PATHWAYS FOR AFRICA'S ENERGY FUTURE

The 27th UNFCCC Conference of the Parties (COP27) to be held in Africa brings a unique opportunity to lay the foundations for the deployment of renewable energy to address the overlapping energy and environmental challenges now facing the continent.

This report demonstrates that with the right planning and investment, renewable energy can reduce energy costs and increase energy access across Africa, enabling economic development, driving progress, and supporting communities.

The first steps for a flexible renewable grid must be taken this decade to successfully unlock these benefits. While African countries have different contexts and priorities, our modelling of power systems in Nigeria, South Africa and Mozambique demonstrates that renewable energy can provide a reliable and cost-effective alternative to baseload fossil fuels, while increasing energy access.

However, this challenge cannot be taken alone. Developed economies have a responsibility to support Africa's energy transition through financial support to unlock the continent's potential. By providing a window into the future, this report is designed to support Africa's path towards clean affordable power systems and energy access.

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FOREWORD

Last year's 26th Conference of the Parties (COP26) in Glasgow produced landmark commitments as world leaders united to "keep 1.5ºC alive". However, COP26 President Alok Sharma admitted that the 1.5ºC goal "will only survive if we keep our promises and translate commitments into rapid action."

The past year has made that ambition more challenging. The global economy has faced significant supply disruptions which have severely impacted electricity and food prices. In response, countries have prioritised security over climate ambition; having "consigned coal to history" at COP26, the fuel has made a remarkable return this year. These decisions, though temporary to tide over the current crisis, will push the world further off track if left unchecked.

With COP27 upon us, the priority must now be recentring our focus on decarbonisation. Not only should the world reaffirm its support for timely climate action, but also should find ways to accelerate the transition to cleaner sources of energy.

In September 2022, the International Energy Agency's (IEA) Breakthrough Agenda report called for $1 trillion per year to be invested globally in quadrupling renewable energy installation. As energy leaders, it is this level of action and ambition that must be delivered if we are to achieve the 1.5ºC goal.

The low-hanging fruit of global decarbonisation lies in replacing costly, polluting legacy fossil fuel power plants with low-cost renewable energy technologies such as wind and solar. We must seize this moment.

Modelling in an unstable world

In the past year, Russia's invasion of Ukraine has caused seismic global change. Energy prices have increased by as much as 400% in some markets, leading to widespread inflation.

Amid this instability, our Wärtsilä energy experts have conducted a series of power system modelling projects and the conclusion is overwhelming: doubling down on renewable energy systems is the way out of the energy crisis.

For example, we found that Europe can reduce energy costs by $356 billion and increase energy independence by 2030 if it rapidly scales up its renewable and flexible capacity.[1)]

In Southeast Asia, renewable-based power systems backed by grid balancing engines and energy storage can cut the levelised cost of electricity (LCOE) by over 20% when considering likely future carbon taxes.[2)]

However, this is only part of the picture. As the transition picks up speed in developed and emerging countries, a lack of access to capital is stalling traction in developing countries, especially in Africa, where net zero targets are not yet widespread.[3)]

[1)] Compared to the baseline modelling in the IEA's Renewables 2021: Analysis and forecast to 2026 report

[2)] Savings in excess of 20 per cent are calculated when factoring in the IEA's predicted carbon prices, as set out in its World Energy Outlook 2021

[3)] Net Zero Stocktake 2022 report, Net Zero Tracker

Africa on the front line of climate change

Despite contributing less than 3% of the world's energy-related CO2 emissions,[4] African countries are among the hardest hit by climate change, with the continent reportedly losing 5-15% of its per capita economic growth due to global heating,[5] and reversing its push to improve energy access, with 4% more people living without electricity in 2021 than in 2019.[6]

That's why the location of this year's COP – Sharm El Sheikh, Egypt – is key. By drawing attention to the challenges of decarbonisation and energy access in the Global South, we have an opportunity to stimulate action to address these points and unlock affordable, reliable and sustainable energy across the continent.

The dawn of a renewable energy age

Despite the economic challenges that Africa and other developing regions face, the energy transition holds unprecedented promise for development, energy independence, and prosperity. To kickstart this new age, the foundations for sustainable and reliable power systems must be built now. Africa is home to 60% of the best solar resources globally and solar PV is already the cheapest source of power in many regions, yet the continent has only 1% of the world's installed solar PV capacity.[7] Unlocking this resource will have a transformative impact on millions of Africans – improving lives and transforming communities.

[4] Africa Energy Outlook 2022: World Energy Outlook Special Report, IEA

[5] 'Africa losing up to 15% of GDP growth to climate change, African Development Bank says', Reuters, 13 September 2022

[6] Africa Energy Outlook 2022: World Energy Outlook Special Report, IEA

[7] Ibid.

Breaking the green finance deadlock

Access to capital for developing countries is a vast challenge. Achieving the energy and climate goals of African countries means more than doubling energy investment this decade, to over $190 billion each year from 2026 to 2030, with two-thirds going to clean energy.[8] Wealthy nations still have not delivered on the promise made in 2009 to deliver $100 billion a year in climate finance from 2020,[9] and this must be urgently addressed to fully unlock Africa's renewable potential.

Laying the foundations for decarbonisation

Increasing energy access and laying the foundations for cheap, sustainable electricity demands a multi-year transformation. Key energy challenges, such as low energy access, volatile fuel costs, lack of evacuation infrastructure and poor quality of power are putting power systems under increasing stress. For all these challenges, the transition to renewable energy – supported by flexibility – holds the key to Africa's economic development. Flexibility, from balancing engines and demand-side assets, such as energy storage, is the crucial technological fix to 'level-up' renewables into the dominant source of power.

To simulate what this looks like, we have modelled the immediate next steps for three key African markets – Nigeria, South Africa and Mozambique – to lay the foundations for decarbonisation and electrification at the lowest cost and risk, while maximising reliability and affordability. By building a stable base in the next decade that will be ready for a massive addition of renewables, African countries can leapfrog to renewable energy systems and avoid the costly carbon-intensive mistakes made by the Global North.

This report gives African leaders and investors a roadmap to build power systems of the future. If policymakers in the Global South attending COP27 set ambitious decarbonisation targets, and are supported by the Global North, it is possible for renewable energy to power economic development and improve energy access across the continent.

Håkan Agnevall
President and CEO, Wärtsilä

[8] Ibid.

[9] Sedláček, S., and Wettengel, J., 'Wealthy nations' $100bn climate finance pledge delayed to 2023', Clean Energy Wire, 25 October 2021

PIONEERING NIGERIA'S NET ZERO TRANSITION THROUGH RENEWABLE ENERGY

Nigeria is quickly emerging as an African powerhouse, with the continent's largest economy growing steadily over the past two decades.[10] However, the country's power system continues to face major challenges, with an estimated 60-70 million people left without access to grid power.

While Nigeria's carbon emissions remain comparatively low, inflexible technologies that run on fossil fuels dominate its power system. A lack of flexibility through insufficient gas distribution infrastructure and a poor transmission grid has hampered progress and led to blackouts and fuel shortages. Despite major solar and wind potential, renewable energy represents just 5% of total power generation.

To combat these challenges, Nigeria recently launched its Energy Transition Plan,[11] setting out proposals to merge its two key priorities – economic development and climate action – to achieve a true 'just transition'. The plan includes net zero by 2060 and the '30-30-30' target: 30 GW of grid-connected capacity with at least 30% of renewable capacity by 2030.

But Nigeria's discovery of large gas reserves has raised concerns that it may renew its reliance on fossil fuels. The country is at a crossroads: lock in large amounts of baseload gas infrastructure (future stranded assets), or use its domestic gas as a bridging fuel?

We modelled Nigeria's power system, and our analysis shows that by adding the right mix of technologies (incl. renewables, balancing technologies such as energy storage and engine power plants capable of running on sustainable fuels, and carbon capture) the country can reliably meet expected demand between now and 2060, while also meeting the country's targets.

Step 1

2023–2030

Meeting '30-30-30' and building the foundations for 2060

To reach its ambitious renewable targets, Nigeria must invest in around 2.7 GW of wind and 5 GW of solar power, which would halve the electricity shortage by 2030.

Renewables would be optimally coupled with flexible capacity, provided by around 12.2 GW of grid balancing engines, plus around 2.5 GW of gas turbine capacity. While the system's emissions temporarily increase to 90 million tonnes to meet rising energy demand, they progressively drop to zero by 2060.

Step 2

2031–2040

Providing universal electricity access

Even larger quantities of new capacity are added in the 2030s, with 110 GW of solar and 14 GW of wind capacity added to the system, enabling electricity shortage to drop significantly, and for universal electricity access to be achieved by 2040.

Around 21 GW of grid balancing engine power plants (of which 5.3 GW are fitted with carbon capture technology) should be added by 2040, plus around 24 GW of energy storage capacity.

[10] World Economic Outlook Database: April 2022, International Monetary Fund

[11] Energy Transition Plan, Nigerian Government

Step 3

2041–2060

Net zero power system

In the final stage of the transition, the following capacity additions are implemented, so Nigeria's power system can reach net zero by 2060, with a total installed capacity of 1,200 GW, including:

- 616 GW of solar and 62 GW of wind power
- 259 GW of energy storage

The modelling also shows it will be commercially feasible to add 51 GW of electrolysers by 2060, enabling Nigeria to convert excess renewable power into green hydrogen. Existing grid-balancing power plants could then be converted to run on green hydrogen to create a zero-carbon power system.

Building flexibility into plans

Our modelling demonstrates that a cost-optimal, reliable and rapid energy transition is within reach. Significantly, in the modelled system the costs of electricity production plummet from nearly $250 per MWh now to $102 per MWh by 2030, reaching a low of $63 per MWh by 2060, a 74% decrease.

To effectively balance the influx of intermittent renewable power, flexible balancing engines are required to cope with regular and quick starts and stops. Their modularity allows them to be easily constructed and deployed as needed. They also enable power companies to hedge against fuel supply risk, and can be operated with minimal water, a crucial advantage in Nigeria.

Financing a renewable future

If Nigeria can improve its power transmission infrastructure, develop a sound policy framework, and deploy a data-driven plan based on renewable energy and flexibility, it can take a giant step towards universal access to affordable, reliable and fully decarbonised electricity.

Delivering this ambitious growth and the benefit of a decarbonised system requires international support, a total investment of $68 billion is needed by 2032. We sincerely hope that our modelling helps Nigeria both in its planning for a power sector-led transition to net zero emissions, as well as in securing the finance to realise its ambitious commitment.

Based on our modelling, renewable energy has a crucial role to play in supporting Nigeria to lift 100 million people out of poverty by 2030, bring energy access to the country's population and shift to cleaner energy sources.[12)]

Wale Yusuff
Business Development Manager, Wärtsilä

[12)] Ibid.

SOUTH AFRICA'S 'JUST ENERGY TRANSITION' CAN SET A GLOBAL EXAMPLE

South Africa is in a state of transition. Africa's third-largest economy is built on coal,[13] which provides more than 80% of its energy needs. However, with an estimated 1 GW of baseload coal likely to be removed annually over the next 30 years,[14] South Africa is now facing an acute challenge which is exacerbating ongoing blackouts.

Simultaneously, the effects of climate change are already being felt. Like many other countries in Sub-Saharan Africa, South Africa faces extreme droughts and floods. As COP27 arrives in Africa, the global focus on climate change and the coal phase-out has never been more urgent.

South Africa has already taken positive steps towards decarbonisation. In 2020, it announced plans to reach net zero by 2050, touting the importance of renewable sources such as solar and wind. At COP26, it joined the world's first 'Just Energy Transition Partnership' – the deal, announced alongside the US, UK and European Union, unlocks $8.2 billion of funding to support the country's transition away from coal.

South Africa's ability to deal with the overlapping energy and environmental challenges hinges on replacing coal power. Recently, South Africa's President said that $38 billion was needed in external funding to support this transition. With climate finance set to be a central issue at COP27, South Africa can seize the initiative by doubling down on its renewable commitment.

Renewable energy and gas can provide the solution to South Africa's overlapping challenges

To assess the adequacy of South Africa's proposed energy crisis mitigation measures and understand how it can successfully transition to renewable energy, we modelled the following scenarios over the next decade to 2032.

The Planned World scenario: considers a system where 16 announced crisis mitigation measures from South Africa are realised to their full potential and in line with their timeframes.

The Reality Check scenario: considers how each of those measures could either be delayed and/or reduced in capacity based on historical experience and/or anticipated behaviours.

The Perfect World scenario: considers the optimal capacity mix without imposing any of the known new capacity addition opportunities and/or restrictions.

The modelling reveals that the Planned World scenario yields virtually no load shedding over the next few years, enabling the country to address its present energy crisis. However, when considering the potential real-world delays in the Reality Check scenario, it is more likely that a fair portion of these measures will not be fully realised. This potentially leaves South Africa in a worse situation than present, with even higher levels of load shedding.

[13] Ibid.

[14] Integrated Report 2021: Towards a New Energy Future, Eskom

The solution, as demonstrated in the Perfect World scenario, is to add as much renewable energy into the power system as possible. According to the modelling,

> an additional 40 GW of wind and solar PV by 2032 can help to meet future energy demand, enabling a 17% reduction in emissions and a cumulative system saving of $26 billion versus the Reality Check scenario by 2032.

Crucially, the model underlines that this must be supported by flexibility in the form of balancing engines and energy storage. While 8 GW of energy storage can provide short-term flexibility requirements, 10 GW of balancing engines will play a far broader role in supporting the power system by providing a significant amount of both energy and operational reserves to the grid. Energy capacity factors can fluctuate between 1-30% in 'ideal' circumstances but grow to 60% when 'reality' creeps in. Similarly, up to 80% reserve capacity factors are called upon from gas power.

The pathway to a perfect world

South Africa has the potential to become a global economic force in renewable energy. Based on our modelling, renewable energy can solve South Africa's overlapping challenges of energy security and decarbonisation. Crucially, a renewable-led system, as mapped out in the Perfect World scenario, also unlocks significant cost savings compared to the Planned World scenario.

Flexible gas is the enabler of this transition, allowing for renewables to be integrated into the power system by adequately providing fast response to meet fluctuations in supply due to intermittency. These balancing engines can also enable the future transition to sustainable fuels, helping bridge the gap to a net zero renewable power system.

To achieve this, the next revision of the Integrated Resource Plan (IRP) should provide further key details on the characterisation of such flexibility (such as preferred technology, reserve requirements, and capacity factors) and that upcoming gas Independent Power Producer (IPP) procurements should adequately value flexibility as part of their evaluation criteria.

The Perfect World scenario requires significant ambition from South African energy leaders, and significant financial support from developed countries. The total investment cost of the next decade stands at $46 billion, and South African energy leaders have already underlined the urgent need for this support.

As COP27 approaches, South Africa can send a clear signal of intent by committing to renewable and flexible gas, catalysing internal action and external support. By aligning with our report's recommendations, South Africa can demonstrate its international leadership in the transition from a coal to a renewables-based economy.

Wayne Glossop
Business Development Manager, Wärtsilä

ENERGY FOR CHANGE IN MOZAMBIQUE

Mozambique has the largest power generation potential in Southern Africa, but only 38.6% of the population had access to electricity in 2021.[15] Resolving this paradox is central to Mozambique's economic development over the next decade.

As COP takes place in Africa for the first time, global attention is turning to how developing countries can use renewable energy to transform their power systems. Mozambique can set an example by developing a flexible, renewable power system that increases energy access and enables greater prosperity for the country. However, it cannot do this alone. Significant investment in new technologies requires financial support from developed countries.

Mozambique can reap the rewards of a sustainable power system. With the cost of solar PV and wind generation plummeting over the past decade, our modelling shows that renewables – supported by flexible balancing engines and energy storage – can now unlock cheaper, cleaner energy and greater energy access in Mozambique. On the other hand, a fossil fuel pathway could embed emissions for longer, increasing energy bills and harming wider energy access.

A window into Mozambique's energy future

To provide insight into Mozambique's energy future over the next decade, we compared a low renewable scenario with a high renewable scenario to show the most cost-effective pathway to develop Mozambique's power system from 2022 to 2032.

Positive steps

In the low renewable scenario, only 1 GW of solar and wind capacity is added by 2032. This cap is based on the average historical renewable energy capacity additions and corresponds to the prevailing view of Mozambique's main utility Electricidade de Moçambique (EDM). Without the use of further renewables, 1.5 GW of new baseload gas and 230 MW of new flexible gas projects are required from 2025 to 2032 to meet demand. To support this system, 23 MW of new energy storage capacity is needed to store and shift the variable renewable energy generated.

A giant leap

In the high renewable scenario, a maximum of 3 GW of renewable capacity is added by 2032. The system requires significantly more flexibility to manage the influx of intermittent renewables, including 205 MW of new energy storage capacity and 1 GW of balancing engine capacity.

A renewable pathway can unlock cheaper energy

By increasing the share of low-cost renewable energy, our analysis shows that Mozambique can affordably and sustainably meet electricity demand over the next decade,

> Mozambique can affordably and sustainably meet electricity demand over the next decade, reducing carbon emissions by five million tonnes and generating savings of $84 million.

[15] Solar energy is the fastest growing source of electricity in Mozambique, Profile, 05 October 2022

By adding significant amounts of new renewable energy, Mozambique can lay the foundations for growth and reliably meet electricity demand by the 2030s, dramatically increasing energy access and transforming lives and livelihoods at a low cost. The significant flexibility in the high renewable scenario ensures that Mozambique can meet energy demand through a modular approach without the risk of stranded assets. This is because balancing engines can be built to exact requirements, as and when needed, and converted to run with sustainable fuels such as hydrogen.

The time is now for Mozambique to kickstart its renewable energy journey

By taking the higher renewable path, Mozambique will not only reduce energy costs and avoid locking in baseload fossil fuels but will lay the foundations for more secure, accessible and clean electricity for its entire population.

Wärtsilä is perfectly positioned to support Mozambique in planning and implementing an updated Integrated Resource Plan that would guide the delivery of distributed renewable power generation and flexibility close to areas of major demand. Through this combination of detailed planning and ambitious delivery, Mozambique can leapfrog more developed nations to increase access to clean, reliable energy.

However, our modelling demonstrates that, to achieve the high renewable scenario, the total system investment over the next decade must be $5.3 billion. Financial support from developed countries is therefore crucial to support the renewable transition.

As COP27 arrives in Africa, Mozambique serves as the perfect example of how we can tackle the joint issues of energy access and decarbonisation through a combined approach of bold internal planning and supportive external financing. Now is the time.

Wallace Manyara
Business Development Manager, Wärtsilä

PATHWAYS FOR CLEAN ENERGY ACCESS

It is clear in the modelling of power systems in Nigeria, South Africa and Mozambique that these countries – and all African nations – can find an economically viable path to full electrification while helping to address the climate challenges.

Despite the diversity of the African countries, the ingredients of the energy transition are similiar for every nation. Renewable energy, supported by flexible balancing capacity, is the most effective way to replace coal and diesel generation, reduce energy costs, increase energy access, and improve reliability while laying the foundations for net zero energy systems.

Additionally, due to the large quantities of excess power inherently produced by renewable systems, issues such as load shedding would be a thing of the past. Importantly, gas will continue to play a key role in African power systems, although its use will shift from baseload to bridging fuel.

Achieving clean energy access

Universal access to clean energy would be transformative for Africa, economically, politically and socially – changing lives for the better and equipping countries to better respond to the climate emergency.

That future is within reach if Africa transitions rapidly to the clean energy systems of the future. For example, the modelling highlights that renewable energy coupled with balancing technologies can reliably meet demand in the future. Alongside appropriate grid infrastructure in place to support full electrification, close to 100 million more people could receive access to electricity by 2032, through the optimal decarbonisation pathways set out in this report:

- Nigeria: improved energy access for 74 million people
- South Africa: improved energy access for 9 million people
- Mozambique: improved energy access for 21 million people

Finance is the key to unlocking Africa's clean energy future

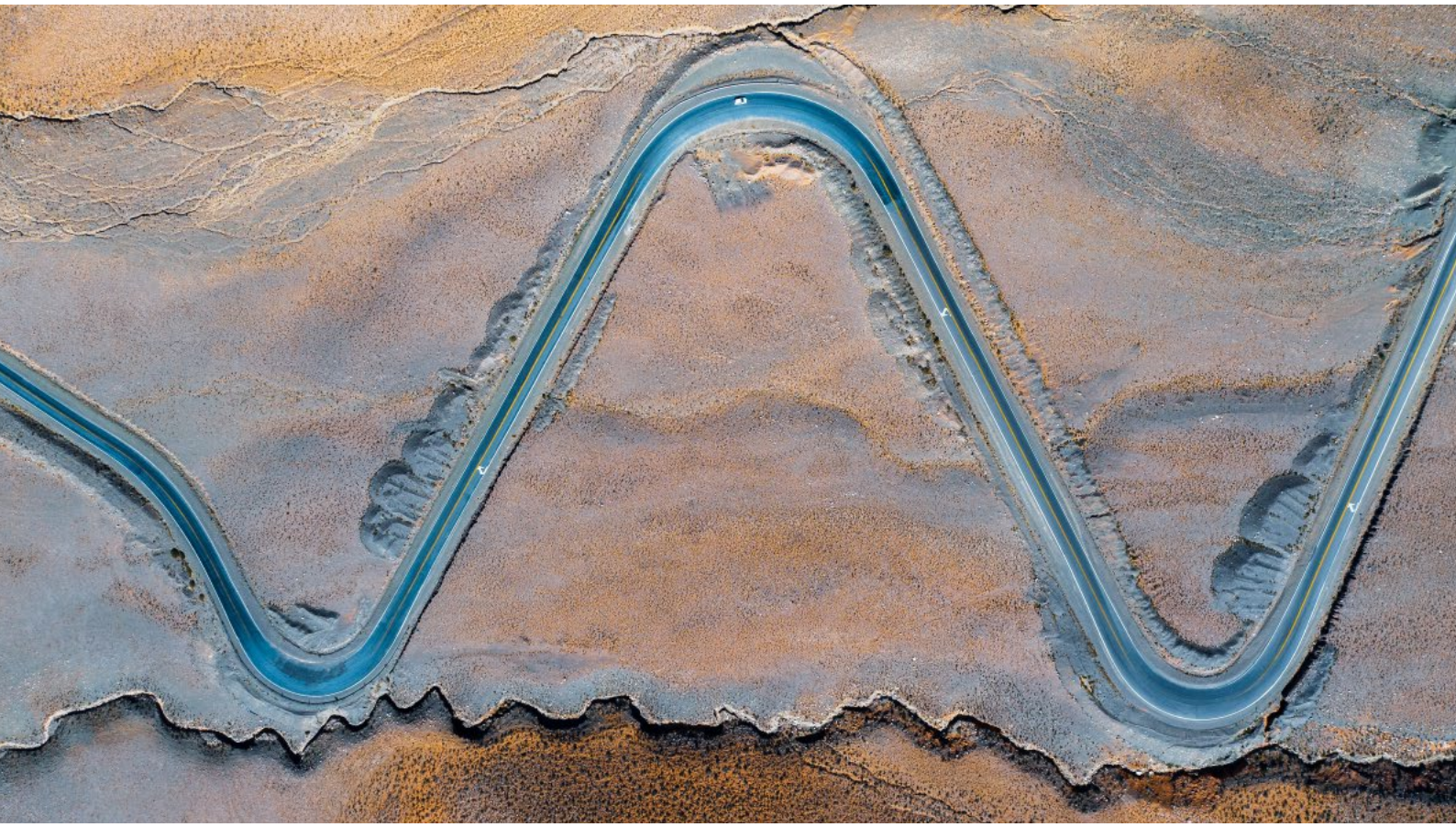
To build the modelled power systems in these three countries, around $119 billion is needed over the next decade. On a macro scale, achieving Africa's clean energy goals requires over $126 billion each year from 2026 to 2030.[16] In aggregate to date, 48 African countries have requested over $1,200 billion of international financial support by 2030 to implement their Nationally Determined Contributions (NDCs).

First and foremost, high-income counties must deliver on their responsibilities to fund Africa's transition. African countries can help to stimulate investments by setting out clear strategies to build well-functioning flexible renewable grids, showcasing the new opportunities those conditions create, such as green hydrogen production. Regulatory reform is also needed to place a value on flexibility and encourage the market.

[16] Africa Energy Outlook 2022: World Energy Outlook Special Report, IEA

The key is to start now. If power producers and policymakers can work together to lock in plans to front-load investment on renewable capacity – and ratchet up over time – they will see that, as renewable capacity grows, the running hours of inflexible, legacy power plants decreases. Momentum is key to justifying further investment, giving confidence that net zero targets can be set and met in Africa.

By laying this foundation, African countries can use renewable energy, supported by flexible balancing technologies, as a springboard for economic development, reducing energy costs and leapfrogging developed countries where inflexible legacy fossil fuel technologies used for baseload are locked into the system. With COP27 around the corner, now is the time to catalyse action. By bringing leaders together we can fully understand the 'win-win' opportunity available by levelling up Africa's vast renewable energy capacity into the continent's dominant power source.



METHODOLOGY

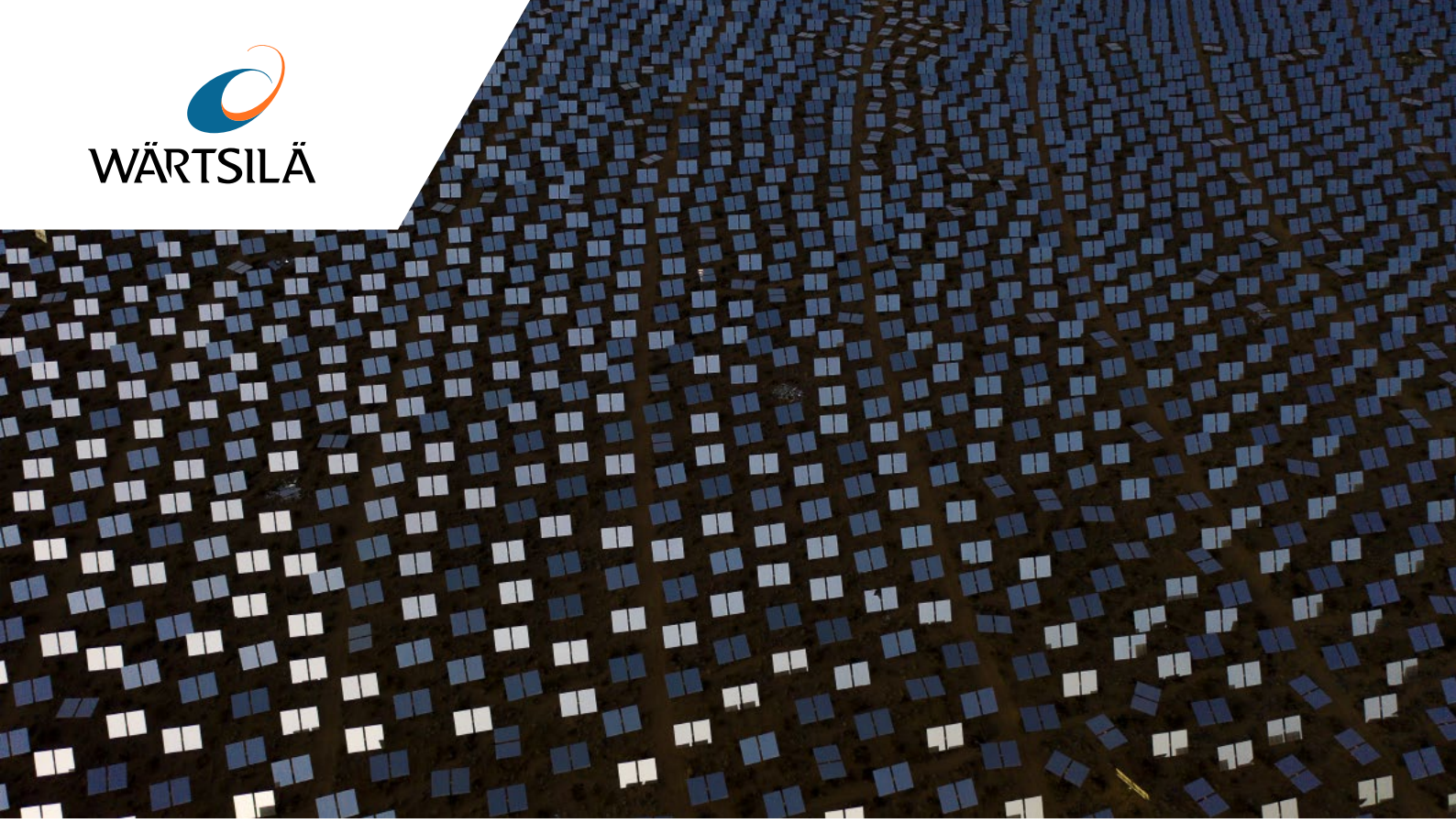
Wärtsilä has examined how an optimal power system could evolve in Nigeria, South Africa and Mozambique given the changes in technology, availability of domestic fuel and growing electricity demand across different scenarios from 2022 to 2032.

Wärtsilä used PLEXOS, a leading power market simulation software, for the report's power system modelling. The modelling defined a cost-optimal energy system structure and operation mode for a given set of constraints in each region: power demand; available generation and storage and balancing technologies; financial and technical assumptions; and limits on the installed capacity for all applied technologies.

The modelling is based on linear optimisation and performed on an hourly resolution for the planning horizon. The system-level cost is the estimated sum of the annualised capital expenditures including the cost of capital, operational expenditures (including ramping costs) and fuel costs for all available technologies.

The scenarios modelled by Wärtsilä are designed to enable policymakers to make informed long-term decisions on building a cleaner and more modern power system for the country. Wärtsilä has modelled over 190 power systems across the world and regularly advises customers and policymakers on optimal future-proof power systems.

Unless otherwise specified, $ refers to USD throughout.



ABOUT WÄRTSILÄ

Wärtsilä leads the transition towards a 100% renewable energy future. We help our customers to decarbonise by developing market-leading technologies. These cover future-fuel enabled balancing power plants, hybrid solutions, and energy storage and optimisation technology, including the GEMS energy management platform. Wärtsilä Energy's lifecycle services are designed to increase efficiency, promote reliability and guarantee operational performance. Our portfolio comprises 76 GW of power plant capacity and more than 110 energy storage systems delivered to 180 countries around the world.

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