EGU General Assembly 2024

HS5.2.3 PICO spot A

Innovation in Hydropower Operations and Planning to integrate Renewable Energy Sources and optimizes the Water-Energy Nexus

Assessment of Hydropower Generation and Green Hydrogen Production Potential in Jebba Dam, Nigeria, West Africa

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WASCAL West African Science Service Centre on Climate Change and Adapted Land Use

Federal Ministry of Education and Research

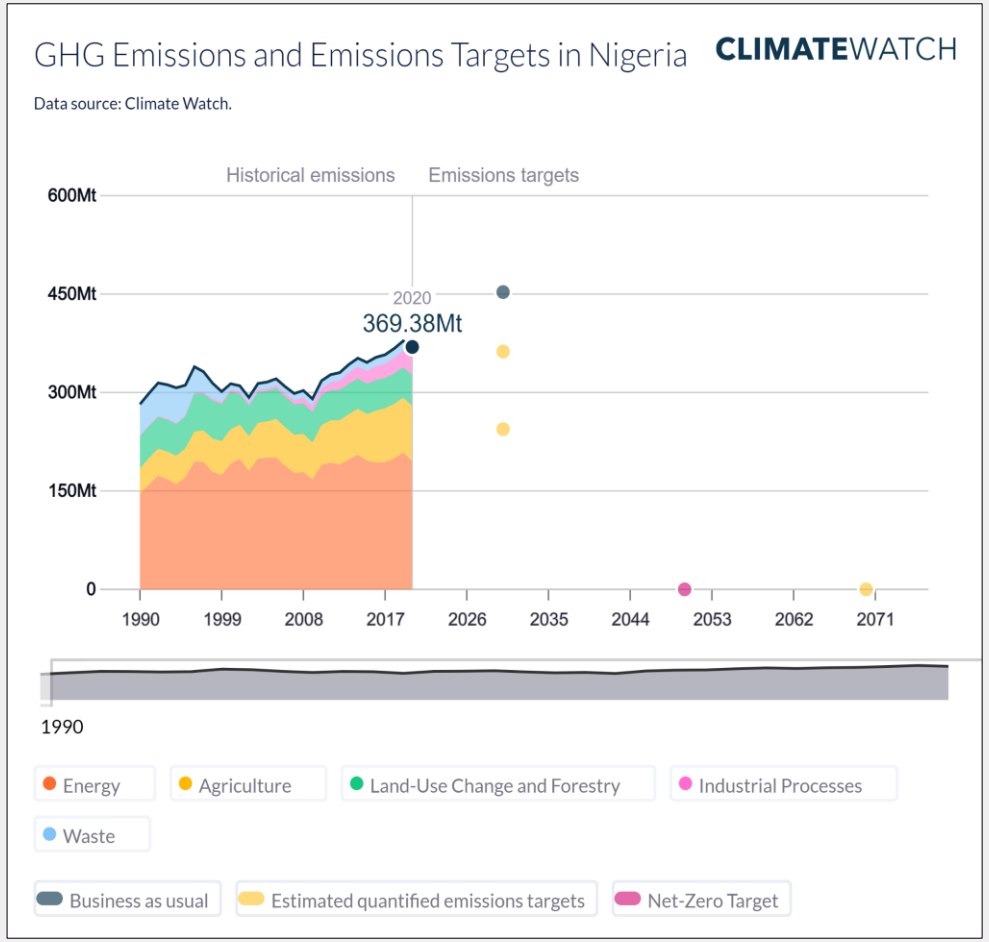
CONTEXT OF STUDY

Two Minutes Madness

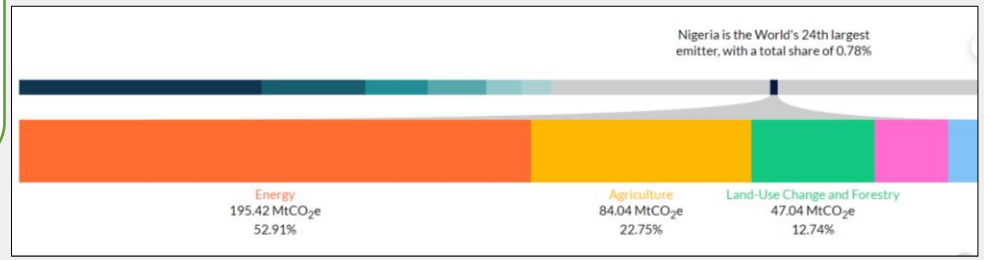
According to Climate Watch (2024), Nigeria was reported to be the world's 24th largest emitter of GHG, with a share of 0.78% in **2020.**

Energy was noted to be the largest emitter of C02 with **195.42 MtCO2e (55.91%)**

Climate Watch (2024)



Source: Adapted from Climatewatchdata.org (2024)

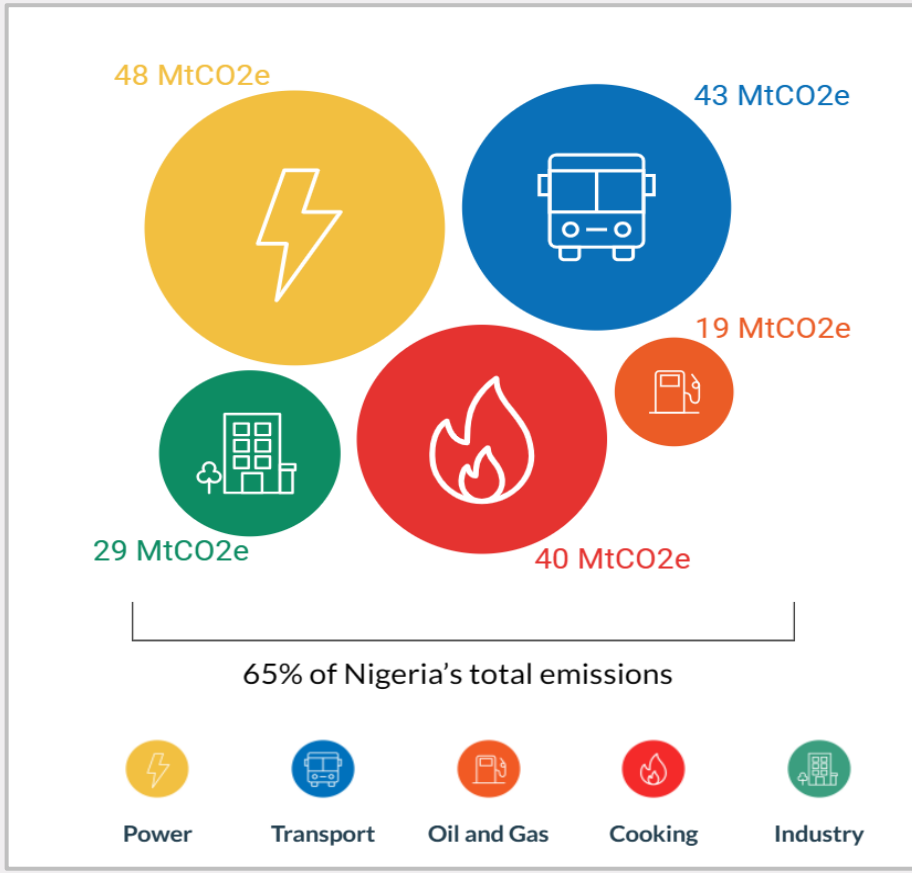


Source: Adapted from Climatewatchdata.org (2024)

Cooking is the third largest emitter.

Transport is the second largest emitter.

Power Generation is reported to be the largest emitter of CO2



Source: Adapted from [2] Nigeria Energy Transition Plan (2022)

PROBLEM AND POSSIBLE SOLUTION

Two Minutes Madness

Image Credit: Punch Newspaper

"Nigeria is the highest user of fossil fuel generators in the world **for power generation**, with about 10 to 14 million generators, **the highest in the world**" – [3] (Vanguard 2021)

As the world races towards a net-zero emission target, Nigeria plans to achieve carbon neutrality by 2060

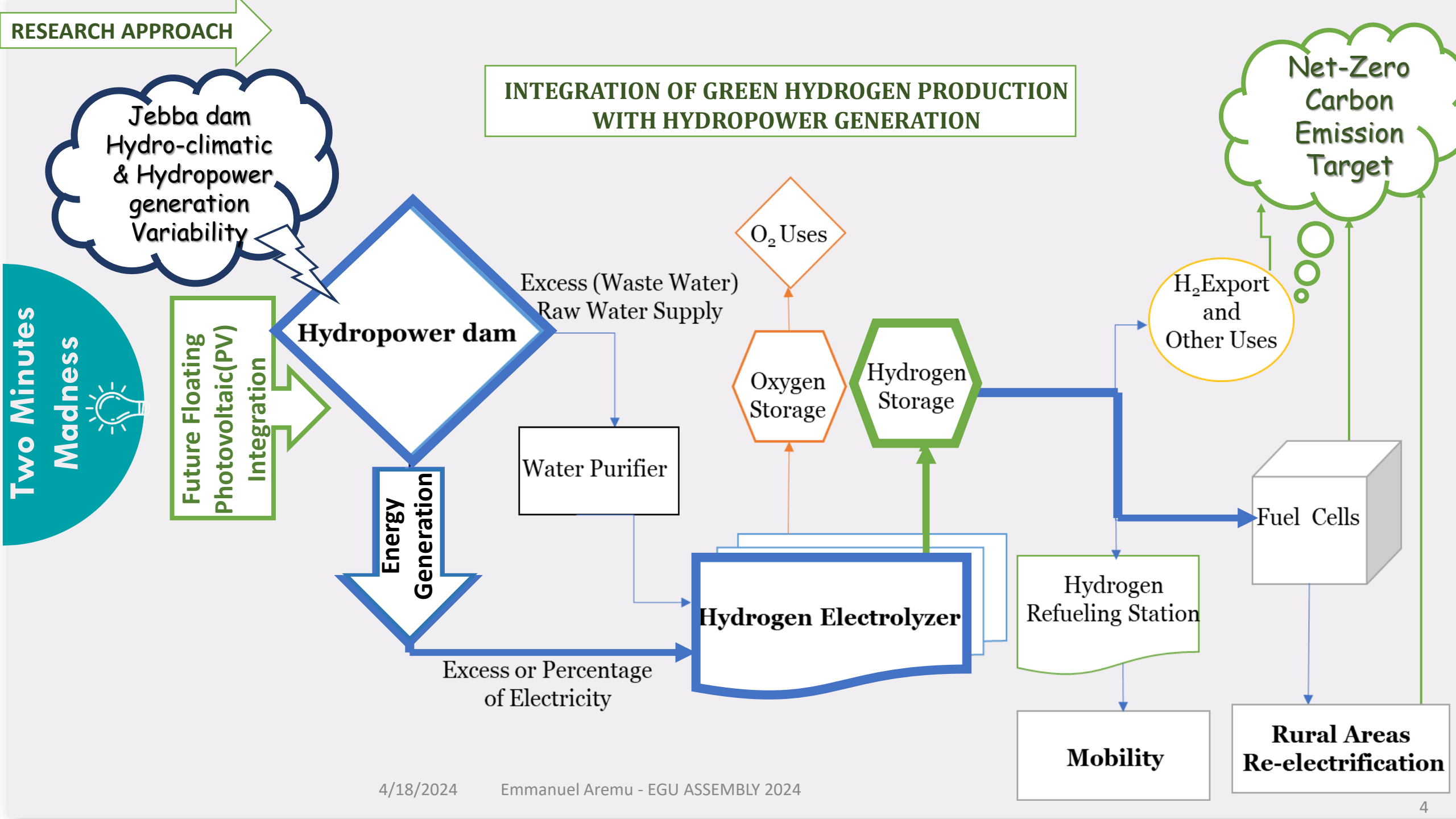
Image Credit: ICCDI AFRICA

The replacement of fossil fuels with clean fuel, e.g., diesel or gasoline generators with fuel cell generators, can accelerate the 2060 Net Zero Goal.

Image Credit: H2X Global

RESEARCH APPROACH

INTEGRATION OF GREEN HYDROGEN PRODUCTION WITH HYDROPOWER GENERATION



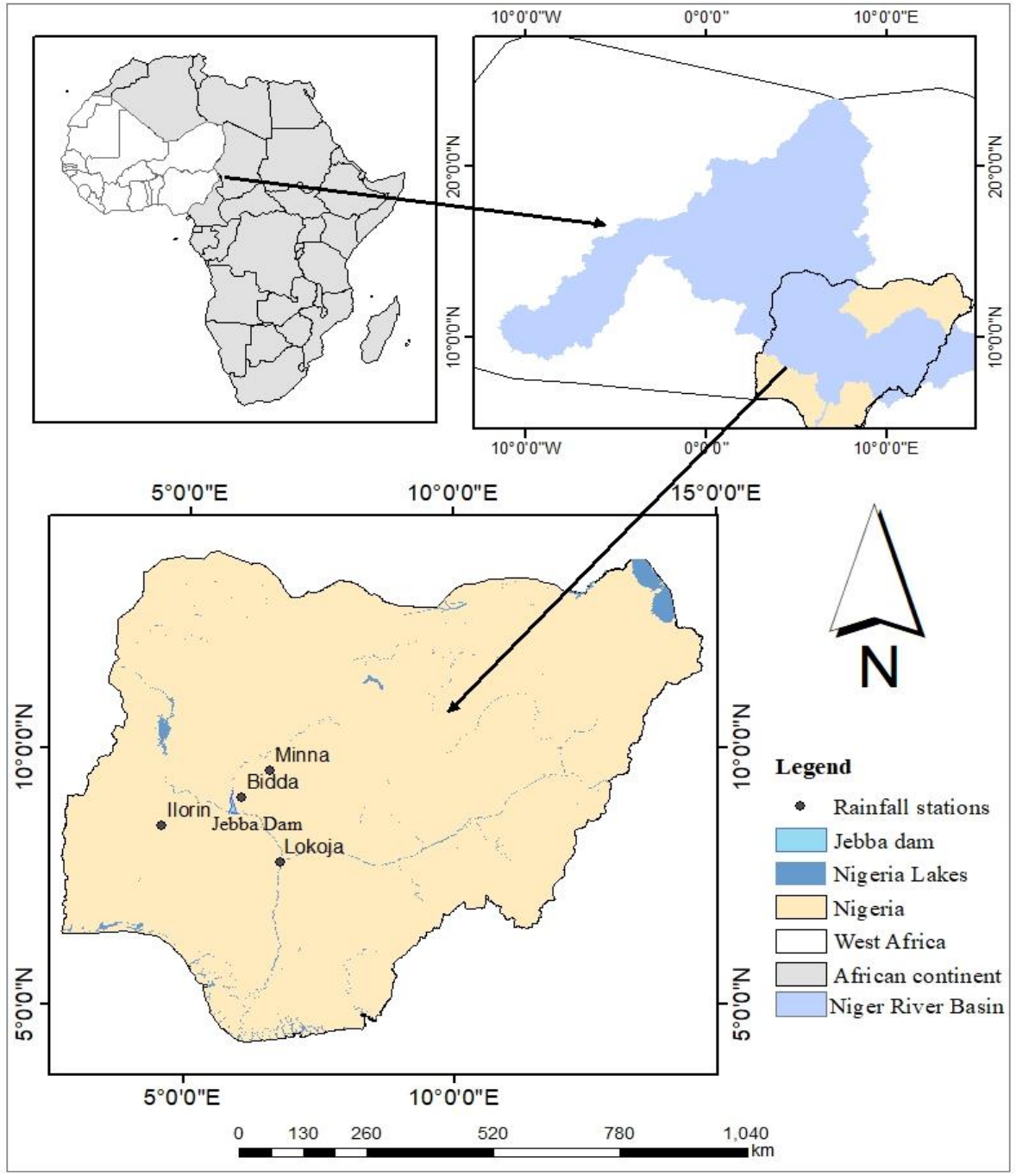
Description of Study Area;
Jebba Hydropower Dam In Niger River Basin

Study Area

- The Niger River Basin (NRB), located in West Africa, is the second largest river in Africa, covering an area of 2.27 million km².

- Jebba Dam is located within the Niger River Basin in Nigeria.

- The dam is an earth dam and Nigeria's third operational hydroelectric power plant, with a capacity of 578.4 MW and six (6) turbines of 96.4 MW each.



Research Questions & Objectives

The following research questions were formulated;

QUESTION 1

Is hydropower from Jebba hydro-station a reliable asset?

QUESTION 2

How much hydrogen can we expect?

QUESTION 3

How much fossil fuel can be displaced and CO_2 emission reduced?

To answer the research questions, the following steps were followed;

Methodology

For **question 1, steps 1-2** were followed.

1. • Trend and seasonality of hydroclimatic variables and hydropower-generation.
2. • Impact of hydro-climatic variables on hydro-energy generation.

For **question 2, step 3** was followed.

3. • Estimation of green hydrogen production potential from available hydropower.
4. • Evaluation of hydrogen re-electrification potential using fuel cells.

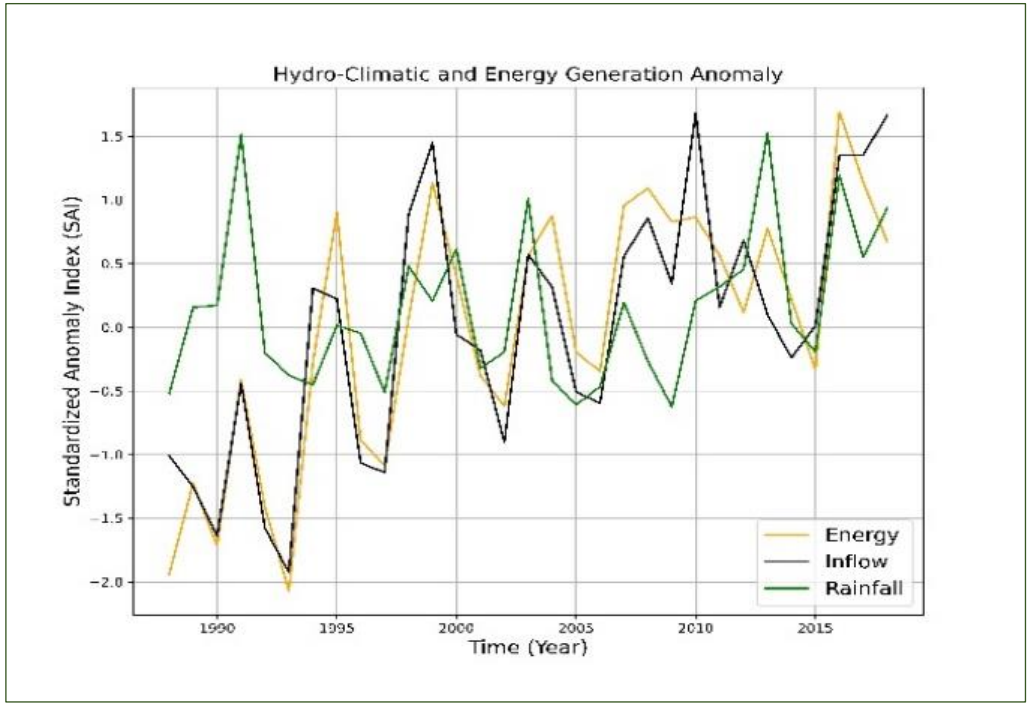
For **question 3, steps 4-5** were followed.

5. • Quantification of fossil fuel replacement and greenhouse gas emissions prevented.

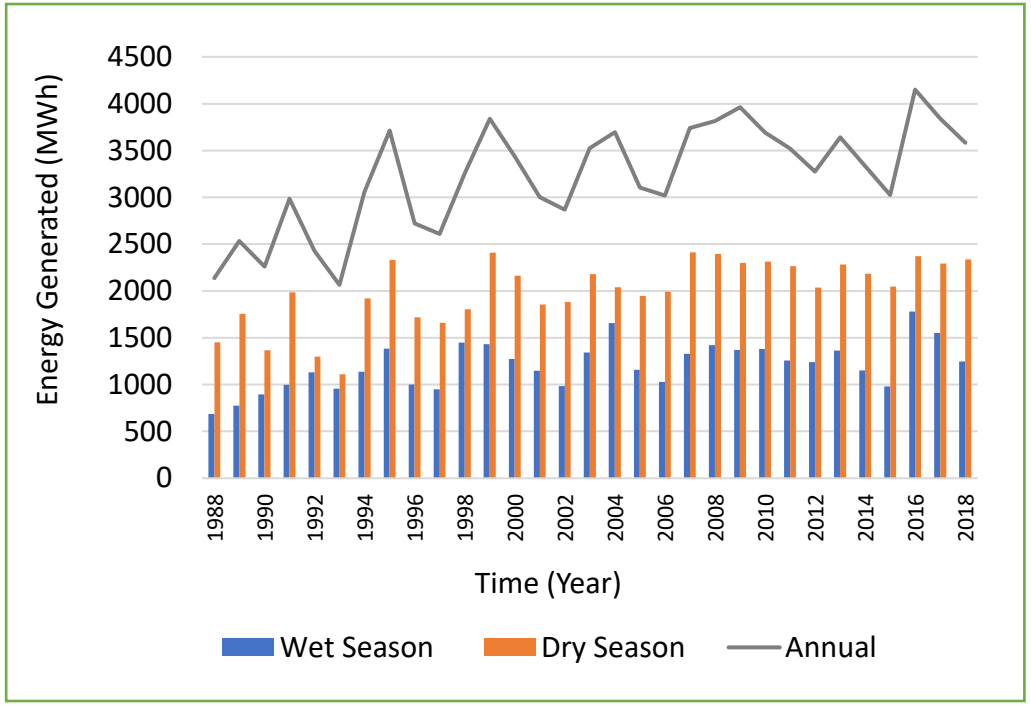
Results

1. An increasing trend in annual flow and generation provides a reliable source of energy to support hydro-to-hydrogen production. However, seasonality might need to be considered in the storage approach.

- The average energy generation's inter-annual variability rose from as low as **2065 MWh in 1993** to as high as **4150 MWh in 2016**, signifying a **50.2%** increase, which was majorly influenced by the **reservoir inflow.**



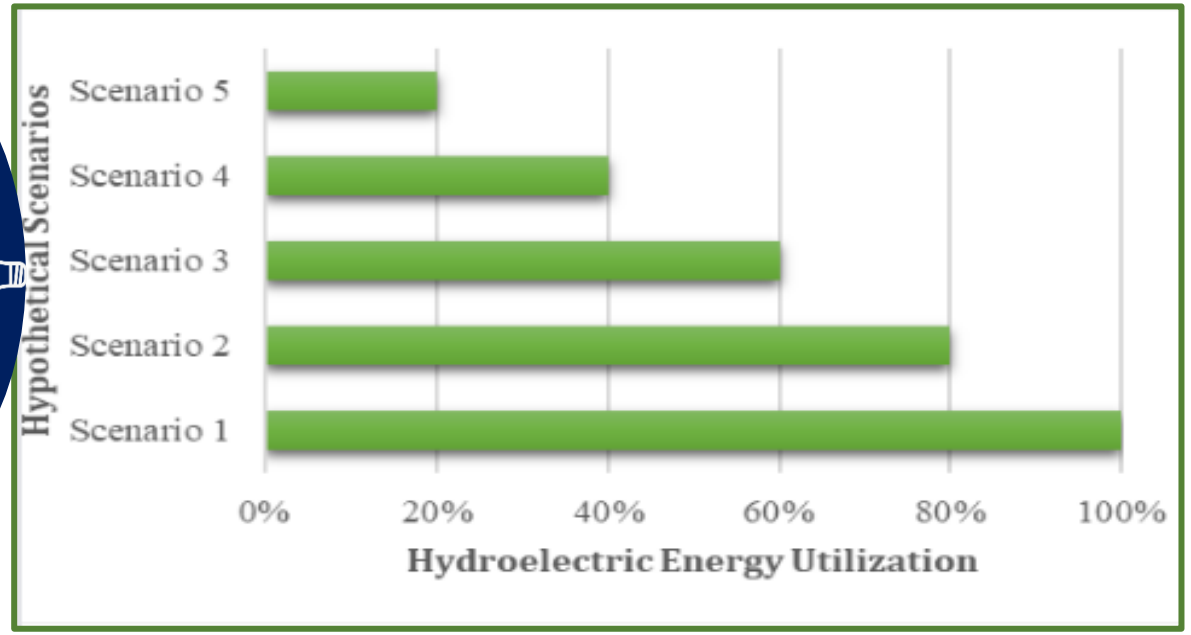
- **The seasonality** shows that there is a higher generation in the **dry season** (periods of little or no rainfall) than in **the wet season** (rainfall periods). This disparity could be traced to the **moderate inflow** in the dry season and the **flooding** that occurs during the wet season.



- **The trend analysis** reveals that the inflow, turbine discharge, and energy generation have increased significantly, which provides a potential reliable source of energy to support **hydro to hydrogen**.

2. How much hydrogen can be expected? 5 scenarios based on how much hydropower is available for hydrogen production

Methodology



- **Scenario 100 (S1)**: **100%** hydroelectricity for GH production.
- **Scenario 80 (S2): 80%** hydroelectricity for GH production.
- **Scenario 60 (S3): 60%** hydroelectricity for GH production.
- **Scenario 40 (S4)**: **40%** hydroelectricity for GH production.
- **Scenario 20 (S5)**: **20%** hydroelectricity d for GH production.

The 20 % hydropower-to-hydrogen scenario is assumed to be more realistic for the station.

The annual & quarterly **hydroelectricity generated** from 2002 to 2022 was translated to **Green hydrogen production.**

The **produced green hydrogen** was assumed to be utilized in **fuel cell generators**, and the **re-electrification potential** was calculated.

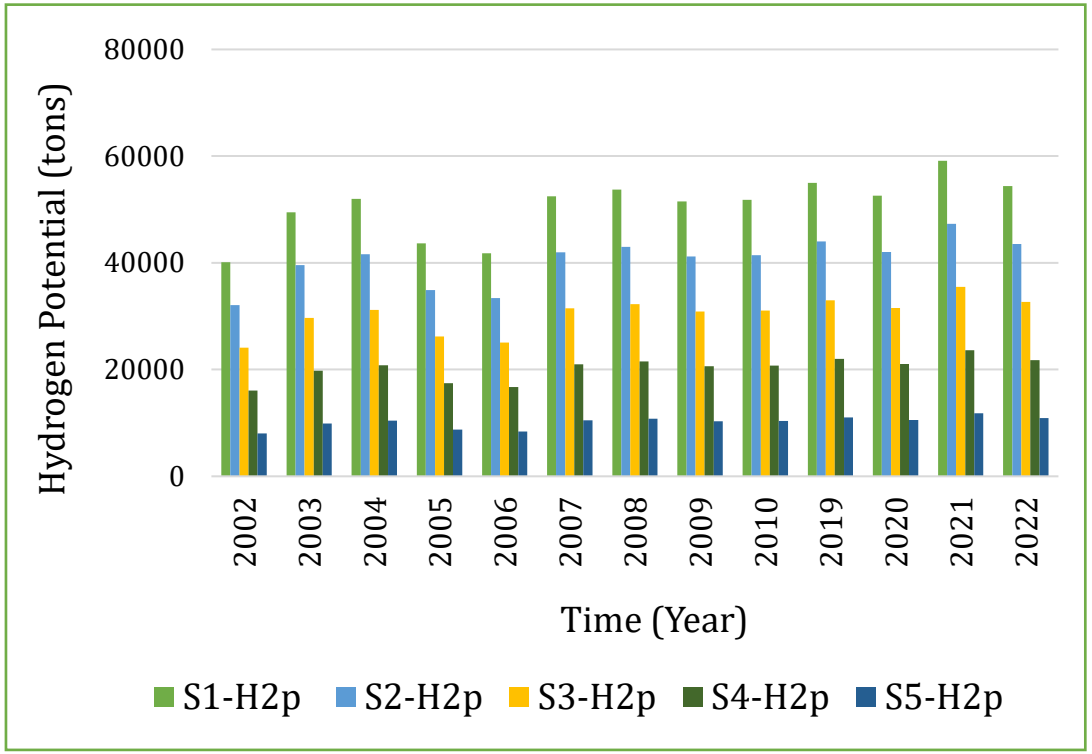
The amount of **fossil fuel (petrol)** that would be replaced using the **fuel cell generators** was estimated.

The **GHG (CO_2 and CO)** emissions that would be prevented using hydrogen fuel cell were quantified.

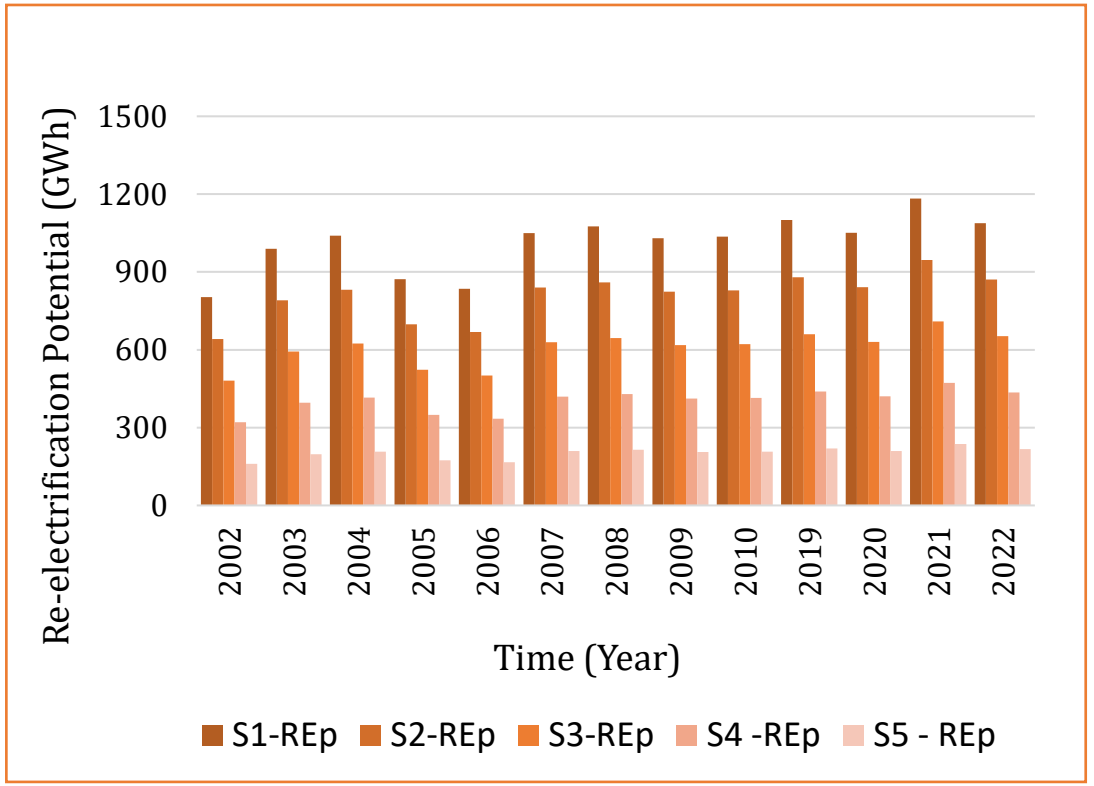
How much hydrogen can be expected per year?

Results

- **Hydropower generation** significantly determines the amount of hydrogen that can be expected per year, with a high of **59,111 tons** in **2021** and a low of **40,125 tons in 2002**, the years with the highest and lowest hydropower generation

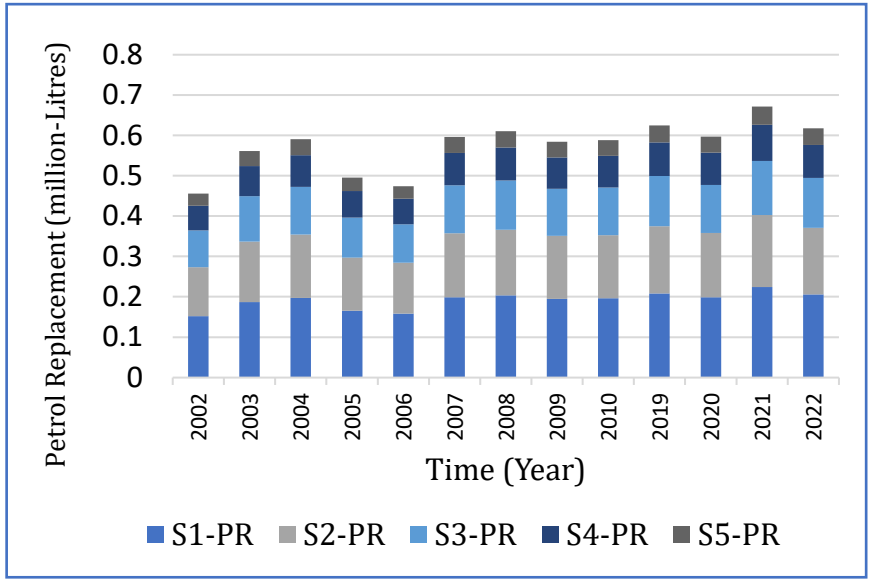


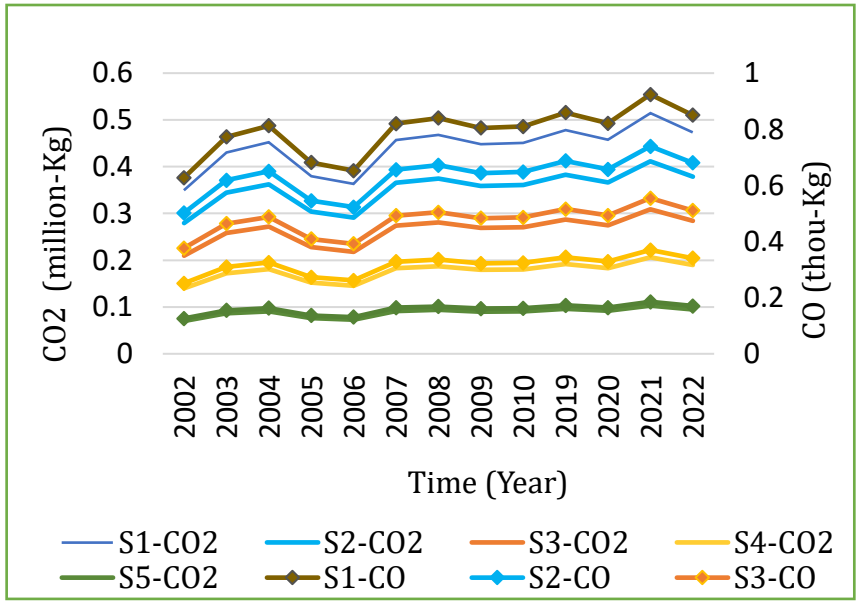
- **Scenario 5 of 2021** (20% of hydropower) has the potential to produce 11,822 tons of hydrogen, which has a re-electrification potential of **236 GWh** if used to power hydrogen fuel cells.



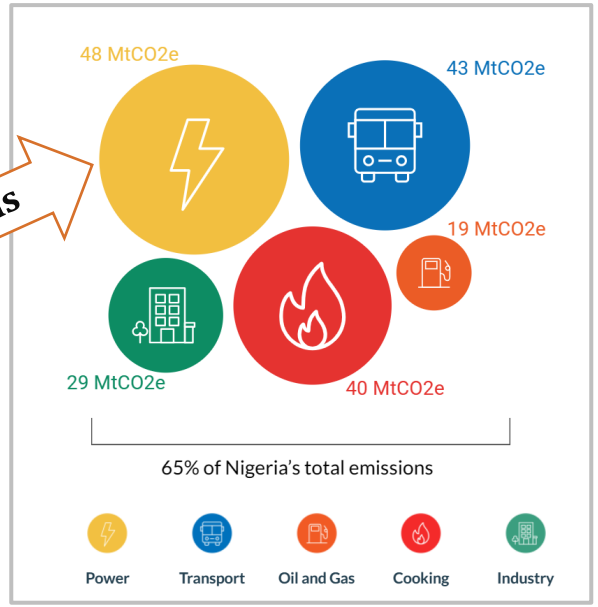
If 20% of hydropower were in excess and available for hydrogen, it could support a gradual decrease in CO2 emissions (as little as 0.00021%) through the replacement of fossil fuel generators.

Results





- In scenario 5 of 2021, using the 11,822 tons of hydrogen produced to power fuel cells could potentially replace **0.2237 million liters** of fossil fuel (petrol), which is **0.57% of the 39.4 million liters** daily consumption rate reported by the Country's Federal Ministry of Petroleum Resources in 2020 (The Guardian 2023).



Source: Adapted from [2] Nigeria Energy Transition Plan (2022)

- If 20% excess hydropower (5th scenario in 2021) were translated to hydrogen production to replace fossil fuel (petrol) generators, it would likely prevent the emission of ≈ **0.0001029MtCO$_2$,** which is **0.00021%** out of the reported emission **of 48MtCO2e** from **power generation in 2020**, thereby contributing to the country's climate change mitigation efforts.

Summary & Conclusion

1.
   - The study concludes that **hydroclimatic variability impacts** the amount of **hydropower generated** from the Jebba hydropower station.
   - The impact of hydro-climatic variability on hydropower generation **will affect the quantity of green hydrogen** that can be expected from the hydropower station.

2.
   - A small percentage **(20% of hydroelectric energy)** could be used for green hydrogen production during excess electricity generation or off-peak hours when electricity demand is much lower on the grid.
   - The **hydrogen could be stored** for use in fuel cells for re-electrification and replacement of fossil fuel generators.

3.
   - Hydrogen production **from excess renewable energy sources (hydropower, solar, wind)** can be a niche opportunity to contribute to the country's energy transition and climate change mitigation efforts.
   - **Future work: Integration of floating photovoltaic(PV) on the hydropower dam**

KEY REFERENCES

[1.] Climate Watch, (2024): https://www.climatewatchdata.org/countries/NGA?end_year=2020&start_year=1990

[2.] Nigeria Energy Transition Plan, (2022): https://energytransition.gov.ng/

[4.] The Guardian (2023): Fuel subsidy and daily consumption rate in Nigeria; https://rb.gy/0x60w9

[3.] Vanguard, (2021): https://www.vanguardngr.com/2021/10/nigeria-fuels-14m-generators-with-16m-annually-adaju/

For further inquiries, collaboration, or partnership, kindly contact

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