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Climate Technology Centre & Network

Federal Ministry of Environment - Department of Climate Change

Federal Ministry of Science and Technology – Department of Environmental Sciences and Technology

Technology Needs Assessment and associated action plan for climate change mitigation and adaptation in Nigeria's most vulnerable economic sectors

Mitigation technologies in the energy sector

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Contents

1. Introduction/Overview

The objective of this assignment is to develop a comprehensive Technology Needs Assessment (TNA) and associated action plan for Nigeria's climate change mitigation and adaptation. To achieve this objective, it is necessary to identify the relevant technologies that can contribute to Nigeria's climate objectives, especially in the three priority sectors, namely, agriculture and land use, energy, and industry and commerce. From the three priority sectors, sub-sectors were pre-selected and identified for each sector by performing a thorough assessment and desktop review of key national strategies and sectoral policies in Nigeria. In this context, the next step is to identify and confirm the mitigation and adaptation technologies that can be applicable to each subsector, which will be the basis for Nigeria's TNA and action plan.

This report, therefore, will first discuss the sector and subsector prioritization process, including the process taken for sector and subsector selection and the results of the prioritization process. Then, the report will provide a general overview of gender considerations that are relevant to the sectors and subsectors that have been prioritized. It will then shift the focus on the energy sector and its subsectors, and provide a list of technologies applicable to the subsectors. This section will include an assessment of how the technologies contribute to climate change mitigation/adaptation and identify the barriers and gaps of implementing the technology. Finally, the report will present a summary of mitigation technologies that were considered during the process.

2. Institutional arrangement and stakeholder involvement

As part of conducting the TNA, the TNA Project Committee was established representing the key stakeholders from each prioritized sector. The main objective of the TNA Project Committee is to oversee the progress of the TNA and to ensure the engagement of key stakeholders throughout the TNA process. In this regard, to determine the appropriate composition of the TNA Committee, the consulting team conducted a stakeholder mapping for the purpose of identifying key stakeholders in the public sector, private sector, civil society, academia, and NGOs to ensure proper sectoral, transversal and climate-relevant representation of stakeholders. The stakeholder analysis was later refined by stakeholder consultations, which was generally conducted bilaterally. In coordination with the National Project Coordinator and the Deputy TNA Project Coordinator of the TNA Project Committee, these stakeholder consultations and analysis supported the finalization of the TNA Committee in Nigeria and assured the full representations of key stakeholders in the TNA process. In this context, there was an emphasis on ensuring equal representation of women and men as well as participation of gender focal points and associations that promote gender equality and the empowerment of women (GEEW) and other vulnerable groups. Throughout the TNA process, the consulting team also made sure that there was an engagement and consultation with representations from the private sector.

3. Sector and subsector prioritization process

For Nigeria's TNA, the three priority sectors were selected in the inception workshop led by the Federal Ministry of Science and Technology (FMST), in collaboration with Federal Ministry of Environment's Department of Climate Change (FMEnv – DCC) in September 2018. As mentioned earlier, the three priority sectors for Nigeria's TNA are: agriculture and land use, energy, and industry and commerce. The three key sectors are not only significant for Nigeria's long-term development, but also climate sensitive and vulnerable to the impacts of climate change. The subsectors, therefore, were identified and pre-selected from the three priority sectors.

To pre-select the subsectors, all key national strategies and sectoral policies were reviewed and analyzed to identify development priorities as well as climate change priorities. In this process, a total of 17 documents were reviewed and assessed, which led to the identification of the subsectors. For the agricultural and land sector, four sub-sectors were identified, namely, crop production, livestock production, forestry, and fish production. As for the energy sector, electricity supply, energy demand and energy efficiency were identified as the sub-sectors for this sector. Finally, for the industry and commerce sector, the subsectors are agribusiness and agro-allied sectors, solid minerals and metals, oil and gas-related industries, and construction and manufacturing.

Consequently, these subsectors were then pre-scored by the consulting team by using a set of criteria, which included (1) relevance to development priorities; (2) potential for climate change mitigation; (3) potential for climate change adaptation; and (4) overall enabling environment, including regulatory, institutional, and financial information. The purpose of the initial scoring was to assist the stakeholders in the actual selection and prioritization process that took place in the validation workshop on June 9th, 2021.

The stakeholders' validation workshop was conducted as hybrid meeting in Abuja, Nigeria and on the virtual platform, in which a total of 47 stakeholders participated in the workshop, 26 physical participants and 21 virtual participants. The stakeholders' validation workshop provided an opportunity for the stakeholders to have an overview of the subsector prioritization process, to discuss on issues regarding each subsector, and to revisit the scoring of the subsectors. In this regard, the stakeholders provided valuable inputs or feedbacks including, but not limited to, whether to incorporate the latest political negotiations as well as gender implications in the prioritization process, to add another subsector reflecting the results of agricultural activities, and to change the subsector from "construction, light manufacturing and services" to "construction and manufacturing". In addition, as part of the interactive session of the validation workshop, the initial scoring of each subsector was assessed by the stakeholders, mainly taking into account all discussions raised across the criteria, including the potential for climate change mitigation and adaptation, as well as the role of enabling environment.

The scoring was confirmed as shown in the table below:

Sector	Sub-sector	Potential for climate change mitigation (GHG emissions)	Potential for climate change adaptation (vulnerability)	Relevance to development priorities	Overall enabling environment	Total score
Agriculture and land	Crop production	3	3	3	2	11

Sector	Sub-sector	Potential for climate change mitigation (GHG emissions)	Potential for climate change adaptation (vulnerability)	Relevance to development priorities	Overall enabling environment	Total score
use	Livestock production	3	3	3	2	11
	Fish production	1	3	3	2	9
	Forestry	3	3	3	2	11
Energy	Electricity supply	3	3	3	3	12
	Energy demand	3	3	3	2	11
	Energy efficiency	3	3	3	1	10
Industry and commerce	Agribusiness and agro-allied sectors	2	2	3	1	8
	Solid minerals and metals	3	1	3	1	8
	Oil and gas-related industries	3	2	3	1	9
	Construction and manufacturing	3	1	3	1	8

As a result, the prioritized subsectors were confirmed with consensus from the TNA Committee: crop production, livestock production, forestry, electricity supply, energy demand, energy efficiency, agribusiness and agro-allied sectors, solid minerals and metals, construction and manufacturing. Therefore, the preliminary long-list of technologies was prepared by the consulting team based on the prioritized subsector and the discussions from the validation workshop. In this context, the subsequent sections will identify and assess the technologies for each subsector that can contribute to climate change mitigation in Nigeria.

4. Methodology

After the prioritized sectors and subsectors were confirmed with consensus from the TNA Committee, the consulting team developed the preliminary long-list of technologies.
These technologies were then evaluated against the following criteria:

(a) **Potential impact on climate change mitigation/greenhouse gas emissions reduction** in the context of Nigeria's climate change targets. Indicators may include GHG emission share of sub-sector in which the technology could be applied, and theoretical or practical effects of the technology itself in the reduction of GHG emissions.

3: High	The sub-sector is a major source of GHG emissions, and the technology could bring about a large emission reduction effect.
2: Moderate	The sub-sectoral emission share is moderate, but the technology could bring about a large emission reduction effect. Or, while the sub-sector accounts for a large portion of GHG emissions, the expected emission reduction effect of the technology is not particularly large.
1: Low	The emission reduction effect is negligible.
0: Null	Not applicable.

(b) **Potential impact on climate change adaptation,** if any, in the context of Nigeria's climate change targets. Indicators may include the size of population and economy (e.g., sub-sectoral GDP) which could be affected by the climate change related events that the technology tackles with, and theoretical or practical effects of the technology itself on adaptation to climate change.

3: High	The sub-sector is a major industry and the potential for the technology to enhance climate resilience is expected to be large.
2: Moderate	While the sub-sector is a major industry, the expected impact of the technology on climate resilience is not particularly large. Or, the size of population and/or economy of the sub-sector is moderate, but the technology could bring about a large positive impact on climate resilience.
1: Low	The effect on adaptation to climate change is negligible.
0: Null	Not applicable.

(c) **Alignment with climate change policies and priorities**: Evaluates to what extent the technology aligns with key national strategies and sectoral policies, and climate change priorities. Strategies and priorities to be reviewed are those analyzed for the sub-sector selection. Indicators may include whether the technology is mentioned in the policies or priorities and whether the technology could be expected to address the major challenges identified in the policies or priorities.

3: High	The technology is mentioned in several (more than one) key policies or priorities.
2: Moderate	The technology is mentioned in one of the key policies or priorities. Or, the technology is related to several focus areas of investment in the key policies or priorities.
1: Low	The technology itself is not mentioned in any policy or priority, but it could be related to one of the focus areas of investment in the key policies or priorities.
0: Null	Implementation of the technology is not necessarily prioritized in the key policies or priorities.

(d) **Consideration of co-benefits** (environmental, social, and economic):

i. Environmental: the potential impact on Nigeria's environment

ii. Social: the potential impact on Nigeria's employment/poverty reduction

iii. Economic: the potential impact on Nigeria's economy

3: High	Implementation of the technology could bring about co-benefits in three categories.
2: Moderate	Implementation of the technology could bring about co-benefits in two categories.
1: Low	Implementation of the technology could bring about co-benefits in one of the three categories.
0: Null	Implementation of the technology is not expected to bring about any co-benefit.

(e) **Technological constraints**: Evaluates how practical or realistic the implementation of the technology is in general. Indicators may include the maturity level of the technology, the number of use cases around the globe or in developing counties, and the magnitude of barriers to implementing the technology.

3: High	The technology has already been widely used commercially, and no or only minor barriers are expected in implementing the technology.
2: Moderate	There are some use cases but not yet widely used commercially.
1: Low	The technology is still at the pilot test stage.
0: Null	The technology is still at the research/study stage and is not expected to be used in practice as of now.

(f) **Readiness of Nigeria for the technology**: It evaluates to what extent Nigeria has the appropriate and sufficient environment to implement the technology. The indicators may include the number of use cases in the country, policy environment which could facilitate the implementing of the technology, and acceptability of stakeholders.

3: High	There are several use cases in Nigeria, and no or only minor barriers are expected in implementing the technology.
2: Moderate	There is/are (a) use case(s) in Nigeria. Despite the existence of some challenges in implementing the technology, these could be addressed in the short-term.
1: Low	There is no use case in Nigeria, but there is the environment which could support the implementation of the technology.
0: Null	There is no use case or policy which could promote the use of the technology in Nigeria, and there are many challenges to overcome to implement the technology as of now.

The result from this exercise will provide a total score for each technology, which will be used as a reference to guide the actual section and prioritization of technologies by the stakeholders in the next step.

5. Gender considerations

The UNFCCC and Federal Government of Nigeria recognize the importance of developing national-level climate change policies that are gender-responsive. This section provides an overview of gender priorities, issues and concerns for the prioritized TNA sectors and subsectors. According to the World Economic Forum's 2021 World Gender Gap Report, Nigeria ranks 139 of 156 countries on gender equality.[1] As of 2019, women held 5.6 percent of seats in the lower house of parliament and 6.4 percent of seats in the upper house.[2] A woman has never held the position of governor of any of Nigeria's 36 states. According to the World Bank data for 2019, men's participation in the workforce in Nigeria was 60.89 percent, and women's participation was 48.52 percent.[3]

The majority ethnic groups in Nigeria - the Hausa-Fulani, Igbo and Yoruba – make up around 60 percent of the country's population.[4] Minority groups face political, economic and cultural marginalization.[5]

The population of persons with disabilities in Nigeria was at 3.3 million - 2.32 percent of the population - at the 2006 Nigerian census.[6] Persons with disabilities face environmental,

[1] World Gender Gap Report: http://www3.weforum.org/docs/WEF_GGGR_202117.pdf
[2] Inter-Parliamentary Union, Women in national parliaments: http://archive.ipu.org/wmn-e/classif.htm
[3] https://data.worldbank.org/indicator/SL.TLF.CACT.FE.ZS?locations=NG
[4] The World Factbook: Explore All Countries – Nigeria: https://www.cia.gov/the-world-factbook/countries/nigeria/
[5] An International Journal of Arts and Humanities. Ethnic Minorities and The Nigerian State. Page 90
[6] Nigeria-Population Census 2006 : http://nigeria.opendataforafrica.org/xspplpb/nigeria-census

institutional, and social challenges,[7] limiting their opportunities to actively participate in society in general, and in the workforce in specific.[8]

Almost half of Nigeria's population is under the age of 15.[9] Older adults (65 years and above) make up 3.1 percent of the total population.[10] Seventy-five percent of children live in poverty,[11] while 40.1 percent of Nigeria's total population lives below the poverty line.[12]

5.1. Energy Sector

As an Economic Community of West African States (ECOWAS) member state, Nigeria has adopted ECOWAS's Policy for Gender Mainstreaming in Energy Access and the country is currently drafting its own energy sector gender mainstreaming plan. Energy has also been identified as a priority sector in Nigeria's National Action Plan on Gender and Climate Change.

5.1.1. Electricity supply

There is a dearth of women employees in public energy sector institutions, electric distribution companies and the off grid/renewable sector.[13] The disparity between women and men is most profound in leadership and decision-making positions. Reasons for the lack of female representation are the lack of women in science, technology, engineering and mathematics (STEM) fields; workforce policies that are not women-friendly; a male bias in hiring and retention processes; and cultural norms that discourage women from working in some technical fields.[14] The renewable energy sector has generally been found to be more accepting of women than the on-grid sector.[15]

5.1.2. Energy demand

Inadequate access to energy disproportionately affects women and girls. Exposure to pollution resulting from petroleum products and biomass – which the majority of Nigerians use for cooking – results in an estimated 600,000 deaths per year of mostly women and children across Africa.[16] Energy access is linked to physical safety and emotional wellbeing. Having electricity means women and girls – who bear the burden of collecting alternative sources of energy – will not have

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[7] Nigerian Country Report on Disability: http://www.disabilityrightsfund.org/wp-content/uploads/Country-Report_Nigeria_2018.pdf

[8] Models of Equal Employment Opportunity: https://doi.org/10.1300/J156v02n03_06

[9] UNICEF, Situation of women and children in Nigeria: https://www.unicef.org/nigeria/situation-women-and-children-nigeria

[10] Tanyi, Perpetua, Pelser, Andre, Mbah, Peter 2018/12/03 Care of the elderly in Nigeria: Implications for policy, VL - 4 10.1080/23311886.2018.1555201 Cogent Social Sciences

[11] UNICEF, Situation of women and children in Nigeria: https://www.unicef.org/nigeria/situation-women-and-children-nigeria

[12] World Bank data: https://data.worldbank.org/indicator/SI.POV.NAHC?locations=NG

[13] Power Africa. Power Africa Gender Analysis. Pages 9-12

[14] Ibid

[15] Ibid. Page 11.

[16] Ngum, Sohna Aminatta Ngum, "Empowering women and girls in the quest for universal energy access for all," AFDB. https://www.afdb.org/en/blogs/investing-in-gender-equality-for-africa%E2%80%99s-transformation/post/empowering-women-and-girls-in-the-quest-for-universal-energy-access-for-all-15625/

to travel long distances to collect firewood, for example.[17] The availability of well-lit public spaces can also help prevent gender-based violence and increase mobility.[18]

Studies show that access to electricity is an important tool in the economic empowerment of women. Women with electricity are more likely to work outside the home, they have greater access to information and their income is higher than those without electricity.[19]

Inadequate electricity supply is implicated in lower educational outcomes for girls and boys; higher incidences of child marriage;[20] poor healthcare;[21] and insufficient physical, psychological, economic and social services for older adults and persons with disabilities.[22] [23] Location plays an important role in access to electricity, as urban areas in Nigeria are better served by on-grid electricity than rural ones.[24]

5.1.3. Energy efficiency

While women play a key role in energy monitoring and management at the household level,[25] and while women and youth can play important roles as energy efficiency advocates and change agents, women - especially those who are illiterate - continue to be marginalized in energy efficiency messaging.[26] Women or men with disabilities (who are deaf or blind for example) will also be marginalized.

5.2. Gender-Responsive Approach to the Implementation of Mitigation Technologies

The aim of implementing gender-responsive technology programming is twofold:

- To prevent existing **gender inequalities** from being exacerbated by climate change and
- To prevent the exacerbation of **climate change impact** due to existing gender inequalities.

Key tools to address gender in climate change mitigation programs are gender analyses to identify gaps; gender-responsive budgets; gender targets and indicators; and sex-and age-disaggregated data.

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[17] Power Africa. Exploring the Relationship Between Energy Access and Gender-Based Violence. https://powerafrica.medium.com/exploring-the-relationship-between-energy-access-and-gender-based-violence-ee8d9e320437

[18] Ibid

[19] Ibid

[20] Ibid

[21] Ibid

[22] Ibid

[23] Tanyi, Perpetua, Pelser, Andre, Mbah, Peter 2018/12/03 Care of the elderly in Nigeria: Implications for policy, VL - 4 10.1080/23311886.2018.1555201 Cogent Social Sciences

[24] Made for Minds. Living in the Dark in Rural Nigeria. https://www.dw.com/en/living-in-the-dark-in-rural-nigeria/a-46755603

[25] World Bank Group. Gender Equality and Energy. Page 8

[26] Power Africa. Power Africa Gender Analysis. Pages 9-12

When women and men, regardless of age, disability status, ethnicity, or geographical location, participate in decision-making and have equal access to assets, resources, knowledge, and skills they jointly assist in building the resilience of communities.

6. Assessment of technologies in the Energy sector

6.1. Electricity supply

1. Solar PV (cross-cutting)

➢ Introduction

Solar Photovoltaic refers to the technology of using solar cells to convert solar radiation directly into electricity[27]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Solar power generation can greatly contribute to reducing GHG emissions from the existing energy mix.	3
Potential impact on climate change adaptation	Utility-scale Solar PVs are not severely impacted by extreme weather events such as rise in sea level, droughts, or flooding, compared with fossil-fuel based power plants and other renewable energy technologies. In addition, distributed Solar PV application could make the power system more resilient to extreme climate events compared to the conventional centralized systems. It would allow for more spatial diversification of energy supplies, which reduces the vulnerability of the energy supply from a single event or a single critical location, which increases overall energy system resilience.	2
Alignment with climate change policies and priorities	Solar PV has been explicitly identified in the NDC as a key climate change mitigation measure. Specific targets for Solar PV include a 6.5GW capacity for on-grid electricity, and 13GW off-grid RE (i.e., mini-grids, solar home systems and streetlights, and self-generation) which are more likely to be achieved through Solar PV.	3
Consideration of co-	*Environmental*	3

[27] CTCN, "Solar PV" Available at: Solar PV | Climate Technology Centre & Network

benefits (environmental, social, and economic)	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation. *Social* The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty. *Economic* Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Solar power technologies are overall around the stage of "early adoption", where the technologies are commercially available and becoming widely implemented, according to IEA (2020)[28]. In fact, both utility- and small-scale solar power systems have been widely installed and operated across the globe. Furthermore, lifecycle cost of solar power generation has been decreasing rapidly, which is now more or less cost competitive against that of thermal power generation.	3
Readiness of Nigeria for the technology	Although Solar PV application in Nigeria is very low, especially for utility-scale, Nigeria has identified solar technologies as the most promising among renewable energy sources. Nigeria's annual solar radiation ranges between 12.6 to 25.2 MJ/m^2/day, with an average sunshine of 6.5 hours per day. The available solar energy is about 27 times the country's total fossil fuel resources and over 115,000 times the electrical power generated.[29]	2

2. Concentrated Solar Power (Solar Thermal)

➢ Introduction

CSP systems generate electricity by concentrating solar energy using mirrors or lenses into a receiver. Electricity is generated when the concentrated energy from the sun heat fluid to superheated steam which is used to turn turbines to generate electricity.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring

[28] IEA (2020) "ETP Clean Energy Technology Guide"
[29] Federal Republic of Nigeria (2020) "Third National Communication of the Federal Republic of Nigeria under the United Nations Framework Convention on Climate Change"

Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Solar power generation can greatly contribute to reducing GHG emissions from the existing energy mix.	3
Potential impact on climate change adaptation	CSP could make the power system more resilient to extreme climate events compared with conventional power systems, although not as resilient compared with Solar PV applications.	1
Alignment with climate change policies and priorities	Solar thermal technology was not specifically identified as a mitigation measure in the NDC. However, the TNC includes CSP as one of the low carbon development options. Similarly, CSP is identified as part of solar technologies considered in the NREEEP.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, potentially reducing poverty.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	CSP technology is at the stage of "early adoption" according to IEA (2020)[30]. In fact, CSP had a total installed capacity of over 6.5 GW globally in 2019[31].	3
Readiness of Nigeria for the technology	Studies have been conducted on the potential of solar technologies in Nigeria, including CSP indicating promising potential for grid-connected electricity. However, this has not yet been implemented in the country.	0

3. Run-of-river Hydropower

[30] IEA (2020) "ETP Clean Energy Technology Guide"

[31] Reve "Concentrated solar power had a global total installed capacity of 6,451 MW in 2019" Available at https://www.evwind.es/2020/02/02/concentrated-solar-power-had-a-global-total-installed-capacity-of-6451-mw-in-2019/73360

➢ Introduction

Run-of-river hydropower is a generation technology utilizing river flow and micro turbine generators to produce electricity.[32]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Hydropower generation can greatly contribute to reducing GHG emissions from the existing energy mix or use of diesel gensets.	3
Potential impact on climate change adaptation	Small-scale hydropower generation could make the power system more resilient to extreme climate events compared with conventional power systems, although hydropower in general tend to be more affected to the effects of climate change.	1
Alignment with climate change policies and priorities	Run-of-river hydropower technology was not specifically identified as a mitigation measure in the NDC. However, the TNC includes small-scale hydropower as one of the low carbon development options. The NREEEP priority include fully harnessing hydropower potential and extending electricity to rural and remote areas.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, potentially reducing poverty and increasing industrial activity.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Hydroelectric power is the most mature, reliable,	3

[32] CTCN, "Run of river hydropower" Available at: [Run of river hydropower | Climate Technology Centre & Network]()

	and cost-effective renewable power generation technology presently commercially viable on a large scale, producing around 16% of the world's electricity and over 80% of the world's renewable electricity.[33]	
Readiness of Nigeria for the technology	Hydropower is the main renewable energy source for Nigeria currently, with over 2,110MW in capacity installed as of 2019. Nigeria has also developed several small-scale hydropower plants.	3

4. Wind Power

➢ Introduction

Wind power is a renewable energy power generation technology using wind turbines.[34] This considers both on-shore and off-shore wind generation.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Wind power generation can greatly contribute to reducing GHG emissions from the existing energy mix.	3
Potential impact on climate change adaptation	Wind power could make the power system more resilient to impacts of climate change through the increase of generation capacity from renewable energy source. However, it is more vulnerable to extreme weather events compared with other RE technologies.	1
Alignment with climate change policies and priorities	Wind power has been explicitly identified in the NDC as a key climate change mitigation measure. Specific targets for Wind include a 3.2GW capacity for on-grid electricity., and 5.3GW off-grid RE target for mini-grids, which could be achieved through Wind.	3
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	

[33] Guyana Energy Agency "Hydro" Available at https://gea.gov.gy/hydro/
[34] CTCN, "On-shore wind" Available at: On-shore wind | Climate Technology Centre & Network)

	The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Wind power technologies are overall around the stage of "early adoption", where the technologies are commercially available and becoming widely implemented, according to IEA (2020)[35]. In fact, both off-shore and on-shore wind power farms have been constructed and operated across the globe. Furthermore, lifecycle cost of wind power generation has been decreasing.	3
Readiness of Nigeria for the technology	Wind power is an untapped renewable energy source in Nigeria. There are no grid-connected commercial wind power plants but an ongoing installation of a 20MW plant as per the TNC.	1

5. Geothermal Energy (cross-cutting)

➢ Introduction

Geothermal energy is the use of thermal energy that is generated and stored in the Earth.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Power generation from geothermal sources can greatly contribute to reducing GHG emissions from the existing energy mix.	3
Potential impact on climate change adaptation	Geothermal energy could make the power system more resilient to extreme climate events. In addition, geothermal technology is not severely impacted by extreme weather events such as rise in sea level, droughts, or flooding, compared with fossil-fuel based power plants and other renewable energy	2

[35] IEA (2020) "ETP Clean Energy Technology Guide"

	technologies.	
Alignment with climate change policies and priorities	Geothermal is not included in Nigeria's climate change priorities, nor in its renewable energy development plans. Although, the NREEEP acknowledges the country's potential for geothermal and encourages further development on research and data gathering to be utilized when competitive.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Geothermal technologies for direct uses (e.g., district heating, geothermal heat pumps, greenhouses, and for other applications) and for electricity generation from hydrothermal reservoirs with naturally high permeability are mature and have been widely used.[36]	3
Readiness of Nigeria for the technology	Geothermal energy is not implemented in Nigeria.	0

6. Waste-to-energy (biomass power generation)

➢ Introduction

Waste-to-energy technologies refer to the combustion of solid waste as an alternative source to produce heat or electricity.[37] In the context of electricity supply, this includes the use of agricultural biomass waste or municipal solid waste as fuel for the generation of electricity.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$	3

[36] IRENA "Geothermal energy" Available at https://www.irena.org/geothermal
[37] CTCN, "Energy supply from waster" Available at: Energy supply from waste | Climate Technology Centre & Network

mitigation/greenhouse gas emissions reduction	in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. Power generation from renewable biomass sources can greatly contribute to reducing GHG emissions from the existing energy mix.	
Potential impact on climate change adaptation	Biomass energy could make the power system more resilient to extreme climate events, especially for decentralized (off-grid/mini-grid) applications wherein the area affected by power outage is limited.	1
Alignment with climate change policies and priorities	Efficient utilization of biomass is part of the climate priorities of Nigeria. However, this focuses on its efficient use rather than as fuel for power generation. The NREEEP identifies strategies to promote biomass power generation in the country.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	A shift toward renewable energy improves environmental quality by reducing air pollution emitted from conventional electricity generation. In addition, utilization of biomass, especially solid waste, avoids improper disposal that pollutes the environment.	
	Social	
	The expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Biomass power generation technologies are generally mature and considered to be competitive wherever low-cost agricultural or forestry waste is available. Additionally, new technologies that show significant potential of further cost reductions are emerging. Yet, technologies to make pollutant emissions reduced to acceptable levels are required in the case of using municipal solid waste, which could result in higher total costs.[38]	3

[38] IRENA "Bioenergy for Power" Available at https://www.irena.org/costs/Power-Generation-Costs/Bioenergy-for-Power

Readiness of Nigeria for the technology	Nigeria has abundant biomass resources in the form of wood waste, agricultural residues, and municipal solid waste. However, biomass power generation has not been implemented yet in the country.	0

7. Co-generation

➢ Introduction

Co-generation refers to the production of heat and electricity from the same primary fuel.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants, mainly from gas-fired plants. Co-generation systems typically achieve overall efficiency of 60 to 80 percent to produce electricity and thermal energy by recovering the wasted heat.[39] Moreover, producing electricity onsite also avoids transmission and distribution losses and thereby contributes to saving energy.	2
Potential impact on climate change adaptation	If installed onsite, co-generation systems could provide electricity to houses/buildings even during a power outage. Therefore, it has the potential to enhance climate resilience of power systems.	1
Alignment with climate change policies and priorities	Nigeria includes in its NDC target, 100% of diesel and single cycle steam turbines replaced with combined cycle.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Efficient electricity generation improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	No significant co-benefits in terms of employment or poverty reduction.	
	Economic	
	Increased efficiency in energy generation ensures economic growth and development.	
Technological constraints	Co-generation is a mature technology and has been widely used.	3

[39] US EPA "CHP Benefits" Available at https://www.epa.gov/chp/chp-benefits

Readiness of Nigeria for the technology	Nigeria has several utility-scale combined cycle power plants of around 3,000MW installed capacity in total.	2

8. Hydrogen Thermal Power Generation

➢ Introduction

Hydrogen can be used as fuel in gas in turbines, which can reduce carbon emissions compared to traditional thermal power generation using fossil fuels.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Emissions from the energy sector comprise 60% of total emissions in Nigeria, amounting to 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions. Nigeria's energy mix is dominated by fossil-fuel fired thermal power plants. According to the paper by Mitsubishi Heavy Industries, a fuel mix of 30 percent hydrogen can reduce GHG emissions by approximately 10 per cent compared to natural gas burning thermal power generation.[40]	3
Potential impact on climate change adaptation	Hydrogen power could make the power system more resilient to impacts of climate change through the increase of generation capacity.	1
Alignment with climate change policies and priorities	Hydrogen thermal power generation is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	The use of hydrogen for electricity generation improves environmental quality by reducing air pollution.	
	Social	
	The expansion of low-carbon industries contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty.	
	Economic	
	Increased generation capacity from low-carbon technologies ensures economic growth and	

[40] MHI (2018) "Research and Development on Gas Turbine Capable of Hydrogen Co-firing"

	development toward low-carbon economy.	
Technological constraints	Technologies for using hydrogen-mixed fuel in thermal power generation is still under development, and there is limited number of use cases around the globe. There is no commercialized case of a complete hydrogen-fired gas turbine.	1
Readiness of Nigeria for the technology	Hydrogen technologies have not been implemented yet in Nigeria.	0

9. Carbon Capture and Storage

➢ Introduction

Carbon Capture and Storage (CCS) is the process of capturing CO_2 from emission sources such as power plants, transporting, and storing it in underground geological formations.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	CCS prevents CO_2 release into the atmosphere. It contributes to GHG emission reduction even in hard-to-abate sectors such as cement industry.	3
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	CCS is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	1
	CCS contributes to improving environmental quality by reducing air pollution from the treatment process.	
	Social	
	No significant social co-benefit	
	Economic	
	No significant economic co-benefit	
Technological constraints	There are 26 large-scale CCS facilities are operating commercially in the world.[41] Yet, it is hard to say that CCS technologies are mature and widely deployed. Several applications of CCS, including chemical absorption of CO_2 from ammonia production and natural gas processing, are already	1

[41] Statista "Number of large-scale carbon capture and storage (CCS) facilities worldwide as of 2020, by status" Available at https://www.statista.com/statistics/726624/large-scale-carbon-capture-and-storage-projects-worldwide-by-status/

	widely deployed today. Many of other applications are still at the early adoption stage, such as chemical absorption from coal-fired power generation and hydrogen production from natural gas, compression of CO_2 from bioethanol production and coal-to-chemicals plants, and CO_2 storage in saline aquifers. Several other applications, including DAC (direct air capture) and CO_2 capture from cement and iron and steel making, are still at the pilot stage.[42]	
Readiness of Nigeria for the technology	CCS have not been implemented yet in Nigeria.	0

10. Energy Storage System (cross-cutting)

- Introduction

Energy storage systems refer to technologies converting electrical energy from power systems into a form that can be stored and converting back to electrical energy when needed. Many storage technologies have been considered for utility-scale use such as pumped hydro, batteries (including conventional and advanced technologies), superconducting magnetic energy storage, flywheels and supercapacitors/ultracapacitors.[43]

- Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Energy storage system allows efficient use of surplus renewable electricity. It plays an important role in integrating large volumes of variable renewable energy sources into the grid system without impacting system stability.	2
Potential impact on climate change adaptation	Energy storage system could make the power system more resilient to extreme climate events as it stores electricity hours or days and provides electricity in the case of a power outage. Furthermore, being installed at the household or community level, it could be an alternative power source for the house or area even when the transmission line is damaged due to, for example, extreme whether events.	2

[42] IEA "CCUS technology innovation" Available at https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-technology-innovation
[43] CTCN, "Batteries", Available at https://www.ctc-n.org/technology-library/energy-storage/batteries

Alignment with climate change policies and priorities	Energy storage is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	Energy storage supports the roll out of renewable energy, consequently supporting environmental protection.	
	Social	
	Energy storage supports the roll out of renewable energy, consequently supporting the expansion of RE industry leading to generation of employment and livelihood.	
	Economic	
	Increased generation capacity from renewable energy ensures economic growth and development toward low-carbon economy.	
Technological constraints	Out of the battery technology systems, only the lead acid battery system has reached full commercial maturity and cost certainty. Other technologies are still under development.	1
Readiness of Nigeria for the technology	Energy storage have not been implemented yet in Nigeria.	0

11. Micro-grid (cross-cutting)

- Introduction

Micro-grid systems are local energy grid with control capacity and is disconnected from the larger, main grid.

- Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Micro-grid systems do not result in GHG emission reductions. But in the context of Nigeria wherein priorities include off-grid and mini-grid application of renewable energy technologies, this can contribute to meeting the country's mitigation targets.	2
Potential impact on climate change adaptation	Mini-grids increase resilience of power systems to extreme climate events due to its decentralized nature, and will not be affected by power outages from the main grid.	3
Alignment with climate change policies and priorities	Nigeria have specific targets of increasing off-grid renewable energy capacity to 13GW, which include a target of 5.3GW for mini-grids.	3
Consideration of co-	*Environmental*	3

benefits (environmental, social, and economic)	For a renewable energy based mini-grid, it will improves environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	For a renewable energy based mini-grid, the expansion of the renewable energy industry contributes to generating more sustainable employment and livelihood. It also increases access to electricity, especially for off-grid applications, potentially reducing poverty and increasing commercial activities.	
	Economic	
	For a renewable energy based mini-grid, it Increases generation capacity from RE ensuring economic growth and development toward low-carbon economy.	
Technological constraints	Large variety of technologies are now available for renewable energy based mini- and micro-grids, including small hydro, biomass-to-power, mini-wind, PVs, hybrids, with or without storage.[44]	3
Readiness of Nigeria for the technology	Mini-grid systems have been deployed in Nigeria. In addition, the Rural Electrification Agency (REA) supports the development of private sector mini grids in unserved areas through its Nigeria Electrification Project – Solar Hybrid Mini Grids Component.[45]	3

12. Power to Hydrogen (cross-cutting)

- Introduction

Electricity produced from renewable energy can be used to produce hydrogen. An electrolyser splits water into hydrogen and oxygen using electricity. In this way, hydrogen becomes a carrier of renewable energy. Producing hydrogen from renewable power can help avoid curtailment, which occurs when there is excess renewable electricity generation in the power system, and thereby contributes to promoting renewable electricity generation.[46]

- Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring

[44] CTCN, "Green Mini-Grids: Towards financially viable business models", Available at https://www.ctc-n.org/sites/www.ctc-n.org/files/ctcn_cpcs_webinar_towards_financially_viable_business_models.pdf
[45] Rural Electrification Agency, "Solar Hybrid Mini Grids", Available at https://rea.gov.ng/minigrids/
[46] IRENA (2019) "Innovation landscape brief: Renewable Power-to-Hydrogen"

Potential impact on climate change mitigation/greenhouse gas emissions reduction	Like energy storage system, power to hydrogen allows efficient use of surplus renewable electricity by converting power into hydrogen during low energy demand periods and converting back to power. It plays an important role in integrating large volumes of variable renewable energy sources into the grid system without impacting system stability.	2
Potential impact on climate change adaptation	Power to hydrogen could make the power system more resilient to extreme climate events as it stores electricity and provides electricity in the case of a power outage. Furthermore, compared to battery storage, power to hydrogen is more suitable for storing large amount of electricity, which in turn enables providing electricity for a longer period during the outage.	2
Alignment with climate change policies and priorities	The technology is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	Depending on the sector in which the technology is used, the potential to improve air quality.	
	Social	
	The expansion of low-carbon industries contributes to generating more sustainable employment and livelihood	
	Economic	
	Depending on the sector, it can improve production as well as the economy	
Technological constraints	Even though there are commercial developments in several counties, the technology overall is still at the R&D or pilot stage.	1
Readiness of Nigeria for the technology	Hydrogen technologies have not been implemented yet in Nigeria	0

13. Tidal Stream Generator

➢ Introduction

Tidal stream generator is a technology that extract the kinetic energy of moving water to move the turbines, similar to the way wind turbine does from wind streams[47].

[47] UNEP-DTU Partnership "Technology Fact Sheet: Tidal Stream Generator"

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Tidal stream turbines have the potential to reduce emissions by 434 to 975 gCO2 per kWh of electricity produced from natural gas and coal-fired turbines respectively[48]. This technology, therefore, can address emissions from the energy sector, which comprises 60% of total emissions in Nigeria	3
Potential impact on climate change adaptation	Tidal stream generators could make the power system more resilient to impacts of climate change through the increase of generation capacity.	1
Alignment with climate change policies and priorities	The technology is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	It can improve environmental quality by reducing air pollution emitted from conventional electricity generation.	
	Social	
	It can generate new job opportunities as the renewable energy market expands.	
	Economic	
	Increasing generation capacity ensures economic growth and development toward low-carbon economy.	
Technological constraints	Tidal stream generators are still considered as an emerging technology that is still at the pilot stage.	1
Readiness of Nigeria for the technology	There is no known application of this technology in Nigeria.	0

14. Ocean Thermal Energy Conversion (OTEC)

➢ Introduction

Ocean Thermal Energy Conversion (OTEC) technologies produce energy by harnessing the temperature differences (thermal gradients) between ocean surface waters and deep ocean waters.[49] The temperature difference is used to power a turbine, which is then can be used for supplying electricity.

➢ Evaluation of the technologies against criteria

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[48] Ibid.
[49] Energy Information Administration "Hydropower explained: Ocean thermal energy conversion"

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	OTEC technologies can contribute to reducing GHG emissions by diversifying Nigeria's energy mix, which is dominated by fossil-fuel fired thermal power plants. Nigeria's energy sector is responsible for 60% of total emissions in Nigeria with 209 $MtCO_2e$ in 2018. Of which, electricity generation (on-grid and off-grid) contributes 24% of the sector's GHG emissions.	3
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	The technology is not mentioned in any of key policies or priorities in Nigeria. However, it could contribute to overall goal for CO_2 emission reduction.	1
Consideration of co-benefits (environmental, social, and economic)	*Environmental* OTEC systems can produce desalinated water which can address water scarcity. *Social* It can generate new job opportunities as the renewable energy market expands. *Economic* Increasing generation capacity ensures economic growth and development toward low-carbon economy.	3
Technological constraints	Even though there are commercial developments and demonstrations in several counties, the technology overall is still at the R&D or pilot stage.	1
Readiness of Nigeria for the technology	OTEC technologies have not been implemented yet in Nigeria. Significant amount of initial investments will be required to implement the technology.	0

6.2. Energy demand

1. Improved Cook Stoves (cross-cutting)

➢ Introduction

Improved cook stove technologies pertain to cooking stoves with improvement in efficiency (available in different forms and sizes).[50]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring

[50] CTCN, "Improved Cook Stoves" Available at: Improved Cook Stoves | Climate Technology Centre & Network

Potential impact on climate change mitigation/greenhouse gas emissions reduction	In Nigeria, about 50% of the population depends on traditional biomass for their energy needs, with only 45% of the population having access to electricity (2016). Since those without electricity use firewood as their primary fuel source, improving the energy efficiency of cook stoves by introducing alternative fuels such as sustainable biomass or liquefied petroleum gas is expected to result in significant emission reduction in rural areas.	3
Potential impact on climate change adaptation	Promoting the use of improved cook stoves leads to less use of firewood. This prevents deforestation, which in turn makes the land resilient against flooding.	2
Alignment with climate change policies and priorities	Efficient and sustainable use of biomass resources is a priority for Nigeria considering that demand for biomass leads to deforestation. The NDC and TNC identifies efficient cookstoves to reduce biomass fuel demand, along with alternative heating sources such as LPG. Specific targets include, 48% of population (26.8 million households) using LPG and 13% (7.3 million) using improved cookstoves by 2030.	3
Consideration of co-benefits (environmental, social, and economic)	*Environmental* Improves environmental quality by reducing air pollution. Contributes to forest conservation. *Social* Improves health, empowers women, and saves lives, especially in rural population. *Economic* Efficient cooking saves time, in turn, leading to more time for other activities contributing to economic growth.	3
Technological constraints	Improved cook stove technologies are mature and widely deployed around the globe, especially in developing countries.	3
Readiness of Nigeria for the technology	Improved cook stoves have been implemented in Nigeria, including those under the clean development mechanism (CDM). In addition, the Federal Government of Nigeria intends to implement a programme to meet the country's clean cooking targets.	3

2. Demand-side Management

➢ Introduction

Demand-side management consist of the planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage.[51] It allows distribution utilities to satisfy power needs of more customers with little to no increase in power supply generation.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	While demand-side management could contribute to GHG emission reduction, its impact could be limited in Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these targets.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	No significant social co-benefits	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	Demand side management technology is mature and has been successfully implemented in developing countries. In particular, and relevant to Nigerian context is Brazil, which has the same generation mix of hydro and thermal power.[52]	3
Readiness of Nigeria for the technology	While information on demand-side management in Nigeria is limited, it is assumed that Nigeria has the potential to implement given the government's strategy to promote energy efficiency.	1

[51] U.S. Energy Information Administration, "Electricity Utility Demand Side Management" Available at: Electric Utility Demand-Side Management (eia.gov)
[52] Ikpe, E. and Torriti, J. (2018) "A means to an industrialisation end? Demand side management in Nigeria"

3. Smart Grid

➢ Introduction

Technology for the electrical system that can sensibly execute the operations to all interconnected elements from generator to consumers.[53]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	While smart grid system could contribute to GHG emission reduction, its impact could be limited in Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NDC also includes improving the electricity grid as one of its key measures. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these energy efficiency targets of Nigeria.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	No significant social co-benefits	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	Although smart grid is a relatively new concept, its deployment is increasingly progressing, with China, India and Brazil leading smart grid development among developing countries.	2
Readiness of Nigeria for the technology	Smart grid technology has not been deployed in Nigeria.	0

6.3. Energy efficiency

[53] CTCN, "Smart grid", Available at: Smart grid | Climate Technology Centre & Network

1. Energy Management Systems

➢ Introduction

This involves the introduction of energy management tools aimed at improving energy use in mining, manufacturing including food and beverage, and chemical industries through introduction of innovative technologies such as high energy efficiency and variable motors, on-site electricity generation, energy system optimization and energy management standards.[54]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	While energy management systems could contribute to GHG emission reduction, its impact could be limited in Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these targets.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	3
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	This technology can create an energy management industry, potentially resulting in job creation.	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	Energy management system is mature technology and widely deployed at factories, buildings, households around the globe.	3
Readiness of Nigeria for the technology	While information on energy management systems in Nigeria is limited, it is assumed that Nigeria has the potential to implement given the government's strategy to promote energy efficiency. In addition,	2

[54] Republic of Zambia, "Technology Needs Assessment: Mitigation"

	there exist energy management companies providing such service in the country.	

2. Energy Efficient Buildings

➢ Introduction

Buildings that incorporate measures to alter energy-consuming behavior and as a result, reduce overall energy consumption.

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Energy efficient buildings could contribute to GHG emission reduction. However, its impact could be limited in Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	Energy efficient building designs incorporate more resilient materials for structure, as well as incorporate the use of on-site electricity generation (i.e., Solar PV). This results in increased climate resilience.	1
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these targets.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	No significant social co-benefits	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	Technologies associated with energy efficient building, including solar power, energy storage system, and energy management system, are mature technology and widely deployed around the globe.	3
Readiness of Nigeria for the technology	While information on energy efficient buildings in Nigeria is limited, it is assumed that Nigeria has the	2

	potential to implement given the government's strategy to promote energy efficiency. In addition, there exist energy management companies providing such service in the country.	

3. Energy Efficiency Standards and Labels

➢ Introduction

Energy efficient standards and labels are sets of procedures and regulations that, respectively, prescribe the minimum energy performance of manufactured products and the informative labels on these indicating products' energy performance.[55]

➢ Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	Energy efficiency standards and labels could contribute to GHG emission reduction. However, its impact could be limited in Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these targets.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	No significant social co-benefits	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	Energy efficiency standards and labelling do not require any sophisticated technologies, while it is required to establish the evaluation and monitoring system, including human and financial resources.	3

[55] Energy Charter Secretariat (2009) "Policies that work: Introducing Energy Efficiency Standards and Labels for Appliances and Equipment"

Readiness of Nigeria for the technology	While information on energy efficiency standards and labelling in Nigeria is limited, it is assumed that Nigeria has the potential to implement given the government's strategy to promote energy efficiency.	2

4. Dynamic line rating

- Introduction

Dynamic line rating (DLR) systems collects real-time weather conditions as well as line environment, which allows transmission system operators to adapt to shifting conditions, improving transmission efficiency and enhance transmission capacity of transmission lines.[56] In general, transmission lines are operated using static line rating which is based on conservative conditions. However, conservative conditions rarely occur, leading to under utilization of transmission assets.

- Evaluation of the technologies against criteria

Criteria	Evaluation	Scoring
Potential impact on climate change mitigation/greenhouse gas emissions reduction	While DLR systems could contribute to GHG emission reduction by promoting an efficient use of electricity, its impact could be limited in the Nigerian context considering the level of electrification in the country, as well as emissions related to household, commercial and institutional use of electricity.	2
Potential impact on climate change adaptation	No significant impact on climate resilience	0
Alignment with climate change policies and priorities	Although the technology is not explicitly identified, the NDC identifies economy-wide energy efficiency as a key mitigation measure, with a target of 2% per year in energy efficiency. The NREEEP encourages energy efficient measures. This technology can contribute to meeting these targets.	2
Consideration of co-benefits (environmental, social, and economic)	*Environmental*	2
	Using electricity efficiently contributes to improving environmental quality by reducing emitted air pollutants from electricity generation.	
	Social	
	No significant social benefits	
	Economic	
	Improvements in energy efficiency have positive macroeconomic impacts, boosting economic activity.	
Technological constraints	DLR system is a relatively mature technology that is commercially available in many countries.	3

[56] IEA "ETP Clean Energy Technology Guide: Dynamic line rating"

Readiness of Nigeria for the technology	DLR technology has not been deployed in Nigeria.	0

7. Summary of list of mitigation technologies

Technology	(a) Potential impact on climate change mitigation/ greenhouse gas emissions reduction	(b) Potential impact on climate change adaptation	(c) Alignment with climate change policies and priorities	(d) Consideration of co-benefits	(e) Technological constraints	(f) Readiness of Nigeria for the technology	Total
Energy: Electricity Supply							
Solar PV	3	2	3	3	3	2	16
Concentrated Solar Power (Solar Thermal)	3	1	2	3	3	0	12
Run-of-river hydropower	3	1	2	3	3	3	15
Wind Power	3	1	3	3	3	1	14
Geothermal energy	3	2	1	3	3	0	12
Waste-to-energy (biomass power generation)	3	1	2	3	3	0	12
Co-generation	2	1	2	2	3	2	12
Hydrogen Thermal Power Generation	3	1	1	3	1	0	9
Carbon Capture and Storage	3	0	1	1	1	0	6
Energy Storage System	2	2	1	3	1	0	9
Micro-grid	2	3	3	3	3	3	17

Power to Hydrogen	2	2	1	3	1	0	9
Tidal stream generator	3	1	1	3	1	0	9
Ocean Thermal Energy Conversion (OTEC)	3	0	1	3	1	0	8
Energy: Energy Demand							
Improved Cook Stoves	3	2	3	3	3	3	17
Demand-side management	2	0	2	2	3	1	10
Smart grid	2	0	2	2	2	0	8
Energy: Energy Efficiency							
Energy management systems	2	0	2	3	3	2	12
Energy efficient buildings	2	1	2	2	3	2	12
Energy efficiency standards and labels	2	0	2	2	3	2	11
Dynamic line rating	2	0	2	2	3	0	9