Integration of non-programmable Renewable Energy in the National Electric System of Kenya

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Abstract

Kenya is rich in renewable energy resources, namely hydro, wind, solar, biomass, and geothermal energy. This outstanding potential can be efficiently exploited in the power sector to boost generation so to cope with the strong load growth and enhance the electrification of the country that is still poor in the rural areas. However, the deployment of RES generation, especially if non-programmable (NP) as in the case of PV and wind, shall be accurately designed to ensure the compliance with reliability standards and security constraints. In particular, flexibility of the generation fleet becomes of utmost importance for following the load pattern and for dealing with the intermittency of wind and PV generation.

Furthermore, an appropriate design of Feed-in Tariffs or other schemes (e.g. auctions) can bring advantages in terms of reduced electricity costs with a consequent benefit for the country's economy and society. Indeed, the decreasing upfront investment costs on PV and wind plants make these forms of generation attractive for the investors and economically fruitful for the users.
Finally, the role of the transmission grid shall not be neglected to avoid occurrences of Renewable Energy Sources (RES) generation curtailments due to network bottlenecks.
All the above aspects are addressed in an integrated way in this study, which examined the evolution of the Kenyan power system until the year 2030 with different scenarios in order to account for uncertainties in the generation expansion plans.
The execution of this study has been requested by the Kenyan Ministry of Energy and Petroleum and coordinated by RES4Africa.

Objective of the study

The study is focused on the integration of non-programmable renewables into the Kenya's electrical grid taking into account the development scenario until 2030. The analysis has been carried out adopting a complete generation and transmission model of the Kenyan power system. The demand trend, the evolution of the generation fleet and the transmission grid have been considered to build a future base-case scenario. Several sensitivities were investigated versus the base-case scenario to account for uncertainties on the main parameters such as the composition of future mix of generation.

The results have been obtained through the application of state-of-the-art computational tools, developed by CESI, simulating the system reliability with a probabilistic algorithm and the market mechanisms with a deterministic algorithm.

Conclusions

The study clearly shows that the deployment of Renewable Energy Sources (RES) generation, including non-programmable RES such as wind and PV power plants, brings benefits for the system in terms of enhanced reliability, reduced consumption of fossil fuels and reduction of system generation costs. Therefore the exploitation of outstanding renewable potential resources in Kenya is very important to reduce dependency of energy supply of Kenya from other countries. This additional benefit plays a remarkable strategic role in the Country's policy. Furthermore, benefits arise from the avoided emission of GHG, particularly CO_2, that in the future could be traded as happens already in the European Union and in many states of the USA. The transmission grid expansion plan outlined in the Master Plan issued in 2016 allows the development of RES generation considered in the reference scenario without any major restrictions. Nevertheless, the need for a small set of additional reinforcements has been detected. The additional reinforcements are located in specific areas (areas of Malindi, Olkaria, Rabai and Ngong Hills) and can be easily integrated in the transmission grid Master Plan.

The analyses clearly highlights that additional capacity of non-programmable (NP) RES generation can be integrated, on top of the projects already in the Country's pipeline, provided that adequate measures are taken to ensure a flexibility in the management of generation. Indeed, a

critical aspect is related to the flexibility of the generation fleet that shall be able to cope with the daily and seasonal load patterns as well as the intermittency of NP RES.

Finally, a suitable evolution to lower feed-in tariffs (FIT) for RES generation has been considered. An alternative scheme can be based on auctions, the prices of which shall reflect competitiveness as well as cost reduction trend of RES generation investment. The breakeven values of RES generation FIT evaluated in the various scenarios, or alternatively the expected auction prices for RES, show already today the potential reduction of the Country's generation costs for the final users, as well as the economic attractiveness for Independent Power Producers (IPP) investors.

Introduction

Kenya is endowed with outstanding renewable energy resources, namely hydro, wind, solar, biomass, and geothermal[1]. In particular, Kenyan geothermal potential is estimated between 8-12 GW that can be efficiently exploited as base load generation. As for solar, Kenya has high insolation rates, and the potential for photovoltaic generation (PV) is estimated around 23 TWh/year mostly concentrated in the central and western areas (Fig. 1).

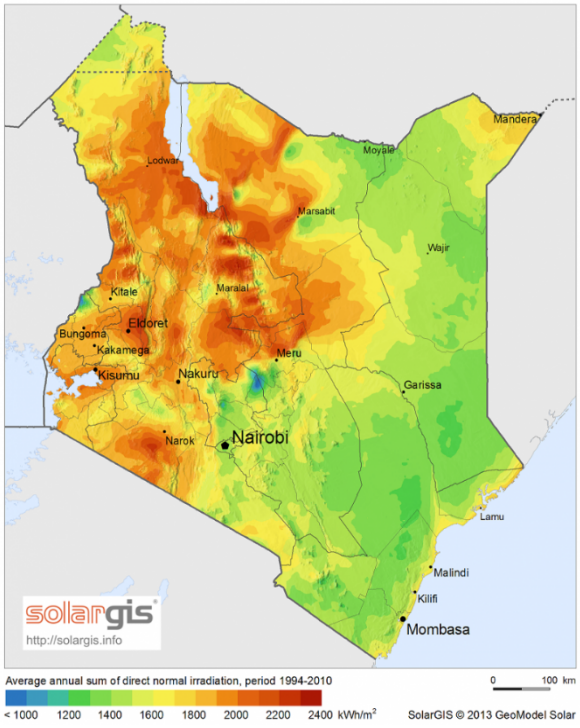


Fig. 1-Direct Normal Irradiation in Kenya (source GeoModel Solar)

The country has also a promising wind power potential. Referring to an average capacity factor greater than 30%, the country potential output is about 4.4 TWh/year. In particular the territory offers some excellent wind regime areas, notably the northwest of the country (Marsabit and Turkana districts) and the edges of the Rift Valley are the two windiest areas (with average wind speeds of over 9m/s at 50 metres) (Fig. 2).

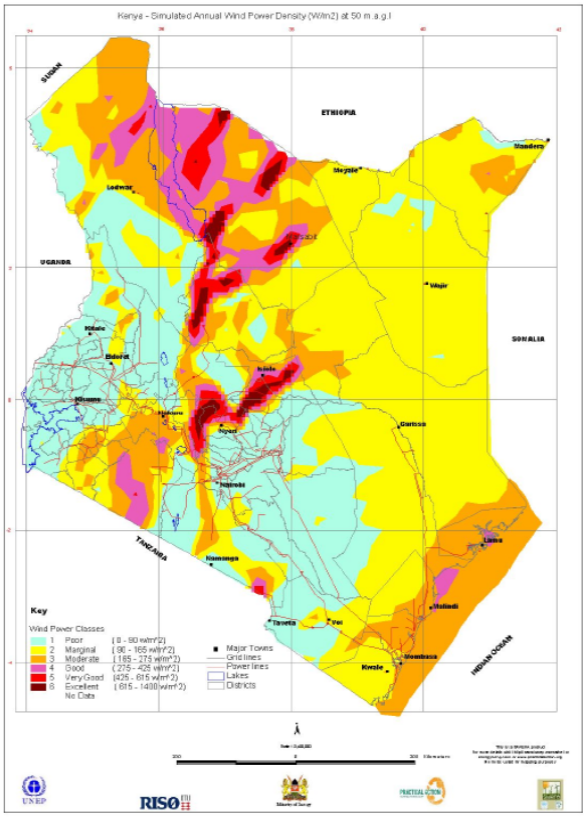


Fig. 2-Annual wind power density at 50 m. above ground (source: UNEP: Kenya Country Report)

Finally, concerning hydro resources, the potential for medium to large-scale hydroelectric power development is estimated to be 1,500 MW, of which 1,310 MW is feasible for projects with a capacity of at least 30 MW. Furthermore, the potential for small, mini and micro hydroelectric systems (with capacities of less than 10 MW) is estimated as high as 3,000 MW nationwide.

The above renewable energy resources can be efficiently exploited to cope with the robust demand growth exceeding 7% per year.

Whilst the exploitation of hydro and geothermal power is already experienced as

[1] Source: RECP – Africa-EU Renewable Energy Cooperation Programme

several installations are already in operation in Kenya, grid-connected wind and solar power plants are still not very common. Deployment of non-programmable renewable energy resources (NP RES) requires proper integration strategies, so to warrant sufficient security margins and reliability levels.

This study addresses namely the integration of non-programmable renewable generation into the power system of Kenya for the years 2025 and 2030, identifies possible criticalities and suggests remedial measures concerning either the operation of the generation system and the network.

The execution of this study has been requested by the Kenyan Ministry of Energy and Petroleum, supervised and coordinated by RES4Africa association and carried out by CESI with the collaboration of a Kenyan Working Group (KWG) consisting of a group of stakeholders led by Kenya Power and Lighting Company (KPLC). The other members of KWG are from Ministry of Energy and Petroleum (MOEP), Energy Regulatory Commission (ERC), Kenya Electricity Generating Company (KENGEN), Kenya Transmission Company (KETRACO), Strathmore University and Rural Electrification Authority (REA).

The Kenyan power system today

Despite the outstanding potential of renewable energy resources, the national electrification rate in Kenya is rather poor. Whereas the urban electrification rate attains 60%, in rural areas the electrification rate is less than 10% and this circumstance is typically compensated by a strong use of solid biomass for cooking and heating

In 2016 the net energy demand recorded in Kenya was 9.6 TWh, with a net peak power demand equal to 1,550 MW. Annex 1 depicts the current generation capacity mix: the generation heavily relies on liquid fossil fuels, geothermal and hydropower sources. On the contrary, wind and PV installations are very marginal.

In other words the country is at the beginning of a "green revolution" that shall see an increasing role of non-programmable (NP) RES generation.

Scenarios

The study covers the period until 2030, with special focus on two target years: a mid-term, year 2025, and a long term, year 2030.

The study performed by the MOEP "*Development of a Power Generation and Transmission Master Plan (PGTMP), Kenya. Long Term Plan 2015-2035*" (Oct. 2016) and the EAGER study "*Technical & Commercial Options for Optimising Dispatch of Geothermal Power in the Kenyan Power Market*" (Jan. 2017) is taken as a basis for the setting up of the reference scenario (Fig. 3). Furthermore, several sensitivities have been set up to cope with the various uncertainties in the power system development.

Table 1 shows different scenarios examined and their respective NP RES generation mix:

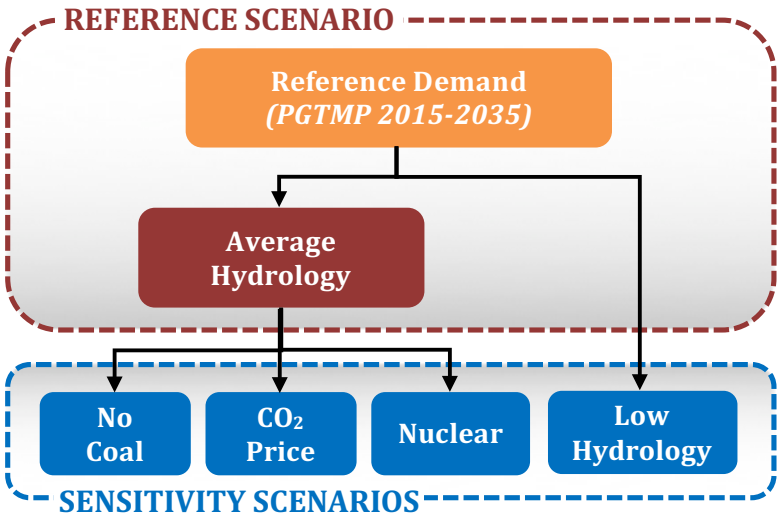
- ✓ *Master Plan* (MP): wind and PV capacities in compliance with the long term PGTMP 2015-2035;
- ✓ *Enhanced NP RES deployment scenario* (ENHAN): scenario with the same roadmap of wind generation development as in the MP, whereas a higher amount of PV installation has been considered on the basis of the good potential in the territory.

Wind and PV capacities were connected to the grid according to the projects in the pipeline (see Annex 2). These latter are less than the NP RES capacity considered in our scenarios. The additional capacity was distributed in the system taking into account the sites with higher wind and solar potential.

The reference scenarios are based on a reference demand growth rate (according to PGTMP 2015-2035), average hydro conditions and a programmable generation fleet according to data collected by the KWG.

Starting from the reference scenario, a set of sensitivities has been investigated:

- ✓ *No Coal* (S1): postponed commissioning of Lamu coal power plant (3x327 MW);
- ✓ *CO_2* (S2): considering the impact of an Emission Trading Scheme (ETS) (25 US$/ton$CO_2$ at 2025 and 30 US$/ton$CO_2$ at 2030);
- ✓ *Low Hydro* (S3): considering the impact of a drought year in the period of analysis;
- ✓ *Nuclear* (S4): considering the commissioning of a nuclear power plant.



Set of analysed scenarios and sensitivities	
2025	***2030***
Reference Scenario based on PGTMP	
S1: No Coal Sensitivity	S1: No Coal Sensitivity
S2: CO_2 Sensitivity	S2: CO_2 Sensitivity
S3: Low Hydro Sensitivity	S3: Low Hydro Sensitivity
-	S4: Nuclear Sensitivity

Fig. 3. Reference scenarios and sensitivities

Table 1. Level of NP RES installation on the various scenarios

Year	2025		2030	
Scenario	**MP**	**ENHAN**	**MP**	**ENHAN**
Wind Capacity	626 MW	626 MW	726 MW	726 MW
PV Capacity	80 MW	400 MW	150 MW	570 MW

Demand forecast in the reference scenario

Demand forecast in the reference scenario is based on the MOEP data. The total net energy demand expected by 2025 is about 18.4 TWh, CAGR +7,5% with a net peak power demand of 3,145 MW, CAGR +8,2%, and average HV network losses equal to 4.2% of gross demand... In 2030, the annual demand reaches 26.2 TWh (CAGR +7.3% in 2025-2030) with a net peak load of 4,527 MW (CAGR +7.6% in 2025-2030) and HV network losses 4.3% of gross demand (Fig. 4).

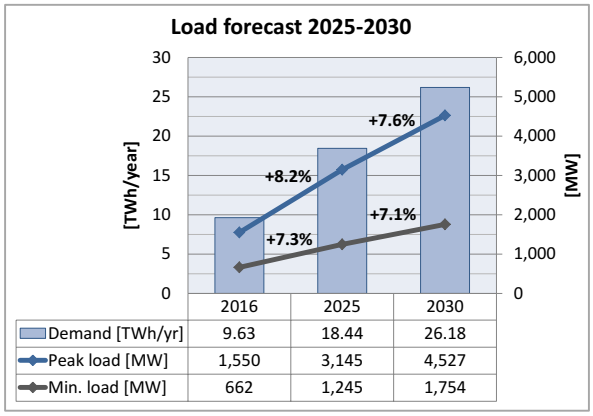


Fig. 4. Kenyan load forecast for 2025 and 2030 (Reference Scenario)

Generation mix

Evidently, such an important growth rate shall be sustained by a correspondent and robust power generation growth roadmap.

The Master Plan elaborated by MOEP is the basis of the generation growth roadmap for the reference scenario, taking into account the decommissioning of old units and the commissioning of new power plants, both programmable and non-programmable (wind and PV power plants), needed to ensure the system security and to cover the expected consumptions. Table 1 shows two levels of NP RES estimated capacities.

The time period from now to 2030 shall witness a rapid growth of RES power plants installations in hydro (+115%), geothermal (+140%) and wind, PV and biomass the amount of which is currently negligible (28 MW). In 2030, the fossil fuel generation will rely only on one large power plant, Lamu, fuelled with imported coal; whereas the other units, like diesel, would be used only as a backup in case of emergency (see Annexe 1).

Moreover, it is worth mentioning that the Kenyan power system will be soon interconnected with Ethiopia by 2019 through a strong 2,000 MW 500 kV HVDC link. This will allow having access to further source of power generated by hydro plants on the Blue Nile. A long-term (25 years) power purchase agreement (PPA) of 400 MW with Ethiopia has already been signed with capacity factor of 85% corresponding to about 3,000 GWh/yr.

Referring to the above generation mix scenario, a key question arises on whether such development plan is feasible. Initial observation is that the future generation mix might not be flexible enough to cope with the daily load profile. Geothermal and coal units are usually operated as baseload, hydropower is subject to minimum water discharge levels and exposed to poor rainfalls periods risk, whilst wind and PV generation is not programmable. Moreover, the flat 400 MW imported power from Ethiopia based on a PPA will further reduce the residual load to be fed with RES generation. However, as reported later, the non-programmable RES generation contributes to enhance the security of supply.

Hence, one of the steps in the study process addressed namely the reliability of the power system in presence NP RES considering the technical constraints of the generating units and the load patterns.

System reliability

For the target years, the quantitative evaluation of static reliability of the electric power system (adequacy) is obtained computing risk indexes. They are evaluated by applying a probabilistic procedure that allows simulating a whole year taking into account all scheduled and forced outages of generating units and network components as well as the volatility of PV and wind generation. The computational tool adopted for the simulations is GRARE (Grid Reliability and Adequacy Risk Evaluator)[2], based on a hybrid Monte Carlo algorithm and developed by CESI on behalf of Terna, the Italian Transmission System Operator.

The following reliability indexes are considered:

- *Expected Energy Not Supplied* (EENS): expected yearly energy average value of unsupplied load due to unavailability of generation and/or transmission equipment, caused by scheduled maintenance and/or forced outages (MWh/year or p.u.[3] of annual demand);
- *Loss of Load Expectation* (LOLE): period in which demand is not supplied (hours/year).
- *Loss of Load Probability* (LOLP): probability of not being able to meet the expected weekly peak load (%).

The following standards for the Kenyan power system are adopted (Table 2).

Table 2. Kenyan standards for reliability indexes

Index		Limit	Unit
EENS(**)	≤	$1 \cdot 10^{-4}$	p.u. of yearly demand
LOLE (*)	≤	48	h/year
LOLP(**)	≤	1	%

(*) *Source: PGTMP 2015-2035*
(**) *Source: values adopted in sub-Saharan countries.*

The progressive deployment of RES generation, notably PV and wind, shall not worsen the reliability standards.

Furthermore, another index is relevant for our analysis: the risk of RES generation curtailment due to constraints on the generating units, combined with the load pattern and the generation from NP RES plants.

Table 3 shows the EENS index obtained in the Reference Scenario at the year 2025.

Table 3. Expected energy not supplied (MWh/year)– Reference scenarios 2025 (*)

NP RES	TOTAL (MWh/yr)	TOTAL (p.u.MWh/yr)
MP	**591**	**$0.321 * 10^{-4}$**
ENHAN	**516**	**$0.280 * 10^{-4}$**

(*) values neglecting "network splitting" and "isolated nodes".

According to the above, the introduction of wind and PV, notwithstanding their nature of non-programmable generation sources contributes to increase the reliability of the system. Furthermore, better results are obtained in case of the enhanced RES scenario (ENHAN). A similar trend holds true also in the Reference Scenarios at year 2030.

With regard to RES generation curtailment due to network congestion, in 2025 such risk is very limited and mainly related to wind power plants.

[2] See www.cesi.it/grare
[3] p.u.: per unit

In 2030, NP RES generation is affected by curtailments of circa 5% of the total NP RES yearly production.

The role of the transmission grid

The role of the transmission grid is essential to ensure a reliable power supply. Regardless the presence of non-programmable RES, due to its radial configuration and poor meshing, the reliability indices risk to exceed the quality thresholds (Table 2). The network transmission development plan outlined in the PGTMP and validated by the KWG is coherent with the roadmap of NP RES development in both scenarios, MP and ENHAN, with few exceptions.

In fact, the probabilistic model simulation of the power system yearly behaviour highlights local network congestions (see callouts in the single line diagram of Fig. 5):

- double circuit 220 kV line "*Suswa – Olkaria 4*". This line allows the exploitation of geothermal productions from the Great Rift Valley to cover the national demand, particularly concentrated in the biggest load centres of Nairobi area. The commissioning of new geothermal capacity between 2025 and 2030 (+430 MW reaching total 1,519 MW installed capacity) is not sufficiently supported by the network. In fact, the line is overloaded for more than half of the hours of the year, with geothermal production curtailments needed to solve the congestions. The reinforcements of this 220 kV line would be useful to improve geothermal exploitation.
- 1st and 2nd 220/132 kV "*transformer in Rabai substation*". The growing demand in Kilifi, Mombasa and Kwale Counties, together with the decommissioning of some conventional power plants (e.g. Kipevu 1 and Kipevu 2), creates significant congestions with big power flows streaming from 220 kV to 132 kV network.
- 220 kV line "*Garsen – Malindi*" and 132 kV line "*Kilifi – Malindi*", in the Coast area, which are overloaded for more than 1,000 hours/year.
- 66 kV line "*Ngong RD – City Square*" whose power flow is affected by the commissioning of wind farms in the area of the Ngong Hills (south-west Nairobi). This is the only line that becomes critical when installing such wind farms in that sub-region.

System reliability: sensitivity analysis

The impact on system reliability from sensitivity scenarios can be summarised as follows:

- *No Coal (S1):* the possibility of a postponed commissioning of Lamu coal power plant worsens the reliability indexes due to lack of generation. Thus, in case of postponing the Lamu coal power plant commissioning, other generation capacity shall be considered. In particular, additional 530 MW wind capacity could be able to cover part of the lack of power arising if a postponement in Lamu commissioning occurs. In this latter case, only in some peak hours the system may not be able to fully cover the load.
- *Low Hydro* (S3): when low hydro conditions occur, the system reliability is assured (i.e. all indexes are lower than reliability thresholds), in fact the lack of hydro power is replaced by the available generation fleet. No major impact on curtailment of NP RES.

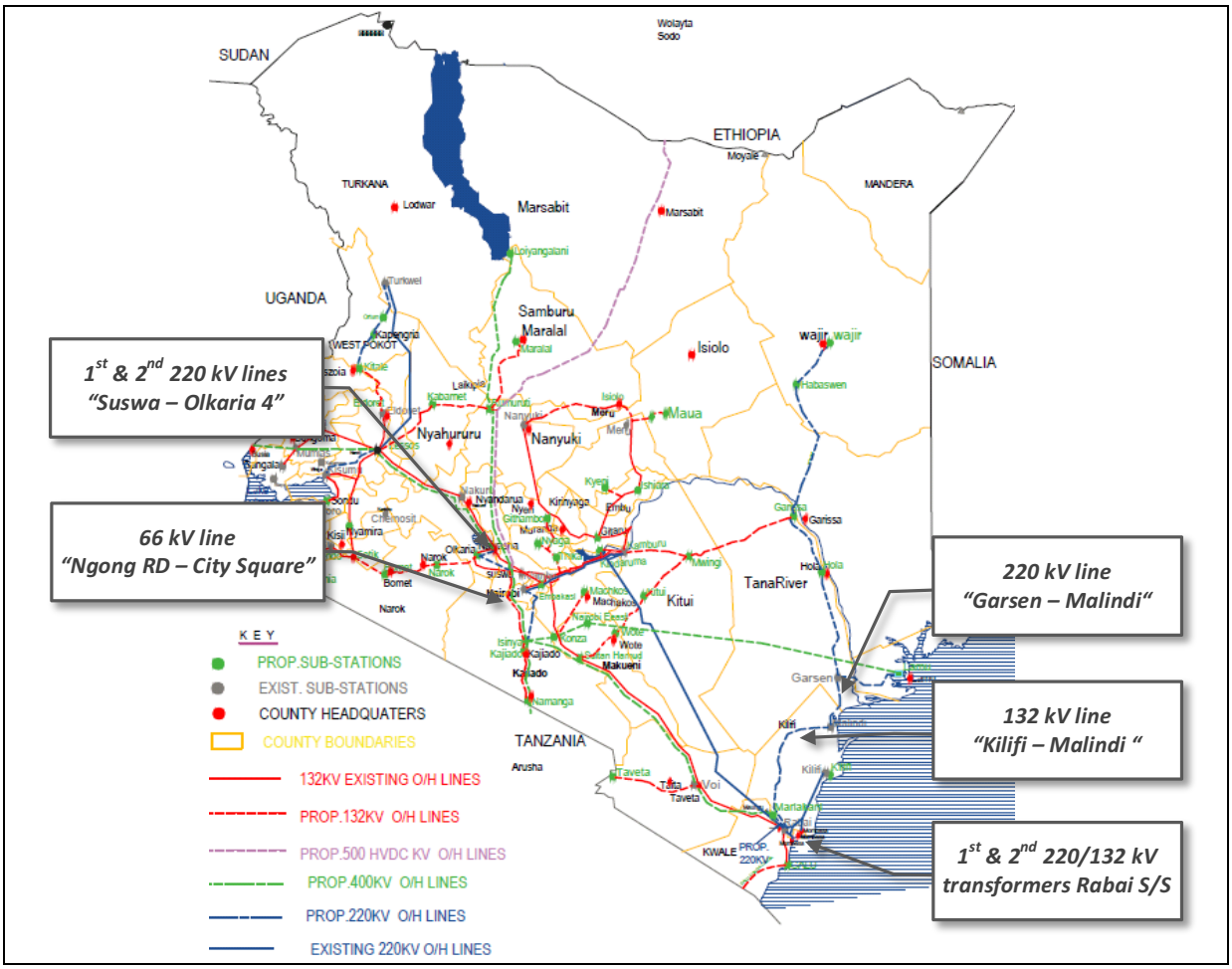


Fig. 5. Kenyan transmission grid (source KPLC – Annual report and financial statements 2016)

• *Nuclear* (S4): The nuclear power plant replaces generation from coal power plant keeping the system adequate, but makes it more difficult the exploitation of NP RES with consequent higher risk of curtailment. Furthermore, the risk of commissioning postponement is very high with consequent lack of power supply.

Finally, the introduction of an Emission Trading Scheme (S2) does not have any impact on system reliability, but only on dispatching costs.

Over-generation in systems with a high share of non-programmable RES

Over-generation (OG) is the share of generation, which cannot be integrated in the electric power system and has to be curtailed to assure the demand-generation balance. The OG phenomenon may occur due to operational system requirements and operational constraints of power plants. The Kenyan system is characterized by low generation flexibility, which leads to a relevant presence of OG throughout the year. An example of OG phenomenon is highlighted in Fig. 6.

In the study, the OG has been divided into two clusters:

- *Vented geothermal steam:* this is a solution to reduce geothermal production when overproduction occurs. Similarly to the Master Plan assumptions (PGTMP), geothermal power plants have been assumed as non-flexible single-flash technology. Therefore, reduction of their power output can only be obtained through venting steam in the atmosphere. Vented geothermal steam occurs every time geothermal power plant does not operate at its maximum power. The introduction of binary technology for future geothermal plants could mitigate vented steam.
- *Excess energy*: share of OG that still occurs after the reduction of geothermal generation.

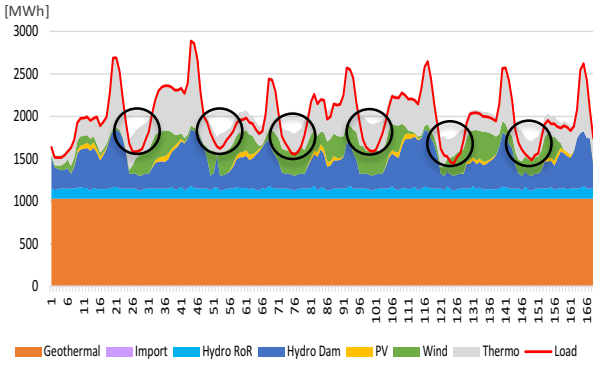


Fig. 6 -. Example of hourly generation in the first week of the year 2025 (note: in this simulation the import from Ethiopia was not considered). -The share of OG is highlighted with black circles

Electric market simulation and risk of over-generation in Kenya

The impact of non-programmable RES generation on the operating costs of the Kenyan system and the overall costs due to RES integration have been evaluated.

To this purpose, the analyses have been performed by means of a day-ahead market simulator developed by CESI, named PromedGrid[4]. PromedGrid software carries out an optimal coordinated hydrothermal scheduling of the generation fleet over a period of one year with an hourly time discretization.

Beside the operating costs, the day-ahead market simulator allowed quantifying the risk of OG due to NP RES showing when and what amount of production risks to be curtailed.

In fact, already today the OG problem affects the Kenyan electric power system. The occurrence of OG is related to the inflexibility of the generation fleet and this issue risks to be more critical in the mid-long term, particularly due to:

- must-run capacity of geothermal power plants. These units are designed to operate at maximum power; a regulation bandwidth (77%÷100% of available capacity) is admitted by PPAs but any reduction of geothermal production under 100% of maximum power causes a loss of energy (geothermal steam), unless a more flexible technology is used;
- Take-or-pay power import through the HVDC link Ethiopia-Kenya (400 MW);
- Minimum outflow of hydro power plants;
- Priority dispatch of non-programmable RES (wind and PV).

In order to reduce this effect, the generation from geothermal power plants has to be

[4] E.Elia et alii, "*Market integration and storage resources optimization to mitigate the risks of over-generation from non-programmable RES: the Italian prospective*", CIGRE General Session 2014, Paris, paper C5-306

curtailed. As shown in Fig. 7, geothermal generation reductions were applied also in 2016 due to the low flexibility of the existing geothermal fleet.

The integration of NP RES might increase the OG situations. The reasons for this behaviour are mainly due to the difficult exploitation of wind generation during the night hours with low load and the high value of minimum generation to be kept in service for stability reasons (power plants that provide reserve) and commercial constraints (geothermal units and import from Ethiopia) (Table 4).

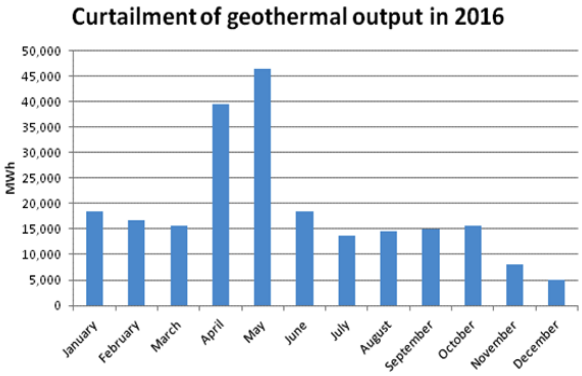


Fig. 7. Curtailment of geothermal output in 2016

A summary of the energy curtailed in the Reference Scenarios is shown in *Table 4*. The year 2025 is the most critical year for OG, while later on the risk of OG drops due to the increase of the demand.

In order to reduce the OG in the system some actions are recommended:

- The portion of vented steam could be reduced through the introduction of binary technology for new geothermal units. In fact, more flexible units avoid wasting of steam;
- A lower amount of OG can be attained by means of agreements with the neighbouring interconnected countries to export the excess of generated energy. In case of Ethiopia a renegotiation of import PPAs in term of take-or-pay provisions could be considered;
- The postponement in geothermal power plants commissioning would reduce the over-generation in the system, in particular in the year 2025;
- The likely postponement in coal power plant commissioning reduces the risk of over-generation. Moreover, without the energy produced by the coal plant at the year 2025, some additional space for different and cheaper generation is available, in order to avoid the risk of energy not supplied in the peak hours.

Table 4. Energy curtailment at 2025 and 2030 in the examined scenarios

	Scenario	WIND capacity [MW]	PV capacity [MW]	OG (% on total generation) Vented Steam + Excess Energy
2025	**MP**	626	80	1,487 GWh (7.2%)
	ENHAN	626	400	1,700 GWh (8.0%)
2030	**MP**	726	150	826 GWh (2.9%)
	ENHAN	726	570	843 GWh (3.0%)

Cost assessment related to non-programmable RES integration

An economic analysis of the impact of NP RES in the Kenyan power system has been carried out including power market simulations over one year time period for different time horizons (2025 and 2030) and different power system development assumptions (Reference, CO_2, Low hydro and No Coal scenarios for 2025 and 2030 and a Nuclear scenario for the year 2030 only). For each scenario the yearly benefits have been evaluated, being:

- reduction of fuel consumption;
- reduction of CO_2 emissions that can be valorized only in case of an Emission Trading Scheme will be introduced (CO_2 scenario where the avoided emission right costs have been considered);
- reduced risk of energy not supplied that can be valorised multiplying the EENS reduction by the Value of Lost Load (VOLL).

In order to evaluate the economic impact of introducing the NP RES in the Kenyan power system, the above mentioned yearly benefits have been compared with the additional annual system costs related to Feed In Tariffs (FITs) for NP RES. In the current framework, FITs for wind and PV generation are paid also in case of production curtailment, with a small reduction (-10% of full FIT). Therefore the expected energy curtailment has been valorized accordingly. The FITs considered for the cost evaluation are in line with the more recently signed Long Term-PPA. Nevertheless in the future, other mechanisms such auctions or FIT reduction, can be adopted to better dynamically reflect the LCOE decrease of NP RES generation, reducing the costs for the Kenyan system accordingly.

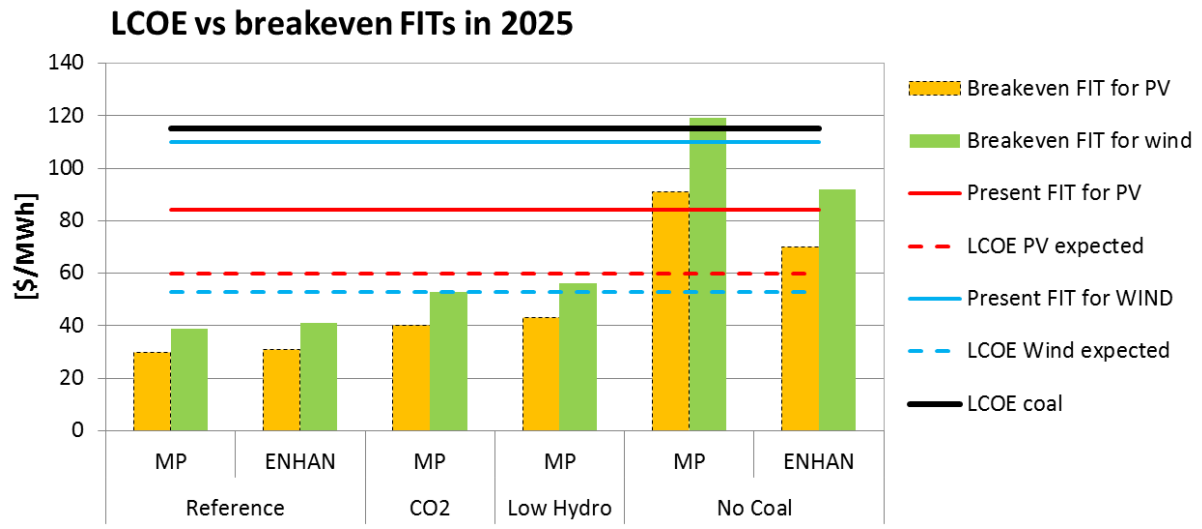
Additional costs related to network reinforcements are very low. In fact, such reinforcements are already considered in the Master Plan and mostly related to the 66 kV line in the area of Ngong Hills.

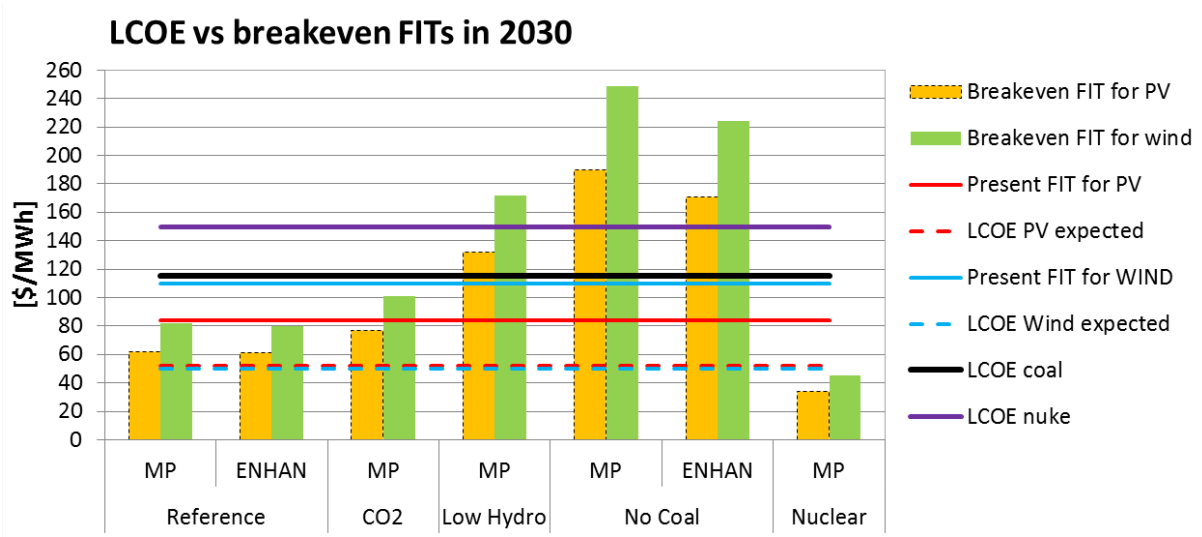
Based on the methodology here above, the so called break-even Feed in Tariffs have been evaluated as the theoretical maximum tariff of renewable sources which would allow such power generation to decrease the electricity price for users. Therefore, if the LCOE and PPA prices of the RES technologies are lower than such break-even FIT benchmark, the additional RES will decrease Kenyan electricity costs. In some cases, such break-even tariffs are already in line with the expected LCOE (see the following two diagrams). In particular, the figures show how the expected LCOE for NP RES technologies[5] are already in line with the break-even FIT in 2025 scenarios, whereas lower in 2030. Furthermore, as shown in the same diagrams, the LCOE of NP RES technologies is much lower than coal[6] and nuclear [7] ones, thus suggesting the convenience of a slower commissioning of coal-fired and nuclear capacity than planned and replacing this capacity with renewable technologies.

[5] Source IRENA, Power to Change, 2016

[6] Coal LCOE has been derived from PGTMP (Vol. II page. 157), applying the capacity factors resulting from the Reference scenario without NP RES for the year 2030 and considering a different variable cost component consequent to the different fuel cost assumption adopted in this study with respect to the PGTMP one.

[7] Nuclear LCOE: source IEA, Projected Costs of Generating Electricity, 2015 Edition (Table 3.18 page 59). LCOE calculated with the capacity factor resulting from Nuclear scenario without NP RES.





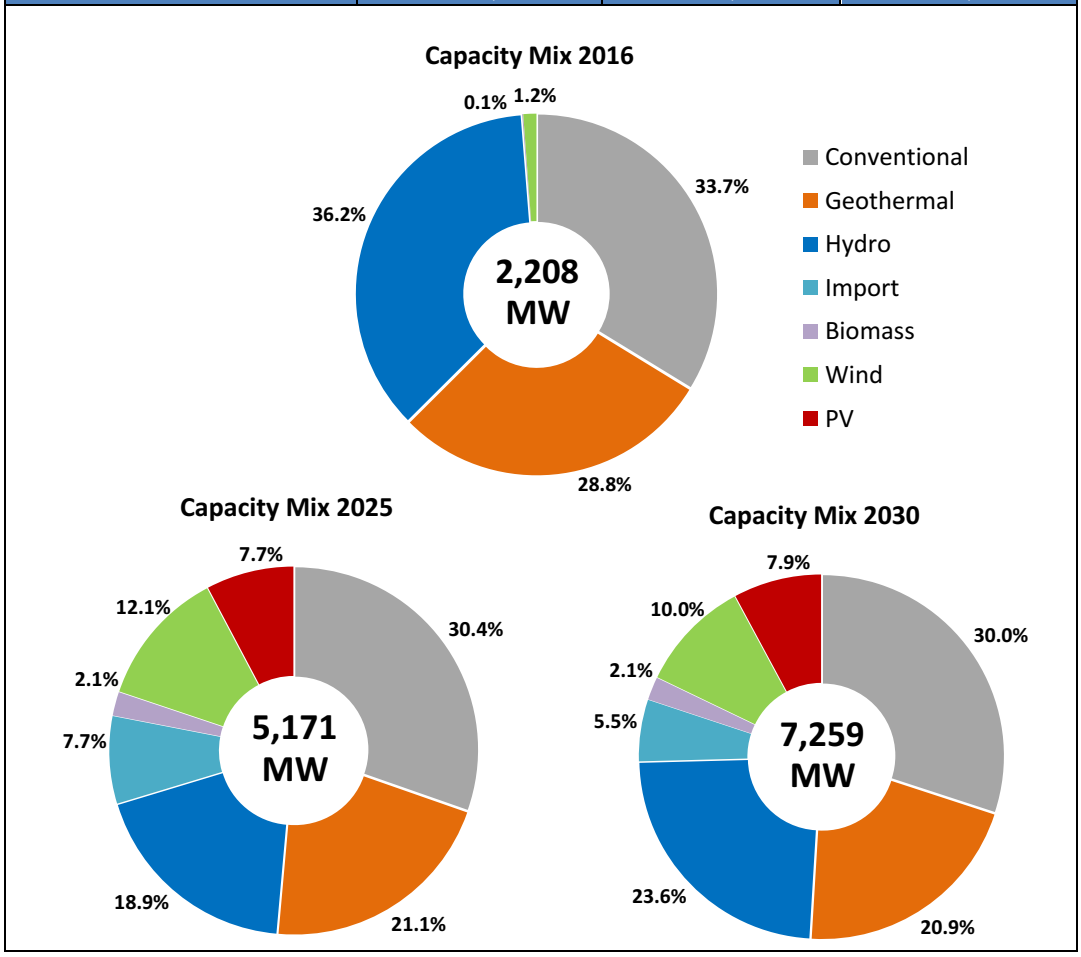
In conclusion, non-programmable RES are already competitive and economic for the Kenyan system today, if prices lower than current FIT are adopted. Lower wind and PV PPA prices can be easily obtained by decreasing national FIT levels or by structuring international RES auctions (f.i. like in RSA, Zambia, Ethiopia, Senegal or other countries outside Africa). In particular, auction systems allow the Country to lower the energy bill and increase attractiveness of reliable investors, reducing RES project's time to market.

Hence, when adopting alternative measures, such as auctions, lower auction clearing values with respect to the break-even FIT would be obtained. This would create value to the electricity market with benefits for the final users while ensuring the profitability for the investors.

Annex 1

Generation Mix in 2016 and estimated at year 2025 and 2030 in Enhanced NP RES deployment scenarios

Source	2016	2025	2030
Conventional	745	1,570	2,180
Coal	-	981	981
Diesel engines	691	449	359
Gas turbines (gasoil)	54	-	-
Generic back-up	-	140	840
Hydropower	799	977	1,715
Geothermal	636	1,089	1,519
Cogeneration/biomass	2	109	149
Wind	26	626	726
PV	-	400	570
Import	-	400	400
Total	**2,208**	**5,171**	**7,259**



Annex 2

Wind and PV projects in the pipeline

Wind Project	Pmax [MW]	Substation	Area
Ngong 1, Phase I-II	26	Ngong 220/66 kV	Nairobi
Ngong 1, Phase III	10	Ngong 220/66 kV	Nairobi
Lake Turkana – Phase I – Stage 1,2,3	300	Loiyangalani 400/220 kV	Western
Northern Project Limited	60	Isiolo 220/132/33 kV	Mt Kenya
Meru Phase I	80	Isiolo 220/132/33 kV	Mt Kenya
Prunus Wind	50	Ngong 220/66 kV	Nairobi
Chania Green	50	Kajiado 132/33 kV	Nairobi
TOTAL	**576**		

PV Project	Pmax [MW]	Substation	Area
Strathmore	0.25	Nairobi East 220/66 kV	Nairobi
Garissa Solar	50	Garissa 220/132/33 kV	Mt Kenya
Marco Borero	1.5	Kiganjo 132/33 kV	Mt Kenya
Greenmillenia	40	Isiolo 220/132/33 kV	Mt Kenya
Alten	40	Eldoret 132/33 kV	Western
Radiant	40	Eldoret 132/33 kV	Western
Eldosol	40	Eldoret 132/33 kV	Western
Quaint	10	Homa Bay 132/33 kV	Western
Kenergy	40	Nanyuki 132/33 kV	Mt Kenya
Vateki (Malindi Solar)	40	Malindi 220/132 kV	Coast
TOTAL	**302**		