06 November 2015

LEVELISED COST OF ELECTRICITY

DFID priority countries

Bloomberg NEW ENERGY FINANCE

Possible Policy Conclusions: DFID

The detailed country level LCOE estimates undertaken by Bloomberg New Energy Finance in this report have been created based on a set of real world data and assumptions that reflect project costs by technology at a single point in time.

The analysis should help identify areas where country governments and donors may (or may not) need to focus interventions designed to foster greater private investment in electricity generation and ongoing economic growth.

Recognising the limitations of data availability for many of the countries considered, the report infers a number of possible high level **policy conclusions** for donor organisations, national governments and the private sector:

- Countries should seek a mix of generation to increase electricity independence and security of supply.
- Despite dramatic reductions in the costs of wind and solar technology, support is still needed to improve renewables competitiveness in many markets. Financing, operation and capital costs can be reduced through ongoing deployment and building local experience. In particular:
  - Finance costs can be reduced by educating local banks and investors to overcome perceived technology risk and build confidence. Partnerships may be effective.
  - Capital costs can be reduced by supporting continued development of supply chains for new technologies.
  - Make use of reverse auctions or other competitive tendering to ensure efficient price discovery and market development.
- Government and the private sector should be helped to realise the potential of small hydro, where resources are available.
- Government or donor finance should not be necessary for gas-fired power generation in most countries, but there may be scope for donor finance where electricity supply is significantly constrained (although the fundamental barriers to investment should be considered).

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INTRODUCTION

PROJECT DESCRIPTION

The UK Department for International Development (DFID) has commissioned Bloomberg New Energy Finance (BNEF) to provide information on the full lifecycle cost of a range of utility-scale electricity generation technologies to help it support developing countries in determining the most sustainable and affordable energy pathways for growth, improve energy access, highlight where and how government/donor support may be appropriately deployed to support more diverse generation, and to give private sector investors visibility of potential future opportunities. To meet this need, BNEF has examined levelised costs of electricity (LCOE) for major generation technologies across DFID's 28 priority countries which are:

Middle East: Afghanistan, Occupied Palestinian Territories, Yemen.

Africa: Democratic Republic of Congo, Ethiopia, Ghana, Liberia, Malawi, Mozambique, Kenya, Nigeria, Rwanda, Sierra Leone, Somalia, Sudan, South Africa, South Sudan, Tanzania, Uganda, Zambia, Zimbabwe.

Asia: Bangladesh, Kyrgyzstan, Nepal, Tajikistan, Pakistan, Burma, India.

LCOE estimates are a good way to track and compare the financial cost competitiveness of different power generation technologies, taking into account the full project life-cycle from development to financing to construction and then operation.

Although we have calculated LCOEs for all significant comparable generation technologies there are instances where a technology is considered to be unfeasible in a particular country. This means we only calculate coal, gas and geothermal LCOEs for countries that either have installed capacity, or if not, have reserves that either are or could be utilised in the future. Due to the low deployment rate as well as the high cost of the technology solar thermal electric LCOEs have only been calculated in the two countries covered in this report where we currently see commissioned capacity (South Africa and India). Wind, solar, small hydro and biomass technologies are deemed deployable in all countries so have full coverage.

LCOE TECHNOLOGY COVERAGE BY COUNTRY I

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The set of technologies covered by country is outlined in the table below. This is the result of our assessment of resource availability and energy infrastructure for each of DFID's target countries. See Appendix 2 for reasons for inclusion/exclusion of technologies.

Country	CCGT	Coal	Biomass Incineration	Geothermal Binary	Solar Thermal	Solar PV	Wind Onshore	Small Hydro
Afghanistan	✓	✓	✓			✓	✓	✓
Bangladesh	✓	✓	✓			✓	✓	✓
Burma	✓	✓	✓	✓		✓	✓	✓
DRC	✓	✓	✓			✓	✓	✓
Ethiopia	✓		✓	✓		✓	✓	✓
Ghana	✓		✓	✓		✓	✓	✓
India	✓	✓	✓	✓	✓	✓	✓	✓
Kenya	✓		✓	✓		✓	✓	✓
Kyrgyzstan	✓	✓	✓			✓	✓	✓
Liberia			✓			✓	✓	✓
Malawi		✓	✓	✓		✓	✓	✓
Mozambique	✓	✓	✓	✓		✓	✓	✓
Nepal		✓	✓			✓	✓	✓
Nigeria	✓	✓	✓			✓	✓	✓

LCOE TECHNOLOGY COVERAGE BY COUNTRY II

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The set of technologies covered by country is outlined in the table below. This is the result of our assessment of resource availability and energy infrastructure for each of DFID's target countries. See Appendix 2 for reasons for inclusion/exclusion of technologies.

Country	CCGT	Coal	Biomass Incineration	Geothermal Binary	Solar Thermal	Solar PV	Wind Onshore	Small Hydro
Palestine	✓		✓			✓	✓	✓
Pakistan	✓	✓	✓	✓		✓	✓	✓
Rwanda	✓		✓			✓	✓	✓
Sierra Leone			✓			✓	✓	✓
Somalia	✓		✓			✓	✓	✓
South Africa	✓	✓	✓	✓	✓	✓	✓	✓
South Sudan	✓		✓			✓	✓	✓
Sudan	✓		✓			✓	✓	✓
Tajikistan	✓	✓	✓			✓	✓	✓
Tanzania	✓	✓	✓	✓		✓	✓	✓
Uganda	✓		✓			✓	✓	✓
Yemen	✓		✓			✓	✓	✓
Zambia		✓	✓	✓		✓	✓	✓
Zimbabwe		✓	✓			✓	✓	✓

WHAT IS AN LCOE?

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LCOE: DEFINITION AND INTERPRETATION I

LCOE Definition

The Bloomberg New Energy Finance definition of levelised cost of electricity (LCOE) is the long-term off-take price needed to achieve a required equity hurdle rate for a new power generation project. The Bloomberg New Energy Finance LCOE model is based on a pro-forma project finance schedule which runs through the full accounting life of the project, based on a set of project inputs. This allows us to capture the impact of the timing of cash flows, development and construction costs, multiple stages of financing, interest and tax implications of long-term debt instruments and depreciation, among other drivers. The LCOEs shown in this report reflect the cost of building (capital costs), operation and maintenance and financing new electricity generation technologies.

$$\text{LCOE} = \frac{\text{Total life cycle costs}}{\text{Total lifetime energy production}}$$

- **Capital Costs:** include equipment costs (eg. turbines, towers, modules), non-equipment construction costs (eg. foundations, facilities, security, on site electrical), and pre-constructions costs (eg. permitting, application, siting and land).
- **Operating and Maintenance Costs:** fixed O&M costs do not change with level of production and include annual administrative, rent/lease contract costs, insurance, wages. Variable O&M costs vary with the level of production and include annual fuel, carbon, and ad hoc maintenance.
- **Financing Costs:** includes cost of debt and equity. Debt costs include annual principle repayment along with interest. Equity costs are calculated as a annual required return as a percent of the total equity invested. Due to the lack of project experience in many of the focus countries, as well as the general lack of disclosure of finance information, we have constructed debt and equity costs using a “rate build-up” methodology (see Appendix 1).

LCOE: DEFINITION AND INTERPRETATION II

LCOEs exclude costs of grid connection and transmission. They also exclude all subsidies and incentives. However they include conventional taxes such as corporation tax. For each country, we apply the standard local corporate tax rate and an inflation rate of the International Monetary Fund's forecast US CPI rate, extrapolating the rate out to 2060 according to the previous five year average (see Appendix 1). LCOEs are calculated assuming a development timeline from today. Today's LCOE is then inflated each year to reflect the fact that project revenues are typically inflation-linked.

Help with interpretation

- The LCOE is equivalent to the wholesale tariff at commissioning date, that a project owner would need in order to cover all project costs (excluding grid connection) and achieve a required equity return rate on the project, in the absence of subsidies.
- Since cost components will vary from project to project, our LCOEs are presented as a range. The bottom end of the range includes publicly quoted all-in project LCOEs where available. Otherwise these ranges are constructed by varying capex and capacity factors by ±10%.
- LCOEs for solar and wind can differ from quoted power purchase agreements (PPAs) or winning auction bid prices for a number of reasons. Perhaps the most significant is that capacity is often awarded at auctions with a 3-5 year grace period for construction. Since wind and solar LCOEs are falling with lower technology costs and experience, project developers may choose to bid lower than today's costs. State-sponsored, low-cost finance can also make a material difference to the final LCOE.
- LCOEs do not take account of grid connection and transmission costs as the standard assumption is that all technologies must pay equivalent costs. In practice, connection costs can vary with proximity to demand centres. These LCOEs also exclude other externalities such as pollution, destruction of local habitats and any social costs, that may arise from building or operating the plants.
- There are currently no carbon price mechanisms in place in any of the DFID priority countries. Should they be introduced, these costs would be applied as a variable cost per MWh and would act to increase the final LCOE.

LCOE: DEFINITION AND INTERPRETATION III

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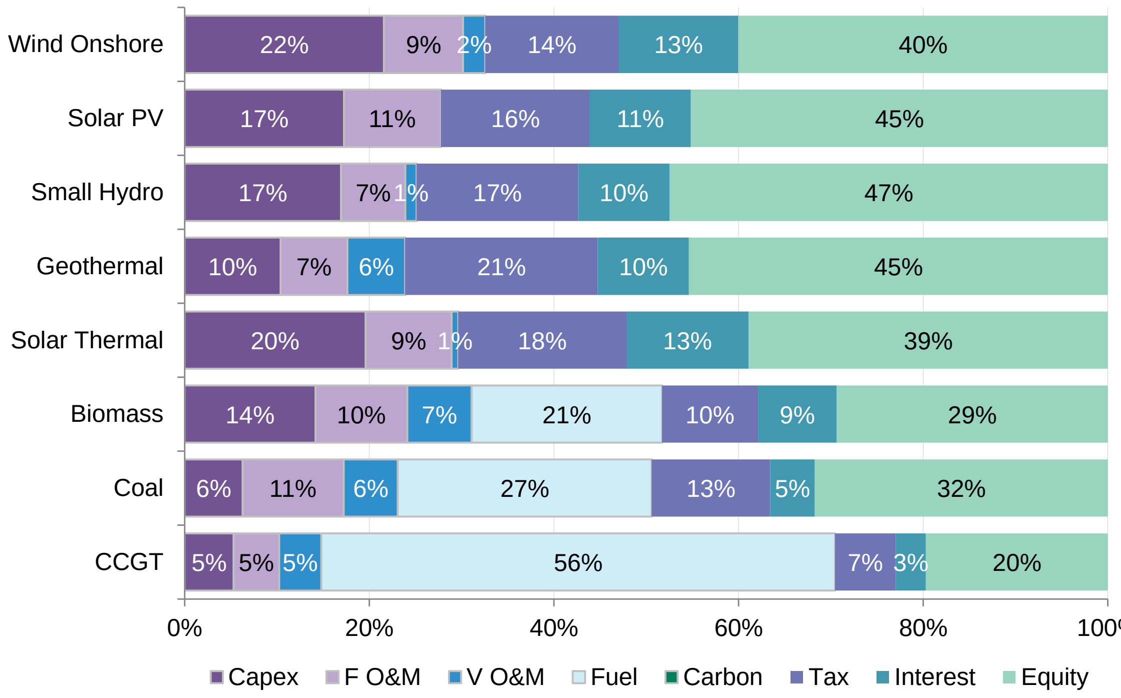
- Debt and equity finance costs vary across countries and technologies depending on country risk premium, the perceived reliability of each technology type and experience. In countries assigned a high value for country risk such as Afghanistan, South Sudan, Palestine, Yemen and Somalia, bank (debt) financing is assumed to not be available.
- The chart on the right shows the attribution of component costs to the average LCOE, for each technology in countries covered by this study. It can be used to identify the key cost drivers.
- The final LCOE for renewable technologies is generally influenced strongly by capital costs and financing costs. This is because renewables have very low variable operating costs and no fuel costs.
- In contrast, over half the final LCOE for a new natural gas plant can be attributed to fuel costs. However financing is still important.
- Another important component that will determine the final LCOE is the average capacity factor. Fossil fuel plants with reliable fuel availability will have much higher capacity factors than renewable energy plants, where capacity factors tend to reflect resource availability. In countries where fuel availability is unreliable, capacity factors can be significantly lower, increasing the final LCOE.

Attribution of component costs to average LCOE, by technology



Source: Bloomberg New Energy Finance

LCOE TECHNOLOGY DEFINITIONS

Technology	Definition
Coal	Pulverised coal fired power plants fuelled by either hard, sub bituminous or lignite coal.
CCGT	Combined cycle gas turbine (CCGT) burns natural gas to power a combustion turbine but then also recaptures the excess heat to produce steam to drive a secondary steam turbine.
Wind Onshore	Utility scale (1MW+) generation from wind turbines. Capacity factor measurements are based on wind speed and terrain roughness data assuming a GE 103m rotor, 2.75MW turbine at 85m hub-height.
Solar PV	Utility scale (1MW+) generation from fixed axis solar crystalline silicon photo voltaic panels, an optimized module inclination depending on location, and 14% system loss estimation.
Geothermal	Binary cycle geothermal power that can generate electricity from cooler reservoirs than dry or flash plants.
Biomass	Pure play biomass incineration for electricity generation. We assume wood pellet feedstock.
Small Hydro	Hydro generation up to 50MW in capacity.
Solar Thermal	Solar thermal electric generation (STEG) generation from heat gathered from parabolic trough collectors.

Large hydro

Hydro electric plants above 50MW are considered 'Large'. We exclude this technology from this analysis as projects of this size and engineering complexity can not be generalized across countries as project costs are affected by factors such as local geology, accessibility, political risks and environmental factors such as up-stream and down stream flow issues and flooding. The projects are also not deployable on a standard time-frame and have a range of development, build and operating lifetimes.

Small scale solar PV

We classify small scale solar as installations under 1MW in size. It would be inaccurate to try to compare this technology which offsets retail and commercial tariffs, with utility scale projects competing on the wholesale market. For off-grid or micro-grid connected small solar, a direct comparison would require an specific assessment of grid build-out and connection costs which an LCOE analysis doesn't require. In general utility scale solar PV capex is 28% cheaper than small solar PV due to economies of scale.

KEY FINDINGS

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EXECUTIVE SUMMARY

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- New utility-scale wind and solar PV are still more expensive than coal and gas-fired power in DFID's 28 priority countries across Africa, Asia and the Middle East. This is mainly due to a lack of development, construction and financing experience, and established supply chain, all of which drive up lifetime costs.
- Small hydro (<50MW) and biomass are much more likely to be competitive, and in many countries small hydro is the lowest cost option for new power generation. However both small hydro and biomass can be hard to deploy at sufficient scale to meet rapidly rising demand, due to resource availability, geography and feedstock supply.
- **Solar**: India and South Africa have the lowest cost new solar PV at $97/MWh and $115/MWh respectively. India has high capacity factors of around 19% and relatively low all-in capex of around $1m/MW. In recent auctions developers have bid as low as $74/MWh, however to generate at this price projects must either be loss-leaders, or have access to particularly cheap financing. South Africa has excellent solar resource with a an average capacity factor of around 21%, but this is offset by higher capital costs. Like India, recent bids have come in low, some as low as $60/MWh for a 20 year term. However with a grace period of up to 4 years and expectations for a currency rebound, we believe these PPA's do not represent the LCOE for projects that will begin construction today. The average cost of new utility scale solar PV is also likely to be under $200/MWh in Pakistan, Myanmar, Yemen, Ethiopia, Uganda and Zimbabwe.
- **Wind**: The average cost of new onshore wind is likely to be under $150/MWh in Mozambique, Malawi, Yemen, Kyrgyzstan and Ethiopia. In Mozambique, for example, we the cost of an average wind project is around $129/MWh, assuming an all-in capex of around $1.25m/MW and average capacity factor of 22%. Again, India and South Africa appear to have the cheapest new onshore wind at $79/MWh and $98/MWh. With plenty of prior construction experience, wind is one of the cheaper technology options for India and at the highest wind speed sites, is competitive with new coal. The average capacity factor for onshore wind in South Africa is around 30% making it competitive with new gas- and coal-fired power at high wind speed sites. In contrast, the cost of new wind in Bangladesh and Rwanda can be more than $300/MWh, and in Sierra Leone more than $400/MWh due to poor wind resources.
- **Natural gas:** Nigeria, South Africa, Myanmar and India have the lowest cost new gas-fired capacity. In Nigeria natural gas is likely to be around $80/MWh as the country has plenty of experience with this technology which has lowered capex and financing costs, and rising electricity demand which means gas plants run at very high capacity factors (>90%). This is common in other countries, such as Pakistan, where demand for electricity exceeds supply and power shortages are often experienced.

EXECUTIVE SUMMARY

- **Coal**: Some of the cheapest coal in the world is in India where we estimate an average LCOE of around $48/MWh. This is due to very low capex and fixed O&M costs, as well as cheap domestic fuel. Of the countries with access to coal supply; Malawi, Kyrgyzstan, Tajikistan, South Africa, Myanmar and Bangladesh, all have LCOEs under $80/MWh.
- **Solar thermal**: India and South Africa are the only two of DFID's priority countries to have deployed solar thermal to date. This technology is generally more expensive than other renewables due to high installation costs. In India it has an LCOE of $115/MWh and in South Africa, $168/MWh. However it continues to be deployed in very small volume to take advantage of its thermal inertia and potential for storage which can help meet evening peak demand.
- **Geothermal**: the East coast of Africa, India, Pakistan and Myanmar have geothermal resources that can be exploited for power generation. The LCOE is lowest in Myanmar at $86/MWh and highest in Pakistan at $168/MWh.
- This analysis focusses on the cost of grid-connected, utility-scale technologies. However solar PV, biomass and small-hydro can de readily deployed off-grid at small-scale. This is of particular interest in central African countries with low electrification rates (See appendix 2). Small-scale deployment generally has higher $/MW capex, however it may still be more cost effective depending on the cost of building-out grid infrastructure. That assessment is beyond the scope of this project.
- There is clearly a growing interest in wind and solar deployment to meet rapidly increasing demand, as countries anticipate lower costs over time. Moreover these technologies are attractive because they can be deployed quickly, and carry no fuel price, or fuel supply risk. Project costs will continue to decline with technology innovation in manufacturing, however deployment experience is needed to build supply chains and reduce balance of plant and operating costs. Concessional finance from development banks will also help lower the overall LCOE. Auction mechanisms have proved effective at generating competition amongst developers and driving down costs. Finally, carbon constraints or carbon pricing, will increase the lifetime cost of new coal, gas and oil-fired power generation, in favour of renewables.
- Calculating the LCOE for a particular technology in a country with little, or no history of deployment is highly theoretical. Relying on reported numbers also introduces the likelihood of inflated, value-based pricing that can distort the final LCOE. More granular in-country research and an increasing number of real world data points will make underlying costs more visible, and increase the accuracy of this assessment.

COUNTRY LCOE PROFILES

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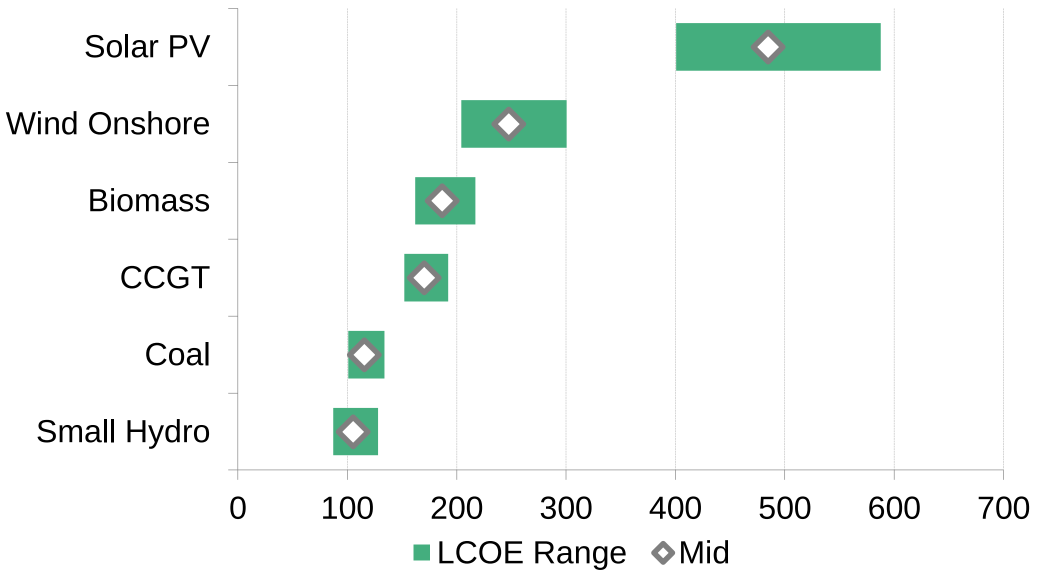
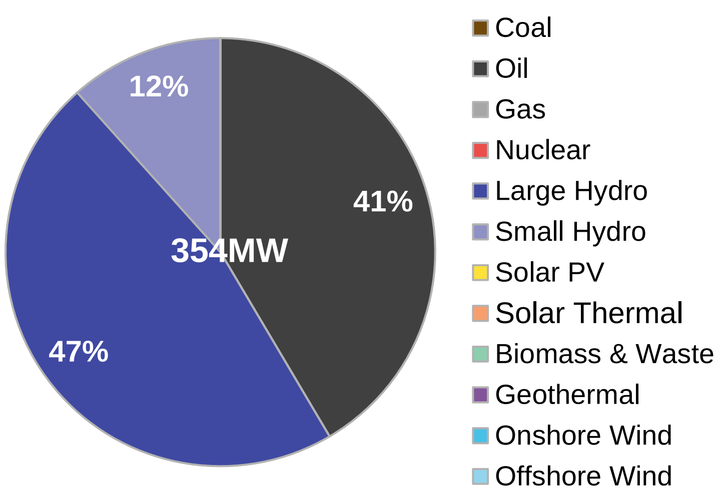
AFGHANISTAN

Afghanistan LCOE ranges (US$/MWh), 2015



Afghanistan capacity mix, 2014



- Afghanistan has 354GW of installed power generation capacity, around 60% of which is hydro producing the bulk of the country's large-scale electricity supply. The country also imports electricity via a high voltage transmission line from Uzbekistan to Kabul.
- 147MW of diesel/fuel oil is the only recorded fossil fuel capacity installed, but this is highly under utilized due to the high costs of this fuel type and the availability of cheaper alternatives.
- The cost of new power supply in Afghanistan is high as country risk makes debt finance difficult, and equity rates high. Thermal assets are also likely to have low utilization rates (capacity factor) due to uncertain fuel supply.
- Hydro potential is thought to be in excess of 23,000 MW and with small hydro being the cheapest technology ($105/MWh) this is an appealing source of new renewable power.
- Although high by world standards, coal also appears relatively competitive at $115/MWh and would be lower if debt finance were available.
- Utility-scale solar PV remains expensive in Afghanistan due to high capex and fixed O&M costs (as estimated by the Asian Development Bank), despite good solar potential in the southern provinces of Nimruz, Helmand and Kandahar. Wind potential is best in the Western Iranian border regions of Nimruz and Farah.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.77	1.77	2.01	3.00	2.11	-	3.64
Capacity factor	68%	55%	21%	17%	50%	-	70%
Fixed O&M ($/MW/yr)	59,597	27,752	19,777	63,000	19,000	-	113,091
Debt ratio	0%	0%	0%	0%	0%	-	0%
Cost of debt	0.0%	0.0%	0.0%	0.0%	0.0%	-	0.0%
Cost of equity	18.2%	18.2%	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**115.6**	**170.3**	**247.6**	**484.9**	**105.5**	**-**	**186.9**

Source: Bloomberg New Energy Finance

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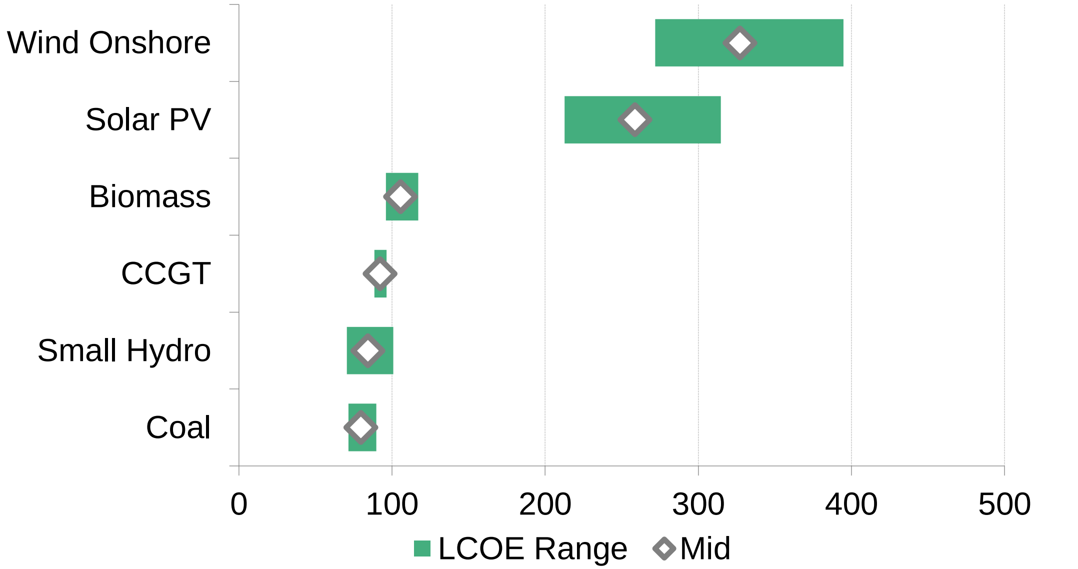
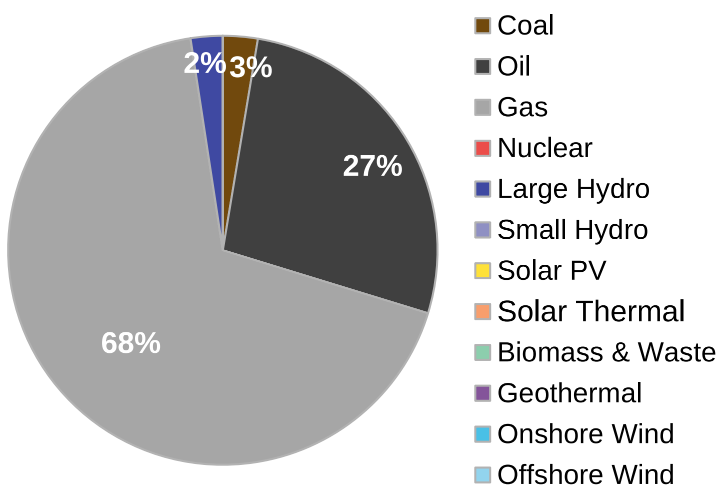
Bangladesh LCOE ranges (US$/MWh), 2015



Bangladesh capacity mix, 2014



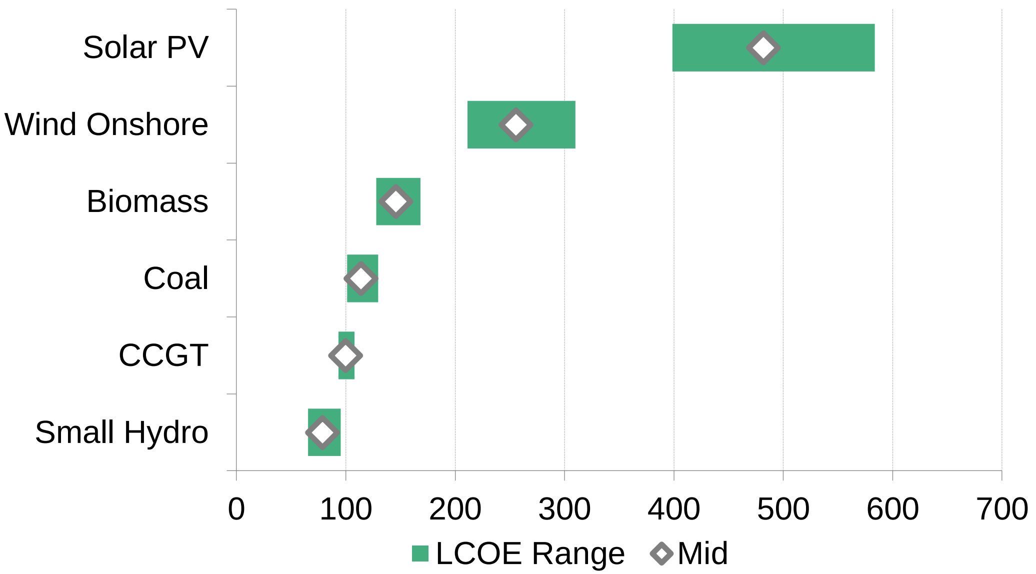
- Coal, natural gas CCGT and small hydro are the most cost effective new power generation options for Bangladesh, according to our estimates.
- Though coal currently makes up just 3% of existing capacity, our fuel price assumptions of around $2.1/MMBtu for coal and $6.4/MMBtu for gas, makes the former the cheapest new electricity, despite the fact gas has lower capex, operating costs, better capacity factor and more efficient heat rates.
- This would explain why Bangladesh plans to build over twice as much coal than gas by 2030 according to plans set out by the Power Development Board.
- Small hydro is the cheapest renewable option, however a lack of significant potential for this technology has led the country's Sustainable and Renewable Energy Development Agency (SREDA) to focus on developing wind and solar.
- However the cost of solar PV and wind appears particularly high. Both suffer from relatively high financing and capex costs in a country with limited experience of either technology. Wind capacity factors are also low. A feed-in tariff for these technologies is being considered by SREDA which may help lower the cost of these technologies as capacity is deployed.
- Electricity demand in Bangladesh was 72,205 TWh in 2014, and is targeting significant capacity growth (20,000MW by 2020) to make up for the 40% proportion of the country that is still not connected to the grid.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.30	0.88	2.00	2.30	2.33	-	2.10
Capacity factor	55%	85%	11%	15%	50%	-	85%
Fixed O&M ($/MW/yr)	71,590	38,237	35,000	15,000	51,263	-	187,000
Debt ratio	70%	70%	70%	70%	70%	-	70%
Cost of debt	9.2%	9.2%	9.7%	10.2%	9.7%	-	10.2%
Cost of equity	12.2%	12.2%	12.7%	13.2%	12.7%	-	13.2%
LCOE ($/MWh)	**79.7**	**92.0**	**327.2**	**258.5**	**84.1**	**-**	**105.5**

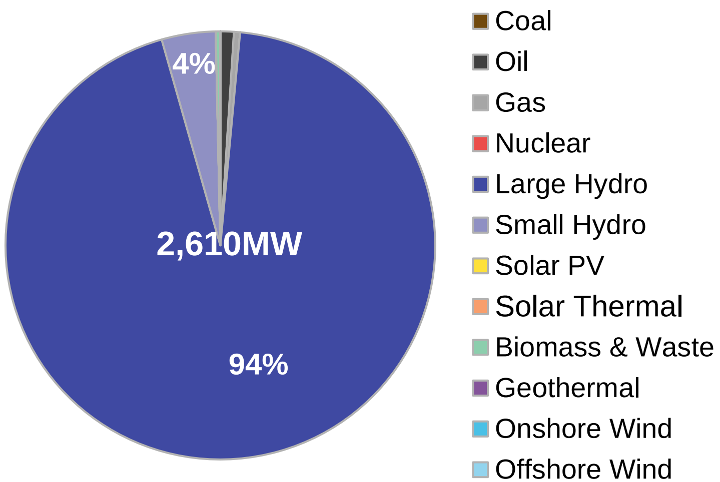
Source: Bloomberg New Energy Finance

CONGO DEM. REP.

Congo Dem. Rep. LCOE ranges (US$/MWh), 2015



Congo Dem. Rep. capacity mix, 2014



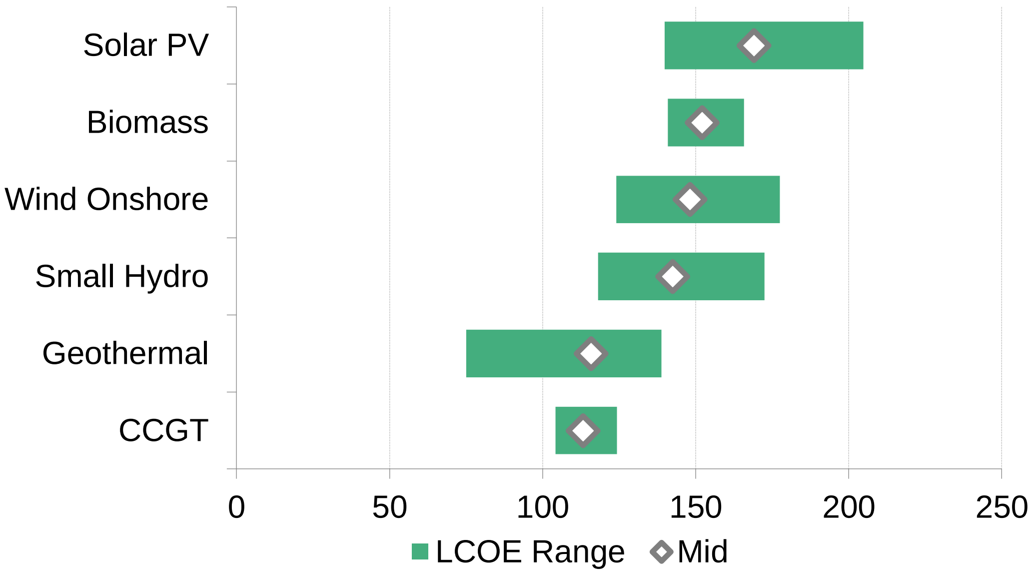
- Around 98% of the 2.6GW of installed power generation capacity in DRC is hydro. This is perhaps unsurprising considering the country has Africa's largest hydro resource, with estimated potential of 100GW.
- Goods including solar panels are subject to an import tax of 10%, an additional VAT of 16% and other import related taxes. Overall, duties can amount to up to 40% which has contributed to a particularly high capex of around $3m/MW (observed on 2 plants proposed for Kinshasa by an Egyptian state fund) and an LCOE of $400-500/MWh.
- The DRC's Electricity Sector Law, adopted in June 2014, draws on pilot projects, liberalizes the sector and aims at promoting private investment in generation and distribution. However over the last ten years few pilot projects have started operations.
- Aside from small hydro, coal and gas LCOEs are the lowest in our calculations, ranging between $100-115/MWh, with coal-fired power at the higher end of that range due to a lower capacity factor of 55%. This is the result of uncertain fuel supplies restricting total generation.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.41	1.02	1.74	3.00	1.67	-	3.12
Capacity factor	55%	75%	16%	15%	50%	-	70%
Fixed O&M ($/MW/yr)	74,188	34,344	21,767	59,351	42,445	-	62,843
Debt ratio	70%	70%	70%	70%	70%	-	70%
Cost of debt	12.7%	12.7%	13.2%	13.7%	13.2%	-	13.7%
Cost of equity	15.7%	15.7%	16.2%	16.7%	16.2%	-	16.7%
LCOE ($/MWh)	**114.0**	**99.8**	**255.6**	**481.8**	**78.9**	**-**	**145.9**

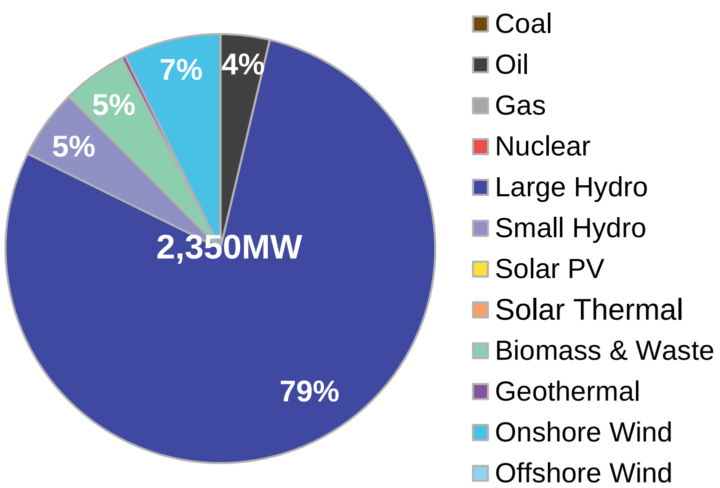
Source: Bloomberg New Energy Finance

Bloomberg NEW ENERGY FINANCE

Ethiopia LCOE ranges (US$/MWh), 2015



Ethiopia capacity mix, 2014



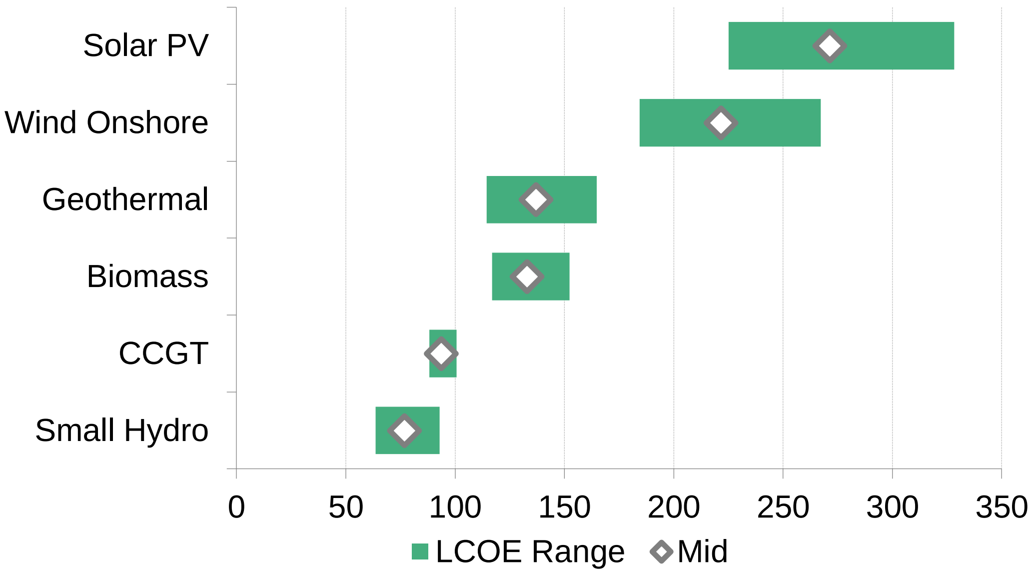
- Around 84% Ethiopia's installed power capacity is hydro. However we estimate that both natural gas CCGT ($113/MWh) and geothermal ($116/MWh) are the country's cheapest new build options.
- Ethiopia doesn't currently have commissioned gas capacity, however it does have proven reserves. The LCOE for CCGT in this analysis is based on data gathered from the Ethiopian Power System Expansion Master Plan. We assume a 55% capacity factor to reflect uncertainty in fuel availability.
- The country has an estimated 5GWe geothermal resource that remains largely untapped. And although there are no government targets set out in the country's 'Growth and Transformation Plan for 2015-20', the state owned power sector is looking to invest. The 20MW Reykjavik Phase I project reached financial close in August 2015 with a PPA of $75/MWh, and plans to develop a further 500MW by 2023. This price seems ambitious and may require the developer to make concessions on its required rate of return.
- Wind makes up 7% of Ethiopia's installed capacity, which takes advantage of good average wind speed across the country, and despite limited local experience, large-scale solar PV also has competitive capex values at $1.50m/MW. The Africa average in this report is $2.27m/MW). The country has stated its interest in making use of this potential with a Wind and Solar Master Plan being conducted in 2012 with financing support from the Chinese government.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.30	1.76	1.50	3.72	4.00	2.20
Capacity factor	-	55%	25%	18%	50%	90%	70%
Fixed O&M ($/MW/yr)	-	24,000	25,200	25,000	65,982	60,616	58,000
Debt ratio	-	70%	70%	70%	70%	70%	70%
Cost of debt	-	10.7%	11.2%	11.7%	11.2%	12.7%	11.7%
Cost of equity	-	13.7%	14.2%	14.7%	14.2%	15.7%	14.7%
LCOE ($/MWh)	**-**	**113.2**	**148.1**	**169.1**	**142.5**	**115.8**	**152.1**

Source: Bloomberg New Energy Finance

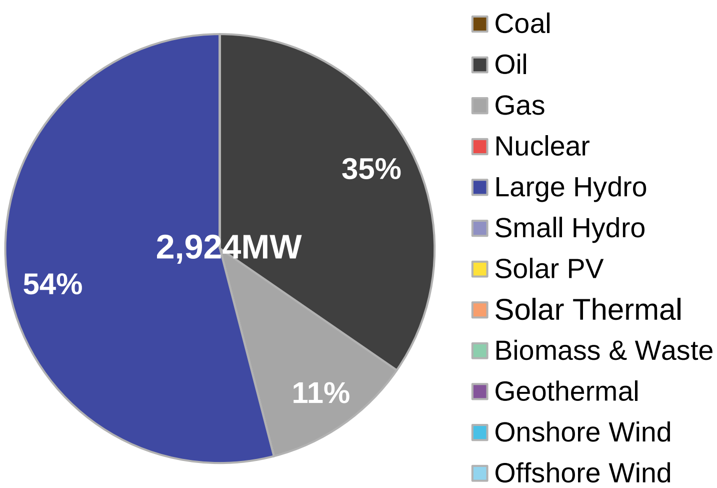
GHANA

Ghana LCOE ranges (US$/MWh), 2015



- Around 54% of Ghana's power capacity is hydro, with the remaining 46% oil and gas. The country doesn't currently use or have access to coal supplies.
- With 800bcf of proven gas reserves and over 320MW of installed capacity, its likely that natural gas CCGT capex in Ghana would be around $1m/MW, with 75% capacity factor, and overall LCOE of around $94/MWh.
- Ghana has set a feed-in-tariff for renewables to reach 10% installed capacity by 2020. As much as 20% of this target may already have been met through the 155MW Nzema solar PV plant which has now been given planning permission according to the developer, Blue Energy. This project has qualified for the feed-in-tariff despite being larger than the 150MW project cap.
- Wind resources in Ghana are mediocre with only a 14% capacity factor compared to about 19% on average across sub-Saharan Africa. Solar resources, on the other hand, are relatively strong with 17% capacity factor.
- The country's feed-in-tariff has been attracting more solar than wind, despite wind looking cheaper on a levelised basis. Experience in both however will help reduce capex and financing costs and make them increasingly competitive with natural gas.

Ghana capacity mix, 2014



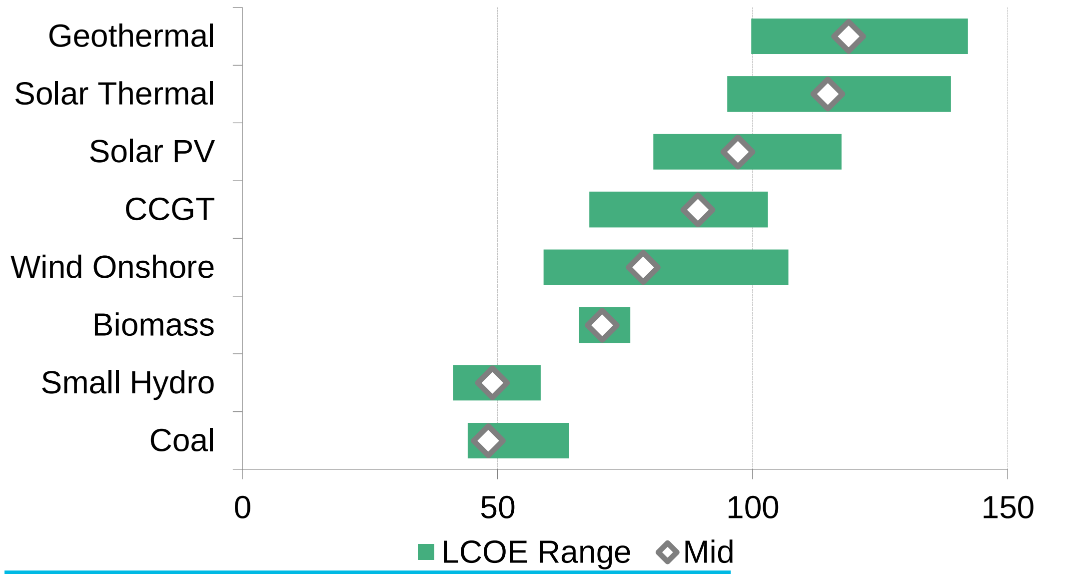
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.02	1.47	2.14	2.12	4.08	3.11
Capacity factor	-	75%	14%	17%	55%	80%	70%
Fixed O&M ($/MW/yr)	-	30,000	38,000	45,376	37,011	62,523	54,798
Debt ratio	-	70%	70%	70%	70%	70%	70%
Cost of debt	-	11.7%	12.2%	12.7%	12.2%	13.7%	12.7%
Cost of equity	-	14.7%	15.2%	15.7%	15.2%	16.7%	15.7%
LCOE ($/MWh)	**-**	**93.7**	**221.7**	**271.4**	**76.8**	**137.1**	**132.9**

Source: Bloomberg New Energy Finance

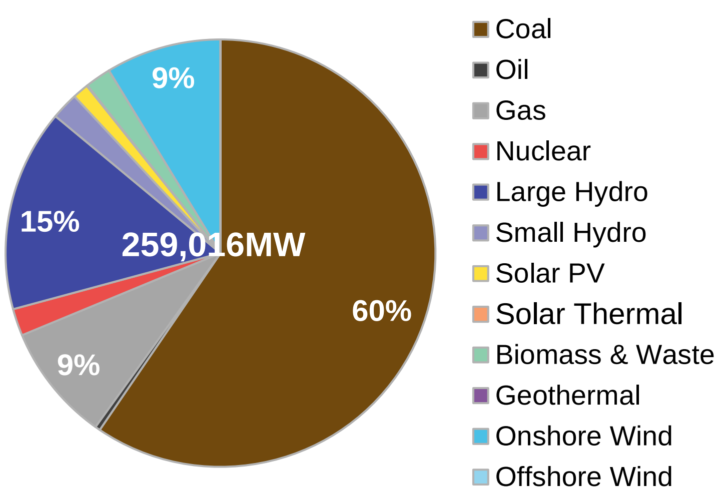
INDIA

Bloomberg NEW ENERGY FINANCE

India LCOE ranges (US$/MWh), 2015



India capacity mix, 2014



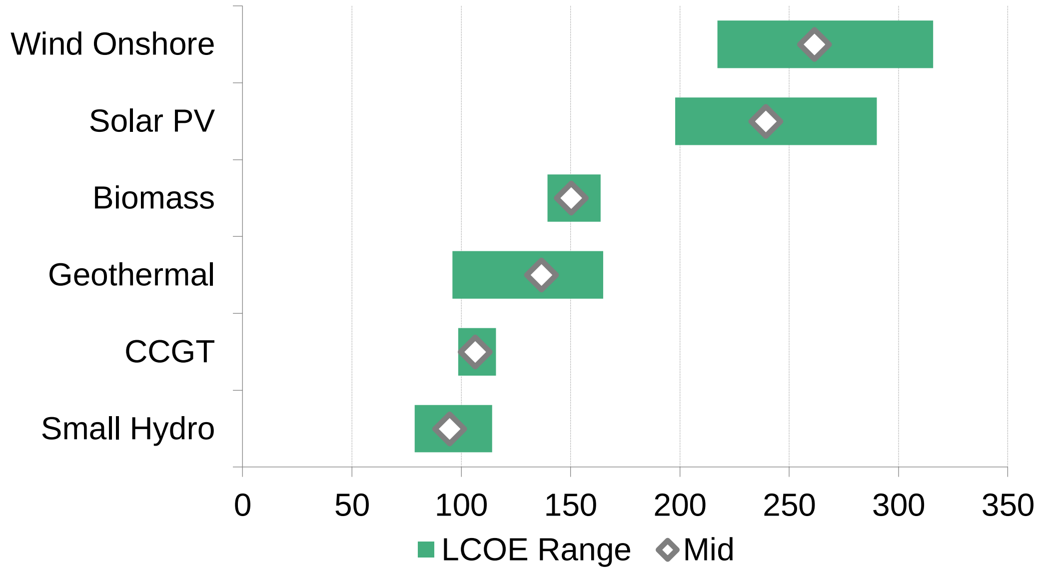
- With 154 GW of installed capacity coal is the dominant power technology in India, and the cheapest form of new electricity at $48/MWh. This is due to very low capex and fixed O&M costs, as well as cheap domestic coal.
- The LCOE for new gas CCGT is almost double that of coal, despite a low capex of around $0.68/MW. This is because gas supply is unreliable in India attracting a low capacity factor of 40%. As a result, the country is also importing significant quantities of more expensive LNG.
- With an average cost of around $79/MWh and plenty of prior construction experience, wind is one of the cheaper technology options for India. At the highest wind speed sites, wind can even be competitive with new coal.
- Solar PV is generally more expensive than wind, however in recent auctions developers have bid as low as $74/MWh. To generate at this price projects must either be loss-leaders, or have access to particularly cheap financing.
- India has targets to build 60GW of new large scale solar, 60GW of wind, 10GW of biomass and 5GW of small hydro by 2022. As deployment increases we expect capex, O&M and financing costs to further reduce.
- Small hydro is the cheapest renewable technology, but its potential is limited based on location and geology.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass	Solar Thermal
Capex ($m/MW)	0.88	0.68	1.10	1.03	1.21	4.38	1.04	1.92
Capacity factor	70%	40%	23%	19%	45%	80%	80%	33%
Fixed O&M ($/MW/yr)	28,562	46,345	16,443	17,801	34,037	75,113	71,547	28,357
Debt ratio	70%	70%	70%	70%	70%	70%	70%	70%
Cost of debt	8.1%	8.1%	8.6%	9.1%	8.6%	10.1%	9.1%	10.1%
Cost of equity	11.1%	11.1%	11.6%	12.1%	11.6%	13.1%	12.1%	13.1%
LCOE ($/MWh)	**48.2**	**89.3**	**78.6**	**97.1**	**49.0**	**118.8**	**70.5**	**114.7**

KENYA

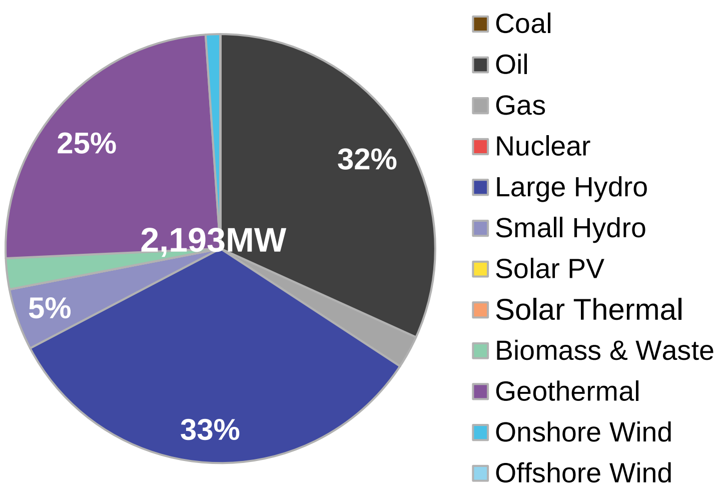
Bloomberg NEW ENERGY FINANCE

Kenya LCOE ranges (US$/MWh), 2015



- Around 32% of Kenya's installed capacity comes from oil. These plants were commissioned in the 1980s and 1990s when diesel was relatively cheap. As oil prices rose, other technologies such as geothermal (25%) and hydro (38%) and more recently wind have been developed.
- Kenya plans to make clean energy a significant part of its ambitious 'Least Cost Power Development Plan' which targets 22.7GW of capacity by 2033
- Capex for wind is still high in Kenya at around $2.6m/MW. This figure is based on disclosed data from the Isiolo I wind farm. Recently a number of other projects were financed, including the 310MW Lake Turkana wind farm.
- The country has good potential for small hydro as well as significant geothermal resources (estimated at 10GW) which is to undergo a fast track development plan by the government owned Geothermal Development Company (GDC).
- Solar has struggled to gain a footing in Kenya despite the country's feed-in-tariff, as the rate offered has proven to be too low for project developers.
- Kenya has no proven domestic reserves of natural gas or coal however it does have some existing natural gas capacity which suggests supply is available.

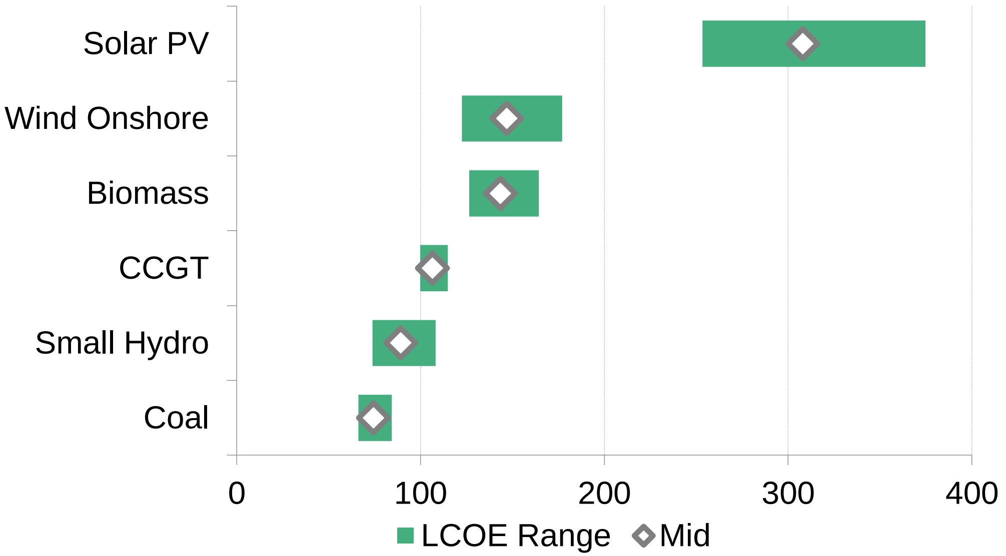
Kenya capacity mix, 2014



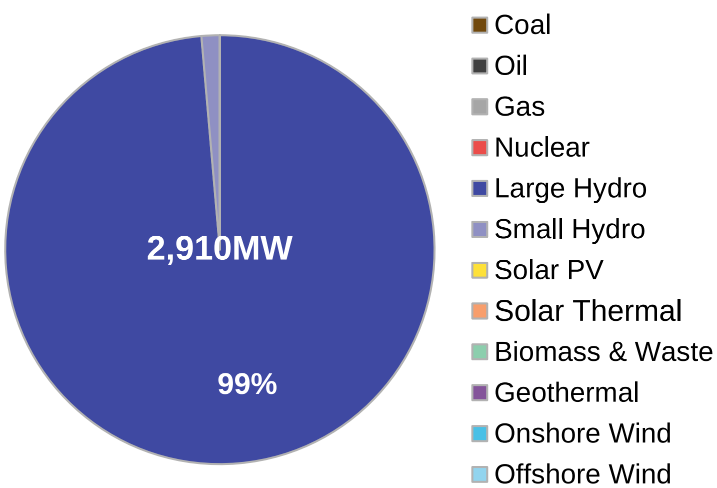
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.41	2.60	2.12	2.66	4.04	2.34
Capacity factor	-	75%	21%	19%	60%	80%	80%
Fixed O&M ($/MW/yr)	-	29,797	38,000	35,000	70,000	60,616	58,000
Debt ratio	-	72%	70%	70%	70%	70%	70%
Cost of debt	-	11.6%	12.1%	12.6%	12.1%	13.6%	12.6%
Cost of equity	-	14.6%	15.1%	15.6%	15.1%	16.6%	15.6%
LCOE ($/MWh)	**-**	**106.4**	**261.6**	**239.4**	**94.7**	**136.8**	**150.4**

Source: Bloomberg New Energy Finance

Kyrgyzstan LCOE ranges (US$/MWh), 2015



Kyrgyzstan capacity mix, 2014



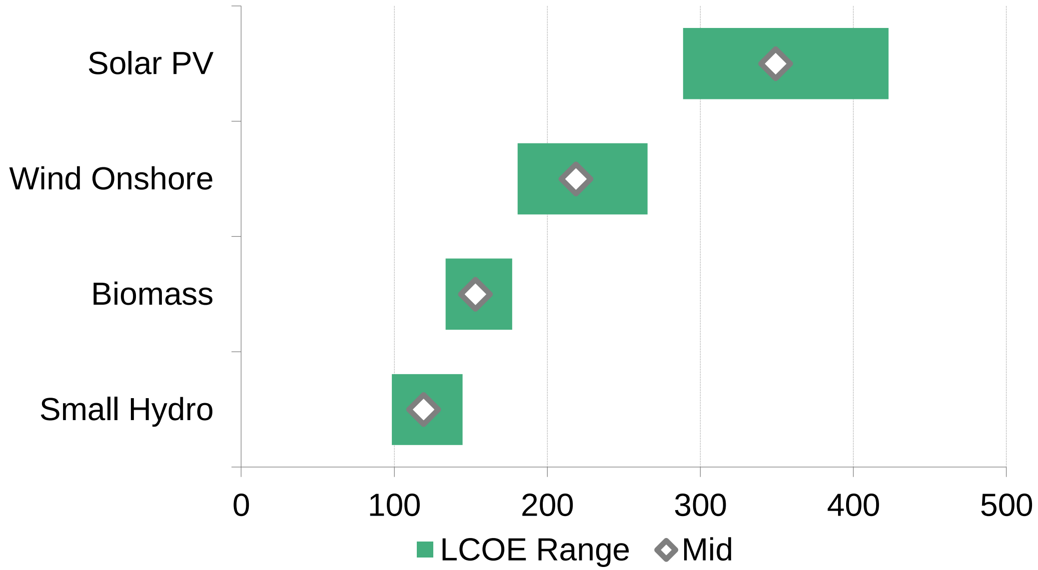
- Kyrgyzstan has no other recorded installed capacity other than hydro electricity (2,910 MW). Despite having lignite and natural gas reserves the country is yet to develop any power generation from these technologies.
- Considering that the country has 100% electrification and still exports energy to Uzbekistan, South Kazakhstan and Russia, there does not appear to be immediate need for new large scale developments.
- Small hydro is estimated to be the lowest cost renewable technology for Kyrgyzstan. Capex is based on the 11.4MW Chon Ak Suu project, which Is currently seeking finance. However at $2.7m/MW this project is still relatively high compared to the average $2.2m/MW for the middle east and Asian countries studied in this report. According to Kyrgyz legislation, hydro power plants with an installed capacity of less than 30 MW should be built, owned and operated by the private sector, and laws allow international investors identical rights to that of domestic investors.
- With limited data availability for this country, cost inputs from Pakistan (coal and gas), Bangladesh (solar and wind) and South Africa (biomass) were used as benchmarks in the LCOE calculation, adjusted according to land, labour and PPP differentials.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.38	1.07	2.03	2.33	2.74	-	3.64
Capacity factor	55%	55%	26%	13%	50%	-	70%
Fixed O&M ($/MW/yr)	27,396	29,964	36,631	17,074	20,515	-	113,440
Debt ratio	70%	70%	70%	70%	70%	-	70%
Cost of debt	10.7%	10.7%	11.2%	11.7%	11.2%	-	11.7%
Cost of equity	13.7%	13.7%	14.2%	14.7%	14.2%	-	14.7%
LCOE ($/MWh)	**74.4**	**106.6**	**147.0**	**308.1**	**89.3**	**-**	**143.5**

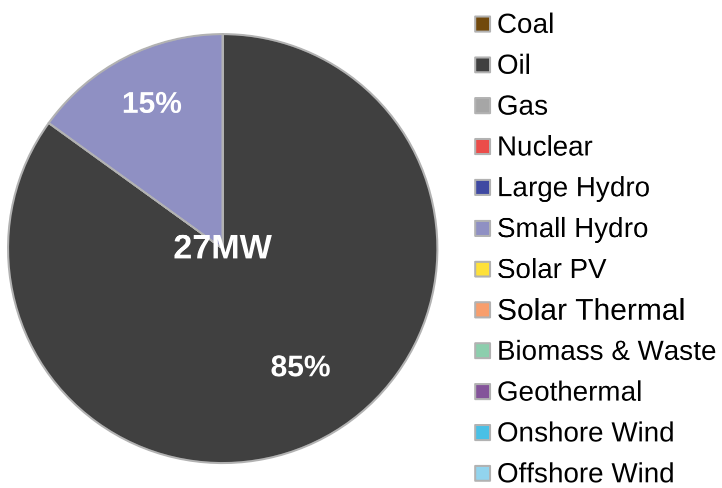
LIBERIA

Bloomberg NEW ENERGY FINANCE

Liberia LCOE ranges (US$/MWh), 2015



Liberia capacity mix, 2014



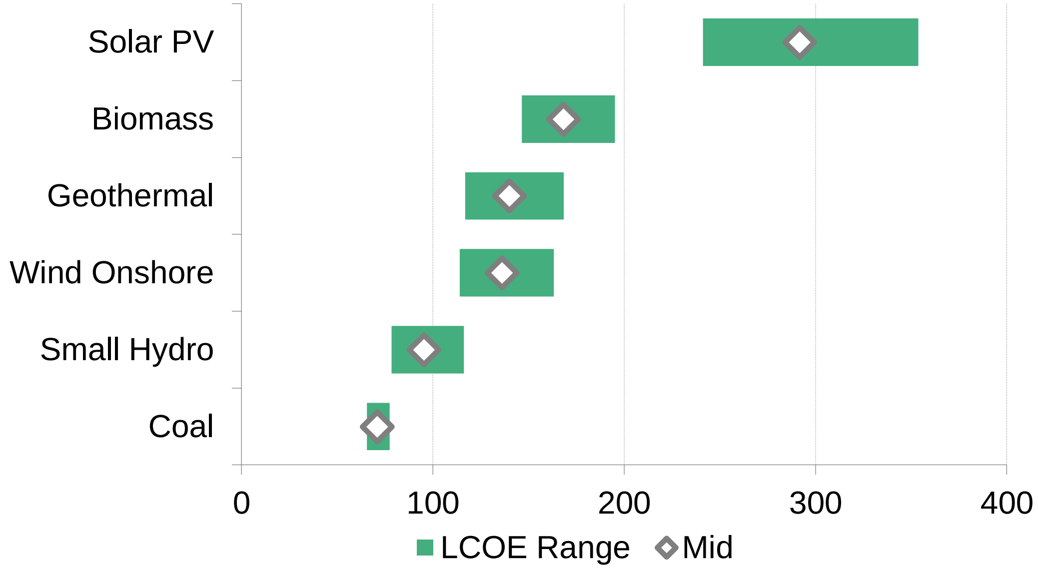
- Liberia has very little centralised power generation capacity, with the majority of electricity coming from privately owned distributed capacity. Oil (23MW) and Small Hydro (4MW) make up the only recorded capacity.
- There are no proven reserves or installed on grid capacity of coal and gas within the country.
- With limited data availability for this country, copst inputs from Zimbabwe (biomass), Zambia (small hydro), Kenya (solar) and Mozambique (wind), were used as benchmarks and adjusted based on land, labor and purchasing power parity differentials.
- Small hydro is the most competitive of the technologies assessed due to its relatively low capex ($2.45m/MW), and high capacity factor compared to other non-thermal technologies.
- Biomass is the second cheapest viable utility scale technology due also to our relatively low capex estimate ($3.10m/MW compared to an Africa regional average of $3.75m/MW). This calculation assumes wood pellet fuel prices are fixed at a $55/t average over the life of the project.
- Costs for solar and wind are particularly high due to the poor wind and solar resources – 15% capacity factor for wind in Liberia compared with 19% on average across Africa, and 16% for solar compared with an average of 18%.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	-	1.32	2.13	2.45	-	3.10
Capacity factor	-	-	15%	16%	50%	-	70%
Fixed O&M ($/MW/yr)	-	-	18,674	44,645	36,415	-	53,915
Debt ratio	-	-	70%	70%	70%	-	70%
Cost of debt	-	-	15.7%	16.2%	15.7%	-	16.2%
Cost of equity	-	-	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**-**	**-**	**218.8**	**349.1**	**119.2**	**-**	**153.1**

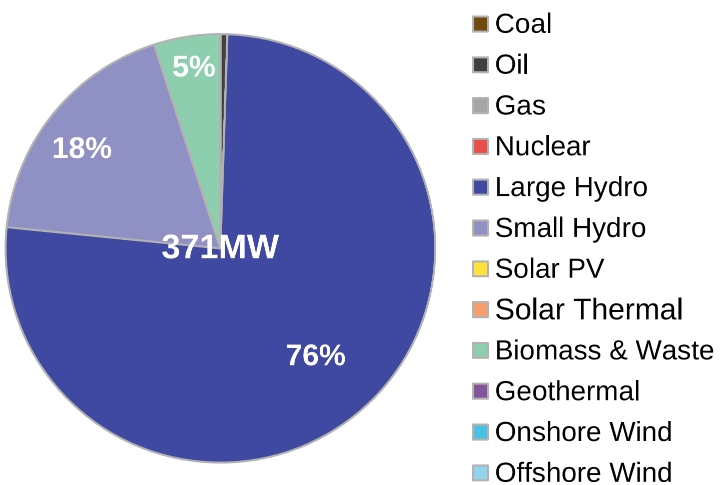
MALAWI

Bloomberg NEW ENERGY FINANCE

Malawi LCOE ranges (US$/MWh), 2015



Malawi capacity mix, 2014



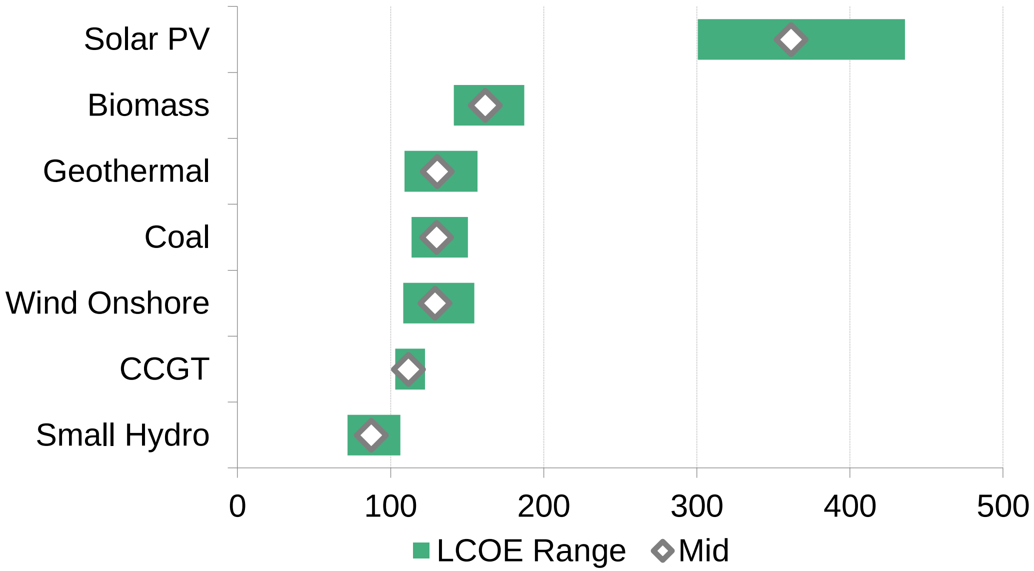
- Malawi's on-grid installed capacity is dominated by hydro (351MW) with a small amount of Biomass (19MW) and oil generation (2MW).
- Despite no installed coal or gas generation, there are reserves of lignite within the country, although this is yet to be exploited.
- Coal is the cheapest form of new generation in the country due to low capex of $0.61m/MW, well below the Africa average of $1.89m/MW. The country is currently looking to develop a 1GW plant at Kam'mwamba which plans to take advantage of cheap coal from Mozambique along the newly constructed Vale rail-line.
- Small hydro is also a low-cost option, and offers potential for development with only 1 (4.5MW Wovwe project) out of the 12 potential sites identified by the Malawi's National Water and Resource Master plan having been developed.
- Capex for onshore wind for Malawi was estimated using Mozambique as a benchmark. With this assumption, along with a high capacity factor Malawi has one of the cheapest wind LCOEs in the region.
- Geothermal resources are also known to be in the country with plans for future development, however the potential has not yet been properly surveyed. The high capacity factor of geothermal gives it its relatively low LCOE of $140/MWh.
- Although Solar LCOEs are high compared to the other technologies, good solar resources offer future potential should capex come down in line with experience.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	0.61	-	1.29	2.57	2.65	4.03	4.04
Capacity factor	55%	-	22%	19%	53%	80%	70%
Fixed O&M ($/MW/yr)	52,090	-	43,865	41,672	10,418	60,425	113,052
Debt ratio	70%	-	70%	70%	70%	70%	70%
Cost of debt	11.7%	-	12.2%	12.7%	12.2%	13.7%	12.7%
Cost of equity	14.7%	-	15.2%	15.7%	15.2%	16.7%	15.7%
LCOE ($/MWh)	**70.9**	**-**	**136.2**	**291.8**	**95.4**	**140.1**	**168.4**

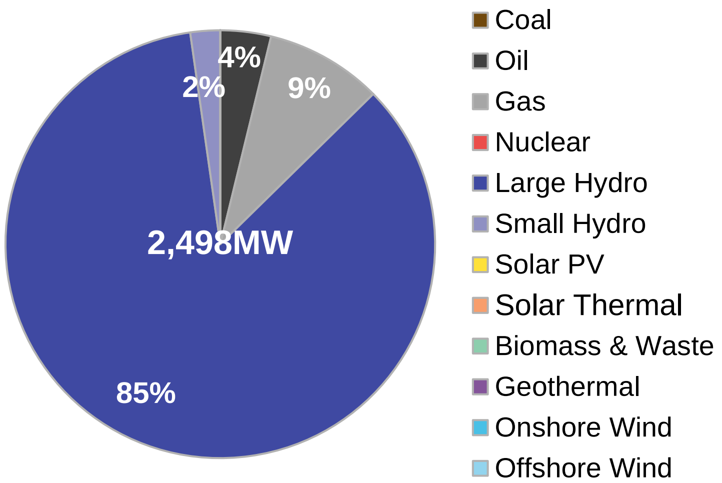
MOZAMBIQUE

Bloomberg NEW ENERGY FINANCE

Mozambique LCOE ranges (US$/MWh), 2015



Mozambique capacity mix, 2014



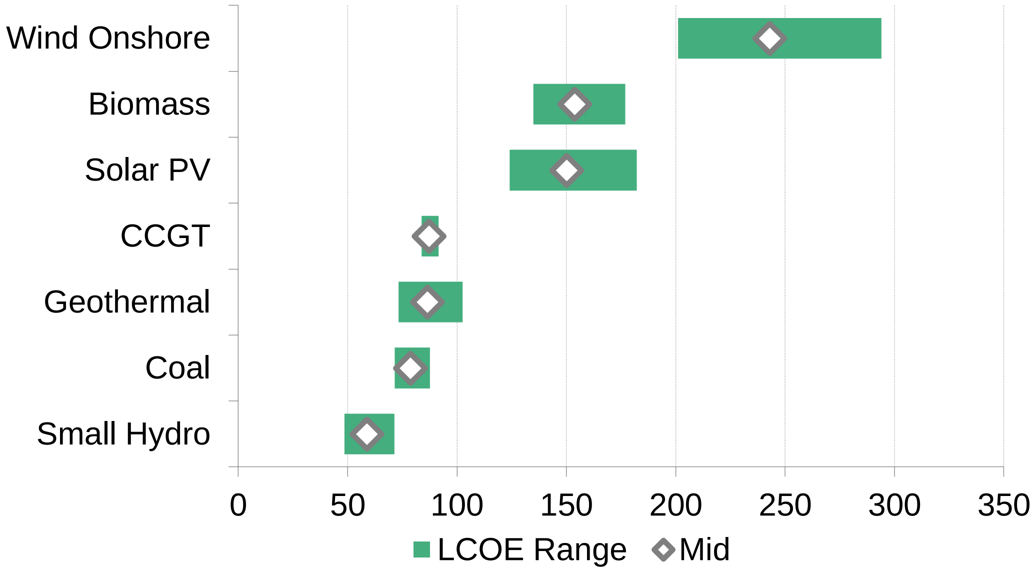
- Hydro (2183MW) and gas (220MW) make up the majority of Mozambiqe's on grid installed capacity, supported by a small amount oil (95MW).
- Concerns are growing that the demand for electricity – 12TWh in 2014 – could soon outstrip supply, as the economy grows and the electrification rate increases. This is particularly the case in the southern grid area around Maputo.
- Small hydro has the lowest LCOE, with the greatest potential in the central and north provinces, but generally very poor potential in the southern provinces where demand is highest.
- Gas has the second lowest LCOE at $112/MWh as the country appears to have a reliable fuel supply and established infrastructure. It is also looking to expand with the proposed 100MW Maputo CCGT plant.
- A wind feasibility study conducted by the Ministry of Energy (DNER) and Risø in 2008 suggests that installation costs were as low as $2m/MW ($1.25m/MW in 2015 when accounting for falling wind costs since then). This along with good wind resources (22% capacity factor) makes wind the third most competitive technology.
- There is also plans to utilise domestic coal resources with the development of the Moatize IPP coal plant that will be supplied coal by Vale from the adjoining mine. This secure supply allows for a higher capacity factor of 75%. The plant is expected to come at a cost of $3.3m/MW – high compared with the average of African countries in this report ($1.9m/MW).

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	3.33	1.70	1.25	2.66	2.44	3.98	4.03
Capacity factor	75%	75%	22%	16%	50%	80%	70%
Fixed O&M ($/MW/yr)	51,876	29,107	40,000	71,037	10,375	58,293	109,575
Debt ratio	70%	70%	70%	70%	70%	70%	70%
Cost of debt	10.7%	10.7%	11.2%	11.7%	11.2%	12.7%	11.7%
Cost of equity	13.7%	13.7%	14.2%	14.7%	14.2%	15.7%	14.7%
LCOE ($/MWh)	**130.1**	**111.7**	**129.1**	**361.6**	**87.3**	**130.4**	**161.9**

Source: Bloomberg New Energy Finance

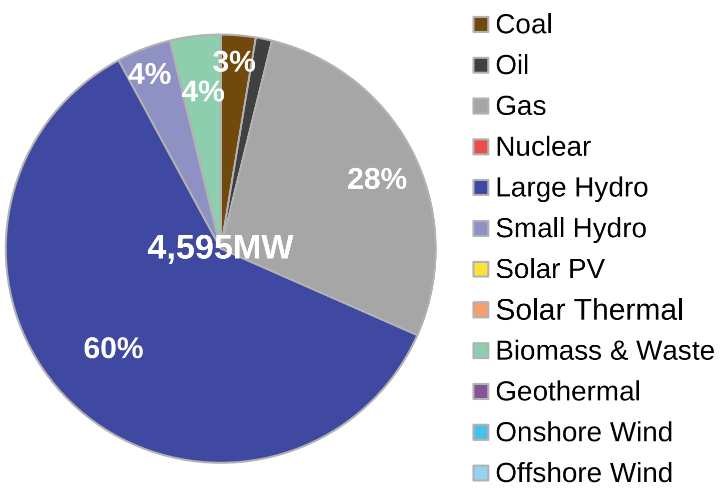
MYANMAR

Myanmar LCOE ranges (US$/MWh), 2015



- Myanmar has 4,595MW of installed power generation capacity, 64% of which is hydro and 28% gas.
- Low fuel costs – $3.0/MMbtu compared to gas at $6.4/MMbtu – as well as the longer life expectancy observed for coal plants of 35 years compared to 25 years for CCGT plants, make coal the cheapest new fossil fuel generation.
- Myanmar also has geothermal resources which has yet to be fully explored and developed, much of which is located around the northeast region on the border with Thailand. The geothermal LCOE for Myanmar appears to be relatively low at $2.8m/MW, according to capex data gathered from a CDM feasibility study for a plant in the Tacheleik region.
- Solar too is relatively low cost in Myanmar with an LCOE of $130/MWh. This is due to particularly low capex estimates based in part on the 210MW currently being developed by Green Earth Power.
- Small hydro is the lowest cost renewable energy option in the country due to low capex and high capacity factor.

Myanmar capacity mix, 2014



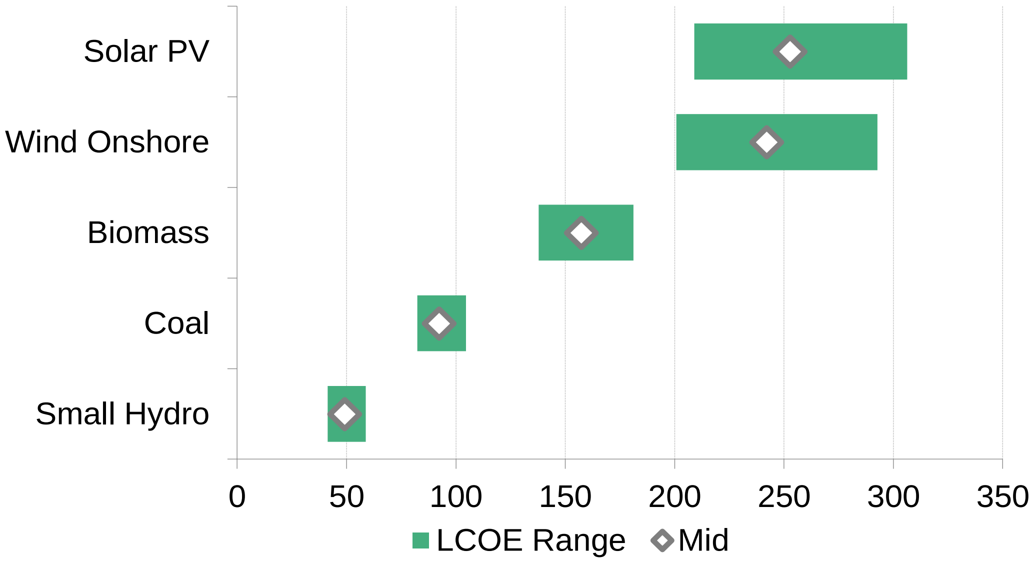
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.81	0.87	2.05	1.40	1.86	2.85	4.20
Capacity factor	80%	85%	14%	16%	50%	80%	70%
Fixed O&M ($/MW/yr)	58,333	30,102	22,386	16,004	19,100	76,017	117,108
Debt ratio	70%	70%	70%	70%	70%	70%	70%
Cost of debt	9.2%	9.2%	9.7%	10.2%	9.7%	11.2%	10.2%
Cost of equity	12.2%	12.2%	12.7%	13.2%	12.7%	14.2%	13.2%
LCOE ($/MWh)	**78.8**	**87.3**	**242.9**	**150.2**	**58.8**	**86.4**	**153.8**

Source: Bloomberg New Energy Finance

NEPAL

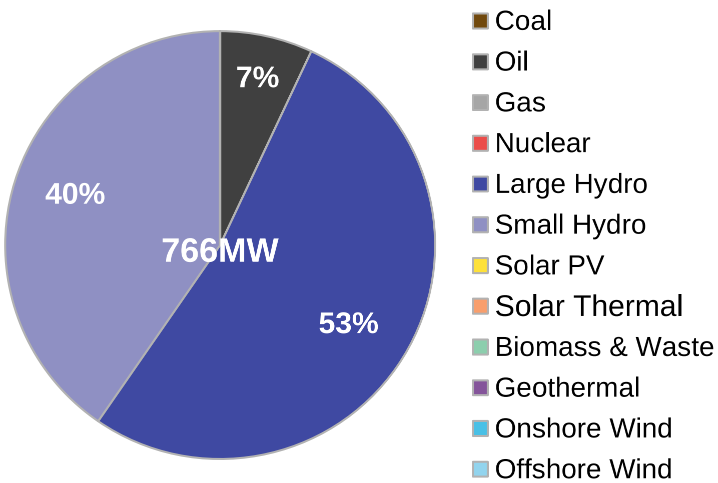
Bloomberg NEW ENERGY FINANCE

Nepal LCOE ranges (US$/MWh), 2015



- 93% of Nepal's installed capacity is made up of hydroelectric plants, of which almost half is small hydro. Nepal is rich in water resources with an estimated hydro potential of 83GW, and an economically viable potential of 43GW.
- The cost of small hydro in Nepal is once again low based in part to benchmarking against low capex figures from India, adjusted for land, labour, and power purchasing parity differentials.
- Nepal has an estimated 1 million tons of recoverable lignite reserve that remains undeveloped. Although there is currently no coal-fired generation in the country, we estimate coal has an LCOE of around $92/MWh based on the potential for domestic fuel supply.
- Nepal's wind and solar resources are relatively poor compared to other countries in the region. Its wind capacity factor is just 10%, and its solar capacity factor just 13%. In the case of solar PV, Nepal's lower capex costs for the technology offset the low capacity factor returning an $253/MWh LCOE for solar PV that is cheaper than the regional average.

Nepal capacity mix, 2014



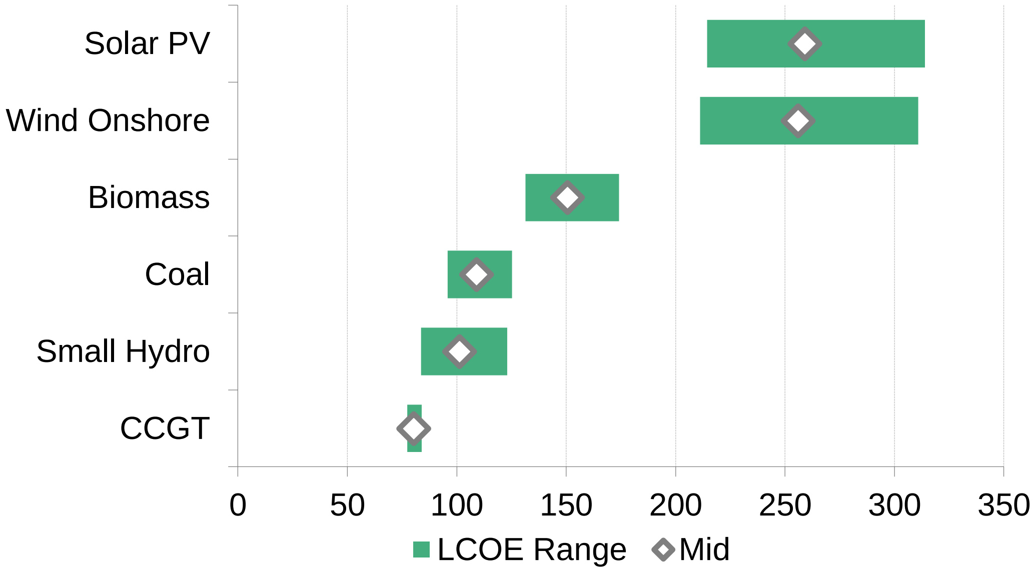
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.38	-	1.26	1.74	1.22	-	4.03
Capacity factor	55%	-	10%	13%	50%	-	70%
Fixed O&M ($/MW/yr)	98,860	-	17,044	25,000	35,281	-	113,781
Debt ratio	70%	-	70%	70%	70%	-	70%
Cost of debt	10.7%	-	11.2%	11.7%	11.2%	-	11.7%
Cost of equity	13.7%	-	14.2%	14.7%	14.2%	-	14.7%
LCOE ($/MWh)	**92.3**	**-**	**242.1**	**252.7**	**49.2**	**-**	**157.3**

Source: Bloomberg New Energy Finance

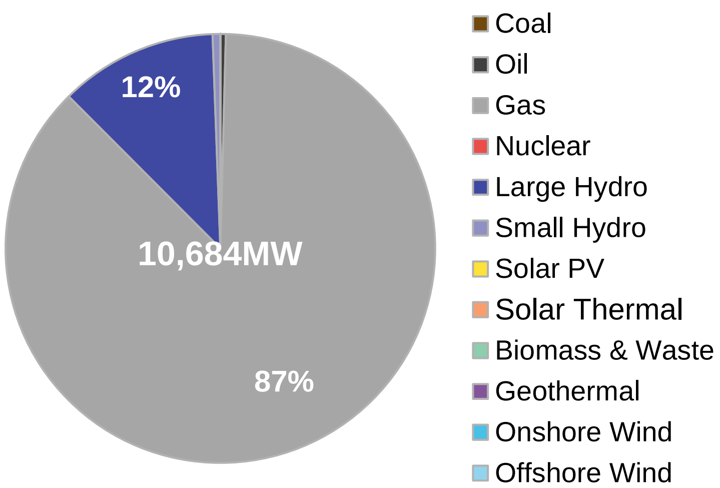
NIGERIA

Bloomberg NEW ENERGY FINANCE

Nigeria LCOE ranges (US$/MWh), 2015



Nigeria capacity mix, 2014

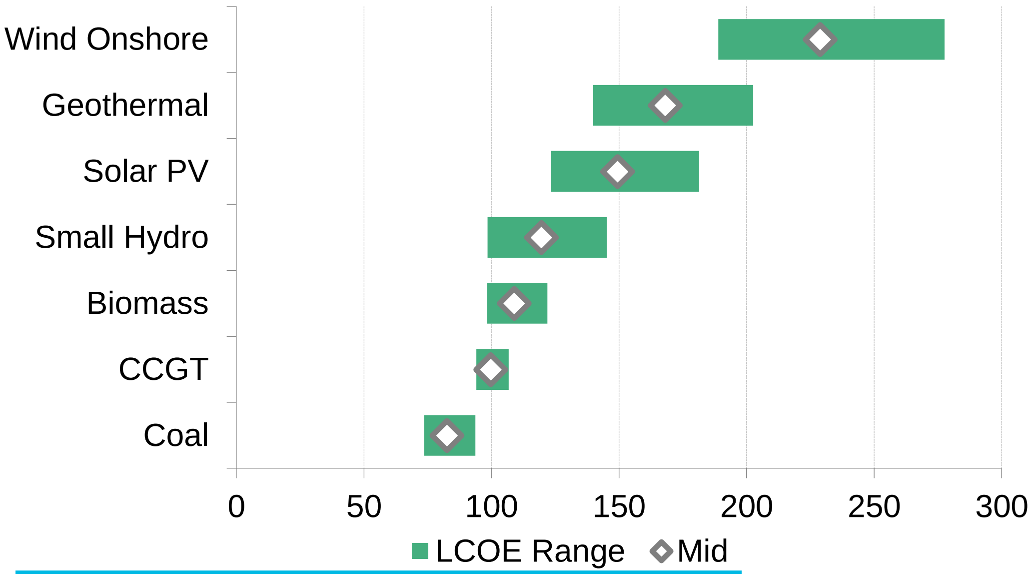


- Power in Nigeria is dominated by natural gas which accounts for 87% (9.3GW) of total installed capacity and a majority of generation. Large hydro accounts for (1.3GW) but the country has no installed wind or solar despite having put a feed-in tariff in place following major power sector reform earlier in 2015.
- With regular blackouts, a high GDP growth rate of 6.3% per year and a target to increase electrification rates in the country from 56% to 75% by 2020, demand for generation is going to be particularly high for the foreseeable future.
- Gas is the cheapest new build electricity in Nigeria as the country has plenty of experience with this technology which means lower capex and financing costs and rising demand and access to gas supplies means very high utilization rates.
- Despite local production of lignite, coal is more expensive. This is due to the high capex required to build coal plants in remote locations close to lignite mines to avoid high transportation costs.
- Renewables are high on the agenda of the newly elected APC party, and Nigeria has set aside 10% of its 40GW 2020 target for renewables. Solar costs are high despite good sunshine. Further experience through deployment could reduce cost of solar to around $115/MW – the same as South Africa which has similar solar irradiance.
- Small hydro is the cheapest of the renewable sources. There is also plenty of opportunity with over 277 sites identified with a combined potential of 734MW. To this point only 62MW of small hydro has been developed.

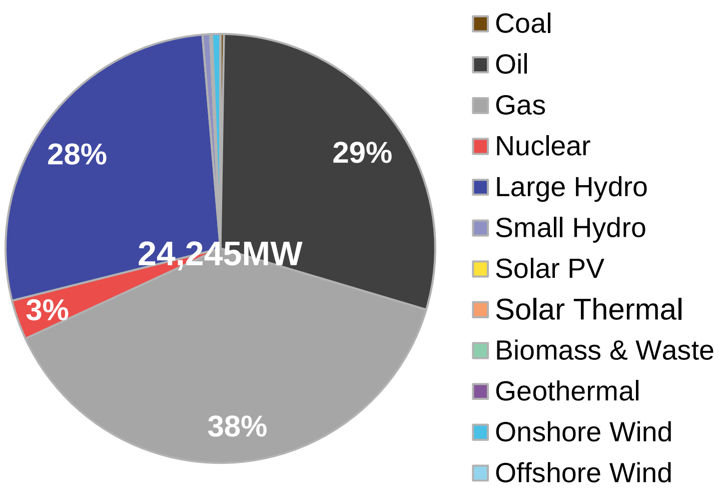
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	2.90	0.75	2.06	3.00	3.72	-	4.25
Capacity factor	70%	95%	14%	21%	60%	-	68%
Fixed O&M ($/MW/yr)	55,623	45,818	18,572	44,400	36,215	-	53,619
Debt ratio	70%	70%	70%	70%	70%	-	70%
Cost of debt	9.2%	9.2%	9.7%	10.2%	9.7%	-	10.2%
Cost of equity	12.2%	12.2%	12.7%	13.2%	12.7%	-	13.2%
LCOE ($/MWh)	**109.1**	**80.3**	**256.0**	**259.1**	**101.3**	**-**	**150.7**

PAKISTAN

Pakistan LCOE ranges (US$/MWh), 2015



Pakistan capacity mix, 2014



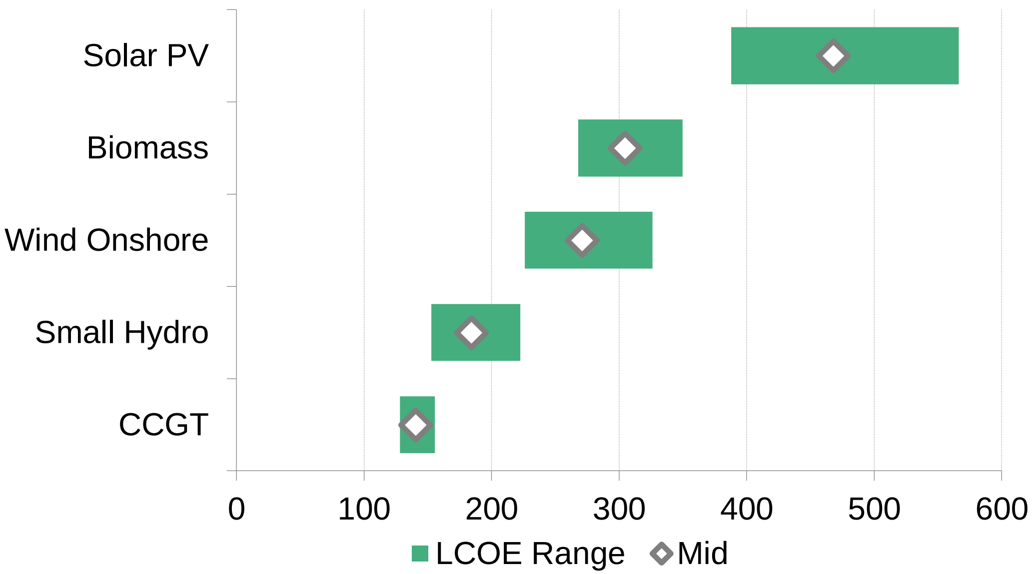
- Gas-fired generation is currently the main source of electricity in Pakistan. The country has around 24,700bcf of proven reserves, so fuel supply is reliable. Demand also exceeds supply for electricity with the country and power shortages are often experienced. For this reason we observe capacity factors as high as 96% as plants to try to meet this demand. We also estimate relatively high financing costs. Overall our LCOE estimate stands at $100/MWh.
- Pakistan also has 2,070 million tonnes of recoverable lignite reserves and while it currently only has 65MW of coal-fired capacity, low fuel costs means coal is probably the cheapest new electricity in the country at $83/MWh.
- At $149.5/MWh, Pakistan has some of the cheaper solar in the region, mainly due to low capex and high insolation. And while it only has 100MW of solar PV commissioned, it has a pipeline of over 1.1GW.
- Pakistan also has 106MW of wind commissioned. However high capital costs (based on the dollar adjusted investment in the Tenaga 50MW wind plant), mean our LCOE estimate is high at $229/MWh despite good average wind speed in the country.
- With 79,606 TWh of demand in 2014, Pakistan is an energy-deficit country looking to develop quickly in order to alleviate power shortages by 2018.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.38	1.07	2.14	1.07	3.65	4.11	1.75
Capacity factor	84%	96%	22%	18%	69%	80%	80%
Fixed O&M ($/MW/yr)	98,991	28,543	19,461	17,656	19,542	63,896	132,000
Debt ratio	70%	68%	70%	75%	70%	70%	70%
Cost of debt	13.7%	13.7%	14.2%	14.7%	14.2%	15.7%	14.7%
Cost of equity	16.7%	16.7%	17.2%	17.7%	17.2%	18.7%	17.7%
LCOE ($/MWh)	**82.6**	**99.7**	**228.8**	**149.5**	**119.5**	**168.1**	**108.9**

Source: Bloomberg New Energy Finance

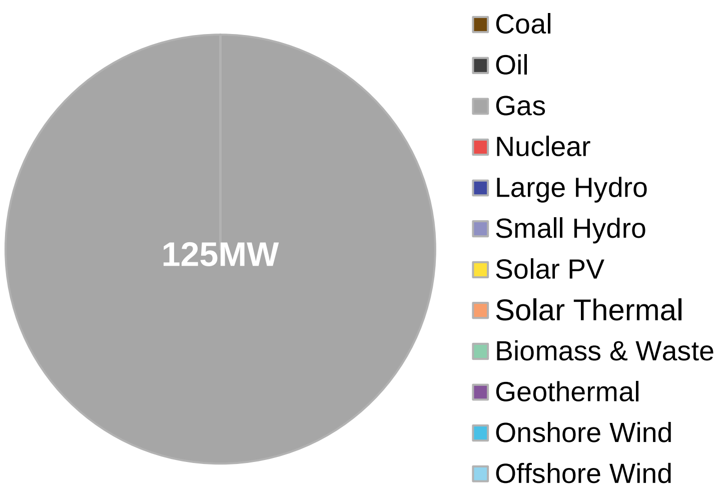
PALESTINIAN TERRITORIES

Palestinian territories LCOE ranges (US$/MWh), 2015



- Palestinian Territories have a total installed capacity of 125MW, all of which is gas-fired.
- Energy projects in the Palestinian Territories are assumed to be 100% equity financed due to the high risk environment in the country.
- Due to a lack of experience and available data for the different cost inputs and relevant macroeconomic indicators to create benchmark values, we have adopted the highest capex, O&M, and risk assumptions as inputs.
- We assume standard inputs such as plant lifetimes of 35 years for coal and 25 years for gas, as well as development and construction times, however these may be too high considering the particular unstable conditions on the ground in this country.

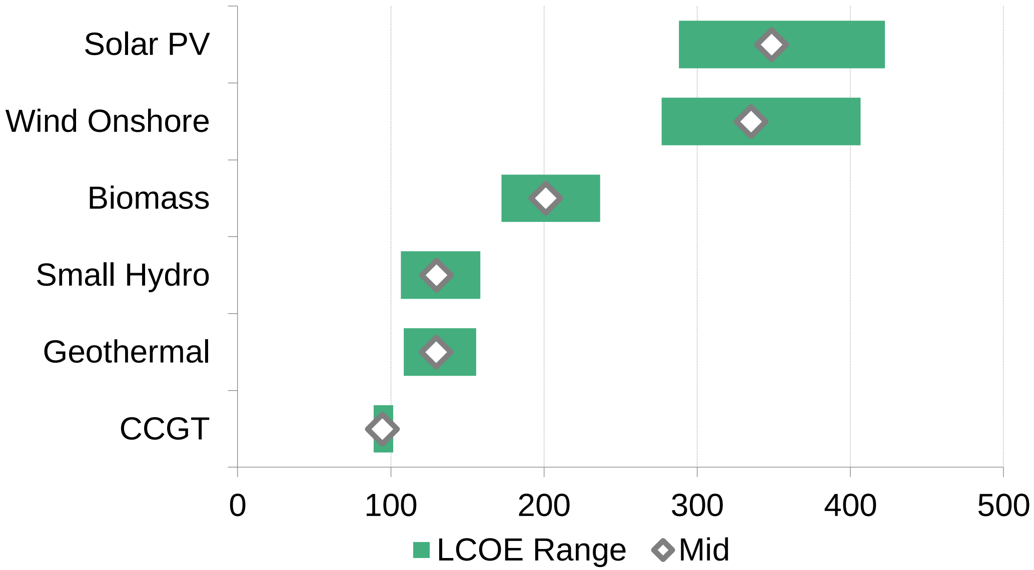
Palestinian territories capacity mix, 2014



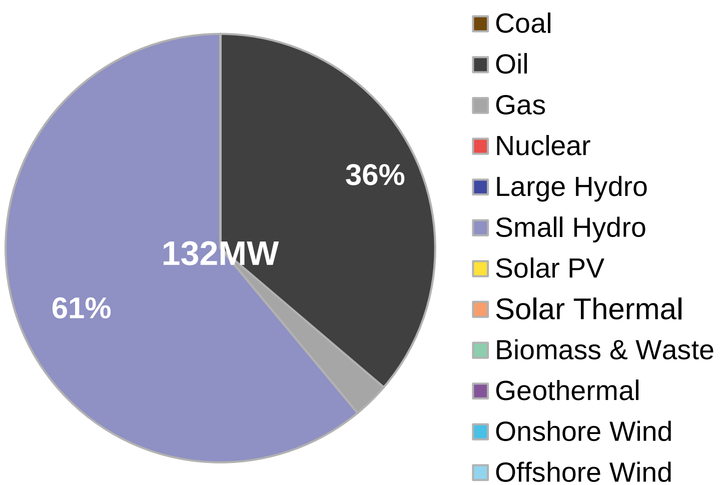
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.70	2.62	3.00	3.72	-	5.68
Capacity factor	-	75%	26%	17%	50%	-	70%
Fixed O&M ($/MW/yr)	-	46,345	60,000	75,000	70,000	-	187,000
Debt ratio	-	0%	0%	0%	0%	-	0%
Cost of debt	-	0.0%	0.0%	0.0%	0.0%	-	0.0%
Cost of equity	-	18.2%	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**-**	**140.5**	**271.1**	**468.1**	**184.1**	**-**	**304.7**

RWANDA

Rwanda LCOE ranges (US$/MWh), 2015



Rwanda capacity mix, 2014

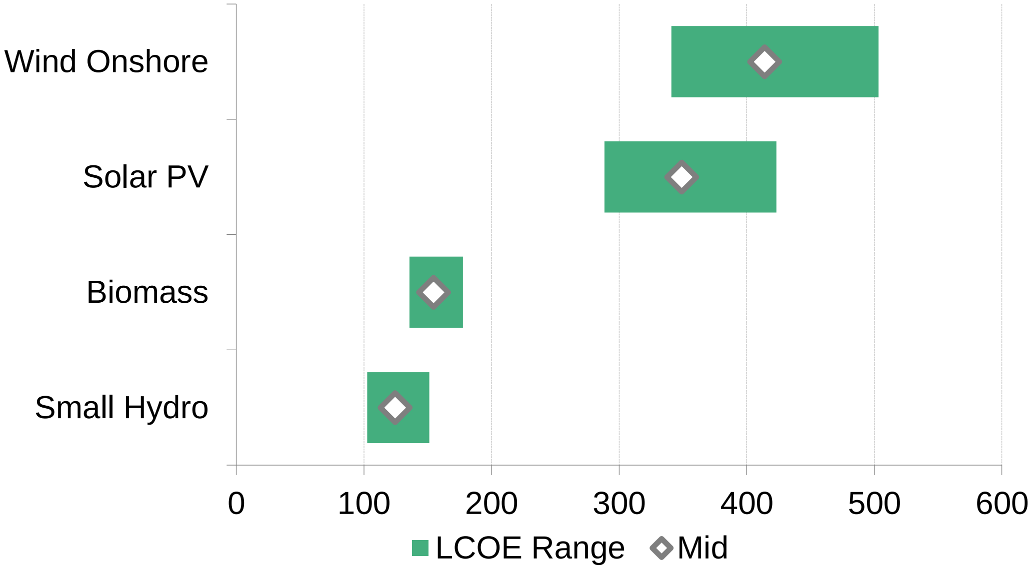


- Rwanda has one of the smaller energy sectors among sub-Saharan countries with 132MW total installed capacity. Around 61% of this is small-hydro, 36% is oil and 3% is gas.
- The country has 2,000bcf of natural gas reserves and 3MW of gas-fired capacity installed. Low capex, O&M and an assumed capacity factor of 75% makes gas CCGT the lowest cost technology option of those we assessed, at $95/MWh.
- Initial reports from the Ministry of Infrastructure suggest 300 MW of geothermal potential are available in Rwanda which they are keen to utilise. We benchmarked our capex and O&M figures for Rwanda on data from Kenya.
- Small hydro is the next best at $130/MWh – higher than other estimates for this technology due to a capacity factor at 50%. There is 14MW of this technology currently under construction.
- Rwanda is landlocked. As such, it as very low wind speeds that translate into an average capacity factor of 10% which gives onshore wind a high LCOE of around $335/MWh.
- Rwanda currently has 9MW of solar PV commissioned with another 19 in planning, however solar still appears expensive in Rwanda, due to high capex and lower capacity factor.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.02	1.66	2.58	3.45	4.05	5.68
Capacity factor	-	75%	10%	16%	50%	80%	70%
Fixed O&M ($/MW/yr)	-	26,640	18,528	42,917	10,729	61,730	36,671
Debt ratio	-	70%	70%	70%	70%	70%	70%
Cost of debt	-	11.7%	12.2%	12.7%	12.2%	13.7%	12.7%
Cost of equity	-	14.7%	15.2%	15.7%	15.2%	15.0%	15.7%
LCOE ($/MWh)	**-**	**94.6**	**335.2**	**348.6**	**129.9**	**129.7**	**201.1**

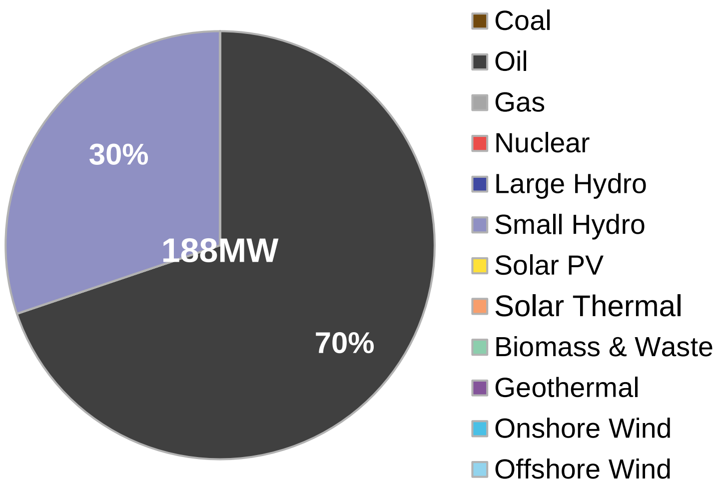
Source: Bloomberg New Energy Finance

Sierra Leone LCOE ranges (US$/MWh), 2015



- Around 70% of Sierra Leone's 188MW of installed power capacity is oil. However the country has no domestic supply and currently imports all petroleum products used in its power and transport sectors.
- The remaining 30% of the country's installed capacity is small-hydro. Like other countries in the region, small hydro is likely to be the Sierra Leone's cheapest form of new electricity with an LCOE of $124/MWh. The country currently has 54MW of new capacity under construction.
- Onshore wind appears to be particularly expensive with very low wind speeds translating into an average 9% capacity factor, pushing the LCOE up to over $400/MWh.
- The lifetime cost of solar PV also appears high. Our estimate of $349/MWh is primarily due to high capex assumptions. However the 6MW Freetown PV plant is now under construction and another 20MW project is in planning.
- Sierra Leone has a low electrification rate of 14%, which might make decentralized generation more interesting for the country.

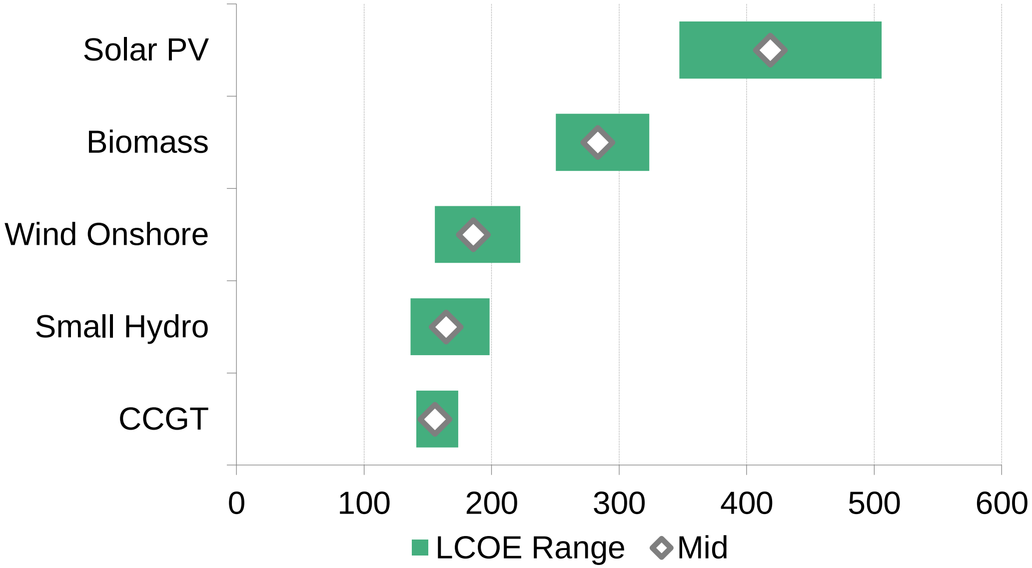
Sierra Leone capacity mix, 2014



	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	-	2.03	2.78	3.40	-	3.60
Capacity factor	-	-	9%	16%	50%	-	70%
Fixed O&M ($/MW/yr)	-	-	17,650	42,196	34,418	-	130,000
Debt ratio	-	-	70%	70%	70%	-	70%
Cost of debt	-	-	11.2%	11.7%	11.2%	-	11.7%
Cost of equity	-	-	14.2%	14.7%	14.2%	-	14.7%
LCOE ($/MWh)	**-**	**-**	**414.0**	**349.1**	**124.4**	**-**	**154.6**

Source: Bloomberg New Energy Finance

Somalia LCOE ranges (US$/MWh), 2015



- Somalia has an estimated 80MW of installed capacity, most likely to be oil-fired. However this fact remains uncertain as publicly available sources did not reveal the technology mix.
- All energy projects in Somalia are assumed to be 100% equity financed due to the high risk environment in the country.
- Due to a lack of experience and available data for the different cost inputs and relevant macroeconomic indicators to create benchmark values, we have adopted the highest capex, O&M, and risk assumptions as inputs.
- Perhaps surprisingly, our onshore wind LCOE estimate is competitive with small hydro and natural gas CCGT due to high average wind speeds.
- We assume standard inputs such as plant lifetimes of 35 years for coal and 25 years for gas, as well as development and construction times, however these may be too high considering the particular unstable conditions on the ground in this country.

Somalia capacity mix, 2014

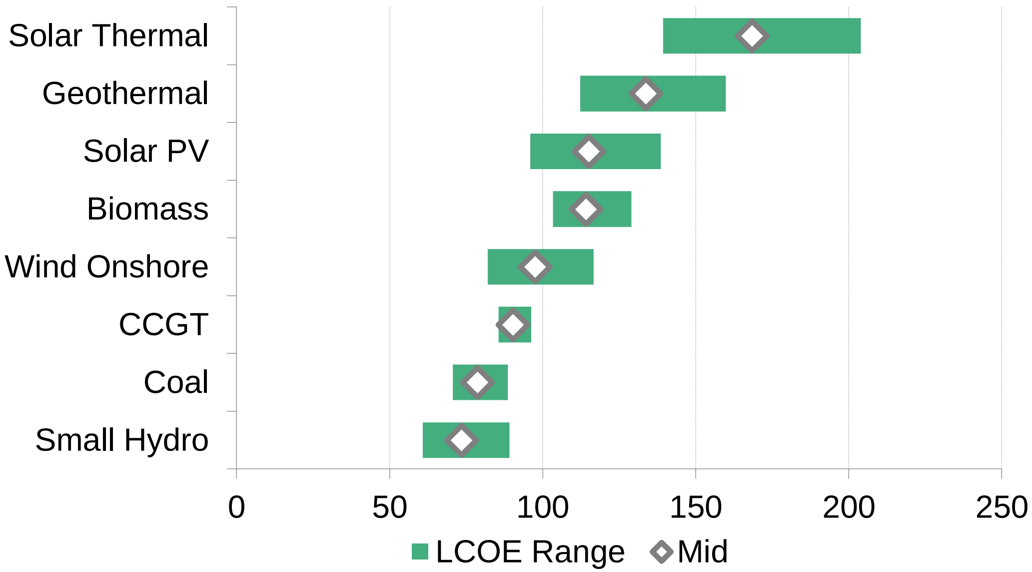
80GW
Details unknown

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.70	2.62	3.00	3.72	-	5.68
Capacity factor	-	55%	35%	17%	50%	-	70%
Fixed O&M ($/MW/yr)	-	46,345	60,000	75,000	70,000	-	187,000
Debt ratio	-	0%	0%	0%	0%	-	0%
Cost of debt	-	0.0%	0.0%	0.0%	0.0%	-	0.0%
Cost of equity	-	18.2%	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**-**	**155.6**	**185.6**	**418.6**	**164.3**	**-**	**283.2**

Source: Bloomberg New Energy Finance

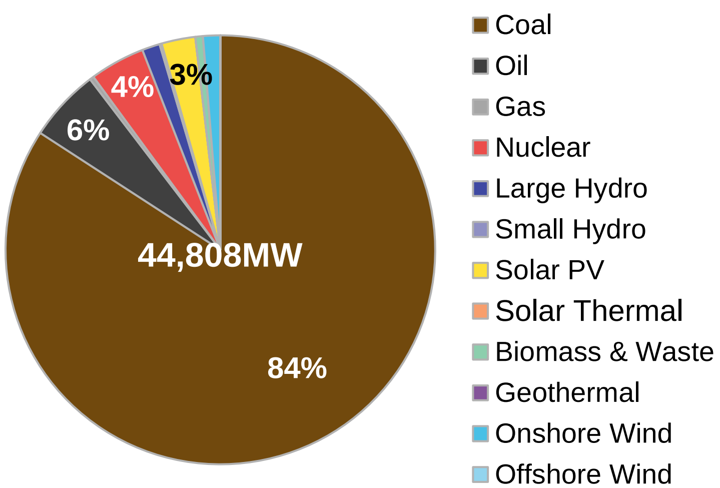
SOUTH AFRICA

South Africa LCOE ranges (US$/MWh), 2015



- Coal makes up 84% of South Africa's installed capacity. However the country is looking to expand renewable generation to help meet demand and help manage supply issues.
- The country enjoys excellent wind and solar resources with solar capacity factors at 22% and wind 30% on average. We estimate the all-in cost of solar PV at $115/MWh and wind at $98/MWh.
- Since 2011 the 'South Africa Renewable Energy Independent Power Producers Procurement (REIPPP) Programme' has operated a capacity auction to help the country hit its 17.8GW target for renewable capacity by 2030. So far 6.3GW has already been allocated. The most recent auction (Round 4) was held in April and June 2015, allocating 2.2GW.
- Bids for solar have recently been coming in as low as $60/MWh with wind at around $50/MWh for 20 year terms. However with a mandated build period of up to 4 years and expectations for a currency rebound we believe these PPA's do not represent the LCOE for projects that will begin construction today.
- Small hydro is the cheapest technology where sites are available. However continuing drought in the region makes this technology difficult to develop.

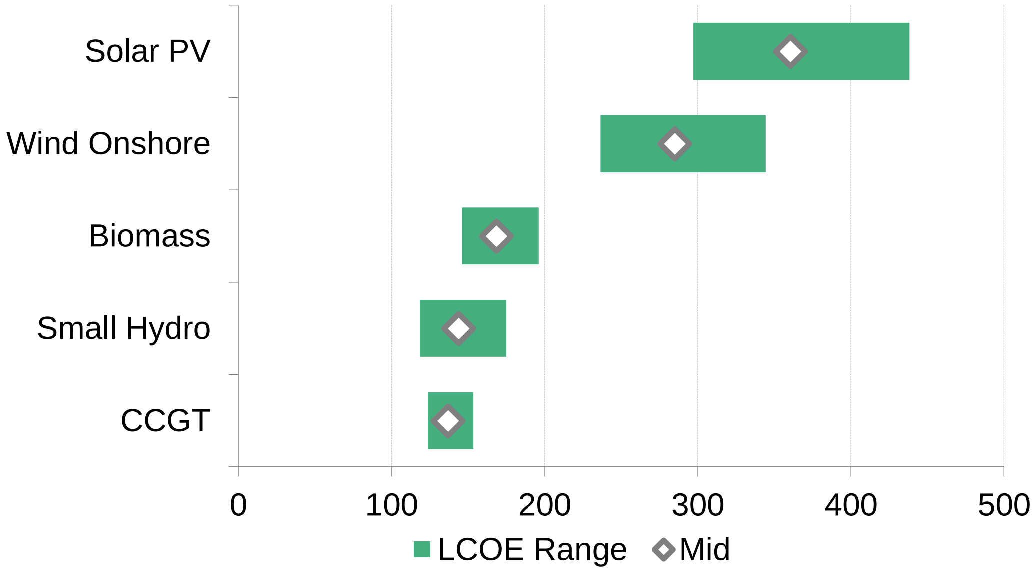
South Africa capacity mix, 2014



	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass	Solar Thermal
Capex ($m/MW)	2.39	1.23	1.68	1.49	2.50	5.11	3.66	3.85
Capacity factor	85%	75%	30%	22%	50%	80%	91%	43%
Fixed O&M ($/MW/yr)	64,000	21,000	26,070	36,000	25,250	106,657	120,639	54,019
Debt ratio	70%	70%	80%	80%	70%	70%	70%	70%
Cost of debt	8.1%	8.1%	8.6%	9.1%	8.6%	10.1%	9.1%	10.1%
Cost of equity	11.1%	11.1%	11.6%	12.1%	11.6%	13.1%	12.1%	13.1%
LCOE ($/MWh)	**78.8**	**90.4**	**97.6**	**115.1**	**73.6**	**133.7**	**114.2**	**168.4**

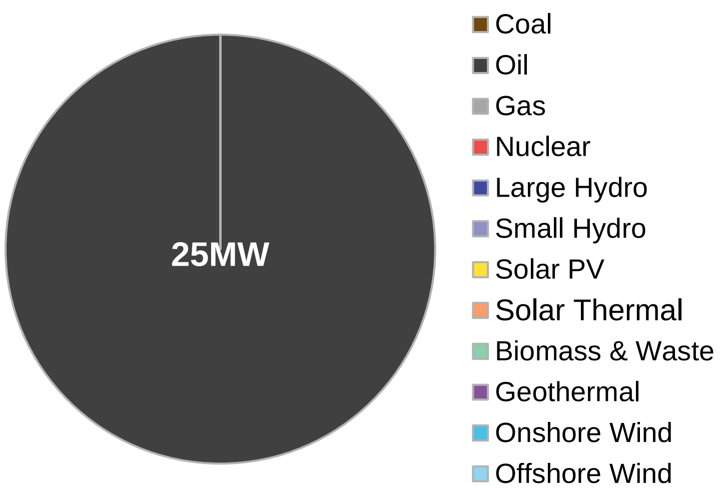
SOUTH SUDAN

South Sudan LCOE ranges (US$/MWh), 2015



- Energy projects in South Sudan are assumed to be 100% equity financed due to the high risk environment in the country.
- South Sudan has a 5% electrification rate and a total installed capacity of around 28MW.
- In order to estimate inputs for sectors other than onshore wind, which are assumed to be the same as Sudan, we used Kenya (small hydro and solar pv) as well as Zimbabwe (biomass) and Tanzania (CCGT) as benchmarks, and adjusted the data according to land, labour and PPP differentials.
- Input assumptions like the operating lifetime of plants as well as development and construction times may also vary from our standard assumptions of 35 years for coal and 25 years for gas due to atypical circumstances arising from conflict, arson, corruption, and other related factors.

South Sudan capacity mix, 2014

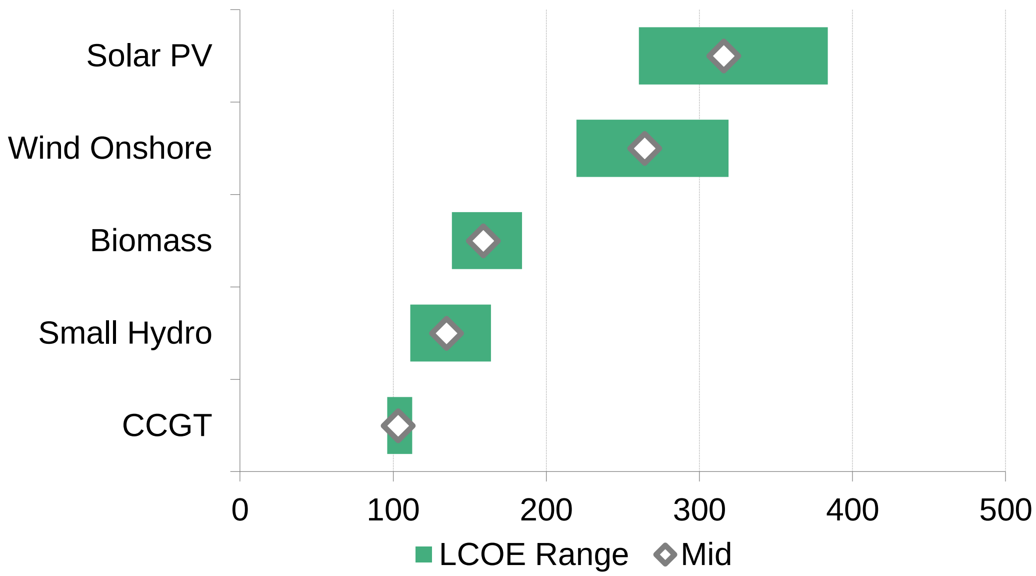


	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.17	1.72	2.08	2.60	-	3.09
Capacity factor	-	55%	18%	17%	50%	-	70%
Fixed O&M ($/MW/yr)	-	26,883	34,864	32,111	33,389	-	49,435
Debt ratio	-	0%	0%	0%	0%	-	0%
Cost of debt	-	-	-	-	-	-	-
Cost of equity	-	18.2%	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**-**	**137.0**	**284.9**	**360.5**	**143.9**	**-**	**168.6**

Source: Bloomberg New Energy Finance

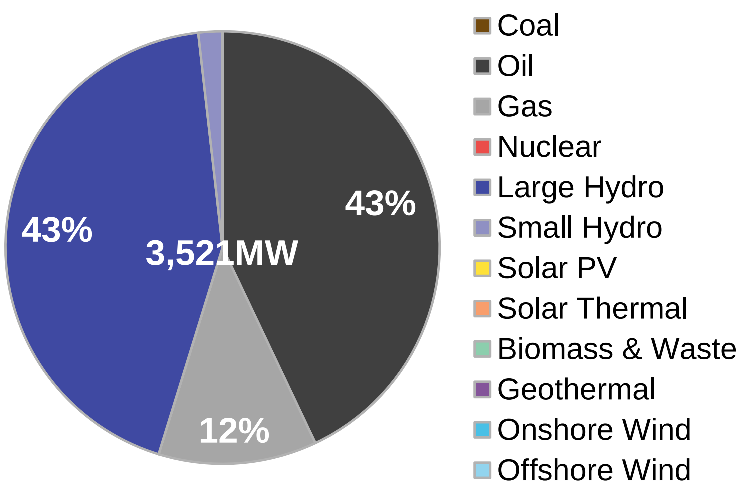
SUDAN

Sudan LCOE ranges (US$/MWh), 2015



- Hydro and oil make up around 88% of the 3,521MW of capacity in Sudan. Another 12%, or 415MW, is natural gas.
- All new technologies in Sudan have inflated LCOEs due to high cost of capital assumptions that reflect country risk.
- The country has proved natural gas reserves of 3,000bcf , however it has yet to be developed. Despite this, CCGT may be the cheapest source of electricity in the country at $103/MWh, around $3 cheaper that the regional average. This is due to the lower capex costs.
- Around 2% of Sudan's installed capacity is small hydro, which with an LCOE of $135/MWh is significantly higher than the African average due to the high cost of debt.
- Sudan also has two solar thermal plants in planning – the 100MW Euromed Darfur I, and the 150MW Euromed Darfur II. These plants were originally due for completion in 2014, however following political instability and the separation of South Sudan in 2011, there has been little news on progress since their announcement.

Sudan capacity mix, 2014

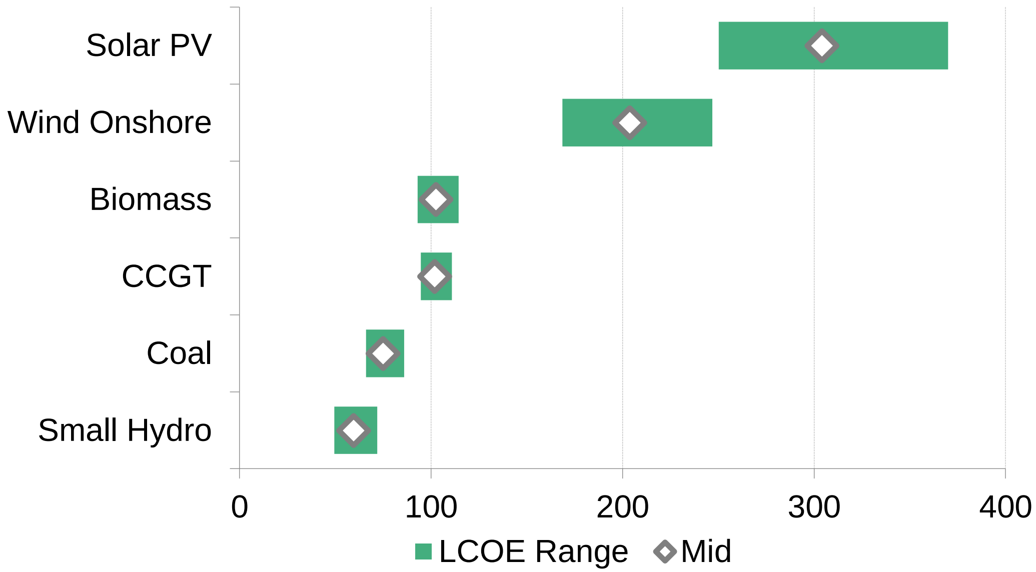


	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	0.94	1.72	2.09	2.62	-	3.10
Capacity factor	-	75%	18%	18%	50%	-	70%
Fixed O&M ($/MW/yr)	-	29,954	35,889	33,056	34,395	-	50,925
Debt ratio	-	70%	70%	70%	70%	-	70%
Cost of debt	-	15.2%	15.7%	16.2%	15.7%	-	16.2%
Cost of equity	-	18.2%	18.7%	19.2%	18.7%	-	19.2%
LCOE ($/MWh)	**-**	**103.4**	**264.4**	**316.0**	**134.9**	**-**	**159.0**

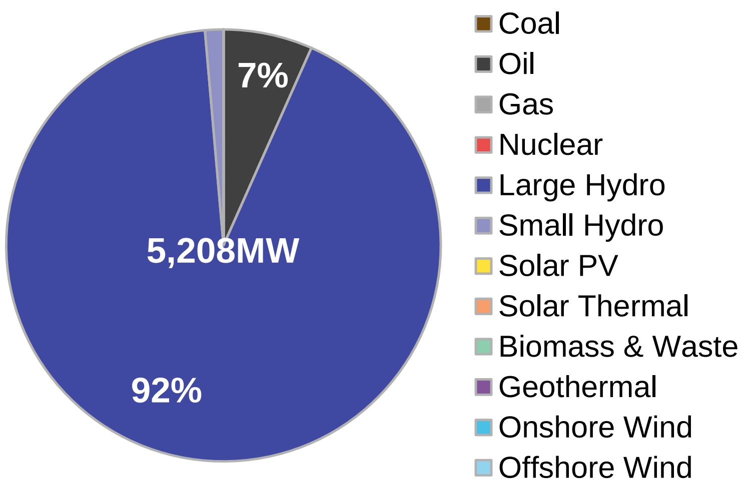
TAJIKISTAN

Bloomberg NEW ENERGY FINANCE

Tajikistan LCOE ranges (US$/MWh), 2015



Tajikistan capacity mix, 2014

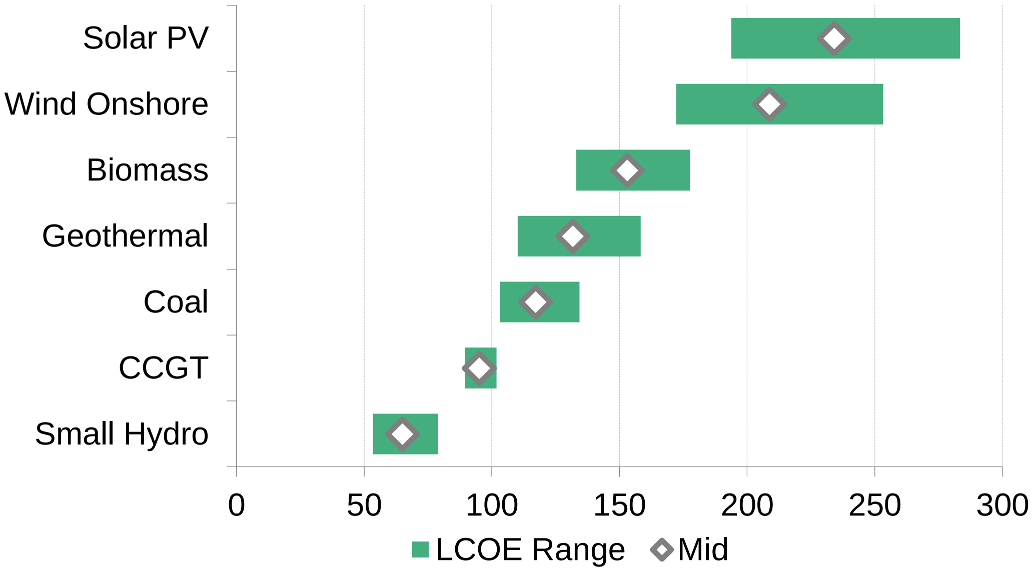


- Tajikstan's 5,208MW of installed power generation capacity is 93% hydro. The remainder is oil.
- There is significant small-hydro potential in the country and we estimate it to be the lowest cost option of the technologies we assessed, with an LCOE of around $60/MWh followed by coal at $75/MWh.
- Tajikistan has recoverable coal reserves of 178Mtoe and domestic production of 140ktoe per year according to the World Energy Council, however this is exclusively coking coal used in industry.
- With no experience in most technologies other than hydro and limited relevant data availability for capex and O&M assumptions, we used benchmark countries – Pakistan for coal, CCGT and biomass, and Bangladesh for solar and wind – all adjusted the according to land, labour and PPP differentials.
- Aside from the high capex assumptions for solar PV, Tajikistan has relatively low solar irradiation resulting in a capacity factor of 14% and an LCOE of $304/MWh.

	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.38	1.07	1.98	2.29	2.13	-	1.75
Capacity factor	55%	55%	18%	14%	65%	-	70%
Fixed O&M ($/MW/yr)	27,990	28,813	19,793	17,445	19,727	-	111,813
Debt ratio	70%	70%	70%	70%	70%	-	70%
Cost of debt	10.7%	10.7%	11.2%	11.7%	11.2%	-	11.7%
Cost of equity	13.7%	13.7%	14.2%	14.7%	14.2%	-	14.7%
LCOE ($/MWh)	**74.9**	**101.9**	**203.9**	**304.1**	**59.5**	**-**	**102.6**

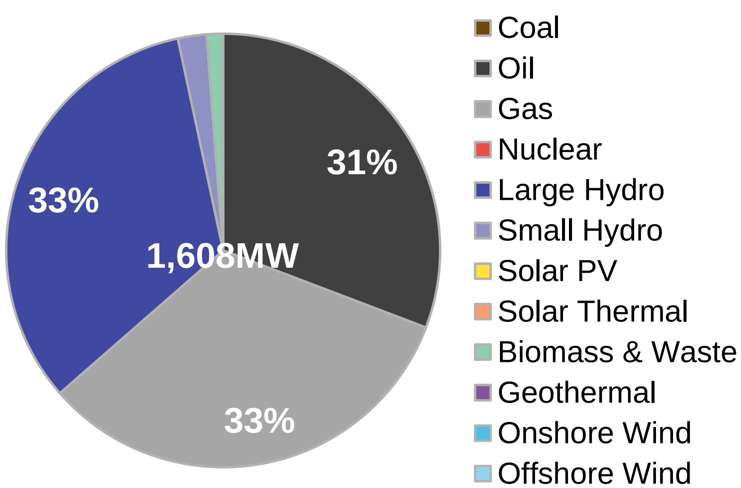
TANZANIA

Tanzania LCOE ranges (US$/MWh), 2015



- Tanzania's 1,608MW of power generating capacity is made up of natural gas, oil and hydro and a very small amount of biomass.
- Small hydro has the lowest LCOE of the technologies we assessed, but its capacity factor is uncertain due to regular drought.
- We estimate the LCOE for CCGT at $95/WMh which reflects low capex and high capacity factor due to the country's experience with the technology and available supply of natural gas.
- Tanzania has around 200 million tonnes of recoverable coal reserves, however the country has no existing coal capacity, leading to high capex assumptions.
- Tanzania has geothermal resource potential of approximately 650MW. Two 100MW projects have been announced – though neither have reached financial close. Our LCOE estimate for a binary geothermal power plant is in line with figures for the region at $132/MWh.
- Tanzania has no installed wind capacity, but has over 2GW in planning, including the giant 1.8GW Singida Wind Farm Phase II.
- The country's first utility-scale solar PV – the 5MW Kigoma plant – is currently under construction. However with an LCOE of over $230/MWh, solar is not yet a strongly competitive option..

Tanzania capacity mix, 2014

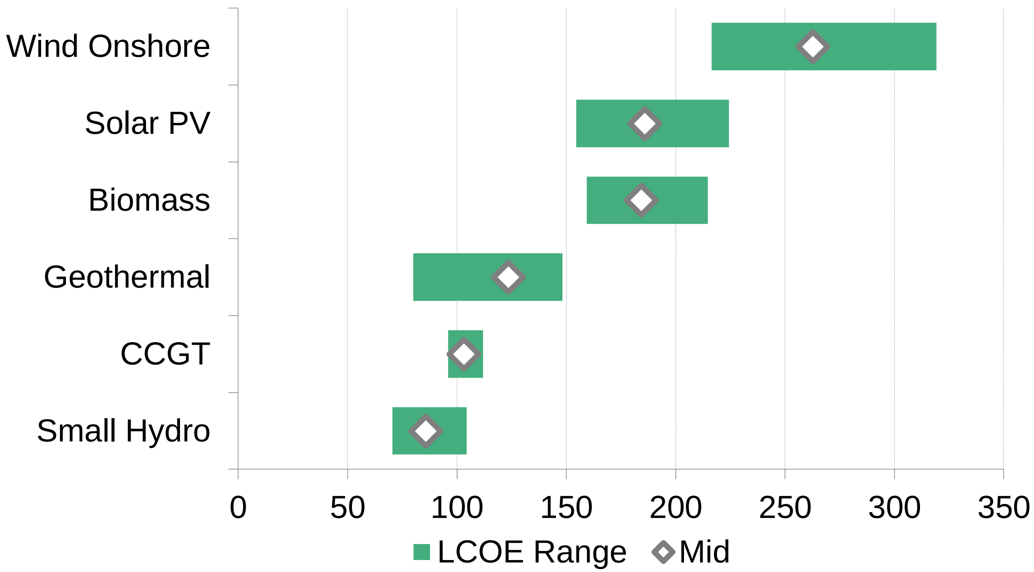


	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	2.75	1.17	2.13	2.10	1.81	3.98	4.02
Capacity factor	75%	85%	20%	19%	51%	80%	70%
Fixed O&M ($/MW/yr)	50,000	27,365	17,950	40,000	10,000	58,242	40,000
Debt ratio	70%	70%	70%	70%	70%	70%	70%
Cost of debt	10.7%	10.7%	11.2%	11.7%	11.2%	12.7%	11.7%
Cost of equity	13.7%	13.7%	14.2%	14.7%	14.2%	15.7%	14.7%
LCOE ($/MWh)	**117.2**	**95.1**	**208.7**	**234.1**	**65.0**	**131.8**	**153.1**

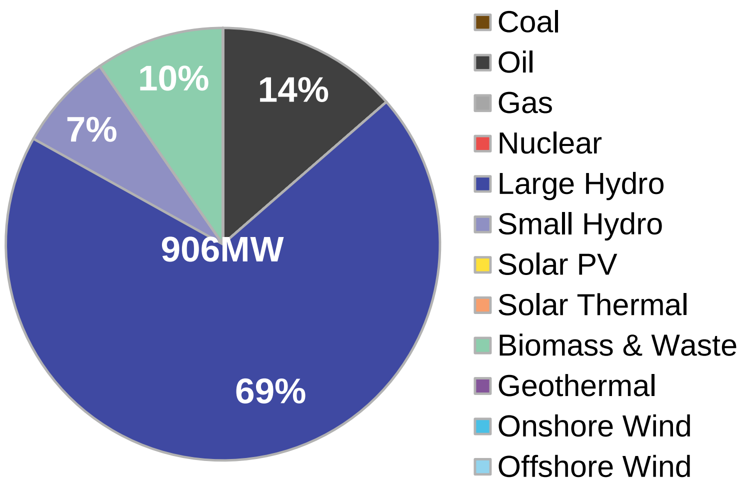
Source: Bloomberg New Energy Finance

UGANDA

Uganda LCOE ranges (US$/MWh), 2015



Uganda capacity mix, 2014



- Uganda is rich in hydro resources, which has thus shaped its energy mix. However the country has only 18% electrification.
- Small hydro – which currently accounts for 7%, or 66MW of installed capacity – is the cheapest of the technologies assessed. This is due to relatively low capex and O&M costs which reflect local experience. The country currently has around 60MW under construction and a further 100MW in the pipeline. Small hydro could be the only remaining hydro option when considering a 2008 report from Aldwych that suggests the completion of the Bujagali and Karuma large hydro projects have exhausted the larger scale options available outside the Murchison National Park.
- The same Aldwych report also mentions biomass as a feasible alternative to expensive emergency oil generation capacity, citing the benefits of local fuel supplies and an estimated $4.3m/MW capex costs (converted to $4.95m/MW in 2015 dollars). Despite this, at $184/MWh, the cost of new biomass appears relative high on a regional basis.
- Uganda has proven gas reserves, but no domestic production and no installed gas-fired power capacity. Applying a low capacity factor of 55% due to uncertainty about fuel availability, we estimate an LCOE for CCGT at $103/MWh.
- At $1.57/W, Uganda's solar PV capex is one of the lowest in the region. This reflects all-in bids by solar developers as low as $163.8/MWh. The country has around 72MW of solar PV in the pipeline.

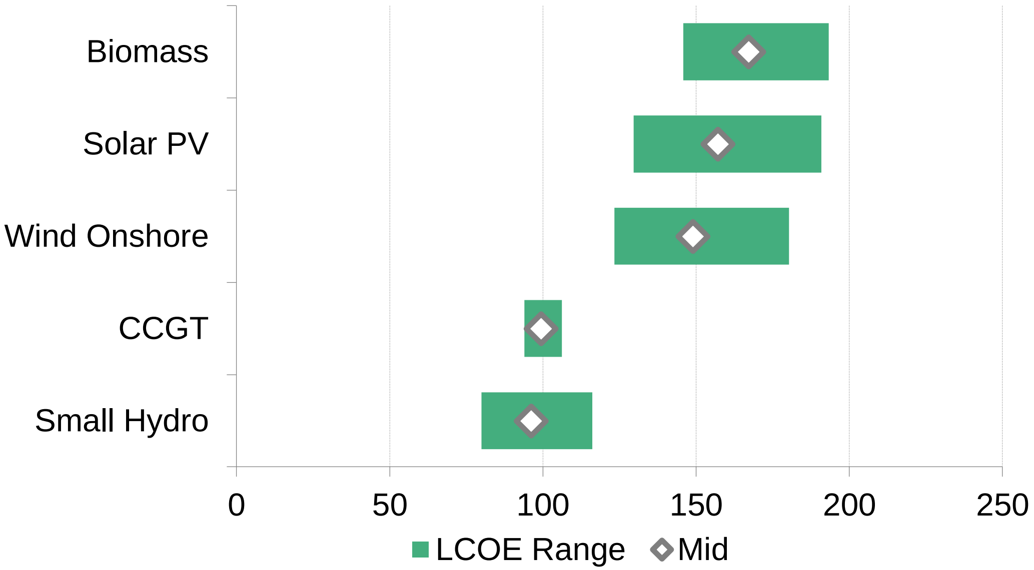
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.01	2.56	1.57	2.43	3.98	4.95
Capacity factor	-	55%	18%	18%	50%	80%	70%
Fixed O&M ($/MW/yr)	-	26,048	17,841	39,067	9,767	55,419	111,325
Debt ratio	-	70%	70%	70%	70%	70%	70%
Cost of debt	-	10.7%	11.2%	11.7%	11.2%	12.7%	11.7%
Cost of equity	-	13.7%	14.2%	14.7%	14.2%	15.0%	14.7%
LCOE ($/MWh)	**-**	**103.2**	**262.7**	**186.0**	**85.8**	**123.5**	**184.2**

Source: Bloomberg New Energy Finance

YEMEN

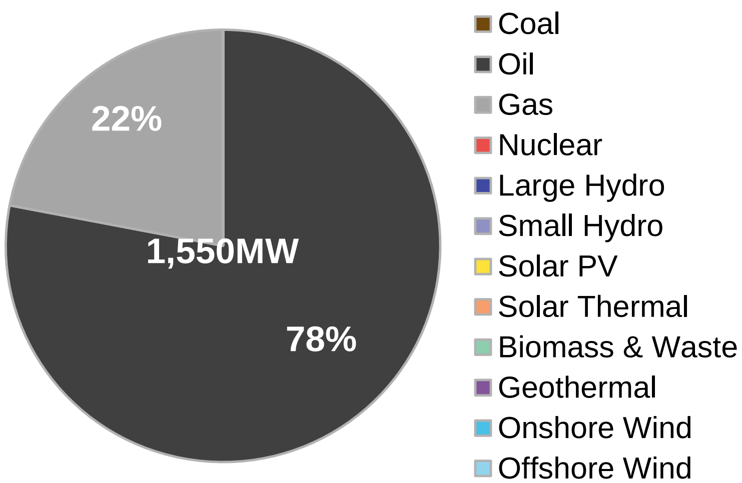
Bloomberg NEW ENERGY FINANCE

Yemen LCOE ranges (US$/MWh), 2015



- Yemen's electricity sector is made up of oil and gas-fired generation.
- Natural gas CCGT is the cheapest of the generation technologies assessed, at around $99/MWh. Experience with this technology and gas management explains our relatively low capex and O&M cost assumptions.
- Yemen holds around 17tcf of proved natural gas reserves, and is considering expanding its gas power generation infrastructure due to domestic fuel availability.
- Due to the political turmoil and high country risk, we have assumed 0% debt financing for all technologies in Yemen.
- Although Yemen has no experience installing onshore wind and solar PV which leads to high capex assumptions, it has excellent wind and solar resources that yield high capacity factors. Overall we estimate wind at $149/MWh and solar PV at around $157/MWh.

Yemen capacity mix, 2014



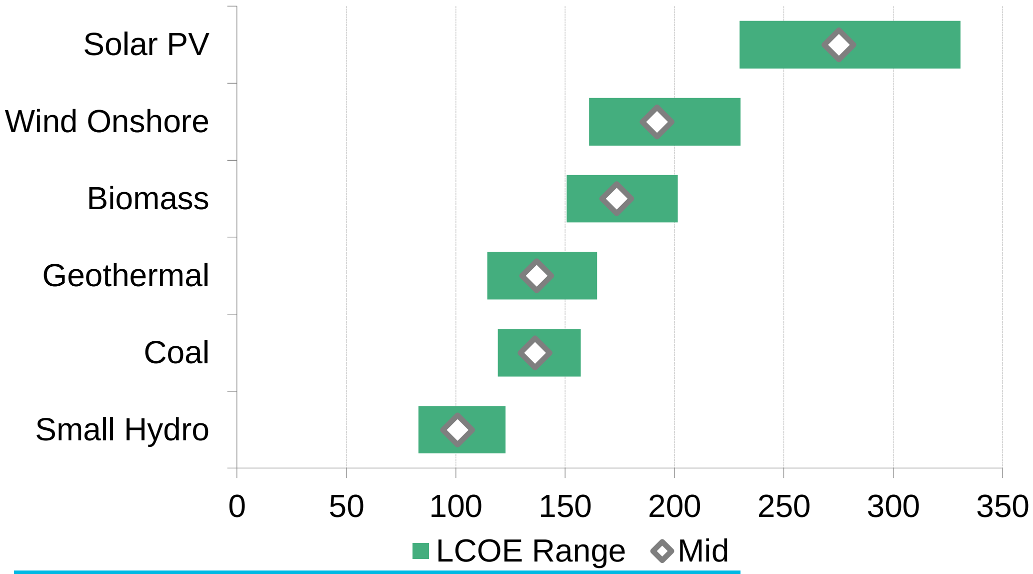
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	-	1.02	1.78	1.54	1.22	-	4.05
Capacity factor	-	75%	24%	20%	25%	-	70%
Fixed O&M ($/MW/yr)	-	28,636	16,667	18,298	19,606	-	111,165
Debt ratio	-	0%	0%	0%	0%	-	0%
Cost of debt	-	0.0%	0.0%	0.0%	0.0%	-	0.0%
Cost of equity	-	13.7%	14.2%	14.7%	14.2%	-	14.7%
LCOE ($/MWh)	**-**	**99.4**	**149.0**	**157.2**	**96.2**	**-**	**167.2**

Source: Bloomberg New Energy Finance

ZAMBIA

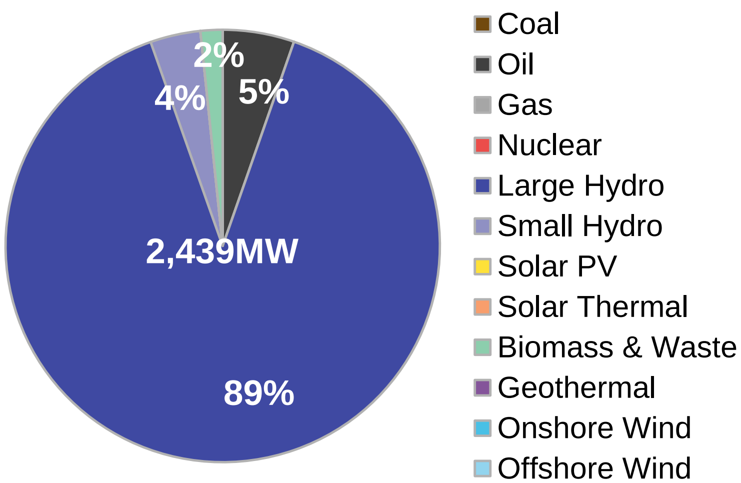
Bloomberg NEW ENERGY FINANCE

Zambia LCOE ranges (US$/MWh), 2015



- Around 89% of the 2,439MW of installed capacity in Zambia is large hydro.
- Small hydro accounts for just 4% but is likely to be the cheapest form of new electricity generation in the country. Although its 45% capacity factor is somewhat lower than average for small-hydro it is likely to have relatively low capex and fixed O&M costs based on benchmark data collected for Tanzania. Zambia has 43MW of small-hydro in the pipeline, 41MW of which is currently under construction.
- Zambia has 10 million tonnes of recoverable coal reserves however ithas no domestic coal production. To reflect the resultant uncertainty in fuel supply and the lack of domestic experience we have applied a 55% capacity factor and higher than average capex. Together these push the LCOE for coal to $136/MWh.
- Zambia has no experience deploying solar PV or onshore wind and so despite good capacity factors, capex, O&M and financing costs are high, with final LCOEs estimated at $275/MWh and $192/MWh respectively

Zambia capacity mix, 2014



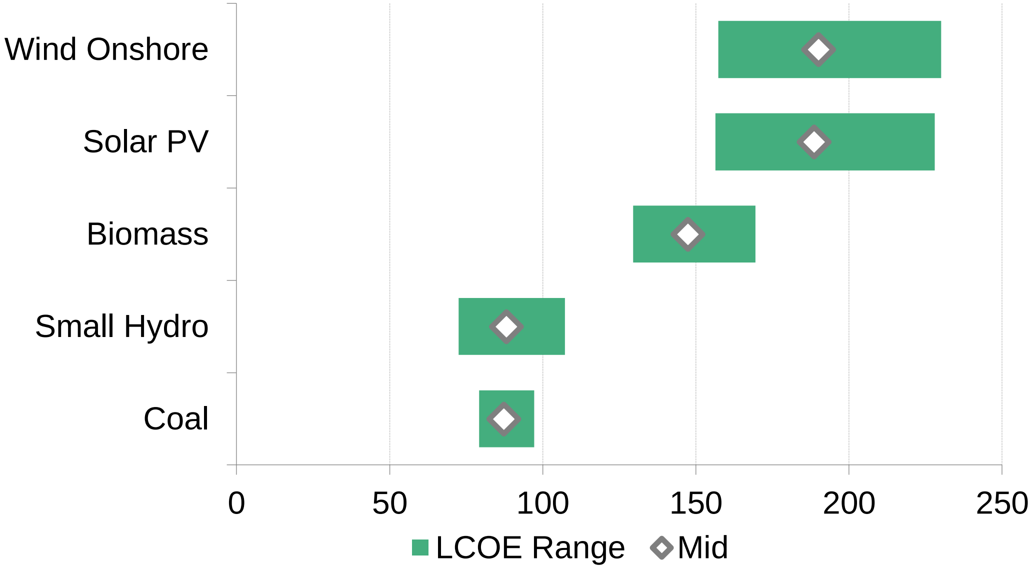
	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	2.39	-	1.67	2.14	2.47	4.09	4.37
Capacity factor	55%	-	20%	18%	45%	80%	70%
Fixed O&M ($/MW/yr)	57,954	-	60,000	75,000	11,591	62,709	111,571
Debt ratio	70%	-	70%	70%	70%	70%	70%
Cost of debt	10.7%	-	11.2%	11.7%	11.2%	12.7%	11.7%
Cost of equity	13.7%	-	14.2%	14.7%	14.2%	15.7%	14.7%
LCOE ($/MWh)	**136.3**	**-**	**192.1**	**275.2**	**100.8**	**137.0**	**173.6**

Source: Bloomberg New Energy Finance

ZIMBABWE

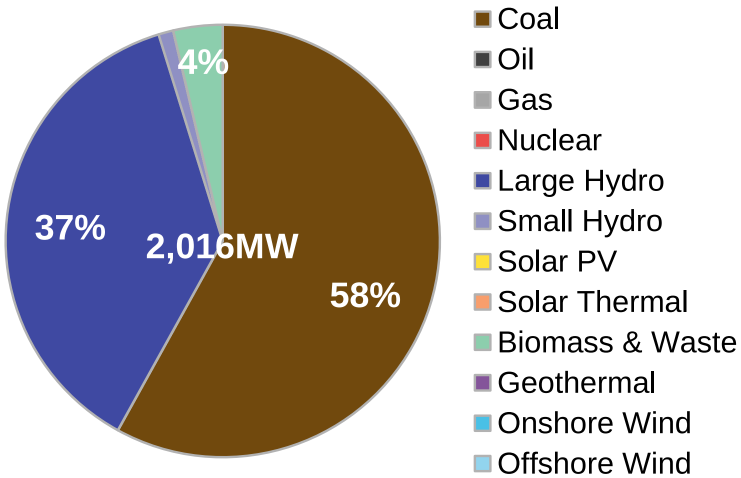
Bloomberg NEW ENERGY FINANCE

Zimbabwe LCOE ranges (US$/MWh), 2015



- Coal-fired power generation currently accounts for 58% of Zimbabwe's 2,016MW of installed power capacity, supported by domestic coal production. It is perhaps not surprising therefore that coal has the lowest LCOE at $87/MWh.
- Zimbabwe has a significant hydro potential. The Zambezi river has the potential to generate 37TWh of electricity per annum, of which about 10TWh per annum have been harnessed.
- Potential for small-scale hydropower also exists in Zimbabwe, and is mostly concentrated in the Eastern part of the country where terrain and rainfall patterns make it most viable. In February 2015, the 15MW Pungwe B small hydro plant was commissioned and there is another 8MW of small-hydro in the development pipeline, 3MW of which is currently under construction.
- Zimbabwe has no installed wind or solar capacity, however the country does have a large pipeline with 900MW of solar PV under development spread over 11 projects.
- Good solar resource and relatively strong wind speeds for sub-Saharan Africa should make both technologies increasingly attractive if capex and financing costs can be brought down.

Zimbabwe capacity mix, 2014



	Coal	CCGT	Wind Onshore	Solar PV	Small Hydro	Geothermal	Biomass
Capex ($m/MW)	1.30	-	1.73	1.47	2.20	-	3.12
Capacity factor	75%	-	20%	18%	50%	-	70%
Fixed O&M ($/MW/yr)	71,469	-	21,239	33,671	14,294	-	112,833
Debt ratio	70%	-	70%	70%	70%	-	70%
Cost of debt	12.7%	-	13.2%	13.7%	13.2%	-	13.7%
Cost of equity	15.7%	-	16.2%	16.7%	16.2%	-	16.7%
LCOE ($/MWh)	**87.3**	**-**	**190.1**	**188.6**	**88.1**	**-**	**147.5**

LCOE SUMMARY BY TECHNOLOGY

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ONSHORE WIND LCOE BY COUNTRY ($/MWH)

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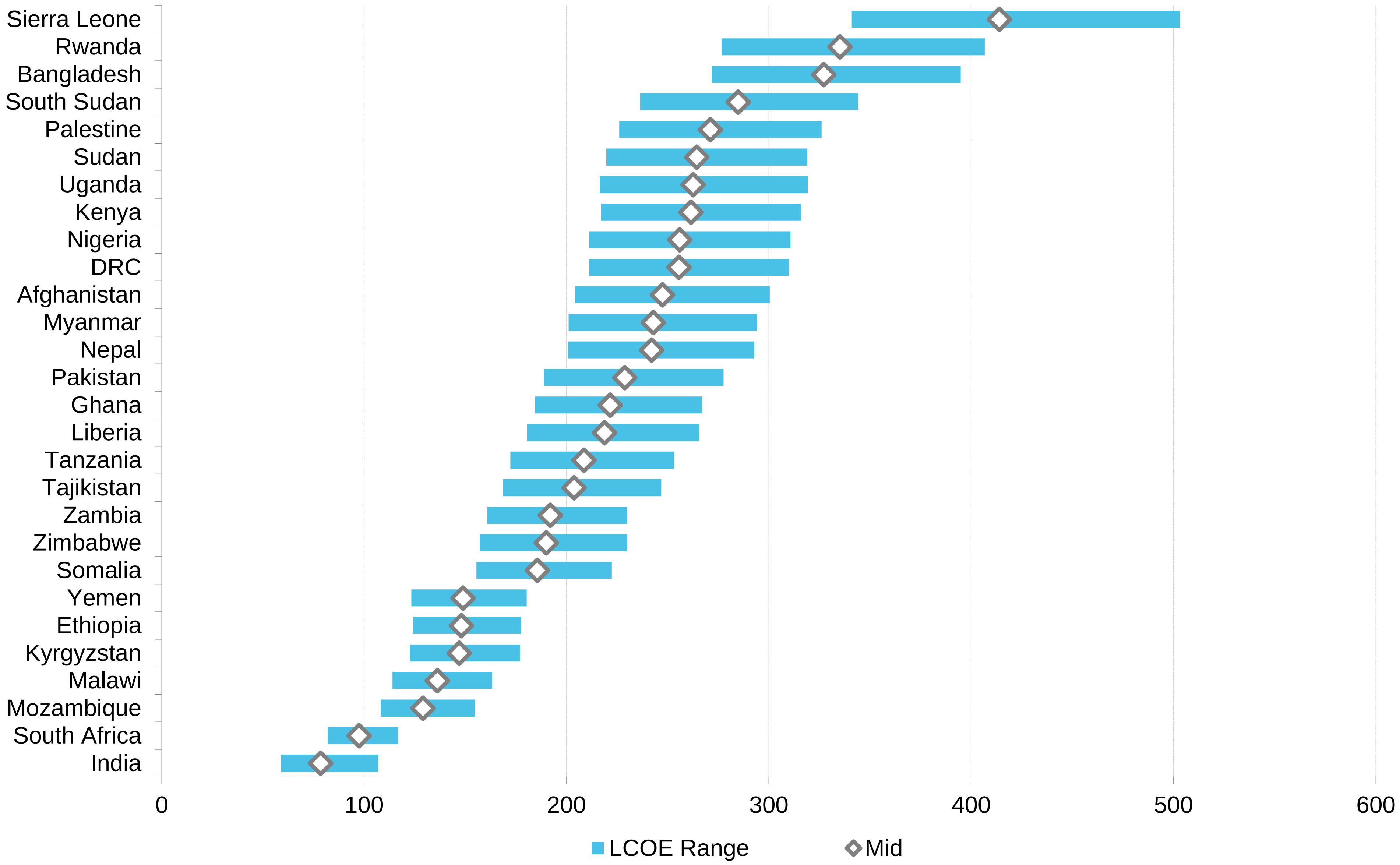

SOLAR PV LCOE BY COUNTRY ($/MWH)

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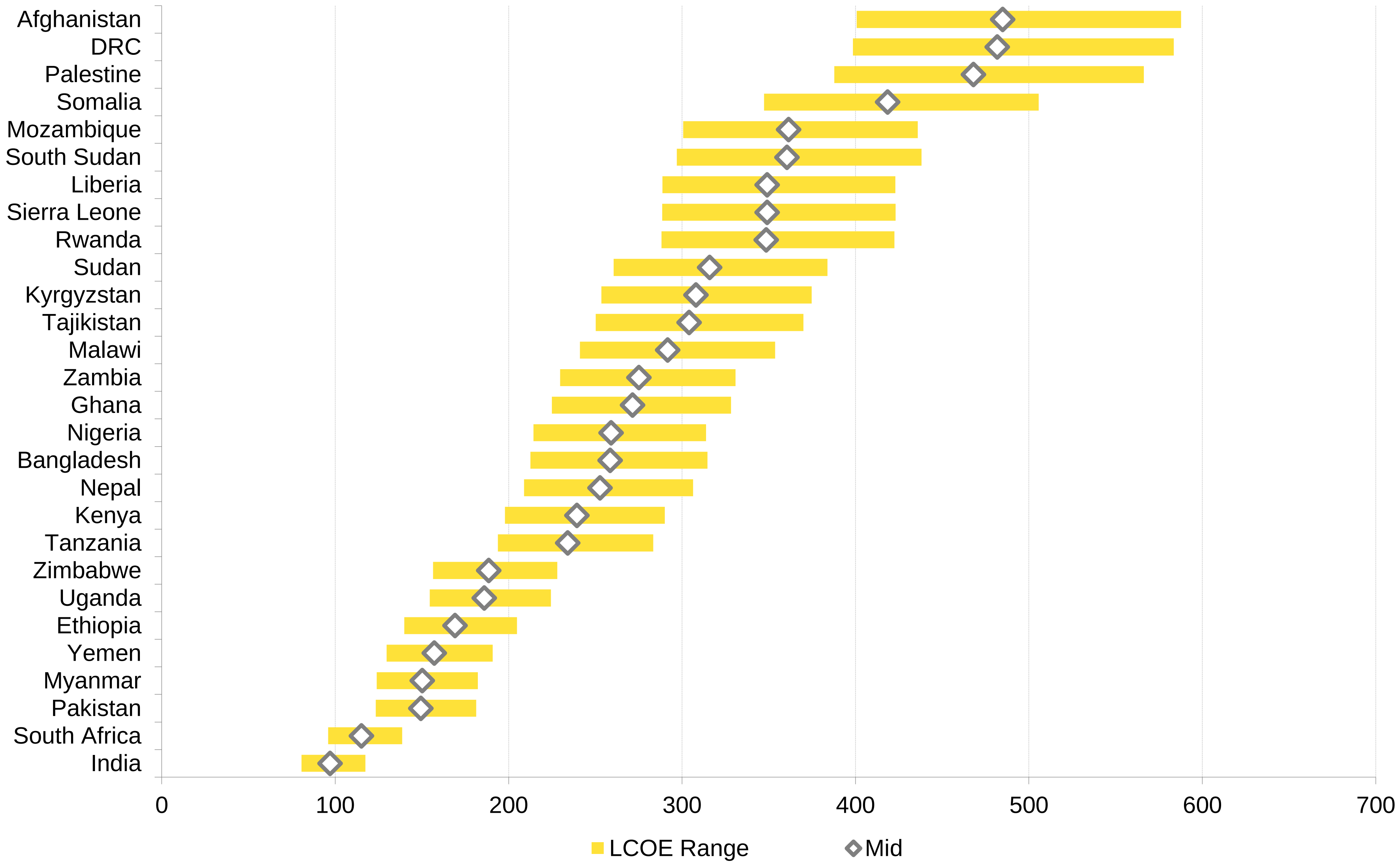
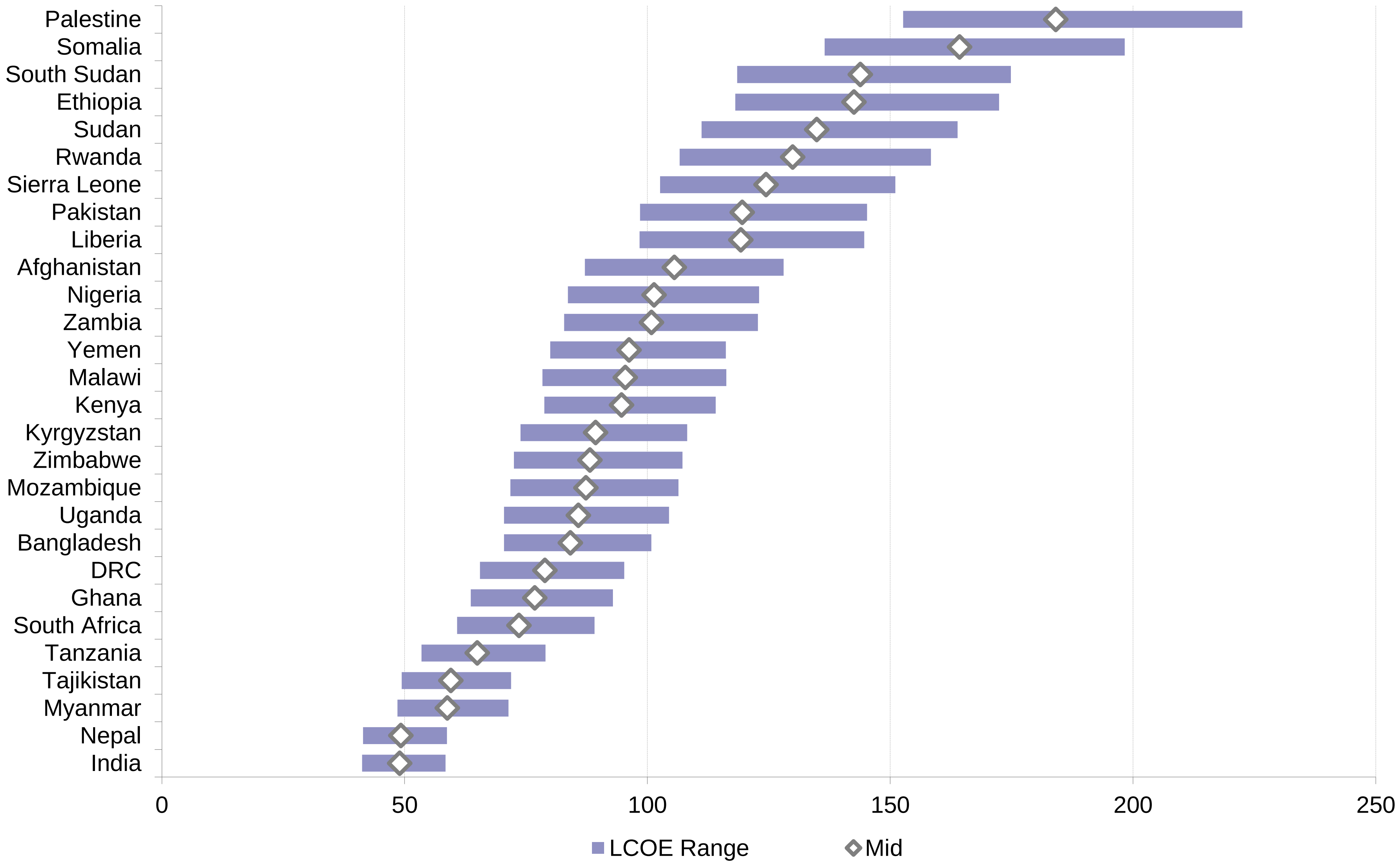


SMALL HYDRO LCOE BY COUNTRY ($/MWH)



BIOMASS INCINERATION LCOE BY COUNTRY ($/MWH)

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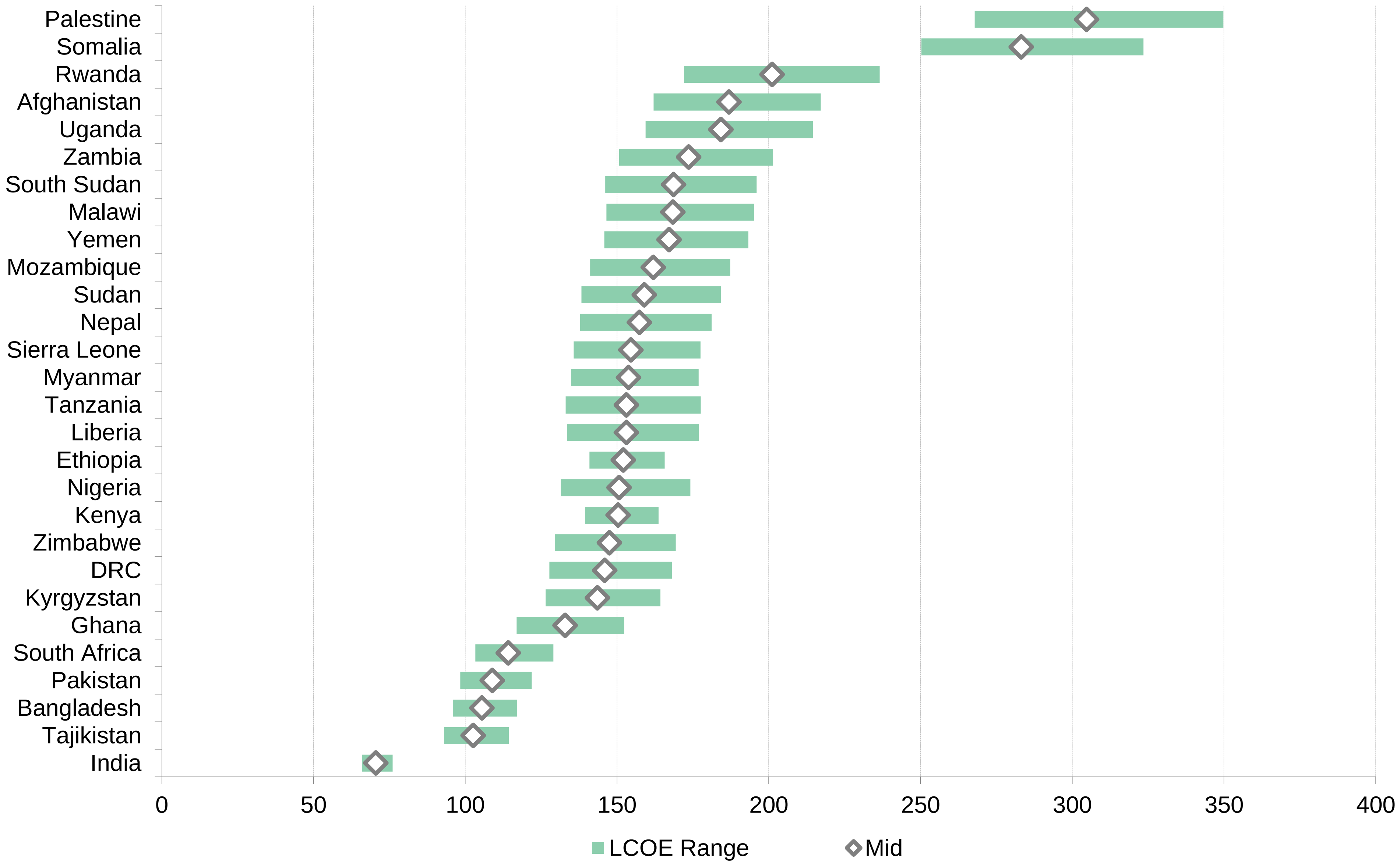
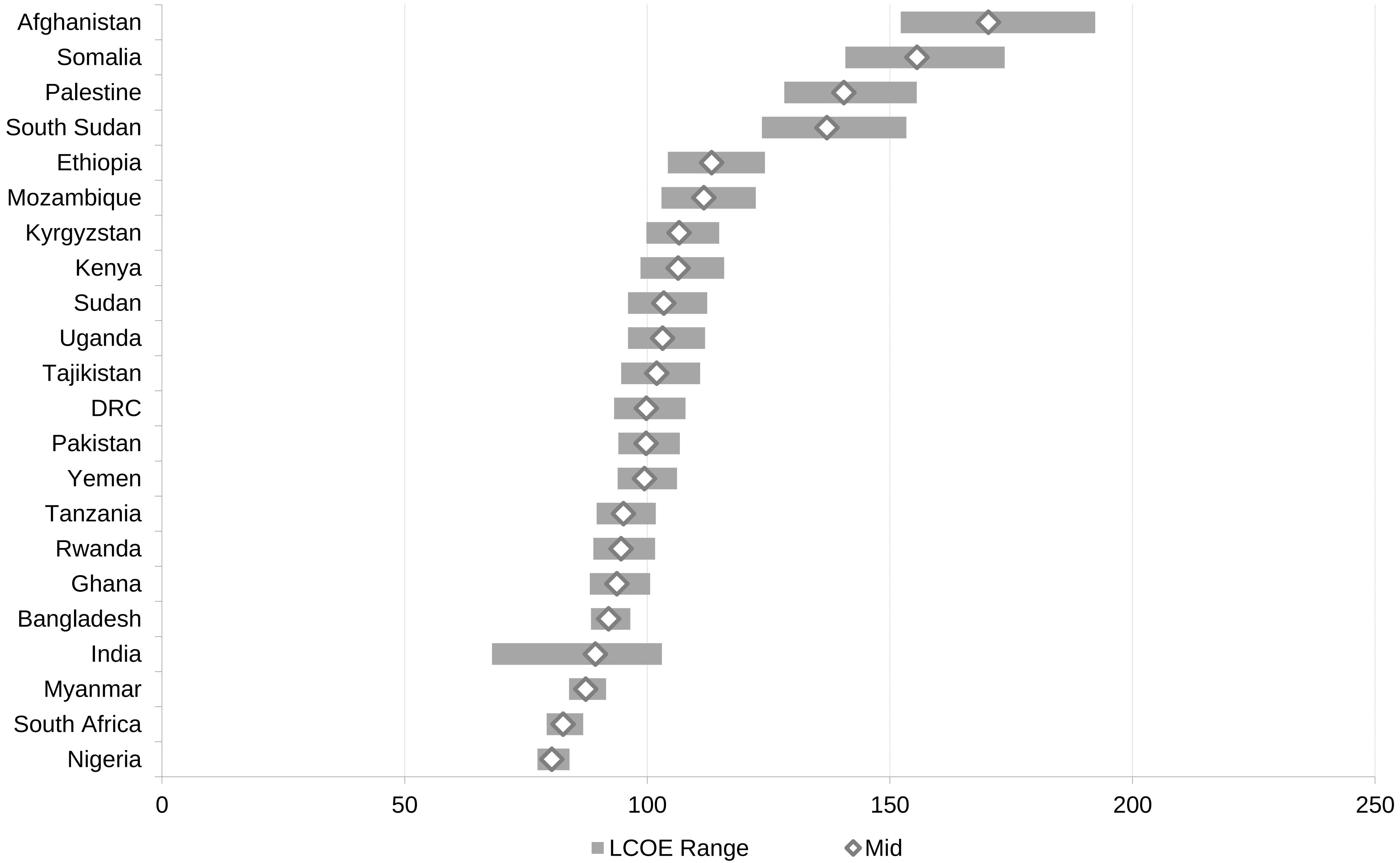


CCGT LCOE BY COUNTRY ($/MWH)



COAL LCOE BY COUNTRY ($/MWH)

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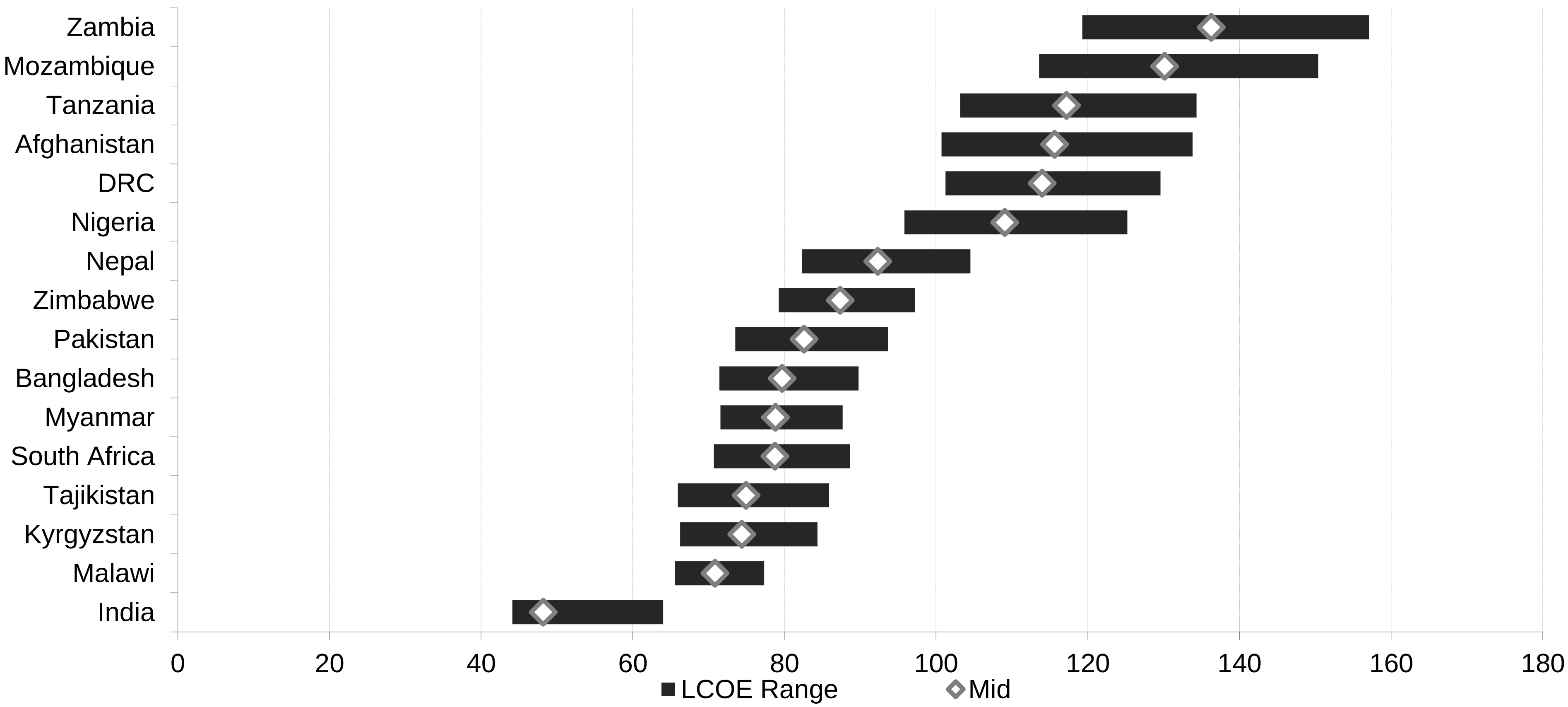

APPENDIX 1: DETAILED METHODOLOGY

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DATA COLLECTION

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- We have used a “three option” approach to data collection. Option A is data collection from disclosed project information, third party research and institutional datasets. When no data can be found under Option A, Option B is followed which involves creating local data sets using regional benchmarks, adjusted using macroeconomic differentials. In some particularly difficult cases where there is no available data and no macroeconomic data with which to create regional benchmarks, we apply cost estimates from a comparable country.

OPTION A

USE DATA AVAILABLE

- Data from publicly available project information, research reports and institutions. This data is used to directly build up the LCOE. On-the-ground primary data collection is beyond the scope of this project.

OPTION B

NO DATA BUT EXTRAPOLATION POSSIBLE

- Where raw data is not disclosed we extrapolate data by creating benchmarks against which relevant macro comparables such as land & labour differentials, purchasing power parity comparisons and country risk indexes can be applied to create local estimates.

OPTION C

NO DATA AND NO POTENTIAL FOR EXTRAPOLATION

- In particularly difficult cases where no data exists and no reliable macro indexes can be applied to extrapolate the data, we revert to using figures derived from either plan A or plan B for a comparable country.

LCOE: DEFINITION AND INTERPRETATION II

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LCOE Component	Units	Definition
Capacity Factor	%	Ratio of total generation to the total nameplate capacity.
Degradation	%	The annual degradation in the capacity factor
Availability	%	The proportion of time the plant is available for generation
Capex	$	Core component costs, (eg: turbines, towers, modules), non-equipment construction costs, (eg: foundations, facilities, security, on site electrical) and pre constructions costs, eg: permitting, application, siting, land. Excludes grid connection or off site transmission costs
OPEX (Fixed)	$/MW/year	Annual operating costs that will remain fixed regardless of total generation levels, eg: administrative, rent/lease contract costs, insurance, fees
OPEX (Variable)	$/MWhr	Cost that are dependent on generation, eg: fuel, carbon, maintenance (if there is no fixed contract).
Heat rate	MWhr/Fuel unit	An indicator of fuel efficiency, it shows how much electricity can be generated per unit of fuel combusted. This is the result of both plant efficiency and fuel heat content.
Equity hurdle rate (IRR)	%	The required return rate for the equity share of the project
Term loan tenor	Years	Average number of years over which the project loan is repaid
Term loan rate	bps	All in interest rate for the loan on the project which is used to refinance construction debt.
Tax rate	%	Country specific corporation tax at which project revenues will be taxed

METHODOLOGY – CAPEX

CAPEX data collection and treatment

- Capex figures are obtained, where available, through BNEF proprietary or publicly available data sets.
- These figures are then adjusted to 2015 $US in order for them to be comparable. For solar PV and onshore wind, an additional technology-specific discount is applied to reflect costs reductions over time in line with established technology learning curves. For solar PV, we assume a 16% decrease in system costs for every doubling of capacity double of capacity, this figure stands at 14% for onshore wind. We also assume that wind and solar installed capacity double every two years, resulting in a 7% and 8% yearly learning rate for onshore wind and solar pv, respectively.
- Capex figures for the remaining technologies (coal, gas, biomass, small hydro, geothermal, and solar thermal) are adjusted at a 2% inflation rate.

CAPEX extrapolation in the case of missing data

- In instances when capex data is unavailable for a given country and/or technology, we extrapolate by benchmarking against a comparable country, and adjust for labour, land, and purchasing power parity differentials using the following methodology:
  - 15% of the 'balance of plant' capex component are adjusted for: labour (5%), land (5%), and for purchasing power parity (5%) differentials.

$$[\text{CAPEX}]_i = [\text{Development costs}]_i + [\text{Balance of plant}]_i + [\text{Equipment costs}]_I$$

$$[\text{CAPEX}]_{\text{extrapolated from } i} = [\text{Development costs}]_i + 85\%[\text{Balance of plant}]_i + 15\%[\text{Balance of plant adjusted for land (5\%), labor (5\%) and PPP (5\%)}] + [\text{Equipment costs}]$$

METHODOLOGY – O&M

O&M data collection

- O&M figures are obtained, where available, through BNEF proprietary or publicly available data sets.
- We differentiate between two types of operational expenditures, both of which exclude fuel costs:
  - Fixed operation and maintenance costs, and
  - Variable operation and maintenance costs.

O&M extrapolation in the case of missing data

- In instances when O&M data is unavailable for a given country and/or technology, we extrapolate by benchmarking relevant data points using the following methodology:
  - For fixed O&M: 15% of the comparable fixed O&M is adjusted for: labour (5%), land (5%), and for purchasing power parity differentials (5%).

$$\textbf{[Fixed O\&M]}_{\textbf{extrapolated from i}} \textbf{ = 85\%[Fixed O\&M]}_{\textbf{i}} \textbf{ + 15\%[Fixed O\&M}_{\textbf{i}} \textbf{ adjusted for land, labor and PPP]}$$

  - For variable O&M: 10% of the comparable variable O&M is adjusted for: labour (5%), and for purchasing power parity differentials (5%).

$$\textbf{[Variable O\&M]}_{\textbf{extrapolated from i}} \textbf{ = 90\%[Variable O\&M]}_{\textbf{i}} \textbf{ + 10\%[Variable O\&M}_{\textbf{i}} \textbf{ adjusted for labor and PPP]}$$

METHODOLOGY – CAPACITY FACTORS

Capacity factor data collection

- Capacity factors represent the total actual generation of a plant as a proportion of its nameplate generation capacity.

$$\textbf{Capacity Factor} = \frac{\textbf{Elecicity generation per year}[\textbf{MWh}]}{\textbf{Nameplate capacity }[\textbf{MW}]\textbf{ x Number of hours per year }[\textbf{hr}]}$$

In theory this means that the capacity factor is derived from a combination of:

- The available generation potential, eg: solar irradiation or fuel availability
- The plant efficiency, and
- The proportion of total available generation that is utilised for the grid (load factor).

METHODOLOGY – CAPACITY FACTORS

Capacity factor calculation, data gathering, and assumptions

- Solar PV capacity factors are modelled using PVGIS data, and assuming a crystalline silicone module with a free-standing mounting position, an optimized module inclination depending on location, and 14% system loss estimation. The resulting solar capacity factors are obtained using a national average which is calculated based on a set of data points collected for each country.
- Onshore wind capacity factors are modelled using the BNEF tool: WCFT. Measurements are performed assuming a General Electric 103 meter rotor 2.75MW turbine with an 85 meter hub height. The resulting wind capacity factors are obtained using a country average which is calculated based on a set of data points collected for each country.
- For the remaining technologies (coal, gas, biomass, small hydro, geothermal, and solar thermal), capacity factor figures are obtained, when available, from publicly available resources.
- In instances when capacity factor data is unavailable for a given country and/or technology, then a technology-specific capacity factor is allocated. It is important to highlight that capacity factors for thermal technologies can vary greatly depending on local grid characteristics.

METHODOLOGY – COST OF FINANCE

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Cost of finance methodology assumptions

- Many of the countries covered for the DFID study suffer from volatile currency regimes, high inflation environments and underdeveloped domestic capital markets. As a further practical constraint, data on local debt costs and return expectations is incredibly scarce. Most project investments in the countries in question are likely to be supported and/or funded by international players, in addition to local developers.

- We have model LCOEs from the point of view of international investors seeking to invest $US and receive $US returns. All our cost inputs that were originally in local currencies are translated into $US at current exchange rates. We then assume debt is raised in $US at a rate equivalent to the rate available to US investors plus default and country risk premiums for the specific markets, as derived from market rates where possible. We have followed a similar approach for required equity returns, which are based on equity returns observed in the US plus premiums that compensate investors for taking on exposure to the different emerging economies. This methodology results in an estimated commercial debt rate based on risk premiums observed in the market. In reality, developers may receive access to lower debt rates through concessional financing, which is designed to de-risk the market-based risk premiums.

- We assume inflation to be the same as in the US. This is because local-currencies in most countries covered in the study are likely to exceed US rates substantially. We assume that power-purchasing parity will hold, so that the value of the local currency will depreciate to keep the USD value of foreign currency unchanged.

METHODOLOGY - COST OF FINANCE

Cost of finance methodology

- The cost of debt build-up is calculated using the following formula:

[Required rate of return] = [Real risk-free rate] + [Risk premium] + [Inflation premium] + [Country risk premium]

Where:

- The **required rate of return** is the nominal rate of return that an investor needs in order to make an investment worthwhile.
- The **real risk-free rate** is equivalent, in our case (USD finance), to a risk free US 12 year (term length) bond yield.
- The **risk premium component** is split into:
  - **Technology risk premium**: The technology risk premium is reflective of the risks associated with different technologies (i.e: revenue uncertainty (wind speeds, insolation…) , cost uncertainty). This component is varied depending on the nature of the technology (e.g: riskier for renewables, less risky for fossil fuel technologies), and maturity of the technology (e.g: riskier for geothermal, less risky for wind).
  - **Company risk premium**: The company risk premium is reflective of the risk associated with the company going bankrupt. Because a company's shares can go up and down in price, or the company could go bankrupt or forgo its dividend payments, investors expect to earn on average a higher return for owning the shares than they would expect for a less-risky asset.
  - **Project risk premium**: The project risk premium is reflective of the risks associated with a specific project defaulting.

METHODOLOGY - COST OF FINANCE

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Cost of finance methodology

- We assume a fixed 2% **company + project risk premium**, and a risk premium per technology as per the following table:

Technology	Risk Premium (bps)
Utility Scale Solar PV	200
Onshore Wind	150
Geothermal	300
Small Hydro	150
Biomass - Incineration	200
CCGT	100
Coal Plant	100
Solar Thermal	300

- The **inflation premium** is considered to be 0; this is because the model assumes USD financing.
- The **country risk premium** is calculated using the following method:
  - Typical default spreads for each country rating class are calculated by averaging CDS spreads and sovereign US$ bond spreads by ratings class, at the start of every year. The spreads per class would then reflect the risk premium by country rating. Countries that do not have a sovereign rating are grouped and benchmarked according to their PRS score.

METHODOLOGY - COST OF FINANCE

Cost of finance methodology

- Below is the suggested country risk premium by country rating:

Rating	Country risk premium (bps)
A1	70
A2	85
A3	120
Aa1	40
Aa2	50
Aa3	60
Aaa	0
B1	450
B2	550
B3	650
Ba1	250
Ba2	300
Ba3	360
Baa1	160
Baa2	190
Baa3	220
Caa1	750
Caa2	900
Caa3	1000

METHODOLOGY - COST OF FINANCE

Cost of finance methodology

- Typical default spreads for each country rating class are calculated by averaging CDS spreads and sovereign US$ bond spreads by ratings class, at the start of every year. The spreads per class would then reflect the risk premium by country rating. Countries that do not have a sovereign rating are grouped and benchmarked according to their PRS score.
- Below is the suggested country risk premium by country rating:

Rating	Country risk premium (bps)	Rating	Country risk premium (bps)
Aaa	0	**Ba1**	250
Aa1	40	**Ba2**	300
Aa2	50	**Ba3**	360
Aa3	60	**B1**	450
A1	70	**B2**	550
A2	85	**B3**	650
A3	120	**Caa1**	750
Baa1	160	**Caa2**	900
Baa2	190	**Caa3**	1000
Baa3	220		

Equity hurdle rate methodology

- The equity hurdle rate build-up methodology assumes an equity premium of 3%, reflecting an average equity premium generally seen in similar markets, under the same conditions assumed in the methodology.

[Equity hurdle rate] = [Real risk-free rate] + [Risk premium] + [Inflation premium] + [Country risk premium] + [Equity premium (=3%)]

METHODOLOGY - COST OF FINANCE

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Cost of finance methodology

Country	Risk Free rate: (US 12 Year Swap)	Company + project risk premia	Country Premium	All in Debt cost		Equity Hurdle Premium	Equity Hurdle (IRR)	
Afghanistan	3.20%	2.00%	9.00%	14.20%	+ technology risk premium (See above)	3.00%	17.20%	+ technology risk premium (See above)
Bangladesh	3.20%	2.00%	3.00%	8.20%		3.00%	11.20%	
DRC	3.20%	2.00%	6.50%	11.70%		3.00%	14.70%	
Ethiopia	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Ghana	3.20%	2.00%	5.50%	10.70%		3.00%	13.70%	
India	3.20%	2.00%	1.90%	7.10%		3.00%	10.10%	
Kenya	3.20%	2.00%	5.40%	10.60%		3.00%	13.60%	
Kyrgyzstan	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Liberia	3.20%	2.00%	9.00%	14.20%		3.00%	17.20%	
Malawi	3.20%	2.00%	5.50%	10.70%		3.00%	13.70%	
Mozambique	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Myanmar	3.20%	2.00%	3.00%	8.20%		3.00%	11.20%	
Nepal	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Nigeria	3.20%	2.00%	3.00%	8.20%		3.00%	11.20%	
Palestinian Territories	3.20%	2.00%	9.00%	14.20%		3.00%	17.20%	
Pakistan	3.20%	2.00%	7.50%	12.70%		3.00%	15.70%	
Rwanda	3.20%	2.00%	5.50%	10.70%		3.00%	13.70%	
Sierra Leone	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Somalia	3.20%	2.00%	9.00%	14.20%		3.00%	17.20%	
South Africa	3.20%	2.00%	1.90%	7.10%		3.00%	10.10%	
South Sudan	3.20%	2.00%	9.00%	14.20%		3.00%	17.20%	
Sudan	3.20%	2.00%	9.00%	14.20%		3.00%	17.20%	
Tajikistan	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Tanzania	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Uganda	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Yemen	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Zambia	3.20%	2.00%	4.50%	9.70%		3.00%	12.70%	
Zimbabwe	3.20%	2.00%	6.50%	11.70%		3.00%	14.70%	

APPENDIX 2: RESOURCE AVAILABILITY

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RESOURCE AVAILABILITY

- We look at the resource availability for two reasons:

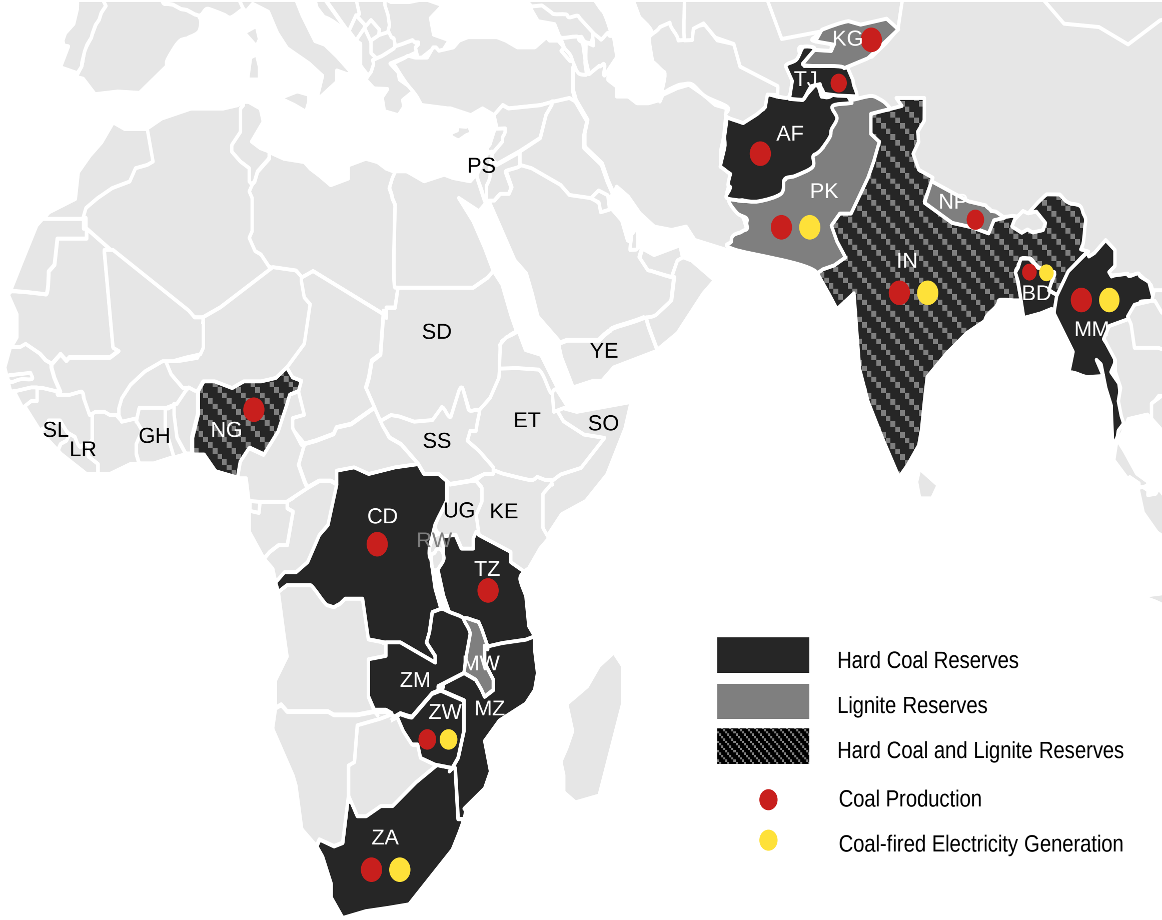
  (1) To calculate average capacity factors for wind and solar based on wind speed and solar irradiation data

  (2) To identify where it is viable for coal, natural gas and geothermal power generation technologies to be deployed.

- We calculate LCOEs for wind, solar, small hydro and biomass in every country. However we only calculate coal, gas and geothermal in countries where there is either installed capacity or proven coal, gas or geothermal reserves.
- Solar thermal electric generation LCOEs are calculated in the two countries we have so far seen this technology deployed or financed – South Africa and India.
- The following show this resource analysis in detail.

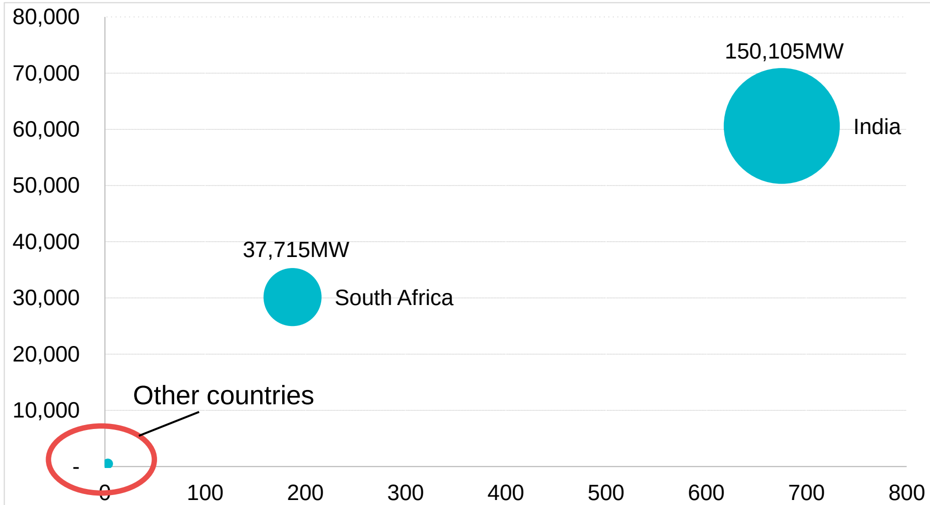
COAL RESOURCE AVAILABILITY

Coal resources and infrastructure



Source: Bloomberg New Energy Finance, EIA. Note: Coal production is the sum of sales, mine consumption, issues to miners, and issues to coke, briquetting, and other ancillary plants at mines. Production data include quantities extracted from surface and underground mines, and normally exclude wastes removed at mines or associated reparation plants.

X-axis: annual total coal production, y-axis: proved reserves (Mtonnes), and installed capacity (MW)

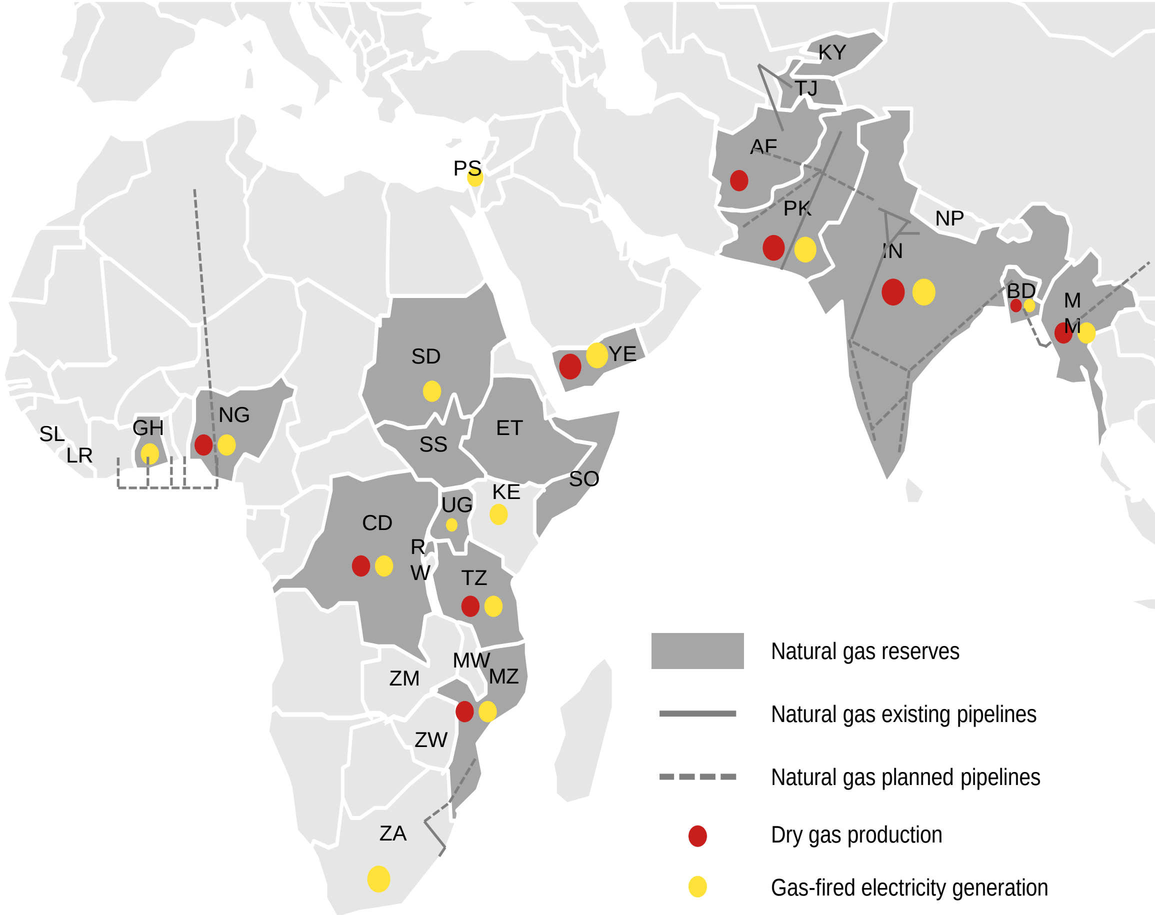


Country	Coal-fired installed capacity in MW, 2014	Proved coal reserves in million tonnes, 2011
Bangladesh	250	293
Burma	120	2
India	150,105	60,600
South Africa	37,715	30,156
Zimbabwe	1,170	502

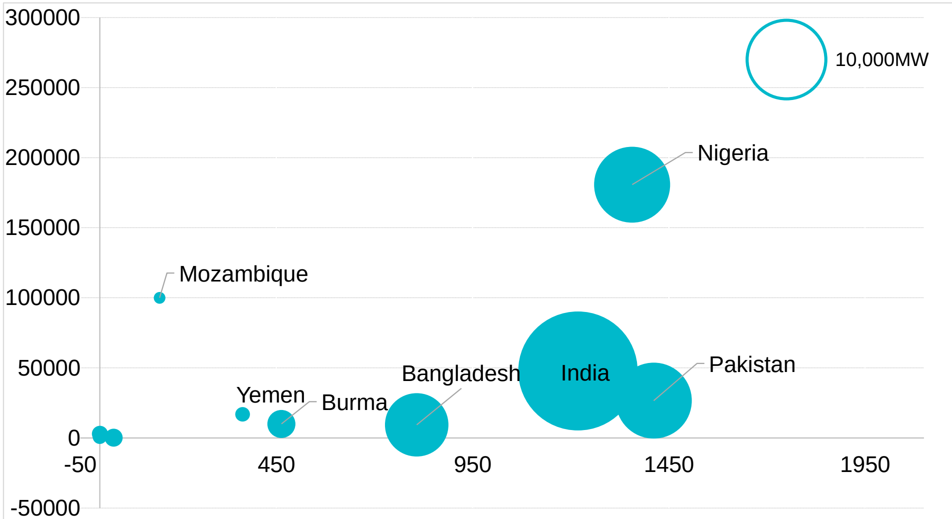
GAS RESOURCE AVAILABILITY

Bloomberg NEW ENERGY FINANCE

Gas resources and infrastructure



X-axis: annual dry natural gas production, y-axis: natural gas proved reserves (bcf), and installed capacity (MW)

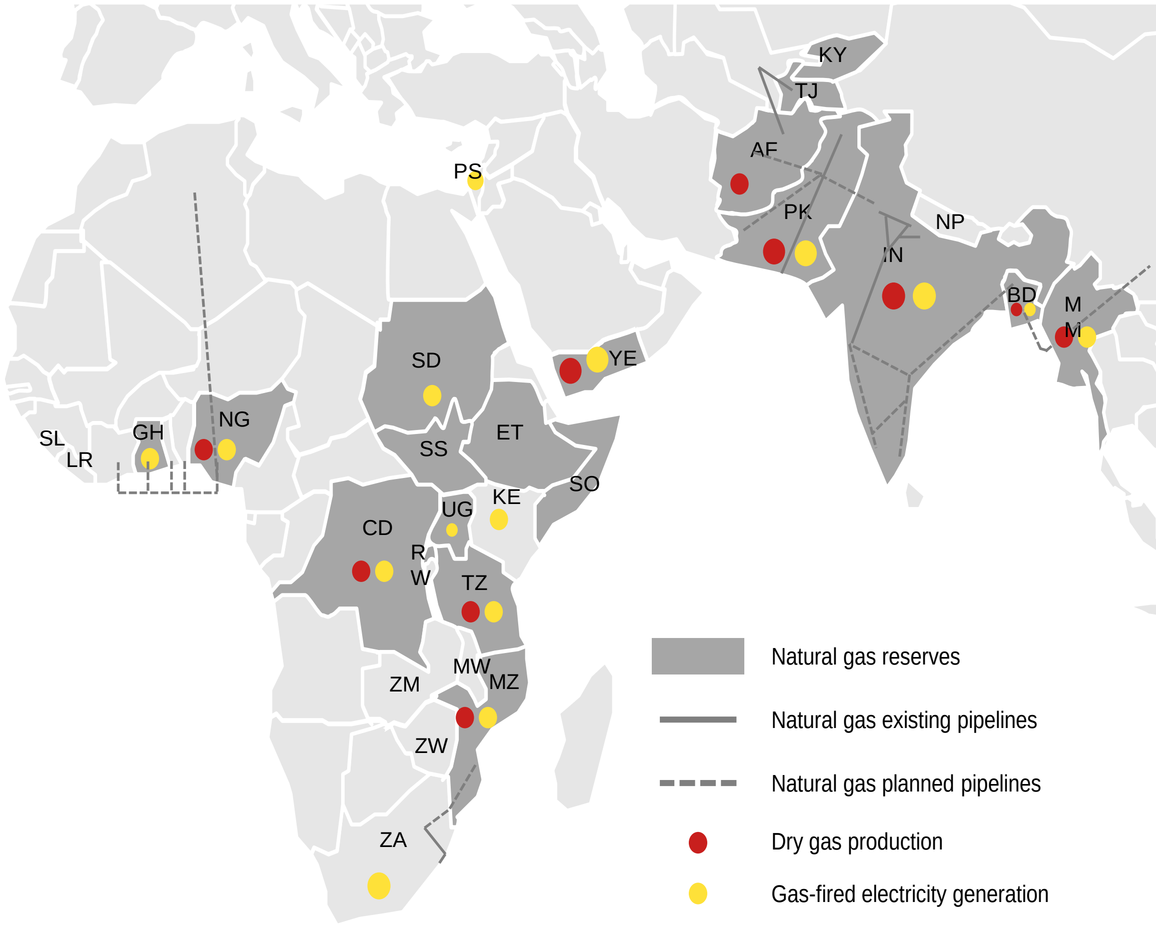


Source: Bloomberg New Energy Finance, EIA. Note: Dry natural gas production is the process of producing consumer-grade natural gas. Natural gas withdrawn from reservoirs is reduced by volumes used at the production (lease) site and by processing losses. Volumes used at the production site include (1) the volume returned to reservoirs in cycling, repressuring of oil reservoirs, and conservation operations; and (2) gas vented and flared. Processing losses include (1) nonhydrocarbon gases (e.g., water vapor, carbon dioxide, helium, hydrogen sulfide, and nitrogen) removed from the gas stream; and (2) gas converted to liquid form, such as lease condensate and plant liquids. Volumes of dry gas withdrawn from gas storage reservoirs are not considered part of production. Dry natural gas production equals marketed production less extraction loss.

GAS RESOURCE AVAILABILITY

Bloomberg NEW ENERGY FINANCE

Gas resources and infrastructure



List of countries with installed gas-fired power plants

Country	Gas-fired installed capacity in MW, 2014	Proved gas reserves in bcf, 2014
Bangladesh	6,481	9,344
Burma	1,277	10,000
Congo Dem. Rep.	12	35
Ghana	332	800
India	22,916	47,842
Kenya	54	-
Mozambique	220	100,000
Nigeria	9,307	180,737
Palestine	125	-
Pakistan	9,330	26,650
Rwanda	3	2,000
South Africa	140	-
Sudan	415	3,000
Tanzania	527	230
Yemen	341	16,900

Source: Bloomberg New Energy Finance, EIA.

WIND – AFRICAN COUNTRIES

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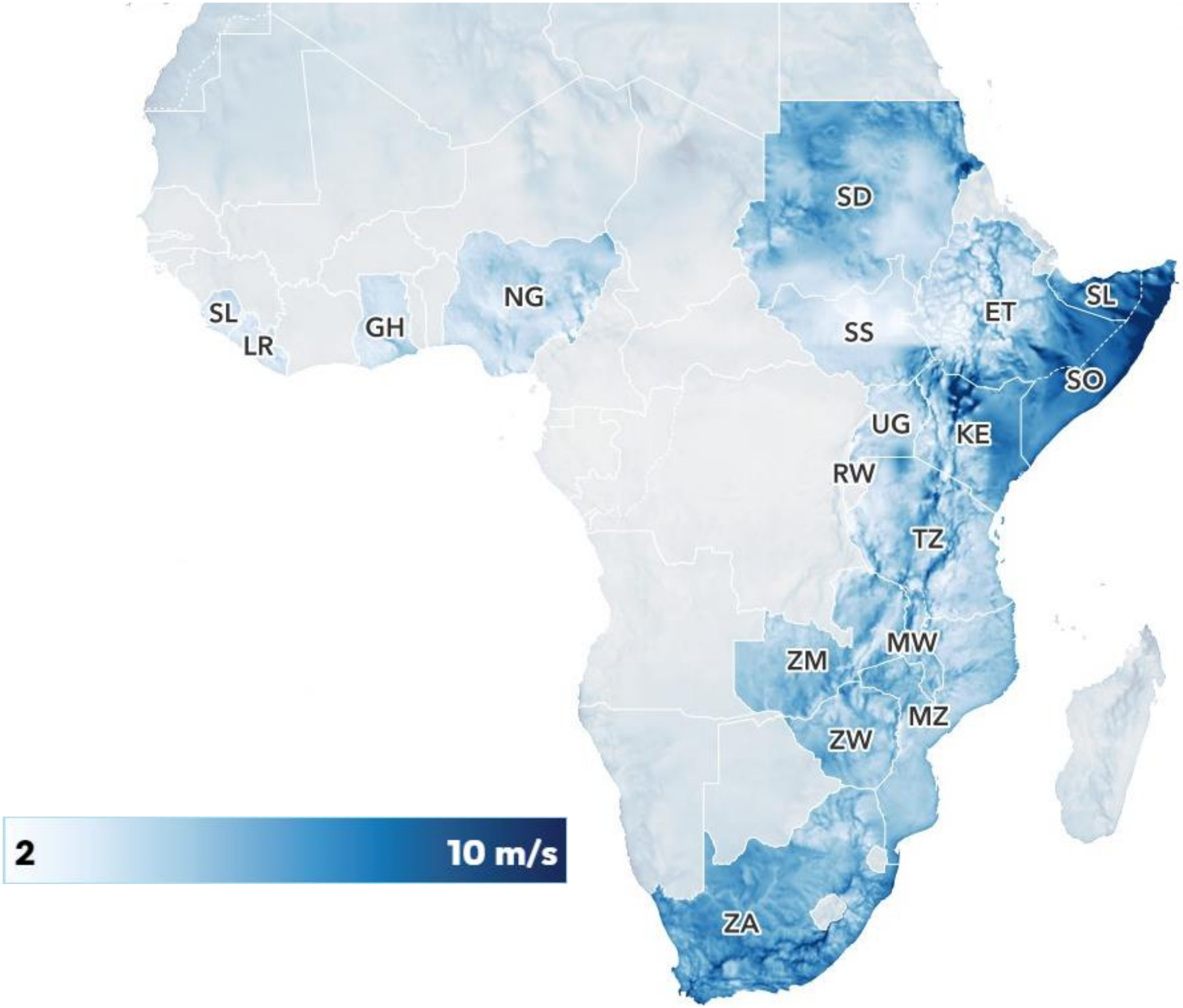
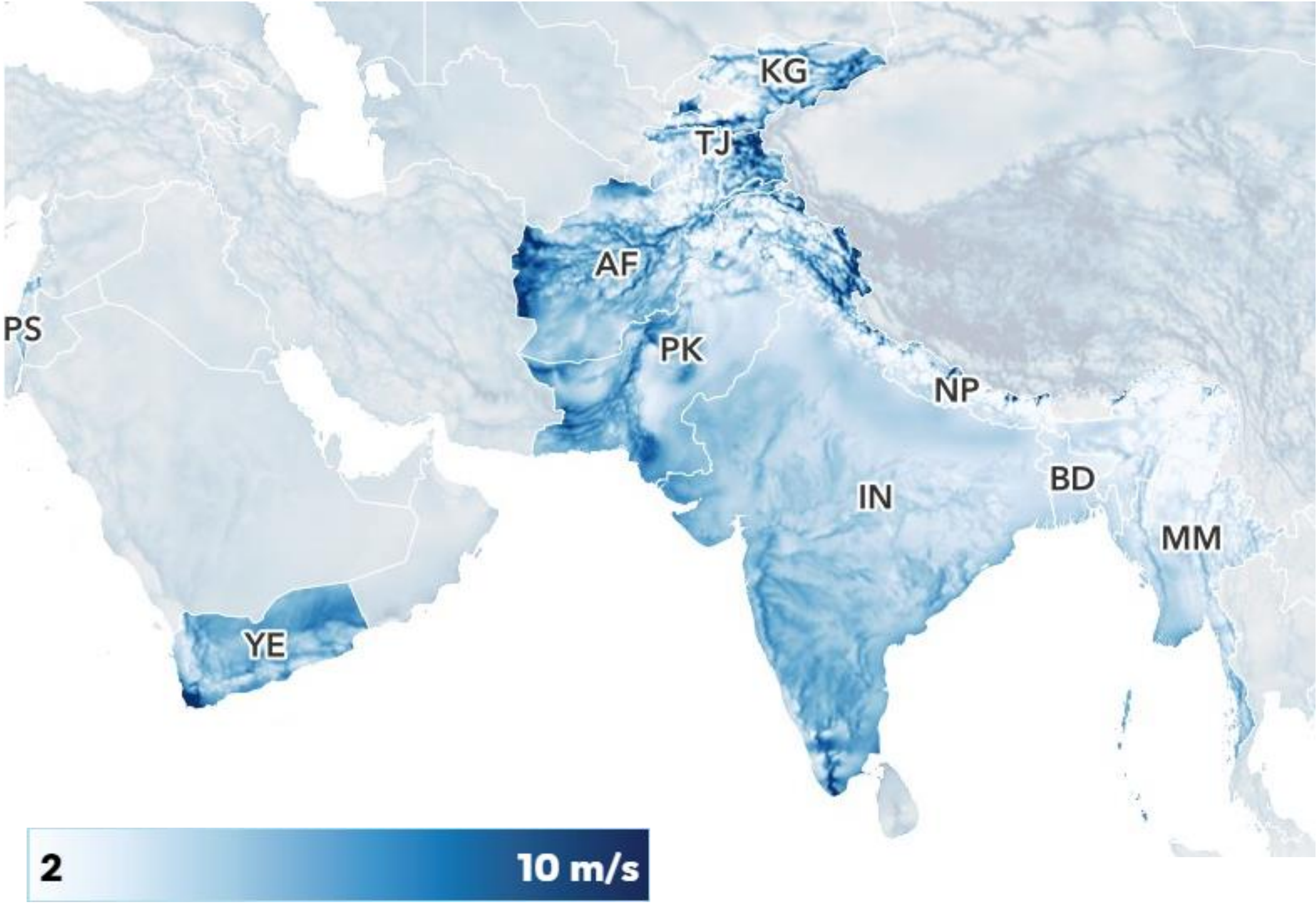


Country	Wind Capacity Factor
DRC	16%
Ethiopia	25%
Ghana	14%
Kenya	21%
Liberia	15%
Malawi	22%
Mozambique	22%
Nigeria	14%
Rwanda	10%
Sierra Leone	9%
Somalia	35%
South Africa	30%
South Sudan	18%
Sudan	18%
Tanzania	20%
Uganda	18%
Zambia	20%
Zimbabwe	20%

Source: Bloomberg New Energy Finance, Vaisala.
Note: Capacity factor measurements are performed using GE 103m rotor, 2.75MW turbine at 85m hub-height.

WIND – ASIAN COUNTRIES

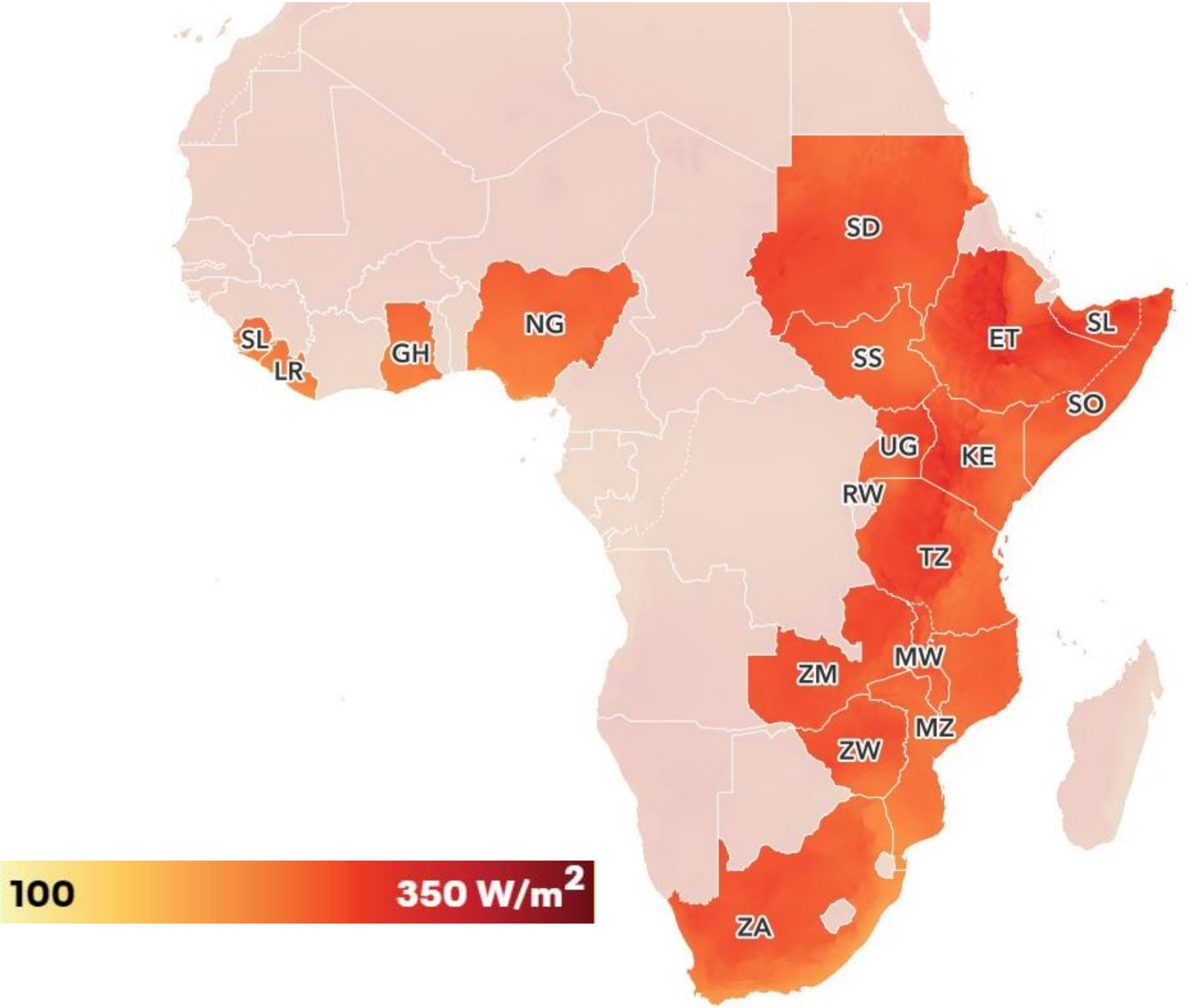


Country	Wind Capacity Factor
Afghanistan	21%
Bangladesh	11%
Myanmar	14%
India	26%
Kyrgyzstan	26%
Nepal	10%
Occupied Palestinian Territories	26%
Pakistan	22%
Tajikistan	18%
Yemen	24%

Source: Bloomberg New Energy Finance, Vaisala.
Note: Capacity factor measurements are performed using GE 103m rotor, 2.75MW turbine at 85m hub-height.

SOLAR – AFRICAN COUNTRIES

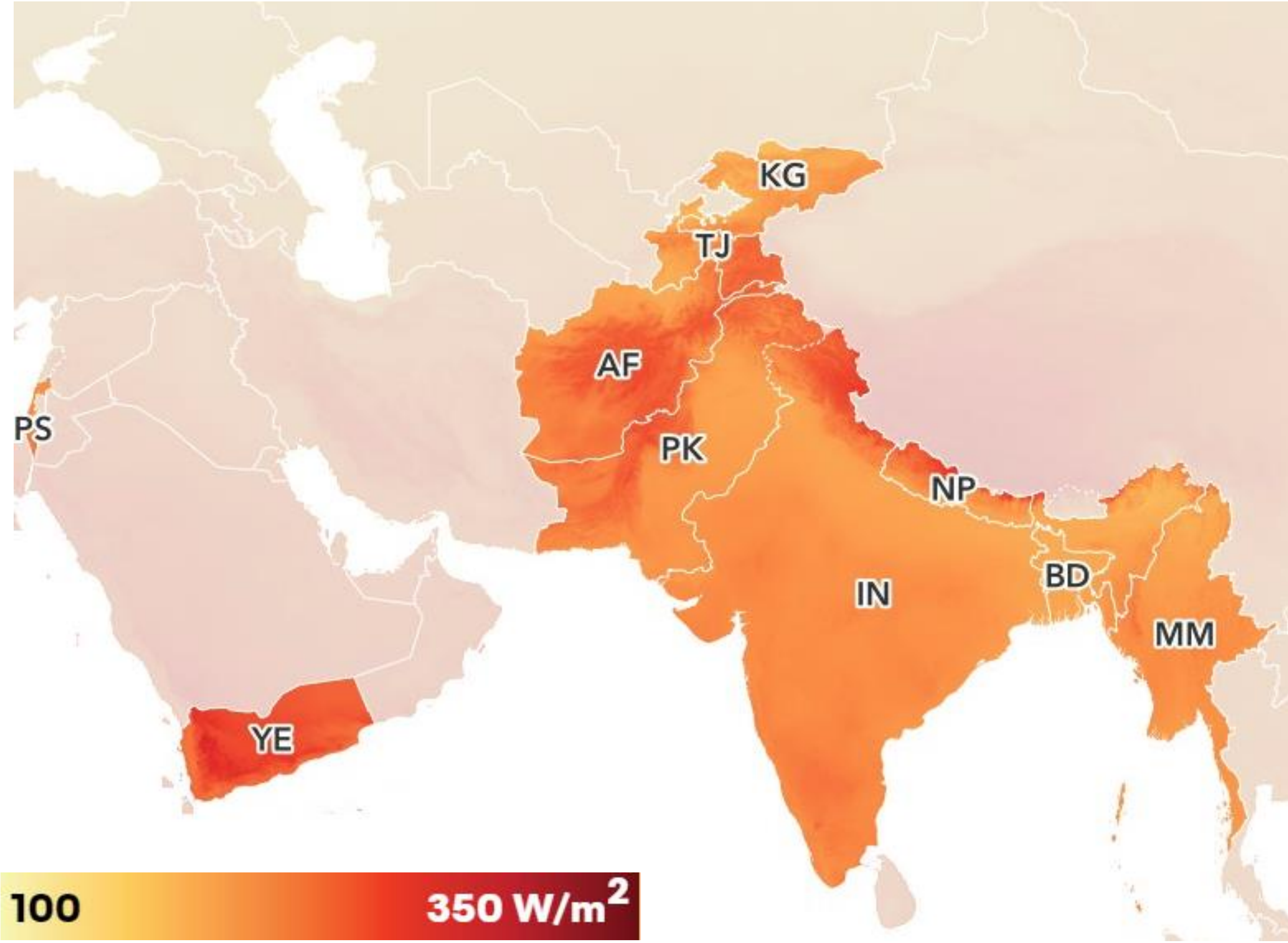
Bloomberg NEW ENERGY FINANCE



Country	Solar Capacity Factor
DRC	16%
Ethiopia	18%
Ghana	17%
Kenya	19%
Liberia	16%
Malawi	18%
Mozambique	18%
Nigeria	17%
Rwanda	15%
Sierra Leone	17%
Somalia	19%
South Africa	18%
South Sudan	18%
Sudan	20%
Tanzania	17%
Uganda	18%
Zambia	18%
Zimbabwe	18%

Source: Bloomberg New Energy Finance, Vaisala

SOLAR – ASIAN COUNTRIES

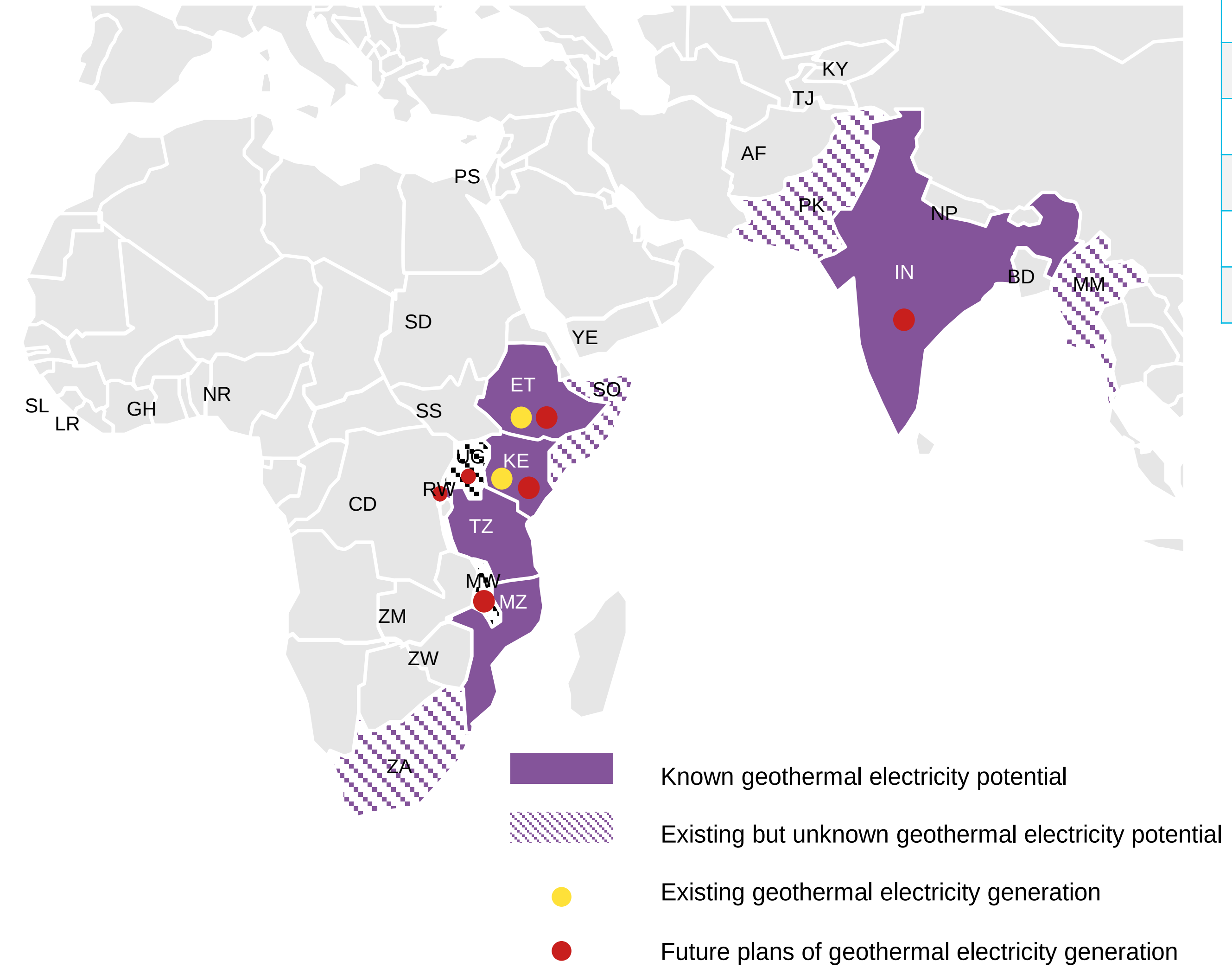


Country	Solar Capacity Factor
Afghanistan	19%
Bangladesh	16%
Myanmar	16%
India	18%
Kyrgyzstan	14%
Nepal	17%
Occupied Palestinian Territories	19%
Pakistan	19%
Tajikistan	15%
Yemen	20%

Source: Bloomberg New Energy Finance, Vaisala

GEOTHERMAL RESOURCE AVAILABILITY

Geothermal resources and infrastructure



Country	Potential (MWe)
Ethiopia	5,000
India	10,000
Kenya	10,000
Mozambique	>25 (based on 1978,1982 studies)
Rwanda	700
Tanzania	380

Source: Bloomberg New Energy Finance, International Geothermal Association

ELECTRIFICATION RATE

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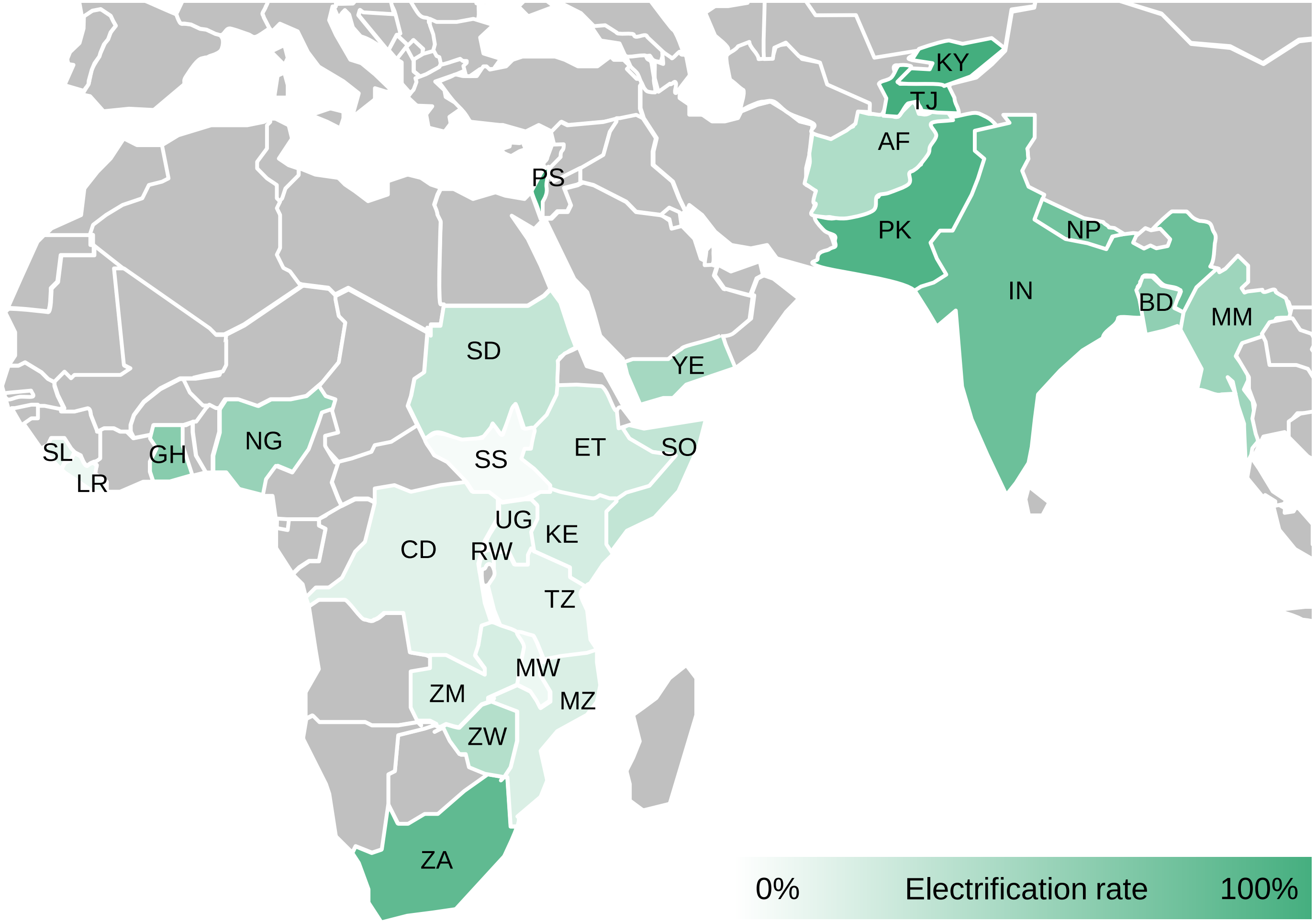
Electrification rates



Country Name	Electrification rate
Afghanistan	43.00%
Bangladesh	59.60%
Burma	52.40%
DRC	16.40%
Ethiopia	26.60%
Ghana	64.10%
India	78.70%
Kenya	23.00%
Kyrgyzstan	100.00%
Liberia	9.80%
Malawi	9.80%
Mozambique	20.20%
Nepal	76.30%
Nigeria	55.60%
Occupied Palestinian Territories	98.9%
Pakistan	93.60%
Rwanda	18.00%
Sierra Leone	14.20%
Somalia	32.70%
South Africa	85.40%
South Sudan	5.10%
Sudan	32.60%
Tajikistan	100.00%
Tanzania	15.30%
Uganda	18.20%
Yemen	48.40%
Zambia	22.10%
Zimbabwe	40.50%

Source: Bloomberg New Energy Finance, World Bank

APPENDIX 3: FUEL PRICES & HEAT RATES

FUEL PRICES

- There are no publicly quoted fuel price indexes for the majority of the DFID focus country. To construct fuel price curves we have used a “benchmark plus transport” methodology that assumes domestic fuel prices are set by the relevant international coal price indicator plus cost for seaborne and/or overland shipping. This approach assumes domestic fuel can be exported and the price is set at the opportunity cost. This is an imperfect solution, but one that fell within the scope of the work.

Coal price assumptions

- Coal prices are approximated using one of the following:
  - For coastal countries: coal price indicator + 4% seaborne transportation.
  - For inland countries: coal price indicator + 4% seaborne transportation premium + 8% overland transportation premium
  - The coal price indicator alone is used for countries of origination.
  - These spot coal prices are then inflated as US-inflation rate to 2060.

- The coal price indicator is set based on the location and type of coal:
  - **Indonesian Coal**: used as coal price indicator for Asian countries that use sub-bituminous coal.
  - **Newcastle Coal** (Australia): used as coal price indicator for Asian countries that use hard coal.
  - **Richards Bay Coal** (South Africa): used as coal price indicator for African countries that use sub-bituminous coal.
  - **Nigerian Lignite**: used as coal price indicator for African countries that use lignite.

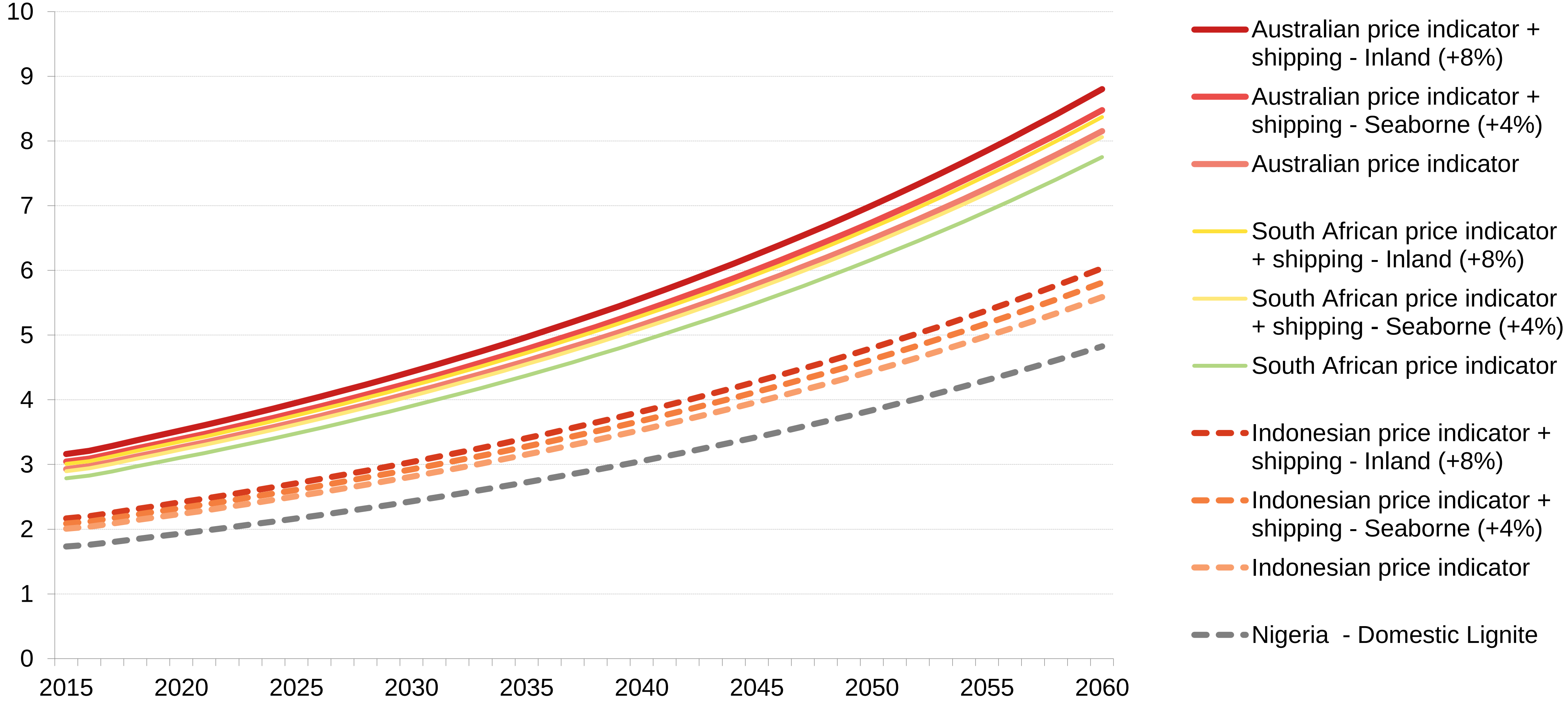
Gas price assumptions

- Gas prices are calculated using the same “benchmark plus transport” methodology as coal, but with a single gas price indicator. This is the BNEF LNG price forecast to 2030 (which includes shipping). Prices from 2030 are inflated using US inflation rates. India is the only country for which we use a different benchmark gas price.

FUEL PRICES

Bloomberg NEW ENERGY FINANCE

Coal price forecast ($/MMBtu nominal)



Coal assumptions

Country	Fuel price	Heat rates (MWh/MMBtu)
Afghanistan	Indonesian Coal + Overland Transportation (+8%)	0.104308
Bangladesh	Indonesian Coal + Seaborne Transportation (+4%)	0.108812
DRC	Richards Bay Coal + Overland Transportation (+8%)	0.108527
India	Indonesian Coal + Seaborne Transportation (+4%)	0.096312
Kyrgyzstan	Indonesian Coal + Overland Transportation (+8%)	0.104308
Malawi	Richards Bay Coal + Overland Transportation (+8%)	0.108527
Mozambique	Richards Bay Coal + Seaborne Transportation (+4%)	0.108527
Myanmar	Newcastle Coal + Seaborne Transportation (+4%)	0.114116
Nepal	Indonesian Coal + Overland Transportation (+8%)	0.104308
Nigeria	Nigerian Lignite	0.089686
Pakistan	Indonesian Coal + Seaborne Transportation (+4%)	0.104308
South Africa	Richards Bay Coal	0.127841
Tajikistan	Indonesian Coal + Overland Transportation (+8%)	0.104308
Tanzania	Richards Bay Coal +Seaborne Transportation (+4%)	0.108527
Zambia	Richards Bay Coal + Overland Transportation (+8%)	0.108527
Zimbabwe	Richards Bay Coal + Overland Transportation (+8%)	0.108527

FUEL PRICES

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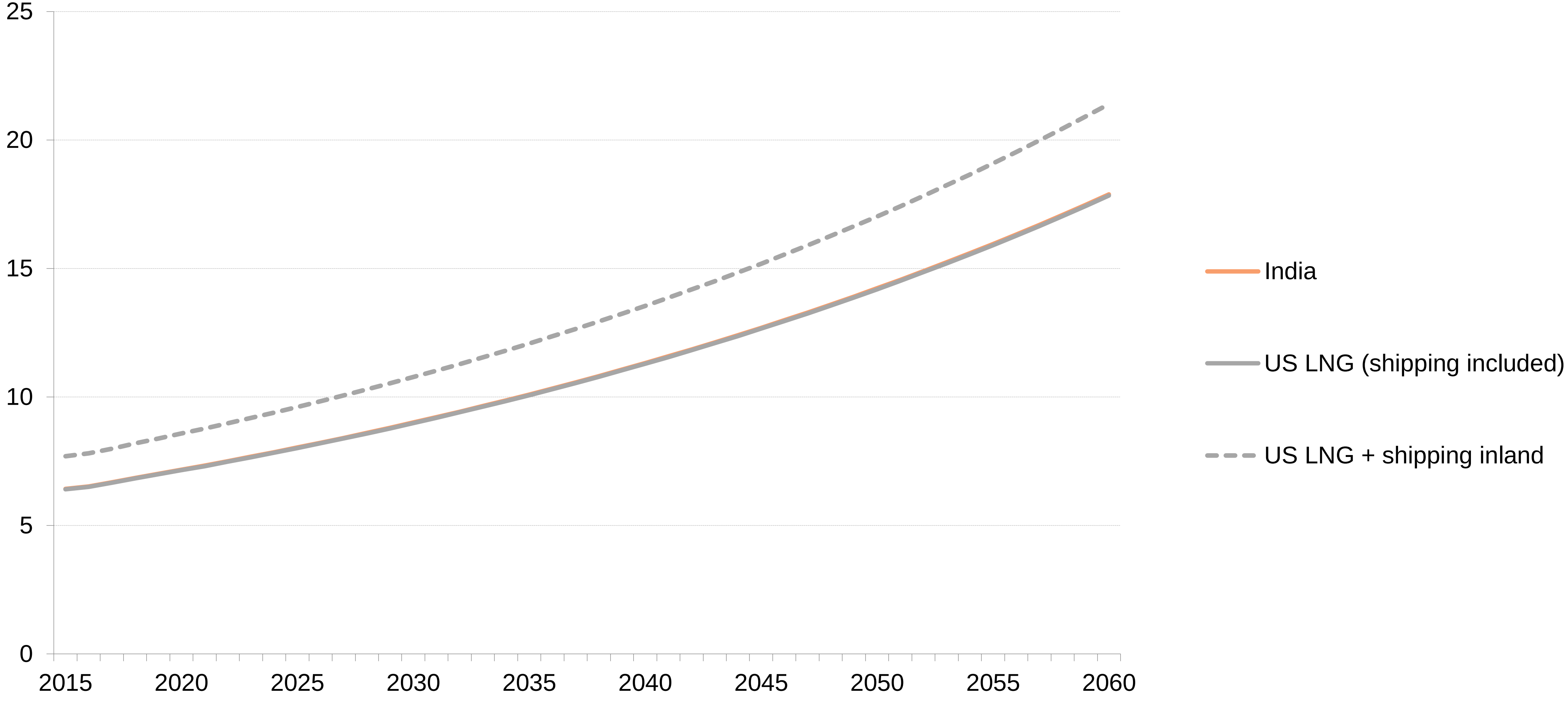
Gas price forecast ($/MMBtu nominal)



FUEL PRICES

Bloomberg NEW ENERGY FINANCE

Gas price assumptions

Country	Fuel	Heat rate (MWh/MMBtu)
Afghanistan	Natural Gas - US LNG + shipping inland	**0.142857**
Bangladesh	Natural Gas - US LNG + shipping to shore	
DRC	Natural Gas - US LNG + shipping inland	
Ethiopia	Natural Gas - US LNG + shipping inland	
Ghana	Natural Gas - US LNG + shipping to shore	
India	Natural Gas – India	
Kenya	Natural Gas - US LNG + shipping to shore	
Kyrgyzstan	Natural Gas - US LNG + shipping inland	
Mozambique	Natural Gas - US LNG + shipping to shore	
Myanmar	Natural Gas - US LNG + shipping to shore	
Nigeria	Natural Gas - US LNG + shipping to shore	
Palestinian Territories	Natural Gas - US LNG + shipping to shore	
Pakistan	Natural Gas - US LNG + shipping to shore	
Rwanda	Natural Gas - US LNG + shipping inland	
Somalia	Natural Gas - US LNG + shipping to shore	
South Africa	Natural Gas - US LNG + shipping to shore	
South Sudan	Natural Gas - US LNG + shipping inland	
Sudan	Natural Gas - US LNG + shipping to shore	
Tajikistan	Natural Gas - US LNG + shipping inland	
Tanzania	Natural Gas - US LNG + shipping to shore	
Uganda	Natural Gas - US LNG + shipping inland	
Yemen	Natural Gas - US LNG + shipping to shore	

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