Renewable Senegal

Opportunities for German-Senegalese development cooperation towards a sustainable future

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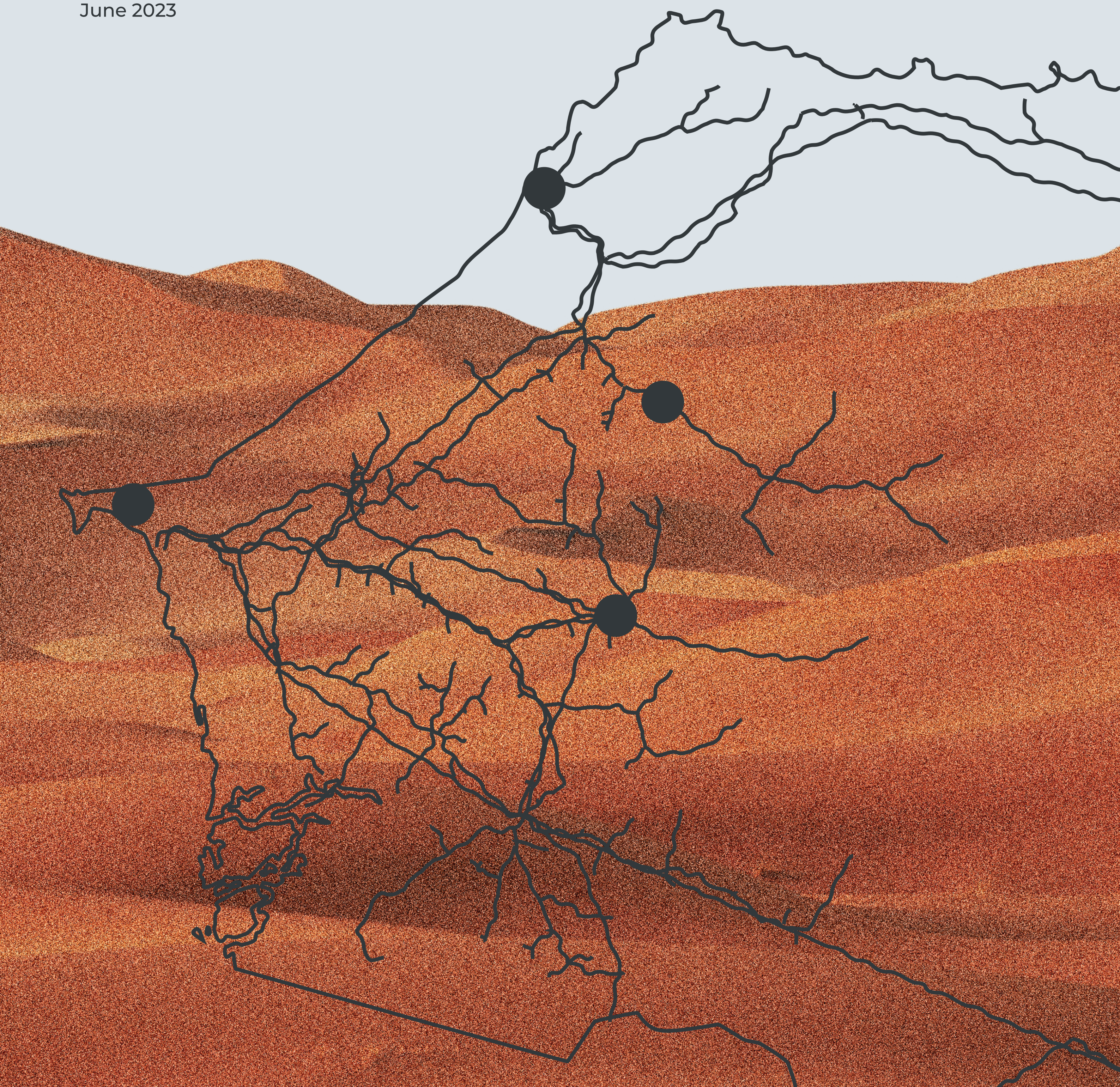

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Opportunities for German-Senegalese development cooperation towards a sustainable future

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Zusammenfassung

Der Senegal ist ein Land mit reichlich erneuerbaren Energieressourcen, vor allem Solar- und Windenergie. Die nationale Strategie für ein "aufstrebendes Senegal" hat das Ziel, bis 2025 landesweite Energieversorgung sicherzustellen und Senegal bis 2035 zu einem Land mit mittlerem Einkommen zu machen. Bei der Gestaltung seiner Energiezukunft steht der Senegal jedoch vor einer wichtigen Entscheidung: Entweder kann das Land diese Ziele durch die Nutzung seines Potenzials an erneuerbaren Energien erreichen oder es riskiert "Stranded Assets" und hohe Emissionen, wenn es sich auf seine neu entdeckten fossilen Brennstoffressourcen verlässt. Auch wenn der Senegal historisch gesehen wenig Verantwortung für den Klimawandel trägt, wäre der Sprung in die Zukunft der erneuerbaren Energien ein Weg, der mit den Zielen des Pariser Abkommens zur Begrenzung der durchschnittlichen globalen Erwärmung auf 1,5°C bzw. deutlich unter 2°C im Einklang steht und zahlreiche weitere Vorteile mit sich bringen würde.

Der Senegal verfügt über enorme erneuerbare Ressourcen und hat bereits große Erfolge bei der Entwicklung erneuerbarer Energien erzielt. Der Senegal hat eine durchschnittliche Sonneneinstrahlung von 4,2 bis 5 kWh/m²/Tag - fast 70 % mehr pro Quadratmeter als Norddeutschland. Das Land hat bereits eine Reihe von PV-Parks gebaut und Programme zur Förderung dezentraler PV-Anlagen in ländlichen Gebieten aufgelegt. Der Senegal verfügt außerdem über ein beträchtliches Windenergiepotenzial, vor allem in den Küstenregionen des Landes, wo starke und beständige Winde wehen. Im Jahr 2021 wurde in Senegal Taïba N'Diaye, das größte Windkraftprojekt Westafrikas, eröffnet - ein weiterer Beweis dafür, dass das Land sein Potenzial für erneuerbare Energien bereits teilweise nutzt. Dieser Erfolg ermöglichte es dem Senegal, die ehrgeizigen Ziele für erneuerbare Energien für 2030, die in seinem NDC festgelegt sind, bereits im Jahr 2022 zu übertreffen.

Um auf diesem Erfolg aufzubauen, wird zusätzliche Unterstützung benötigt. Um die positive Erfolgsbilanz weiter fortzuführen werden weitere Maßnahmen erforderlich um die Netzflexibilität zu verbessern und einen höheren Anteil erneuerbarer Energien am Strommix zu ermöglichen. Das derzeitige Energiesystem Senegals wird immer noch von teuren importierten fossilen Brennstoffen dominiert: Schweröl macht nach wie vor den größten Anteil an der Stromerzeugung des Landes aus. Diese Abhängigkeit von importierten fossilen Brennstoffen belastet die Wirtschaft stark und führt dazu, dass der Senegal die höchsten Strompreise in Afrika hat. Neben dem wachsenden Anteil an erneuerbaren

Energien kann der Ausstieg aus Schweröl und Kohle durch die einheimischen Gasressourcen des Senegals erfolgen. Während Gas potenziell dazu beitragen könnte, die variable Verfügbarkeit erneuerbarer Energien auszugleichen, indem es dann ans Netz geht, wenn die Sonne nicht scheint und der Wind nicht weht, birgt der Ausbau der Gasverstromung auch das Risiko, dass entweder hohe Emissionen gebunden werden - was die erneuerbaren Energien verdrängen würde und ihren Ausbau untergraben könnte - oder dass sie bei einer schnellen Energiewende als "Stranded Assets" enden. Diese Risiken lassen sich durch Übertragungs- und Systemflexibilitätsmaßnahmen weitgehend vermeiden, so dass Senegal auf seinen bisherigen Erfolgen im Bereich der erneuerbaren Energien aufbauen könnte.

Zu diesen Maßnahmen gehören Speicher- und intelligente Netztechnologien, einschließlich Lastmanagement, eine verbesserte Übertragung und Verteilung sowohl im Senegal als auch in der gesamten westafrikanischen Region sowie Reformen der Strommärkte und des Netzmanagements. Die Sektorkopplung und die Prüfung von Optionen für die Umnutzung oder Stilllegung der bestehenden fossilen Kraftwerkflotte beschleunigen die senegalesische Energiewende weiter. Um der Bedrohung entgegenzuwirken, die der Netzausbau für Betreiber von Mini-Grids mit erneuerbaren Energien darstellt, könnten neue Modelle für die Berücksichtigung von Mini-Grid Betreibern untersucht werden, damit diese als kleine Stromerzeuger und -verteiler neben dem Hauptnetz bestehen können. Dies könnte wichtig sein, um die Untergrabung der derzeitigen Investitionsmöglichkeiten für Mini-Grids zu überwinden, wenn die senegalesische Regierung beabsichtigt, das nationale Netz auszubauen und Lücken in der ländlichen Elektrifizierung zu schließen, bis das nationale Netz ausgebaut werden kann. Die Entwicklung Senegals zu einem erneuerbaren Energiesystem ist ein ehrgeiziges, aber erreichbares Ziel, das dem Land erhebliche wirtschaftliche, soziale und ökologische Vorteile bringen kann.

Deutschland und sein Know-How haben das Potenzial, eine wichtige Rolle bei der Unterstützung des Senegals bei einer gerechten Energiewende und der Erreichung seiner Ziele für nachhaltige Entwicklung zu spielen. Deutschland ist gemeinsam mit Frankreich federführend innerhalb der G7 bei der Aushandlung von Just Energy Transition Partnerships - einem neuen Modell für die Nord-Süd-Zusammenarbeit, das erstmals mit Südafrika bei den Klimaverhandlungen in Glasgow 2021 vorgestellt wurde. Deutschland sollte getreu seines Engagements im Pariser Klimaabkommen, sowie seiner Verpflichtungen aus Glasgow und der G7, die öffentliche Finanzierung für fossile Brennstoffe beendend und keine weitere Förderung von fossilen Brennstoffen fördern. Ausnahmen können nur unter klar definierten Umständen zulässig sein (1.5°C Kompatibilität). Während private Investoren ihre Bereitschaft gezeigt haben und bereits in Projekte für erneuerbare Energien im Senegal investieren, können die JETP-Partner die Mobilisierung privater Investitionen verbessern und erleichtern, indem sie den Senegal dabei unterstützen, günstige politische Rahmenbedingungen für die weitere Dekarbonisierung zu schaffen. Begrenzte Zuschüsse und Kredite zu Vorzugsbedingungen werden am besten zur Unterstützung weiterer Reformen, Machbarkeitsstudien und zur weiteren Ermöglichung privater Finanzierungen durch De-Risking und Mischfinanzierung eingesetzt.

Senegals erneuerbare Ressourcen verleihen dem Land das Potenzial für die Produktion von grünem Wasserstoff, allerdings mit Vorbehalten. Angesichts der zunehmenden weltweiten Bestrebungen zur Dekarbonisierung der Industrie und der Suche nach alternativen Kraftstoffen für den internationalen Luft- und Seeverkehr wird Wasserstoff zunehmend als eine Chance für Entwicklungsländer mit großen erneuerbaren Ressourcen gesehen. Trotz erheblicher Herausforderungen könnten die umfangreichen erneuerbaren Ressourcen Senegals mittel- bis langfristig auch Wasserstoff für den inländischen Gebrauch und möglicherweise für den Export produzieren. Ein Haupthindernis für die Wasserstoffproduktion dürfte die Verfügbarkeit von Frischwasser für die Elektrolyse sein, die angesichts des Klimawandels zu einer immer größeren Herausforderung wird. Für die Wasserstoffproduktion in größerem Maßstab wird schließlich eine wachsende Menge an entsalztem Wasser benötigt, dessen Produktion sorgfältig gesteuert werden muss, um die umliegenden Meeresökosysteme und Fischbestände zu schützen, von denen die lokale Fischereiindustrie abhängt.

Eine erfolgreiche Energiewende im Senegal wäre ein wichtiges Signal für die gesamte westafrikanische Region und künftige JETP-Kandidaten. Ein rascher Ausbau zu einem nachhaltigen, gerechten und kohlenstoffarmen Energiesystem ist von entscheidender Bedeutung, um die schlimmsten Auswirkungen des Klimawandels abzumildern, und zwar nicht nur in den großen, von Kohle abhängigen Ländern, sondern auch in den Ländern, die möglicherweise einen von fossilen Brennstoffen abhängigen Weg einschlagen wollen, der mit einem erhöhten Risiko von "Stranded Assets" und "Lock-in" bei fossilen Brennstoffen verbunden ist. Der Senegal ist als relativ stabile Demokratie eine wichtige stabilisierende Kraft in der Region mit bedeutenden wirtschaftlichen Beziehungen zu seinen Nachbarn. Im Vergleich zu anderen JETP-Ländern hat der Senegal noch keine nennenswerten Emissionen, und das Land trägt kaum historische Verantwortung für den Klimawandel. Seine Auswahl als JETP-Kandidat, insbesondere vor dem Hintergrund seiner Öl- und Gasfunde, ist ein wichtiges Signal sowohl für andere westafrikanische Länder als auch für andere künftige JETP-Kandidaten in Bezug auf das Potenzial für eine auf erneuerbaren Energien basierende Energiewende. Neben seinem potenziellen Pioniercharakter im Allgemeinen hätte ein Erfolg in Senegal auch direkte positive Auswirkungen auf die Klimafreundlichkeit anderer Länder im Westafrikanischen Strompool, indem er deren Emissionen durch den Stromhandel senkt, und die regionale Wirtschaft, mit der Senegal eine Wirtschafts- und Währungsunion bildet, stärkt.

Summary

Senegal is a country with abundant renewable energy resources notably solar and wind. The national strategy for an “Emerging Senegal” sets the objectives of providing universal energy access by 2025 and become a middle-income country by 2035. However, Senegal faces an important choice in laying out its energy future: it can either accomplish these goals with its renewable potential or risk stranded assets and high emission lock-in by relying on its newly discovered fossil fuel resources. While Senegal bears little historical responsibility for climate change, leapfrogging to the renewable energy future follows a pathway consistent with Paris Agreement's objectives of limiting average global warming to 1.5°C / well below 2°C and brings multiple other benefits.

Senegal has vast renewable resources and has already had major success in renewable energy development. Senegal enjoys an average of 4.2 – 5 kWh/m²/day of solar irradiation – almost 70% more per square meter than Northern Germany. The country has already built a number of utility-scale solar PV plants and has launched programmes to support decentralized solar PV systems in rural areas. Senegal also has significant wind power potential, particularly along the country's coastal areas, where there are strong and consistent winds. In 2021, Taïba N’Diaye, West Africa’s largest utility scale wind project, was opened in Senegal another strong demonstration of the country taking advantage of its renewable potential. This success enabled Senegal to overachieve what may have seemed to be ambitious renewable energy targets for 2030 laid out in its NDC already in 2022.

Additional support will be needed to build on this success. This positive track record is likely coming to a threshold where other measures will be needed to improve grid flexibility and enable a higher penetration of renewables in its electricity mix. Senegal's current energy system is still dominated by expensive imported fossil fuels: heavy fuel oil continues to make up the largest share of the country's electricity generation. This dependence on imported fossil fuels has placed a major strain on the economy and led to some of the highest electricity prices in Africa. In addition to the growing renewable portfolio, phasing out heavy fuel oil and coal can be done with domestic Senegalese gas resources. While gas could potentially help balance the fluctuating availability of renewables by coming online when the sun isn’t shining and the wind isn’t blowing, gas to power expansion also runs a risk of either high emission lock-in – competing and undermining renewables – or ending up as stranded assets in a more rapid transition. These can largely be avoided with transmission and system flexibility measures to allow Senegal to build on its existing renewable success.

Such measures include storage and smart grid technologies, including demand response, improved transmission and distribution both in Senegal and in the wider West African region, and reforms in electricity markets and network management. Sector coupling and exploring options for the repurposing or retirement of the existing fossil fuel power plant fleet further accelerate the Senegalese energy transition. To avoid threatening the business model of renewable mini-grid operators, new transition models could be explored for them to co-exist with the main grid as small-scale electricity producers and distributors. This could help offset the decline in investment in mini-grids in cases where the Senegalese government intends to extend the national grid and fill the gaps in rural electrification until the national grid can be extended. Senegal's transition to a renewable energy system is an ambitious but achievable goal that can bring significant economic, social, and environmental benefits to the country.

Germany and its know-how has the potential to play an important role in supporting Senegal with a just energy transition and reaching its sustainable development goals. Germany is a co-lead, together with France, within the G7 to negotiate Just Energy Transition Partnerships – a new model for north-south cooperation first launched with South Africa at the Glasgow climate negotiations in 2021. In this role, it is important that Germany is guided by its overall commitment to the Paris Agreement, as well as its Glasgow and G7 commitments to phase out public financing for fossil fuels except in limited and clearly defined circumstances that are consistent with a 1.5°C warming limit and do not foster fossil fuel lock-in. While private investors have shown willingness and are already investing in renewable energy projects in Senegal, JETP partners can enhance and facilitate mobilisation of private investment by supporting Senegal to set the right general policy environment for continued decarbonisation. Limited grant funding and concessional finance are best used to support continued reforms, feasibility studies, and further enabling private finance through de-risking and blended finance.

Senegal's renewable resources have potential for green hydrogen production but with caveats. With increased global ambition for industrial decarbonisation and the search for alternative fuels for international aviation and maritime transport, hydrogen is increasingly seen as an opportunity for developing countries with large renewable endowments. Although there are significant challenges, in the medium to long term Senegal's vast renewable resources could also produce hydrogen for domestic use and potentially for export. For hydrogen, one major barrier is likely to be the availability of fresh water for electrolysis, which will become a growing challenge with the changing climate. Larger scale hydrogen production will eventually require a growing amount of desalinised water, the production of which must be carefully managed to protect surrounding marine ecosystems and fish stocks on which the local fishing industry depends.

A successful transition in Senegal would be an important signal for the wider West African Region and future JETP candidates. A rapid transition to a sustainable, just, low-carbon energy system is essential to mitigate the worst impacts of climate change not only in large coal dependent countries but also in countries that may consider starting down a fossil fuel dependent pathway with heightened stranded asset and fossil fuel lock-in risk. Senegal, as a relatively stable democracy is an important stabilising force in the region with important economic ties to its neighbours. Compared to other JETP countries, Senegal does not yet have significant emissions and the country bears little historical responsibility for climate change. Its selection as a JETP candidate especially in the context of its oil and gas discoveries is an important signal to both other West African countries and other future JETP candidates about the potential for a renewable based energy transition. In addition to its potential pioneering character more generally, success in Senegal would also have a direct positive climate impact on the other countries in the West African Power Pool by lowering their emissions through electricity trading as well as growing the regional economy with which Senegal shares an economic and monetary union.

Résumé

Le Sénégal est un pays qui dispose d'abondantes ressources en énergies renouvelables, notamment solaires et éoliennes. La stratégie nationale pour un "Sénégal émergent" fixe comme objectifs de fournir un accès universel à l'énergie d'ici 2025 et de devenir un pays à revenu intermédiaire d'ici 2035. Cependant, le Sénégal est confronté à un choix important dans l'élaboration de son avenir énergétique : il peut soit atteindre ses objectifs grâce à son potentiel renouvelable, soit risquer des actifs échoués et des émissions élevées en s'appuyant sur des ressources d'énergies fossiles récemment découvertes. Le Sénégal n'a qu'une faible responsabilité historique dans le changement climatique. Sauter l'étape fossile pour aller directement vers les énergies renouvelables serait cohérent avec les objectifs de l'Accord de Paris de limiter le réchauffement moyen de la planète à 1,5°C / bien en dessous de 2°C et apporterait de nombreux autres avantages.

Le Sénégal dispose de vastes ressources renouvelables et connait déjà un grand succès dans le développement des énergies renouvelables. Le Sénégal bénéficie d'un rayonnement solaire moyen de 4,2 à 5 kWh/m²/jour, soit près de 70 % de plus par mètre carré que l'Allemagne du Nord. Le pays a déjà construit un certain nombre de centrales solaires photovoltaïques à grande échelle et a lancé des programmes pour soutenir les systèmes solaires photovoltaïques décentralisés dans les zones rurales. Le Sénégal dispose également d'un important potentiel éolien, en particulier le long des zones côtières du pays, où les vents sont forts et constants. En 2021, Taïba Ndiaye, le plus grand projet éolien d'Afrique de l'Ouest, a été inauguré au Sénégal, ce qui prouve que le pays sait tirer parti de son potentiel en matière d'énergies renouvelables. Ce succès a permis au Sénégal de dépasser dès 2022 ses objectifs en matière d'énergies renouvelables fixés dans sa contribution déterminée au niveau national (CDN) pour 2030.

Un soutien supplémentaire est nécessaire pour tirer parti de ce succès. En effet, ce bilan positif devrait atteindre un seuil où d'autres mesures sont nécessaires pour améliorer la flexibilité du réseau et permettre une plus grande pénétration des énergies renouvelables dans le mix électrique. Le système énergétique actuel du Sénégal est toujours dominé par des combustibles fossiles importés et coûteux : le fioul lourd continue de représenter la plus grande part de la production d'électricité du pays. Cette dépendance à l'égard des combustibles fossiles importés a pesé lourdement sur l'économie et entraîné des prix de l'électricité parmi les plus élevés d'Afrique. En théorie, l'élimination progressive du

fioul lourd et du charbon pourrait être réalisée grâce aux ressources nationales en gaz du Sénégal, car le gaz a l'avantage de pouvoir équilibrer la disponibilité fluctuante des énergies renouvelables en l'absence de vent et de soleil. Mais la production d'électricité à partir du gaz court également le risque d'un verrouillage des émissions à un niveau élevé – tout en entrant en concurrence avec les énergies renouvelables et en leur nuisant - ou de finir comme actifs échoués en cas de transition plus rapide. Ces risques peuvent être largement évités grâce à des mesures de flexibilité du système de transmission qui permettraient au Sénégal de tirer parti de ses succès en matière d'énergies renouvelables.

Ces mesures de flexibilité comprennent le stockage et les technologies de réseau intelligent, y compris de réponse à la demande, l'amélioration de la transmission et de la distribution au Sénégal et plus largement en Afrique de l'Ouest, ainsi que les réformes des marchés de l'électricité et de la gestion des réseaux. Le couplage des secteurs et l'exploration des options pour la réaffectation ou le retrait du parc existant de centrales électriques à combustibles fossiles pourraient accélérer encore davantage la transition énergétique du Sénégal. Pour éviter de menacer le modèle économique des opérateurs de mini-réseaux renouvelables, de nouveaux modèles de transition pourraient être explorés pour ceux-ci afin qu'ils puissent coexister avec le réseau principal en tant que petits producteurs et distributeurs d'électricité. Cela pourrait contribuer à compenser la baisse de l'investissement dans les mini-réseaux dans les cas où le gouvernement sénégalais a l'intention d'étendre le réseau national et de combler les lacunes dans l'électrification rurale jusqu'à ce que le réseau national puisse être étendu. La transition du Sénégal vers un système d'énergie renouvelable est un objectif ambitieux mais réalisable qui peut apporter des avantages économiques, sociaux et environnementaux significatifs au pays.

L'Allemagne et son savoir-faire peuvent jouer un rôle important en aidant le Sénégal à opérer une transition énergétique juste et à atteindre ses objectifs de développement durable. L'Allemagne est, avec la France, l'un des chefs de file du G7 pour la négociation de partenariats pour une transition énergétique juste (Just Energy Transition Partnerships, JETPs), un nouveau modèle de coopération nord-sud lancé pour la première fois avec l'Afrique du Sud lors des négociations sur le climat de Glasgow en 2021. Dans ce rôle, il est important que l'Allemagne maintienne son engagement global envers l'Accord de Paris, ainsi que ses engagements de Glasgow et du G7 « à cesser d'apporter une aide publique directe au secteur international des combustibles fossiles sans dispositif d'atténuation d'ici à la fin de l'année 2022, hormis dans un nombre limité de cas clairement définis par chaque pays conformément à la limite d'élévation de la température de 1,5°C et aux objectifs de l'Accord de Paris ». Alors que les investisseurs privés investissent déjà dans des projets d'énergie renouvelable au Sénégal, les partenaires du JETP peuvent renforcer et faciliter la mobilisation de l'investissement privé en aidant le Sénégal à mettre en place un environnement politique général favorable à la poursuite de la décarbonisation. Les précieuses subventions et les financements concessionnels sont utilisés au mieux pour soutenir la poursuite des réformes, les études de faisabilité et la facilitation du financement privé par le biais d'une réduction des risques et d'un financement mixte.

Les ressources renouvelables du Sénégal offrent un certain potentiel pour la production d'hydrogène vert, avec d'importantes réserves cependant. L'ambition mondiale de décarbonisation industrielle et la recherche de carburants alternatifs pour le secteur de l'aviation et le transport maritime font de l'hydrogène une opportunité intéressante pour les pays en développement dotés d'importantes ressources renouvelables. Bien qu'il existe des défis importants, à moyen et long terme, les vastes ressources renouvelables du Sénégal pourraient également servir à produire de l'hydrogène pour usage domestique et potentiellement pour l'exportation. Cependant, l'un des principaux obstacles concerne la disponibilité d'eau douce nécessaire à l'électrolyse, un défi croissant avec le changement climatique. Une production d'hydrogène à plus grande échelle nécessiterait une quantité croissante d'eau désalinisée, dont la production doit être gérée avec soin pour protéger les écosystèmes marins environnants et les stocks de poissons dont dépend l'industrie locale de la pêche.

Une transition réussie au Sénégal serait un signal important pour l'ensemble de la région de l'Afrique de l'Ouest et pour les futurs candidats au JETP. Une transition rapide vers un système énergétique durable, juste et à faible teneur en carbone est essentielle pour atténuer les pires effets du changement climatique, non seulement dans les grands pays dépendants du charbon, mais aussi dans les pays tentés de s'engager sur la voie de la dépendance aux combustibles fossiles, avec un risque accru d'actifs échoués et de verrouillage dans une trajectoire de développement à émissions élevées. Le Sénégal, en tant que démocratie relativement stable, est une force stabilisatrice importante dans la région, avec des liens économiques importants avec ses voisins. Comparé à d'autres pays du JETP, le Sénégal n'a pas encore d'émissions significatives et le pays porte peu de responsabilité historique dans le changement climatique. Sa sélection en tant que candidat au JETP, en particulier dans le contexte de ses découvertes de pétrole et de gaz, est un signal important pour les autres pays d'Afrique de l'Ouest et pour les futurs candidats au JETP par son potentiel de transition énergétique basée sur les énergies renouvelables. Outre ce caractère pionnier, le succès du Sénégal aurait également un impact climatique positif direct sur les autres pays du pool énergétique ouest-africain en réduisant leurs émissions par le biais du commerce de l'électricité et en développant l'économie régionale avec laquelle le Sénégal partage une union économique et monétaire.

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Abbreviations

AFD	Agence française de développement (French Development Agency)
AfDB	African Development Bank
BAU	Business as Usual
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Economic Cooperation and Development)
BCEAO	Banque Centrale des Etats de l'Afrique de l'Ouest (Central Bank of West African States)
BESS	Battery Energy Storage System
BOAD	Banque Ouest Africaine de Développement (West African Development Bank)
CCGT	Combined Cycle Gas Turbine
CFA	West African CFA franc
DFI	Development Finance Institution
ECOWAS	Economic Community of West African States
EIB	European Investment Bank
FONSIS	Fonds Souverain d'Investissements Stratégiques de Senegal (Senegalese Sovereign wealth fund)
GCF	Green Climate Fund
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German Agency for International Cooperation)
HFO	Heavy Fuel Oil
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
JETP	Just Energy Transition Partnership
KfW	Kreditanstalt für Wiederaufbau
LoSENS	Lokale nachhaltige Energiesysteme in Senegal (Local sustainable energy systems in Senegal)
LPG	Liquified Petroleum Gas
Mtoe	Millions of tonnes of oil equivalent
OMVG	Organisation pour la Mise en Valeur du Fleuve Gambie (Gambia River Basin Development Authority)
OMVS	L'Organisation pour la mise en valeur du fleuve Sénégal (Senegal River Basin Development Authority)
PPA	Power Purchase Agreement
PtL	Power to Liquids
PV	Photovoltaic
SDG	Sustainable Development Goal
SHS	Solar Home Systems
SMEs	Small and Medium Sized Enterprises
TWh	Terawatt-hour
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
US MCC	United States Millennium Challenge Corporation
WAEMU	West African Economic and Monetary Union
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WAPP	West African Power Pool

01 Introduction

Access to reliable and affordable energy is critical for economic development, social progress, and human well-being. In Senegal, although most of the urban population has electricity access, energy access overall remains a significant challenge, with approximately 4.8 million people still lacking access to electricity and relying on unreliable and polluting energy sources including firewood and charcoal for cooking (Our World in Data, 2023c). The country continues to heavily rely on imported fossil fuels to meet its energy needs.

In 2014-2017, international exploration and extraction companies found large oil and gas deposits off the coast of Senegal (Schaps, 2014; BP, 2017). Since then, Senegal has seen the exploitation of these resources as a way to help achieve universal energy access and raise revenue for economic growth and eliminate poverty. Currently, almost 40% of Senegal' population lives under the poverty line for lower-middle income countries (Our World in Data, 2023d). While Senegal has had major success in expanding renewable energy – the variable nature of wind and solar energy and the existing electricity system means that further grid integration is starting to become a growing challenge. Moving forward, policy decisions to be taken both in Dakar and in donor country governments will have a large influence over the role of fossil fuels in Senegal for the foreseeable future and to what extent Senegal locks itself into higher fossil fuel dependency. Here, it is important that Senegal is empowered to leapfrog the emissions intensive patterns seen with many developing countries with domestic oil and gas discoveries. Although there are clear local benefits in choosing a renewable development pathway, there are also major challenges and Senegal will need significant support to reconcile its national development goals with the global temperature limitation objectives of the Paris Agreement.

Germany has the potential to play a critical role to support Senegal's transition to a decarbonised renewable energy system, achieve universal energy access in the country, enable sustainable economic growth, and avoid stranded assets in the oil and gas sector. With its experience with the energy transition at home and building on its existing track record in development cooperation, Germany can work with other international partners and Senegal to implement and upscale the necessary measures to transition to reach its energy access and development goals while decarbonising. Such support would be consistent with Germany's commitments under the COP 26 Glasgow Statement to "end new direct public support for the international unabated fossil fuel energy sector [...] except in limited and clearly defined circumstances that are consistent with a 1.5°C warming limit and the goals of the Paris Agreement", a commitment similarly reiterated in the 2022 G7 leaders communiqué drafted under the German G7 Presidency (UK COP 26 Presidency, 2021; G7 Germany, 2022). A renewable transition in Senegal would have an immediate positive climate impact on the countries with which Senegal shares the West African Power

Pool, and more broadly support sustainable economic growth in the broader West African region notably through the West African Economic and Monetary Union (WAEMU) and the wider Economic Community of West African States (ECOWAS). It would also send a positive signal to potential future JETP candidates considering embarking on a clean energy transition.

This paper aims to provide an overview of the opportunities to support Senegal in its transition to a decarbonised, renewable energy system, including a discussion of the challenges associated with this transition and the role that Germany can play in overcoming them. First, the paper examines the current energy system in Senegal, including the energy access challenges in the country, its current reliance on fossil fuels, recent success in renewable development as well as Senegal's current climate policies, and the potential Just Energy Transition Partnership (JETP) that is currently under discussion. This sets the background for a discussion of the potential for a renewable focused development pathway for Senegal, ranging from its vast renewable energy resources, cost considerations, the superior resiliency of a renewables-based system, as well as other sustainable development benefits. Such a pathway is however not without major challenges, which Senegal will need international support to overcome. The following section discusses the principal areas where Germany and other international partners can work with Senegal to overcome these challenges, with a focus on measures to enable a higher integration of renewable energy into the system. In addition, considering the growing international discussions around potential for hydrogen production in Africa, the paper then discusses the potential medium to long-term challenges and opportunities for the development of green hydrogen for both domestic use and export. The paper concludes with a summary of recommendations for Germany to engage with international partners and Senegal to accelerate the West African nation's energy transition to reach its development goals while decarbonising.

02 Background and context

Senegal is a lower-middle income country (World Bank, 2023b) where 9.3% of the population lived on less than USD 2.15 a day as recently as 2018 (World Bank, 2023c). Senegal's current energy system faces several challenges, including high dependence on imported fossil fuels, inadequate electricity supply, some of the highest electricity prices in Africa, and a lack of access to electricity especially in rural areas.

Currently, slightly over 70% of the Senegalese population have access to electricity (World Bank, 2023c), which, thanks to recent reforms already represents significant progress compared to 2010 when only 43% had access. Despite this progress, there is a large disparity between urban and rural areas: less than 5% of the urban population lacking access compared to over 52% in rural areas (IEA et al., 2021). Looking forward, the country still faces significant challenges in ensuring reliable, affordable, and sustainable energy for all.

The Emerging Senegal Plan (Plan Sénégal Emergent) is the reference framework for Senegal's economic and social policy for inclusive growth up to 2035. An important part of the vision is the objective of universal energy access by 2025 (Senegal, 2020a). The Senegalese Government's electricity reform priorities have focussed primarily on expanding grid access, improving governance of the electricity market, and promoting rural electrification through mini-grids and solar home systems (SHS) (Apfel and Herbes, 2021). Although it has not been reiterated in Senegalese government documents, Senegal signed the Climate Vulnerable Forum Marrakech Communiqué which includes a commitment to strive "to achieve 100% renewable energy the latest between 2030 and 2050" (Climate Vulnerable Forum, 2016).

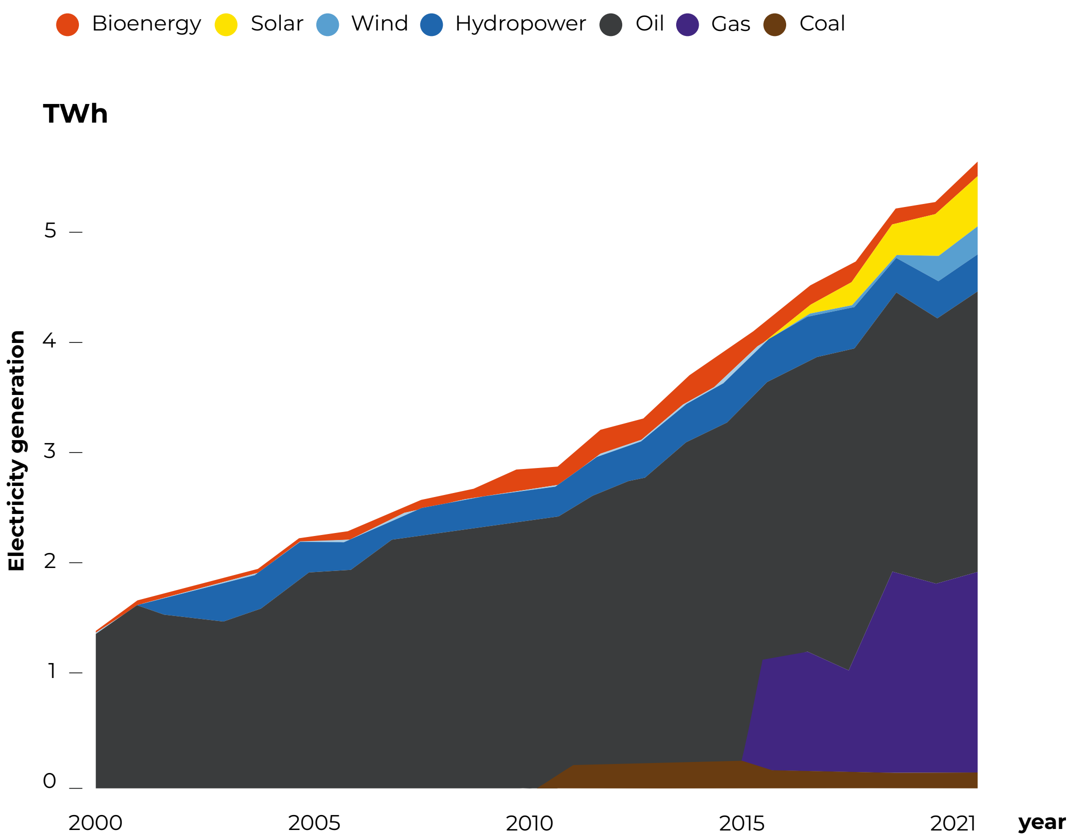
In 2020-2021, Senegal had around 1.2-1.5 GW of installed power generation capacity (Reuters Staff, 2021; Wane, 2021) generating 5.61 terawatt hours of electricity (Our World in Data, 2023e). Significant additional capacity was added in 2022. Although as recently as 2010, Senegal generated as much as 85% of its electricity from Heavy Fuel Oil (HFO), this percentage has steadily decreased with a large shift to gas, some coal[1], and more recently growing solar and wind capacity – see Figure 1 (Our World in Data, 2023e). Despite progress with regard to diversification, notably a large jump in renewable generation in 2022, fossil fuels, mainly heavy fuel oil (HFO) continue to represent the largest single fuel in the electricity mix. This exposes the country to volatility in global coal, oil, and gas markets and the necessity to import these fuels at high cost has historically had a large negative impact on the Senegalese economy which suffers from the high cost of electricity. Largely because of the expense of importing HFO and coal to generate electricity, the cost of generation of a kilowatt hour in Senegal run from USD 0.34-0.38 (US Internal Trade Administration, 2023), significantly more expensive than in other African countries such as Mauritania, Morocco,

1 Notably the highly controversial Sendou power plant, partially financed by the AfDB and the Dutch FMO. See FMO's Statement: https://www.fmo.nl/environmental-and-social-risks-sendou.

South Africa, or Tunisia (IEA, 2023b). Consumers pay a still high, discounted rate of approximately USD 0.24 cents per kWh leaving the government to cover the gap through subsidies (US Internal Trade Administration, 2023). This historically inhibited the ability of Senelec, the national electric utility, to carry out maintenance or make new investments, while at the same time posing major challenges to business and households which must contend with unreliable service at high prices.

Senegal's demand for energy is projected to grow quickly reflecting its population growth of between 2-3% per year (World Bank, 2023a), urbanisation, economic growth and the aspiration to reach middle income status by 2035, a rapidly growing industrial base (KfW et al., 2020), increasing energy access, and

Figure 1
Electricity generation by source



Source: Own elaboration based on Our World in Data based on BP Statistical Review of World Energy (2022); Ember (2023) · CC BY longer life expectancies. According to the IEA's "Africa Case", which is built on the African Union's "Agenda 2063" and incorporates rapid economic expansion and universal access to electricity and clean cooking, Senegal's overall electricity demand will more than double to 12.9 TWh in 2030 and more than triple to almost 20 TWh in 2040 from a baseline of 5.6 TWh in 2018 (IEA, 2019b).

It is possible for Senegal to meet this demand on its way towards full decarbonisation primarily with its renewable capacity and Senegal has already made major progress in promoting utility scale renewables. Such a pathway however may be threatened by the discovery of large offshore oil and gas reserves in 2014-2017 and eminent start of commercial extraction, which in theory could present an opportunity for the country but also poses major risks for the country and its energy future. According to Climate Analytics, under 1.5°C compatible pathways, Senegal's uptake of renewable energy must rapidly increase to 94-97% by 2030 with a shift to 100% renewables by 2040 at the latest (Climate Analytics, 2022). While such a target is extremely challenging both to 2030 and to 2040, every effort must be made to come as close as possible, and Senegal will require international support in order to do so.

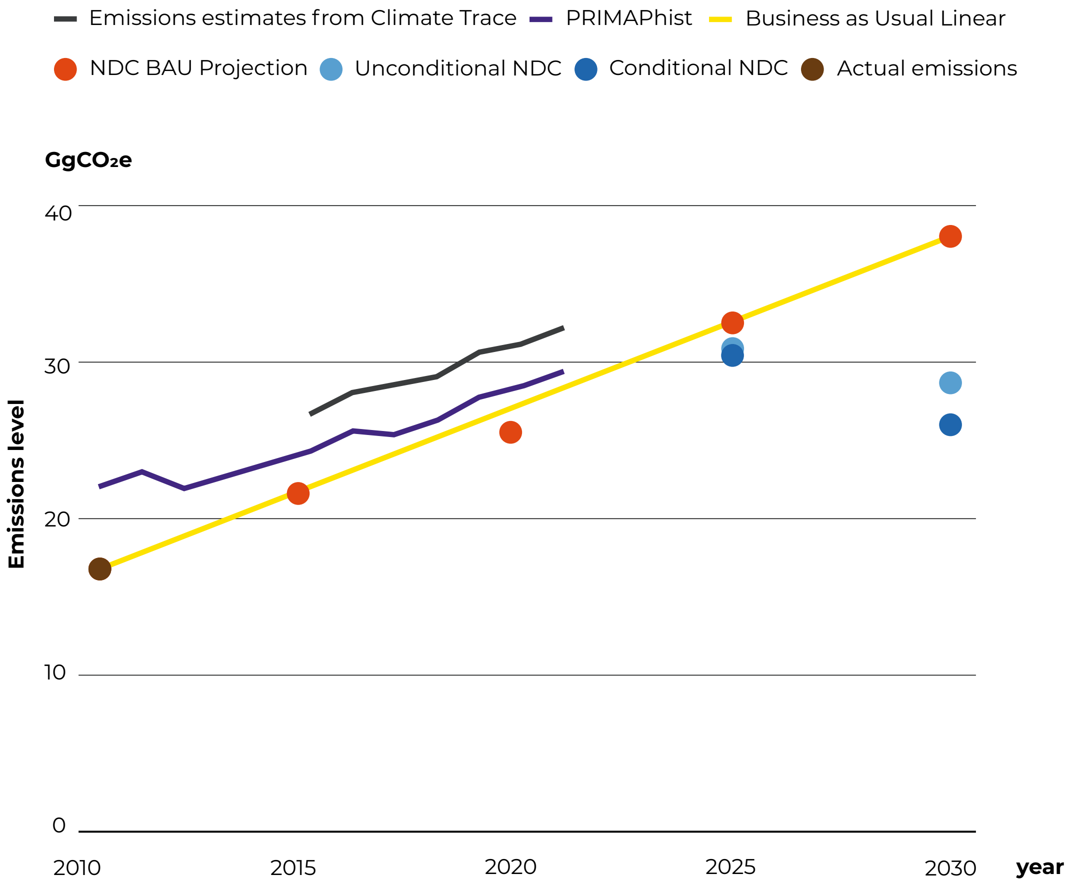
2.1 Senegalese climate policy

Senegal's 2020 Nationally Determined Contribution (NDC) includes unconditional and conditional targets, broken down both into emissions and other measures. Alone, Senegal has an "unconditional" target to reduce GHG emissions by 5% in 2025 and 7% in 2030 from a Business-as-Usual (BAU) Scenario projected from a base year of 2010. Conditional on international support, Senegal said it could reduce GHG emissions by 23% in 2025 and 29% in 2030 (Senegal, 2020b). As of May 2023, Senegal had not submitted a Long-Term Strategy to the UNFCCC.

Third party emissions data suggest that the 2010 base for the BAU projection was underestimated leading to uncertainties on whether Senegal will reach its NDC target even without the increase in emissions from oil and gas resource extraction. Gütschow et al. (2023), which includes third party data, suggests higher emissions than estimated in the 2010 Senegalese inventory. Similarly, according to data compiled by Climate Trace[2], which uses artificial intelligence to compile information from satellite imagery and other forms of remote sensing, Senegal may have underestimated its emissions and actual emissions have consistently and significantly exceeded emissions projected by the 2010 BAU projection from 2015-2021 (Climate Trace, 2023).

2 https://climatetrace.org/

Figure 2
Emissions levels and NDC targets



Source: Authors based on Senegal 2020, PRIMAPhist / Gütschow et al 2023, and Climate Trace 2023

2.2 Current energy policy

The Senegalese government has made considerable efforts to improve governance of the energy sector, reduce costs, and improve service. Historically, there was a lack of separation between the government's energy sector regulatory functions and the government owned Senelec utility, which had a general monopoly on the generation, transmission, and distribution of electricity in the country. Reforms supported by the World Bank and other international donors partially unbundled the vertical integration in the 1990s allowing for private participation in generation, separated the government's regulatory functions from Senelec, and ultimately separated the utility into three independent operating companies for generation, transmission, and distribution/sales (Reuters Staff,

2021) helping to improve electricity service leading to a notable reduction of power cuts from 950 hours in 2011 to 24 hours in 2018 (Energy Capital & Power, 2019).This unbundling has increasingly led to increased private investment in the power sector through Independent Power Producers (IPPs) in both fossil fuels and large expansion in renewables.

On one hand, the Senegalese government has created an attractive investment environment for renewable investment (Kitetu et al., 2021) and has an official policy to meet the country's electricity needs at the lowest possible cost (Senegal, 2019). Such a lowest possible cost strategy should be further supportive of further renewable growth. On the other hand, since its oil and gas discoveries, Senegal has also developed a "Gas to Power strategy" which sets the official goal of reducing dependency on diesel and HFO while significantly increasing the role of gas in the electricity system (Senegal, 2018b) . While the various energy system reforms over the past few years have been highly successful in reducing power outages, reducing costs, promoting renewables, and expanding access, the Gas to Power Strategy may pose a threat to the continued growth of renewable energy's role in the energy system. Analysis conducted as part of a 2019 policy based lending operation supported by the World Bank found that Senegal was expected to have phased out HFO from its electricity mix and continue to expand renewable capacity, but to have increased the share of gas to 54% of generation by 2026 (World Bank, 2019).

The NDC sets the following 2030 targets for renewable energy **(→ see Table 1)**: an unconditional target, achieving a cumulative installed capacity of 235 MW in solar, 150 MW in wind, 314 MW in hydroelectricity (Senegal, 2020, pg. 25). In addition, Senegal set targets to build additional installed capacity of 300 MW conditional on international support. This is split into: 100 MW solar, 100 MW wind, 50 MW biomass, and 50 MW Concentrated Solar Power (Senegal, 2020b). The distinction of unconditional and conditional is only marginally relevant

Table 1
NDC Renewable Energy Targets for 2030

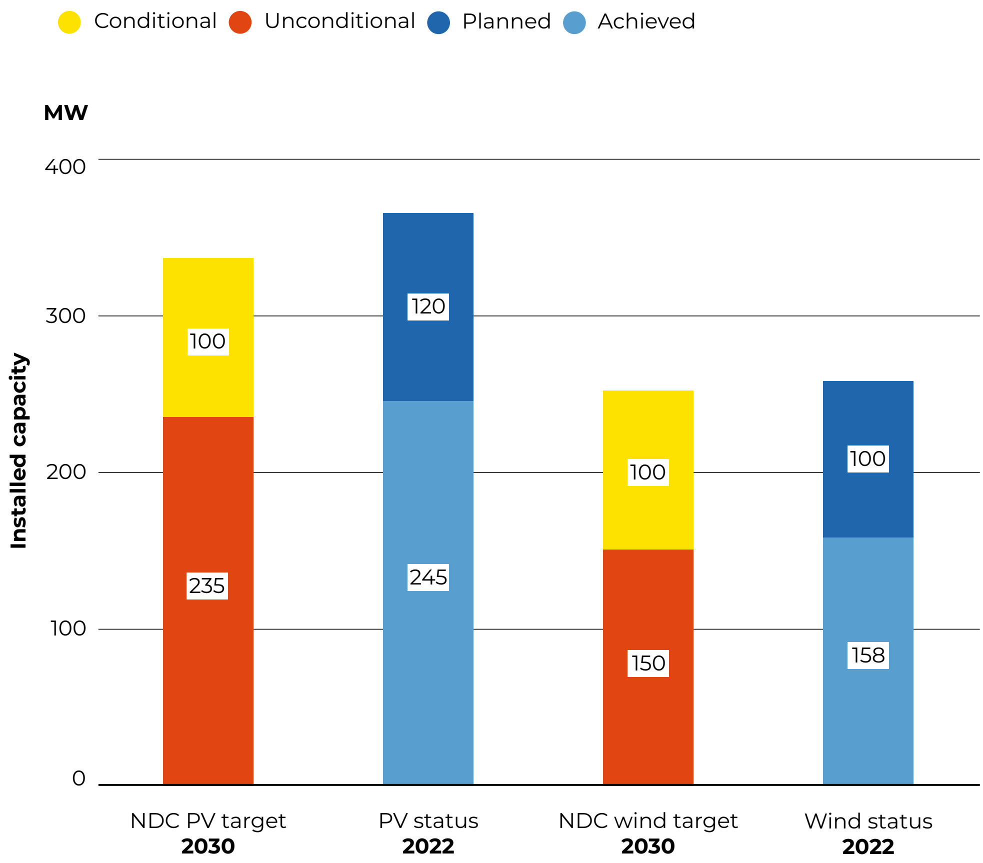
Energy sources	Unconditional (MW installed capacity)	Conditional (MW installed capacity)
Solar	235	335
Wind	150	250
Hydro	314	314
Biomass	-	50
CSP	-	50
Total	**699**	**999**

since essentially all large infrastructure projects in the country, including all renewable projects, are beneficiaries of some kind of international support – increasingly from private sector investors.

Since the submission of the NDC in 2020, it has become clear that Senegal has seen great success in setting the regulatory framework for utility scale renewable power development and will very easily overachieve these targets. Senegal has already far overachieved its conditional 2030 PV target in 2022, with further projects already in the planning / construction stage. Further, with the completion of the Taïba Ndiaye wind farm's 158.7 MW of capacity and a further expansion of 100 MW and other potential projects now being considered, Senegal will similarly achieve its installed wind capacity target far before its 2030 deadline. With the construction of the 128 MW Sambangalou hydroelectric dam (Takouleu, 2023) and other projects in the planning and construction phases, Senegal will similarly be well on its way to reaching its hydro capacity target.

Figure 3

Senegal's NDC targets for renewable energy and 2022 status



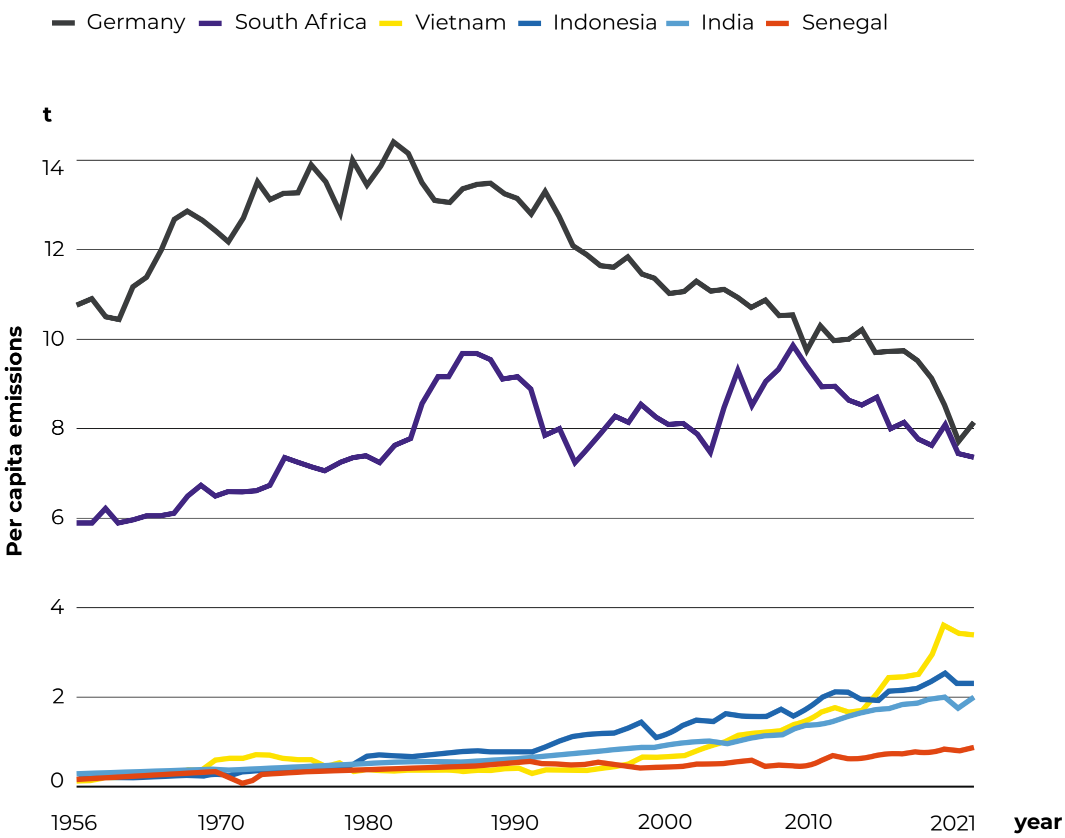
Source: Authors and Senegal (2020)

2.3 A Just Energy Transition Partnership for Senegal

International support and cooperation will need to play a critical role in supporting Senegal to provide clean dependable energy access to its entire population while supporting the objectives of the Paris Agreement. In this context, Senegal is a candidate for a "Just Energy Transition Partnership" (JETP). The first political agreement for a JETP (International Partners Group, 2021) was announced in 2021 at COP26 in Glasgow, when the United Kingdom, the United States, France, Germany, and the European Union proposed to fund South Africa's transition out of coal. The partnership was funded by an announced initial amount of USD 8.5 billion over three to five years (Presidential Climate Finance Task Team & International Partners Group, 2022).

Figure 4

Per capita CO_2 emissions in JETP Countries and Germany



Source: Our World in Data based on the Global Carbon Project (2022)OurWorldInData.org/co2-and-greenhouse-gas-emissions · CC BY

In 2022, the G7 Leaders' communiqué included references to negotiations for a second series of JETPs with India, Indonesia, Senegal, and Vietnam (G7 Germany, 2022). Among these countries, Senegal is important not only as a regional hub and comparatively stable democracy – it is the only JETP candidate that is not heavily dependent on coal nor has very high GHG emissions in either absolute or per capita terms. Senegalese GHG emissions per capita amounted to 0.81 t in 2021, less than an eighth of German per capita emissions and far lower than other JETP candidates **(see → Figure 4)** (Our World in Data, 2023a). Senegal's selection as a JETP candidate, especially in the context of its oil and gas discoveries, is an important signal to both other West African countries and other future JETP candidates about the potential for a renewable based energy transition not only in coal dependent countries but in countries that may now be embarking on a high emissions pathway.

In that context, although Senegal is not coal intensive, its electricity mix is still highly oil dependent, and the country faces the challenge of phasing out its coal and HFO plants, while charting a course and avoiding potential asset stranding and a lock-in to a gas dependent pathway.

Here, the Senegalese government has been an advocate of including the promotion of gas within the framework of its JETP (Caramel, 2022; Lo, 2022). Although a fuel switch from coal to gas, or in the case of Senegal from HFO to domestic gas would reduce emissions, the potential role of gas in such a partnership remains highly controversial, notably considering various international commitments of G7 partners regarding public fossil fuel finance. Germany and other JETP donors including Canada, France, Italy, the United Kingdom, and the United States have signed the COP26 Glasgow Statement to "end new direct public support for the international unabated fossil fuel energy sector […] except in limited and clearly defined circumstances that are consistent with a 1.5°C warming limit and the goals of the Paris Agreement" (UK COP 26 Presidency, 2021). Japan joined these countries with similar language in the 2022 G7 leaders communiqué drafted under the German G7 Presidency (G7 Germany, 2022, p. 5). G7 countries have committed to provide an update on the implementation of these pledges by the end of 2023 (G7 Japan, 2023). Civil society actors have called for a strict interpretation concluding that investments in fossil fuels including gas are incompatible with the climate and just transition goal of JETPs (Dewi, 2022; Kramer, 2022; Wemanya and Opfer, 2022).

03

The advantages of a renewable development pathway for Senegal

Expanding renewable energy in Senegal can provide several benefits, including lower costs in the trade balance by reducing dependence on fossil fuels which are currently imported, the potential for job creation, increased energy access, and reduced greenhouse gas emissions. In contrast to many heavily coal dependent countries, Senegal's current fossil fuel fleet is dependent on imported fossil fuels, and the existing system is not a comparatively large employer. In the medium to long-term there may also be opportunities for Senegal to harness its renewable potential for hydrogen and other renewable based fuel exports.

3.1 Senegal's vast renewable potential

Senegal has a rich endowment of renewable energy potential, particularly in solar and wind (IRENA, 2012; Global Solar Atlas, 2019) and this potential represents a major advantage in a decarbonising world. These resources have the potential to not only provide domestic needs with a reliable and sustainable energy supply, but also for Senegal to become an exporter to neighbouring countries in West Africa, and potentially for hydrogen or other synthetic fuels in the medium to long term. While large scale renewable projects can also be associated with human rights, land conflict, and environmental degradation issues, renewable development in Senegal – a comparatively stable democracy – have not so far proven to have been a major subject of strife or conflict. Still local stakeholder consultation and free prior and informed consent will be key to avoiding conflict in further renewable development.

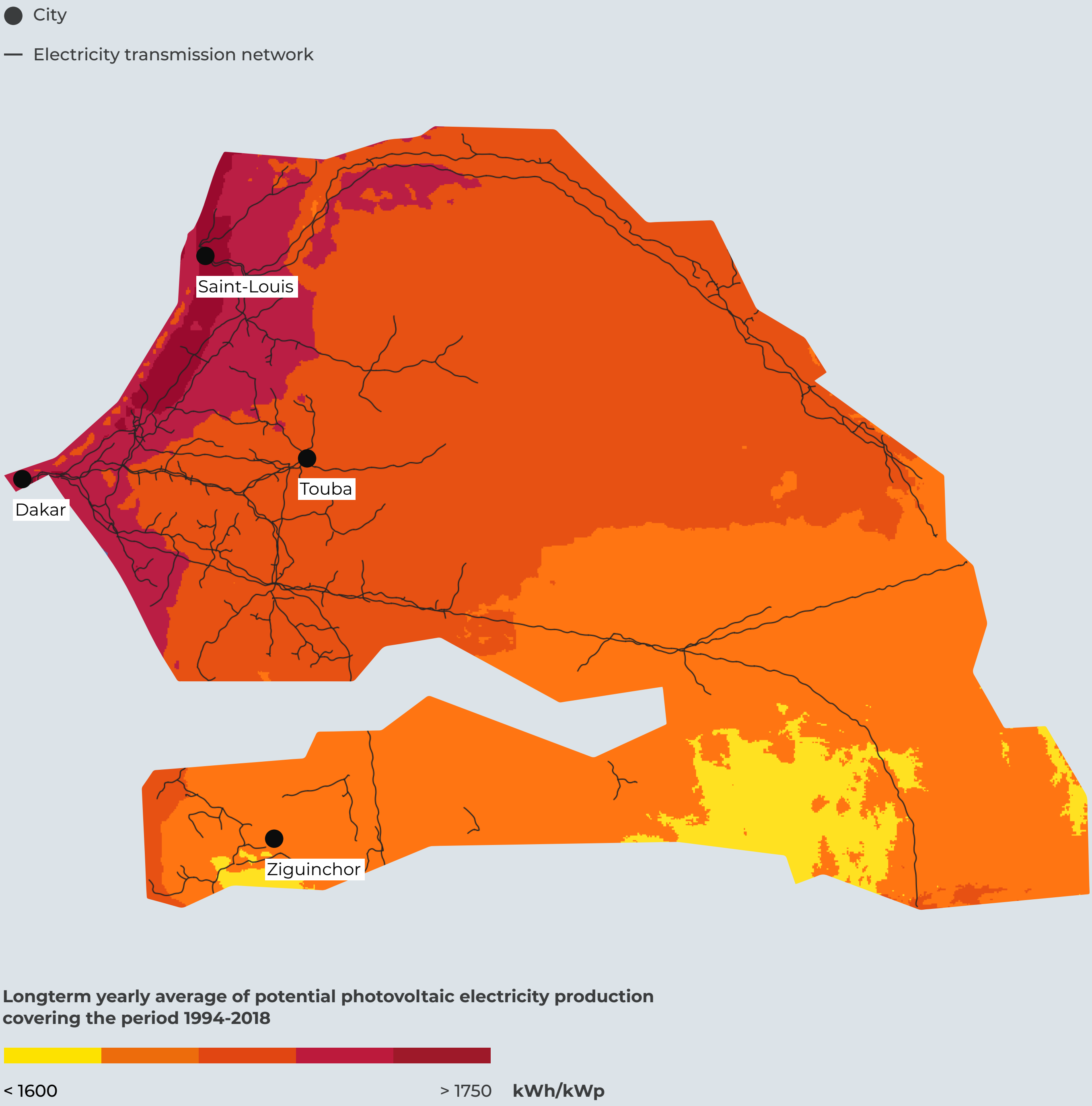
3.1.1 Solar Power

Solar power is a particularly attractive option for Senegal, as the country is located in a region with abundant sunshine, especially in the northwest of the country where the largest cities of Dakar and Saint Louis are located and there are already comparatively good transmission lines. The country benefits from plentiful daily direct solar normal irradiation of 4.2 – 5 kWh/m² - see → **Figure 5** (Solargis et al., 2023), 90% of the country has 1600 to 1800 kWh/m² per year of direct normal irradiation - almost 70% more per square meter than Northern Germany (IRENA, 2012; Solargis et al., 2023). In 2018, IRENA estimated PV potential of 37,233 MW (IRENA, 2018)[3].

3 These estimates based on various assumptions including land availability and cost factors will require updating and would be much higher with updated information and other parameters.

Figure 5

Solar power potential



Source: Own elaboration based on (Solargis et al., 2023)

After various political and regulatory reforms starting in 2010, Senegal has had particular success promoting renewable development through tendering utility scale solar PV plants (Lecoufle, 2018). Since the inauguration of the first plants in Bokhol (2016), Malicounda (2016) and Santhiou Mékhé (2017), a larger pipeline of projects has been developed. Already in 2022, Senegal had overachieved the unconditional solar PV target it had set in its NDC for 2030. Many of these projects benefited from a variety of forms of support including grants for feasibility studies, debt financing from multilateral and bilateral lenders such as the IFC, the EIB, Proparco; export credits; guarantees from institutions like MIGA against non-commercial risks. However private investors have played an important and growing role, notably the Senegalese sovereign wealth fund FONSIS. Given the right enabling framework, Senegal has the potential to build on this success and set significantly higher PV targets.

3.1.2 Wind Power

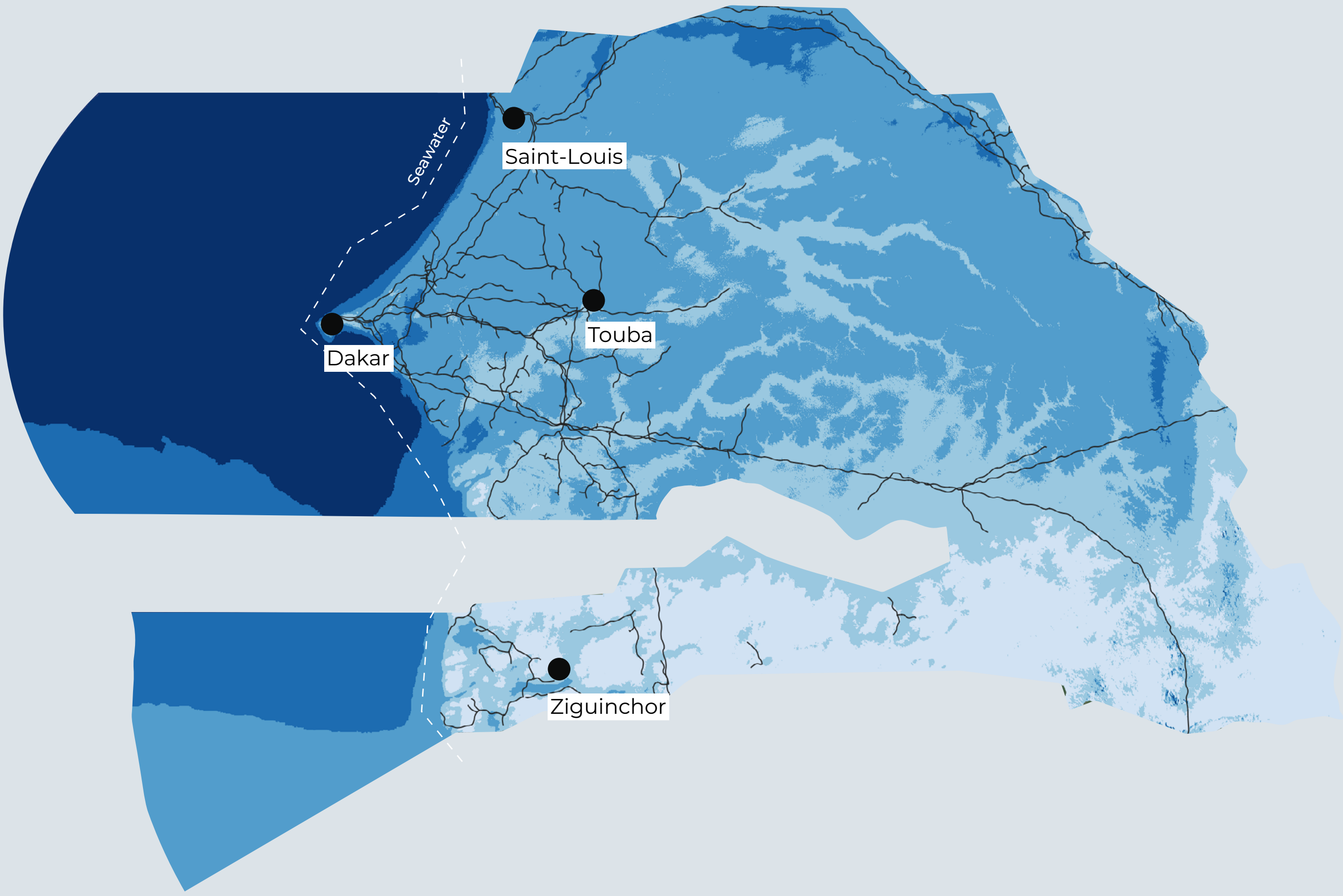
Senegal has significant wind resources that can be harnessed to provide clean, reliable, and affordable energy. The country's coastal areas have some of the strongest and most consistent wind resources in West Africa, particularly along the coast in the north and south of the country, where there is wind potential of 4-6 m/s (IRENA, 2012). IRENA modelling from 2018 suggests that Senegal has total potential (onshore) wind capacity of 4.5 GW (IRENA, 2018)[4]. In addition, the World Bank estimates an offshore potential of 45 GW – 13 GW of fixed potential and 32 of floating (DTU et al., 2023)[5]. Wind also complements solar relatively well, as solar PV electricity peaks at midday, while wind in Senegal picks up in the evening and night (Sterl et al., 2020).

4 These estimates based on various assumptions including land availability and cost factors will require updating and would be much higher with current information and other parameters.

5 Based on a different methodology than that of IRENA and not directly comparable.

Figure 6
Wind power potential

● City
— Electricity transmission network



Average wind speed potential (at a height of 50 m)

< 4.2 > 6.3 **m/s**

Source: Own elaboration based on (DTU et al., 2023)

Senegal is notably already host to the largest wind farm in West Africa. The Lekela Taïba N'Diaye is an onshore project completed in 2021 with a capacity of 158 MW generating 400 GWh each year (Connor, 2022). This single plant is particularly significant considering its scale in the Senegalese electricity generation fleet – when the full project went online it immediately accounted for 15% of Senegal's entire electricity generation capacity (Takouleu, 2021). Although the project benefited from public US, Danish, and multilateral financing, reinsurance, export credits, political risk insurance as well as grants in its early development phase, Lekela, a private renewable power generation company played a leading role in its financing and development.

Looking forward, Senegal is likely to attract much more wind investment and the Taiba N'Diaye wind farm is already set for expansion. The U.S. Trade and Development Agency provided a grant for a feasibility study for the addition of a battery energy storage system (BESS) of 40 MW to provide 175 MWh of electricity (DNV, 2020). Financial closing for the construction of the BESS system is reported to be expected in spring 2023 (Antonopoulos, 2023), and potentially enable further expansion of the wind park of 100 MW (Constructionreview, 2021).

3.1.3 Hydropower

While Senegal's renewable energy potential is mainly in solar and wind power and Sterl et al (2020) recommend that Senegal concentrate on its regional comparative advantage in solar and wind, the country also has some hydropower potential. Until around 2012, the only renewable source of energy feeding into the Senegalese grid was the Manantali hydro power plant in Mali which was co-developed with Senegal, and which provides Senegal with electricity via the West African Power Pool (WAPP) (AfDB, 1994). Since then a number of additional hydroelectric dams have been built or are planned in the WAPP, including a 59 MW "run of the river" project in Felou, Mali (Energypedia, 2015; Tchanche, 2020). Although Senegal has approximately 1400 MW of hydroelectric potential on the Senegal and Gambia Rivers (IRENA, 2012), most hydro capacity available to Senegal is located primarily in neighbouring countries (Sterl et al., 2020).

Recognizing the regional resource, Senegal has joined with regional partners to found two organisations to develop hydroelectricity resources: The Senegal River Basin Development Authority (OMVS[6]) founded by the governments of Mail, Senegal, and Mauritania; and the Gambia River Development Organisation (OMVG[7]), which includes Gambia, Senegal, Guinea, and Guinea Bissau as members. These organisations co-develop hydroelectricity for the larger region of the respective river basins. One large hydro project is currently under construction on the Gambia river in south-eastern Senegal. When completed, the Sambangalou hydroelectric dam is expected to have a capacity of 128 MW

6 L'Organisation pour la mise en valeur du fleuve Sénégal.

7 L'Organisation pour la Mise en Valeur du Fleuve Gambie.

(Moraes, 2023; Takouleu, 2023). Hydropower can be used to complement solar and or wind on the grid by accumulating water in reservoirs as an alternative to batteries (KfW et al., 2020). Transmission throughout the WAPP can help connect countries with larger hydro potential, such as Ghana to Senegal, which can complement and trade with its comparative larger solar and wind potential (Sterl et al., 2020). Importantly, hydropower can provide a power system with inertia, which can keep a power system stable if there are failures in the system (Denholm et al., 2020). Expanded transmission capacity for hydropower can also be used for floating PV plants on reservoirs which reduce evaporation. Such a plant is already under way in Côte d'Ivoire (Konandi, 2022), which is also a member of the WAPP.

However, there are limitations to developing sustainable large hydropower projects in Senegal considering the large impact that dams and resulting reservoirs have on local populations and ecosystems and the variability of water availability due to droughts and climate change. Senegal has already experienced more frequent and severe droughts in recent years (Faye et al., 2019), making it challenging to rely on a large expansion of hydropower as a consistent future source of electricity. IRENA modelling similarly sees drought as a constraint for hydro capacity (IRENA, 2018). However integrated planning of hydro, wind, and solar based generation can take advantage of the storage potential of hydropower dams and at the same time reduce over-dependence on hydro (Sterl et al., 2020).

3.2 Cost advantages of renewables over gas dependency

In contrast to electricity systems in Europe or North America where expanded renewable capacity progressively replaces existing fossil fuel resources in an electricity system characterized with comparatively limited growth in demand, Sub-Saharan Africa has the opportunity to build a "greenfield" renewable electricity system to meet rapidly growing demand from scratch leap-frogging the build out of fossil fuels (Sterl et al., 2020; Kitetu et al., 2021). Building such a system primarily based on renewables from the start is cheaper overall than an electricity system that primarily uses domestic gas to reduce dependency on imported HFO and coal and then later paying to convert it to renewables.

In the short term, expansion of renewable energy in Senegal would reduce, and already is progressively reducing, dependence on imported fossil fuels. This provides greater energy security and reduces the vulnerability of the economy to global energy price shocks – a major challenge that Senegal has historically struggled with.

While Senegal has domestic gas resources, some of which will likely come online in 2024 (Ford, 2023), their domestic use will not necessarily shield Senegal from international market volatility. Any gas used domestically comes at an opportunity cost, as it could have been exported. Here, the case of Tunisia provides a warning. A net energy exporter until the early 2000's, its lack of renewable investment meant that its domestic demand for energy grew faster at a time when its domestic production started into decline (Cherif and Mobarek, 2016). It's lack of renewable investment has meant that the once oil and gas exporter is now again at the mercy of international energy markets (Cherif and Mobarek, 2016).

Box 1

A View from Senegalese Civil Society:
Limited use of fossil gas to achieve 100% renewable energy and a prosperous country in 2035

Given the inevitability of some gas exploration off the Senegalese coast, it will be necessary to promote all aspects of sustainable development, including environmental and social safeguards. This ambition will have to go beyond the intergenerational sovereign wealth fund, which was mandated by law in September 2022 to yield returns for the benefit of future generations, utilizing the returns fossil gas extraction and trade. A major effort is therefore needed to achieve an energy transition that reduces dependence on fossil fuels through the responsible management of hydrocarbon reserves. To this end, most of the revenues from the exploitation of oil and gas should be used to invest in the development of renewable energies (solar, wind and hydroelectric). Moreover, the Senegalese Government's "Gas to Power" plan should be revised to "Green Power Plan" in order to achieve 100% renewable energy by 2035.

Given the impact of hydrocarbon projects for at least another 30 years, and the significant quantities of solutions that come from agricultural practices, it is necessary to accompany local actors towards alternative or complementary livelihoods for farming and fishing communities. This can be done by promoting green and blue economy in collaboration with vocational training, higher education and research institutions, etc. This is an opportunity to combat poverty, inequality and climate change, and one where cooperation between Senegal and Germany can be very impactful.

Senegal's energy transition strategy must be fair, impartial and equitable to ensure energy security and affordable access to energy for all, everywhere.

LEGS
Leadership, Éthique, Gouvernance, Stratégies pour l'AFRIQUE

Senegalese plans for expanded generation with gas, as laid out in its "Gas to Power Strategy" first drafted in 2018 (Senegal, 2018b), may reduce emissions compared to power production with coal or heavy fuel oil (HFO), but there are also significant and expensive lock-in risks with a large expansion of a gas-based electricity system. In particular, a large scale switch to gas in Senegal is likely to have a significant impact delaying decarbonisation (McJeon et al., 2014).

The lock-in risk and lack of compatibility with an expanded renewable role in the grid is particularly an issue for Combined Cycle Gas Turbines (CCGT), which are generally designed to be run with high load factors, regardless of the availability of solar or wind energy at any given time (Marquardt and Kachi, 2021). A study by Wärtsilä found that a large expansion of CCGT capacity could cost Senegal up to USD 480 million more by 2035 than an alternative scenario of higher renewables generation and smaller internal combustion engines (Huhdanmäki, 2022). Modelling by Sterl et al. found that an optimised use of wind, solar, and hydro in the broader West African region "could generate electricity at grid parity with cheap natural gas in less than 10 years, and 10% more cheaply by 2030" (Sterl et al., 2020, p. 713). Accordingly, there is significant potential for higher ambition in terms of progress towards decarbonisation while meeting Senegal's sustainable development goals, especially with improved cooperation with Senegal's neighbours.

3.3 Superior resiliency of renewables

An energy system based on renewables is more resilient to climate change than a system based primarily on fossil fuels. High air temperatures have a negative impact on thermal power plant efficiencies (Singh and Kumar, 2012). In addition, with the expected growth in extreme hot weather and drought, thermal fossil fuel power plants may need to be curtailed due to water stress or a reduced capacity for water to cool the plants (Byers et al., 2018; Coffel and Mankin, 2021).

In addition, much of the Senegalese fossil fuel fleet is located in vulnerable coastal areas. The Sendou coal power plant in Bargny, is one of the coastal areas most vulnerable to erosion and sea level rise in Senegal (Caramel, 2015). Although a comprehensive vulnerability assessment has not been conducted, the development of renewable energy sources particularly such as solar, wind which do not need cooling water and which can be located farther from the coastal areas is critical for increased resiliency of the Senegalese energy system.

3.4 Economic growth and other sustainable development benefits

There are also other multiple benefits of a clean energy transition in Senegal. Fundamentally, affordable energy access is key to sustainable development and economic growth. Cheaper renewable energy both through grid extension and mini-grids is key to rural electrification, enabling energy access, reducing energy poverty, and furthering general economic growth – especially for Senegal's small and medium sized enterprises (SMEs).

Replacing the existing HFO and coal fleet would reduce the cost of importing these fuels, reduce air pollution, and improve public health. Access to affordable clean energy and expanding the domestic renewable energy development business sector will play an important factor in economic diversification and it is important that Senegal avoids "Dutch disease", where potential expansion of domestic oil and gas resources undermines the rest of the economy. The reduced dependency on thermal power plants that discharge cooling water would reduce pressure on marine ecosystems (Roy et al., 2022), on which the local fishing industry, a major employer, depends. Renewable energy projects create green jobs in the construction and maintenance phases, and in the economy overall. According to the Climate Action Tracker, which adapted the employment factor approach from Rutovitz et al. (2015), a 1.5°C compatible pathway for Senegal would create 1.4 million more job years than a gas based scenario over the period 2021-2030 (Climate Action Tracker, 2022).

In the longer term, Senegal's renewable energy endowment can lend itself to green hydrogen production and represent an important additional opportunity for economic growth. Although not without challenges, green hydrogen production may have multiple sustainable development benefits not only in the production and export of hydrogen, but also for food security (SDG 2), and clean water and sanitation (SDG 6). Senegal must currently import fertiliser at high international prices. With domestic hydrogen production, Senegal could produce its own fertilisers reducing import dependencies and foster a new domestic industry potentially enough to export to other countries. These opportunities are further discussed in → **Chapter 5**.

04

Priority areas and forms of support for a renewable energy system

While Senegal has demonstrated that with international support it can successfully attract private investors for renewable energy projects, in terms of emissions, what matters most is the proportion of electricity actually consumed that comes from renewables and the overall grid emission factor. A 2015 Senegalese government planning document set a target of 20% renewable electricity (including hydro) in the electricity mix in 2020 and 23% in 2030 (Senegal, 2015). The same year, a new target of 30% for PV and wind in the electricity generation mix was set for 2025, with the intention on maintaining the 30% share of generation despite fast growing demand to 2030 (Niane, 2015).

Although the 20% target was narrowly missed in 2020, it was reached in 2021 with a renewable share of electricity production of 20.14% (Our World in Data, 2023b). Since then it has increased even more: with the completion of the Taïba N'Diaye wind farm in 2022 (Hollands, 2021) and the Diass solar PV plant (Takouleu, 2022), Senegal is reported to have reached 36.6% in consumption in 2022 (Connor, 2022). 2018 modelling by IRENA found that renewable power capacity could potentially reach levels near 65% of electricity at times of peak demand across West Africa by 2030 (IRENA, 2018), an increase from a previous 2013 IRENA estimate of 52% in 2030. With the continued progress of renewable promotion, Senegal and its neighbours are likely to be able to increase that percentage even more. In order to enable a higher percentage of renewable in the electricity generation mix, it is important to support Senegal in building a flexible responsive electricity system as well as to improve the general enabling environment including building capacity of local financial institutions to invest in the Senegalese energy transition.

4.1 Fostering a flexible and responsive electricity system

Despite Senegal's success so far, multiple experts note that at around 36.6%, Senegal may already be approaching a threshold beyond which additional renewable capacity may become a challenge for grid stability (OECD/IEA, 2018; De Vivero-Serrano et al., 2019; IEA, 2019c; World Bank, 2019). Beyond this threshold, as generation and consumption on the grid must coincide and actual consumption does not aways correspond with peaks in solar and wind generation, variable renewables from solar and wind may require curtailment without additional flexibility measures.

In order to enable further growth of renewables in the share of Senegalese electricity generation, it is essential to implement measures to increase the flexibility of the system. These include storage and smart grids; improved electricity network management; improved transmission and distribution including with the wider WAPP; and finding options to repurpose the existing fossil fleet.

4.1.1 Storage and Smart Grids

The integration of renewable energy sources into the grid requires the development of new infrastructure and technologies for energy storage and management. The development of energy storage notably BESS, integrating complementary hydro production, and eventually pumped hydroelectric storage can help to overcome the challenges associated with the variable nature of renewable energy sources. Storage and smart grids can also help to reduce the need for costly upgrades to the grid and transmission infrastructure.

A recent Australian study found that large scale batteries provide significant advantages for electricity peaking services both in terms of cost, flexibility, and emissions compared to open-cycle gas turbine plants (Clean Energy Council, 2021). Several renewable plants in Senegal already include BESS, and more are in the feasibility study, planning, and construction phases. For example, in addition to the aforementioned Taïba N'Diaye BESS awaiting financial closure, a plant combining 30 MW of PV and storage of between 15-45 MWh hours is being developed in Niakhar (Magoum, 2020). Senegal also installed the first fully digital high voltage substation in Africa in 2021 (IEA, 2022). Further, as part of a larger KfW Entwicklungsbank, AFD funded project to help Senelec modernise and reinforce the electric grid, another public tendering process for the supply of equipment and construction of a 56 MW / 56MWh BESS was underway in March 2023 (dg Market, 2023; KfW, 2023c).

Sterl et al. (2020, p. 710) note that hydropower plants with reservoirs are well suited to complement the variability of wind and solar considering hydro's "low minimum loads, quick start-up times, fast ramping rates, low marginal costs and seasonal energy buffering capability". Although the various hydroelectric projects in the WAPP are not yet clearly used to balance wind and solar production and consumption, they have the future potential to depending on contractual agreements within the WAPP. These systems can help increase the penetration of renewable energy sources to store excess energy during times of high renewable energy production and release it during periods of low production or high demand. Although they are constrained by the necessity to ensure some flow to provide river basin ecosystem services, their storage capacity to complement renewables is essential to reducing the need for back-up fossil fuel generation and thereby reduce greenhouse gas emissions. Although more expensive, in the future, pumped hydro storage could further complement increased solar and wind generation in the future (Sterl et al., 2020).

In addition to energy storage, the development of smart grids can also help to manage the integration of renewable energy sources into the grid. Smart grids use advanced monitoring, communication, and control technologies to manage the flow of electricity between producers, consumers, and the grid. Smart grids can similarly help to balance supply and demand by adjusting electricity prices, managing peak demand, and integrating distributed energy resources such as rooftop solar and energy storage systems. An Energy Futures Lab paper from Imperial College London explores the concept of “smart and just grids” adapting smart grids specifically for sub-Saharan Africa (Bazilian et al., 2011). Rwanda, Nigeria, and Egypt are already implementing smart grid projects (Omata, 2023) and can offer potential lessons for Senegal. In some instances, off grid metering is smarter than on grid metering considering the particular context of consumption and billing. The KfW is already active in supporting the installation of prepaid electricity meters and smart meters in Senegal to facilitate billing processes and giving consumers a better understanding of their consumption (KfW, 2023b).

Demand response incentives are another important low-cost potential measure, allowing consumers to respond to signals from the grid by reducing their electricity usage during times of peak demand and time energy use to correspond to increased renewable generation. Demand response can help to balance the grid by reducing the need for costly peak power plants and transmission lines. The use of demand response can also help to reduce overall energy consumption and costs for consumers. Its potential is already being explored in South Africa which suffers from regular blackouts (CTCN, 2021). Demand response systems, while they require smart meters, are relatively cheap options to shift electricity demand towards times of abundant renewable production and away from reliance on fossil fuels (Lorenzi and Silva, 2016).

4.1.2 Transmission and the West African Power Pool (WAPP)

A large expansion of transmission and distribution infrastructure is also a key enabling factor to support further renewable energy development. The expansion of the electricity grid remains a high priority in Senegal since grids still do not cover the whole territory. Large financing programmes from international donor’s further support transmission and distribution infrastructure maintenance, upgrading, and expansion in Senegal and the wider WAPP region. This includes a USD 550 million grant from the U.S Millennium Challenge Corporation specifically for Senegal (MCC, 2023) and a USD 465 million World Bank project for the WAPP region (World Bank, 2021).

Senegal is not isolated in terms of its electricity generation and transmission capacity, and instead shares interconnections with a number of other countries in the WAPP, a regional initiative aimed at developing a unified electricity market in West Africa through the interconnection of national electricity grids and the development of cross-border transmission infrastructure[8]. Such

8 WAPP members include: Benin, Burkina Faso, Ghana, Guinea, Guinea Bissau, Ivory Coast, Mali, Niger, Nigeria, Gambia, Togo, Senegal, and Sierra Leone.

expanded transmission enables hydroelectric reservoirs in one country to better complement wind and hydro elsewhere (Sterl et al., 2020). IRENA modelling finds that cross border transmission infrastructure is beneficial to renewable deployment across the region in all modelled scenarios (IRENA, 2018).

The modernization and expansion of transmission infrastructure through the WAPP can help to overcome the challenges associated with the variable nature of renewable energy sources, by providing greater access to a larger market and enabling the transfer of excess energy from areas with high renewable energy production to areas with high demand. The development of transmission infrastructure can also help to improve the reliability and efficiency of the electricity system by reducing transmission losses and improving the balance of supply and demand. WAPP member countries traded 5,585 gigawatt-hours of electricity across national borders in 2018 (Climatelinks, 2019). Modelling by Sterl et al (2020) suggest that increased transmission capacity in the region, could allow Senegal to concentrate on the development and export of wind and solar, and benefit from hydro and future potential pumped hydro-storage potential in other countries such as Guinea and Ghana. Despite some regional cooperation, most countries continue to concentrate their power planning on the national level disregarding potential efficiencies for cross-border trading and the corresponding opportunity to renewable energy penetration in the generation portfolio (World Bank, 2019; Sterl et al., 2020). International support to help foster regional trust and improved regional planning is critical to making the most of the potential efficiency of regional cooperation.

Box 2

Rural electrification

Rural electrification is a priority in Senegal's objective of universal electricity access by 2025. The Senegalese government has prioritised extending the grid to cover 95% percent of the rural population by 2025 (Senegal, 2018a). Senegal is making progress towards this goal though it is uncertain if it will be completely reached by 2025. This expansion however still leaves a gap in rural areas and there remains significant potential and need for increased rural electrification efforts both in areas until the grid can be expanded and in areas where no grid extension is planned. After initial challenges when the first major initiatives were launched around 2008, Senegal has emerged as a regional leader in off-grid solar access in terms of mini-grids installed per capita. Innovative payment systems to recoup the costs of installations has been a key factor in overcoming affordability constraints (Diop, 2022).

Currently, there is a tension between the government's grid expansion plans and mini-grid operators – who, according to government planning will serve only 4% of the rural population in 2025, with another 1% being served with solar home systems (SHS) (Senegal, 2018a). While grid extension represents an economic risk to mini-grid operators, Kitetu (2021) suggests that there are opportunities to integrate distributed renewable energy mini-grids into a new model for electricity systems leapfrogging the centralised electricity system development found in the global north. Here, an expansion of energy prosumerism[9], where for example mini-grid operators become a small power producer and distributor within the overall grid can help ensure a business model for continued investments (Tenenbaum et al., 2018). To foster such a model, further reforms in the electricity code, increased engagement with Senelec, and increased awareness among potential producer are necessary.

German companies working with Senegalese partners are already playing an important role in enabling rural energy access through the construction of mini-grids in Senegal. Grips Energy, a renewable project development company has recently opened a subsidiary in Senegal, serving as a hub for French speaking West Africa (Econnext, 2022). GAUFF engineering, a company based in Nürnberg, won a contract to electrify 300 villages with PV mini-grids with battery storage including components from SMA Solar – a project that benefitted from financing from the KfW IPEX-Bank and export credits from Euler Hermes (Gauff Engineering, 2019; Klügling, 2023). Africa GreenTec AG is another German company with a local presence in Senegal that has specialised in rural electrification and has notably implemented a holistic solar PV project that combines water filtration and refrigeration of perishable goods in Ndiob, a village far from Senegal's main electricity grid (BMWK, 2022). Further, projects such as "Energy 4 Impact" demonstration project, supported by the GIZ on behalf of the BMZ could be scaled up. The project focusses on the rehabilitation and improvement of an underperforming solar-powered mini-grid in eastern Senegal, addressing both supply and demand side issues to increase commercial viability and expand service to more customers (Energy4Impact, 2022).

9

See → **Chapter 4.1.5**
Sector coupling and prosumerism.

4.1.3 Regulatory reforms, electricity markets, and network management

After failed attempts to privatize Senelec without robust regulatory structures (Youssef et al., 2016), Senegal has already made significant progress in improving its policy framework for energy markets and reducing Senelec's dependency on government subsidies, in part with the support of World Bank policy-based loans (World Bank, 2019; Neunuebel et al., 2022). Importantly with the passage of the new electricity code in 2021, Senelec was converted into a holding company with separate units for electricity generation and transmission and distribution (Enerdata, 2021). Further reforms however are important to avoid gas lock-in and encourage and accelerate increased renewable penetration in the Senegalese energy mix. One important measure would be to reform pricing structures in the electricity code to encourage BESS development, even independently from renewable project development. This is not currently the case but would be an important measure to improve the financial return of charging systems when renewables are abundant, but demand is low and feeding energy back into the grid at times of high electricity demand – a key measure to enable higher penetration of renewables in the grid on the way towards decarbonisation.

Ongoing GIZ projects are already relevant and supporting efforts in this direction and could be expanded. One specific GIZ project aims to support the Senegalese Ministry for Petroleum and Energy with policy reforms and to build capacity and another targeting a "climate friendly reform" of the ECOWAS electricity market (GIZ, 2023). Another particularly important initiative is the Senegal Masterplan Development Support Programme, which will help the Senegal Ministry of Petroleum and Energy (MPE) build capacity in long-term energy planning using IRENA's SPLAT-MESSAGE model for power system capacity planning (IRENA, 2023). Here, it will be important to incorporate a high ambition scenario that assumes a highly flexible modern smart grid with demand response measures; continued cost reductions in PV, wind, and BESS; improvements in the performance of BESS; and increase cooperation in the WAPP.

Senelec would further benefit from capacity building and technical assistance for a number of measures to better accommodate renewables in the grid. These include for example, advanced grid management capability including automatic generation control to adjust power plant operations at multiple plants to accommodate changes in electricity supply and demand on the grid, as well as weather and power plant forecasting (Kitetu et al., 2021). The current contracts that Senelec has with IPPs do not include measures such as voltage support and frequency regulation. According to Kitetu et al. (2021, pg. 6) "markets for other ancillary services that can also be supplied by batteries would also help generate revenues and recover costs."

4.1.4 Sector coupling and prosumerism

Electrification and decarbonization of other sectors of the economy, such as cooking, land transport, small industry, and manufacturing, are critical components of Senegal's transition to a 100% renewable energy system. Currently, these sectors are heavily reliant on fossil fuels, which contribute to greenhouse gas emissions and air pollution.

Clean cooking

Cooking is one of the largest energy consumers in Senegal, with approximately 70% of the population relying on traditional biomass fuels such as charcoal and firewood (Sow, 2022), and the other 30% largely relying on liquified petroleum gas (LPG) (IEA, 2019a). According to the World Health Organisation, although more people are gaining access to electricity, the overall trend is moving in the wrong direction with a growing portion of the population without access to clean cooking. The use of wood and charcoal not only contributes to deforestation and environmental degradation but also has negative health impacts, particularly for women and children who are exposed to indoor air pollution. Electrification of cooking through the use of electric stoves and induction cooktops, powered by renewable energy sources, can provide a clean and sustainable alternative to traditional biomass fuels (Nilsson et al., 2021).

Although Germany has an existing BMZ/GCF initiative that is already supporting improved cookstoves in rural Senegal (BMZ, 2022), the biggest sustainable development challenge is a shift towards electric cooking, which offers the greatest benefits in terms of health, forest preservation, and GHG emissions. With expanding access to stable electricity from the grid, electric cooking, in particular using efficient induction technology, becomes a more feasible option. Germany has several induction cookstove manufacturers that could expand to serve the Senegalese market potentially starting with commercial hotel and restaurant kitchens. Leading Senegalese chefs and electricians could be recruited to promote these efforts.

Other sectors and energy “prosumerism”

Small industry and manufacturing are also important sectors of the economy that can benefit from electrification and decarbonization by investing in their own renewable energy generation such as rooftop solar. The history of unreliable electricity service from Senelec has driven many of those that can afford it to install diesel based back up capacity, which not only contribute to greenhouse gas emissions but also expose residents and workers to harmful pollutants. This, in combination with the high cost of electricity from the grid leaves a potential market for consumer-owned, behind-the-meter generation, including battery storage (Wood Mackenzie, 2022). For private households, businesses, and industrial consumers such a model is an attractive option and can help add renewable capacity while placing minimal strain on the grid. If combined through "behind the meter storage" and smart grids. Central management of such distributed electricity generation and storage can help the entire system balance supply and demand.

Despite its potential benefits and the fact that Senegal has implemented electricity reforms including a feed-in-tariff, this form of energy prosumerism is not common. Households and SMEs lack awareness about business models and options to generate, store, and interact with the Senelec managed electricity grid (Apfel and Herbes, 2021). This is in part due to the fact that energy prosumerism has not been a priority of the Senegalese government, likely partially because it may pose a challenge to the revenue streams of Senelec (Apfel and Herbes, 2021; Apfel, 2022), which has historically struggled to recoup its costs. Senelec could however find alternative sources of revenue, for example through the electrification of other sectors of the economy including transportation. Specifically, despite the existence of the feed in tariff, the electricity code could be reviewed to better accommodate and encourage energy prosumerism both for businesses, households, as well as mini-grid operators **(see → Box 2)**. Here Germany has already developed expertise and has a number of businesses specialising in enabling prosumer models including tying them together into virtual power plants (Seidl et al., 2016; Siemens, 2019).

Transport

In the ground transport sector, the majority of vehicles in Senegal run on gasoline or diesel, contributing to air pollution and greenhouse gas emissions. The transition to electric vehicles (EVs) powered by renewable energy sources can help to improve air quality and reduce the country's carbon footprint. According to the IEA's scenario projections, Senegal's stock of 2-3 wheelers is set to grow rapidly in both the Stated Policies Scenario and the "Africa Case". The IEA notes that electrification of these vehicles "would help to free oil for other productive uses" (IEA, 2019b). The sale of electricity for electric mobility could represent an additional customer base for energy services companies in the country such as Senelec.

Senegal has already taken initial steps towards the electrification of its transport sector. Together with "Team Europe" including the EIB, the French Development Agency, and the KfW, Senegal hosts a 320-450 million EUR "Global Gateway" project to build an electric rapid bus transit (RBT) system in Dakar (EIB, 2023). This includes 121 electric buses equipped with batteries with a capacity of 563.8 kWh each, and 23 charging stations in 14 Dakar councils (Hampel, 2022). Optimal charging of these buses could be integrated in a smart grid pilot programme adding to grid stability. With adjustments, the charging stations could also contribute to charging infrastructure for private electric vehicles.

Already recognizing the potential of market growth for electric 2-3 wheelers, the Indonesian Ambassador has started promoting Indonesian electric vehicle manufacturers exports to Senegal (Indonesian Embassy Dakar, 2021). The motor bikes will also be used by Ndiaye Transport, a motorbike taxi service in Thies (Indonesia Window, 2021). This follows a trend in other emerging markets, where electric 2-3 wheelers are quickly gaining market share: in India, over 50% of three-wheel models sold in 2022 were electric (Campbell and Muir, 2023).

4.1.5 Renegotiating existing fossil PPAs and repurposing and retirement of the existing fossil fleet

Up until the relatively recent success of grid connected renewable power plants, Senegal was overwhelmingly dependent on a fleet of fossil fuel plants, primarily HFO (Our World in Data, 2023e) but also coal through the Sendou coal power plant built in Bargny (Caramel, 2015), and also gas. In electricity markets in Europe and North America, such fossil plants not only make money from the sale of electricity, but also from the provision of ancillary services such as voltage support and frequency regulation (Kitetu et al., 2021). Although Senelec owns a large share of the existing fossil generation, fossil IPPs also play a significant role with locked-in take or pay PPA contracts at high prices which protect their investment. There is a lack of full transparency with regard to the details of such PPAs, but it is likely that these contracts lack provisions for ancillary services which undermine their ability to play a complementary role to renewables in the Senegalese electricity system.

In many cases, building new renewables may be cheaper than the operational running costs of existing fossil plants, but many such plants are protected from competition by contractual PPAs which lock in continued electricity sales at high prices (Bodnar et al., 2021). These PPAs may lead to curtailment of wind and solar, posing a challenge to higher renewable penetration even in times of abundant sun or wind. If these PPAs were to be renegotiated to include ancillary services, be placed into capacity reserves, or retired and repurposed, they could enable higher penetrations of wind and solar in the electricity grid, reduce costs, air pollution, and greenhouse gases.

The Senegalese NDC includes plans to increase electricity production from gas through the replacement of fuel oil by natural gas in dual fuel/gas plants and an explicit plan to convert the 320 MW Jindal coal plant by combined cycle gas plants, bringing the total installed natural gas capacity to 600 MW between 2025 and 2030 (Senegal, 2020b). This appears to be a mistake in the formulation of the NDC as the Global Coal Plant Tracker lists the Jindal coal plant as having been cancelled and never built (Global Energy Monitor, 2023a). Instead, this is likely a reference to the existing Sendou "Bargny" power station, with a smaller capacity of 125 MW (Caramel, 2015; Global Energy Monitor, 2023b), which media reports is supposed to be converted to gas. When and if this conversion takes place, it is particularly important for the flexibility of the grid to include ancillary services to enhance flexibility for the grid to enable increased renewable penetration.

4.2 Current German development cooperation with Senegal

Germany supports a large number of projects involving Senegal, and the two countries have been working together within the framework of a "reform partnership" since 2019. "Climate and Energy, Just Transition" and "Sustainable management, Training and Employment" are two of the core themes of this partnership, primarily implemented through the GIZ and KfW (German Embassy in Senegal, 2023).

The GIZ has 12 current projects specifically with Senegal, and a further 41 involving Senegal in various contexts through global projects, projects with the African Union, or through ECOWAS (GIZ, 2023), notably one specific Programme for sustainable energy (PED II), which is already in its second phase. The KfW Entwicklungsbank has 15 projects involving Senegal including 5 targeted specifically at energy efficiency, energy access, or renewable energy integration (KfW, 2023a). The BMBF's support to Senegal includes a research project (Local sustainable energy systems in Senegal) through "WASCAL" (West African Science Service Centre on Climate Change and Adapted Land Use). While WASCAL is a longer-term, large-scale initiative for multiple West African Countries, the project term of LoSENS will come to an end in September 2023. Twenty-two additional International Climate Initiative (ICI) funded projects involve Senegal. The BMWK's Renewable Energy Solutions Programme has also supported renewable energy in Senegal with a reference project consisting of a PV system, BESS, water filtering technology, and refrigeration for foodstuffs (BMWK, 2022).

Despite the benefits of these various development cooperation initiatives, the German government does not have an overall Senegal strategy involving all relevant ministries and implementing organisations, which may lead to missed opportunities to maximise synergies in the bilateral relationship. Moving forward and as part of future negotiations both between "Team Germany", the larger group of donors, and Senegal in the context of a potential JETP, it is important to take stock of these various efforts, engage in improved donor coordination, identify any potential gaps and carefully consider the forms of support available and how best to target them to the above-mentioned priority areas.

4.2.1 De-risking and capacity building of local financial institutions

Despite Senegal's success in attracting private finance for renewable energy projects in the country, in addition to the risk of gas lock-in, there may be other challenges on the horizon. While there is negligible currency exchange risk and the CFA is pegged to the Euro at 1 euro to 656, the European Central Bank's interest rate increases mean that interest rates in Senegal are also going up rapidly (Aboa, 2019). This means that access to capital and de-risking will become even more important for Senegalese financial institutions and renewable energy project developers.

Increased local participation in the development and finance of renewable projects is one important opportunity. Most project developers are international, with international know-how, expertise backed by international investors. With the exception of the Senegalese Sovereign Wealth Fund (FONSIS) and some other Senegalese equity investors, local financial institutions do not yet play a significant role in financing domestic projects to support the energy transition. Even in the case of FONSIS and other local investors, they are minority shareowners and investors playing a relatively subordinate role. Local project developers working with local banks would benefit from more experience and awareness of the financial opportunities in developing renewable energy and energy efficiency investment portfolios. Systematic approaches such as the UNDP "Derisking Renewable Energy Investment" (DREI) programme has the potential to help address this awareness, capacity, and financing gap.

While the Central Bank of West African States (BCEAO) is a member of the Network for Greening the Financial System[10] this has not yet led to a mainstreaming of investment strategies in local financial institutions and a corresponding growth in local renewable lending and investment. Similarly the West African Development Bank (BOAD) has financed renewable projects in Togo, Guinée Bissau, and Côte d'Ivoire, it has only participated in the financing of one mini-grid programme in Senegal (BOAD, 2023). African Development Bank has played an important role in transmission and distribution expansion – including for rural electrification and the connection of hydro-electric dams, but its Senegalese project portfolio is fossil fuel focused (coal, HFO, and diesel) and it has not played a leading role in Senegalese on grid renewable development (AfDB, 2023).

10 https://www.ngfs.net/en/about-us/membership

05

Hydrogen production in the medium to long term

The potential of production and use of green hydrogen has recently emerged into international cooperation discussions as a future alternative to fossil fuels for both domestic needs and international markets. Green hydrogen is expected to have important applications in fertilisers, certain heavy industries such as steel production, long distance transportation (aviation and shipping) through “Power to Liquids” (PtL), and potentially power generation for long dark doldrums periods without wind or sun. Given its rich endowment of renewable energy, a growing number of development cooperation institutions have started to propose it as an alternative export revenue source for African countries (Englert et al., 2021; Corporate Value Associates, 2022). Indeed, given its rich endowment of sun and wind, in the medium to long-term, Senegal may have the potential to produce sufficient renewable electricity to produce green hydrogen both for its own needs and for export abroad. Eventually, production of hydrogen in Senegal may represent an alternative to prospective revenues from oil and gas in a world where, given the climate commitments of the international community, global demand for fossil fuels is projected to decline and global demand for green hydrogen to rise.

Although a 2021 World Bank report found insufficient data for Senegal, the report found that neighbouring Mauritania, a country with relatively similar conditions has “promising potential” (Englert et al., 2021). A study commissioned by the European Investment Bank listed Senegal as a country with “areas with suitable conditions to develop systems of cheap green H_2 generation” (Corporate Value Associates, 2022). Lekela Power BV, owner of the Senegalese Taiba N’Diaye wind park has already announced that is exploring hydrogen production opportunities in Africa (Sguazzin, 2022).

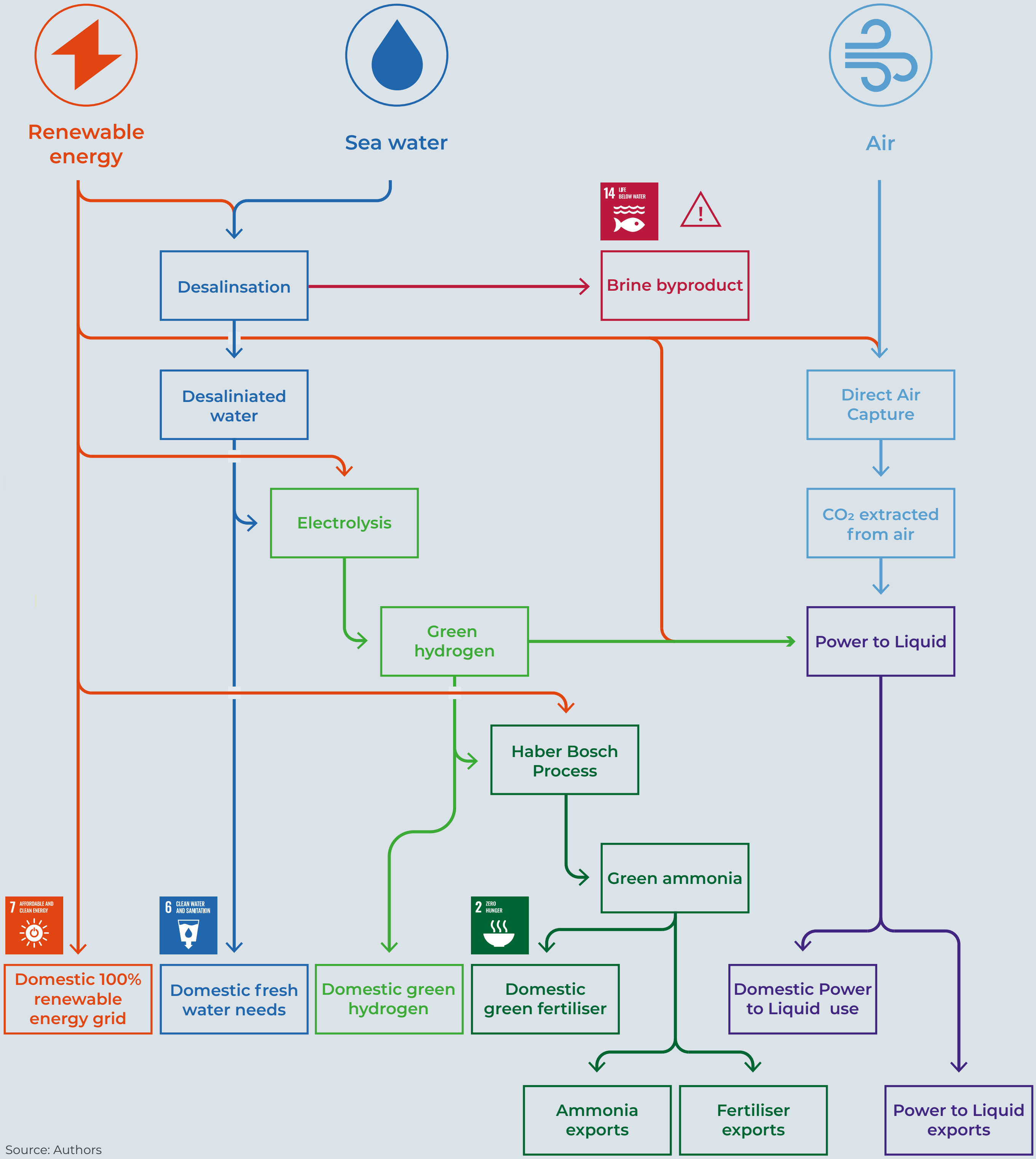
However, the production and use of green hydrogen faces several important challenges along the value chain **(see → Figure 7)**.

Green hydrogen production requires significant investment in renewable energy, freshwater resources and other infrastructure, including electrolysers and storage facilities. Hydrogen is a highly flammable gas that requires special handling and transportation infrastructure. It also needs to be stored at high pressure or low temperatures, which can be costly and energy intensive. Metal embrittlement, where hydrogen degrades certain metals often used for gas transport is a further challenge. Given the infrastructure needs and the necessity for investment in renewables there are other steps that must be taken on the way before Senegal can consider green hydrogen export.

Senegal does not yet have universal energy access and until it does, it is a highly questionable proposition to divert renewable energy produced for hydrogen exports (Morgen et al., 2022; Villagrasa, 2022). Even when universal energy access (SDG 7) in the country is reached, keeping up with energy demand given the

Figure 7
Green hydrogen and the associated value chain

● Renewable energy ● Sea water ● Air ● Negative byproducts ● Green hydrogen production
● Green fertiliser production ● Power to Liquid production



Source: Authors

growing population, economic growth including a growing industrial sector will already require significant and continued investments in scaled up electricity generation.

In order for hydrogen to be considered green, it must be produced with 100% renewable energy. According to the Öko-Institut, hydrogen produced from electrolysis only has a climate benefit when the renewable share of electricity production is over 70% (Heinemann and Kasten, 2019). As mentioned, Senegal is currently highly dependent on fossil fuels for electricity production. With the discovery of oil and gas reserves as well as the government's "Gas to Power Strategy", while the GHG intensity of electricity in Senegal may decline, it is far from being 100% renewable. At the same time, depending on the flexibility of the fossil fuel contribution to the Senegalese electricity mix in the medium term, there may be times of the day when the grid approaches 100% renewable electricity, and there is excess renewable energy produced beyond what is being demanded at that time. At such times, in a progressively decarbonising electricity system, such electricity should first be stored via batteries or through other options before renewable energy plants are curtailed – or restricted from feeding into the electricity grid. Once this starts to occur on a regular basis, it could make sense for Senegal to produce hydrogen with such "excess" renewable energy.

Another limiting factor however is the availability of freshwater. To generate green hydrogen, renewable energy must be used to split water molecules through electrolysis. Despite some ground water resources and some freshwater sources on the Senegal and Gambia rivers, Senegal is a relatively arid country and is facing increasing scarcity in the face of climate change (Tomalka et al., 2022). Hydrogen production should not pose a competition for growing domestic demand for farming, industrial, commercial, and residential use – and ensuring that Senegal achieves SDG 6 – clean water and sanitation for all. Demand for fresh water in the major population centres of Dakar, Thies, and Mbour are expected to double by 2035 (Ollivier, 2022) and Senegal has already started to resort to desalinisation of sea water to meet its freshwater needs, even without hydrogen production. Hydrogen cannot be produced directly from sea water because the salt content of sea water poses problems for electrolysers meaning that it must be desalinised first. Desalinisation of sea water itself is extremely energy intensive and although generally this is not considered by the definition of "green hydrogen" – in order for it to be truly green, the desalinisation of sea water for electrolysis must similarly be carried out with 100% renewable energy. At the same time, desalinisation plants may be built to meet both local freshwater needs and hydrogen production (Morgen et al., 2022).

Large scale desalinisation plants however produce a brine by-product with concentrated salinity and other minerals that have negative repercussions on marine ecosystems. This is a particular challenge for local Senegalese fish habitats on which local fishing industries – a major employer in Senegal – are dependent (Ollivier, 2022). Addressing and mitigating these negative impacts both for drinking water as well as for future hydrogen production are particularly important to the achievement of SDG 14 to “conserve and sustainably use the oceans, seas and marine resources for sustainable development”.

When overcoming the above challenges, Senegal could eventually become a hydrogen producer for both domestic needs and for export. With regard to exports, another challenge may be whether Senegal has a comparative advantage and can compete in international hydrogen markets against other countries including Morocco, Namibia, South Africa, or its neighbour Mauritania. The future international demand for green hydrogen is relatively uncertain as is the pace of potential future growth. The high energy losses involved in the production, liquification and transport of hydrogen, it makes sense to electrify all sectors of the economy possible and the pace of growth for international hydrogen demand is related to both the ambition of international climate targets and the technological pathway that countries choose to take (Liebreich, 2020). Morocco and Mauritania’s proximity to Europe mean that they may have a comparative advantage with regard to transporting green hydrogen to Europe (Morgen et al., 2022). South Africa already has a number of green hydrogen projects in various stages of development which may give it a head start (IEA, 2023a). Kenya, South Africa, Namibia, Egypt, Morocco and Mauritania joined together to from an “African Green Hydrogen Alliance” (Climate Champions, 2022). Comparatively the Senegalese has not shown a great deal of interest and is currently more focused on eminent gas exports which in of itself may put the country at an early disadvantage.

While Senegal may have the potential to produce green hydrogen or green hydrogen-based fuels in the medium to long term, such challenges must be addressed early. Pilot programs and support for a future hydrogen strategy could help address challenges before they have large scale negative sustainable development impacts.

06 Conclusion and recommendations

Senegal has vast renewable resources

Senegal has vast renewable resources at its disposal – particularly solar and wind. These have the potential to play the leading role in achieving the country's universal energy access and sustainable development goals on the way to becoming an emerging economy by 2035. The abundance of these resources in Senegal are not only relevant for Senegal but can also play an important role providing the whole region with clean, reliable and affordable energy through the West African Power Pool. Taking full advantage of these resources has the potential to enable economic growth, reduce greenhouse gas emissions, and improve energy security in Senegal and the wider West African region.

Major progress already been made in renewable development

Today, Senegal has already managed to make major progress in reducing the chronic power cuts that plagued the country and has become a leader for renewable energy. It is host to the largest wind farm in West Africa, has a growing number of utility scale PV plants, and in 2022 had already overachieved a number of the renewable targets set in its NDC targeted for 2030. This is not only a benefit for the climate, but also for the Senegalese economy more broadly as it is an important demonstration for how renewables can help meet rapidly increasing demand and at the same time reducing expensive fossil fuel imports, primarily heavy fuel oil, which were a major burden on households and businesses alike.

An attractive investment landscape for international investors

Much of this success is attributable to reforms that Senegal has made and its corresponding ability to attract international investment. Where international donors have provided grants for feasibility studies, loans, guarantees, and export credits, domestic and international project developers have been able to attract significant finance from the private sector showing that with the right framework in place, climate finance will flow. Grants and concessional capital and are now best targeted towards continuing to improve the overall policy landscape and de-risking continued private finance mobilisation.

Additional measures needed to sustain renewable growth and avoid locking-in emissions

There are however significant challenges associated with the continued development of renewable energy projects, including the already high penetration of renewables in the grid, which will require further measures for load balancing. Having discovered offshore deposits of oil and gas in 2014-2017, it is tempting to make use of them to balance out the intermittency of renewables – as many countries with existing gas power plants are doing. This however comes with higher GHG emissions and important transition and lock-in risks. These should be carefully weighed against the clean future proof alternatives including: increased energy storage, demand response measures, smart grids, improved transmission and distribution, and more electricity trading with neighbours with complementary renewable resources. These solutions, while increasingly economically competitive with gas back up, may be associated with increased upfront investment costs, for which Senegal will need international support to overcome.

In the medium to long-term these renewable resources may enable Senegal to produce green hydrogen for both domestic use for example fertiliser production and eventually exports. Effective stakeholder engagement and community involvement can ensure that the Senegalese energy transition develops in a way that is socially and environmentally responsible.

Germany can be an important partner for Senegal on its clean development pathway

Germany, together with other international partners, has the opportunity to play a critical role in supporting Senegal to reach universal affordable energy access while simultaneously phasing out HFO, coal, and eventually gas - while phasing in ever more renewables, and avoiding the transition and lock-in risks associated with expanded fossil fuel infrastructure. Germany has a long history of development cooperation with Senegal, including support for renewable energy projects and the development of energy infrastructure. Germany also has an economic interest in promoting a renewable energy transition in Senegal as the German industry has increasingly benefited from its positioning in the growing global market for environmental technology.

We therefore come to the following conclusions:

1

Scale up and de-risk storage and flexible and responsive grids

→ Although battery storage systems are increasingly becoming standard in the planning and development of renewable energy projects in Sub-Saharan Africa in general and in Senegal more specifically, they remain expensive and significantly increase the cost of renewable project development. Replicating and upscaling projects like the current KfW / AfD tendering of a battery storage system near the Diass substation (GTAI Germany Trade & Invest, 2023), will be key to enabling increased renewable investment in Senegal. Grant funding for feasibility studies for the addition of battery storage for the existing utility scale PV plants that do not yet include storage systems, would be an important step further.

→ The development of smart grids and demand response systems would equally enable a larger share of renewables on the grid. While experience with smart responsive grids in Africa is still at relatively early stages, Senegal may be able to learn from the first experiences of Rwanda, Nigeria, and Egypt which have already started smart grid efforts. In the initial stages, this could start with large consumers of electricity such as public buildings and large commercial facilities, before wider deployment to households, which may increasingly play a distributed "prosumer" role in the electricity system.

2

Improve finance and planning for transmission and distribution both in Senegal and the larger West African Power Pool

→ Large investments in transmission grid infrastructure both in Senegal and the larger West African region will be essential to enable increased renewable development in Senegal and neighbouring countries. To complement the ongoing efforts of the US MCC and World Bank in terms of transmission grid improvements, Germany and France on behalf of the JETP IPG, can investigate further opportunities to support such investments.

→ Despite the ambition of the ECOWAS and WAPP policy makers, energy trading between West African countries lags behind its potential and what would be an optimal outcome enabling increased renewable investment in the region. German-Senegalese development cooperation should keep the larger West African context in mind in planning. The hydro and other renewable potential in neighbouring countries notably Guinea, Mali, and the Gambia are key to complementing renewable potential in Senegal. In addition to the GIZ supported program to build the Senegalese Ministry of Petroleum and Energy's capacity with the use of the IRENA System Planning Test (SPLAT) model for Senegal, engagement with other West African Countries can support updating of the 2018 IRENA SPLAT model the wider West African region, as well as other members of the WAPP.

→ International partners can engage with the Senegalese government, Senelec, and mini-grid operators to explore new models for prosumerism that enable mini grid operators to transition to small power producers and distributors when the national grid is extended to rural areas. This can help Senelec see mini-grid operators as partners instead of competitors and address the threat that grid extension poses to mini-grid operators' business models. Critically this can also help address the remaining gap in rural electrification until the main grid is extended.

3

Support ongoing capacity building and reform efforts

→ An overall long-term vision for the decarbonisation of the economy and for existing opportunities in the national, regional, and global transition is important to inform both current local and national policy planning as well as to help set new NDC targets under the UNFCCC. Planned support for Senegalese participation in the Deep Decarbonisation Pathways program can support Senegalese discussions to develop a long-term strategy (LTS), which Senegal has not yet submitted to the UNFCCC. This process should be supported with external modelling and the convening of stakeholder consultations to gain important inputs from civil society, industry, and academia potentially coordinated between the Senegalese government and the GIZ.

→ The BMZ, GIZ, and IRENA support to the MPE for SPLAT modelling will be important to help ministry officials develop capacity to model potential renewable pathways for energy system planning. Here it is important that the assumptions behind the modelled scenarios are constantly updated with the latest information with regard to technological development, benefits from regional trading, current deployment, and costs.

→ Given the danger of locking-in GHG emissions and potential future stranded assets through excessive fossil fuel infrastructure in Senegal, such modelling exercises will serve as an important information basis for investment decisions to minimise emissions and contribute to the objectives of the Paris Agreement and achieve Senegalese energy access and development goals.

4

Support electrification of other sectors of the economy and energy "prosumerism"

→ Development cooperation projects for clean cooking should be expanded to not only look at options for "cleaner" cookstoves or a switch to liquified petroleum gas, but also urgently start promoting electric cooking solutions. This is particularly important for the next phase of GIZ clean cooking projects. Here, Senegalese chefs and electricians are important stakeholders to mobilise.

→ Capacity building programmes can support Senelec to simplify and facilitate "prosumer" models so that households with solar home systems, and mini-grids can also benefit from integration with the larger grid. Senegal already has an existing feed-in-tariff system, but there is a lack of awareness of the programme and there may be other hurdles for grid connections and crediting (Apfel, 2022).

→ The KfW's support for smart meter installation can be combined with smart grid pilot projects to learn and improve on pilot projects in Rwanda, Nigeria, and Egypt. Notably including the charging system being built for Dakar's new electric bus system.

→ Although electric passenger cars are still comparatively expensive, the rapid growth of electric 2-3 wheelers in the Global South provides an opportunity to reduce pollution and promote more climate friendly mobility. Charging options for these vehicles could also be integrated in a smart grid pilot.

5

Support conversion, repurposing, or retirement of the existing fossil fuel fleet

→ Explore legal options to renegotiate Power Purchase Agreements with existing fossil fuel plants. This could be done by offering Senelec legal support to revisit its existing contracts and the development of financing schemes to compensate IPPs. Although exact information on contracts is lacking, it is likely that most if not all PPAs with HFO

IPPs plants do not include provisions for ancillary services, which represents an important barrier to renewable integration as they then cannot effectively complement the variability of solar and wind power. The monetary cost of not buying electricity under existing take or pay PPAs even if there is sufficient renewable generation at a given time is an important economic challenge for the electricity system. The oldest and dirtiest plants should be the focus of PPA renegotiation efforts.

→ Explore near term options to shut down or convert the two existing coal fired power plants. The highly controversial Sendou plant not only exposes Senegal to volatile international coal markets, its necessity is questionable, and is also the source of high local air pollution and has negative repercussions on the local fishing industry (Feiger and Vasudevan, 2021).

6

Take stock of and carry out a strategic evaluation of "Team Germany", "Team Europe", and multilateral initiatives with Senegal

→ In order for Germany to live up to its full potential as a partner to Senegal both in the context of the bilateral relationship and as co-lead for Senegal among the G7 JETP partners, it is important to take stock of these various efforts, engage in improved donor coordination, identify any potential gaps and carefully consider the forms of support available and how best to target them to the above-mentioned priority areas.

→ This requires an understanding of the energy transition challenges and opportunities in Senegal and a comprehensive understanding of ongoing German "Team Germany" initiatives, "Team Europe" initiatives, other donors work as well as the current planning of relevant DFIs including the World Bank, the EIB, and the AfDB.

7

De-risk and build capacity of local project developers and financial institutions

→ Against the background of a rising cost of capital generally as well as specifically for renewable energy and investments in the Senegalese energy transition, local banks would benefit from more experience and awareness of the financial opportunities in developing renewable energy and energy efficiency investment portfolios.

→ A UNDP program "Derisking Renewable Energy Investment" (DREI) has been developed to support understanding of options to de-risk renewable energy projects including for utility scale projects, on-grid rooftops, off-grid mini-grids, and solar home systems (UNDP, 2020). German support enable Senegalese or external consultants to apply the methodology to Senegal not only for renewables, but also for BESS.

→ Twinning and support similar to KfW efforts with other national development banks abroad could help BOAD work with other local financial institutions to gain knowledge and mobilise increased domestic climate finance flows.

8

Develop a future strategy for green hydrogen production, use, and export

→ While Senegal's vast renewable energy resources may eventually lend themselves to green hydrogen in the medium to long term, there are major challenges including the necessary built out of renewable energy, investments in electrolysers, ensuring freshwater availability without compromising marine ecosystems, and overcoming barriers to storage and transport in the context of international competition.

→ Support for early planning to overcome these challenges, develop a vision and mitigate potential negative sustainable development impacts could ensure a smoother pathway for Senegal to become a hydrogen producer.

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