From sand to gas to green?

Perspectives on the natural gas and green hydrogen sectors in Mauritania

REPORT

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CROSSBOUNDARY

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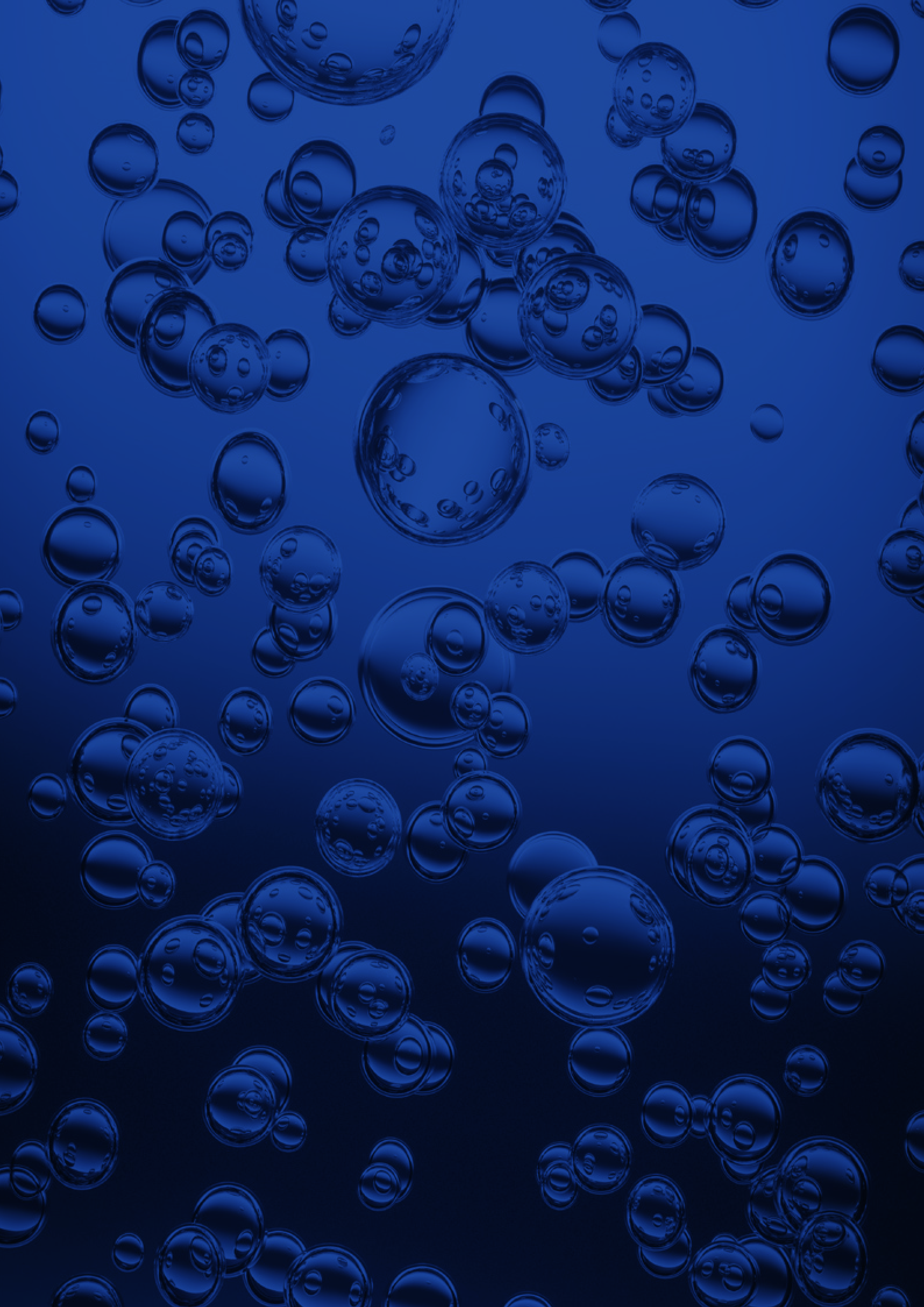


Contents

1. Executive summary

THE ENERGY markets will undergo significant changes over the coming decades as result of global efforts to reduce carbon emissions, but natural gas is expected to remain a critical component of the global energy mix. Global demand for LNG, in particular, is projected to grow significantly. Based on new liquefaction plants sanctioned or under construction and expected demand, a supply-demand gap will emerge in the mid-2020s, creating room for new investments in LNG production. In parallel, the production of green hydrogen (produced from the electrolysis of water with renewable energies) is expected to grow drastically from nil today to replace grey hydrogen (hydrogen derived from hydrocarbons). In its more ambitious scenarios, the bp Energy Outlook of 2022 projects that green hydrogen production will reach between 16 and 26 million tonnes in 2030 and between 175 and 294 million tonnes in 2050. Nevertheless, for this to happen, technological developments will be required to decrease the production and transport costs of green hydrogen and make it cost-competitive with grey and blue hydrogen.

Mauritania will become a gas exporter in 2023, with the completion of phase I of the Grand Tortue Ahmeyim (GTA) gas project, with a production capacity of 2.45 million tonnes per annum (MTPA). The GTA field is shared between Mauritania and Senegal and developed by oil companies bp and Kosmos in partnership with SMH and Petrosen, the respective countries' national oil companies. The project is critical for Mauritania and will position it as a new player in global energy markets. The project's expansion to increase capacity to 9.80 MTPA is currently being appraised. Given Mauritania's strategic location and close proximity to Europe, the country has the potential to become a critical energy partner for the continent.

The development of the gas sector will positively impact government revenues, albeit initially to a limited extent. To estimate the impact of gas exports, three price scenarios (US$ 4.1, US$ 6.8 and US$ 9.5 per million BTU on a cost, insurance, and freight basis) have been reviewed. Before investment costs are recovered, phase I of the GTA project is anticipated to result in yearly government revenues of US$ 32 million, US$ 50 million, and US$ 68 million in each respective scenario. Subsequently, they will grow to US$ 60 million, US$ 150 million, and 245 million depending on the scenario. These figures could grow if current record-level gas prices are sustained over the end of 2023 and in subsequent years and if other projects, such as the Bir Allah field, are developed.

Multiple countries and project developers are positioning themselves in the green hydrogen sector. And several export-oriented projects have been proposed in Australia, Saudi Arabia, Chile, Morocco, Namibia, Vietnam, Mauritania, and other countries. Mauritania has world-class renewable energy potential and is relatively close to a potentially large export market such as the EU, which makes it an attractive destination for prospecting project developers. The country has recently signed preliminary framework agreements with CWP Global and Chariot, proposing two projects with a potential combined capacity of 40 GW. Both projects are at an early stage, having recently started their feasibility studies, and it is thus too premature to estimate potential government revenues deriving from them. Instead, this report presents the results of a high-level financial model to illustrate the main drivers of project feasibility. They include the price of hydrogen and ammonia (conversion to ammonia is one of the most feasible options for hydrogen shipping), which will need to increase compared to their historical prices. Other critical factors include electrolyzer capacity utilization, the cost of capital, and the cost of electrolyzers. For the envisaged renewable power plant to guarantee the required high-capacity utilization of the electrolyzer, wind and solar resources will need to be both of high quality and highly complementary.

To compete against alternative geographies, the Government of Mauritania and its partners have started laying the foundations required for developing the hydrogen sector. CWP Global and Chariot are undertaking the required feasibility studies. Meanwhile, the Government is completing a multi-year strategy with support from the World Bank and is developing the required legal and regulatory framework with the support of CONNEX Support Unit and the European Union. To complement these initiatives, the Government is encouraged to continue fostering a conducive investment climate, implement policies that decrease the country risk perception and the cost of capital, promote Mauritania as an investment destination and invest in capacity-building efforts for public officials and workers required to meet the needs of the energy sector.

In this context, the Government's commitment to the principles of the Extractive Industries Transparency Initiative remains highly relevant. Once the GTA project becomes operational, authorities and other stakeholders must create realistic expectations and report on the impact of gas revenues on the government budget and public finances. In addition, given the size of the proposed investments, the Government of Mauritania should consider expanding the scope of the EITI initiative to the green hydrogen sector. Indeed, while the EITI initiative has typically focused on the mining and oil and gas sectors, some countries have extended its scope to other sectors, such as forestry, fisheries, and renewable energies. This would require, for instance, publishing (once available) the documents defining the fiscal regime and regulatory framework for green hydrogen projects, including procedures for granting licenses, contracts, etc. This will increase transparency in the sector and support efforts to mobilize funding for the sector's development.

2. Purpose of this report

Mauritania is at the heart of the challenges and opportunities related to the global transition towards a lower-carbon economy with significant potential for growth in the extractive sectors. From being a net energy importer and heavily reliant on oil imports used for electricity production, the country will become a gas exporter once phase 1 of the Grand Tortue Ahmeyim (GTA) gas field project starts operations in 2023. Phases 2 and 3 of the GTA project are being assessed. Additionally, the Bir Allah project has significant resources in place, although the feasibility of development is still to be confirmed. Mauritania has also attracted the interest of green hydrogen project developers and has recently signed preliminary framework agreements with CWP Global and Chariot, proposing two projects with a potential combined capacity of 40 GW.

The purpose of this report is to review the status and prospects for the development of the gas and green hydrogen sectors in Mauritania and the extent to which global carbon-reduction policies may hamper or support their development. In particular, the report aims to answer the following questions: will carbon emission reduction policies significantly reduce the demand for oil and gas and hamper the prospects of Mauritania's nascent gas export sector? Similarly, are the same policies conducive to the development of a green hydrogen sector in Mauritania? What may be the potential impact of the development of both sectors in Mauritania, particularly on government revenues? Which opportunities and challenges exist, and what initiatives can Government and donors undertake to foster the development of both sectors? To achieve this, the report reviews the status of maturity of the major proposed projects, the challenges to be surmounted to bring them to light, and the potential impact on them of alternative price scenarios. The study also aims to support the Mauritania EITI office, strengthening its role in providing analysis of available data that is useful to policymakers, private sector developers, and other stakeholders, including civil society and the public at large.

3. Developments in and perspectives on the natural gas sector

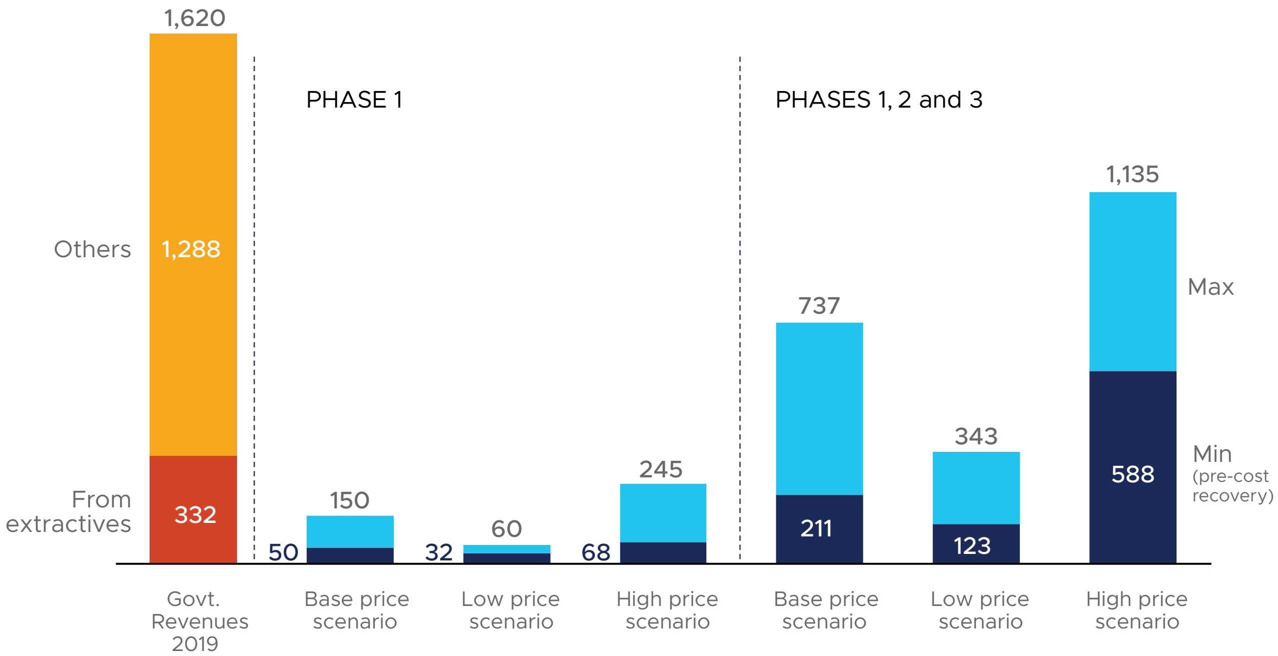
Mauritania is on track to become an exporter of Liquified Natural Gas (LNG) in 2023. Mauritania is a relatively newcomer to the oil and gas industry. In 2014, the first large discovery was made by Kosmos Energy at the GTA gas field, an ultra deepwater deposit shared between Mauritania and Senegal. The GTA field is being developed by BP and Kosmos in partnership with national oil companies SMH in Mauritania and Petrosen in Senegal and is estimated to have reserves of around 15 TCF shared between Mauritania and Senegal. The first phase, with a processing capacity of 2.45 MTPA, is to start production in 2023.

At least initially, the GTA project's impact on government revenues will be limited. A financial model has been built to estimate the impact of the GTA project on government revenues (detailed assumptions and results are presented in Annex 1). Three price scenarios have been considered. A free-on-board (FOB) gas price of US$ 6.6 per million BTU has been assumed for the base case scenario, US$ 4.0 per million BTU for the low case scenario, and US$ 9.2 per million BTU for the high price scenario. In the initial years of production, before investment costs are recovered, phase I of the GTA project is projected to result in annual government revenues of US$ 50 million, US$ 32 million, and US$ 68 million in each of the three alternative scenarios. Subsequently, once investment costs have been recovered, annual government revenues are projected to increase to US$ 150 million, 60 million, and 245 million in the respective scenarios. This compares to total government revenue of US$ 1.6 billion in 2019.

But an expansion of the GTA project would drastically boost government revenues. A second and third phase of the GTA project to increase production to 9.8 MTPA are currently being appraised. The expansion of the GTA project would significantly increase annual government revenues to an estimated US$ 737 million in the base price scenario, US$ 343 million in the low price scenario, and US$ 1,135 million in the high price scenario. Given the unpredictability of energy markets and prices, the country will benefit from adopting a prudent fiscal policy to manage oil and gas revenues.

FIGURE 1

Potential annual government revenues from the GTA project, compared to 2019 total government revenues (MM US$)

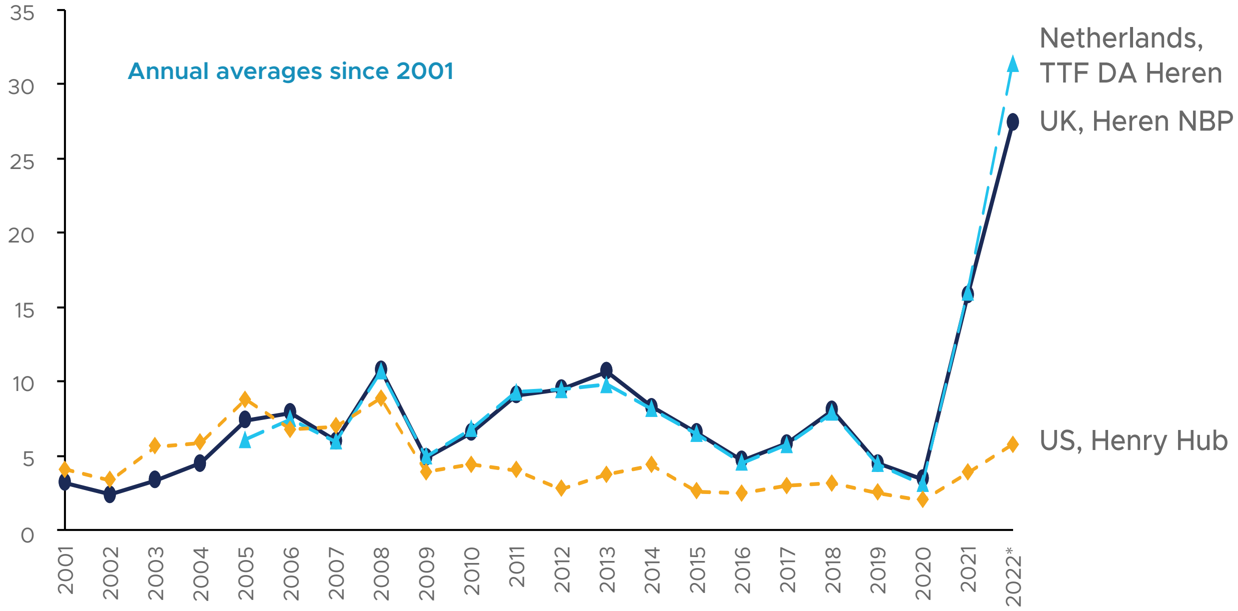


Source: EITI reports and CrossBoundary calculations

These projections are conservative in terms of price, partially ignoring the drastic increase in gas prices over 2021 and 2022. Price scenarios take as reference historical UK gas import prices (Heren NBP), which are closely aligned with the Netherlands TTF prices. For the base scenario, conservatively, we have assumed a cost, insurance, and freight (CIF) price of US$6.8 per million BTU, the average annual UK Heren price for 2001 to 2020. The low case scenario assumes a CIF price of US$4.1 per million BTU, a 40% decrease over the base scenario. The high case scenario assumes a CIF price of US$9.5 per million BTU, a 40% increase over the base scenario. To estimate FOB prices, transport costs are assumed to account for 3 % of CIF prices. Given the spike in gas spot prices in 2021 and 2022, these price assumptions may seem conservative. Over the first five months of 2022, UK prices averaged US$27.4 per million BTU, and Netherlands TTF prices averaged US$31.4 per million BTU. Nevertheless, in the mid-term, as demand and supply adjust, prices are assumed to revert to historical prices partially. Given that the model extends over 30 years, the considered price scenarios are reasonable.

FIGURE 2

Natural gas prices, (US dollars per million BTU)



Total averages since 2001 (excluding 2022)	
Netherlands, TTF	7.45
UK, Heren NBP	6.81
US, Henry Hub	4.42

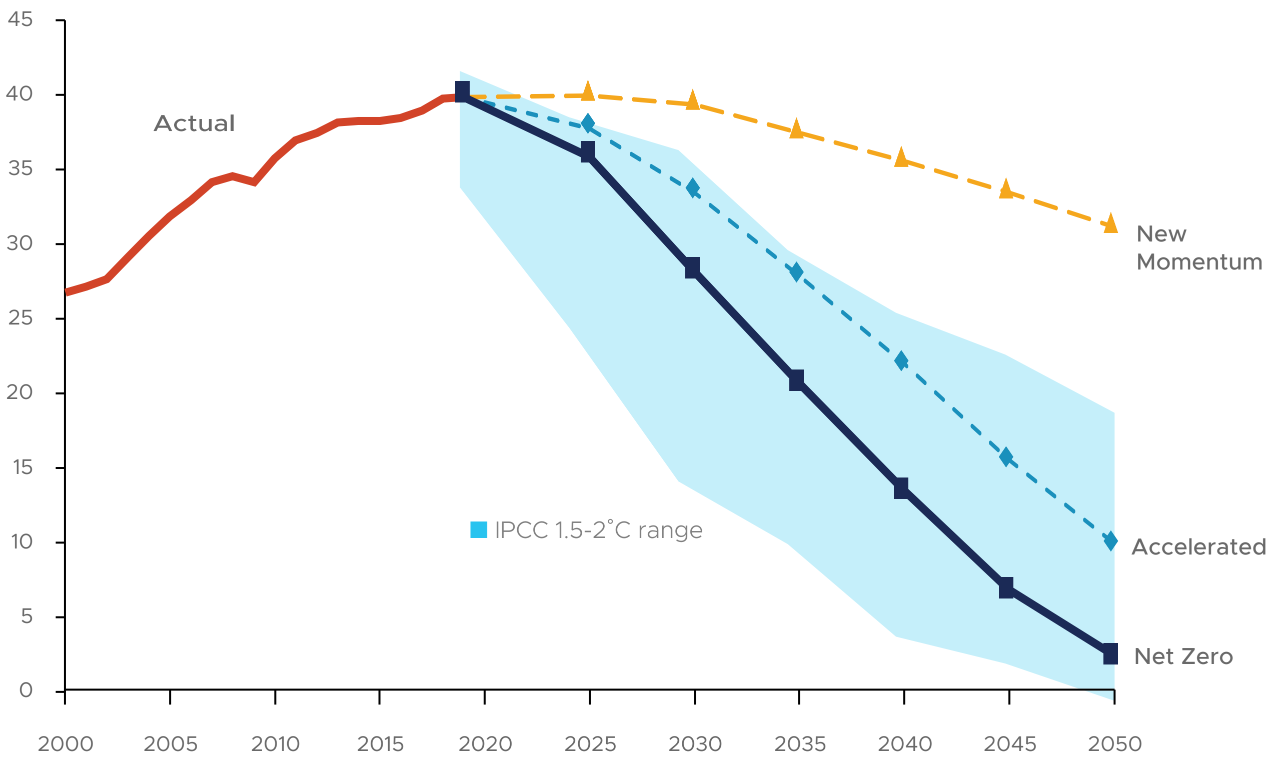
** Average prices as of end of May*
Sources: bp Statistical Review of World Energy 2022 until 2021. EIA and Fitch

The country has significant upside potential to grow production over the next decade. The Bir Allah gas field, participated by BP (62%), Kosmos Energy (28%), and SMH (10%), was discovered in 2018 and is believed to have circa 50 TCF of gas initially in place (GIIP). However, the feasibility of development is still unclear. If feasible, the Bir Allah field could dwarf the size and revenues of the GTA project. The offshore Banda gas field (discovered in 2003 and for which a gas-to-power project was proposed in 2014) was never developed and was ultimately abandoned by Tullow in 2021. Other developers have shown interest in reviving the gas-to-power project and are in preliminary stages of discussion with government authorities.

Global efforts to decarbonize the economy should not necessarily prevent Mauritania from increasing its gas production over the next decade. On the contrary, gas demand may be boosted in the short and mid-term, given its role as a transition fuel in decarbonization efforts. The bp Energy Outlook for 2022 presents three alternative scenarios for the energy sector up to 2050. Two scenarios (Net zero and Accelerated) are aligned with the Intergovernmental Panel on Climate Change (IPCC) scenarios consistent with maintaining the global average temperature below 2˚C. In the third scenario (New Momentum), CO_2 emissions decrease more slowly, from 39.8 Gt in 2019 to 31.1 Gt in 2050. While oil demand is projected to decrease in the three scenarios, demand for gas is expected to remain significant.

FIGURE 3

Global carbon emissions scenarios included in bp Energy outlook 2022, Gt of CO_2e



Source: bp Energy Outlook 2022

FIGURE 4a

Global oil demand, MMb/d

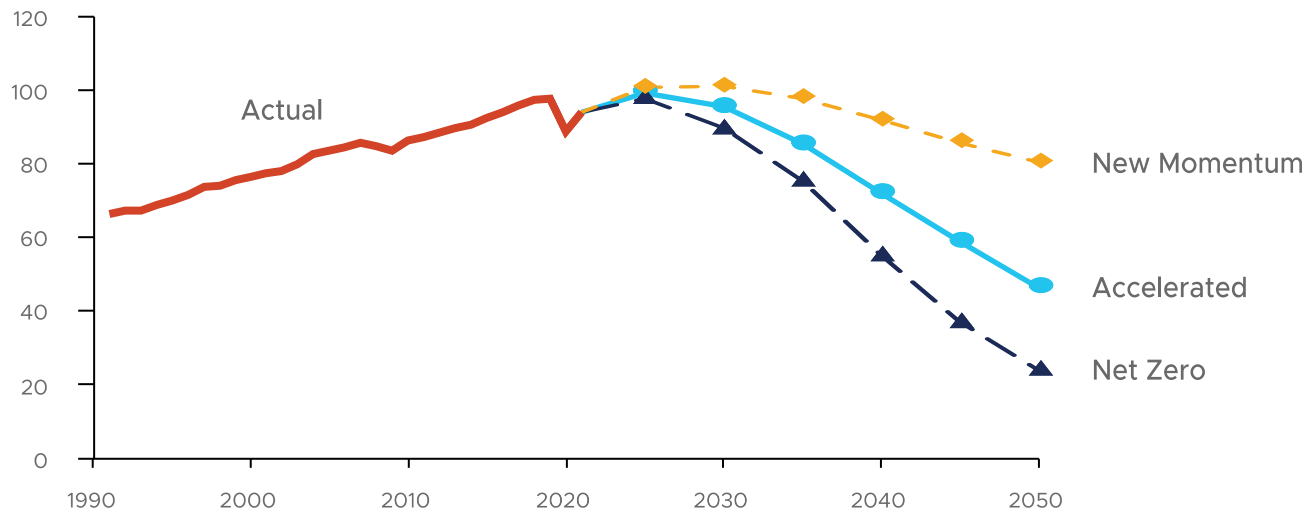
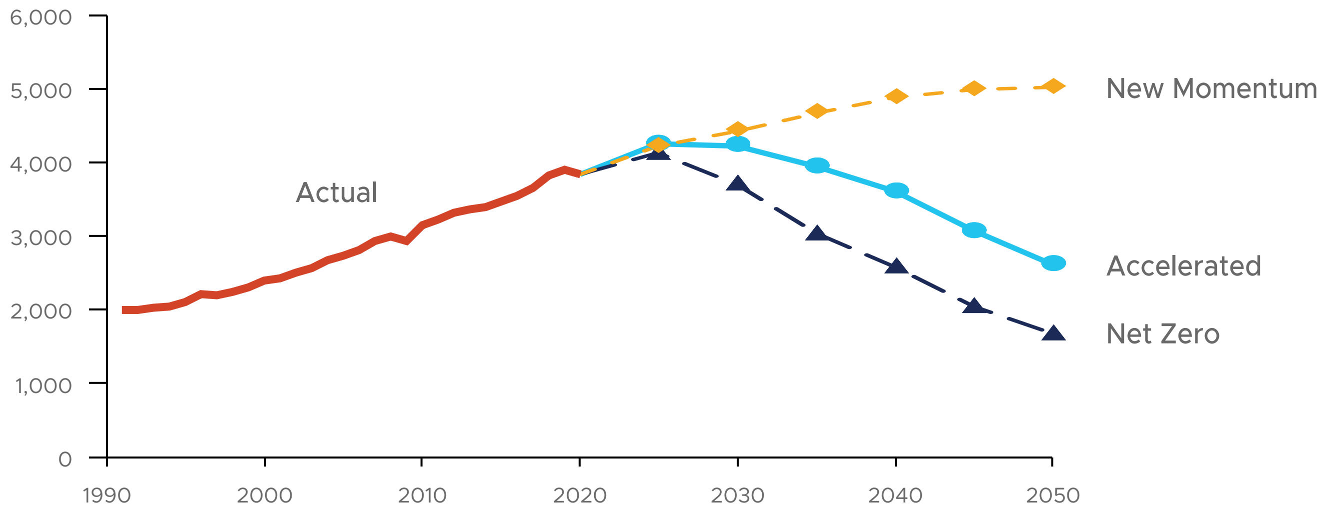


FIGURE 4b

Global natural gas demand, Bcm



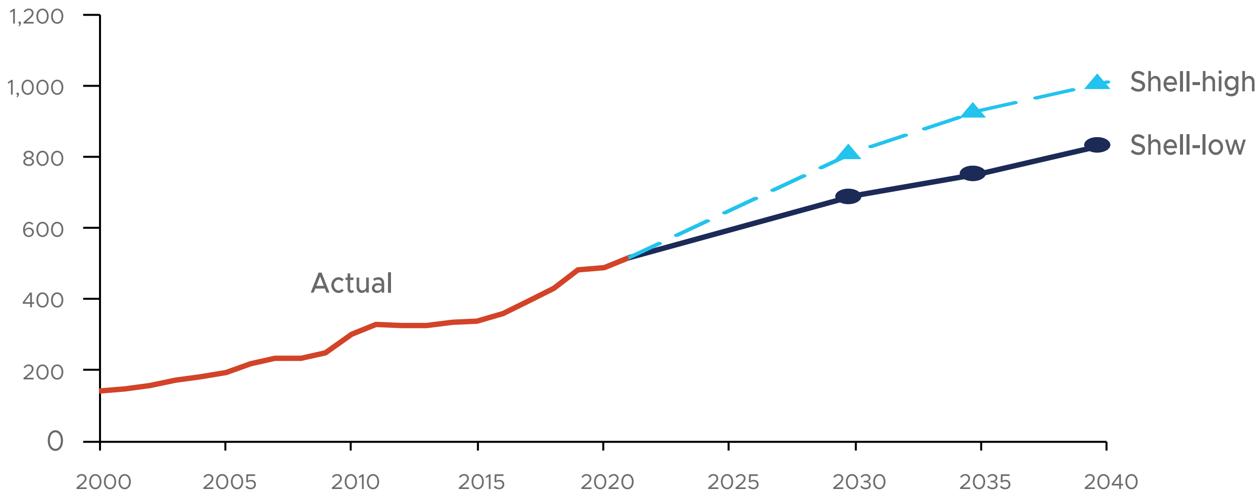
Source: bp Energy Outlook 2022, bp Statistical Review

In particular, LNG demand may grow in the next two decades. The Shell LNG Outlook 2022 forecasts that global LNG demand will keep growing to reach 800 to 1,000 Bcm/per year by 2040. Meanwhile, based on new liquefaction plants sanctioned or under construction[i], annual LNG liquefaction capacity is to grow from 628 Bcf in 2021 to 801 Bcf in 2026, indicating a supply-demand gap emerging in the mid-2020s and creating room for new investments in LNG production. Nevertheless, competition for these investments will be stiff, with 1,034 MTPA of liquefaction capacity currently at the pre-FID stage, mostly in the United States, Canada, and

Russia, and of which 123.9 MTPA in Africa[ii]. Current world tensions and the fragmentation of global energy markets may create further opportunities for Mauritania. The country's strategic location and close proximity to Europe could make it a critical energy partner for Europe at a time when it is seeking alternative gas suppliers to reduce its reliance on Russian gas.

FIGURE 5a

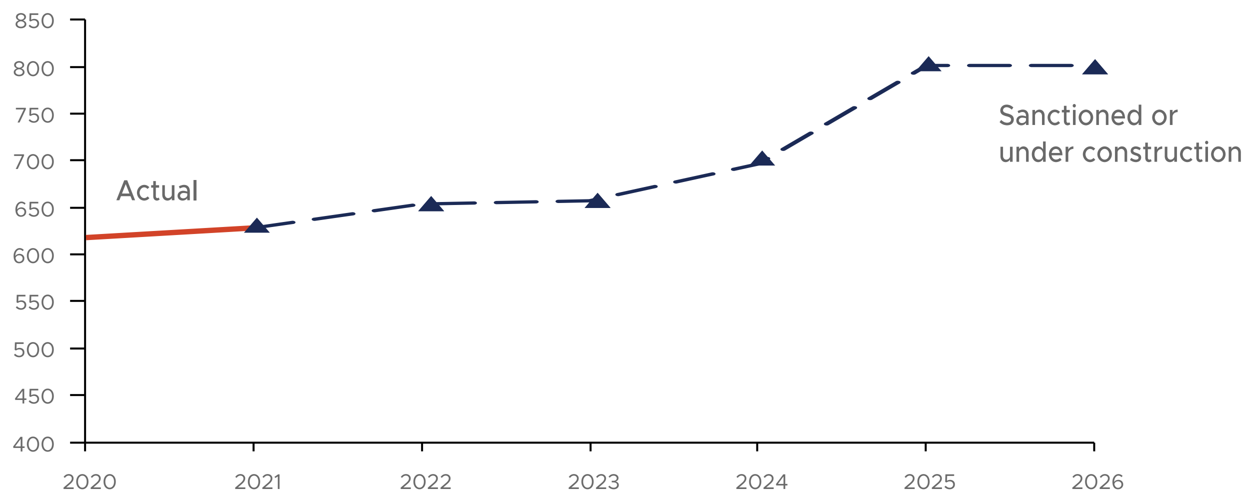
Global LNG demand, Bcm



Source: bp Statistical Review 2022, Shell LNG Outlook 2022

FIGURE 5b

Global LNG liquefaction capacity, Bcm



Source: GIIGNL Annual Report 2022, IGU World LNG Report 2022

FIGURE 6a

Global primary energy by fuel, EJ

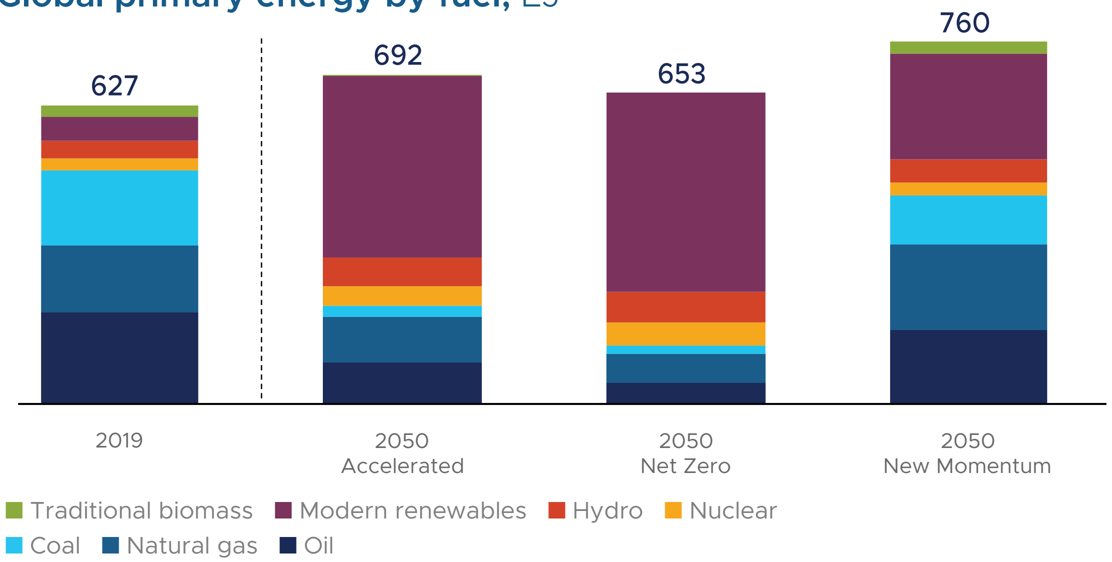
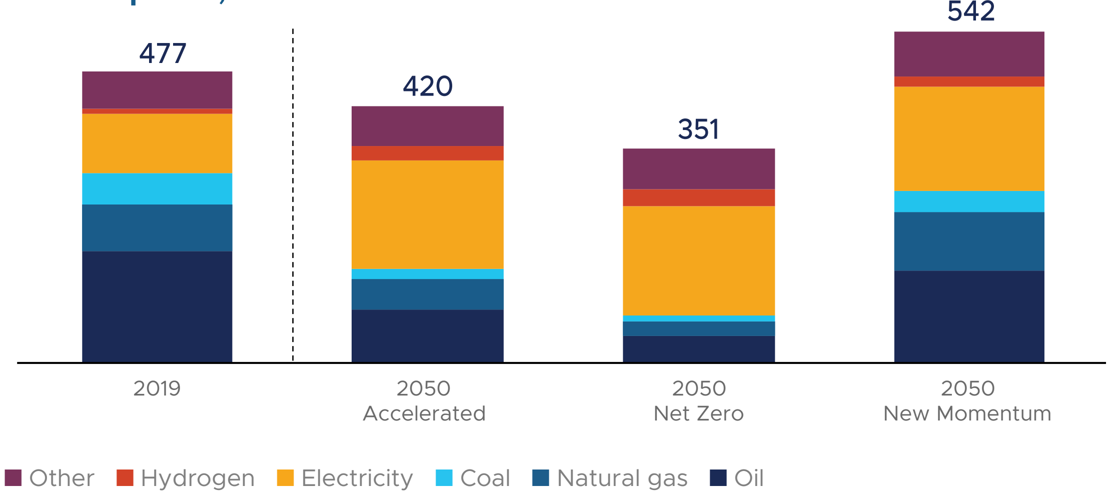


FIGURE 6b

Fuel composition of global final energy consumption, EJ



Source: bp Energy Outlook 2022

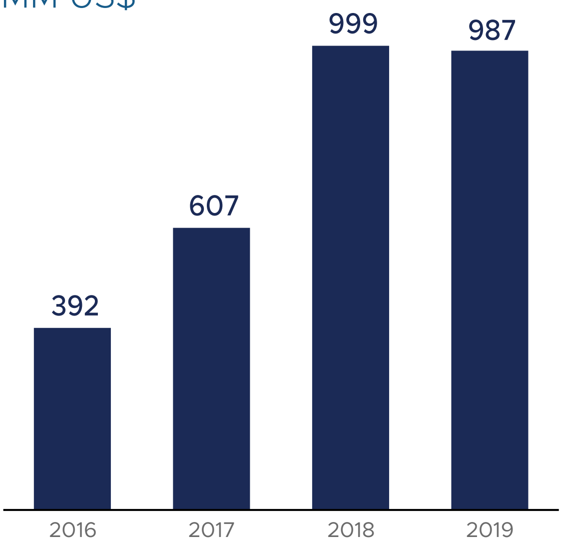
Consequently, Mauritania has realistic prospects to increase its production capacity over the next years. The partnership of Mauritania with bp and Kosmos for the development of phase 1 of the GTA project has been positive and bodes well for future developments. The country should keep engaging with investors and continue building and promoting a conducive investment environment. A follow-up expansion of GTA and other investments in the gas sector would consolidate Mauritania's position in the global energy markets as an investment destination and a serious contender in the green hydrogen sector. Given the significant impact these projects would have on government revenues, the Mauritania authorities should keep strengthening governance and public financial management systems to ensure the country capitalizes on the opportunities related to the development of the natural gas sector and mitigates related risks.

In this context, the Government's commitment to the principles of the Extractive Industries Transparency Initiative remains highly relevant. Once the GTA project becomes operational, it is expected that subsequent annual EITI reports will build on the findings of this document and, with inputs from authorities and other stakeholders, create realistic expectations for local stakeholders by reporting on the actual impact of gas revenues on the government budget and public finances. The Mauritanian EITI initiative can also support authorities by informing public debate and energy transition planning.

Gas resources also offer the opportunity to reduce oil imports and Mauritania's carbon emissions substantially. Mauritania imports US$ 1 billion-worth of oil products annually, with fuel oil used in power generation accounting for a large portion of this amount. While the country has invested significantly in renewable energy over the last decade, with several large-scale solar and wind power farms in operation and development, oil accounts for three-quarters of installed capacity and electricity generation. The country's NDC identifies the energy sector as the main lever to reduce GHG emissions. The NDC foresees increasing the share of renewable energies to 50 % by 2030 with the construction of a 50MW solar plant (Desert to power initiative), the development of the Aman Green Hydrogen project, and the expansion of the Nouakchott wind power plant from 30 MW to 50 MW. The NDC also foresees the construction of two gas-fired power plants of 200 MW and 300 MW to substitute existing diesel power plants such as those of Nouakchott and Nouadhibou. This will rely on the completion of proposed gas projects. Phase 1 of the GTA project includes a domestic supply obligation of 35 million SCF/day to supply a 200 MW power station. Based on electricity generated with diesel in 2020, it is estimated that a shift to gas-powered generation could reduce carbon emissions by 40%, corresponding to circa 155,000 tonnes of CO_2 per year, while significantly reducing electricity generation costs and increasing economic development potential.

FIGURE 7a

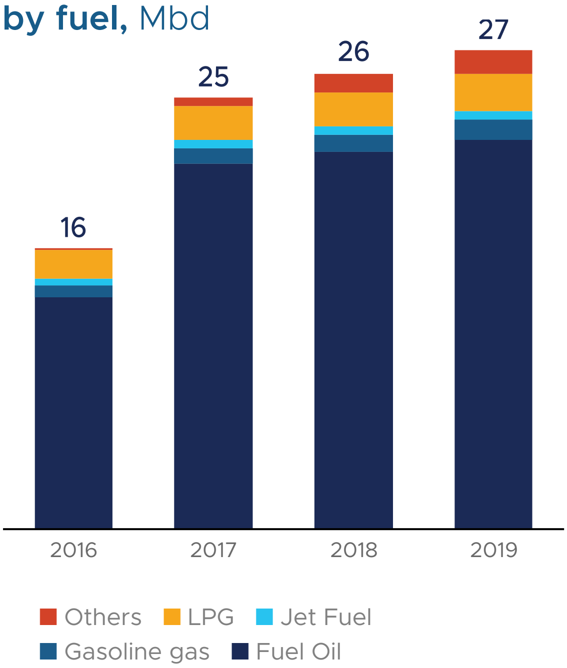
Mauritania oil imports, MM US$



Source: Comtrade

FIGURE 7b

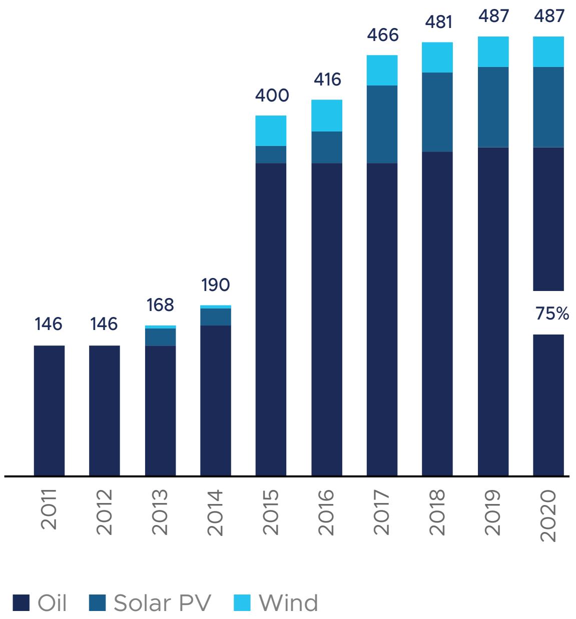
Mauritania oil consumption, by fuel, Mbd



Source: US EIA

FIGURE 7c

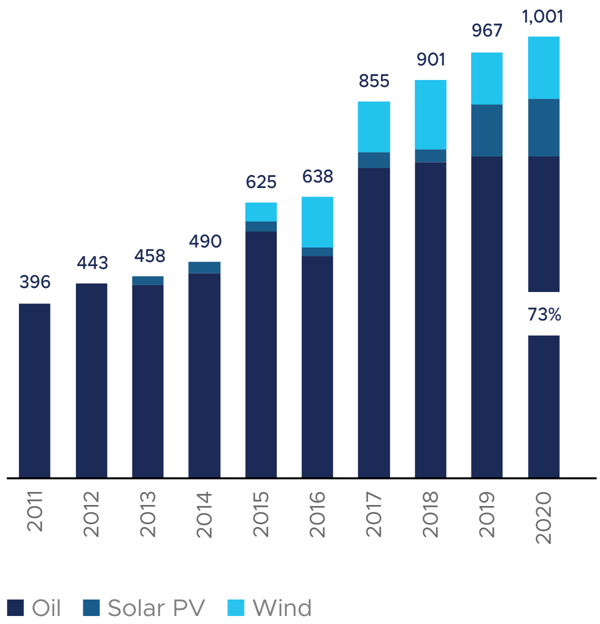
Mauritania installed generation capacity, MW



Source: Climatescope 2021

FIGURE 7d

Mauritania electricity generation, GWh



Source: Climatescope 2021

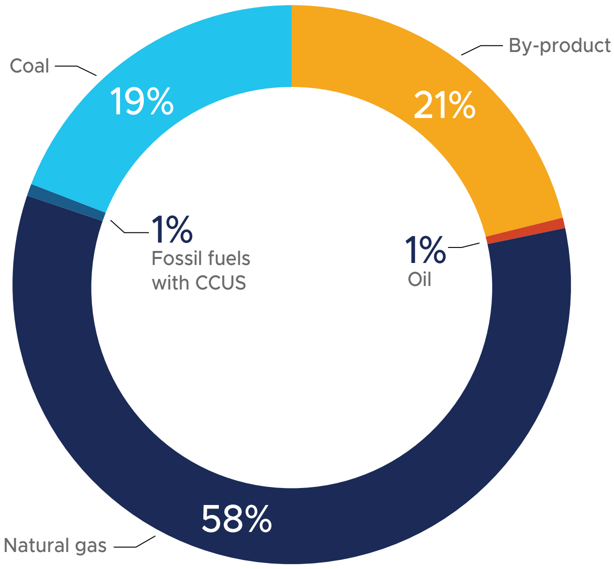
4. Developments in and perspectives on the green hydrogen sector

A. Green hydrogen is a nascent sector with a large potential for development and growth

Green hydrogen can store energy produced from renewable sources and has the potential to become an alternative to hydrocarbon fuels such as diesel or gasoline. Pure hydrogen is typically not found in nature because it is extremely reactive. Currently, hydrogen is produced from fossil fuels and used in refining and industrial processes, with global demand amounting to 67 MM tonnes in 2019[iii] and contributing some 700 MM tonnes of CO_2 emissions per year[iv].

FIGURE 8

Global hydrogen production, by source, 2020

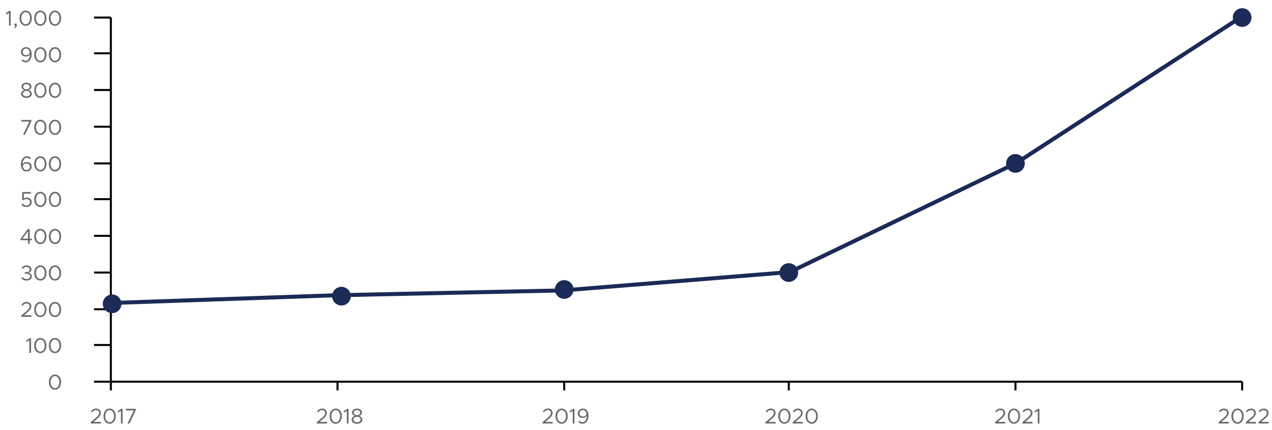


Source: IEA

Hydrogen can also be produced from the electrolysis of water. The process, if powered by renewable energies, has the potential to create a clean fuel to power hydrogen combustion engines and fuel cells. Nevertheless, the technology required to produce green hydrogen is in the early stages of development, and production costs are high. The Levelized Cost of Hydrogen (LCOH) for green hydrogen can reach up to US$ 6 per kg, more than twice the historical cost of grey and blue hydrogen at US$ 1 – 2/kg[v] (although the recent spike in gas prices has significantly increased the cost of hydrogen derived from hydrocarbons[vi]). As a result, production of green hydrogen has been negligible to date, and global installed electrolyzer capacity is still very low, albeit growing, with 300 MW of capacity installed in 2022 and 1 GW of installed capacity expected by the end of 2022.

FIGURE 9a

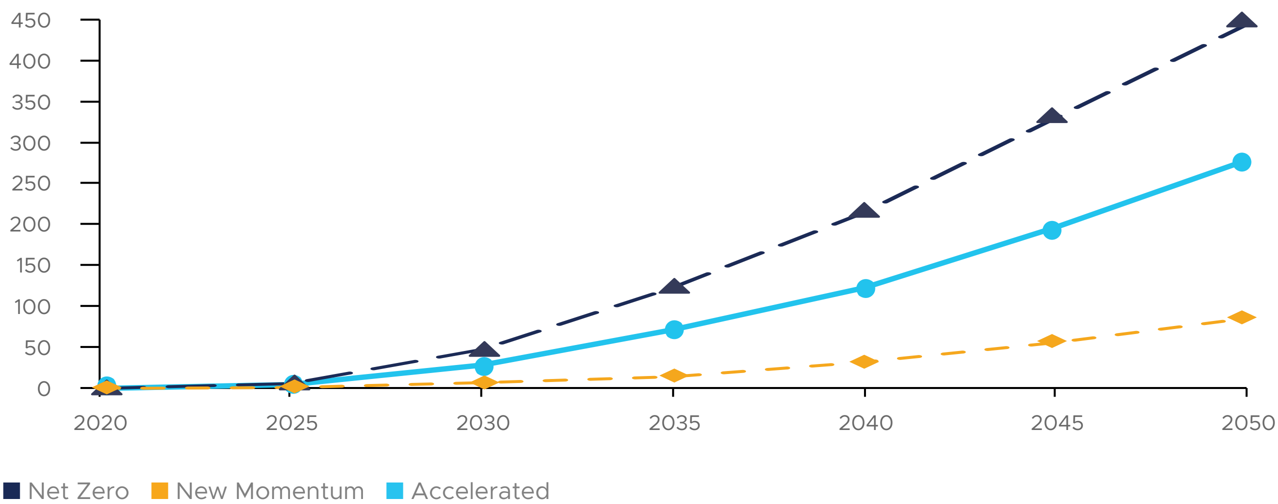
Global electrolizer capacity, MW



Sources: IEA, Rystad Energy, CrossBoundary calculations

FIGURE 9b

Forecasted production of low-carbon hydrogen to 2050, MMt

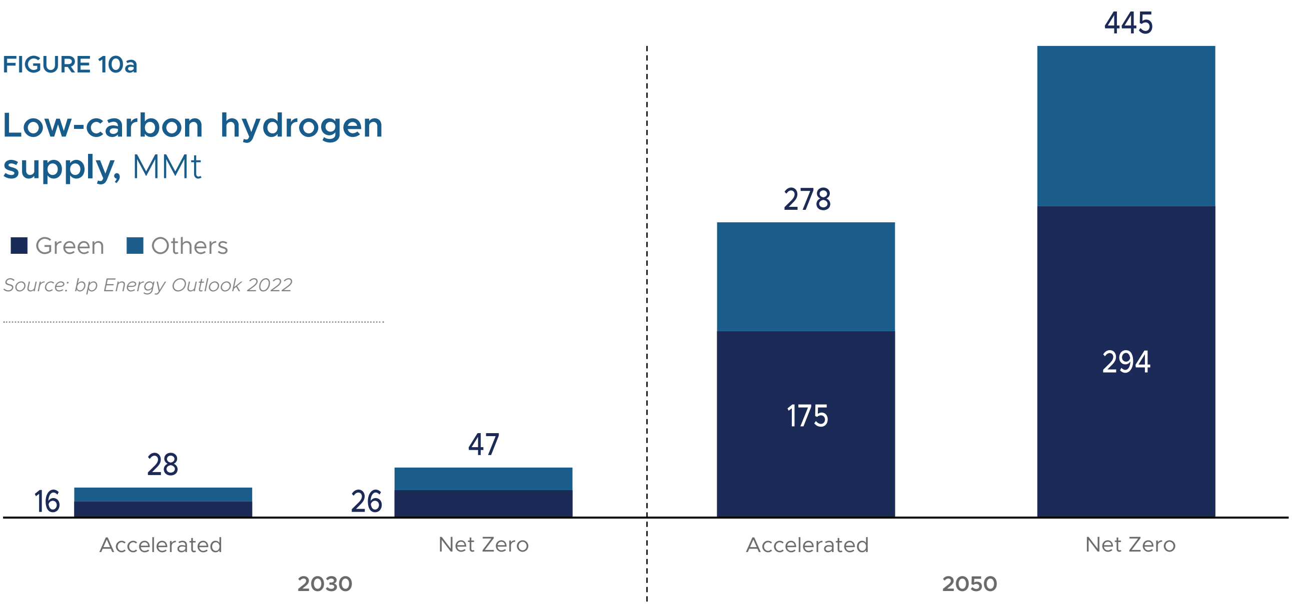


Source: bp Energy Outlook 2022

Production of green hydrogen is expected to increase as it becomes more cost-competitive. Demand growth is expected to be initially driven by efforts to decarbonize existing hydrogen production in the chemical sector and facilitated by hydrogen consumption in new industrial processes. As green hydrogen gradually becomes more cost-competitive with other forms of hydrogen production, its use is expected to expand to new applications, including transport and power generation[vii,viii]. In its more ambitious scenarios, the bp Energy Outlook of 2022 projects that green hydrogen production should reach between 16- and 26-MM tonnes in 2030 and 175- and 294-MM tonnes in 2050, respectively. This is somewhat aligned with the projections of the IEA. To reach the Net Zero goals, installed electrolysis capacity would need to grow from 300 MW today to 850 GW by 2030 and 3,600 GW by 2050[ix].

FIGURE 10a

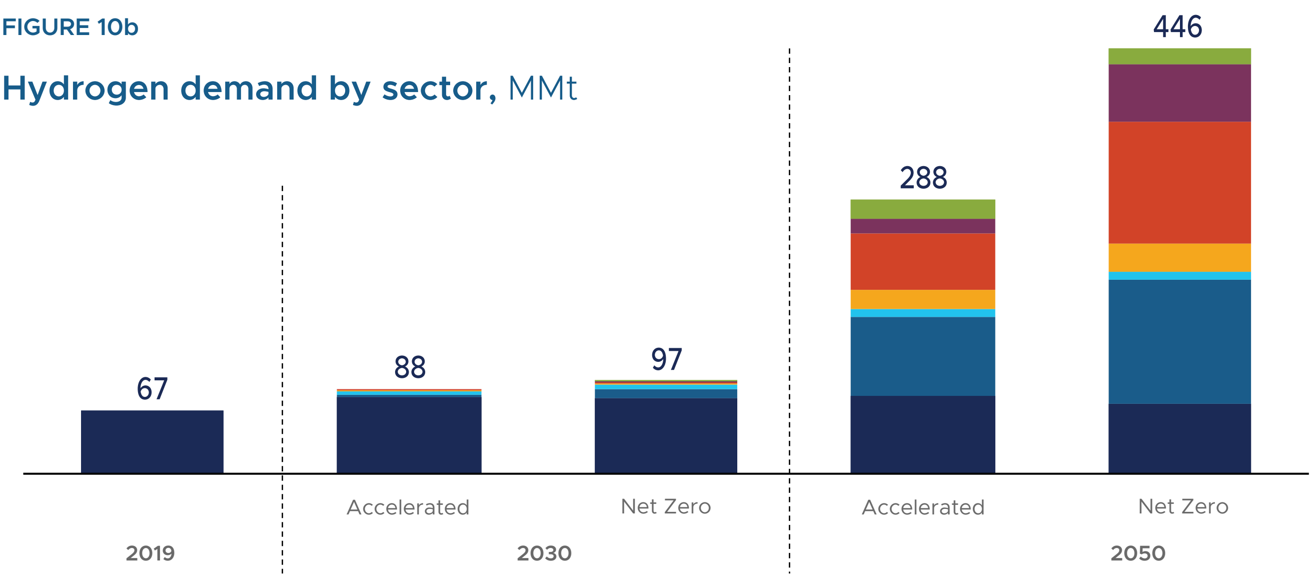
Low-carbon hydrogen supply, MMt



Source: bp Energy Outlook 2022

FIGURE 10b

Hydrogen demand by sector, MMt



Source: bp Energy Outlook 2022

For green hydrogen to become cost-competitive, though, the electrolysis cost must decrease drastically. As highlighted, the electrolysis process to produce hydrogen from water is still up to four times more expensive than the steam methane reforming (SMR) process typically used today to produce hydrogen from hydrocarbons. The electrolysis process consumes on average 55 kWh of electricity and 9 liters of water per kg of hydrogen produced[x]. It is thus highly dependent on the cost of electricity and the load factor of electrolyzers. Typically, electrolyzers must operate at least 5,000 hours per year and ideally 8,000 hours per year to break even, but the intermittence of renewables may limit utilization to 2,000-4,000 hours per year, increasing costs drastically[xi]. Relying on technological developments, the European Commission forecasts the cost of green hydrogen to decrease from 2.5-5.5 €/kg in 2019 to €1.1-2.4/kg in 2030[xii], making it competitive with hydrogen derived from hydrocarbons.

Viable and cost-efficient solutions for the transport of green hydrogen must be developed. Options for seaborne transport of hydrogen are also expensive. An option is to transport hydrogen in liquefied form, but this requires extremely low temperatures of -253˚C (90˚C lower than for LNG) and consumes large amounts of energy (liquefaction processes consume one-third of the energy contained in the hydrogen). An alternative option for the transport of hydrogen in liquid form is to convert it into ammonia or other liquid organic hydrogen carriers (LOHC). However, these are also expensive, requiring conversion before transport and a reconversion at the destination. In addition, ammonia is toxic, and increased transport may raise public safety concerns[xiii].

Despite these challenges, multiple countries are positioning themselves to promote the development of green hydrogen in the coming years. The EU Hydrogen strategy of 2020[xiv] identifies the production of green hydrogen from wind and solar energy as a priority. The strategy sets the objective of installing 6 GW of renewable hydrogen electrolyzers in the EU by 2024, 40 GW by 2030, and seeing it deployed at a large scale between 2030 and 2050 once renewable hydrogen technologies reach maturity. Germany indicates plans to establish up to 5 GW of generation capacity by 2030 and an additional 5 GW by 2040[xv]. France targets 6.5 GW of electrolyzer capacity installed by 2030[xvi]. The UK is aiming for 5GW of low-carbon hydrogen production capacity by 2030[xvii]. Hydrogen Europe, the European hydrogen industry association, proposes an investment plan involving the development of 40GW of electrolyzer capacity in Europe and 40GW in Northern Africa and Ukraine by 2030[xviii]. Japan aims for hydrogen and ammonia to fuel 10% of power generation by 2050. In China, the China Hydrogen Alliance (a state-backed industry group) calls for 100 GW of electrolyzer capacity installed by 2030[xix]. India estimates a potential demand justifying an electrolyzer capacity of 20 GW by 2030[xx]. The Australian Government has invested over USD 1 billion to stimulate the domestic hydrogen industry, and nine gigawatt-scale green hydrogen projects are planned or under development[xxi].

Several proposed hydrogen projects are export-oriented. Given that electricity accounts for a large share of the production cost of renewable green hydrogen, areas with large wind and solar potential may eventually emerge as large export hubs. Large export-oriented projects have been proposed in Australia, Saudi Arabia, Chile, Morocco, Namibia, Vietnam, and Mauritania, amongst others.

B. Mauritania has the potential to become a player in the global green hydrogen sector, but the road to success is not without challenges

With abundant wind, solar, and land resources[xxii], and a convenient geographic position, Mauritania could plausibly become a large producer of green hydrogen. Mauritania has world-class renewable energy potential and is relatively close to a potentially large export market such as the EU. The country has an annual solar energy potential of 2,000 to 2,300 MWh/m2[xxiii] and records wind speeds of up to 9m/s in the Nouadhibou coastal region. In addition, it is relatively close to the EU market, where carbon regulations will drive demand for green hydrogen. These factors could contribute to making Mauritania a low-cost producer of green hydrogen.

Two large green hydrogen projects in Mauritania have been proposed and are at the pre-feasibility stage. Two large projects have been proposed by international developers and are in early stages of development:

- **Aman project.** The project, requiring an estimated investment of more than US$ 40 billion and involving the development of 30 GW of wind and solar power generation capacity, would generate 110 TWh of electricity per year and produce 1.7 million tonnes of green hydrogen and 10 million tonnes of green ammonia. The project has been proposed by USA-based CWP Global, which in 2021 signed an MoU with the Government of Mauritania for the development of the project on an 8,500km^2 site in the country's northern desert. The project is at the pre-feasibility stage, expected to start front-end engineering design by 2024, and targeting the start of operations before 2030.

- **Nour project.** Chariot Ltd is proposing the development of a project to produce green hydrogen and ammonia from seawater. With up to 10 GW of electrolysis installed and 16GW of renewable power generation capacity, the project would also become one of the largest green hydrogen projects globally by 2030. It too is at an early stage with the need to complete feasibility studies.

These projects have the potential to transform the local economy significantly. The Aman and Nour projects will require large investments (an estimated US$ 20 billion for the Nour project and US$ 40 billion for the Aman project), which dwarf Mauritania's GDP of US$ 8 billion in 2020. The development of the proposed green generation capacity could have multiple reverberating effects. Mauritania has a large mining sector (it produces iron ore and copper) that could eventually create a large domestic market for green hydrogen. Abundant production of low-cost renewable energy and availability of green hydrogen could foster the development of a low-carbon mining sector and the transformation of iron ore locally (for instance, into Hot Briquetted Iron) to benefit from new trade and carbon-related instruments, such as the recently proposed EU Carbon Border Adjustment Mechanism (CBAM). These projects, as proposed by developers, would also desalinate seawater to serve agricultural and industrial uses.

Nevertheless, the country also faces multiple challenges that may hamper its ability to compete with other countries such as Australia, Saudi Arabia, India, Chile, and Morocco, that are also positioning themselves in the sector. The country lacks the long track record of countries like Saudi Arabia and Australia in developing large-scale energy projects. These countries already have an industrial base, a more developed services sector, and a more skilled workforce. They also have the infrastructure, such as harbors, storage capacity, pipelines, etc., that can eventually be repurposed for the hydrogen sector. In addition, Mauritania has a very small economy and potential domestic market for hydrogen, which restricts its capacity to foster the development of the sector through policies to promote domestic demand.

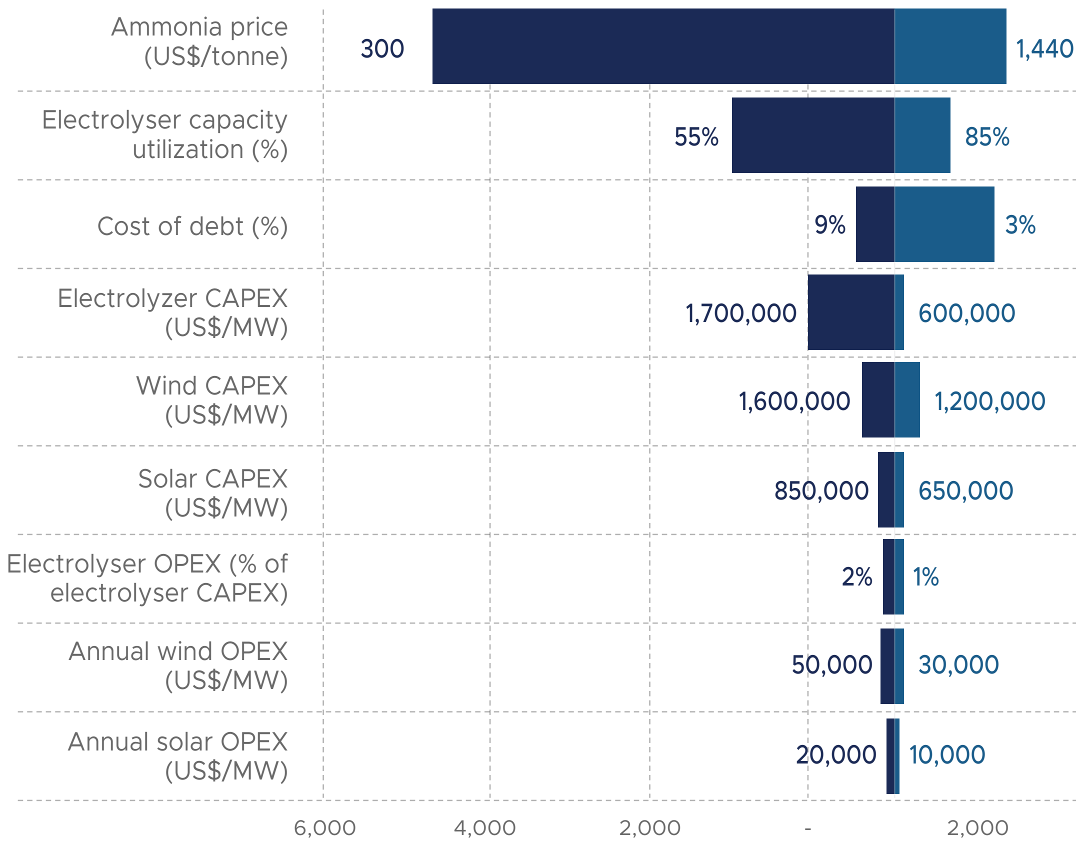
But developers and Government can contribute to make the projects feasible by focusing their attention on some critical levers. Completing a realistic feasibility analysis of a large-scale green hydrogen project may take several years and goes beyond the scope of this study. Nevertheless, a simplified high-level financial model allows for illustrating some critical aspects affecting the feasibility of a large-scale green hydrogen project. Our illustrative project has a total installed capacity of 4,000 MW (2,000 MW of solar PV and 2,000 MW of eolian capacity), an electrolyzer capacity of 1,370 MW, an electrolyzer capacity utilization of 77%, and requires a capital investment of US$ 6.3 billion (details are provided in Annex 2). The model assumes that green hydrogen is converted into and sold as ammonia. It ignores certain costs such as land, transport, etc., and relies on assumptions regarding technological developments and the expected price of electrolyzers at the end of the decade.

Project feasibility depends, to a large extent, on the price of ammonia. The price of ammonia is highly correlated to natural gas prices. From 2000 to 2020, it ranged between US$ 100 and US$ 600 per tonne, and increased drastically at the end of 2021 and through 2022 to surpass US$ 1,000 per tonne and reach US$ 1,500 per tonne on a FOB basis at its peak. The illustrative project would require an ammonia price in excess of US$ 1,000 per tonne to be feasible.

Other critical factors include electrolyzer capacity utilization, the cost of capital, and the cost of electrolyzers. The quality and complementarity of the renewable energy sources and the system configuration determine electrolyzer capacity utilization. In order for the envisaged renewable power plant to guarantee such a high-capacity utilization factor without storage capacity, wind and solar resources will need to be both of high quality and highly complementary. A detailed on-site resource assessment will be required to identify suitable project sites and confirm their potential. Under the current model assumptions, the project NPV is negative when the electrolyzer capacity utilization is below 66%. The cost of capital will also significantly affect the profitability and feasibility of the project. To reduce the cost of debt, the Government of Mauritania should keep strengthening macroeconomic governance and building investors' confidence in the country. Bilateral and multilateral lenders and donors can also contribute to reducing the cost of capital and increasing project feasibility by providing concessional loans and other forms of support, such as grants for technical assistance. An additional driver of profitability is the cost of the electrolyzer and the combined CAPEX. Under an ammonia price assumption of US$ 1,200 per tonne, NPV becomes negative with an electrolyzer cost of US$ 1,690,000 per MW. Policies that contribute to increasing the cost of CAPEX, such as import duties, should thus be avoided.

FIGURE 11

Project NPV as a function of main costs drivers, MM US$



Source: CrossBoundary calculations

The Government and donors should undertake a number of initiatives to support the development of the sector in a transparent and well-governed manner, several of which are already ongoing. To overcome existing challenges and effectively position Mauritania as a strong candidate for multi-billion dollar investments in the green hydrogen sector, the country should develop and implement a range of initiatives, including:

1. **Complete the required feasibility studies to estimate the long term-costs of producing green hydrogen in Mauritania and the feasibility of the proposed projects.** The feasibility analysis of the Aman and Nour projects just started and may take two years to be completed. Such studies should estimate Mauritania's potential levelized cost of hydrogen and ammonia compared to alternative countries. In addition, studies should define infrastructure needs and consider alternative means of transport, including the potential construction of a pipeline connecting Mauritania with the south of Spain (for which a pre-feasibility study is expected to start before the end of 2022). They should also identify cost-reduction opportunities to improve the country's competitive position vis-à-vis other countries and explore related market opportunities, such as the West African market and potential uses of hydrogen in the mining sector.

2. **Complete a multi-year strategy to drive and support the development of the sector and position Mauritania as a key international player.** Mauritania is following the example of competing countries such as Morocco, Chile, Namibia, and India in elaborating a national strategy for developing the sector with support from the World Bank. The strategy should emphasize a strong commitment to transparency and good governance, and include a roadmap with long-term goals (e.g., becoming an exporter of green hydrogen by 2035) and a set of short-term, medium-term, and long-term actions to convert the goals into reality. The roadmap will align relevant government agencies and stakeholders toward a common goal.

3. **Create a conducive legal, regulatory, and fiscal framework for green hydrogen projects.** Mauritania's Government is working on developing a legal and regulatory framework for the green hydrogen sector with the support of CONNEX Support Unit and the European Union through the Technical Assistance Facility (TAF), and is in advanced discussions with CWP Global and Chariot to conclude a global agreement for project development. Given that the economics of the global green hydrogen sector will be significantly different from that of the hydrocarbons sector and the still nascent stage of the technology, projects are expected to rely considerably on government incentives. Unlike Europe, Australia, Saudi Arabia, or the USA, Mauritania will not be able to subsidize investment projects, but it should focus on creating a conducive and transparent regulatory framework for developing the green hydrogen sector.

4. **Continue fostering a conducive investment climate and foster policies that decrease the country's risk perception and the cost of capital.** The proposed green hydrogen projects will only come to light with the participation of international investors. Given the long-term nature and uncertainty of new green hydrogen projects, investors will

strongly factor in elements such as the country's investment climate and political stability. Strengthening macroeconomic governance and building investors' confidence in the country will reduce the country's risk premium and facilitate access to international capital markets at lower rates.

5. **Expand the scope of the EITI initiative to the green hydrogen sector.** Given the size of the proposed investments, the Government of Mauritania should consider expanding the scope of the EITI initiative to the green hydrogen sector. While the EITI initiative has typically focused on the mining and oil and gas sectors, some countries have extended their scope to other sectors, such as forestry, fisheries, and renewable energies. Once available, for instance, authorities should publish the documents defining the applicable fiscal regime and regulatory framework for green hydrogen projects, including procedures for granting licenses, contracts, etc. This will increase transparency in the sector and support efforts to mobilize funding for its development.

6. **Promote Mauritania as a priority green hydrogen supplier and investment destination.** European countries such as Germany and the Netherlands are already engaging with potential hydrogen suppliers such as Australia, Chile, Morocco, Namibia, Tunisia, and Ukraine. The Government of Mauritania should follow these developments closely and engage with prospective importing countries to position Mauritania as a priority investment destination and develop relevant partnerships. Furthermore, the Government should leverage the recent success of the GTA gas project and consider investing in promotional activities to position Mauritania as an attractive investment destination and reliable partner for international customers and investors. Authorities should also engage with relevant industry associations, such as Hydrogen Europe and the African Hydrogen Partnership, which are already advocating for developing 40GW of electrolyzer capacity in Africa and Ukraine to supply Europe.

7. **Create budgetary conditions to support investments in developing the green hydrogen sector.** The investment required to materialize the proposed green hydrogen projects will amount to tens of billions of dollars. Required investments will typically be funded to a large extent by developers and lenders. Nevertheless, once project feasibility is confirmed, the Government may be required to invest in related public goods such as infrastructure, etc. To assess and select relevant investments, the Government will need to rely on the opinion of a highly qualified team of public officials and advisors.

8. **Invest in developing the capacity of public officials to drive and support sector development.** Given the sheer size of the proposed projects, over time the Government of Mauritania should consider recruiting additional resources to expand the team engaged in negotiations with developers and responsible for the development of the sector. In addition, an on-the-job and specific training program should be envisaged to allow officials to keep pace with industry developments.

9. **Plan and promote the development of the required local skills.** The development of the energy sector, including the renewables and green hydrogen subsectors, will require trained professionals. The Government should work with industry and donors to assess evolving human resources needs and promote the development of relevant programs at vocational training institutes and higher education centers.

Donors, which have have invested in Mauritania a yearly average of US$ 518 million in development assistance between 2016 and 2020, should support these initiatives by:

1. **Funding preliminary studies.** Donors can support local authorities and developers by co-funding the previously described pre-feasibility studies.

2. **Providing technical assistance to train officials and support the development of the required regulatory framework.** Donors can support local authorities by providing training and access to technical assistance to develop a good understanding of the green hydrogen sector and put in place a conducive regulatory framework, building on the ongoing initiatives previously described. Support should be flexible and adapted over time to the changing needs of local authorities.

3. **Supporting the establishment of hydrogen diplomacy and facilitating contacts with stakeholders.** For example, Germany, the Netherlands, the EU, etc., should engage with Mauritanian authorities and other stakeholders to support preliminary discussions on financing, market access, and partnership development.

4. **Supporting project development and providing a range of financial instruments such as grants and long-term debt.** In the long term, and given the nascent nature of the sector, a green hydrogen project of the proposed magnitude may only be feasible with the contribution of public funding and concessional finance. Therefore, multilateral and bilateral development banks should develop the financial instruments required to reduce the cost of capital and make projects of the proposed magnitude feasible.

5. **Supporting the development of local skills and capacity.** Donors, such as the Arab Fund, World Bank, EU, France, Saudi Arabia, Germany, and the USA, should support initiatives to promote local skills development.

5. Annex 1: Gas revenue model for GTA project

A. Approach and assumptions

To estimate future government revenues from the GTA project, we have applied the Fiscal Analysis of Resource Industries (FARI) methodology developed by the IMF. The model calculates the different sources of government revenue (government share of profit petroleum, corporate income taxes, and other fees) and the cashflows of international companies and SMH. In addition, we include in our presentation of government revenues net positive cashflows to the state oil company, given that they also represent a direct benefit to the nation of Mauritania and that SMH will be able to invest them in productive projects or distribute them as dividends to the Government. Estimates of contractors' payments to the Government are based on the provisions of the Production Sharing Contract for Block C8 of 2012, which is publicly available as per EITI norms[xxiv].

We have assumed the GTA field to produce 13.82 TCF and 108.8 Million barrels of associated oil over 30 years. Phase 1 will produce 2.45 MTPA of gas, while Phase 2 and 3 will each add a capacity of 3.6 MTPA. Total production will be evenly split between Mauritania and Senegal. We used three price scenarios, varying from US$4.0, to US$6.6, to US$9.2 per MMBtu for LNG and US$38.4, to US$64.0 to US$89.6 per barrel for oil on a free-on-board basis (FOB). The model assumes that all the development costs are financed through equity. Gas and oil allocations, tax and fee payments, etc., are calculated based on the provisions of the Production Sharing Agreement for block C8 of 2021 and the Code of Crude Hydrocarbons of 2010.

Development CAPEX expenditure is assumed to be US$2.5 billion for Phase 1 and US$4.65 billion for Phase 2 and Phase 3. In addition, estimated exploration and decommissioning costs of US$ 200 million are also considered in the model.

The modeled sources of revenue for the GTA project consist of the following:

1. **Profit Petroleum.** The GoM share of Profit Petroleum is progressive in relation to the "R factor" (a ratio between the net cumulative revenues and the cumulative exploration and development costs).

2. **Corporate income tax.** For simplicity, an integrated fiscal system is assumed, where both the upstream and FLNG activities related to Mauritania are consolidated and treated for fiscal purposes under a single fiscal regime. In reality, the upstream portion of the project is subject to a corporate income tax (CIT) of 27%, while the floating LNG portion is subject to the GTA subcontractor tax regime of 25%. We have thus assumed an integrated CIT of 26%.

3. **Other fees and bonuses.** (a) surface fees are based on the size of the land used for exploration and exploitation, (b) training fees, (c) signature bonus tied to the signing of the PSA, and (d) production bonuses based on production milestones that are based on the barrels of crude petroleum produced in a day.

4. **The net cash flows to SMH.** SMH owns a 14% stake in the GTA project. Given that SMH's share of required CAPEX was financed by BP and Kosmos (as defined in the Carry Advance Agreements of 2019), we have assumed that any cashflow in the initial years is used to reimburse these CAPEX costs. Although these cashflows are not strictly part of government revenues, they are a net benefit to the nation. They can eventually be distributed as dividends to the Government or re-invested in the sector development.

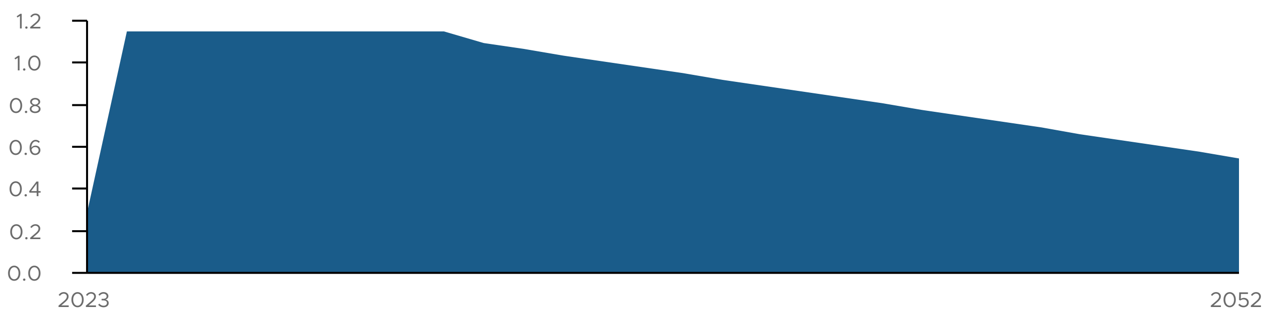
For the first phase of the GTA project, we have assumed a constant gas production volume of 1.2 MM tonnes per annum. In the first year of production (2023), volumes are assumed to be just 0.3 MM tonnes since production is expected to commence in the last quarter. For oil, we have assumed that production amounts to 3,150 barrels per day over the first years of production and that it will constantly decrease subsequently. For Phases 2 and 3 of the GTA project, we assume that gas production will reach 1.8 MM tonnes and that oil production will reach a maximum of 4,725 barrels per day in each phase. The production profiles are assumed to be the same for the three phases of the project.

FIGURE 12a

GTA phase 1. Annual gas production, MMT

FIGURE 12b

GTA phase 1. Annual oil production, MMBbl



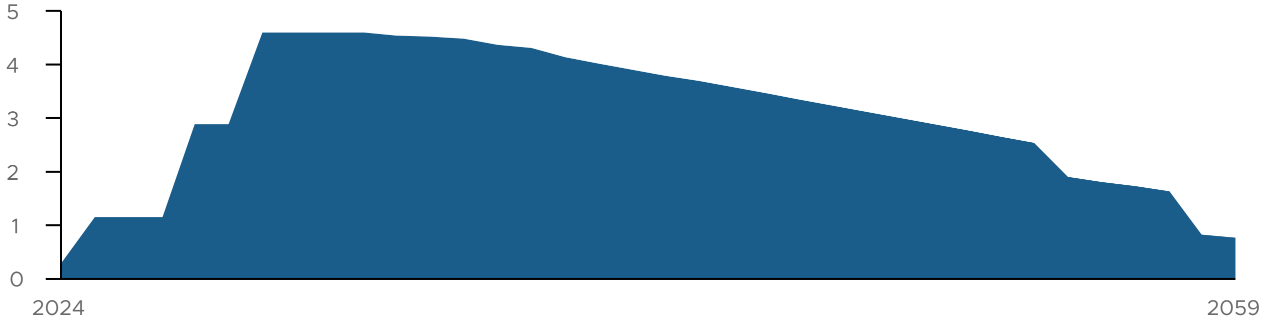
Source: CrossBoundary estimates based on industry sources

FIGURE 12c

GTA phases 1, 2 and 3. Annual gas production, MMT

FIGURE 12d

GTA phases 1, 2 and 3. Annual oil production, MMBbl



Source: CrossBoundary estimates based on industry sources

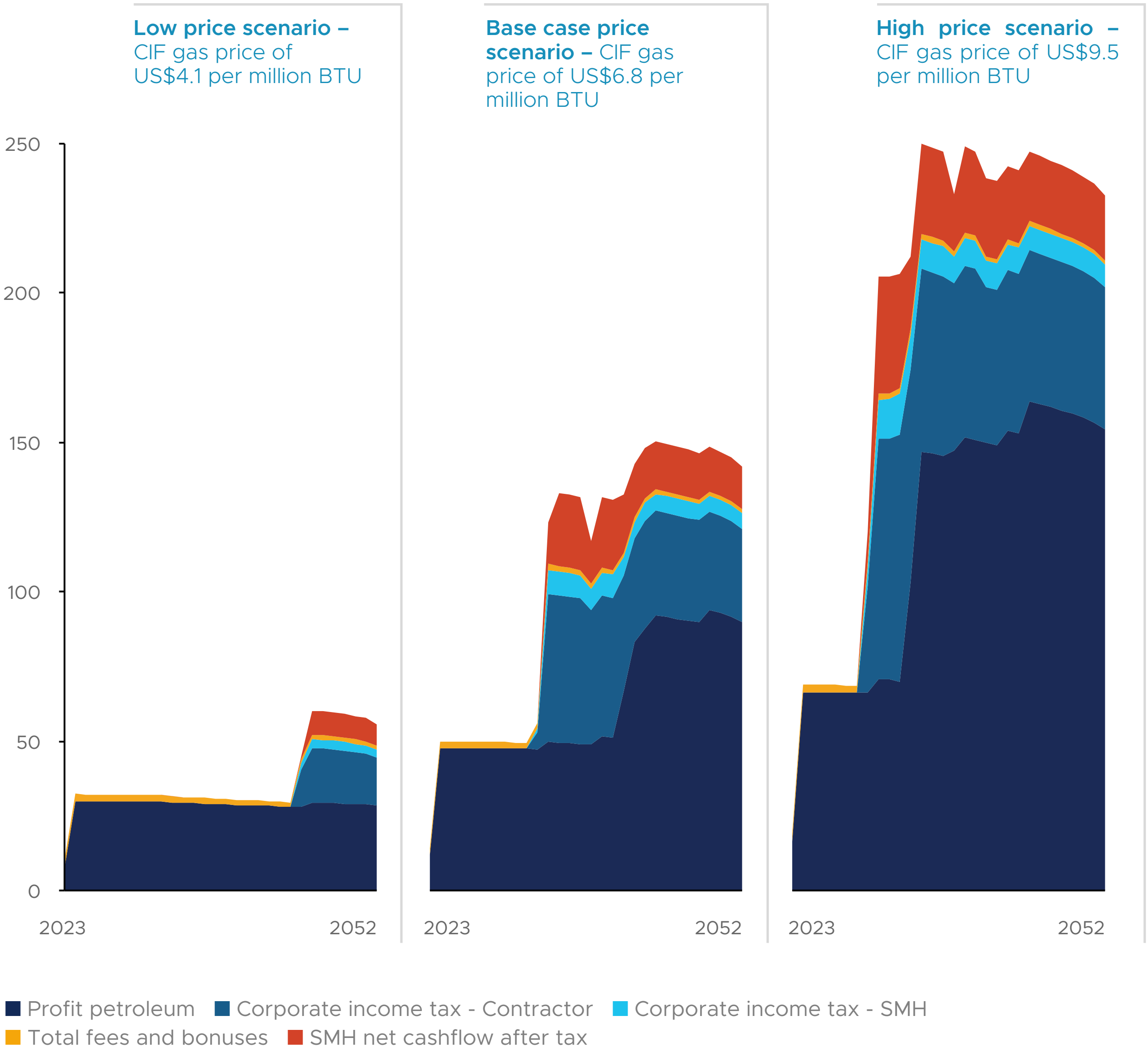
B. Results for GTA phase 1

Government revenues during Phase 1 will mainly be driven by two large components: profit petroleum and corporate income tax from contractors. In aggregate, these will represent 88%, 84%, and 85% of the total revenues over the project life in the low, base, and high price scenarios, respectively. The ratio of profit petroleum to corporate income tax from contractors ranges between 6.5:1, 2.5:1, and 2.75:1 in the same price scenarios. Total fees and bonuses collected will range between 1%-5% of total government revenue according to the different scenarios. Net cashflows to SMH, while not necessarily government revenue, can be distributed as dividends and have thus been included also in the model.

There is a noticeable increase in the total revenues between two periods of the GTA project: the cost recovery and the post-cost recovery periods. This is because the project will not generate taxable profits in the first years as the contractors recover investment costs. In the post-cost recovery period, annual government revenues are expected to more than double in all the scenarios, from an average of US$ 50 million to US$ 139 million in the base case price scenario, US$ 31 million to US$ 59 million in the low price scenario, and US$ 68 million to US$ 232 million in the high price scenario. The cost recovery period decreases with the increase in gas prices.

FIGURE 13

Government revenues from GTA phase I, MM US$

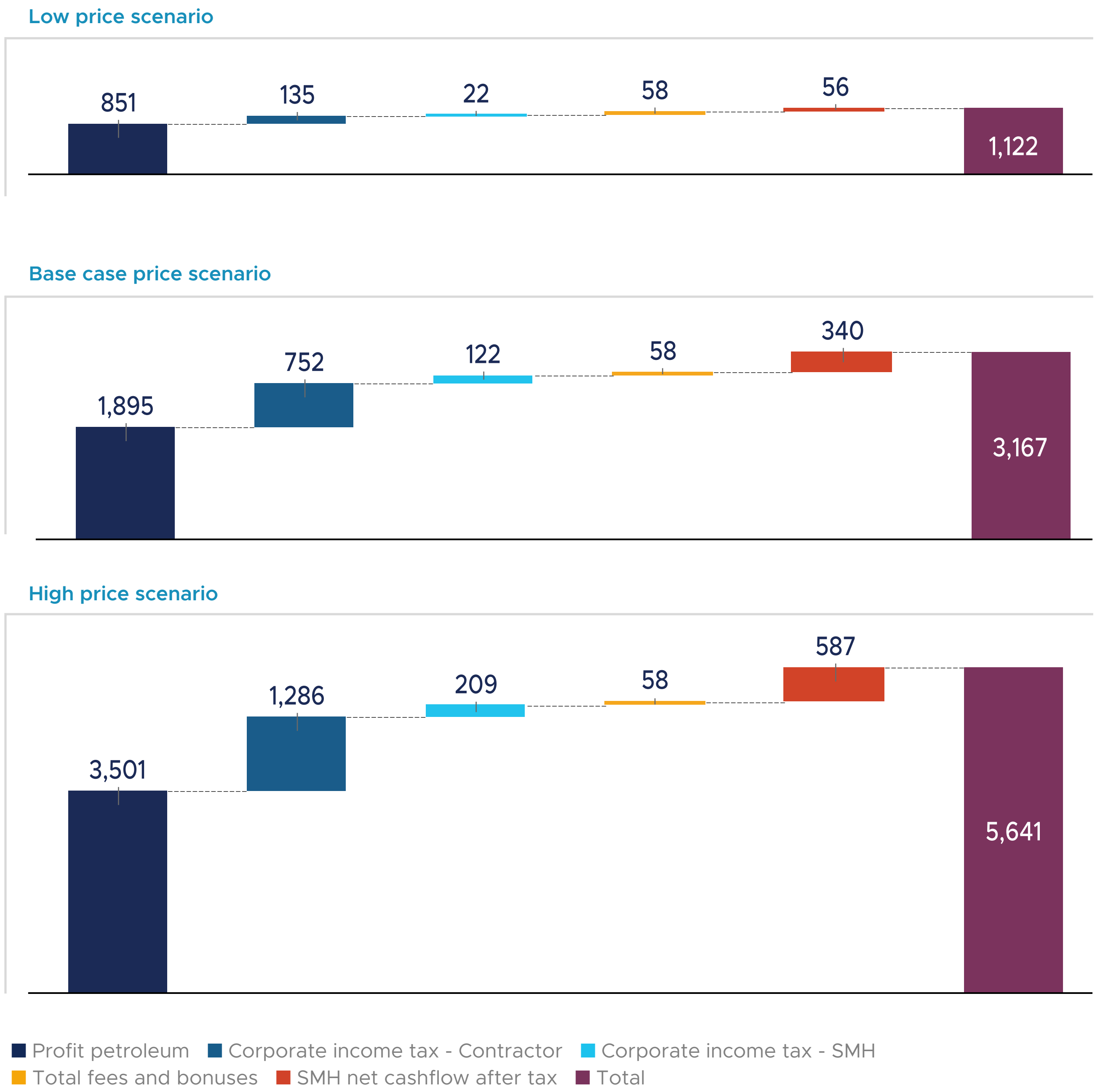


Source: CrossBoundary calculations

Total estimated government revenues over the project life of Phase 1 of the GTA project amount to US$ 1,122 million in the low-price case scenario, US$ 3,168 million in the base price case, and US$ 5,642 million in the high-price case scenario.

FIGURE 14

Total government revenue over project life. Phase 1 GTA, MM US$

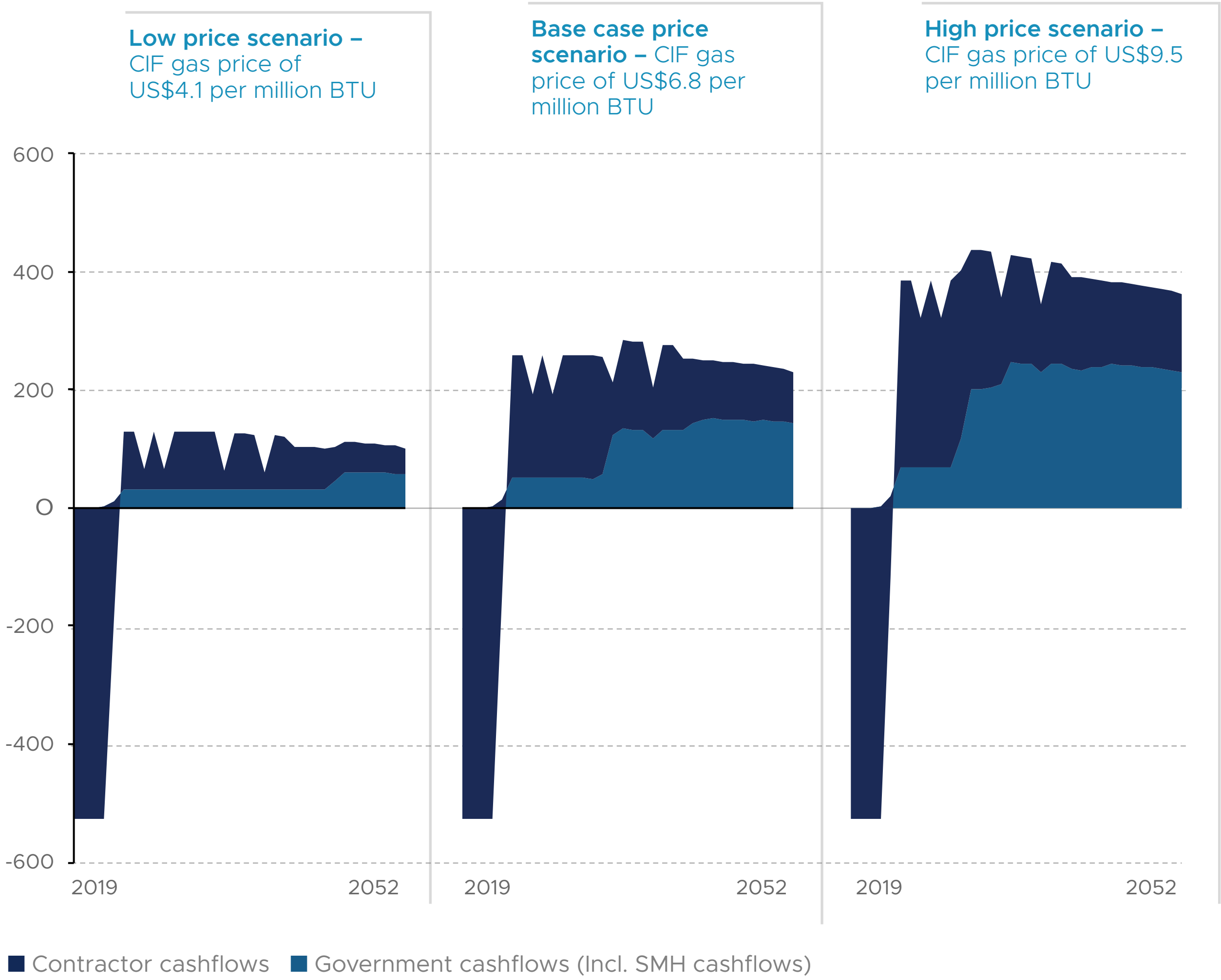


Source: CrossBoundary calculations

In nominal terms, the government share of the GTA project's net cashflows of phase 1 ranges from 73% in the low price scenario to 61% in the high price scenario. Nevertheless, in real terms, given that contractors have fully financed the initial investment, the real government share is 100% in the low price scenario (when the contractors barely break even) and 63% in the high price scenario.

FIGURE 15

Government cashflows to contractor cashflows. Phase 1 GTA, MM US$



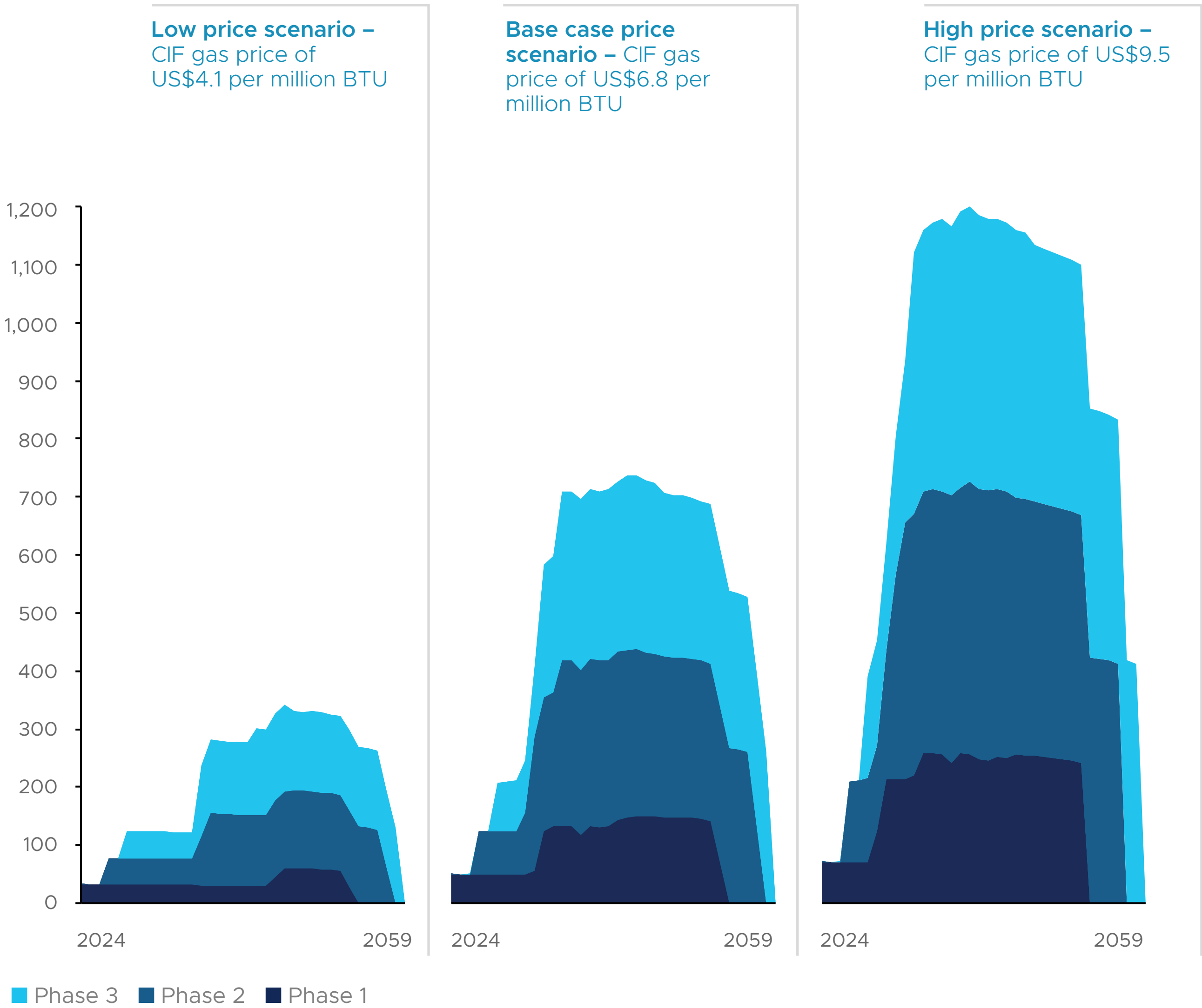
Source: CrossBoundary calculations

C. Results for GTA phases 1, 2, and 3 combined

Expanding the GTA project through phases 2 and 3 would create a significant upside in government revenues. Across the three scenarios, this expansion would lead to a revenue increase of 5x to 7x over phase 1 revenues. In 2030, when all the phases would be in their pre-cost recovery stage, the government revenue is estimated at US$ 123 million, US$ 209 million, and US$ 428 million in the low, base, and high price scenarios, respectively. Subsequently, in 2044, when all phases recover their investment costs, the government revenue is estimated to grow to US$ 300 million, US$ 736 million, and US$ 1,110 million in the respective price scenarios.

FIGURE 16

GTA phases 1, 2 and 3. Annual gas production, MMT

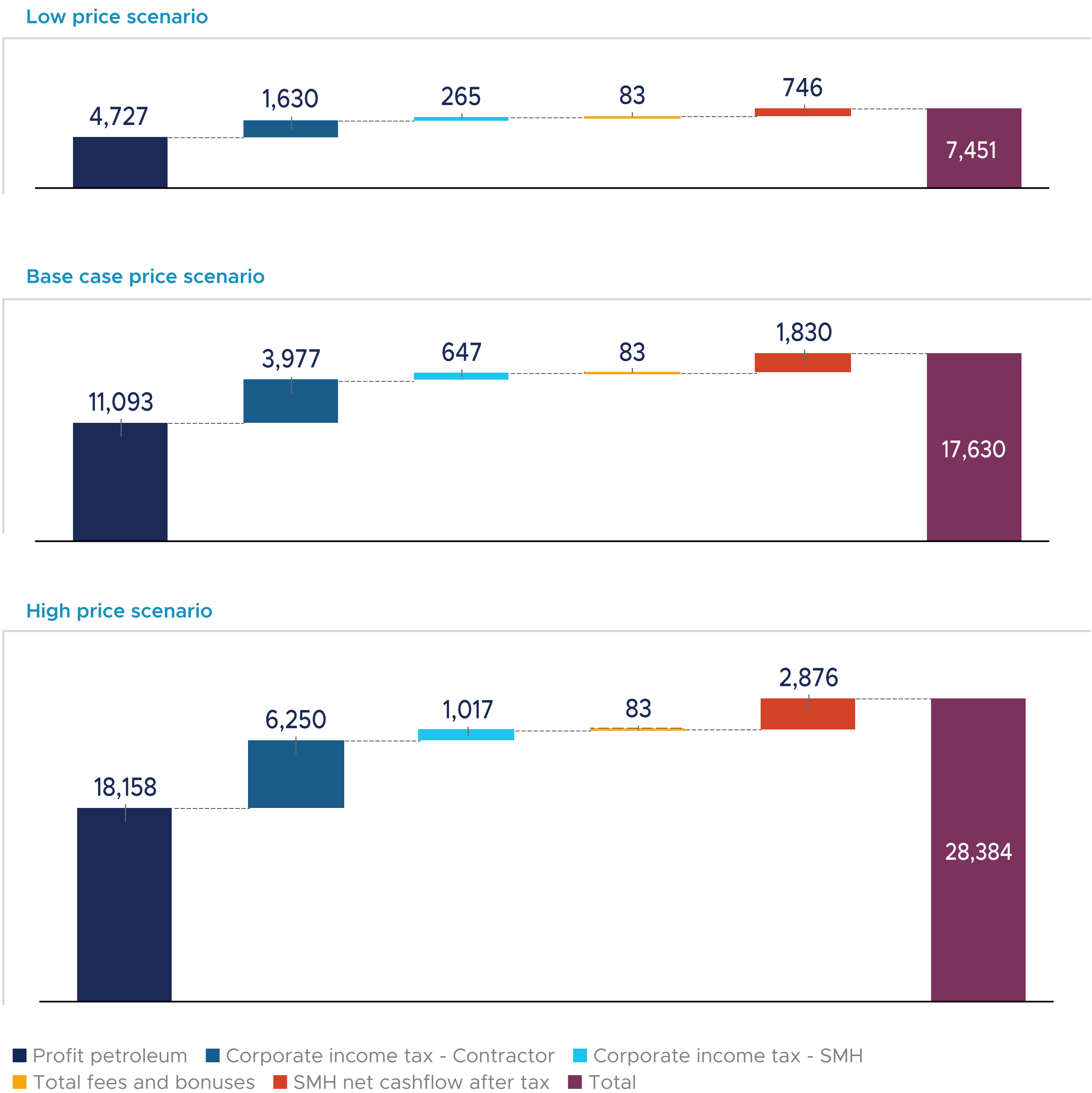


Source: CrossBoundary calculations

In aggregate, over the project's life, all three phases of the GTA project are projected to yield total government revenues of US$ 7,451 million, US$ 17,630 million, and US$ 28,384 million in the low, base, and high price scenarios, respectively.

FIGURE 17

Total government revenue over project life. All 3 GTA phases, MM US$



Source: CrossBoundary calculations

6. Annex 2: Green hydrogen model

A. Approach and assumptions

Given that the green hydrogen projects are in their early stages of development, the prices and costs of the main project drivers remain uncertain. To highlight the main drivers of feasibility, we present a simplified illustrative green hydrogen project with an installed power generation capacity of 4,000 MW (2,000 MW of solar and 2,000 MW of wind generation) and an electrolyzer capacity of 1,300 MW. It is assumed that hydrogen will be converted into ammonia so that it can be transported and sold in export markets. The model allows showcasing of the impact of different revenue and cost scenarios on project feasibility (Net Present Value) and associated government revenue.

The model makes the following assumptions:

i. A 1,370MW electrolyzer with a capacity utilization factor of 55% - 85% with a base case of 77% was assumed in the model. This is the estimated capacity factor for Project GERI being developed by bp in the Mid-West region of Western Australia[xxv], which results in annual production of circa 1 million tonnes of ammonia and 176,000 tonnes of hydrogen.

ii. An ammonia price of US$ 300 – 1,440 per tonne of ammonia and a base case of US$ 1,200 per tonne. The price of ammonia is highly correlated to natural gas prices and ranged between US$ 100 and US$ 600 per tonne between 2000 and 2020. At the end of 2021 and through 2022, ammonia prices increased drastically to surpass US$ 1,000 per tonne and reached US$ 1,500 per tonne in some cases on a FOB basis. In 2020, global demand reached 183 Mt, against a production capacity of around 243 Mt. Currently, around 90% of ammonia is consumed on-site as a feedstock for derivative products. Over the next two decades, the production of green ammonia is expected to increase as it expands the range of its uses both as a fuel and hydrogen carrier.

iii. CAPEX cost assumptions:

a. Solar CAPEX: US$ 650,000 to 850,000 per MW with a base case cost of US$ 750,000 per MW.

b. Wind CAPEX: US$ 1,200,000 to 1,600,000 per MW with a base cost price of US$ 1,400,000 per MW.

c. Electrolyzer CAPEX: US$ 600,000 to 1,700,000 per MW with a base case of US$ 728,000 per MW. Estimating the cost for electrolyzers in 2030 is challenging, given that the technology is still developing. IRENA currently estimates this cost to range between US$ 700,000 to 1,400,000 per MW for PEM electrolyzers and US$ 500,000 – 1,000,000 per MW for AWE[xxvi]. The Institute for Sustainable Process Technology (ISPT) estimates these costs at c. US$ 827,000 per MW for PEM and c. US$ 728,000 per MW for AWE by 2030.

d. Replacement CAPEX: 25% of CAPEX is assumed to be replaced in 15 years at a cost 30% lower than the current CAPEX costs. The model assumes that 15% of the cashflows generated before the 15th year will go into funding a reserve for the replacement CAPEX.

e. Ammonia conversion: based on our internal benchmark, the model assumes a CAPEX cost of circa US$ 1 billion for the ammonia conversion plant.

vi. Operating assumptions:

a. Solar OPEX: US$ 10,000 to 20,000 per MW per year for the solar OPEX and a base case of US$ 15,000 per MW per year. Recently, average utility-scale O&M costs in Europe have been reported at US$ 10,000 per MW per year[xxviii].

b. Wind OPEX: US$ 30,000 to 50,000 per MW per year for the solar OPEX and a base case of US$ 40,000 per MW per year. OPEX costs significantly varied over time and was between US$ 33,000 per MW per year and US$ 59,000 per MW per year for utility-scale onshore wind projects commissioned between 2015 and 2018[xxix].

c. Electrolyzer OPEX: 1 to 2% with a base case of 1.5% of electrolyzer CAPEX.

d. Other OPEX: includes water desalination at the cost of US$ 0.02 / kg of green hydrogen produced in the electrolysis process[xxx].

v. We note that Mauritania has no specific fiscal regime for green hydrogen production. Therefore, the modeled sources of revenue include corporate income tax at 20 to 30%, with the base case at 25%[xxxi], and withholding tax on dividends at 10%[xxxii]. The model also assumes that net operating losses are carried forward for 5 years, and accelerated depreciation is not allowed when computing the taxable profits.

vi. The model also assumes that 70% of the project development costs are financed through debt at an interest rate of 7% per annum and repayable within 18 years of operations. We have assumed a range of 3% to 9% for the cost of debt. The remaining 30% is assumed to be financed through equity, with an assumed cost of equity rate of 15%.

Based on the assumptions above, the computed Levelised Cost of Ammonia (LCOA) for the illustrative project is US$ 1,029 per ton of ammonia produced (excluding land acquisition costs, ammonia transport, marketing costs, etc.). Green ammonia costs are more than twice that of conventional carbon-intensive ammonia[xxxiii]. Green ammonia production costs for new plants are currently estimated to be between US$ 720 and US$ 1,400 per tonne and between US$ 210 and US$ 490 per tonne for low-emission fossil-based ammonia sources (including carbon capture and sequestration costs[xxxiv]. The future cost of green hydrogen is highly dependent on the combination of further reductions in renewable energy generation and electrolyzer costs and gains in efficiency and durability. IRENA estimates that the production cost of ammonia will reduce to US$ 480 per tonne by 2030 and US$ 310 per tonne by 2050[xxxv], at which point the same will be cost competitive when compared to natural gas-based and coal-based ammonia.

7. Annex 3: References

i. IGU World LNG Report 2022

ii. IGU World LNG Report 2022

iii. bp Energy Outlook 2022

iv. Global Hydrogen Review 2021, IEA

v. IRENA, Green Hydrogen for Industry – A guide to policy making, 2022

vi. Think, High gas prices triple the cost of hydrogen production, 2021

vii. https://think.ing.com/articles/hold-1of4-high-gas-prices-triples-the-cost-of-hydrogen-production

viii. A hydrogen strategy for a climate-neutral Europe, COM(2020) 301 final 2020, European Commission

ix. Bp Energy Outlook 2022

x. Global Hydrogen Review 2021, IEA

xi. Les modes de production de l'hydrogène (n° 25 - avril 2021), Assemblée nationale

xii. https://www2.assemblee-nationale.fr/15/les-delegations-comite-et-office-parlementaire/office-parlementaire-d-evaluation-des-choix-scientifiques-et-technologiques/secretariat/notes-scientifiques-de-l-office/les-modes-de-production-de-l-hydrogene-n-25-avril-2021

xiii. Les modes de production de l'hydrogène (n° 25 - avril 2021), Assemblée nationale

xiv. A hydrogen strategy for a climate-neutral Europe, COM (2020) 301 final 2020, European Commission

xv. Global Hydrogen Review 2021, IEA

xvi. A hydrogen strategy for a climate-neutral Europe, COM(2020) 301 final 2020, European Commission

xvii. The National Hydrogen Strategy, Federal Ministry for Economic Affairs and Energy, 2020

xviii. https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

xix. Stratégie nationale pour le développement de l'hydrogène décarboné en France

xx. UK Hydrogen Strategy 2021

xxi. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

xxii. Green Hydrogen for a European Green Deal. A 2x40 GW Initiative, Hydrogen Europe, March 2021

xxiii. https://www.argusmedia.com/en/news/2256750-china-hydrogen-alliance-seeks-100gw-renewable-capacity

xxiv. Harnessing green hydrogen opportunities for deep decarbonisation in India, NITI Aarog, 2021

xxv. Geopolitics of the Energy Transformation. The Hydrogen Factor. Irena 2022

xxvi. IRENA, 2015

xxvii. IRENA, Utility Scale Solar and Wind Atlas, 2021

xxviii. https://www.resourcecontracts.org/contract/ocds-591adf-0048000024

xxix. AUS, bp ghd Renewable Hydrogen and Ammonia Feasibility Study 2021

xxx. IRENA, Green Hydrogen Cost Reduction 2020

xxxi. ISPR, A One-GigaWatt Green-Hydrogen Plant 2022

xxxii. IRENA, Renewable Power Generation Costs 2021

xxxiii. IRENA, Renewable Power Generation Costs 2021

xxxiv. https://pubs.acs.org/doi/10.1021/acsenergylett.1c01375

xxxv. https://taxsummaries.pwc.com/mauritania/corporate/taxes-on-corporate-income

xxxvi. https://taxsummaries.pwc.com/mauritania/corporate/income-determination

xxxvii. https://www.argusmedia.com/en/press-releases/2021/green-ammonia-prices-double-that-of-regular-supplies

xxxviii. IRENA, Innovation Outlook Renewable Ammonia 2022

xxxix. IRENA, Innovation Outlook Renewable Ammonia 2022

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