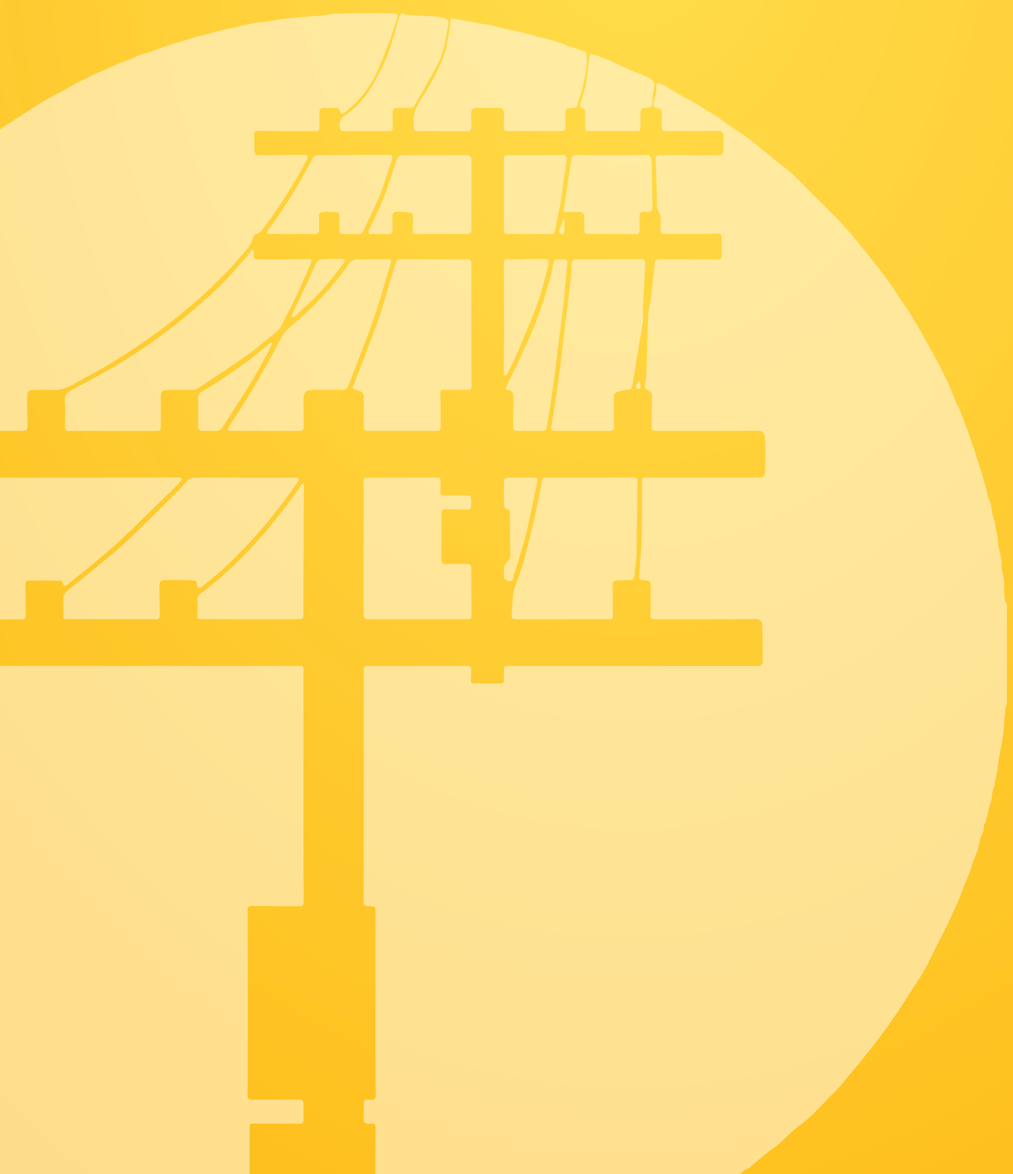
Analysis of

TANZANIA'S POWER SYSTEM MASTER PLAN 2016



Centre for Science and Environment

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TANZANIA'S POWER SYSTEM MASTER PLAN 2016

CENTRE FOR SCIENCE AND ENVIRONMENT

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1. INTRODUCTION

The Power System Master Plan 2016 (PSMP2016) aims to bring about socio-economic development by providing electricity access to all in Tanzania. The Plan aims to ensure energy security and affordability; however, it also discusses sustainability and environmental impact of power generation. 'The overall objective of the Plan is to re-assess generation and transmission requirements and the need for connecting presently off-grid regions, options for power exchanges with neighboring countries, and increased supply of reliable power,' the Plan says.

The PSMP2016 projects large scale expansion of the generation, transmission and distribution capabilities. It considers varying demand projection levels to determine its plan for expansion. The three scenarios—high, low and base—take into account different economic growth rates.

1. Base case: The base scenario assumes that the economic growth (8 per cent per annum) is driven by the population growth (2.7 per cent per annum) and high labor productivity. Under this scenario, the projections show a gradual decrease in the population growth rate to 1.5 per cent per annum with the economy stabilizing at 5 per cent per annum by 2040.

2. High case: The high scenario assumes that the increased economic growth rate—10 per cent per annum between 2035 and 2040—will be facilitated primarily by the development of massive national reserves of natural gas.

3. Low case: The low scenario assumes a feeble economic growth—4 per cent per annum between 2035 and 2040—driven by geo-political and economic impediments.

Overview

The World Bank database[1] shows that in terms of electricity access rates, Tanzania lies in the bottom 20 per cent of the countries. Tanzania's total population is 58 million with an average population density of 65 persons per square kilometer. This comprises a few urban centers that are densely populated and wide swathes of the country that are sparsely populated. The electricity access rate in Tanzania lies well below 50 per cent and, like its population, is unevenly distributed.

Dar es Salaam, the largest city, has the highest electrification rate (around 90 per cent) in the country whereas regions such as Rukwa and Katavi have extremely low electrification rates—around 8 per cent. PSMP2016 aims to increase the national electricity access rates to 90 per cent by 2035–2040. Extending the national grid to the remotest of these consumers (the last 10 per cent) will be expensive and hard to accomplish.

One pronounced problem in Tanzania is the lack of financing available for power infrastructure. Tanzania draws funding from Finland ($65 million during 2016–19) and other European development funds for deploying its energy strategy; however, these are both small and seldom effectively utilized. This is exacerbated by the lack of local technology and skill.

Since its inception in 1964, Tanzania Electric Supply Company (TANESCO) has held a monopoly in the power market. The Electricity Act of 2009 allowed for independent power producers (IPP) to participate in electricity supply through public private partnership (PPP). This move was driven by the fact that, globally, IPP involvement has increased efficiency, quality and reliability of the power supplied. The bidding process among IPPs for developing power plants is expected to enable competition and drive the prices down for the consumers.

The Electricity Supply Industry Reform Strategy and Roadmap (ESI-RSR) was introduced in 2014 for a period of 11 years upto 2025. It projected the need for $1.15 billion in funds to reform the electricity supply industry. It specifically aimed to rid TANESCO of its debt, encourage IPP participation, and facilitate horizontal and vertical unbundling—all necessary to fuel up the power sector. However, since ESI's approval in 2014, the IPP participation has been minimal and TANESCO's debts have increased from $250 million in 2015 to $363 million in 2016.

PSMP2016 is the Tanzanian government's latest attempt to meet the needs of the growing economy and population. PSMP2016 projects a compound annual growth rate (CAGR) of 7.3 per cent with an increase in demand from 7,860 GWh in 2016 to 87,880 GWh in 2040. To meet this projected demand, several scenarios with varying shares of generation sources were considered (see *Table 1: Power development scenarios*). These scenarios consider constraints such as supply reliability (LOLP),[2] reserve capacity, fuel limitations, and restriction on the amount of environmental pollutant emissions etc., for the next 30 years. Scenario 2, with a huge gas (40 per cent) and thermal (35 per cent) capacity and minimal renewable energy (5 per cent), was chosen under PSMP2016.

TABLE 1: POWER DEVELOPMENT SCENARIOS

PSMP2016 considered six generation scenarios and chose scenario-2 after considering several constraints.

Scenarios	Generation mix			
	Gas	Coal	Hydro	Renewable energy
Scenario 1	50	25	20	5
Scenario 2	40	35	20	5
Scenario 3	35	40	20	5
Scenario 4	25	50	20	5
Scenario 5	50	35	10	5
Scenario 6	40	30	20	10

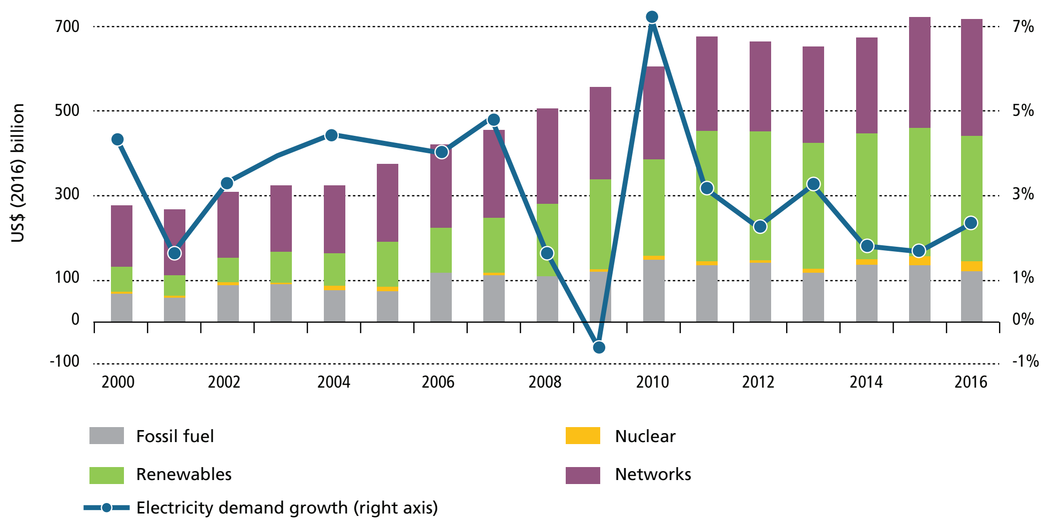
Note: Breakdown of the six scenarios with varying generation capacities from different energy sources (gas, coal, hydro and renewable energy).

Source: PSMP, 2016

Low share of renewable energy in the generation mix can be explained by the assumption that renewable power is expensive and intermittent—sharp fall in renewable and storage cost means that this assumption is now incorrect. Tanzania may also have been hesitant to invest in relatively new technologies to serve as the country's basic power infrastructure. But the renewable energy sector has fundamentally changed in the past few years, and questions surrounding technology reliability are no longer relevant. Global investments in renewable

FIGURE 1: GLOBAL ELECTRICITY SECTOR INVESTMENT 2000-16

In recent years, global investments in renewable energy sector has been two to three times higher than in thermal power sector



Source: IEA World Energy Investment

energy installations have skyrocketed to two to three times the investments in thermal capacities (see *Figure 1: Global electricity sector investment: 2000–16*). Tanzania's non-utilization of its tremendous renewable energy potential and global interest in investing in renewable energy can lead to missed opportunities.

The growth in renewable energy globally has been driven by energy access needs, pollution concerns and rising greenhouse gas (GHG) emissions from fossil fuel-based power, and, most increasingly now, by the cost-competitiveness of renewable energy. The World Future Council, Bread for the World and CAN-Tanzania, in a recent report[3] presented a strategy to achieve 100 per cent renewable power in Tanzania. The report suggested that Tanzania could continue to develop as per the country's National Development Vision 2025, but with the inclusion of renewable energy in its power mix. The report highlighted certain aspects of the National Energy Policy: [4]

- Low private sector participation in large scale power generation
- Reliance on few generation sources
- Expensive energy supply
- Dependence on government subsidies
- Low access to modern energy services
- Inadequate human resource
- Low participation of local industry in the petroleum value chain
- Inadequate financial resources

PSMP2016 has tried to address these bottlenecks in an attempt to improve the power system in Tanzania. But it has left the vast RE potential of the country, which could be an essential resource to meet its objectives, underused. Tanzania's wind potential is high in regions such as Kititimo and Makambako, which have wind speeds of 9.9 miles per second and 8.9 miles per second respectively, ideal for large wind farms. The country receives 2,800–3,500 hours of sunshine per year which implies good solar energy potential from rooftop solar or large solar farms. The country also has a sizable geothermal potential.

The PSMP2016 acknowledges that even a significant increase in coal and gas based power capacity won't be sufficient to fully electrify household—indeed, it plans for 90 per cent electrification by 2035. Part of the difficulty would be in electrifying remote or sparsely populated areas. According to a McKinsey study, it takes 25 years to go from 20 per cent to 80 per cent electrification rate because the success is quicker in easier-to-reach urban households but increasing electrification thereafter is a hurdle. Adding distributed generation using renewable energy could serve as a perfect cost-effective strategy towards electrification goals for the rural-remote households.[5]

2. DEMAND ESTIMATION AND CAPACITY PROJECTION

Today, Tanzania's primary power generation mix of 1,876 MW includes hydro (42 per cent), natural gas (45 per cent) and liquid fuel (13 per cent). In the recent past, TANESCO has had to ration electricity because of the severe drought in the country which impacted hydro generation. To compensate, TANESCO resorted to extensive load shedding and hired emergency power supply equipment at a considerable financial cost.

As a consequence, the Plan looks to diversify its sources. PSMP2016 plans installation of large scale thermal generation, to serve as base load plant as well as peak plants in the absence of hydro generation. Between 2016 and 2040, generation would absorb 80 per cent of the total investment planned in the PSMP2016.[6] This perspective—that looks mainly at thermal generation—broadly covers factors such as long timelines associated with the installation of conventional power plants, and the recurring and increasing fuel costs. It also considers investment and time to build the necessary transmission and distribution network; however, a detailed study would be beneficial to determine the viability of the project.

Peak demand load—highest load drawn from the grid—is a basic parameter for capacity planning. In the base case this has been calculated by assuming a 7 per cent per annum GDP growth in the country. The 93 per cent increase in the projected peak demand from 2015 to 16,050 GWh in 2040, will require an installed capacity of 20,865 MW. However, the breakdown of capacity under scenario 2 amounts to a total installed capacity of 22,596 MW by 2040 (see *Table 2: Scenario 2 breakdown by source type*). This is 1,731 MW higher than the required capacity under the projected assumptions of the base case.

The Indian experience

India has struggled with overestimating demand too. First, India's last several five-year plans consistently overestimated the GDP growth. Second, it gave excessive weightage to the impact of GDP growth on demand for electricity and underestimated the role of energy efficiency and renewable energy technologies. Demand grew at a rate lower than what was projected (see *Table 3: India's GDP and generation growth rate*). The result was that the projected capacity requirements exceeded actual needs. During 2007–16, Indian private power producers installed huge thermal capacity in anticipation of increased demand, which

TABLE 2: SCENARIO 2 BREAKDOWN BY SOURCE TYPE

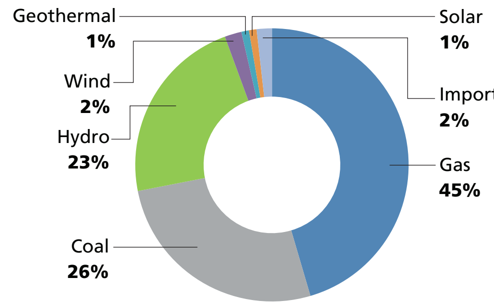
Nearly 70 per cent of power is made available is from coal and gas sources

Source		Installed capacity (MW)		% share
Gas		10,253		45.5%
Coal		6,000		26.5%
Hydro		5,093		22.5%
Renewable	Wind	450	850	3.8%
	Solar	200		
	Geothermal	200		
Import		400		1.8%
Total capacity		22,596		

Source: PSMP, 2016

FIGURE 2: SCENARIO BREAKDOWN BY SOURCE TYPE

Share of renewable energy is restricted to less than 4 per cent



Note: Quantifying capacity addition per energy source in scenario 2 of PSMP2016
Source: PSMP, 2016

TABLE 3: INDIA'S GDP AND GENERATION GROWTH RATE

Growth of power capacity additions in India do not track economic growth

	GDP CAGR (%)	Generation CAGR (%)
1984–94	3.3	6.4
1994–2004	4.4	3.9
2004–14	6.2	4.8

Note: The data here compares the GDP growth and generation growth over the same time frames.
Source: World Bank open data

did not materialize. This has led to a fall in coal-based power sector's plant load factor (PLF) from over 75 per cent to below 60 per cent – at these levels many plants are incurring losses.

In an attempt to avoid repeating this mistake, India reduced its peak demand projections for 2022, from 283 GW in the 18th *Electric Power Survey (EPS)* report to 235 GW in the 19th *EPS* report. The energy requirements were cut from 1,904.8 BU to 1,611 BU, in recognition of improvements in energy efficiency of the economy as a whole.[7]

Currently, the installed generation capacity in India totals to 330 GW, however, the peak demand is only 160 GW. Simultaneously, a large chunk of the population either has no access to electricity or has irregular access to power.[8] The government hopes that India's demand may increase at a fast pace since the country is rapidly expanding power grids and providing electricity connections to all households. But it is more likely that demand growth would be constrained by household income, which depends on overall economic growth. The government doesn't have resources to provide subsidized electricity to all poor households, who are currently not connected, beyond a basic level. Therefore, power demand will not grow materially to offset excess capacity. The target to install 175 GW of renewable power (100 GW solar, 60 GW wind and 15 GW other) may create additional excess capacity and result in even lower PLFs for coal-based power plants, making them unviable.

Master plan assumptions

Tanzania's PSMP2016 assumes that installed capacity needs to be 1.3 times higher than the peak demand to account for the reserve capacity requirement, resulting in a total capacity of 20,865 MW. The assumptions of peak demand requirements need to be carefully scrutinized. Worldwide, economies have become more efficient (in terms of energy consumption) compared to historical norms. This means that to generate the same levels of GDP, a country is likely to consume less energy in the future as compared to its present energy consumption. There are many reasons for this: new energy-efficient technologies, increasing resource efficiency, and streamlined processes that quickly spread across the world. (An IEA study in Indonesia says that introduction of energy efficiency measures would reduce energy use by 4.5 per cent compared to a scenario where no such attempts were made.)[9]

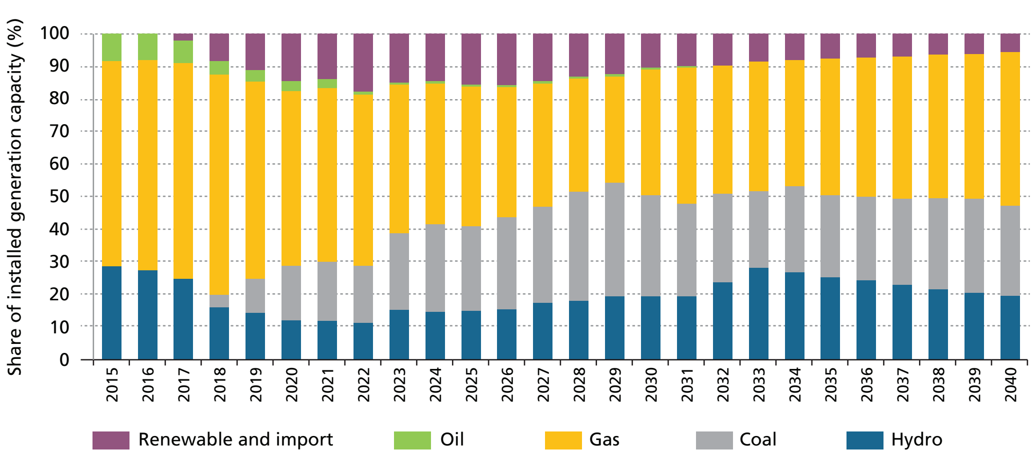
Overestimation of generation needs may lead to expensive, underutilized or even stranded capacities of the conventional thermal systems with large gestation periods. Historically, thermal plants were cheaper, however, renewable sources such as wind and solar are either approaching or have attained cost-competitiveness. Second, any variability in demand growth can be met better by renewable energy such as solar or wind, which are modular - their capacity can be easily increased by adding panels or turbines.

But, Tanzania is projecting only 5 per cent of renewable energy additions and is not exploiting the trend of reducing RE costs and its inherent advantages of smaller scale and distributed nature. As stated earlier, PSMP2016 does not account for the tremendous renewable energy potential of the country for solar (4–7 KWh/m^2/day) with 2,800–3,500 hours of sunshine per year, wind (5.7m/s), and geothermal (650 MW).

On the other hand, the share of installed generation over the years shows an increase in coal- and gas-based generation (see *Figure 3: Share of installed generation capacity by type of plant (Scenario 2) in Tanzania*).

FIGURE 3: SHARE OF INSTALLED GENERATION CAPACITY BY TYPE OF POWER PLANT (SCENARIO 2) IN TANZANIA

Increasing role allocated to coal and gas against decreasing role of renewable energy



Source: PSMP, 2016

Conclusion: *Demand growth has been falling across the world with falling energy intensity per unit of the GDP. Overestimated demand can result in excess capacity that may become stranded. Establishing large size coal-based plants with long life can be counter-productive.*

3. RELIANCE ON COAL AND GAS

By 2040, two-thirds of the electricity will be derived from fossil fuel sources (refer to *Table 1: Power development scenarios*). Coal, which had an insignificant part in the power mix (0.2 per cent in 2013), will contribute 35 per cent to the power mix by 2040.

PSMP2016 looks extensively at Tanzania's untapped reserves of coal and gas potential (see *Table 4: Estimates of coal and gas reserves in Tanzania*) to power the un-electrified population. Geographical studies show a possible coal reserve potential of 5 billion tonnes. Of the total probable coal reserve of 1.9 billion tonnes, Tanzania has a proven reserve of 0.4 billion tonnes.[10] Possible reserves have a 10 per cent probability of recovery, whereas the certainty of recovery with probable and proven reserves is 50 per cent and 90 per cent respectively.

TABLE 4: ESTIMATES OF COAL AND GAS RESERVES IN TANZANIA

Fossil fuel reserve estimates have increased with discovery of new natural resources

Year	Coal reserves	Gas reserves
2012 estimates	535 MT	33 TCF
2016 estimates	870 MT	55 TCF

Source: PSMP, 2012; PSMP, 2016

In the PSMP2016, the price of coal is assumed as $3.53/mm Btu ($70/tonne). Since 2016, the coal market has bounced back and prices today range around $100/tone.[11] With its reserves, Tanzania could supply domestic coal-based power plants at a subsidized price irrespective of the global prices. However, it means that the 'market cost' of electricity is higher than the rate at which the government is providing subsidized electricity. Global pressure on coal mining and lack of investments in the sector from international players means that even the cost of mining domestic coal may rise.

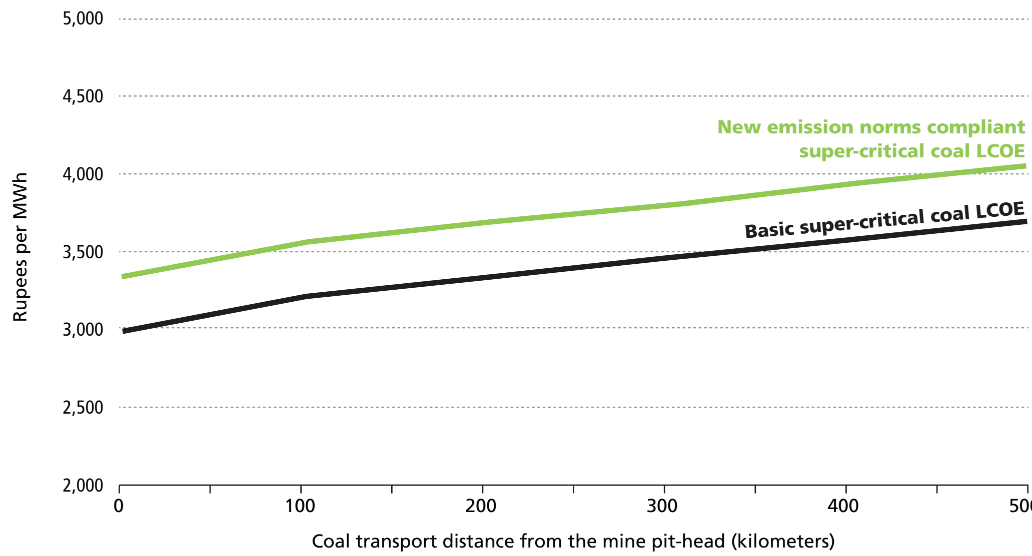
In order to support domestic production of coal, the Tanzanian government has issued a directive to ban coal imports. However, the lack of transport infrastructure in the country has caused a hike in the cost of the domestic coal. Prices were as high as $127.5/tonne for coal produced in Tanzania as compared to $109/tonne for South African coal imported via Tanzanian port of Tanga.[12] For fair comparison, the cost of mining's environmental impacts should also be considered. Finally, transporting coal over long distances adds to the cost of generation. (See *Figure 4: Levelized cost of electricity (LCOE) by coal transport distance in India*)

A similar scenario played out in India—transportation bottle necks have resulted in high cost of coal in certain parts. Coal shortages occasionally disrupt power generation of some plants. Some private companies have gone as far as to set up plants in coastal areas to run them on coal imported from Indonesia, Australia or Africa even though imported coal costs more than the domestic coal.

Conclusion: *While Tanzania has significant coal reserves, it may need to build transportation infrastructure, which is currently a bottleneck, to evacuate coal. High costs of transporting coal over long distances, reduced international investor and development financial institution interest in coal mining and environmental cost of mining are issues that make coal unattractive going forward.*

FIGURE 4: LEVELIZED COST OF ELECTRICITY (LCOE) BY COAL TRANSPORT DISTANCE IN INDIA

Landed cost of coal increases considerably due to transportation costs which can add up to 30 per cent of the delivered coal price



Source: Bloomberg New Energy Finance

Coal-based power plants—Technology choices

In the previous power system master plan, PSMP2012, the base case projected that a total installed power capacity of 2,780 MW was required by 2015–16. However, the total capacity stood at only 1,700 MW in 2015. PSMP2012 planned to install 8,960 MW by 2035, whereas the latest plan (PSMP2016) projects 20,865 MW by 2040. The increase in planned installations can possibly be attributed to the increased proven coal and gas reserves in the country, found in recent years.

Most thermal power projects that are up for development (1,400MW), as per the PSMP2016, are of sub-critical technology. However, the plan does propose one ultra super-critical unit (see *Table 5: New installation of coal power plants*). Thermodynamic efficiencies of ultra su-

TABLE 5: NEW INSTALLATIONS OF COAL POWER PLANTS

Majority of the planned coal power plants are of inefficient subcritical variety

Names	Capacity (MW)	Type
Thermal power development candidates		
Mchuchuma I-IV	150 MW x 4 units	Sub-critical
Kiwira-I	200	Sub-critical
Kiwira-II	200	Sub-critical
Ngaka-I	200	Sub-critical
Ngaka-II	200	Sub-critical
Model units for variable expansion		
	156	Sub-critical
	300	Advanced sub-critical
	700	Ultra super-critical

Source: PSMP, 2016

per-critical power plants (40 per cent) are higher than those of the conventional sub-critical plants (34 per cent). Super-critical plants result in 20 per cent lower CO_2 emissions in addition to offering significant fuel savings when compared to sub-critical plants. Constructing new sub-critical plants means investment in old, inefficient technology with long lifespans and high generating costs. Meanwhile countries across the globe are decommissioning the same plants. However, Tanzania faces a difficult problem wherein ultra super-critical units of small size are uneconomical and constructing few large units would result in concentrated supply in those areas and high transmission costs to transfer power to load centers.

According to the *Brighter Africa* report, the global levelized costs for coal-based power is expected to be around $73–86 per megawatt-hour (MWh) by 2020, and with increasing efficiencies these costs are projected to go as low as $62–73/MWh by 2040.[13] These costs will rise if pollution control measures are implemented to meet international standards for particulate matter (PM), sulphur oxides (SOx) and nitrogen oxides (NOx) emissions. The PSMP2016 must consider the costs of emissions and efficiency measures when determining the cost of coal-based power.

In comparison, Lazard's estimates for unsubsidized LCOE highlight the cost-competitiveness of certain renewable energy sources. In several countries such as Chile, Australia, Brazil and India, costs of installing renewable capacity and tariffs are even lower. In India, for instance, the introduction of auctions led to tariffs of Rs 2.4/kWh (3.6 cents/kWh) for solar and wind energy.

TABLE 6: GLOBAL WEIGHTED AVERAGE LEVELIZED COST OF ENERGY (LCOE) FOR VARIOUS ENERGY SOURCES

Comparing levelized cost of energy of conventional and alternative energy technologies sheds light on the cost-competitiveness of solar and wind

Source type	Energy source	LCOE ($/MWh)
Alternative energy	Solar PV—rooftop residential	187–319
	Solar PV—rooftop C&I	85–194
	Solar PV—crystalline utility scale	46–53
	Solar PV—thin film utility scale	43–48
	Solar thermal tower with storage	98–181
	Wind	30–60
	Geothermal	77–117
	Biomass	55–114
Conventional energy	Diesel reciprocating engine	197–281
	Natural gas reciprocating engine	68–106
	Gas peaking	156–210
	IGCC	96–231
	Nuclear	112–183
	Coal	60–143
	Gas combined cycle	42–78

Source: Lazard

Conclusion: *Levelized cost of generation of renewables – specifically, utility scale solar and onshore wind – are now lower than that of coal and gas-based power in many countries and continue to fall. Moreover, Tanzania is primarily planning sub-critical coal-based plants, which tend to have lower efficiency and are more polluting. If the costs of pollution controls are added, their levelized cost of generation will be even higher.*

Gas based power

Natural gas is projected to be the biggest contributor to the power mix, amounting to 40 per cent of the power generation by 2040. The PSMP2016 allocates 8.015TcF or 20 per cent of recoverable natural gas reserve for power generation within the country.

A Tanzanian Natural Gas Utilization Master Plan[14] (NGUMP) showed that only 30–50 per cent of the gas reserves are financially viable and technically feasible to extract. A large chunk of the gas reserves are deepwater which requires new and expensive technology for extraction. According to the *Brighter Africa* report, the levelized cost of gas in the five gas rich countries of Tanzania, Mozambique, Mauritiana, Nigeria and South Africa would be around $47–65/MWh. It is estimated that over time, with the withdrawal of government subsidies, the levelized cost of gas-fired technology could increase to more than $90/MWh by 2040.[15]

Tanzania, driven primarily by energy security in response to recent droughts, plans to decrease its dependency on hydropower, and is looking to diversify its peak load. Additionally, natural gas is considered the obvious link between dirtier fossil fuels and renewable energy, and will in parallel allow Tanzania to raise flexibility within the grid.

Environment costs of fossil fuel-based power

The PSMP2016 says that the environmental implications of generating electricity need to be considered and pollution needs to be controlled. However, the plan does not detail the health and environmental costs associated with extracting and transporting coal and gas and generating power from fossil fuels. Nor does it detail the amount of additional investment that would be needed to control toxic emissions from fossil fuel-based power plants.

Mining and quarrying activities in Tanzania have increased by 21 per cent, largely driven by an increase in natural gas production and coal output. The extraction processes for gas and coal contaminates both air—fugitive emissions and methane—and water. Natural gas extraction is also associated with high GHG emissions.

Coal and gas combustion are also associated with highly toxic emissions (see *Figure 5: Estimated emissions in implementing PSMP2016 scenario 2 by source*). These emissions include combustion gases (nitrous oxide, N_2O, SO_2, and volatile organic compounds) as well as significant GHG emissions.[16]

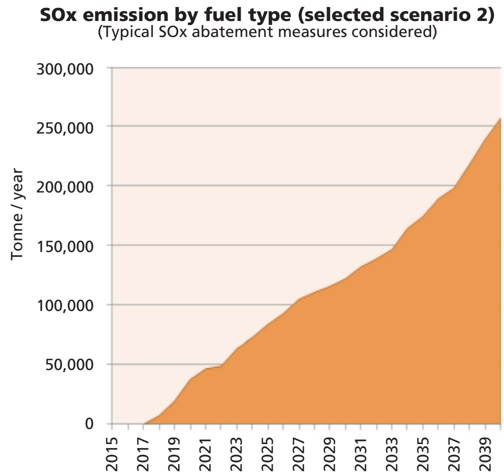
Tanzania has historically had low per capita GHG emissions; however, the planned increase in fossil fuel based generating capacity will sharply increase their emissions. PSMP2016 shows that scenario 2 will result in almost 45 million tonne/year of increase in CO_2 emissions by 2040.

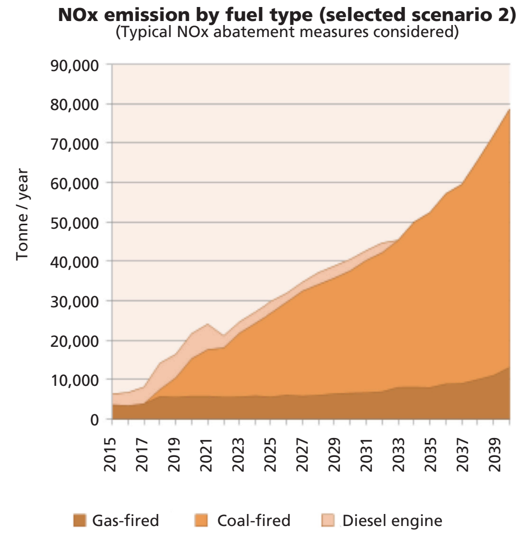
The SOx emissions depend directly on the sulphur content of the fuel. The emissions are produced by oxidation of sulphur during the combustion process of the power plant. The predicted increase in SOx emissions are primarily the result of new coal capacity (see *Figure 5: Estimated emissions in implementing PSMP2016 scenario 2 by source*).

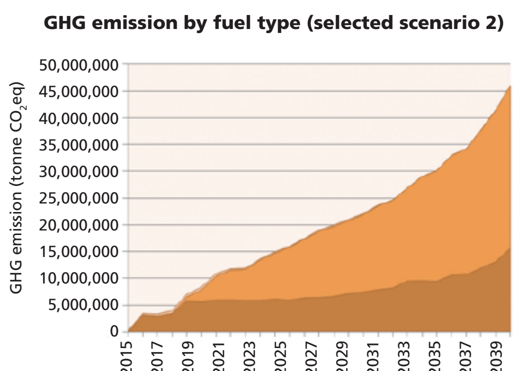
The NOx emissions are also largely produced from burning fossil fuel. NOx emissions are produced when fuel is (inefficiently) burnt at high temperatures, which results in conversion

FIGURE 5: ESTIMATED EMISSIONS IN IMPLEMENTING PSMP2016 SCENARIO 2 BY SOURCE

GHG, SOx and Nox emissions to increase by 13.5, 12.5 and 6.8 times with increased reliance on fossil fuel-based power plants







Note: The amount of emissions was estimated based on the projected annual fuel consumption and guidelines '2006 IPCC Guidelines for National Greenhouse Gas Inventories,' and 'EMEP/EEA air pollutant emission inventory guidebook 2013.'

Source: PSMP, 2016

of Nitrogen in the air to NOx. Predictive projections of NOx emissions show contribution from both coal and gas power plants. Overall, NOx emissions from coal power plants are around eight to ten times the emissions from gas-based plants

Both SOx and NOx are responsible for photochemical smog, which in the presence of water molecules result in acid rain. Apart from their serious effects on health, they contaminate water sources and soil.

The PSMP2016 does not account for the cost for emissions abatement measures. The study does not detail the increased cost of retrofits for pollution control that power plants would need to employ if the country were to introduce regulations to cut toxic emissions. In India, new regulations to reduce sulphur dioxide, nitrogen oxides and particulate matter emissions from coal plants are expected to increase the cost of coal power generation by Rs 0.3-0.4/kWh (0.6 cents/kWh, approx 10 per cent increase in tariff).

4. TARIFFS

Electricity tariff is a challenging issue for the government and TANESCO, which is ridden with debt. In January 2017, the energy ministry stated that it was seeking a loan of $200 million from the World Bank to relieve the indebted national power supplier TANESCO, after the country's president refused to allow the utility to raise prices to cover its costs, stating that 'it would hold back plans to industrialize the east African country'.[17]

TANESCO is stuck in a vicious circle, where they lack funds and struggle to supply power or extend its grid. On the other hand consumers are not motivated to pay for the unreliable electricity they receive. The ESI-RSR too allocated $412 million (of the total $1.15 billion by 2040) to rid the TANESCO of its debt and make the power in Tanzania more affordable.

The existing tariffs in Tanzania extend from $0.04 per unit for consumers who consume less than 75 units per month to $0.13 per unit for consumers who consume more than 75 units at voltages between 230V and 400V (see *Table 7: Electricity tariff charged by TANESCO*).

The tariffs in PSMP2016 are predicted to increase 300–350 Tsh ($0.13–0.15) per kWh and might even rise up to 380 Tsh ($0.17) per kWh under the high case as per PSMP2016. Data from the Tanzanian Investment Centre shows that the highest slab in the tariff structure was already 350 Tsh ($0.16) per KWh. These tariffs are consistent with the tariffs in its neighboring countries – Uganda ($0.13), Kenya ($0.19) and Malawi ($0.19).

The lack of reliable and quality grid supply leads many consumers in the commercial, industrial and residential sectors to use diesel generators for even more expensive power. A *McKinsey* research found that nearly 45 per cent of the businesses in Tanzania own diesel generators, despite the uncompetitive prices. The diesel generators in the long run are more expensive due to fuel costs as compared to the capital intensive solar and wind installations.[18] This highlights the willingness of the business owners in Tanzania to pay high costs for regular electricity that does not hinder their business.

TABLE 7: ELECTRICITY TARIFF CHARGED BY TANESCO

Segments (*Residential and business)	Service cost		Per unit cost	
	In TZS	In $	In TZS	In $
D1 segment: Consumers that consume maximum of 75 units or less per month	No service charges		100	0.04
T1 segment: Users* that on an average use more than 75 units per month at voltage between 230 and 400V	No service charges		292	0.13
T2 segment: Users* that on an average use more than 7500 units per month at 400V under 500 kVA/month	14,233 per month 15,004 per kVA	6.34 per month 6.68 per kVA	195	0.09
T3 - Medium Voltage Segment: Users at 11kV that use more than 500 kVA	16,769 per month 13,200 per kVA	7.47 per month 5.88 per kVA	157	0.07
T3 - High Voltage Segment: Users at 132kV	No service charges 16,500 per kVA	No service charges 7.35 per kVA	152	0.07

Conclusion: *Encouraging distributed generation (solar rooftop, minigrids etc.) can address two different problems – improving energy supply for customers who are able to afford power but are unable to get sufficient electricity due to distribution company issues, some of whom may be using expensive DGs, and improving energy access for the poor.*

5. TRANSMISSION AND DISTRIBUTION

The transmission expansion plan in the PSMP2016 is similar to the earlier plans of 2009 and 2012. In PSMP2016, the total cost for the transmission grid expansion as per the least cost expansion plan will be $10,230 million. Transmission grids are essential for quick evacuation of all the generated power to load centers and their subsequent distribution to houses. A lack of grid could cause black outs, brown outs, inefficient or underutilization of generation capacities etc.

However, for a country like Tanzania, with low population density and widely dispersed population clusters, the study also needs to detail investment required to expand and strengthen the distribution system. PSMP2016 says that costs for Tanzania's distribution system will amount to about twice the investment costs of transmission but does not detail the costs or plans. A study by SNC-Lavalin for India, calculates the marginal costs for specific generation, transmission and distribution system. According to the study, investments drawn towards 'generation is 64 per cent of the total, transmission 11–13 per cent and distribution 23–25 per cent'.[19] The investment required for transmission and distribution could be more for Tanzania since the country is sparsely populated. The high density areas are far away from the generation centers separated by huge areas of forest cover.

In Tanzania, the transmission and distribution (T/D) loss rates have varied sharply over the years, with losses as high as 26 per cent in 2005. PSMP2012 stated 'reduce energy losses from a level of 20.65 per cent to the acceptable level of 18 per cent by 2015'. Today, at 17.5 per cent, the country has achieved its previous target. PSMP2016 aims for T/D losses of 11.4 per cent by year 2025 based on the loss reduction targets set by TANESCO. The transmission expansion plan (PSMP2016) formulated by the WASP-IV does not specifically talk about measures adopted or funds allotted to curb these T/D losses.

TRANSMISSION AND DISTRIBUTION LOSSES

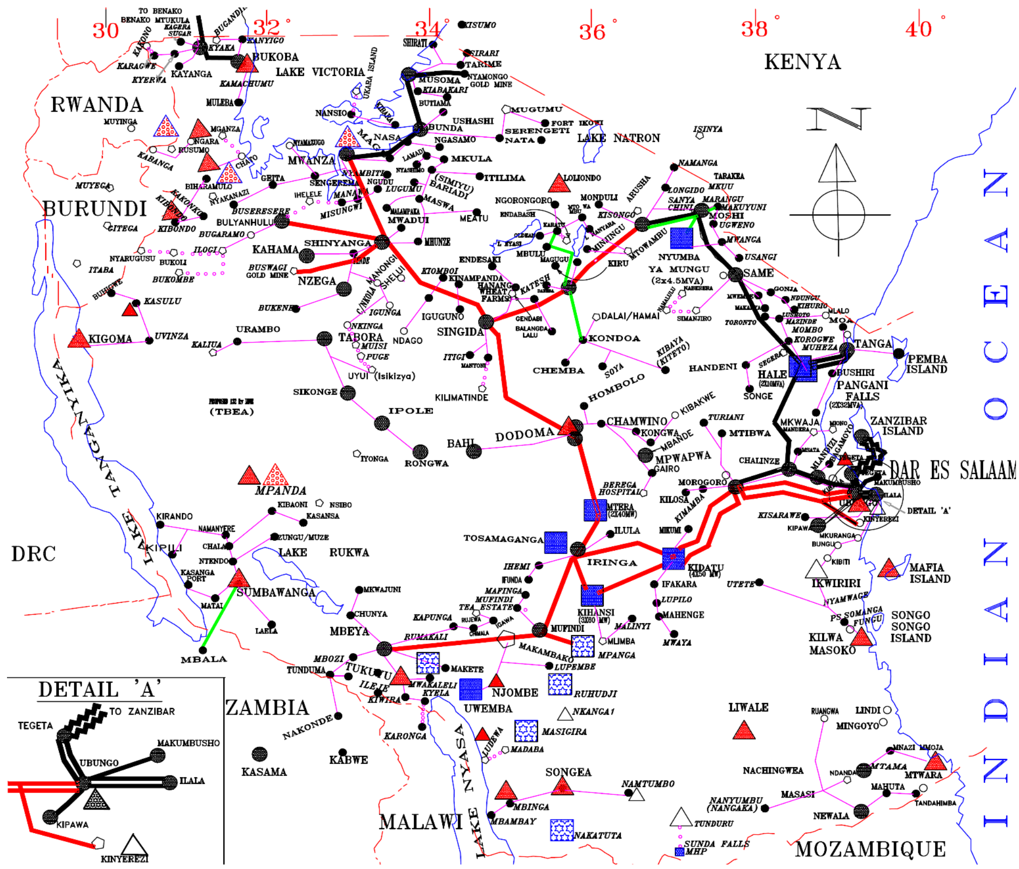
Globally, Germany showcases the lowest T/D losses of about 3.88 percent which can be attributed to significant investments for T/D grid. Sweden with population density similar to Tanzania's invested $1.93 billion in 2014–16 and it has identified investment needs of $7-8 billion up until 2025. These large investments have reduced their T/D losses from 10 per cent in the 1970's to 4.78 per cent in 2014.

Source: World Energy Council Indicators

The existing T/D infrastructure has not been able to meet the targets set for transmission line additions, as stated in the PSMP2012 (*see Table 8: Transmission Line Target for 2015 in PSMP2012*). PSMP2016 should identify the bottlenecks and accommodate for them or the expansion will continue to fall back as the generation increases resulting in congestion and additional losses within the T/D grid.

Additionally the large distances between production centers and load centers will require high voltage lines. Apart from Dar-es-Salaam, the population is concentrated in the north-west (around Mwanza, Shinyanga, Simiyu, Kagera, Kigoma, Tabora etc.) whereas the production is more in the south-east. Therefore, to accommodate for long distances, transmission lines with voltages above 400 kV should be considered. Introduction of high voltage lines (>400

FIGURE 6: LAYOUT OF THE EXISTING GENERATION POINTS AND TRANSMISSION GRID WITHIN TANZANIA



Note: Grid infrastructure is lacking
Source: PSMP, 2016

TABLE 8: TRANSMISSION LINE TARGET FOR 2015 IN PSMP2012

Comparison of targets and installed grid lines highlight the slow progress of grid development

Transmission line voltage	Total installed length in 2012	Target for installed length by 2015	Total installed length in 2015
400 kV		647 + installed	
220 kV	2,732	3,533	2,745
132 kV	1,538	1,834	1,626
66 kV	546		580

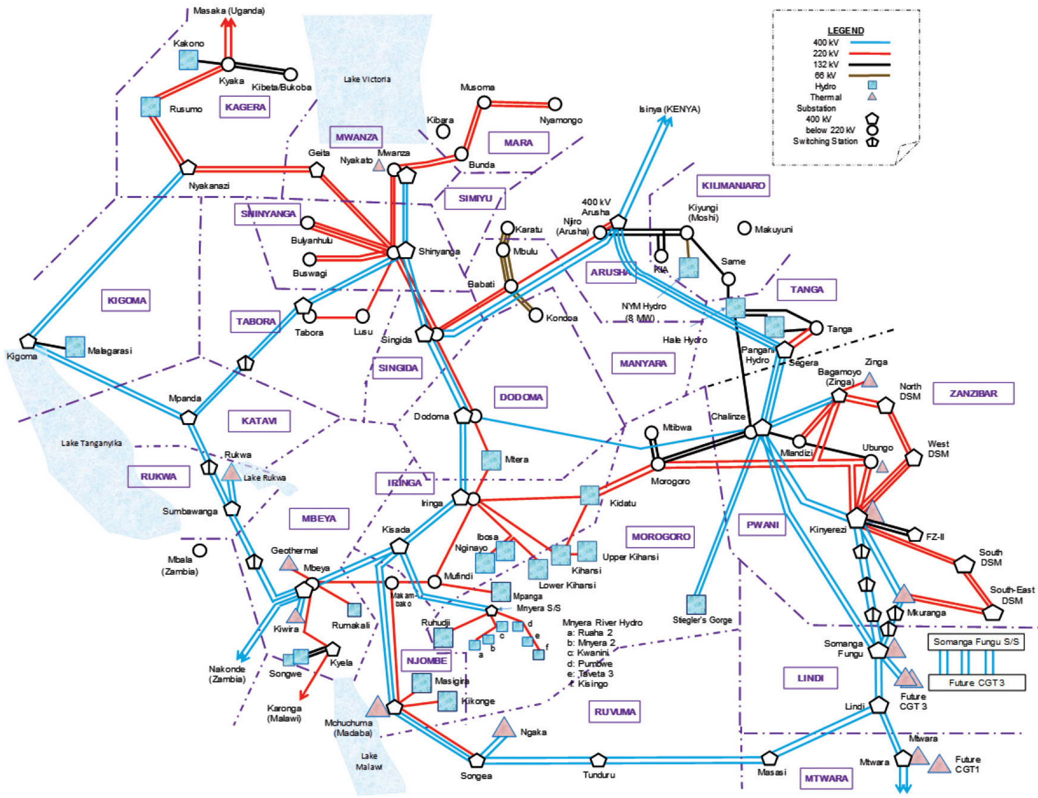
Note: Data for transmission line targets and installed capacities
Source: PSMP, 2016

kV) to reduce the number of lines needed, T/D losses and right of way (ROW) needed. The installation of high tension (HT) lines also help handle congestion—a leading cause for losses.

Tanzania's power agenda is looking to develop a single national grid in the hopes to stabilize electricity supply in the country. Congestion is a result of shortage of transmission capacity. As the demand and generating capacity grow transmission lines operating at their thermal limits will lead to T/D line losses. It's unclear if the PSMP2016 has considered grid congestion or relieving measures. Distributed renewable energy (DRE) generating capacity close to the load center would relieve stress on the transmission grid as it expands out.

FIGURE 7: GENERATION AND TRANSMISSION PLAN FOR 2040

The concentration of energy reserves in the south east will mean setting up expensive transmission and distribution grids across the country. The cost by itself presents a case for the introduction of renewable energy which can be produced at the point of use.



Note: Projected layout of the planned generation points and transmission grid within Tanzania
Source: PSMP, 2016

PSMP2016 acknowledges the need for adjustments in their strategy to include new interconnectors in the coming years. Interconnections offer the possibility of lower price realization for customers, inclusion of variable renewable energy and equally reliable supply at all load centers. However, a study by *Brighter Africa*[20]showed that regional gas production tends to be favored over some of the smaller in-country solar and wind installations. Although gas generation offers flexibility, it will result in increased emissions as compared to renewable energy. Tanzania must invest to 'maximize economic effectiveness of the energy transition while maintaining grid stability in the regional power pool'.

DISTRIBUTED RENEWABLE ENERGY

The aggregate nominal capacity for isolated centers—regions away from the grid—has remained constant since 2012 at 81.5 MW. PSMP2016 should consider utilizing Tanzania's high solar irradiation to power these isolated centers. Distributed renewable energy (DRE) can provide electricity access to unelectrified remote villages for the immediate future. Additionally, this can be combined with TANESCO's plans to connect all isolated generating capacities to the grid by 2032.

Conclusion: *Tanzania's young infrastructure presents a unique opportunity to develop an efficiently managed grid, if the necessary investments are made available.*

6. THE PROMISE OF RENEWABLES

Tanzania's renewable energy potential allows for an increased share of clean energy in the country's power mix without having to compromise its energy security needs. BNEF predicts that 72 per cent of all global investments in power generation will be in renewable energy, driven by significant drop in costs of solar (by 66 per cent) and onshore wind energy (47 per cent) by 2040. PSMP2016 does not reflect this global trend.[21]

Additionally, energy efficiency and conservation measures could decrease the required generation capacity; however, PSMP2016 plans activities pertaining to energy efficiency and conservation for after year 2026. The target efficiency rate is set to reach 0.5 per cent per year after 2026. This becomes especially important since the daily load pattern in Tanzania is still 'lighting peak' type. Using most energy-efficient lights, such as LED, would reduce the need for increasing installed capacity.

Though PSMP2016 discusses environmental protection, it has not looked at renewable energy as a solution to address environmental issues. An 'alternate' energy scenario, which is dominated by renewable energy, needs to be developed. This scenario would allow stakeholders to assess the assumptions, costs, benefits, and the practicality of pursuing large penetration of renewables. For example, PSMP2016 considers low utilization factor for solar (10–15 per cent). Solar plants in India, which has solar insolation in the same range of 4–7 kWh per sq. meter per day, operate at 20 per cent utilization factor.

Further, the cost estimates given for solar and wind energy in the PSMP2016, are high when compared to costs in countries such as South Africa, India etc. (see *Table 9: Renewable energy costs estimates*). Assumptions of lower renewable energy costs would help justify a larger share of renewable energy in the power mix.

TABLE 9: RENEWABLE ENERGY COSTS ESTIMATES

Costs of solar and wind energy have fallen considerably since the introduction of auctions in various countries. In comparison, PSMP2016 assumes twice the cost for the same capacity

RE technology	Appendix estimates		Report estimates		South Africa		India	
	$MM per MW*	Total	$MM per MW*	Total	$MM per MW**	Total	$MM per MW**	Total
Solar (200 MW)	3.95	1,777.50	1.20	540.00	0.55	247.50	0.53	238.50
Wind (450 MW)	2.27	454.00	1.57	706.50	1.24	558.00	0.95	427.50
Total		2,231.50		1,246.50		805.50		666.00

Note: Comparing cost of renewable technology as given in the PSMP2016 with costs obtained in auctions in South Africa and India.
*Source: *PSMP, 2016; **IRENA*

The dominant renewable technologies—wind and solar—generate intermittent power, necessitating investment in the grid to integrate it. Tanzania's relatively nascent infrastructure presents a unique opportunity to develop generation and transmission infrastructure that facilitates the technological measures necessary (storage solutions, efficiency measures, grid infrastructure etc) for renewable energy integration.

To enhance the balancing capabilities of thermal power plants, flexibility parameters such as retrofits may be required. It is unclear if PSMP2016 costs include for retrofitting the Kiwira I and II power station, Mchuchuma I–IV power station, and Ngaka I and II power stations. The costs for retrofitting coal power plants are given below (*see Table 10: Costs of retrofits*). power generators should consider these costs when planning the cost of generation from a power plant. These modifications will help lower minimum load (turndown), emission control, faster start-up, and improve down time and ramp rate. Further, adding these retrofits to coal power plants allow for renewable energy mix to be increased gradually. The development of battery for storage and other renewable energy integration measures could further enhance renewable energy share.

TABLE 10: COSTS OF RETROFITS[22]

The type of retrofits needed vary with the power plant in question, which in general help increase the flexibility of the system

Measures	Cost (million $)		
	Small sub-critical [200 MW]	Large sub-critical [500 MW]	Super-critical [750 MW]
Boiler retrofits	0.3–3	0.5–5	1–7
Coal mill retrofits	0.5–10	1–12	1.5–16
Emissions control retrofits	0.5–2	1–3	1.8–4
Balance of plant retrofits	0.57–4	1.5–7.5	2.25–4
Turbine retrofits	0.25–1	0.75–2	1–4
Chemistry-related improvements	0.3–1.5	0.5–3	3–4

Note: Ranges for costs of retrofits based on the purpose they serve
Source: ISA

T&D systems require on-time management of demand and supply. Additionally, RE additions to the power system mix reduces the utilization of the existing power plants and causes the cost for 'backup' power to increase. An Agora Energiewende report[23] gives the total costs for balancing grids in Germany as $6–$16 per MWh (of additional wind/solar power). Increasing grid connected renewable energy will reduce the operating hours for other conventional power plants. The additional cost associated with the aforementioned is given in the range of $8 and $16 per MWh. This would need to be combined with metering, forecasting and scheduling among other things to help increase the overall efficiency of the system.

Battery systems are essential to manage the high fluctuations and the intermittency with variable renewable energy, specifically for storing surplus energy and releasing it later. Additionally, the daily load pattern of a lighting peak has been used as one of the reasons why solar would not make sense for Tanzania because it cannot be utilized during peak hours unless it is equipped with a storage device.

BATTERY STORAGE

Battery storage is essential for decarbonizing the grid. According to an IRENA study, battery storage in stationary applications is set to increase to 235 GW by 2030. The high specific energy of Lithium ion batteries makes it the best replacement for peaker plants. A BNEF study states that the global market for lithium-ion battery from now to 2040 will be $239 billion. The cost of lithium-ion now ranges from $285 to $581 per kWh; whereas last year it was $321 to $658 per kWh. That's a 12 per cent drop in the median cost in one year. Its lowest-cost use is for frequency regulation, where the minimum cost dropped from $211 per kWh last year to $150 per kWh. Lower installed costs, longer lifetimes, increased number of cycles and improved performance will further drive down the cost of storage services.

Source: Bloomberg New Energy Finance

7. CONCLUSION

1. The PSMP2016 has tried to comprehensively address Tanzania's energy challenge of providing affordable, sustainable electricity to all. However, CSE's analysis, based on our India experience and recent developments in technology and renewable costs, suggests that the Plan should be reassessed.
2. Demand projections—based on GDP growth—may have been over estimated. For example, India's energy policy assumed GDP growth rates that were too high. Improvements in the economy's energy intensity meant that demand grew at a slower pace than what was projected. CSE recommends that PSMP2016 reviews demand projections assuming energy efficiency improvements and demand side management.
3. PSMP2016 plans commissioning of subcritical coal-based plants under the assumption they are cheap. However, they are inefficient and polluting. The true cost of thermal generation must also account for the true cost of fuel (i.e. market prices so it considers the implicit subsidy). Sharp increase in coal capacity combined with slower than projected demand and falling cost of renewables may result in coal capacity that is underutilized. This stranded cost also needs to be estimated.
4. Coal power plants are highly polluting with serious affect on human health, agriculture, water and livestock. Controlling pollution requires additional investment and adds to the cost of power generation. CSE suggests a detailed assessment of these costs.
5. Solar panel costs have fallen sharply over the last 2 years with the result that LCOE of solar is now below that of thermal power plants – the Plan should consider larger share of renewables.
6. Failure to expand the transmission and distribution grid in tandem with its generation has been a hindrance to universal electrification in India and in several other developing countries. We recommend that the Plan should evaluate the investment required to strengthen distribution.

Renewable energy opportunity

1. An analysis of the global renewable energy industry has shown that countries are consciously trading conventional energy systems for renewable energy systems. CSE proposes a reevaluation of the renewable energy contribution in the PSMP2016.
2. Renewable energy today offers a cost-competitive option. The idea is to complement thermal power generation with a larger share of renewable energy.
3. Distributed renewable energy (DRE) is a viable solution to immediately address energy access, especially for sparsely populated Tanzania. The modular nature of the technology can easily accommodate increase in demand.
4. DRE generates electricity close to the load centers eliminating the need for costly and time consuming grid infrastructure and also reduces power losses.
5. Renewable energy is further associated with job creation and GDP growth[24] and offers reliability to industries that due to diesel consumption remain uncompetitive.

The renewable energy industry has undergone a transition, where it is no longer expensive, unreliable and cumbersome. Technology is now demand and location-specific, much more efficient and capable of sustaining households and even countries. The PSMP2016 must weigh all social, environmental, and economic benefits, when determining how to utilize Tanzania's tremendous energy reserve/potential—both from conventional and renewable sources.

REFERENCES

1. The World Bank Database | IBRD IDA |Access to Electricity (% of population). 2018. Last accessed 20 April 2018. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2014&locations=TZ&start=2014&view=map
2. An LOLP (Loss of load probability) of 5 days/ year was considered. used as the indicator for evaluating the reliability of power supply, and the generation expansion plan which possesses the necessary reserve power for satisfying the target of LOLP is compiled
3. Bread for the World; World Future Energy Council; and CAN Tanzania. May 2017. Policy Roadmap for 100% Renewable Energy and Poverty Eradication in Tanzania https://www.worldfuturecouncil.org/file/2017/05/Policy-Roadmap-Tanzania.pdf
4. National Energy Policy, 2015. 2015. Dar es Salaam, Tanzania. Last accessed on 14 February 2018. http://docplayer.net/56869204-National-energy-policy-2015.html
5. Antonio Castellano, Adam Kendall, Mikhail Nikomarov and Tarryn Swemmer. February 2015. Powering Africa https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa
6. Tanzania says needs $46 billion in power investment by 2040. 2017. Reuters. Last accessed on 11 February 2018. https://af.reuters.com/article/idAFL5N1FR0QH
7. Central Electricity Authority. Ministry of Power, Government of India. December 2016. Draft National Electricity Plan http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf
8. Indian Brand Equity Foundation. January 2018. Power. Last accessed on 11 February 2018. https://www.ibef.org/download/Power-Report-Jan-2018.pdf
9. Brian Motherway. 2017. Energy Efficiency 2017. https://www.iea.org/media/publications/eemr/EE2017LaunchPresentation.pdf
10. TanzaniaInvest.com. Coal. 2018. Last accessed on 12 March 2018. https://www.tanzaniainvest.com/coal
11. Adam Lovett and Laura Kiwelu. Norton Rose Fulbright. Investing in Tanzania Electricity Sector. https://www.aef-offgrid.com/article/investing-tanzania-electricity-sector-10-things-know
12. Antonio Castellano, Adam Kendall, Mikhail Nikomarov and Tarryn Swemmer. February 2015. Brighter Africa—The growth potential of the sub-Saharan electricity sector. https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Brighter_AfricaThe_growth_potential_of_the_sub-Saharan_electricity_sector.ashx
13. Antonio Castellano, Adam Kendall, Mikhail Nikomarov and Tarryn Swemmer. February 2015. Brighter Africa – The growth potential of the sub- Saharan electricity sector. https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Brighter_Africa-The_growth_potential_of_the_sub-Saharan_electricity_sector.ashx
14. Natural Gas Utilisation Master Plan 2016-2045. Ministry of Energy and Minerals. 2016. Dar es Salaam. United Republic of Tanzania. https://www.jamiiforums.com/attachments/oil-and-gas-masterplan-pdf.495398/

15. Antonio Castellano, Adam Kendall, Mikhail Nikomarov and Tarryn Swemmer. February 2015. Brighter Africa—The growth potential of the sub- Saharan electricity sector. https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Brighter_Africa-The_growth_potential_of_the_sub-Saharan_electricity_sector.ashx

16. PetroWiki. Emmissions from oil and gas production operations. Last accessed on 25 April 2018. http://petrowiki.org/Emissions_from_oil_and_gas_production_operations

17. Fumbuka Ng'wanakilala. Reuters. January 2017. Tanzania seeks $200m World Bank loan to clear arrears of state utility. https://www.reuters.com/article/tanzania-power/tanzania-seeks-200m-world-bank-loan-to-clear-arrears-of-state-utility-idUSL4N1F63OC

18. Jonathan Knight. Uprise Energy. September 2012. Wind Power vs Diesel Power vs Solar Power http://upriseenergy.com/blog/2012/9/15/wind-power-vs-diesel-power-vs-solar-power-comparison

19. PSMP2016

20. Antonio Castellano, Adam Kendall, Mikhail Nikomarov and Tarryn Swemmer. February 2015. Brighter Africa – The growth potential of the sub- Saharan electricity sector. https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Brighter_Africa-The_growth_potential_of_the_sub-Saharan_electricity_sector.ashx

21. Veronika Henze, Catrin Thomas. June 2017. Global wind and solar costs to fall even faster, while coal fades even in China and India. https://about.bnef.com/blog/global-wind-solar-costs-fall-even-faster-coal-fades-even-china-india/

22. Deloitte. International Solar Alliance. February 2018. Variable Renewable Energy Sources Integration. http://isolaralliance.org/docs/Renewable%20Energy%20Integration%20Background%20paper%20Web(Brand%2019-01-2018).pdf

23. Agora Energiewende (2015): The Integration Cost of Wind and Solar Power. An Overview of the Debate on the Effects of Adding Wind and Solar Photovoltaic into Power Systems https://www.agora-energiewende.de/fileadmin/Projekte/2014/integrationskosten-wind-pv/Agora_Integration_Cost_Wind_PV_web.pdf

24. IRENA (2016), 'Renewable Energy Benefits: Measuring The Economics'. IRENA, Abu Dhabi. http://www.irena.org/publications/2016/Jan/Renewable-Energy-Benefits-Measuring-the-Economics

The Tanzanian Power System Master Plan 2016 (PSMP 2016) is a credible blueprint by the government to address the country's energy challenge—electricity that is widely available, affordable and sustainable. By 2040, Tanzania expects to electrify more than 90 per cent of its households. The PSMP2016, a comprehensive document with detailed assumptions about demand growth and various supply options, suggests that Tanzania's goals will be primarily met by coal and gas.

CSE has studied the PSMP2016 to understand how best Tanzania could meet the energy needs of its people. Recent advances in power generation, transmission and storage suggests that the PSMP needs to be revised. Larger share of power from renewable energy is both technically feasible and economically beneficial.

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