the countries of the world (**Figs. 2-11 and 2-12**). Looking at the economy, while South Africa's biggest export has been coal, iron ore and metals, it cannot ignore the medium- to long-term decline in demand for such products as the world moves to decarbonize. This has prompted the development of a production and supply base for zero-emission vessel fuel that will ensure a new, stable revenue stream for the long-term while jumpstarting economic development. For example, the yearly energy usage of vessels calling at Richards Bay is a considerable 27TWh, with 71% of these vessels being bulk carriers engaged in international maritime transport. Because of this, clean ammonia, which has a higher energy density than hydrogen, is well suited for supplying to vessels. With the deployment of zero-carbon maritime transport technologies at major ports in South Africa, including Richards Bay, the country is said to have the potential to attract land infrastructure investment up to 175 billion rand (1,337 billion yen) by FY 2030.[33]

[32] SASOL (April 13, 2021), 2nd Renewable Hydrogen and Green Powerfuels Webinar, "SASOL's role in unlocking Hydrogen's significant potential to contribute to energy security and trade,"

[33] Ricardo & EDF (June 2021), *South Africa: fueling the future of shipping*, United States: Environmental Defense Fund, p.28



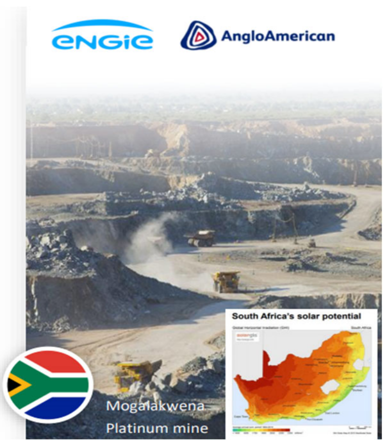


(Source) Richard & EDF (Jun 2021)

Fig. 2-11 Maritime transport traffic at major ports in South Africa Fig. 2-12 Top 15 ports for port traffic (port departures, 2018)

Approach for the mining industry: UK-based Anglo American and France-based ENGIE to advance mining industry decarbonization

Steps are also being taken towards decarbonization in the mining industry. In conjunction with France-based ENGIE, a diversified environmental services company, UK-based Anglo American is working to replace the large trucks used in mining operations with trucks powered by fuel cells. With this project, Anglo American is modifying the large diesel trucks (300-ton load)[34] while ENGIE is operating 3.5MW of water electrolyzers using solar PV deployed at Anglo American's Mogalakwena Platinum Group Metals mine to produce clean hydrogen and supply it to these trucks (**Fig. 2-13**).[35] This mine, together with science and technology parks, will serve as the launching point for the South African government's current Platinum Valley initiative to build up its hydrogen industry.[36]



(Source) METI HEMM (October 14, 2020)[37], FuelCellsWorks[38]

---

[34] Diesel tanks will be converted to hydrogen tanks and engines will be modified to use hydrogen fuel cells and battery packs
[35] Anglo American (October 19, 2019, press release), "Anglo American partners ENGIE to develop world's largest hydrogen powered mine truck," https://www.angloamerican.com/media/press-releases/2019/10-10-2019
[36] allAfrica (October 19, 2020), "South Africa: Science and Innovation on South Africa's Platinum Valley Project," https://allafrica.com/stories/202010200636.html
[37] https://www.nedo.go.jp/content/100925659.pdf
[38] FuelCellsWorks (October 10, 2019), "Anglo American partners with ENGIE to develop World's largest Hydrogen powered mine truck," https://fuelcellsworks.com/news/anglo-american-partners-with-engie-to-develop-worlds-largest-hydrogen-powered-mine-truck/

Fig. 2-13 Project Rhyno concept

3. Future Outlook

As this paper has so far examined, northern African nations and South Africa are making solid progress toward developing their hydrogen industries by leveraging their abundant renewables potential. What possible risks and challenges might they face going forward?

With clear climate change mitigation targets and plans to deploy large-scale renewable energy generation facilities, northern African nations (Morocco, in particular) are in recent years being aided by a number of large-scale projects led by foreign capital, with a focus on wind power. Nothing is more important than political stability if foreign direct investment is to continue, and one must watch for even small changes. With respect to hydrogen, the content of P2X Roadmap 2050 is something to monitor as it comes together. In terms of international cooperation, however, discussions surrounding specific projects between Morocco and Germany appear to have halted over a problem concerning interference into Morocco's internal affairs in Western Sahara,[39] posing a significant risk factor. Whether talks resume with Germany and specific projects take form thereafter will likely be key to advancing Morocco's hydrogen industry. Tunisia has immense renewables potential that is almost completely untapped, and is therefore being watched with interest by the European Commission. Achieving the greenhouse gas emission reduction targets in **Table 1-1** above will require a transition of the energy sector, which currently accounts for 75% of all such emissions. An estimated capital investment of $18 billion will also be needed.[40] While the country's recent political instability is worrying, the stage is set for renewable energy projects to move forward with the help of economic cooperation with Europe.

Similarly, South Africa has established precise renewable energy facility deployment targets which should present attractive infrastructure investment opportunities in areas such as the production and supply of zero-emission vessel fuel. The biggest risks the country faces are political instability coupled with the financial instability of state-run power companies. As foreign direct investment will be essential for economic development, the government is likely to implement an attractive array of policies.

Wrap-up

A keyword to express the future of African nations is "Leapfrog." 46% of Africa's population still has no household access to electricity. Per-capita GDP is low and many countries are still suffering from poverty. Moreover, legal systems, power grids, and other such infrastructure remain inadequate. However, abundant potential is fueling the steady implementation of renewables, which makes high growth likely to continue in the future. This distinctive position could enable these countries to leapfrog away from the large-scale, centralized power production models that have been standard practice, and away from economic and energy poverty. While situations differ among European countries, southern European countries like Spain and Portugal are blessed with solar PV and wind power resources

---

[39] Morocco World News (May 31, 2021), "Morocco Blocks Green Hydrogen Deal With Germany Over Western Sahara," https://www.moroccoworldnews.com/2021/05/342672/morocco-blocks-green-hydrogen-deal-with-germany-over-western-sahara

[40] European council of foreign relations (January 2021), *Power Surge: How The European Green Deal Can Succeed in Morocco and Tunisia*, United Kingdom: European Council of Foreign Relations, pp.10-12

that give Europe as a whole greater renewables potential than Japan. Decarbonizing industry, for which electrification is problematic, will be essential for Europe to achieve its 2050 carbon neutrality goal. Hydrogen will play an important role in this. However, because hydrogen produced in Europe will be insufficient to satisfy total European demand, Germany and Portugal are taking steady and strategic steps that include forming economic partnerships with Morocco and other northern African nations to carry out specific projects. Although country risk for African nations is unfortunately not insignificant, these nations could become an arena for trying out advanced technologies related to hydrogen and ammonia that have been developed by European companies. What Japanese companies need to do is keep a close watch from their European business sites, scrutinize individual business risk and return, and seek to acquire knowledge concerning advanced technologies. With this goal in mind, they will have to form partnerships with European companies and weigh participation in hydrogen and ammonia production projects based on project merits. At the same time, taking cues from international cooperative efforts between Europe and African nations, the Japanese government is likely to utilize G2G to provide even more robust support for forging international cooperative frameworks with Australia, Chile and Middle Eastern nations that are targeting Japan as a consumer of hydrogen and ammonia.

Contact: report@tky.ieej.or.jp