Conceptual Plan for Enhancing Transmission Infrastructure to Expand Electricity Access in the Democratic Republic of the Congo (DRC)

FINAL

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Contents

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Executive Summary

ICF was engaged by the U.S. Agency for International Development (USAID) to identify and develop conceptual plans for expanding, enhancing, and augmenting the Democratic Republic of the Congo's (DRC) transmission and distribution infrastructure. Based on discussions with USAID representatives, ICF shortlisted four cities/population centers—Kikwit (in Kwilu province); Kananga (in Kasai-Central province); Tshikapa (in Kasai-Central province); and Mbuji-Mayi (in Kasai-Oriental province). We reviewed publicly available reports, press articles, and maps to identify the existing and proposed load resources, supply resources, and potential transmission solutions that could improve energy access to the four focus cities/population centers.

An ICF team visited DRC's capital Kinshasa (February 13-23, 2017) and met with several stakeholders, including Ministry of Energie and Hydraulics, GCK, UCM, SNEL, and AEE Power. These meetings provided additional and updated information on current and future projects and plans for DRC's power sector. At the end of the trip, ICF presented this project to all the stakeholders, including the World Bank.

ICF carried out the supply assessment under two distinct scenario frameworks: one involving the development of local supply resources (Scenario 1 framework) and the other involving the development of the Inga III project (part of the Grand Inga) and augmented HVDC/AC transmission lines (Scenario 2 framework). We also project the supply-and-demand trends for individual cities for the next 20 years (until 2035) under these two frameworks. Based on our assessment, we propose the following conceptual transmission solutions to meet the projected peak electricity demand requirements of the cities and improve the overall transmission grid operations in the country:

For a scenario with the development of local hydro resources for individual cities by 2020:

- Local collector-type transmission line projects for the individual cities of Kikwit, Kananga, Tshikapa, and Mbuji Mayi
- Distribution concession system for Kikwit
- 220 kV AC transmission line between Kikwit–Kananga–Tshikapa–Mbuji-Mayi

For a scenario with the development of the 4,800 MW Inga III Project by 2025:

- Augmentation of the 500 kV HVDC Inga–Kolwezi line
- AC "backbone" for the DRC (Grand Inga–Kinshasa–Mbuji Mayi–Lubumbashi)

There are five sections in this report. The first section presents an overview of the electric power sector in the DRC, with a focus on the existing regulatory structure, existing supply resources, historic demand trends, and the existing transmission infrastructure. The second section presents the demand projections for the four cities/population centers using the population estimate and unmet demand projections from a UNDP 2014 DRC Atlas report as the starting basis. We used a standardized formula for projecting future peak system demand, taking into account the population projection, per capita energy access requirements, load factor, and capacity reserves requirement.

In the third section, we have assessed the potential supply-side resources that could meet the local electricity demand in cities. We have relied on the UNDP 2014 DRC Atlas to identify potential energy sites within a 100-kilometer radius of the individual cities. Where available, we included updated information from our meetings in Kinshasa. We have also mapped the potential supply sites, population centers, and other key infrastructure using the expertise of ICF’s GIS team. The fourth section presents a projection of supply-and-demand resources for individual cities under the two scenario frameworks. We project the combination of local generation and transmission supply required to meet the projected peak demand of the focus cities. The final section presents the shortlisted conceptual projects in a fact sheet format. Each project fact sheet is two pages of text, maps, and aerial photographs discussing the proposed projects. The fact sheets are drafted with details like area demographics, economy, project budget, and implementation hurdles, with the aim of soliciting interest from donor countries, private sector investors, and other multilateral institutions.

1. Overview of the Electric Power Sector in the DRC

The Democratic Republic of the Congo (DRC) is the second largest country in Africa, with a total land area of approximately 2.3 million sq. km, slightly less than one-fourth of the size of the United States.[1] The country's population is estimated to be approximately 81.3 million as of 2016.[1] Despite the fact that the DRC is endowed with rich hydropower potential and other renewable resources, there is a substantial unmet electricity demand. The country has one of lowest levels of electricity consumption at 0.11 MWh/capita.[2] According to published reports, the DRC has one of the lowest electrification rates in the world, with approximately only 9% of its total population of 80 million people having access to electricity.[1] The electrification rate for urban areas is approximately 19%, while the rate in rural areas is 2% (as of 2013). [1]

1.1. Overview of regulatory structure

The executive policy for the electricity sector is formulated and approved by the national Ministry on Electricity and Hydraulic Resources (MRHE).[3] In addition, the Ministry of Environment, Tourism and Nature Conservation (MECNT), Ministry of Hydrocarbons, and Ministry of Rural Development also supplement the policymaking process for the energy sector. The electricity sector is dominated by a state-owned monopoly called the Société nationale d'électricité (SNEL). SNEL owns approximately 50 central/distributed units in the country, with 36 hydro-units and 14 thermal units. Cumulatively, SNEL owns approximately 2,442 MW of capacity (or 94% of total installed capacity).[3] In addition, captive producers, chiefly comprising the mining industry in the country, have approximately 135 MW of installed capacity (or 6% of installed capacity).[4]

One of the major recent developments in the energy sector is the Electricity Law of 2014.[5] The law facilitated important changes in the DRC's energy sector, including the creation of the Electricity Regulation Authority (ARE), National Electrification Fund (FONEL), and National Rural Electrification Agency (ANSER).[6] The law provided for diversification of the energy mix, a focus on energy conservation and efficiency measures, and a 60% increase in the overall national electrification rate. The law also put an end to the de facto monopoly in the electric power sector and opened the sector to independent power producers. The law also allows for concessions for generation, transmission, distribution of electricity within a single province. Generation concessions are categorized and priced by size of project: less than 1 MW, 1-5 MW, 5-50 MW and greater than 50 MW.

[1] Discussions in this paragraph are primarily sourced from the CIA World Fact Book on DRC (https://www.cia.gov/library/publications/the-world-factbook/geos/cg.html).
[2] International Energy Agency. Statistics: DRC Indicators for 2014. https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=CONGOREP&product=Indicators
[3] United Nations Development Programme (UNDP). 2014 DRC atlas of renewable energies. http://www.cd.undp.org/content/rdc/en/home/library/environment_energy/atlas-interactif-2014.html
[4] As per UNDP (2014) the list captive producers in the country includes SUCRIÈRE KWILU, NGONGO, PERENCO, MIBA, CFU, PLC, ONG, SNCC, SOKIMO, HYDROFORCE, HEDC and EDC.
[5] For a review of regulatory framework for the electricity sector, see: Essor-UK Aid. (2016). *Essor–Access to electricity–Solar powered mini-grids in the DRC.*
[6] Lighting Africa Initiative. https://www.lightingafrica.org/publication/lighting-africa-policy-report-note-drc/

In addition to these institutions, the task of developing renewable energy potential was given to two agencies within MRHE, namely, the National Services of New Energy (SENEN) and the Technical Support Unit of Energy (CATE). Exhibit 1 highlights the existing and potential energy sources for the different provinces in the country, as compiled by a recent United Nations Development Programme (UNDP) report on the country's energy potential. The report estimates the installed electricity capacity (including distributed resources) to be approximately 2,677 MW, out of which only about 1,300 MW are available for dispatch in 2014. This is reflective of the dilapidated state of the country's electric power sector infrastructure. The report estimates the unmet demand for electricity for individual provinces using population estimates and a threshold per capita electricity demand (see Section 2 for details).

Exhibit 1 Overview of supply resources at a region/province level

Regions and Provinces	Population (2015)		Potential MW	Number of Potential Sites	Installed Capacity (MW)	Available Capacity (MW)	Unmet demand (MW)
	Total	Households					
Bandundu (Kwango, Kwilu, Mai-Ndombe)	9,334,354	1,395,614	172	114	3.57	1	343
Bas-Congo	3,900,605	761	64,000	24	1,867	891	108
Equateur (Equateur, Mongala, Sud-Ubangi, Nord Ubangi, Tshuapa)	9,361,891	1,362,989	122	58	19.3	1.9	345
Kasai Occidental (Sankuru, Kabinda, Tshilenge)	6,451,265	913,358	433	64	9.1	4	229
Kasai Oriental (Kasai, Lulua, Mbuji-Mayi)	6,397,800	1,230,665	252	65	16.5	11	303
Katanga (Lualaba, Haut-Lomami, Haut-Tanganykia, Haut-Katanga)	11,134,237	1,912,324	2,231	70	583.6	350.16	339
Kinshasa	9,380,802	1,707,582		8			442
Maniema	1,993,619	408,321	458	140	18.45	1	103
Nord-Kivu	7,792,284	600,554	332	130	8.84	8.84	139
Province Oriental (Base-Uele, Ituri, Tshopo)	10,309,347	1,645,276	2,684	52	71.37	23	398
Sud-Kivu	5,274,847	739,778	1,197	41	79.54	8.5	180
Total	**81,331,050**	**11,917,222**	**71,881**	**766**	**2,677**	**1,300**	**2,929**

Source: UNDP 2014 DRC Atlas of Renewable Energies, p.30.
http://www.cd.undp.org/content/rdc/en/home/library/environment_energy/atlas-interactif-2014.html

Note: [1] The population numbers are extrapolated for 2015.

[2] Potential MW refers to the untapped hydro-potential that has been identified by the UNDP 2014 DRC Atlas. Also, the number of potential sites refers to the potential hydro-sites identified by the report to date.

[3] Installed capacity refers to the current rated capacity of all power plants (including non-hydro resources).

[4] Available capacity is the MW capacity that is available for dispatch currently (out of the installed capacity).

[5] Unmet demand refers to the current MW required to extend a threshold level of electricity consumption to the remainder of the population without access to electricity.

1.2 Overview of supply resources in the DRC

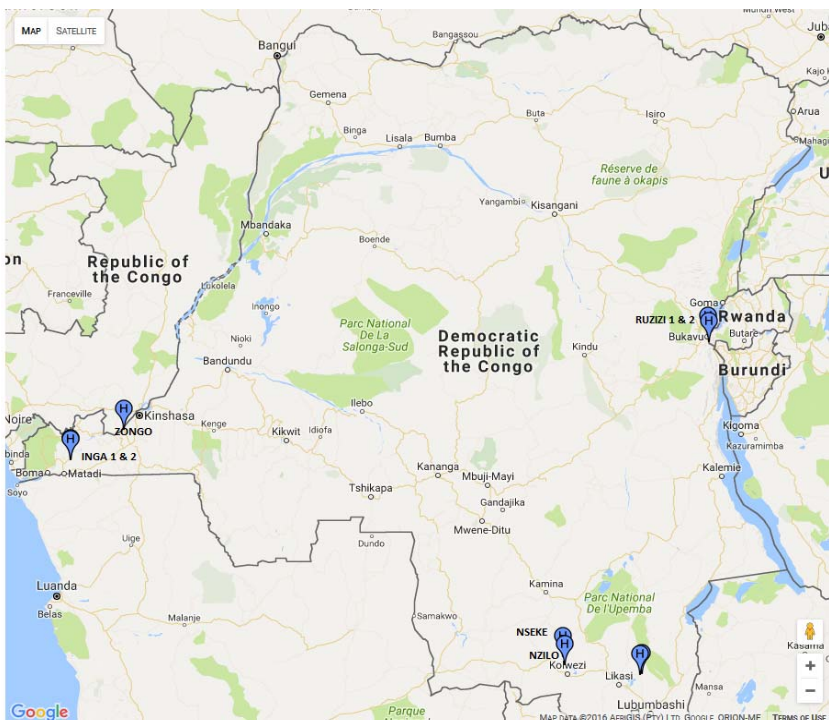
The DRC is richly endowed with renewable resources like hydro, biomass, solar, and wind. The country's hydroelectric potential is estimated to be close to 100 GW, out of which only about 2.4% is currently exploited.[6] The Congo River Basin remains the world's least-tapped source of renewable hydroelectric energy. Nearly half of the untapped hydroelectric power potential (approximately 50 GW) is located downstream of the capital Kinshasa at the Inga rapids in the Bas Congo (Lower Congo) region of the Congo River Basin. In addition, the DRC is also endowed with potential solar and wind generation sites. These non-hydropower resources are yet to be tapped widely on a commercial scale for improving the electrification rates in the country. It should be noted that the discussions in this report do not focus on private distributed energy sources like diesel generators for electricity generation.

1.2.1 Hydroelectric resources—Existing

Currently, the total installed capacity of central power plants in the country is estimated to be 2,590 MW, out which hydro is 2,472 MW and combustible fuels is 34 MW. Only about half of this capacity is available for dispatch at any given time. In recent years, the net import/export of electricity from the country is estimated to be nil, with the exception of 50MW supplied via SNEL to mines in Katanga from the Zambian transmission network. Nearly 98% of the country's electricity needs are met through hydroelectric plants. The largest hydropower plants are the existing Inga I and II accounting for 351 MW and 1,424 MW respectively. The existing hydropower plants are listed in Exhibit 2 with their respective installed capacities.

Exhibit 2 List of major power plants and their locations in DRC

Unit Name	Rated Capacity
Western Grid Network	
Inga I	351 MW
Inga II	1424 MW
Zongo I	75 MW
Southern Grid Network	
Nseke	260 MW
Nzilo	108 MW
Mwadingusha	68 MW
Koni	42 MW
Isolated Hydroelectric Networks	
Ruzizi I & II	44 MW
Sanga	11 MW
Tshopo	18 MW
Kyimbi	18 MW
Mutwanga	10 MW
Other IPPs	135 MW



Sources for Exhibit 2: Kadiayi (2013),[7] SNEL (2013),[8] and Global Energy Observatory (2016) [9](for mapping feature).

The country is proposing to develop the hydroelectric potential at the Inga site (approximately 225 km southwest from the capital city of Kinshasa). This site is ideal for hydroelectric generation as it is located about 50 kilometers upstream from the mouth of the Congo River, the world's second largest in terms of volume of water flow (after the Amazon River). Presently, the Congo River experiences an elevation drop of nearly 96 meters in a series of waterfalls and rapids in a run of about 14.5 kilometers.[10] Different feasibility studies have estimated the hydroelectric potential of the site at 39,000–50,000 MW. Based on a recent feasibility study conducted by EDF-AECOM from 2011 to 2013, the proposed implementation of the Grand Inga project will take place in six distinct phases. As a first step, a 4,800 MW Inga III power project (Phase A of Grand Inga) is proposed to be constructed.[11] The Grand Inga scheme is designed to supply electricity to other countries in the region via a network of high voltage transmission lines. The Republic of South Africa (RSA) has signed a treaty with the DRC to jointly develop the Inga III power project. As part of this agreement, South Africa is expected to purchase 2,500 MW of the total output of this plant. The Inga III project is still in development, but the entire project (including transmission lines to load centers) is expected to cost approximately $12 billion.[10]

In addition to the proposed Inga III project, there are other ongoing hydro-generation projects in the country. The major hydropower projects include Zongo II, Katende, Kakobola, Katende, Matebe, Virunga, and Busanga plants.[12]

- In 2011, the Bank of China EXIM Bank and Sinohydro Corp signed a $360 million agreement to build a hydroelectric plant (Zongo II) at Zongo in Bas-Congo province. The 150 MW project is complete and the first unit is expected to come online in June 2017.[13]
- A 10.5 MW hydropower project at Kakobola in the province of Kwilu is one of two power projects financed by Exim Bank of India and the Government of DRC. The power plant is being executed for a total cost of $57.4 million, of which $42 million is funded by Government of India (GOI) and $15.4 million is funded by Government of DRC.[14] Currently there are proposals to build three transmission lines to Idiofa, Gungu and Kikwit. The transmission lines linking the hydroelectric project to load centers are expected to cost $40 million, of which $34.5 million is funded by GOI and $5.5 million is funded by DRC.[14] The proposed transmission lines are a 33 kV line from Kakobola to PK600, 66 kV lines from PK600 to Kikwit and from PK600 to Idiofa, and a 33 kV line from Kakobola to Gungu.

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[7] Kadiayi, Alex. (2013). Overview of the electricity sector in the Democratic Republic of Congo.
[8] SNEL. (2012). Enterprise plan.
[9] Global Energy Observatory. http://globalenergyobservatory.org
[10] International Rivers. Grand Inga hydroelectric project: An overview. https://www.internationalrivers.org/resources/grand-inga-hydroelectric-project-an-overview-3356
[11] Bidders for the Inga III concession have proposed constructing Inga III at 11,000 MW in one step, instead of in phases as proposed by the EDF-AECOM feasibility study.
[12] Hydroworld. India provides loan for Kakabola hydro plant in Congo. http://www.hydroworld.com/articles/2010/10/india-provides-loan.html
[13] Personal communication with SNEL personnel in Kinshasa.
[14] Personal communication with Kala Eber (Coordinator-GCK)

- A second plant being built with Indian assistance is located in Katende in the Kasai (Occidental) province. This 64 MW, which is 50-60% complete, is being built for a total cost of $280 million, of which $250 million is funded by GOI through its Exim Bank and $30 million is funded by Government of DRC.[14] Currently two 132 kV transmission lines are proposed to connect the power plant to load centers in Kananga and Mbuji Mayi. The transmission lines linking the hydroelectric project to the two load centers are expected to cost $120 million, of which $109.5 million is funded by GOI and $10.5 million is funded by DRC.[15] Once complete, ownership and operation for both Kakobola and Katende hydroelectric units could be given on concession to private parties under Law of 2014.[14]
- In 2015, a 13.6 MW hydro-unit was built in Virunga National Park using assistance from the Howard G. Buffet Foundation (HGB).15 The HGB invested $19.7 million for the project. The plant is located in the town of Matebe in North Kivu and supplies 2.1 MW to approximately 2,200 customers in the Rutshuru area. The HBF is also planning to invest $13 million for a second 12.8 MW project at Lubero. HGB invested $26mm (75% of cost) in a third project, 27-33 MW, 15 km upstream from Matebe, at Rwanguba. Excavation began in Dec-2016 and completion in 2020.
- In 2016, Sinohydro Corp. and China Railway Group Ltd. have concluded an agreement to finance and build the 240 MW Busanga hydroelectric power plant in Katanga province. This power plant is expected to supply 170 MW for the operation of Sicomine copper mines, a joint venture between China and the DRC. The rest of the power plant output is expected to be absorbed by the national grid. [16]

Hydropower Development at Virunga National Park

The Virunga region in North Kivu has eight potential hydropower sites with an estimated potential of 100 MW. Two of these sites (13.8 MW Matebe and 0.38 MW Mtwanga) are currently developed and operational. The smaller Mtwanga plant supplies power to a local soap factory and supports 400 jobs. A third site at Lubero is being developed with a hydroelectric capacity of 12.8 MW. These projects belong to Virunga Sarl, the company that constructs and operates hydro plants and distribution systems in the Virunga Park area. The company offers incentive schemes for commercial/industrial (medium voltage) and residential (low voltage) customers. The scheme involves a lump-sum payment for the first year ($292 for medium voltage and $223 for low voltage) and a regulated tariff for subsequent years (20.26 cents/kWh for medium and 21.50 cents/kWh for low voltage customers).

Source: Personal communication with Ephrem Balole of Virunga Sarl & Laura Parker of HGB.

[15] Virunga National Park. Spotlight on Vvirunga as the president inaugurates two hydroelectric power plants in Eastern Congo. https://virunga.org/news/spotlight-on-virunga-as-the-president-inaugurates-two-hydroelectric-power-plants-in-eastern-congo
[16] Hydroworld. DRC awards US$660 million contract for 240-MW Busanga hydroelectric project in Africa. http://www.hydroworld.com/articles/2016/06/drc-awards-us-660-million-contract-for-240-mw-busanga-hydroelectric-project-in-africa.html

- Rehabilitation of existing units like Nsekem, Zongo I, Koni, and Mwadingusha were also reported in recent years.

1.2.2. Biomass resources—Existing and potential

Biomass is an important primary energy source for the DRC. In spite of the huge biomass resource availability in the country, there are currently no major central plants capable of biomass-based electricity generation. It is estimated that biomass accounts for nearly 95% of the primary energy consumption in the country,[3] with the annual expenditure on charcoal in Kinshasa alone estimated at $1 billion. Biomass is primarily used for heat production in domestic and commercial sectors. International Energy Agency (IEA) statistics show that biomass generates close to 1.1 million TJ (tera-joules) of energy for heat production in the country.[17]

1.2.3. Solar energy—Existing and potential

The solar resource potential for the DRC is immense, with average irradiation ranging from 3.5–5.5 kWh/m^2/day. The map of solar energy potential at a national level is presented in Exhibit 3. Currently, there are 836 distributed solar power systems, with a total power of 83 kW, located in erstwhile Equateur, Katanga, Nord-Kivu, the two Kasaï provinces, and Bas-Congo provinces.[18] In recent years, there have been a couple of proposals to develop grid-scale solar units in the DRC.

Enerdeal, a Belgium-based company, has signed a deal with Forrest International Group to develop a 1 MW solar power plant with a 3 MWh battery storage at Manono in Tanganyika province of the DRC. When completed, this project would be the largest off-grid solar plant in the DRC and one of the largest off-grid solar plants in Africa. Located in a region with no access to electricity, this project is being coupled with several km of medium and low voltage transmission lines, in order to power street lights and households and to enhance the development of new small and medium industries in the area.

In 2015, Megatron Federal, a South African developer, formed a public-private partnership with SNEL to construct a 3 MW solar plant near the city of Kananga.[19] The output from the plant was planned to supply power to the city's public lighting system and to the residential customers of SNEL. To date, only 750 KW of solar have been installed, and the remainder was supplemented with diesel, making it a hybrid PV-diesel generation system. According to reports, the solar component of the plant is not working.[20]

[17] International Energy Agency. Statistics: DRC indicators for 2014. https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=CONGOREP&product=Indicators

[18] Norton Rose Fulbright. (2012). Scaling-up renewable energy in Africa: Democratic Republic of Congo. http://www.nortonrosefulbright.com/knowledge/publications/58927/scaling-up-renewable-energy-in-africa-democratic-republic-of-congo

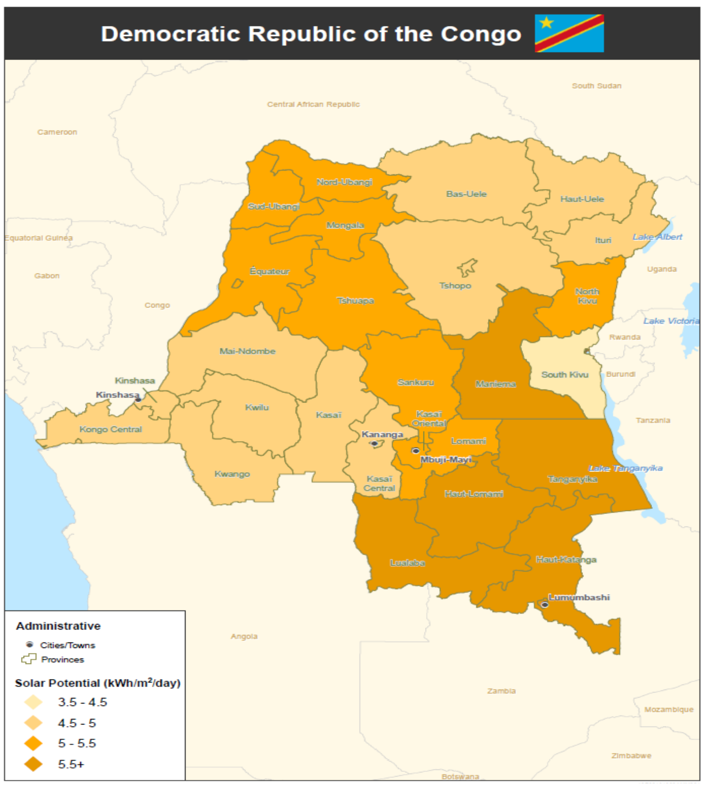
[19] http://kasaidirect.net/wordpress/?p=1705

[20] Conversation with Ministry of Energy and Hydraulics, Mr. Mbafumoya Tchomba

The Egyptian government is also proposing to build two solar units of 1 MW rated capacity each.[21] The units are proposed to be located in Kinshasa. A U.S.-based nonprofit installed a small solar energy-based microgrid at Virunga National Park in Eastern DRC.[22]

There is also a proposed pilot initiative by the United Kingdom's Department for International Development (DFID) to develop solar-based microgrids for five cities in the DRC.[23] Three pilot projects are expected to be tendered out in 2017, followed by 5–10 projects in 2018–19 and 10–20 projects in 2020-21. Each project is expected to be completed within 1–2 years of award. The pilot initiative is expected to be implemented by private entities with concessions for 15–20 years from the applicable Provincial Government (in accordance with the Electricity Law of 2014). The tariffs will be set by the respective developer and approved by the country's Electricity Regulatory Authority (ARE). Each of these projects is expected to supply electricity to at least 100,000 inhabitants in each city.

Exhibit 3 Solar energy potential for DRC



Sources: UNDP 2014 DRC Atlas and ICF.

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[21] Wind Energy and Electric Vehicle Review. Egypt to build 2 solar energy plants in Congo. http://www.evwind.es/2015/05/30/egypt-to-build-2-solar-energy-plants-in-congo/52469

[22] Solar City. GivePower foundation launches global minigrid program to power communities in the developing world. http://www.solarcity.com/newsroom/press/givepower-foundation-launches-global-minigrid-program-power-communities-developing

[23] Essor-UK Aid. (2016). *Essor–Access to Electricity–Solar powered mini-grids in the DRC.*

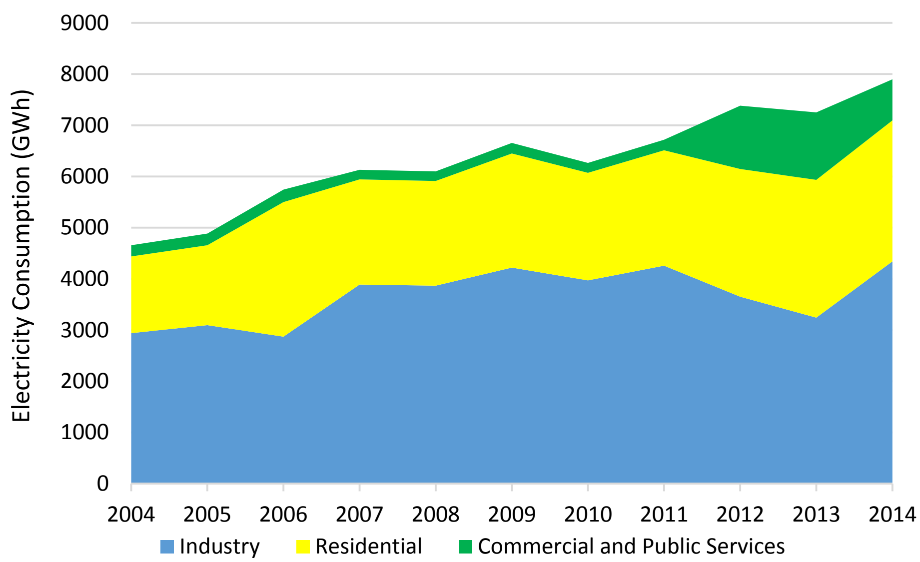
1.2.4. Wind energy—Potential

Like most other parts of Africa, the wind speeds are relatively low for grid-scale wind energy generation. Nevertheless, the DRC, with its huge land area, is endowed with adequate wind resource sites to develop a microgrid or distributed grid networks with wind units. The average wind speed for the country ranges between 2 and 4 m/s[3]. To date, the utilization of wind power for electrical power production in the country is still limited. A significant number of wind turbines are used to pump water rather than to generate electricity in rural communities.

1.3 Overview of historic electricity consumption in the DRC

In 2014, the country generated 8,627 million kWh of electricity.[Error! Bookmark not defined.] According to United Nations (UN) statistics, transmission losses account for nearly 643 million kWh of electricity.[Error! Bookmark not defined.] In 2014, the energy consumed was 7,899 million kWh, out of which 4,342 million kWh were consumed by industries (including mining) and 3,557 million kWh were consumed by residential and commercial customers.[Error! Bookmark not defined.] The government of the DRC has set an ambitious target of electrification of nearly 60% of the population by 2025 (from the current rate of 9%), in accordance with the Sustainable Development Goals (SDGs). The target assumes a 16% annual increase in the electrification rate in rural areas and an average 7% annual rate increase in urban areas.

Exhibit 4 Overview of electricity consumption trends in DRC



Source: International Energy Agency. DRC Statistics.[24]

1.4 Overview of transmission infrastructure

The DRC currently lacks an interconnected national transmission grid network.[25] There are however, three interprovincial/regional grid networks: West (between Central Congo and Kinshasa/Inga site), East (North

[24] International Energy Agency. Statistics: DRC electricity and heat for 2014. https://www.iea.org/statistics/statisticssearch/report/?country=CONGOREP&product=ElectricityandHeat&year=2014

[25] Discussions in this paragraph are sourced from: Essor-UK Aid. (2016). *Essor–Access to Electricity–Solar powered mini-grids in the DRC, pp.13–15.*

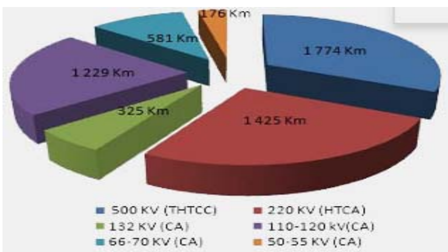
and South Kivu), and South (Haut-Katanga and Lualaba) networks. These networks are operated by SNEL. These grid networks are in turn interconnected with the grids of neighboring countries, facilitating electricity trading. The Western network is interconnected with the Republic of Congo (Brazzaville); the Eastern network with Rwanda and Burundi; and the South with Zambia. Following deregulation of the electricity sector (see Electricity Law 2014), a few local distribution concessionaires have also emerged through public-private partnerships. It is estimated that only 1% of the rural population and 19% of the urban population in the country has access to electricity, with a national average electrification rate of approximately 9%. Erratic electric supply service, prolonged blackouts, and generally low reliability of the power supply are widespread in the country. Accumulated delays in investments in power infrastructure, a lack of viable tariff and revenue recovery mechanisms, degradation and lack of maintenance of existing assets, and chronic mismanagement at the operator utility have resulted in a dilapidated electric power infrastructure in the country.[Error! Bookmark not defined.] The low level of access to reliable energy is also a significant barrier to economic growth and societal prosperity.

The DRC has approximately 5,510 km of high-voltage transmission lines connecting the major power plants at Bas-Congo (i.e., Inga hydro units) to provinces in the central and southeastern parts of the country. In addition, it has 4,484 km of medium-voltage lines and 12,133 km of low-voltage lines. A pie chart of transmission assets in the DRC and a map of existing transmission lines is shown in Exhibit 5. Some of the ongoing transmission and distribution (T&D) projects include: a second 400 kV transmission line for Inga-Kinshasa; a second 220 kV transmission line for export toward Southern Africa Power Pool (SAPP) via Zambia; rehabilitation and extension of the distribution grid of Kinshasa; and rural electrification of five provinces of the DRC. In 2015, the second Inga-Kinshasa 400 kV transmission line was completed. This line was installed in addition to the existing 220 kV line between Inga and Kinshasa. [26] A Western Power Corridor (WEPAC) transmission project was proposed to supply energy from the proposed Inga III hydropower project in the DRC to supply power to Angola, Namibia, Botswana, and South Africa. The project involved construction of a 400 kV HVAC line connecting Inga III to Cabinda Power Station in Angola. From Angola, HVDC lines were proposed to deliver power to other countries. As of 2009, the project appears to have been abandoned due to lack of consensus on funding arrangements.[27]

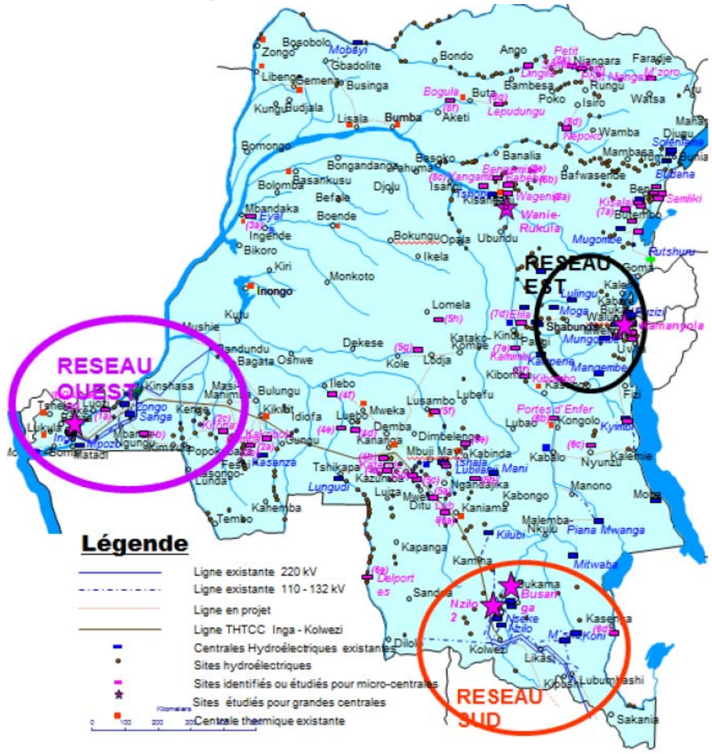
Exhibit 5 Transmission asset inventory in DRC

[26] Africa News. 2ème ligne Inga-Kinshasa : SNEL accomplit sa mission. http://www.africanewsrdc.com/societe/2015/08/26/2eme-ligne-inga-kinshasa-snel-accomplit-sa-mission.html
[27] Wikipedia. Western Power Corridor. https://en.wikipedia.org/wiki/Western_Power_Corridor

Major Transmission Lines	Voltage Level
Inga – Matadi - Boma Monanda	132 kV
Inga – Kinshasa	132 kV
Kinshasa – Bandundu	220 kV
Inga – Kananga – Kolwezi	500 kV (HVDC)
Kilubi – Kamina	70 kV
Kolwezi – Kisanga	132 kV
Kolwezi – Lubumbashi	132 KV
Mwadingusha – Likasi	132 kV
Lubumbashi – Kitwe	132 kV



Existing Transmission Network in the DRC



Sources: SNEL (2015)[28] for the pie chart, USAID-SNEL for the map, and interviews with SNEL for the list of major transmission lines.[29]

[28] SNEL. (2016). Chiffres clés. http://www.snel.cd/stats/chiffres.php
[29] ArcGIS. Democratic Republic of Congo electricity transmission network. http://www.arcgis.com/home/item.html?id=3cb1e7c0461f449aadaaf00091075f2f

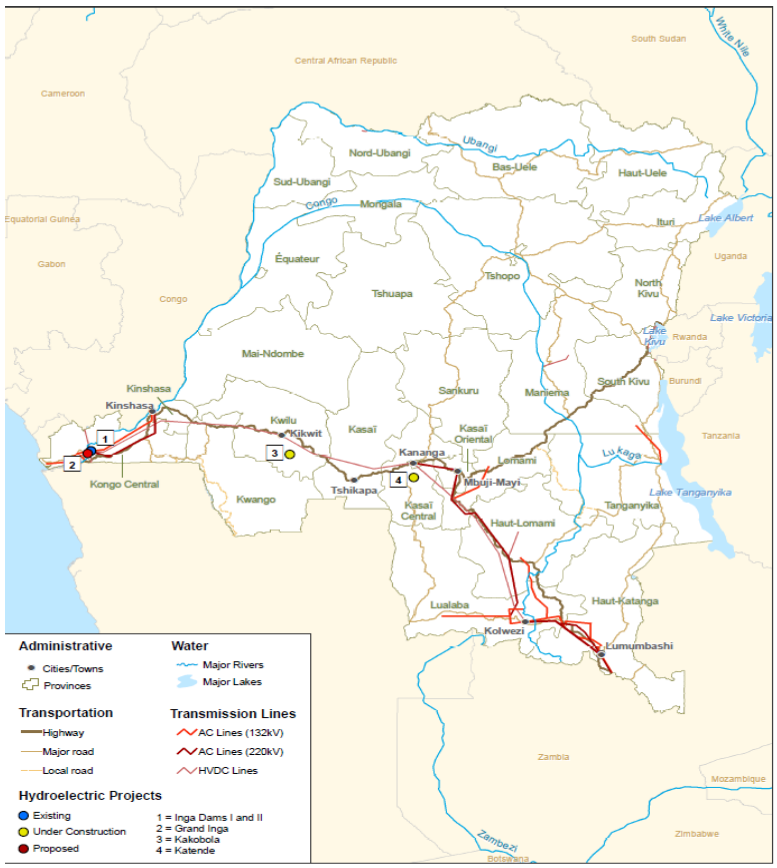
2. Demand Projections for the Focus Cities/Population Centers

The DRC is governed through 25 provinces and the capital city of Kinshasa. As part of the project scope, this report focuses on identifying suitable energy projects that could improve electrification for the following population centers/load centers—Kikwit (Kwilu), Kananga (Kasai-Central), Tshikapa (Kasai-Central), and Mbuji-Mayi (Kasai-Oriental). The list of provinces and the estimated population distribution among provinces are listed in Exhibit 6. The projected demand trends are explained in detail for each population center in this section.

Exhibit 6 Map of provinces of the DRC

#	Province	Capital
1	Kinshasa	Kinshasa
2	Kongo Central	Matadi
3	Kwango	Kenge
4	Kwilu	Kikwit
5	Mai-Ndombe	Inongo
6	Kasaï	Luebo
7	Kasaï-Central	Kananga
8	Kasaï-Oriental	Mbuji-Mayi
9	Lomami	Kabinda
10	Sankuru	Lusambo
11	Maniema	Kindu
12	South Kivu	Bukavu
13	North Kivu	Goma
14	Ituri	Bunia
15	Haut-Uele	Isiro
16	Tshopo	Kisangani
17	Bas-Uele	Buta
18	Nord-Ubangi	Gbadolite
19	Mongala	Lisala
20	Sud-Ubangi	Gemena
21	Équateur	Mbandaka
22	Tshuapa	Boende
23	Tanganyika	Kalemie
24	Haut-Lomami	Kamina
25	Lualaba	Kolwezi
26	Haut-Katanga	Lubumbashi

Location of DRC Provinces



Source: ICF (GIS)

Population trends for individual cities

Territory/City	Population	Density
Kikwit	1,326,068	3605
Tshikapa (incl. Kamonia)	3,450,615	72
Kananga	1,407,070	866
Mbuji-Mayi	3,367,582	13,839

2.1 Energy Access Projections

One key objective of USAID in commissioning this project is to identify solutions that can improve energy access to hinterland cities in the DRC. However, there is no universally accepted or adopted definition of "energy access." International institutions have adopted different metrics and approaches to define the term. The IEA defines energy access based on the threshold level of electricity consumption for households. The initial threshold level of electricity consumption for rural households is assumed to be 250 kWh per year; for urban households, it is 500 kWh per year.[30] The higher threshold for urban areas reflects the typical consumption patterns seen in urban areas. IEA assumes a typical household size to be five. This would translate the threshold to a per capita electricity consumption of 50–100 kWh/capita/year. There have been several arguments against this threshold, as it is too low to make any meaningful impact.[31] The United Nations Sustainable Energy for All (SE4ALL) initiative, a global initiative on energy access, does not explicitly target a threshold consumption but instead focuses on deploying select clean energy technologies.[32] The World Bank encourages the use of a five-tier mechanism to model energy access (see Exhibit 7).[33] The United Nations SE4ALL initiative uses this framework to measure energy access across developing countries.

Exhibit 7 Different tiers of energy access (as defined by the World Bank)

USE OF ELECTRICITY SERVICES

TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
None	Task lighting **AND** phone charging (or radio)	General lighting **AND** television **AND** fan (if needed)	Tier 2 **AND** any low-power appliances	Tier 3 **AND** any medium-power appliances	Tier 4 **AND** any high-power appliances

Source: World Bank (2013)[34]

ICF used the electricity demand gap metric (or unmet demand) from the UNDP Renewable Energy Atlas (2014) to compute the actual per capita electricity demand (see Exhibit 1). In 2014, the unmet demand for the country was estimated to be 2,926 MW, while the available capacity was 1,222 MW. We use the following formula to calculate the unmet demand and projected demand for electricity (for a given year, say, 2035)[35]:

[30] International Energy Agency. World energy outlook: Defining and modeling energy access. http://www.worldenergyoutlook.org/resources/energydevelopment/definingandmodellingenergyaccess

[31] A 100 kWh/capita threshold would be roughly equivalent to a single 60 W bulb operating for 4.5 hours each day in a given year. See: Moss and Gleave. (2013). How much power does power Africa Really Need? Center for Global Development. http://www.cgdev.org/blog/how-much-power-does-power-africa-really-need#_ftn1
Nordhaus, T. (2016). Energy access without development. Brookings Institution. http://thebreakthrough.org/index.php/voices/ted-nordhaus/energy-access-without-development

[32] United Nations. Sustainable energy for all. http://www.se4all.org

[33] Bhatia, M., and Angelou, N. (2013). Capturing the multi-dimensionality of energy access. The World Bank Group. https://openknowledge.worldbank.org/bitstream/handle/10986/18677/886990BRI0Live00Box385194B00PUBLIC0.pdf;sequence=4

[34] World Bank. (2013). Global tracking framework. World Bank Sustainability for All Program. http://trackingenergy4all.worldbank.org

[35] Adapted from Tallapragada et al. (2009). Monitoring performance of electric utilities: Indicators and benchmarking in Sub-Saharan Africa.

$$Current\ Unmet\ Demand(2014) = \frac{(2014\ Population * \%Without\ elec.access) * 250\ kWh}{(24\ hrs.* 365\ days) * 1000 * Load\ Factor} * 1.2\ (Reserves)$$

$$Future\ Demand\ (2035) = Unmet\ Demand\ (2014) + \frac{(2035\ Pop. - 2014\ Pop.) * 425\ kWh}{(24\ hrs * 365\ days) * 1000 * Load\ Factor} * 1.2\ (Reserves)$$

Another complication in determining the future electricity demand is defining the threshold per capita energy consumption. Since the population of the country in 2014 was estimated to be 76 million, the threshold per capita electricity demand in the country is estimated to be approximately 244 kWh/person/year. In comparison, the world average per capita electricity demand for 2014 is approximately 3,100 kWh/person/year.[36] For provinces in the Central DRC region, the threshold per capita demand for electricity in 2014 is estimated to be 172 kWh/person/year. The threshold per capita demand estimate is likely to be *conservative*, since it does not account for industrial, commercial, and other public utility demand. Typically with increasing electrification and economic growth, the per capita electricity demand is likely to go up. Also, increasing electrification rates could alter the choice of fuels used in different sectors and would most likely entail the displacement of biomass in households to other energy sources. Increasing electrification would also displace nonelectric fuel sources for commercial and industrial sectors. We ignore these complication for the time being. We project the expected electricity demand using the population estimates alone. For the current projection, we start with an estimated per capita consumption of 350 kWh/capita/year for all cities/population centers in 2016. This would correspond to a Tier 3 consumption pattern (see Exhibit 7). The per capita consumption is estimated to increase to 525 kWh/capita/year by 2035, which would roughly correspond to a Tier 5 consumption pattern (see Exhibit 7).[37]

We rely on CAID estimates for current population estimates of cities.[38] The population projections for the country are assumed to grow at a rate of *2.8% annually* based on the latest World Bank projections. We assume the same growth rate for individual cites as well. We also assume a uniform population growth rate for the next 20 years, although the growth rate would most likely decline with advances in healthcare, education, and increasing economic prosperity. Also, when projecting the future demand, we assume an annual load factor of 0.55. Load factor is the average electricity load to a peak electricity load over a specified time interval. We ignore the reserve capacity requirements for simplification purposes. If reserve capacity requirements are accounted, the projected peak demand would be greater by 10–20% depending on the assumptions.

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https://www.esmap.org/sites/esmap.org/files/P099234_AFR_Monitoring%20Performance%20of%20Electric%20Utilities_Tallapragada_0.pdf

[36] World Bank. Electric power consumption (kWh per capita). http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

[37] The Breakthrough. Electricity for all: What universal energy access will take. http://thebreakthrough.org/index.php/voices/roger-pielke-jr/electricity-for-all

[38] Cellule d'Analyses des Indicateurs de Développement (CAID) – See https://www.caid.cd/ There is considerable discrepancy between the population estimates by CAID and by the UNDP 2014 Atlas. The Atlas data was considered to be too low by DRC officials, while the CAID estimates are significantly higher. We have used CAID estimates for analysis as it is a DRC source.

2.2. Kikwit [39]

Kikwit is a city of about 1.3 million in the province of Kwilu (formerly with Bandundu) in 2016. Kikwit is part of Bulungu territory and forms an urban sub-district. The erstwhile province of Bandundu has one of the lowest electrification rates in the country at approximately 0.6% (in 2014), with an unmet peak demand of about 346 MW and an available capacity of 13 MW in 2014. The projected electricity demand for Kikwit is the product of per capita electricity demand and projected population. The projected peak demand takes into account load factor and reserve requirements. The projected electricity demand and peak demand for the city of Kikwit is shown in Exhibit 8. The projected electricity demand is expected to increase from 464,124 MWh in 2016 to 1,176,506 MWh in 2035. The projected peak demand for individual cities is estimated using a load factor assumption of 0.55 for all cities. The projected peak demand for Kikwit is expected to increase from 116 MW in 2014 to 293 MW in 2035.

Exhibit 8 Projected demand trends for Kikwit urban area

Kikwit	Projected Population	Unit Per Capita Electricity Demand (kWh/year)	Projected Electricity Demand (MWh/year)	Projected Peak Demand (MW)
2016	1,326,068	350	464,124	116
2020	1,480,943	387	572,891	143
2025	1,700,215	433	736,014	183
2030	1,951,953	479	934,883	233
2035	2,240,964	525	1,176,506	293

Sources: UNDP 2014 DRC Atlas, CAID, World Bank data, and ICF projections.

2.3. Kananga [39]

Kananga is a city in the Kasai-Occidental province. As of 2016, its population is estimated to be approximately 1.2 million with an urban area density of 866 inhabitants/km^2. The province of Kasai-Occidental has one of the lowest electrification rates in the country at less than 1%. The province has an unmet electricity demand of 229 MW and an available capacity of approximately 4 MW in 2014. The projected electricity demand and peak demand for Kananga is shown in Exhibit 9. The projected peak demand for Kananga increases from 111 MW in 2016 to 281 MW in 2035.

Exhibit 9 Projected demand trends for Kananga urban area

Kananga	Projected Population	Unit Per Capita Electricity Demand (kWh/year)	Projected Electricity Demand (MWh/year)	Projected Peak Demand (MW)
2016	1,271,704	350	445,096	111
2020	1,420,229	387	549,405	137
2025	1,630,512	433	705,840	176
2030	1,871,930	479	896,556	223
2035	2,149,093	525	1,128,274	281

Sources: UNDP 2014 DRC Atlas, CAID, World Bank data, and ICF projections.

2.4. Tshikapa

Tshikapa is a city in the Kasai-Occidental province. As of 2016, its population is estimated to be 3.45 million, which also includes the wider Kamonia sub-district. The projected electricity demand and peak

[39] The provincial unmet demand estimates used in this section are sourced from the UNDP 2014 DRC Atlas unless mentioned otherwise. See http://www.cd.undp.org/content/rdc/en/home/library/environment_energy/atlas-interactif-2014.html (pp.77–29).

demand for the Tshikapa region is shown in Exhibit 10. The projected peak demand for Tshikapa increases from 301 MW in 2016 to 762 MW in 2035.

Exhibit 10 Projected demand trends for Tshikapa urban area

Tshikapa	Projected Population	Unit per capita electricity demand (kWh/year)	Projected Electricity Demand (MWh)	Projected Peak Demand (MW)
2016	3,450,615	350	1,207,715	301
2020	3,853,621	387	1,490,743	371
2025	4,424,198	433	1,915,212	477
2030	5,079,256	479	2,432,696	606
2035	5,831,304	525	3,061,435	762

Sources: UNDP 2014 DRC Atlas, CAID, World Bank data, and ICF projections.

2.5. Mbuji-Mayi

Mbuji-Mayi is a major urban center in Kasai-Oriental province with a population of approximately 1.86 million in 2014. As of 2014, the province of Kasai-Oriental has a huge unmet demand of 303 MW and an available supply of 11 MW. The projected electricity demand and peak demand for the city of Mbuji-Mayi is shown in Exhibit 11. The projected peak demand for Mbuji Mayi increases from 294 MW in 2016 to 744 MW in 2035.

Exhibit 11 Projected demand trends for Mbuji-Mayi urban area

Mbuji Mayi	Projected Population	Unit Per Capita Electricity Demand (kWh)	Projected Electricity Demand (MWh/year)	Projected Peak Demand (MW)
2016	3,367,582	350	1,178,654	294
2020	3,760,890	387	1,454,871	362
2025	4,317,737	433	1,869,126	466
2030	4,957,033	479	2,374,158	591
2035	5,690,984	525	2,987,767	744

Sources: UNDP 2014 DRC Atlas, CAID, World Bank data, and ICF projections.

3. Identification of Supply-Side Resources for the Focus Cities/Population Centers

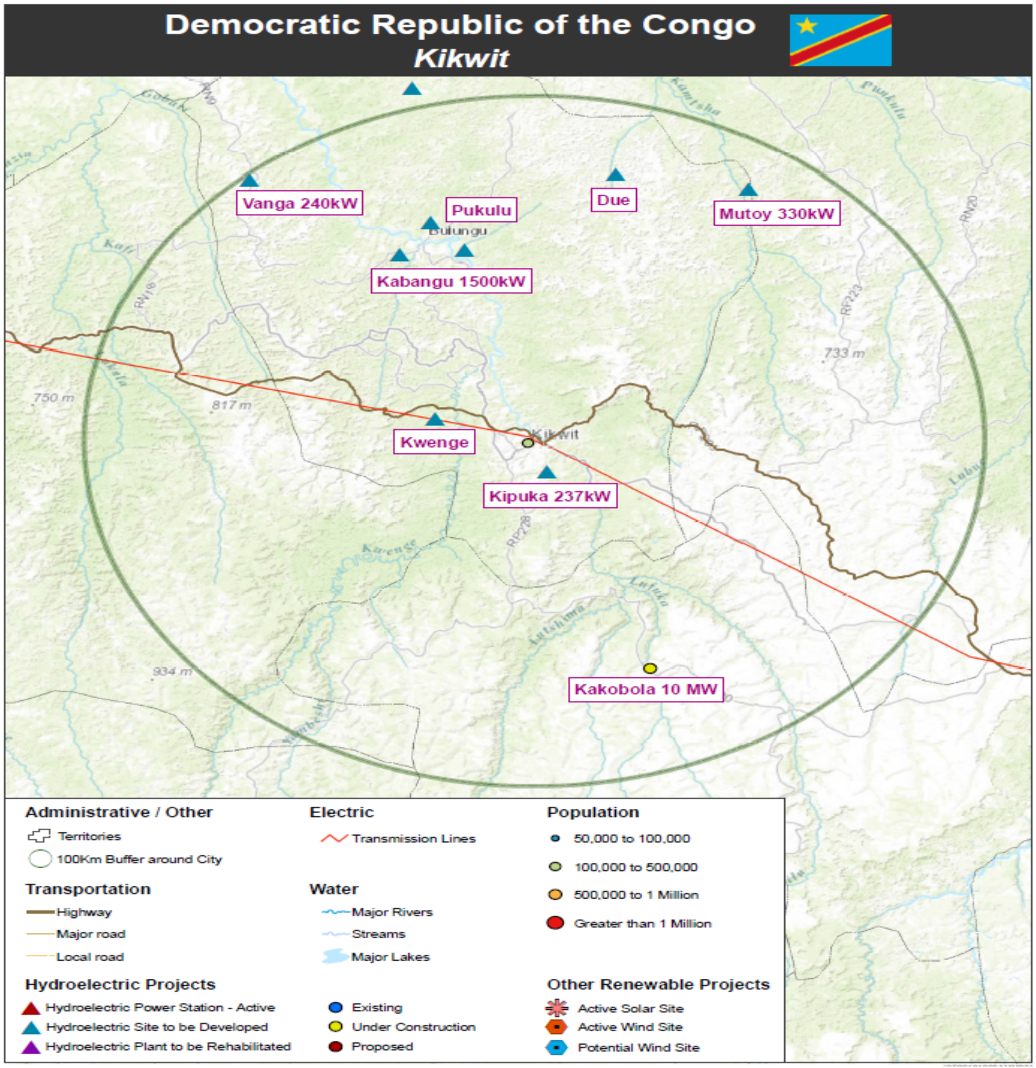
In this section, potential supply-side resources that could meet the local electricity demand for individual cities are assessed. The list of potential sites is sourced from the UNDP 2014 DRC Atlas [3]. The Atlas is the result of survey of potential hydro-sites across the country. The Atlas identified up to 780 sites with a total hydropower potential of nearly 100,000 MW. The Inga site accounts for close to half of the untapped hydropower potential at 44,000 MW. The rest of the potential comes from mid-size and micro-scale hydropower resources across the country. Most of these sites have been assessed using desk research studies using information on each site, the hydrological characteristics of the rivers/streams and the estimated potential and local energy needs. The Atlas also shows all the other renewable resources in the DRC such as solar, wind power, biomass in all its components, as well as thermal and methane gas resources. The World Bank is also currently funding a feasibility study to assess the potential of mid-size hydropower sites in the country.

3.1. Kikwit

The 500 kV Inga–Kolwezi (HVDC) line passes through Kikwit. There are no other transmission lines connecting Kikwit to other transmission networks in the country. Currently, the city of Kikwit has two diesel generators that are rated at 1.2 MW each. A 10.5 MW hydro-unit is under construction at Kakobola which is about 150 km from Kikwit.[40] Out of the total output from Kakobola plant, 4.5 MW is designated to meet the demand in Kikwit and 2 MW for REGIDESCO water treatment. Some of the potential local sites near the city include: Kabangu (1.5 MW); Vanga (0.2 MW); Kipuka (0.2 MW); Mutoy (0.3 MW), Libidi, Kwenge, Due, and Pukulu. In total, the local hydroelectric sites can supply up to 2.2 MW of power to meet Kikwit's electricity demand.

[40] Hydroworld. India provides loan for Kakobola hydro plant in Congo. http://www.hydroworld.com/articles/2010/10/india-provides-loan.html

Exhibit 12 Map of Kikwit metro-region and potential generation resources



Sources: UNDP 2014 DRC Atlas and ICF.

3.2. Kananga

The city of Kananga is currently served by 220 kV Kananga–Mbuji–Mayi transmission lines. In addition, the 500 kV Inga–Kolwezi (HVDC) line also passes through Kananga.[29] As mentioned earlier, a 64 MW Katende hydro-unit is coming up in Kasai-Central province.[41] A 2.5 MW solar PV-diesel plant is being developed currently by a private sector consortium to supply power to Kananga city.[42] In addition, there are also potential local sites within a 100 km radius of the city: Gorge de Lubundaje (24 MW); Masambo (9.4 MW); Kawula (0.8 MW); Dibaya (0.4 MW); Kajangaji (0.3 MW); Dibataye (0.2 MW); Tshibao (0.2 MW); Bukonder (0. 2MW); Tshidimba (0.25 MW); and Moyo (0.2 MW). In total, the potential local hydroelectric sites near Kananga can provide up to 36 MW of installed capacity. In addition, power supply from Katende units (when completed) can also meet the electricity demands of the city.

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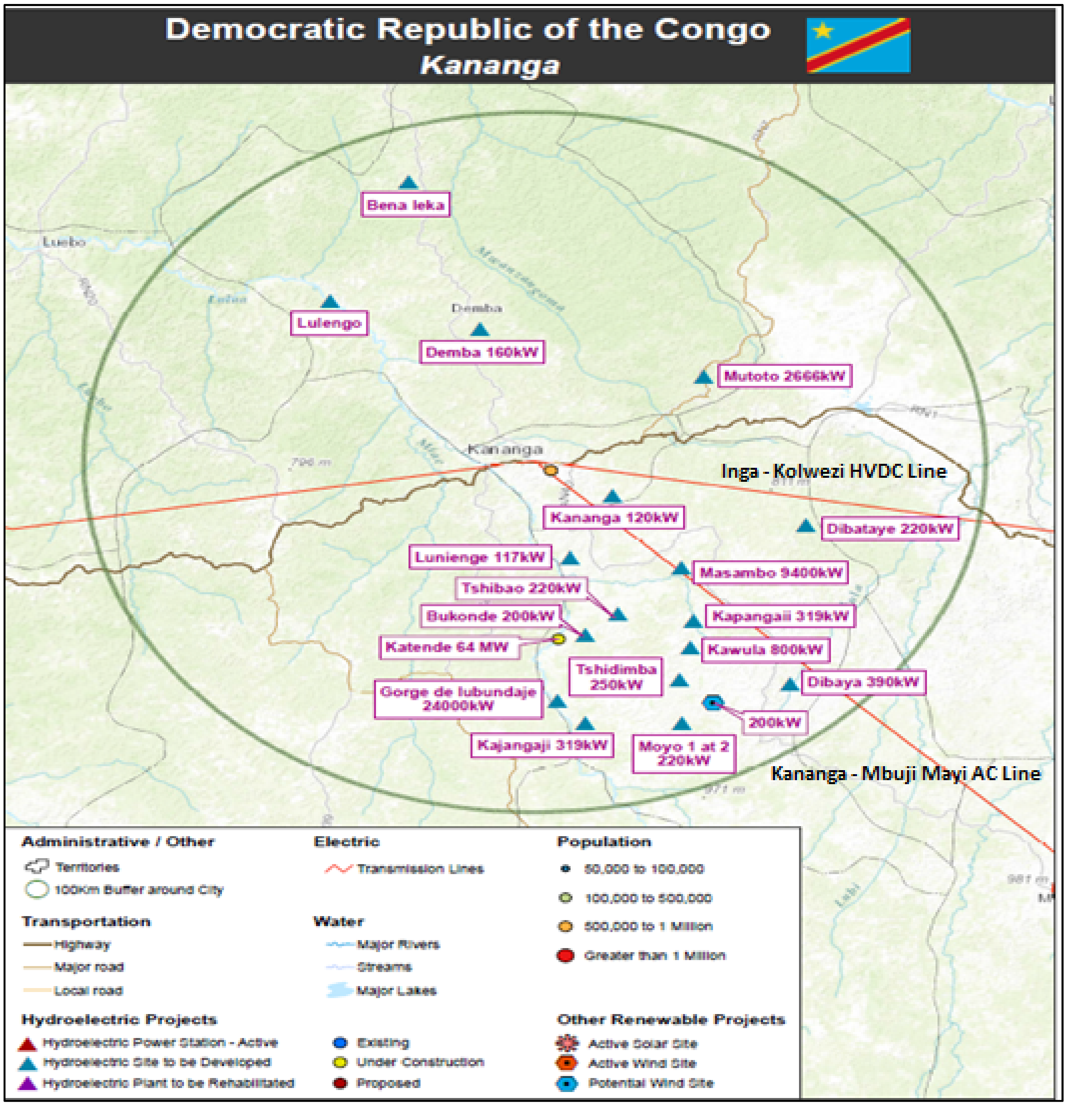
[41] Hydroworld. India provides loan for Kakobola hydro plant in Congo. http://www.hydroworld.com/articles/2010/10/india-provides-loan.html

[42] Essor-UK Aid. (2016). *Essor–Access to Electricity–Solar powered mini-grids in the DRC.*

Exhibit 13 Map of Kananga metro region and potential generation resources



Sources: UNDP 2014 DRC Atlas and ICF.

3.3. Tshikapa

Tshikapa is not currently served by any of the central transmission lines. Instead, the city is served by a local micro-grid. There are only two operating hydropower plants in the region—the 2.6 MW Kazongo plant and a 1.5 MW Lungudi plant. The 1.5 MW Lungudi plant has been recently upgraded by a private entity and offers power to over 3,000 customers in the city.[43] In addition, there are other potential hydroelectric sites in the local region, such as: Lungudi 1 (expansion) (12 MW); Lungudi (128 MW); Lovua Longatathilmo (70 MW); Lovua Longatathilmo 2 (2 MW); Mai Monene (37 MW); Sumabalo; Kitangwa; and Kamwesha. The rated capacity of these potential local units is approximately 250 MW. There are plans by a Brazilian company to develop the Mai Monene hydroelectric site.[44]

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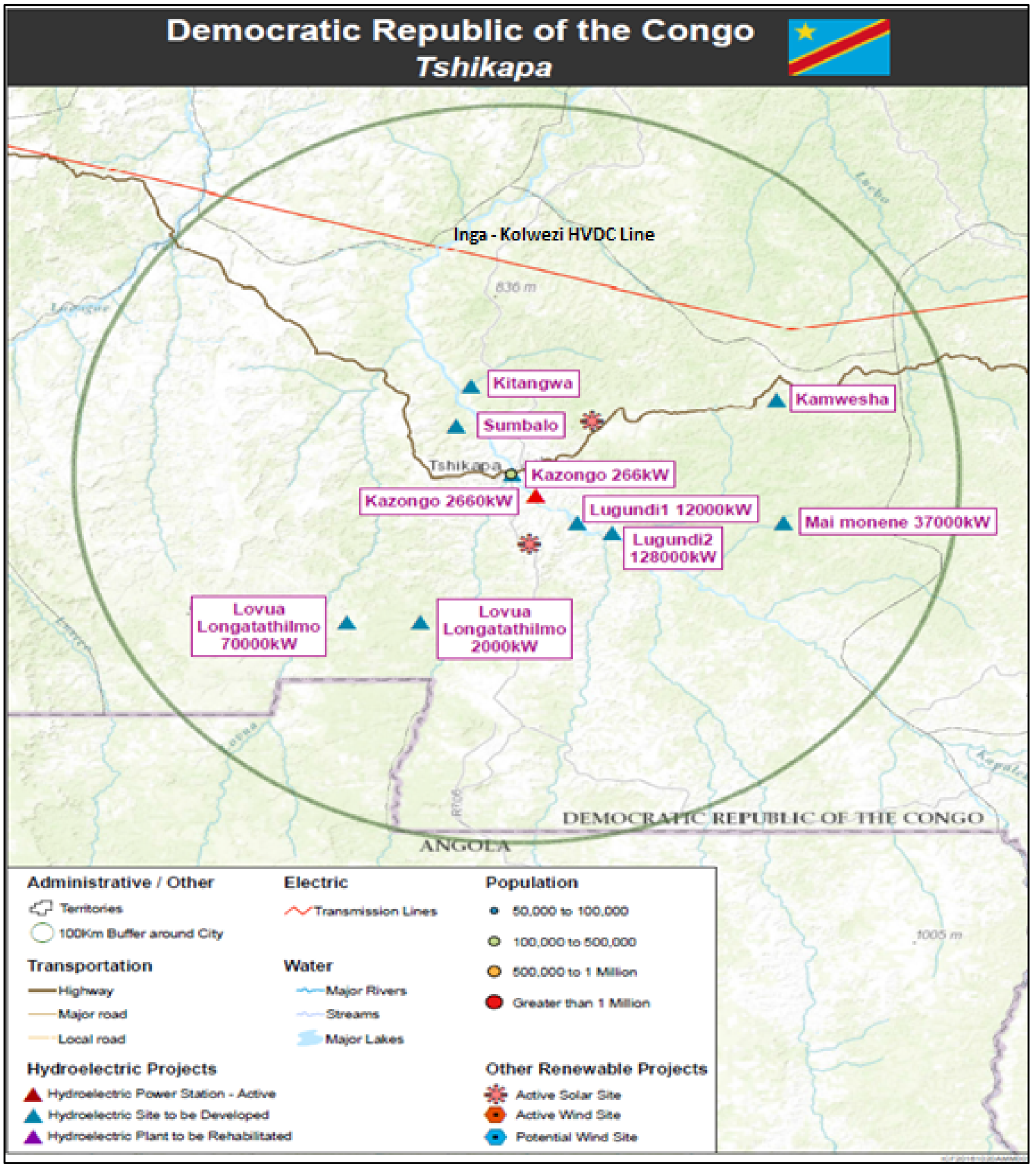
[43] Essor-UK Aid. (2016). *Essor–Access to Electricity–Solar powered mini-grids in the DRC.*

[44] Personal communication with Albert Mbafumoya Tchomba

Exhibit 14 Map of Tshikapa metro-region and potential generation resources

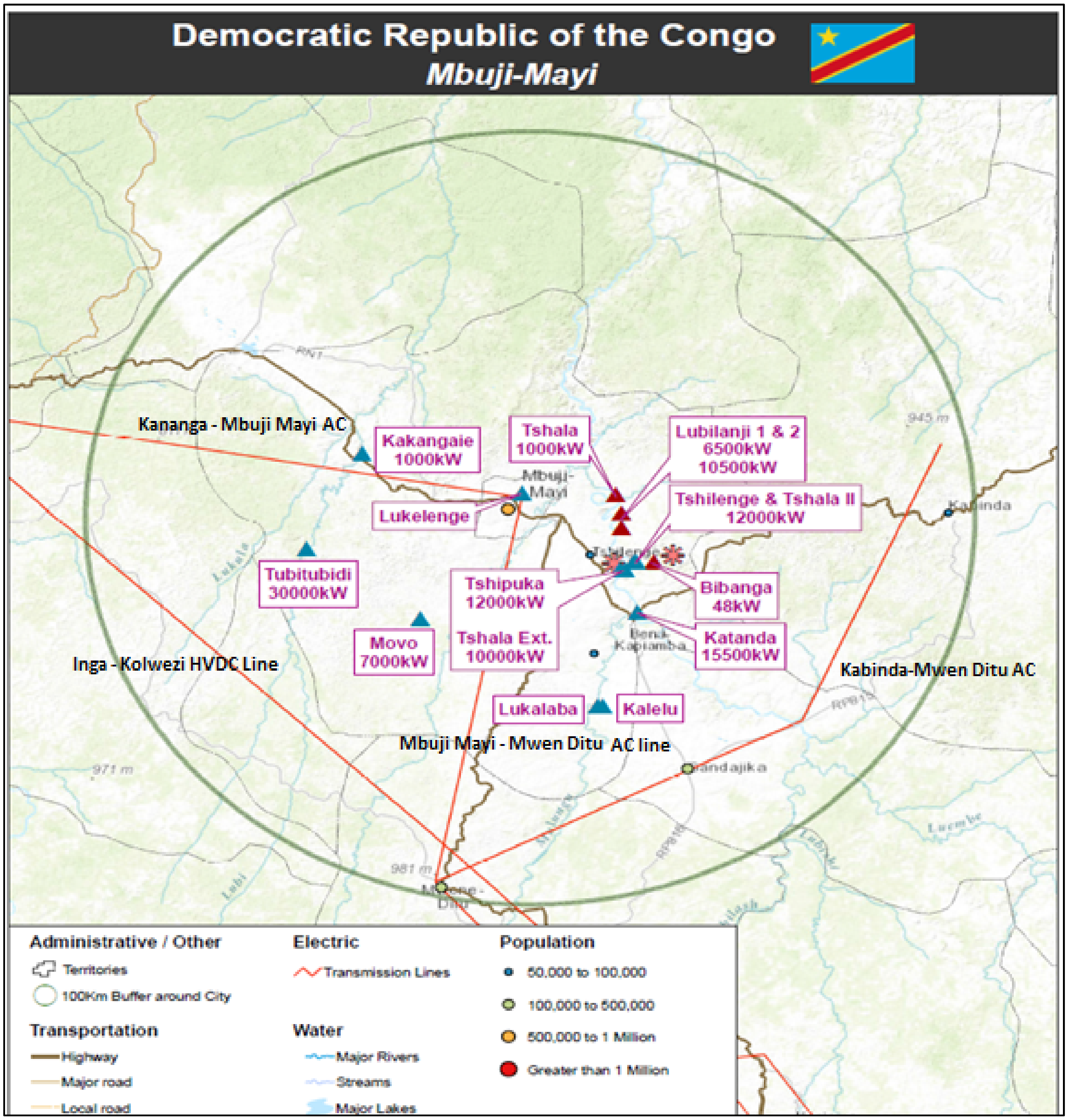


Sources: UNDP 2014 DRC Atlas and ICF.

3.4. Mbuji-Mayi

Mbuji-Mayi is served by the 220 kV Mbuji Mayi–Mweni-Ditu and 220 kV Kananga–Mbuji Mayi lines. Currently, the following hydroelectric plants serve the electricity demands for the city: Lubilanji 1 (6.5 MW); Lubilanji 2 (10.5 MW); Tshala (1 MW); and Bibanga (0.05 MW). In addition, there are other local hydroelectric sites, such as: Tshipuka (12 MW) and Tshipuka Extension (10 MW); Tubitubidi (30 MW); Katanda (15.5 MW); Movo (7 MW); and Kakangaie (1 MW). The total rated capacity of all these potential sites is approximately 75 MW. The power supply from the under-construction Katende units (64 MW) can also meet the electricity demand for the city.

Exhibit 15 Map of Mbuji-Mayi metro region and potential generation resources



Sources: UNDP 2014 DRC Atlas and ICF.

4. Assessment of Supply and Demand Projections for the Four Focus Cities/ Population Centers

In this section, we discuss potential approaches to developing conceptual solutions for meeting projected electricity demands for the four shortlisted population centers. We compare the available supply resources (both local and transmission supply) to the projected peak demand and develop an approach to achieve the desired electricity access outcomes. Our analysis assumes two broad scenarios.

Scenario 1—Local Resource Development: This scenario assumes that emphasis is made on developing local supply resources to meet the energy demands for the four population centers. We define local supply resources as potential energy sites (mostly hydroelectric sites) within a 100 kilometer radius of the individual cities/population centers. In addition to local resources, this scenario assumes that the remainder of the power requirement is supplied by the existing AC transmission lines to the population centers. The remainder of the power requirement is likely to be supplied by major central projects like Zongo 2, Katende, and Kakobola.[45] Under this scenario, we assume that the population centers meet their electricity access goals by 2020.

Scenario 2—Inga III Development: This scenario assumes the development of the 4,800 MW Inga III hydropower project. It is then envisioned that the power from this project is supplied to hinterland population centers through augmented AC and HVDC transmission lines. Other existing power projects (like Zongo 2, Katende and Busanga, and Kakobola) are assumed to be implemented in the near future. Under this scenario, we assume that the population centers meet their electricity goals by at least 2025.

For developing cost estimates, we rely on unit infrastructure cost estimates for power projects based on a report prepared by Africon for the World Bank in 2008.[46] The report sampled 58 power sector projects in Sub-Saharan African countries to arrive at a unit infrastructure costs. The unit infrastructure cost estimates are summarized in Exhibit 16. The costs estimates were originally reported in 2006 US dollars. The estimates are updated using the average GDP/inflation deflator for the region.[47] The deflator is around 6% for the last 10 years for Sub-Saharan African countries. The cost estimates are summarized in Exhibit 16. During the ICF team's field trip to the DRC, different stakeholders voiced concerns that these estimates are too low. As a result, we decided not to rely on these estimates for project budgeting purposes. Instead we have used the actual cost estimates of on-going projects like Katende and Kakobola interconnection. For other conceptual projects discussed in the project fact sheet, we used a cost estimate of $300,000 per km for high voltage transmission (greater than 66kV), $500,000/MVA for substations (up to 100 MVA) and $50,000 per km for distribution networks.

[45] See Section 1.2 for details on the existing projects.
[46] Africon. (2008). Africa infrastructure country diagnostic: Unit costs of infrastructure projects in Sub-Saharan Africa. http://www.eu-africa-infrastructure-tf.net/attachments/library/aicd-background-paper-11-unit-costs-summary-en.pdf
[47] World Bank Data. Inflation, GDP deflator (annual %). http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG?end=2015&locations=CD&start=1961&view=chart

Exhibit 16 Unit infrastructure costs for power infrastructure projects in Sub-Saharan African countries

Type	Unit	Lower Quartile	Median	Upper Quartile
Generation—High Speed Diesel	US $/ MW	762,214	1,390,211	2,304,171
Distribution (less than 66 kV)	US $/line km	8,253	13,986	16,233
Transmission (greater than 66 kV)	US $/line km	34,558	46,684	54,013
Substations (less than 50 MVA)	US $/ MVA	300,634	347,495	396,627
Substations (greater than 50 MVA)	US $/MVA	81,896	116,346	186,123
Service Connection	US $/connection	1,232	1,362	2,450
Service Connection with street lighting	US $/connection	833	1,029	1,112
Street lighting	US $/connection	2,130	2,985	4,102

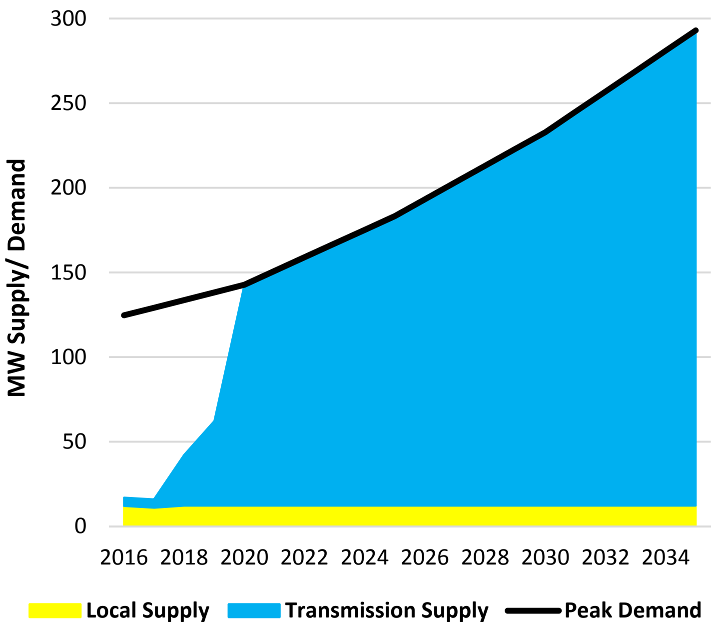
Source: Africon (2006). The cost estimates are inflated to 2015 US dollars using an average annual inflation factor of 6%.

4.1. Supply and demand projections under Scenario 1—Local resource development

4.1.1. Kikwit

The supply and demand projections under the Scenario 1 framework for different population centers are shown in Exhibit 17. The annual peak demand projections are shown by the black line. Projected supply from local resources is shown by the yellow stack, and external transmission supply is shown by the blue stack. The sum of the blue and yellow stack denotes the total supply stack for the given city/population center in a year. The total supply stack is made to match the projected peak demand by 2020 under the Scenario 1 framework. The population center of Kikwit is currently served by a 132 kV line connected to Kinshasa. Currently, a 10.5 MW hydro-unit at Kakobola is likely to be completed in the next year or so. A transmission line connecting Kakobola to Kikwit is needed to serve local power to the city. We assume that Kakobola (10.5 MW) and other local potential sites (2.2 MW) are developed by 2020. The local hydro-sites include Kabangu (1.5 MW); Kipuka (0.2 MW); Mutoy (0.3 MW); and Vanaga (0.24 MW). The rest of peak demand is assumed to be met through power imports from the city of Bandundu (likely from Zongo I and II, Inga I and II, and other units near the capital city). The city of Bandundu is connected by the 220 kV Kinshasa—Bandundu transmission line. Using a combination of local resources and transmission line supply, the projected peak demand for the population center is met by 2020. The increasing demand in later years is likely to be met through increased supply from the transmission line. The supply projection discussed here assumes that only local hydropower sites with rated capacity are being developed (based on the UNDP 2014 DRC Atlas). However, it is also possible to develop other resources (like unrated hydropower sites and solar PV plants) to meet the projected local demand. If any of these unrated resources are developed in the future, the proportion of transmission supply will decline accordingly.

Exhibit 17 Supply and demand projections for Kikwit under the Scenario 1 framework



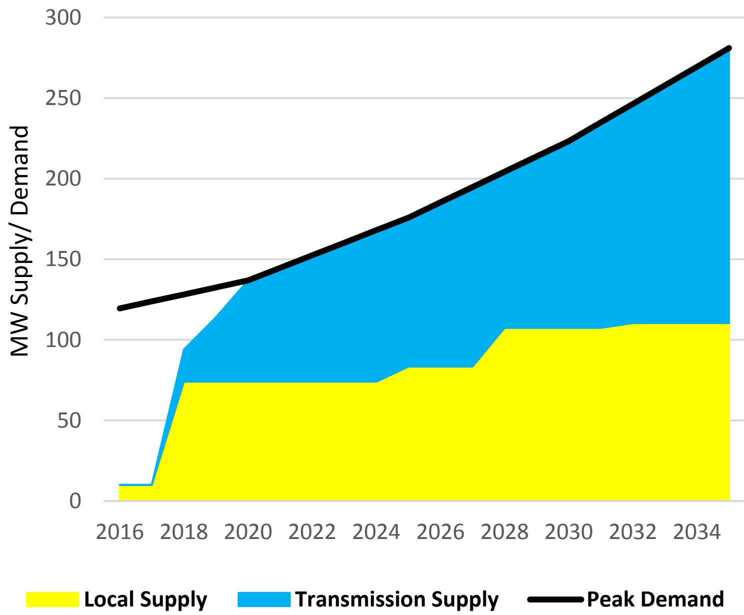
MW	Local Supply	Transmission Supply	Peak Demand
2016	12.0	5.0	124.6
2020	12.2	130.5	142.7
2025	12.2	171.1	183.3
2030	12.2	220.6	232.8
2035	12.2	280.8	293.0

Source: ICF projections.

4.1.2. Kananga

The supply and demand projections for the population center of Kananga is shown in Exhibit 18. The city of Kananga is currently served by the 220 kV Kananga–Mbuji-Mayi transmission lines. In addition, the 64 MW Katende hydropower project that is currently under construction is also located within 50 kilometers of the urban population center. We assume that the 64 MW Katende unit is commissioned by 2018. This would also require a transmission line to be built connecting the plant to the city/population center and the existing 220kV Kananga–Mbuji-Mayi transmission line. Since the plant is located within 70–80 kilometers of the load center, the losses on the transmission line are expected to be low. Beyond 2025, we assume the development of other local hydropower resources to meet the increasing peak demand. We assumed the development of a 9.4 MW Masambo hydro-project in 2025 to meet the increasing demand requirements. Also, this site is ideally located near the 220 kV Kananga–Mbuji-Mayi transmission line. In addition, it is also possible to develop other micro-hydropower projects like Kawula, Diabya, Kajangaji, Dibataye, Tshidimba, Moyo, and Bukonde before 2030 to add to the local supply mix. By the year 2030, we also assumed the development of a 24 MW Gorge du Lubundaje project to meet the increasing demand. These local projects would require their own transmission lines to connect it to the load center in Kananga. The unit could also be connected to the transmission network by extending the transmission line from the Katende unit. Under this scenario framework, Kananga city could require external transmission supply by 2024 to meet the projected demand fully. By 2035, we estimate that a combination of 110 MW of local supply resources and 171 MW of transmission supply would be necessary to meet the projected peak system demand.

Exhibit 18 Supply and demand projections for Kananga under the Scenario 1 framework



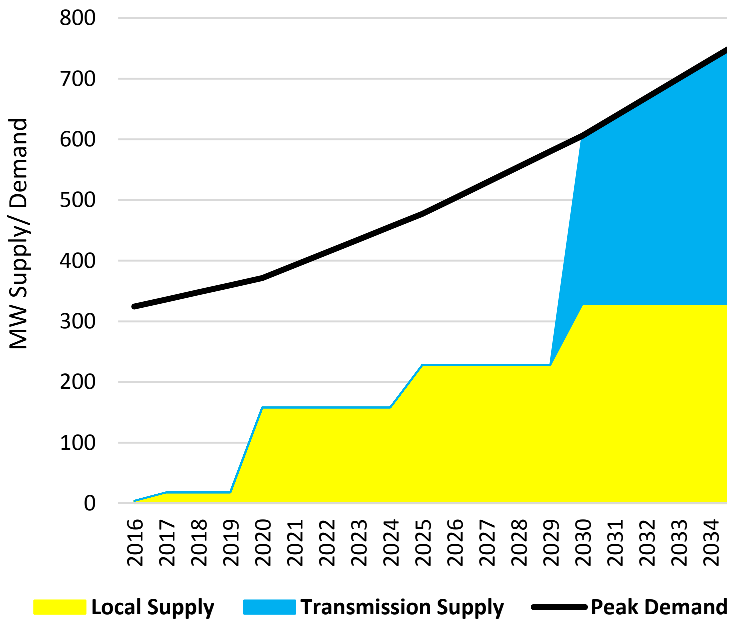
MW	Local Supply	Transmission Supply	Peak Demand
2016	10.0	0.0	119.5
2020	74.0	62.8	136.8
2025	83.4	92.4	175.8
2030	107.4	115.9	223.3
2035	110.4	170.6	281.0

Source: ICF projections.

4.1.3. Tshikapa

The city of Tshikapa is not currently connected to the transmission line network in the country. As a result, the city experiences a high degree of unmet demand. Under this scenario framework, we assume that the city of Tshikapa is not connected to the transmission network in the near future as well. Instead, we envision development of local resources to meet the demand requirements of the city/population center. In the next 2–3 years, we assume that small-scale hydropower projects like Lungudi 1 and Lovua Longatathilmo can be placed online to meet the electricity demand. To meet the universal electricity access goal, the 128 MW Lungudi Expansion project should be placed in service by 2020. By 2025, we assumed the commissioning of the 70 MW Lovua Longatathilmo expansion project. By 2030, there is also a need to implement the 100 MW Mai Monene project. All these major power plants require transmission lines to connect to the load centers of Tshikapa. We assume that Tshikapa would eventually be connected to transmission network in the country by 2030. With these projects in place, the city of Tshikapa should be in a position to meet the projected peak demand of nearly 762 MW by 2035. It should also be emphasized that other local projects like micro-hydro projects and solar PV plants can also be explored to meet the increasing demand. For the years beyond 2030, the city would require the external transmission supply to meet its projected peak demand. By 2035, we estimate that a combination of 265 MW of local supply and 91 MW of external transmission supply would be required to meet the projected peak system.

Exhibit 19 Supply and demand projections for Tshikapa under the Scenario 1 framework



MW	Local Supply	Transmissi on Supply	Peak Demand
2016	4.1	0.0	324.3
2020	158.1	0.0	371.3
2025	228.1	0.0	477.0
2030	328.1	277.8	605.9
2035	328.1	434.4	762.5

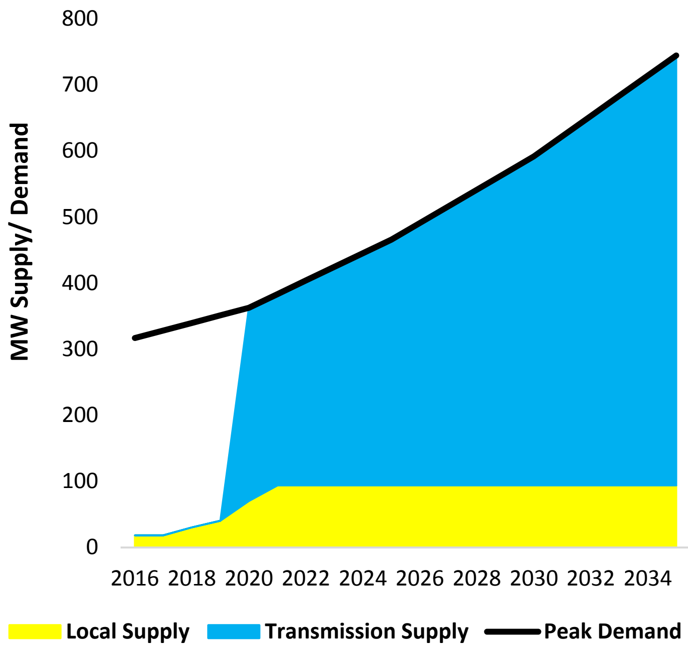
Source: ICF Projections

4.1.4. Mbuji-Mayi

Mbuji-Mayi is currently served by a total of 18 MW of existing power generation capacity from plants like Lubilanji 1 and 2 and Tashala. In addition, the city is also connected to the transmission network in the country through two links: the 220 kV Mbuji-Mayi–Mweni-Ditu and 200 kV Kananga–Mbuji-Mayi lines. In addition, there are other local hydroelectric sites like Tshikapa (12 MW +10 MW); Tubitubidi (30 MW); Katanda (15.5 MW); and Movo (7 MW). The total rated capacity of all these potential sites is estimated to be around 75 MW. To meet the system peak load locally, there is a need to develop Tshikapa 1 and 2 by 2019 and Tubitubidi by 2020. From 2020 onwards, the residual demand is likely to be met by transmission line supply. The units in southern Katanga provinces (like the upcoming 240 MW Busanga project[48]) are likely to supply the city/population center through the 220 kV Mbuji-Mayi–Mweni-Ditu line, while units like Katende, Zongo, and Inga I and II can supply to the city through the 220 kV Kananga–Mbuji-Mayi line. Due to the absence of large-scale local generation, the city would rely on power supplied through transmission lines. It is estimated that nearly 260 MW of transmission supply would be needed by 2035 to meet the city's projected peak demand. Needless to say, the development of other local resources (like micro-hydro or distributed solar PV units) could reduce the reliance on transmission supply in the future.

[48] Hydroworld. DRC awards US$660 million contract for 240-MW Busanga hydroelectric project in Africa. http://www.hydroworld.com/articles/2016/06/drc-awards-us-660-million-contract-for-240-mw-busanga-hydroelectric-project-in-africa.html

Exhibit 20 Supply and demand projections for Mbuji-Mayi under the Scenario 1 framework



MW	Local Supply	Transmission Supply	Peak Demand
2016	18.1	0.0	316.5
2020	70.1	292.3	362.4
2025	93.6	372.0	465.5
2030	93.6	497.8	591.3
2035	93.6	650.6	744.2

Source: ICF projections.

4.2 Supply and Demand projections under Scenario 2: Grand Inga Development

Under this scenario, we envision the development of the 4,800 MW Inga III hydropower project by 2025. We then assume the supply of power to hinterland cities through augmented AC and HVDC lines from the proposed Inga III power plant. The scenario anticipates the completion of the transmission infrastructure by 2025 to deliver the power to the hinterland cities in Southern and Central DRC. In addition, the local projects that are currently under construction (like Katende and Kakobola) are also expected to be in service before 2020. These projects encourage greater system reliability since they are locally based and also avoid transmission losses. The projected supply and demand projections for the four cities are discussed in this section using these assumptions. Local micro-hydro or distributed solar projects are ignored for simplification purposes under this scenario framework. If such resources are developed, the transmission supply is expected to be reduced proportionally. No major local generation projects[49] like the Lungudi Expansion and Lovua Longatathilmo for Tshikapa and Tshiluba and Tubitubidi for Mbuji-Mayi are assumed under this scenario framework.

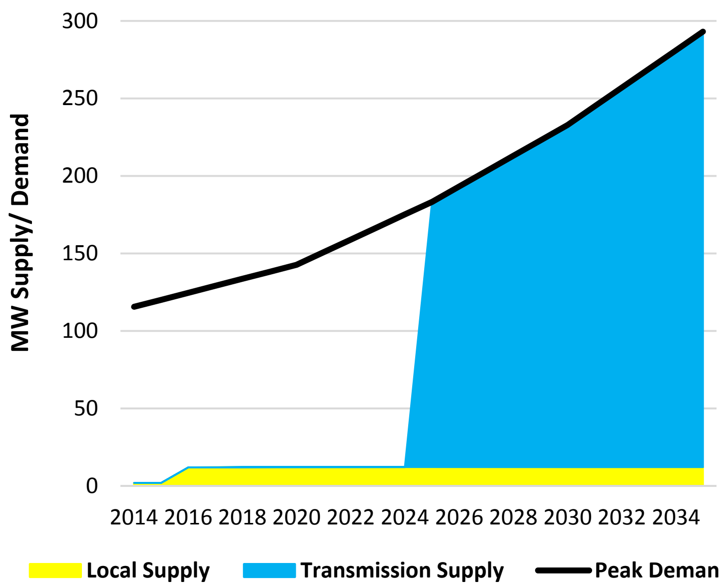
4.2.1. Kikwit

The supply and demand projections for Kikwit are shown in Exhibit 21. Unlike in a Scenario 1 framework, the transmission supply ramp up is expected to occur in 2025 when the Grand Inga project is commissioned. The power output is expected to be supplied through augmented AC lines from Kinshasa or through the refurbished HVDC line with converter stations at Kikwit. Also, the 10.5 MW Kakobola unit is expected to supply to the population center by 2020. Since there are no other major local hydropower

[49] We assume projects/potential hydro-sites exceeding 25 MW rated capacity as major generation projects.

resources being proposed under this scenario framework, the local supply is expected to be constant throughout.

Exhibit 21 Supply and demand projections for Kikwit under the Scenario 2 framework



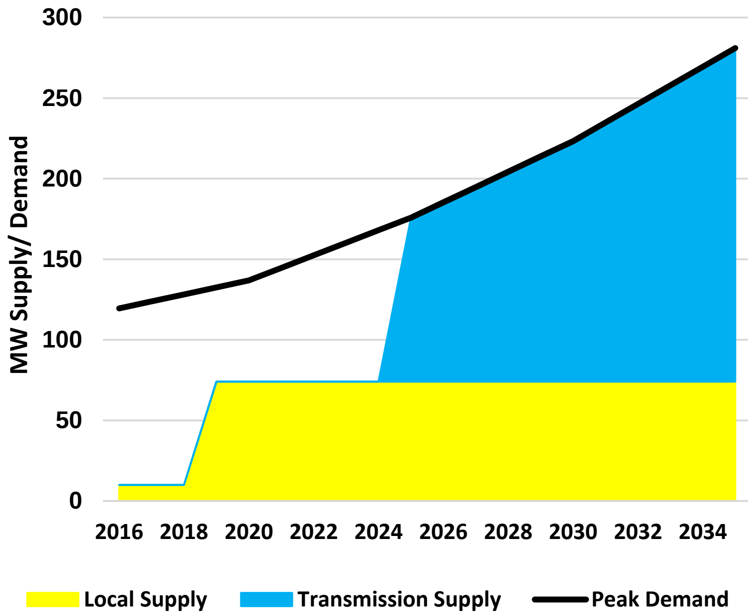
MW	Local Supply	Transmission Supply	Peak Demand
2016	12.0	0	124.6
2020	12.2	0	142.7
2025	12.2	171.1	183.3
2030	12.2	220.6	232.8
2035	12.2	280.8	293.0

Source: ICF projections.

4.2.2. Kananga

The supply and demand projections under a Scenario 2 framework for the population center of Kananga is shown in Exhibit 22. The Katende project is under construction and is expected to be completed by 2019. It is projected to fully satisfy the local demand during its initial years of operation. In the later years, Kananga would require supply from external generation sources through existing or potential AC and HVDC transmission lines. No other major local resources (like Gorge de Lubundaje and Masambo) are assumed to be developed under this scenario framework. By 2035, a combination of 74 MW of local resources and 207 MW of transmission supply is assumed for Kananga.

Exhibit 22 Supply and demand projections for Kananga under the Scenario 2 framework



MW	Local Supply	Transmission Supply	Peak Demand
2016	10.0	0.0	119.5
2020	74.0	0.0	136.8
2025	74.0	101.8	175.8
2030	74.0	149.3	223.3
2035	74.0	207.0	281.0

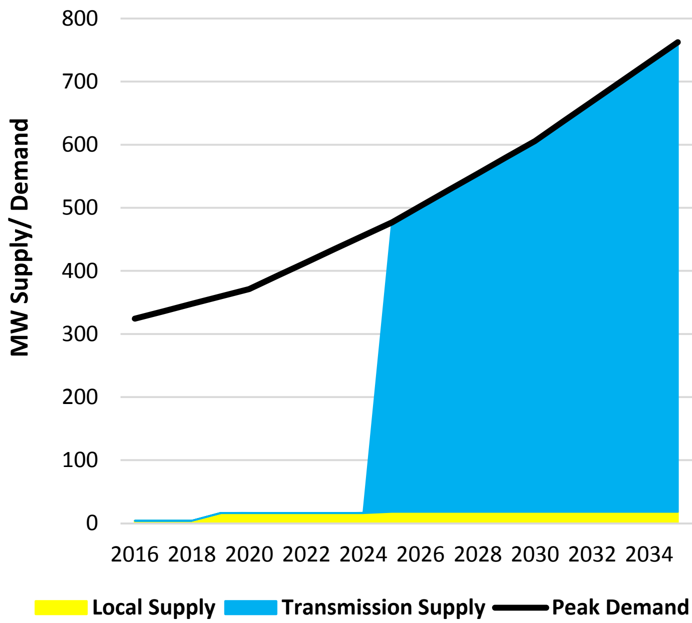
Source: ICF projections.

Note: Local supply is assumed to be 10 MW in 2015.

4.2.3. Tshikapa

Since Tshikapa is a large population center that is not currently connected to the transmission line network in the country, according to ICF's calculations, it has a huge unmet demand. The existing power generation capacity for the city is estimated to be 4 MW. Small-scale local hydro projects are assumed to be developed to meet some portion of the unmet demand for the period before 2025. After 2025, the power supply from the augmented transmission lines is assumed to meet the projected demand for the population center. The supply and demand projections under this scenario framework are shown in Exhibit 23. The bulk of future demand is expected to be met by transmission supply from an augmented AC or HVDC transmission line from the Inga III site. By 2035, a combination of 18 MW of local supply and 774 MW of transmission supply would be necessary to meet the projected peak demand.

Exhibit 23 Supply and demand projections for Tshikapa under the Scenario 2 framework



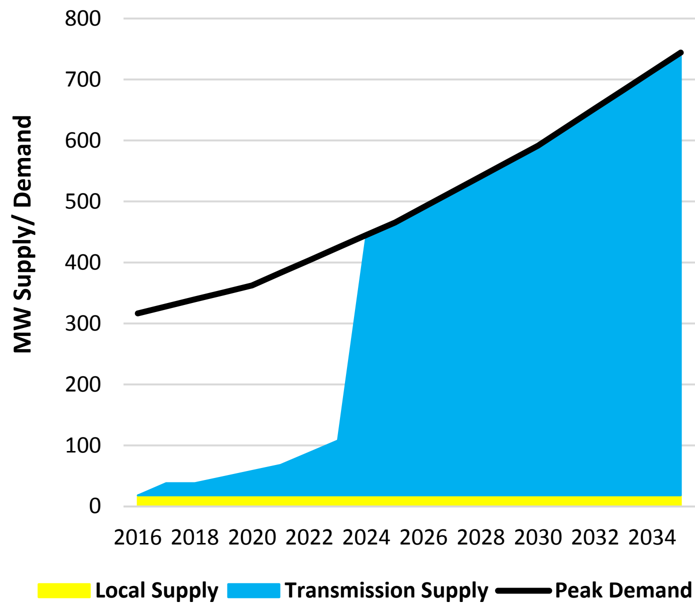
MW	Local Supply	Transmission Supply	Peak Demand
2016	4.1	0.0	324.3
2020	16.1	0.0	371.3
2025	18.1	458.9	477.0
2030	18.1	587.8	605.9
2035	18.1	744.4	762.5

Source: ICF projections.

4.2.4. Mbuji-Mayi

For Mbuji-Mayi, the local generation is assumed to be fixed at the existing level of 18.5 MW. In addition, the augmented AC/HVDC lines are assumed to supply the city from 2019 onwards. From 2025 onwards, the electricity demand for Mbuji-Mayi is likely to be met completely with transmission supplies from the Grand Inga project. The supply and demand projections for Mbuji-Mayi are shown in Exhibit 24. By 2035, nearly 726 MW of transmission supply would be required to meet the projected peak demand.

Exhibit 24 Supply and demand projections for Mbuji-Mayi under the Scenario 2 framework



MW	Local Supply	Transmission Supply	Peak Demand
2015	18.1	0.0	305.0
2020	18.1	40.0	362.4
2025	18.1	447.5	465.5
2030	18.1	573.3	591.3
2035	18.1	726.1	744.2

Source: ICF projections.

5. Compilation of Project Fact Sheets

Based on the discussions so far, we have identified five transmission solutions that can improve the long-term electricity access and reliability for the focus cities/population centers of Kikwit, Kananga, Tshikapa, and Mbuji-Mayi. The solutions are grouped under the two scenario frameworks. In effect, the two frameworks are mutually exclusive, as the first involves the development of local hydropower resources and the second involves the development of the Inga III hydropower project. The project concept fact sheets in this section are meant to solicit interest from donors, private sector investors, and other partners to develop these projects.

Scenario with the development of local hydropower resources for individual cities by 2020[50]:

- **Project 1:** Local Collector Transmission Network for Each Individual City
- **Project 2:** Distribution concession system for Kikwit
- **Project 3:** 220 kV AC transmission line between Kikwit–Kananga–Tshikapa–Mbuji-Mayi

Scenario with the development of the 4,800 MW Inga III Hydropower Project by 2025:

- **Project 4:** Augmentation of Inga–Kolwezi HVDC line
- **Project 5:** AC "backbone" project for the DRC (Grand Inga–Kinshasa–Mbuji-Mayi–Lubumbashi)

[50] Note: The Scenario 1 framework assumes the development of major generation projects for Kananga (Katende, Gorge de Lubundaje); Tshikapa (Lungudi Expansion and Lovua Longatathilmo); and Mbuji Mayi (Tshipuka and Tubitubidi) by 2020 to meet the local demand.

Project 1: Fact Sheet

Local Collector Transmission Network for Individual Cities

Detailed Project Description

The project consists of constructing a collector-type transmission network for individual cities to supply the power output from local hydropower projects to the city centers. The collector system can also be made part of the proposed AC transmission line "backbone" for the country.

The "backbone" is expected to interconnect major hydro-project sites and plants under construction to the city centers. The project would also entail construction of substations at suitable locations to facilitate the integration of power outputs from micro hydro-sites along the transmission corridors. The local projects are potential hydro-sites that are identified by the UNDP 2014 DRC Renewable Energy Atlas and are generally located within a 50 km radius of the city center.

Potential Project Benefits

The transmission projects will improve electricity access to the four cities and also improve overall grid reliability. Since supply resources are located locally, it also avoids major transmission losses. The micro hydro-sites also avoid the environmental impacts associated with large scale hydro-projects.

Budget Cost and Implementation Timeline

Since the projects connect a number of local generation sites to individual city/population centers, a detailed estimation of project cost is dependent on the actual project specification. Also, local generation sites could be developed over the years. In general, a 50 mile (approximately 80 km) collector system with two major substations (at 100 MVA each) and four minor substations (at 25 MVA each) is expected to cost around $190 million (2015 $).

Potential Hurdles

Some of the key hurdles to project implementation includes: lack of accurate data for project planning; lack of viable tariff structure to recoup fixed investment costs; uncertainty in capital cost estimates and lack of integration to a centralised transmission network in the country.

Reference

ICF- USAID Report (2017).

Project Overview

The project involves the construction of a collector-type transmission network to connect local power plant sites to the city centers. The collector-type network is expected to be a 220 kV line and would be a part of the future AC "backbone" network for the DRC.

Demographics, Land Use, Power Infrastructure, and Economy

Kikwit: Kikwit is the largest city and the capital of the province of Kwilu (part of erstwhile Bandundu). Kikwit is part of Bulungu territory and constitutes an urban sub-district. The economy of the city is driven by agricultural production and trading of palm oil, cassava, rubber, peanuts, and maize. Kikwit also has food processing industries and an airport. The city of Kikwit has an estimated population of 0.33 million and a projected electricity demand of 123,366 MWh/year in 2014. The city of Kikwit is currently served by a 132 kV line between Kinshasa and Kikwit. In addition, the 500 kV Inga–Kolwezi (HVDC) line also passes through Kikwit.

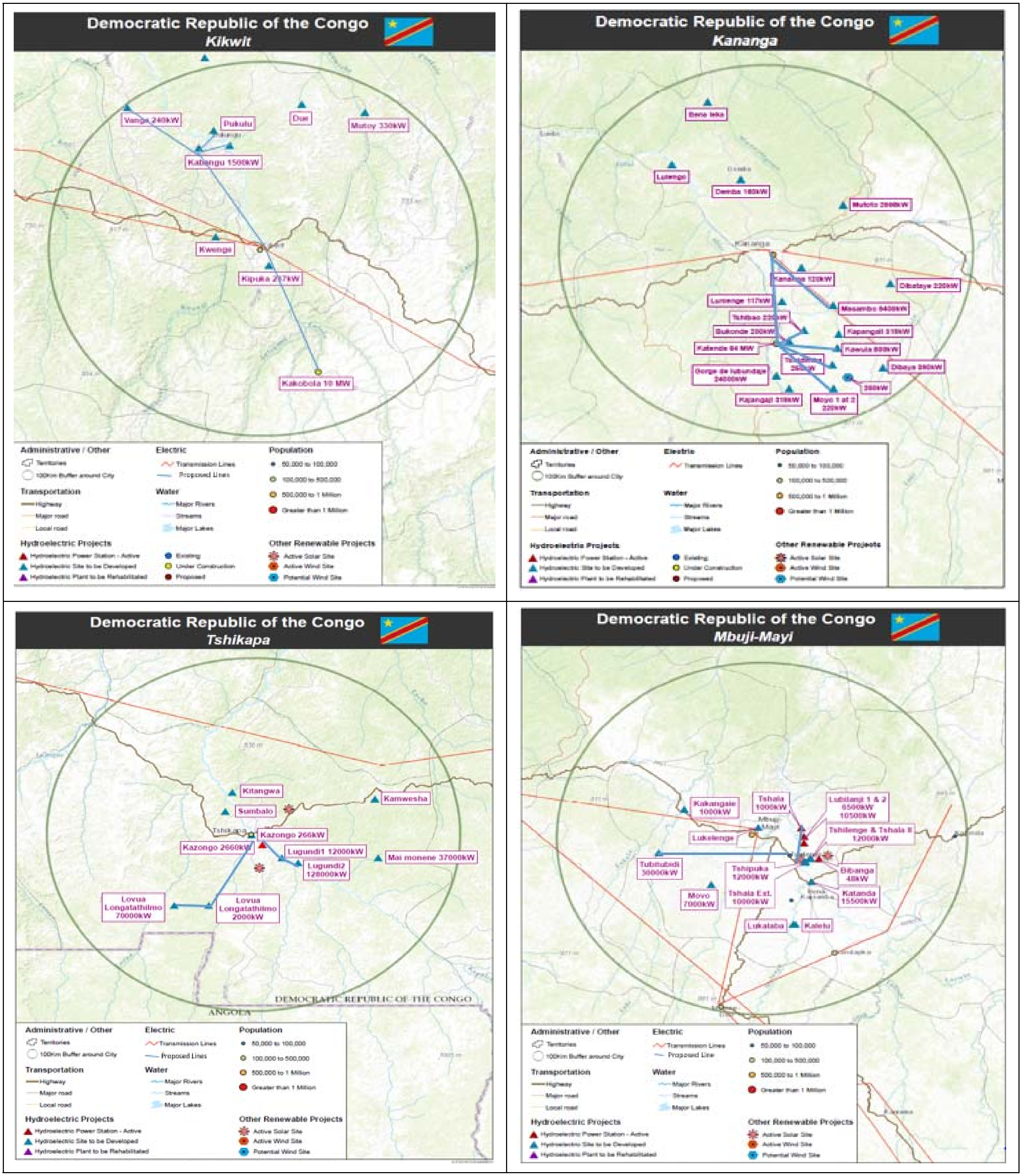
Kananga: Kananga (formerly Luluabourg) is a city in the Kasai-Occidental province. As of 2014, its population is estimated to be approximately 643,388 with an urban area density of 866 persons/km^2 in 2014. The city is along the Ilebo–Lubumbashi railway network. The projected electricity demand for the city in 2014 is 239,340 MWh/year.

Tshikapa: Tshikapa is a city in Kasai-Occidental province. As of 2014, its population is estimated to be 1.83 million, which also includes the wider Kamonia sub-district. Tshikapa is not currently served by the central grid network in the country. Instead, the city is served by a local micro-grid. There are only two operating hydro-units in the region—a 2.6 MW Kazongo unit and a 1.5 MW Lungudi unit.

Mbuji-Mayi: Mbuji-Mayi is a major urban center in Kasai-Oriental province with a population of approximately 1.86 million in 2014. It is the third largest city in the country. Mbuji-Mayi is currently served by a total of 18 MW of existing power generation capacity from plants like Lubilanji 1 and 2 and Tashala. In addition, the city is also connected to the transmission network through two transmission links: 220 kV Mbuji-Mayi–Mweni-Ditu and 200 kV Kananga–Mbuji-Mayi lines.

Project 1: Fact Sheet

Schematic Map of Collector-Type Transmission Networks for the Four Cities/Population Centers



Project 2: Fact Sheet

Distribution Concession System for Kikwit

Image Source: Central African Business

Project Overview

The project involves the construction of transmission linkages connecting the under-construction 64 MW Katende unit to Kananga city and the 10.2 MW Kakobola unit to Kikwit city. The project involves the construction of a 220 kV Katende–Kananga line and a 132 kV Kakobola–Kikwit line.

Demographics, Land Use, Power Infrastructure, and Economy

Kikwit: Kikwit is the largest city and the capital of the province of Kwilu (part of erstwhile Bandundu). Kikwit is part of Bulungu territory and constitutes an urban sub-district. The economy of the city is driven by agricultural production and trading of palm oil, cassava, rubber, peanuts, and maize. Kikwit also has food processing industries and an airport.

The city of Kikwit has an estimated population of 0.33 million and a projected electricity demand of 123,366 MWh/year in 2014. This demand translates to a projected peak demand of 26 MW (assuming a 0.55 load factor and a per capita electricity demand of 372 kWh/year). By 2035, the projected demand is expected to be 220,319 MWh/year with a peak demand of 46 MW. The city of Kikwit is currently served by a 132 kV line between Kinshasa and Kikwit. In addition, the 500 kV Inga–Kolwezi (HVDC) line also passes through Kikwit.

Detailed Project Description

This project would construct a distribution system (11-33kV) emerging from the city's local collector system (Project 1). As a pilot, the network would have 20 x 400 V lines with 500 connections per line. In total, the distribution system is expected to serve 10,000 connections in the city. The project is expected to be taken over by a private entity once implemented by the concession agreement outlined in the DRC's Electricity Law of 2014.

Potential Project Benefits

The projects will greatly improve electricity access at a household level. Projects like these are crucial to achieve the "last mile" electricity access for the country. Similar distribution concession systems could be implemented in other cities too. When projects like these are implemented in other cities, the overall national electrification rates would also improve.

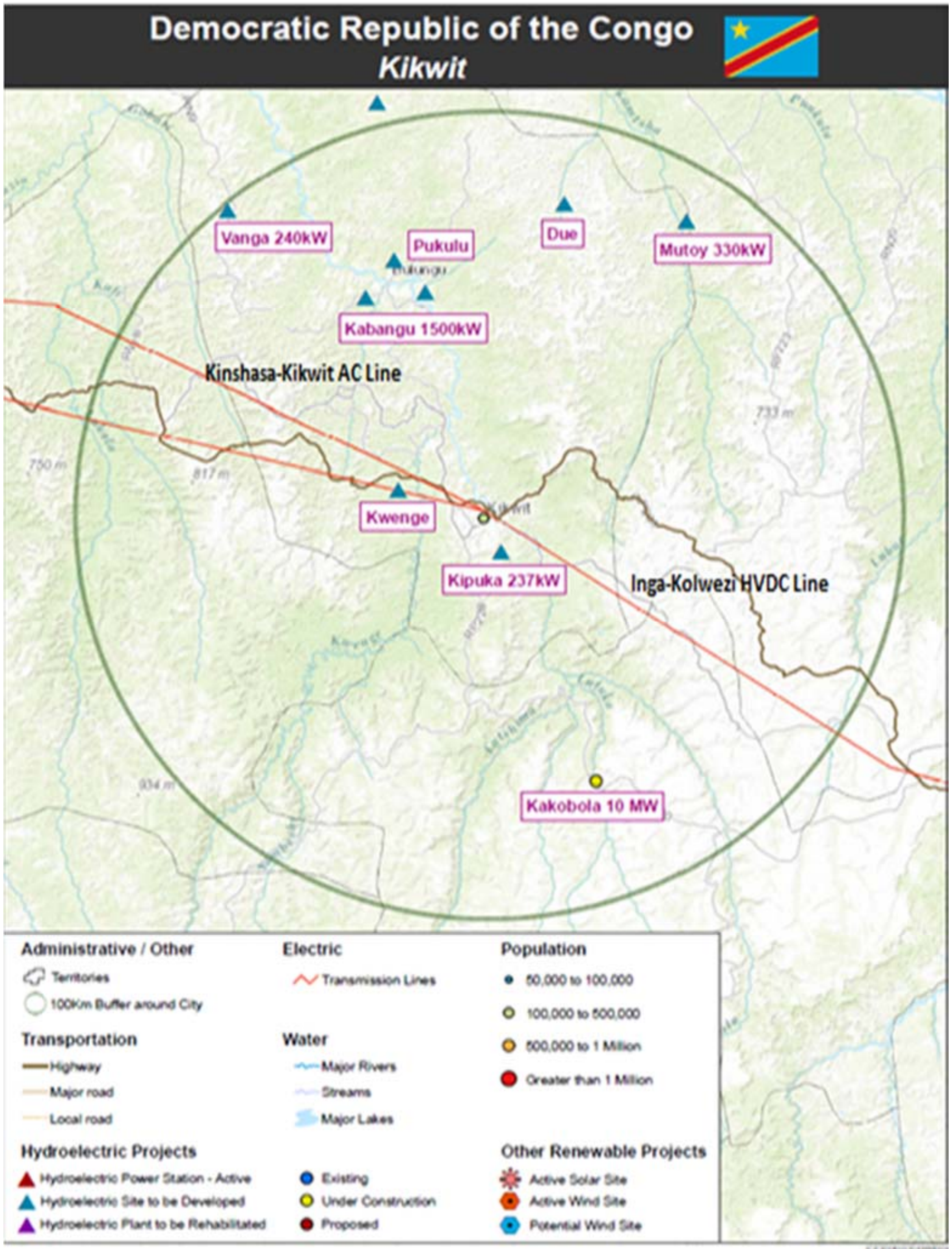
Potential Hurdles

Some of the key hurdles to project implementation includes: lack of accurate data for project planning; lack of viable tariff structure and purchasing power among customers to recover fixed investment costs; uncertainty in capital cost estimates and high tax burden on private concession players in the market.

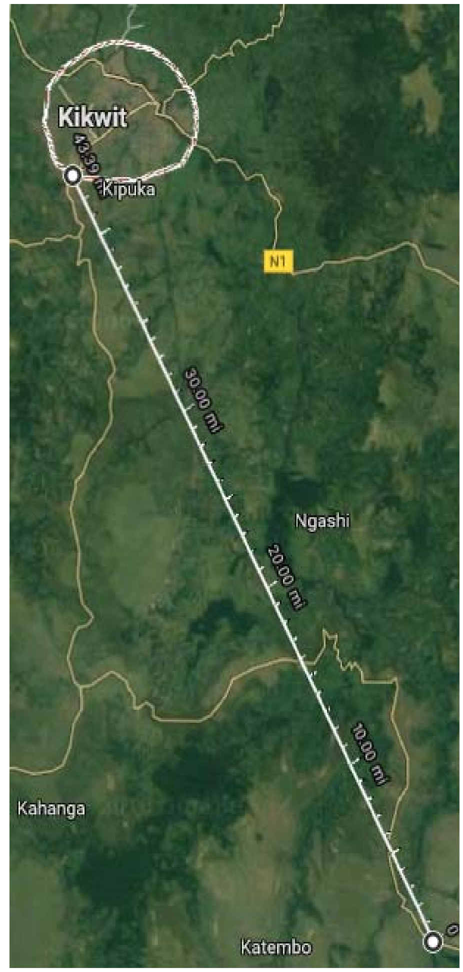
Budgetary Cost and Implementation Timeline

The project can be implemented only after setting up the transmission collector system to deliver power to the city. Based on discussions with stakeholders in the country, ICF estimates the cost of low voltage distribution networks at $50,000 /km. Also, the cost of end-user interconnection is estimated to be around $500 per connection.

Distribution Concession for Kikwit



Proposed Route of Kakobola–Kikwit line



Kakobola Project Site

Reference

ICF- USAID DRC (2017)

Project 3: Fact Sheet

Kikwit–Tshikapa–Kananga–Mbuji-Mayi Transmission Line

Image Source: Hydroworld

Detailed Project Description

The project consists of building a 220 kV AC line connecting the cities of Kikwit–Kananga–Tshikapa–Mbuji-Mayi. The transmission line is expected to be 400 miles (approximately 650 km). The transmission line would be a part of the proposed AC "backbone" for the country. The project is expected to be built along the existing Inga–Kolwezi HVDC line. The transmission line to the city of Tshikapa would require a slight diversion from the existing right-of-way of the Inga–Kolwezi line. In addition, the project would also require the construction of substations at the four cities to tap into the line.

Potential Benefits

An AC transmission "backbone" is expected to improve electricity access and reliability for the entire country. It also serves as a regional grid network to distribute power generated in central provinces. Since the project is expected to be along existing right-of-ways, the siting and project construction is expected to be faster.

Project Overview

This project involves the construction of a 220 kV AC line connecting Kikwit–Tshikapa–Kananga—Mbuji-Mayi. In the future, this line could become a part of the AC "backbone" proposed for the southern provinces in the country. The line is proposed to be parallel to the existing Inga–Kolwezi HVDC line to make use of the existing right-of-way. Also, the project would also connect Tshikapa to the transmission network in the country.

Demographics, Land Use, Power Infrastructure, and Economy

Kikwit: Kikwit is the largest city and the capital of the province of Kwilu (part of erstwhile Bandundu). Kikwit is part of Bulungu territory and constitutes an urban sub-district. The economy of the city is driven by agricultural production and trading of palm oil, cassava, rubber, peanuts, and maize. Kikwit also has food processing industries and an airport. The city of Kikwit has an estimated population of 0.33 million and a projected electricity demand of 123,366 MWh/year in 2014. The city of Kikwit is currently served by a 132 kV line between Kinshasa and Kikwit. In addition, the 500 kV Inga–Kolwezi (HVDC) line also passes through Kikwit.

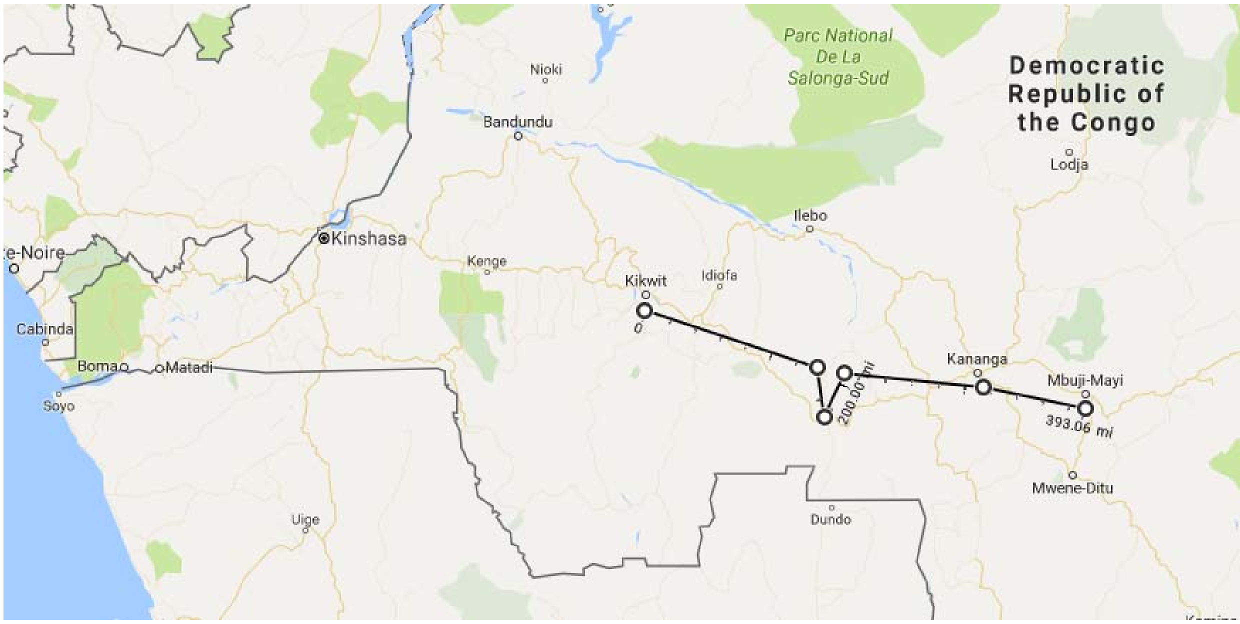
Kananga: Kananga (formerly Luluabourg) is a city in the Kasai-Occidental province. As of 2014, its population is estimated to be approximately 643,388 with an urban area density of 866 persons/km^2 in 2014. The city is along the Ilebo–Lubumbashi railway network. The projected electricity demand for the city in 2014 is 239,340 MWh/year.

Tshikapa: Tshikapa is a city in Kasai-Occidental province. As of 2014, its population is estimated to be 1.83 million, which also includes the wider Kamonia sub-district. Tshikapa is not currently served by the central grid network in the country. Instead, the city is served by a local micro-grid. There are only two operating hydro-unit in the region— a 2.6 MW Kazongo unit and a 1.5 MW Lungudi unit.

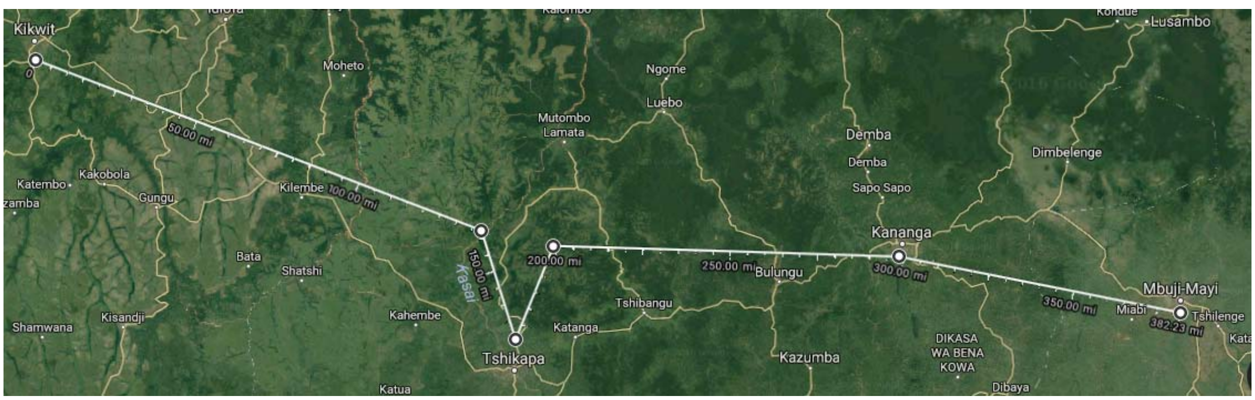
Mbuji-Mayi: Mbuji-Mayi is a major urban center in Kasai-Oriental province with a population of approximately 1.86 million in 2014. It is the third largest city in the country. Mbuji-Mayi is currently served by a total of 18 MW of existing power generation capacity from plants like Lubilanji 1 and 2 and Tashala. In addition, the city is also connected to the transmission network through two transmission links: 220 kV Mbuji-Mayi–Mweni–Ditu and 200 kV Kananga–Mbuji-Mayi lines.

Project 3: Fact Sheet

Schematic Map of Kikwit–Tshikapa–Kananga–Mbuji-Mayi Transmission Line



Aerial map of Kikwit–Tshikapa–Kananga–Mbuji-Mayi Transmission Line



Budgetary Costs and Implementation Timeline

The transmission line for this project is expected to be 450 miles (or approximately 650 km). The unit cost of the high-voltage line is estimated to be \$0.3 million/km based on stakeholder input. This would translate to a project cost of \$195 million (2015 \$) for the transmission line and towers alone. The four 100 MVA substations at each of the cities is expected to cost \$200 million. With a 5% contingency for other expenses (like contracting, import costs, additional labor costs, and land acquisition), the total budget for the project is estimated to be \$415 million (2015 \$). The project can be implemented in a time frame of 4–5 years, since it primarily relies on existing right-of-way.

Potential Hurdles

Some of the key hurdles to project implementation includes: lack of accurate data for project planning, difficulties in acquiring right-of-way and access in remote areas for construction and operation, lack of viable wholesale market arrangements (like wheeling arrangements) to recover fixed investment and line operational costs, uncertainty in capital cost estimates, and a lack of centralised transmission network in the country.

Reference

ICF- USAID (2017)

Project 4: Fact Sheet

Augmentation of Inga–Kolwezi HVDC line

Image Source: Huffington Post

Detailed Project Description

The project involves the construction of a second HVDC line parallel to the existing Inga–Kolwezi line in the DRC. The technical specifications of the line are expected to be finalized based on a technical feasibility report. It is expected that this line will double the transfer capacity from the Inga site to cities in Central and Southern provinces of the DRC. Also, with intermediate converter stations, the project could supply power to hinterland cities like Tshikapa and Mbuji-Mayi.

Potential Benefits

The project offers a cost-effective way of supplying power to cities in the hinterland. The project can also facilitate the export of power to other SAPP countries like Zambia and South Africa. Since the project will be implemented along existing right-of-way, the siting and line construction is expected to be faster. The HVDC lines also minimizes the transmission losses.

Project Overview

The project entails the addition of a second HVDC line between the Grand Inga Project site and the Kolwezi site in Southern DRC. Currently, the HVDC has a capacity of 1,200 MVA, with convertor stations at the Inga and Kolwezi sites. This project would also involve the addition of convertor stations at Tshikapa and Mbuji-Mayi to tap the power from the HVDC line. The line is expected to be in place when the Grand Inga hydro-project is completed by 2025.

Demographics, Land Use, Power Infrastructure, and Economy

The Democratic Republic of the Congo (DRC) is the second largest country in Africa with a total land area of approximately 2.3 million sq km, slightly less than one-fourth of the size of the United States. The country's population is estimated to be approximately 81.3 million as of 2016. Despite the fact that DRC is endowed with rich hydro and other renewable resources, there is a substantial unmet electricity demand. The country has one of the lowest electricity consumption rates at 0.11 MWh/capita.

Currently, the total installed capacity of central power plants in the country is estimated to be 2,590 MW, out of which hydro is 2,472 MW and combustible fuels is 34 MW. Only about half of this capacity is available for dispatch at any given time. The country is looking to tap into the hydroelectric potential at the Inga site (near 225 km southwest of the capital city of Kinshasa). The site is ideal for hydroelectric generation as it is located about 50 km upstream of the mouth of the Congo River.

Based on a recent feasibility study, it is proposed to implement the Grand Inga project in six distinct phases. As a first step, a 4,500 MW Inga Unit III is proposed to be constructed. The project is expected to deliver electricity to other countries in the region. The construction is expected to commence in 2016 and the entire project (including transmission lines to load centers) is expected to cost nearly $80 billion.

The DRC has approximately 5,510 km of high-voltage transmission lines connecting the major power plants at Bas-Congo (i.e., Inga hydro units) to provinces in Central and Southern provinces of the country. The existing HVDC line between Inga–Kolwezi is primarily used to meet the demand in Southern provinces. Currently, the capacity of the line is around 600 MW. ABB is refurbishing this line currently and by the end of next year, the total capacity of the line is expected to double to 1,200 MW. However, this capacity will not be enough to off-take the capacity from the proposed Grand Inga III project. Hence, there is a need to augment the capacity of the HVDC line with intermediate convertor stations for hinterland cities.

Project 4: Fact Sheet

Map of Proposed Grand Inga–Kolwezi HVDC Line

Budget Information and Schedule

The unit cost of the high-voltage line is estimated to be $0.46 million/km as per a recent World Bank assessment of power sector infrastructure projects in Sub-Saharan Africa. Since the length of the line is expected to be 1,060 miles (or 1,700 km), the project cost with transmission line alone is expected to be $794 million (2015 $). The construction cost of an inverter station is assumed to be twice that of a major substation. The cost of an HVDC inverter station is expected to be around $100 million each (2015 $). Since the project requires the construction of four inverter stations (at Grand Inga site, Tshikapa, Mbuji-Mayi, and Kolwezi), the project cost associated with inverter stations alone is expected to be $400 million. With allowances for other incidental costs and overruns, the overall project cost is expected to be around $1254 million (2015 $).

Potential Hurdles

Some of the key hurdles to project implementation includes: lack of accurate data for project planning, difficulties in acquiring right-of-way and access in remote areas for construction and operation, lack of viable wholesale market arrangements (like wheeling arrangements) to recover fixed investment and line operational costs, uncertainty in capital cost estimates, and a lack of centralised transmission network in the country.

Reference

ICF USAID Report (2017).

Project 5: Fact Sheet

AC "backbone" Project for the DRC (Grand Inga–Kinshasa–Mbuji-Mayi–Lubumbashi)

Image Source: Huffington Post

Detailed Project Description

The project involves a construction of an AC "backbone" line (preferably 220 kV) from the Grand Inga site to major cities like Kinshasa, Kikwit, Tshikapa, Kananga, Mbuji-Mayi, Kamina, Kolwezi, and Lubumbashi. The project could be implemented in two phases. In the first phase, the AC line could be extended from Grand Inga to Mbuji-Mayi. In the second phase, the AC line could be extended from Mbuji-Mayi to Lubumbashi.

Project Benefits

The project offers improved reliability and electricity access to hinterland cities. Also, being an AC line, it is easier to tap into the line to supply power to major load and population centers in the hinterland.

Budget Information and Schedule

The unit cost of the high-voltage line is estimated to be $0.46 million/km as per a recent World Bank assessment of power sector infrastructure projects in Sub-Saharan Africa. Since the length of the line from the Grand Inga site to Mbuji-Mayi is expected to be 750 miles (or 1,250 km), the total cost of the Phase I transmission line is $575 million. Since the length of the line between Mbuji-Mayi and Lubumbashi is around 500 miles (or 805 km), the total cost of the Phase II transmission line is $368 million. The total number of substations is expected to be around 12 (corresponding to major cities along the route). With a unit cost of 100 MVA substations at $50 million each, the total construction cost of substations alone is expected to be $600 million. The overall project cost (for both phases) is expected to reach around $1623 million accounting for 5% cost contingency (all in 2015 U.S $).

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Demographics, Land Use, Power Infrastructure and Economy

The Democratic Republic of the Congo (DRC) is the second largest country in Africa, with a total land area of approximately 2.3 million sq km, slightly less than one-fourth of the size of the United States. The country's population is estimated to be approximately 81.3 million as of 2016. Despite the fact that the DRC is endowed with rich hydro and other renewable resources, there is a substantial unmet electricity demand. The country has one of the lowest electricity consumption rates at 0.11 MWh/capita.

Currently, the total installed capacity of central power plants in the country is estimated to be 2,590 MW, out of which hydro is 2,472 MW and combustible fuels is 34 MW. Only about half of this capacity is available for dispatch at any given time. The country is looking to tap into the hydroelectric potential at the Inga site (near 225 km southwest from the capital city of Kinshasa). The site is ideal for hydroelectric generation as it is located about 50 km upstream of the mouth of the Congo River.

Based on a recent feasibility study, it is proposed to implement the Grand Inga project in six distinct phases. As a first step, a 4,500 MW Inga Unit III is proposed to be constructed. The project is expected to deliver electricity to other countries in the region. The construction is expected to commence in 2016 and the entire project (including transmission lines to load centers) is expected to cost nearly $80 billion.

The DRC has approximately 5,510 km of high-voltage transmission lines connecting the major power plants at Bas-Congo (i.e., Inga hydro units) to provinces in Central and Southern provinces of the country. An AC "backbone" network connecting Grand Inga to Kinshasa and other major cities in Central/Southern provinces would improve electricity access and overall grid reliability in the country. It would also help to interconnect other major hydro-projects in the country, like Zongo 2, Busanga, and Katende.

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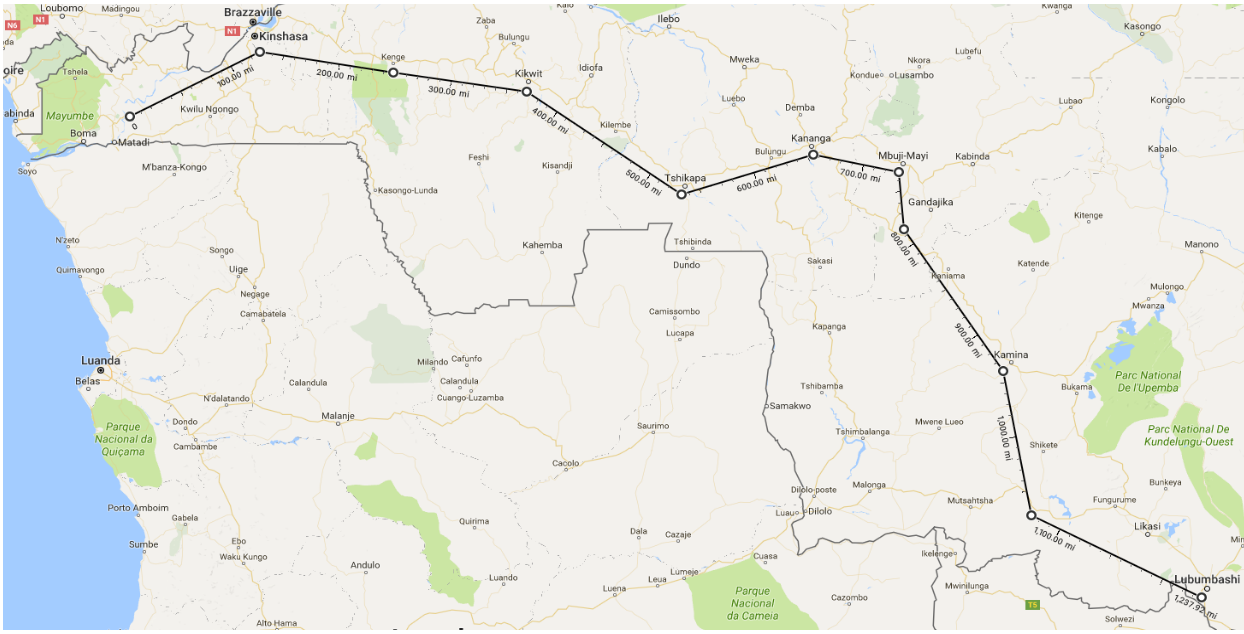
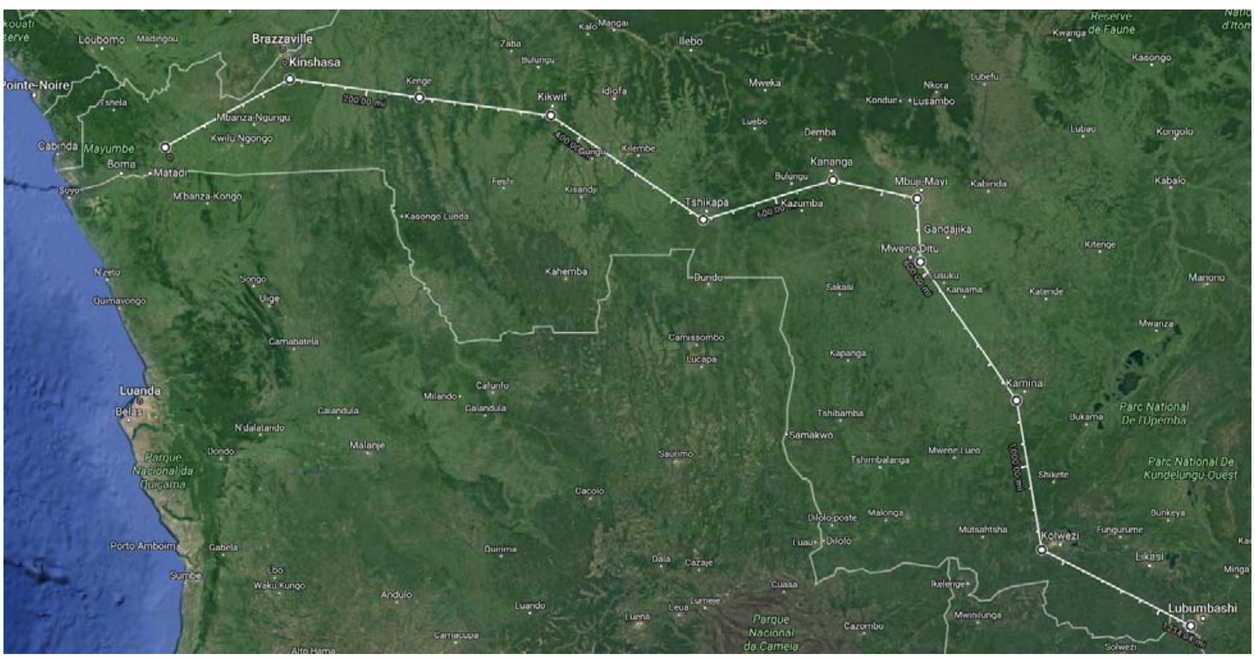
Map of Proposed AC "Backbone" Project for the DRC



Aerial Map of Proposed AC "Backbone" Project for the DRC



Potential Hurdles

Some of the key hurdles to project implementation includes: lack of accurate data for project planning, difficulties in acquiring right-of-way and access in remote areas for construction and operation, lack of viable wholesale market arrangements (like wheeling arrangements) to recover fixed investment and line operational costs, uncertainty in capital cost estimates, and a lack of centralised transmission network in the country.

Reference

ICF USAID Report (2017)

Appendix

Exhibit A-1. Site Photographs of Katende Project

Exhibit A-2. Site Photographs of Kakobola Project

Exhibit A-3. Photographs of a proposed solar plant in Manono

Exhibit A-4 to A-6. Photographs of Distribution Lines in Kinshasa, DRC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