SUSTAINABLE CONSTRUCTION PRACTICES: USING GFRC TO REDUCE CO_2 EMISSIONS OF CONCRETE

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INTRODUCTION

BACKGROUND

Portland cement, the main ingredient in most concrete, is a major source of carbon dioxide. Recent estimates say it produces roughly eight percent of the world's yearly emissions (Sahil, 2020). As pressure grows to cut this footprint, engineers have tested new mixes that keep strength while lowering cement content. One option is glass-fiber-reinforced concrete, or GFRC. It combines ordinary cement paste with fine sand, alkali-resistant glass fibers, and small amounts of polymer. The result is a lighter, tougher composite that resists cracking and weather damage more effectively than standard concrete (Harle, 2014).

PROBLEM STATEMENT

Even with these advantages, GFRC is rare on Nigerian job sites. Builders in Abuja still pour conventional concrete for most projects, which drives local carbon output higher than it could be. High initial cost, limited supply, and a shortage of trained installers all discourage the switch. A focused study on GFRC's real-world performance in Abuja is therefore overdue.

RESEARCH AIM AND OBJECTIVES

The study's central aim is to see how far GFRC can cut carbon emissions in Abuja's buildings and what stands in the way of wider use. To reach that aim it will:

1. Locate and document buildings in Abuja that already use GFRC.

2. Compare the carbon footprint of those buildings with similar projects built from ordinary concrete.

3. Identify economic, technical, and logistical obstacles to adopting GFRC across Nigeria.

4. **RESEARCH QUESTIONS**
   - How does the carbon profile of GFRC compare with that of conventional concrete in Abuja projects?
   - What extra costs or supply hurdles come with using GFRC?
   - Which factors most strongly limit GFRC uptake in the Nigerian building sector?

RESEARCH GAP

A lot of global papers discuss GFRC, yet almost none measure its impact inside Abuja's fast-growing construction market. By drawing on local archival records, this study offers the first detailed view of GFRC in that setting.

NEED FOR THE STUDY

Nigeria's cities are expanding at a rapid pace, turning farmland and small towns into new suburbs and business districts. Choosing lower-carbon materials now can lock in long-term environmental benefits. The data gathered here will give architects, engineers, investors, and regulators clear evidence on when and how GFRC makes sense in Abuja and, by extension, in other Nigerian cities.

LITERATURE REVIEW

OVERVIEW OF GFRC

Glass fiber reinforced concrete, or GFRC, is produced by adding alkali-resistant glass fibers to a finely graded cement-sand matrix. The fibers act in tension, raising the composite's ultimate strength, so the mix can achieve its design load with less cement than ordinary concrete (Harle 2014). Because the glass strands replace most of the steel reinforcement, projects that specify GFRC use fewer steel bars and ties. Reducing steel lowers both material cost and the CO_2 released during the manufacture, transportation, and cutting of rebar (Pessimal et al. 2023). Over the past two decades researchers have tested synthetic-fiber cement products—glass, polypropylene, carbon, and others—in wall panels, roof shells, and industrial floors (Chen and Qiao 2011; Enfedaque et al. 2010; Wu 2004). Yet the synthetic fibers themselves carry an environmental burden, and their purchase price can outstrip that of the base cementitious mix (Coutts 2005).

ENVIRONMENTAL BENEFITS OF GFRC

Lower clinker content translates into a smaller embodied carbon footprint than standard concrete. Life-cycle assessments report meaningful savings in greenhouse-gas emissions, while the lighter weight of finished panels can cut fuel use during transport and reduce the dead load that a building's frame must carry (Mehta 2019). Energy demand in service also drops because thinner GFRC skins, paired with insulation, provide good thermal resistance.

ADOPTION OF GFRC IN CONSTRUCTION

Internationally, GFRC is common in façade cladding, architectural ornament, and lightweight roof shells. The United States and China have long employed it on projects where both form freedom and reduced weight are priorities. In Nigeria, however, uptake is still modest. Few practitioners have hands-on experience, and imported fibers, polymers, and molds raise the bid price (Pessimal et al. 2023). Even so, interest is growing. Rapid urban growth in Abuja and Lagos, paired with heightened concern over construction emissions, is pushing designers to investigate greener alternatives (Stafford 2019; Li et al. 2023). Clients also value GFRC's ability to deliver complex shapes, crisp surface finishes, and resistance to corrosion and cracking, qualities documented by ACI Committee 236 (2016) and the International Institute for Fiber Reinforced Concrete (2022). Forthcoming incentives—duty relief on sustainable materials, possible carbon levies, and stricter public-project specifications—could accelerate its spread.

FUTURE PROSPECTS FOR GFRC IN NIGERIA

Local production is the logical next step. Establishing one or two regional plants would shorten lead times, create skilled jobs, and narrow the price gap with conventional concrete. Policy support can help. Tax concessions for green materials, concessional loans for equipment, or mandatory embodied-carbon caps on public buildings would all make GFRC more competitive. Universities and trade bodies could run short courses in mix design and spraying techniques to build a reliable pool of installers and inspectors. Together, these measures would lower both financial and technical barriers, giving architects confidence to specify GFRC on mainstream projects.

CHALLENGES OF GFRC IMPLEMENTATION

High initial cost is the first hurdle. Alkali-resistant glass fibers and specialty polymers cost more per kilogram than aggregate and cement. When these inputs are shipped from overseas suppliers, exchange-rate swings, freight charges, and import duties push prices even higher (ACI Committee 236 2016; IF-FRC 2022).

Availability is the second hurdle. Nigeria lacks large-scale GFRC factories, so contractors wait for imported stock or small-batch local mixes. Delivery delays complicate scheduling and discourage tightly programmed jobs.

Technical knowledge is the third hurdle. Mixing, spraying, and curing GFRC call for procedures quite different from those used for ordinary concrete. Many site crews and consulting engineers have limited exposure to these methods, raising the perceived risk of specifying an unfamiliar material. Expanding training programs, publishing national guidelines, and showcasing demonstration buildings would reduce that risk and help the industry move beyond pilot projects.

METHODOLOGY

RESEARCH APPROACH

This study uses an archival method. It looks at buildings in Abuja, Nigeria that already use Glass Fiber Reinforced Concrete (GFRC). Information will be collected from construction firms, design records, and regulatory websites. No new structures will be built or tested; only past work will be examined.

DATA COLLECTION

Data will be collected in three main ways:

- From Archives: This includes government records, construction reports, and reliable online sources to identify buildings in Abuja where GFRC was used.
- Recorded Interviews: Professionals in the construction sector may be consulted to understand how GFRC was used in these projects.
- Assessment Checklists: A checklist will help in reviewing how GFRC was applied in each building (e.g., as a cladding or structural material).

POPULATION AND SAMPLE SIZE

The study will focus on 4–10 buildings in Abuja known to have used GFRC. These buildings include both commercial and residential types. The selection depends on how much information is available for each one.

DATA ANALYSIS

The data will be mainly qualitative. This includes interview notes, building documents, and analysis of materials. The study will explore the environmental benefits of GFRC, especially in reducing CO_2 emissions, as well as the barriers to its wider adoption.

PARTICIPANTS / SAMPLE

This study does not involve people as direct subjects. It focuses only on existing data from buildings. To qualify for inclusion:

- The building must be in Abuja, Nigeria.
- It must have been built within the last 15 years
- It must have used GFRC in either its structure or outer layer

Buildings will be excluded if:

- GFRC was used only for decoration, not for structure or cladding

RECRUITMENT STRATEGY

Documents and data will be gathered with help from local construction firms, architects, and city records offices. Permission will be requested where needed. If data is already public or no permission is required, it will be used accordingly.

SAMPLE SIZE JUSTIFICATION

Since this is an archival study, the number of samples depends on how many documented buildings with GFRC can be found. However, even 5–10 well-documented buildings are enough to draw useful insights. Additional literature will help fill any gaps.

MATERIALS AND PROCEDURES

For each building, the following information will be collected:

- The amount and type of materials used
- Load-bearing requirements and design structure
- Estimated carbon emissions (based on life cycle tools)
- Cost comparison between GFRC and regular concrete
- Notes on the building process and labor used

Where possible, extra data such as energy use or building performance after completion will also be included. All data will be organized in Microsoft Excel. SPSS and RStudio will be used to run the analysis.

PLANNED ANALYSES

Emission Comparison:

- CO_2 emissions will be calculated and converted to standard units (like CO_2/ton).

- Emissions from GFRC and regular concrete will be compared.

Cost Analysis:

- All cost figures will be converted to U.S. dollars.
- Costs will be compared to see if GFRC is more expensive.
- It is expected that GFRC will cost more overall.

Barrier Analysis:

- Qualitative records (like memos or expert notes) will be reviewed.
- Common challenges in using GFRC will be identified.

Ethics and Data Management

- All project data will be kept anonymous. No names, addresses, or sensitive business information will be shared.

GFRC Building Data Collection Template:

Field	Description / Notes	Data Entry (for each building)
Building Name / ID	A unique label or name for the building	
Location (District/Area)	Where in Abuja the building is located	

Year Completed	Construction completion year
Building Age	Years since completion (e.g., 2025 - Year Completed)
Building Use	Commercial / Residential / Mixed
GFRC Application Type	Structural / Cladding / Both
Estimated GFRC Quantity Used	In m² or tons (based on available data)
Total Floor Area	In m² (for CO_2 per m² analysis)
Estimated CO_2 Emissions (GFRC)	In CO_2eq (e.g., tons or kg/m²)
Estimated CO_2 Emissions (Traditional Alternative)	For comparison purposes
Estimated % Emission Reduction	[(Traditional - GFRC) ÷ Traditional] × 100%

GFRC Material Cost (USD)	Total estimated cost
Cost of Conventional Alternative (USD)	For comparison
Source of Records	E.g., architectural firm, online archive, gov registry
Data Accessibility	Open access / Permission required / Restricted
Challenges in GFRC Use	Material delays, labor issues, regulatory hurdles, etc.
Project Notes / Comments	Any observations, technical peculiarities, etc.
Energy Modeling or Post-Occupancy Data	If available, e.g., cooling efficiency, durability

GFRC Building Data Collection Table

Category	Building 1	Building 2

Building Name	National Stadium Abuja	Nnamdi Azikiwe International Airport
GFRC Use	Cladding (Membrane)	Structural (For runway)
Building Age	23 years (Since 2003)	8 years (Since 2017)
Estimated GFRC Quantity	Approx. 31,000-33,000 m²	Approx.82,300 m² (50 tonnes of the fibre glass grid)
Estimated Emissions Saved	62 t CO_2-eq (1.88 kg CO_2-eq Per-m²)	tons CO_2
Source of Records	Schlaich Bergermann Partner (archives)	Minister of State for Aviation/Julius Berger
Building Use	Government / Stadium	Government/ Airport
Estimated GFRC Cost (USD)	$181,500.00	$139,087.00
Challenges Noted	–	—

Additional Comments	PTFE coated glass fibre membrane	Excellent heat resistance and stability to a melting point of 900 degrees Fahrenheit .

METHODOLOGY (REVISED WITH GFRC DATA)

PILOT DATA AND FEASIBILITY CHECK

A preliminary archival review yielded data for two GFRC-using buildings in Abuja:

Building Name	GFRC Application	Approx. GFRC Area/Tonnage	Estimated Emissions Saved	Source of Records	Estimated GFRC Cost (USD)
National Stadium, Abuja	Cladding (membrane)	Approx. 31,000–33,000 m²	62 t CO_2-eq (≈ 1.88 kg CO_2-eq/m²)	Schlaich Bergermann Partner (archives)	$181,500.00
Nnamdi Azikiwe International Airport	Structural (runway)	Approx. 82,300 m² (50 tonnes fiberglass grid)	Not specified (pilot)	Minister of State for Aviation / Julius Berger	$139,087.00

Additionally, the cladding at the stadium employs a PTFE-coated glass fiber membrane notable for its high melting point (~900°F).

RESEARCH APPROACH

This study employs an archival research methodology to assess the environmental performance and adoption challenges of GFRC in Abuja's construction sector by analyzing existing buildings using documented data sources, as demonstrated in the pilot dataset above.

DATA COLLECTION PROCEDURES AND POPULATION, SAMPLING

As outlined, building inclusion requires documented GFRC use, age (≤15 years), and sufficient environmental and cost data. The initial two buildings—though one exceeds 15 years—serve as feasibility tests; subsequent selection will prioritize more recent structures that meet all criteria.

PLANNED ANALYSES

Emission Analysis

- **Standardization**: CO_2 emissions will be standardized to kg CO_2-eq per m².
- **Piloted Metric**: The stadium data suggests ~1.88 kg CO_2-eq per m² savings.
- **Benchmarking**: Typical embodied carbon for building slabs is 90–150 kg CO_2-eq per m² (including finishes) (istructe.org).
- **Expectation**: GFRC is expected to reduce emissions by ≥30% relative to conventional concrete.

COST ANALYSIS

- **Conversion to USD**: Already present in the table; cross-checked against industry pricing.
- **Benchmarks**:
    - GFRC mix costs range from approximately \$2.50–\$3.75 per ft² (≈ \$27–\$40/m²) depending on thickness and composition (The Concrete

Countertop Institute).

    - Market prices for GFRC panels range widely—from around $17.79 to $279.52 per m² (shkmgrc777.en.made-in-china.com).

- The Abuja stadium panel cost (~$181,500) averages roughly $5.50/m², which is significantly below many quoted international rates—a point to explore further. *Estimates are strictly based on reported cost per square meters (other logistical costs including profits and overheads were not considered.*

BARRIER ANALYSIS

As before, thematic analysis of qualitative inputs will target challenges like procurement, technical expertise, and policy alignment.

RESULTS AND FINDINGS

The results from the pilot archival dataset (two GFRC projects in Abuja) and an estimate of the missing emissions value for Building 2 (Nnamdi Azikiwe International Airport) derived from industry GFRC emission factors. All calculations, assumptions and sources are reported so readers can reproduce or revise them.

PILOT DATASET (SOURCE:DATA TABLE SUPPLIED)

Building Name	GFRC Application	GFRC Qty (as supplied)	Reported Estimated Emissions Saved
National Stadium, Abuja	Cladding (PTFE-coated membrane)	Approx. **31,000–33,000 m²**	**62 t CO_2-eq** (≈ **1.88 kg CO_2-eq/m²** using 33,000 m²) (file).

Nnamdi Azikiwe Intl. Airport	Structural (fiber grid for runway)	**≈82,300 m² area; 50 tonnes** (50,000 kg) of fiberglass grid	**(no emissions reported — estimated below)**.

Notes: the Stadium's reported per-square-metre saving (1.88 kg CO_2-eq/m²) is consistent with the supplied total (62 t) when using the upper bound area (33,000 m²).

EMISSION- FACTOR SOURCES AND ASSUMPTIONS (TRANSPARENT AND REPRODUCIBLE)

1. **GFRC emission intensity (mass-based)** — Climatiq lists a GFRC emission intensity of **0.7239 kg CO_2-eq per kg GFRC** (cradle-to-gate). This is the authoritative factor used to convert the 50 tonnes of fiberglass grid into CO_2e. (Climatiq)

2. **GFRC panel mass / typical thickness** — industry product data and suppliers report typical GFRC panel weights in the **25–30 kg/m²** range for thin façade panels with thicknesses around **12–19 mm** (useful for cladding-type calculations). For density and typical thickness references see industry datasheets and facade suppliers. (curatedfacade.com, formglas.com)

3. **Concrete baseline factors** — published embodied-carbon data for ordinary Portland cement (OPC) concrete vary by mix and source; Climatiq / ICE and Circular Ecology report typical concrete emission factors in the range **~178–253 kg CO_2-eq / m³** depending on mix strength (we use these sources when benchmarking). (Climatiq)

4. **Façade/HPFRC comparative studies** — LCA literature shows that replacing conventional concrete façades with high-performance fibre-reinforced mixes can reduce embodied carbon **per m²** by roughly **~50%** in some façades studies (note: these figures are for façade replacements and should not be applied uncritically to runways). Use as context only. (ResearchGate)

All subsequent numerical estimates use the GFRC mass-based factor (Climatiq) applied to the **50,000 kg** fiberglass grid reported for the airport. I explicitly state other scenario assumptions when used.

CALCULATIONS OF GFRC-RELATED CO_2 FOR BUILDING 2 (AIRPORT)

Raw data (from the table): fiberglass grid = **50 tonnes = 50,000 kg**; airport covered area = **82,300 m²**.

Emission factor used: 0.7239 kg CO_2-eq per kg GFRC (Climatiq). (Climatiq)

Step-by-step calculation (digit-by-digit shown and reproducible):

1. Multiply mass × emission factor (kg → kg CO_2-eq):
   50,000 kg × 0.7239 kg CO_2-eq/kg = **36,195.0 kg CO_2-eq**.

2. Convert to tonnes: 36,195.0 kg ÷ 1,000 = **36.195 t CO_2-eq**.

3. Per-square-metre value (spread evenly over the reported 82,300 m²):
   36,195.0 kg ÷ 82,300 m² = **0.4398 kg CO_2-eq / m²** (≈ **0.44 kg/m²**).

Result: the GFRC fiberglass grid component of Building 2 is responsible for approximately **36.2 t CO_2-eq** in cradle-to-gate embodied emissions, or **~0.44 kg CO_2-eq per m²** of airport area (this covers only the fiberglass grid mass reported; it does *not* include any GFRC matrix or other materials unless they are included in that 50-tonne figure). (Climatiq)

(Computation reproduced programmatically during checking: 50,000 × 0.7239 = 36,195 kg; 36,195 ÷ 82,300 = 0.4397934 kg/m².)

ESTIMATING EMISSIONS SAVED — TWO TRANSPARENT APPROACHES

A — Conservative, data-anchored estimate (recommended for reporting)

- Use only documented GFRC mass and the GFRC emission factor to report the GFRC **embodied** emissions for Building 2.

- **Embodied GFRC emissions (airport)** = **36.2 t CO_2-eq** (0.44 kg CO_2-eq/m²).
  Rationale: this does not assume any particular concrete displacement and

therefore avoids overreach. Source: Climatiq GFRC EF. (Climatiq)

B — Contextual estimate of possible "savings" (illustrative; explicit assumptions)

- If we conservatively apply the stadium's reported per-m² savings (**1.88 kg CO_2-eq / m²**) to the airport area (this assumes the airport's GFRC application is comparable to the stadium cladding in functional effect), then:
  1.88 kg/m² × 82,300 m² = **154,724 kg CO_2-eq ≈ 154.7 t CO_2-eq** saved.

- **Important caveats:** the stadium saving is for a PTFE-coated cladding membrane; the airport uses 50 t of fiberglass grid (likely a quite different system). This figure (≈154.7 t) is therefore illustrative and **should not** be used as a definitive runway savings number without project-level evidence that GFRC replaced a comparable volume/m² of conventional concrete. The 1.88 kg/m² figure is drawn from the pilot data (Stadium).

C — Literature-anchored percentage reductions (why it was not adopted it as primary)

- Some LCA studies for façade systems report **~50% reduction per m²** when substituting high-performance fibre-reinforced panels for conventional concrete façades. These results are façade-specific and depend on panel thickness, structural backing, and connection systems; they are **not** directly transferable to runway structures. Use only with explicit project-level justification. (ResearchGate, PMC)

SYNTHESIS OF FINDINGS (PILOT RESULTS + ESTIMATE)

1. **Stadium (pilot):** reported savings **62 t CO_2-eq** (≈ **1.88 kg/m²** using 33,000 m²). This stands as an empirically reported pilot value in the archival record supplied.

2. **Airport (pilot):** the archival record lists **50 t** of fiberglass grid over **82,300 m²** but no emitted or saved figure. Using Climatiq GFRC emission intensity (0.7239 kgCO_2e/kg), the airport's **GFRC fibers** alone are responsible for **≈36.2 t CO_2-eq** (≈ **0.44 kg CO_2-eq/m²**). This is a conservative, mass-based embodied-emissions estimate based on supplied mass. (Climatiq)

3. **Comparative note:** the GFRC fiber embodied emissions per m² for the airport (0.44 kg/m²) are substantially lower than the stadium's reported *saved* figure (1.88 kg/m²) because the airport record appears to record only fiberglass mass

(not full GFRC panel skin or its displacement effect). This shows how sensitive “saved” estimates are to the exact material quantities and what the GFRC replaced.

BARRIER THEMES (PILOT QUALITATIVE ANALYSIS)

From the archival notes and industry context, the main barriers that surface even in the pilot records are:

- **Inconsistent documentation** (mass reported for airport, but no per-m² or displacement specification).
- **Cost reporting anomalies** (stadium and airport GFRC costs appear low relative to some international market quotes; local procurement structures and economies of scale may explain variance). (curatedfacade.com, pcr-epd.s3.us-east-2.amazonaws.com)
- **Technical ambiguity** (differences between cladding systems and structural use of fibre grids make cross-project comparison difficult without standardized LCA boundaries). (ResearchGate, Climatiq)

ALTERNATIVE SCENARIO ANALYSIS FOR AIRPORT EMISSIONS SAVINGS

(Variation of previous sections)

To complement the conservative mass-based estimate presented earlier, an alternative analysis was conducted using industry-reported GFRC system masses (25 kg/m² and 34 kg/m²) and a range of concrete replacement scenarios (50 mm and 100 mm thickness, with embodied carbon intensities between 180 kg CO_2/m³ and 250 kg CO_2/m³). This variation provides a **bounded range** of possible emissions savings (or losses) to illustrate the sensitivity of results to material mass and baseline assumptions.

ASSUMPTIONS & SOURCES

1. **Airport area (from the table): 82,300 m²**.

2. **GFRC emission factor (cradle-to-gate): 0.7239 kg CO_2-eq per kg GFRC** (Climatiq). (Climatiq)

3. **GFRC system mass scenarios (two cases):**

    - **Scenario A: 25 kg GFRC / m²**.

    - **Scenario B: 34 kg GFRC / m²** (manufacturer / datasheet example; Formglas/GFRC-L shows ~34 kg/m² for lightweight panels). (formglas.com)

4. **Baseline concrete (what GFRC might replace):** two thicknesses used for comparison — **50 mm (0.05 m)** and **100 mm (0.10 m)**.

5. **Concrete embodied-carbon rates (range): 180 kg CO_2/m³ (low)** and **250 kg CO_2/m³ (high)** — chosen to represent the typical range reported in ICE/Arup embodied-carbon literature. (Arup, circularecology.com)

COMPUTATION METHOD (EXPLICIT)

We compute:

1. GFRC mass = (GFRC mass per m²) × (area).

2. GFRC embodied CO_2 (kg) = GFRC mass (kg) × GFRC EF (0.7239 kg CO_2/kg).

3. GFRC embodied CO_2 (t) = GFRC embodied CO_2 (kg) ÷ 1,000.

4. GFRC embodied CO_2 per m² (kg/m²) = GFRC embodied CO_2 (kg) ÷ area.

5. Baseline concrete embodied CO_2 per m² (kg/m²) = (concrete EF kg/m³) × (thickness m).

6. Saved CO_2 per m² (kg/m²) = concrete per m² − GFRC per m².

7. Total saved CO_2 (t) = (Saved per m² × area) ÷ 1,000.

8. Percent reduction = (Saved per m² ÷ concrete per m²) × 100%.

The exact arithmetic was used in the calculations below.

SCENARIO RESULTS (DIGIT-BY-DIGIT ARITHMETIC SHOWN)

A — Scenario A: 25 kg/m² GFRC

1. GFRC mass = 25 kg/m² × 82,300 m²
   = 25 × 82,300
   = **2,057,500 kg**.

2. GFRC embodied CO_2 = 2,057,500 kg × 0.7239 kg CO_2/kg
   = **1,489,424.25 kg CO_2**.

3. GFRC embodied CO_2 (tonnes) = 1,489,424.25 ÷ 1,000
   = **1,489.42425 t CO_2**.

4. GFRC embodied CO_2 per m² = 1,489,424.25 ÷ 82,300
   = **18.0975 kg CO_2 / m²**.

B — Scenario B: 34 kg/m² GFRC

1. GFRC mass = 34 kg/m² × 82,300 m²
   = 34 × 82,300
   = **2,798,200 kg**.

2. GFRC embodied CO_2 = 2,798,200 kg × 0.7239 kg CO_2/kg
   = **2,025,616.98 kg CO_2**.

3. GFRC embodied CO_2 (tonnes) = 2,025,616.98 ÷ 1,000
   = **2,025.61698 t CO_2**.

4. GFRC embodied CO_2 per m² = 2,025,616.98 ÷ 82,300
   = **24.6126 kg CO_2 / m²**.

Compare with concrete baselines (two thicknesses × two EF levels)

Concrete per-m² emission = (concrete EF kg/m³) × (thickness m).

We compute saved per m² = concrete/m² − gfrc/m², and total saved t = (saved/m² × area) ÷ 1,000.

TABLE — KEY RESULTS (ROUNDED)

GFRC scenario	GFRC kg/m²	GFRC $kgCO_2/m^2$	Concrete thickness	Concrete EF (kg/m³)	Concrete $kgCO_2/m^2$	Saved $kgCO_2/m^2$	Saved total (t CO_2)	% reduction vs concrete
A	25	**18.0975**	0.05 m (50 mm)	180	9.00	**−9.0975**	**−748.72 t**	**−101.1%** (GFRC worse)
A	25	18.0975	0.05 m	250	12.50	**−5.5975**	**−460.75 t**	**−44.78%**
A	25	18.0975	0.10 m (100 mm)	180	18.00	**−0.0975**	**−8.02 t**	**−0.54%**
A	25	18.0975	0.10 m	250	25.00	**6.9025**	**568.08 t**	**27.61%**
B	34	**24.6126**	0.05 m	180	9.00	**−15.6126**	**−1,285.06 t**	**−173.5%**
B	34	24.6126	0.05 m	250	12.50	**−12.1126**	**−997.02 t**	**−96.90%**

B	34	24.6126	0.10 m	180	18.00	**−6.6126**	**−544.07 t**	**−36.74 %**
B	34	24.6126	0.10 m	250	25.00	**0.3874**	**31.86 t**	**1.55%**

(Explanation of signs: negative saved = **GFRC has higher embodied CO_2 than the concrete baseline** in that scenario; positive saved = GFRC reduces embodied CO_2 vs that baseline.)

INTERPRETATION — WHAT THE NUMBERS MEAN

1. **GFRC mass per m² is decisive.** If GFRC panels are **heavy** at 25–34 kg/m², the GFRC embodied emissions per m² (≈ 18–24.6 $kgCO_2/m^2$) become large. In many realistic façade comparisons where concrete cladding thickness is small (50 mm) and concrete embodied-carbon is modest (180–250 $kgCO_2/m^3$), GFRC in these mass scenarios can *increase* embodied emissions rather than reduce them. (See negative saved rows above.)

2. **Concrete thickness matters a lot.** If GFRC replaces **thicker** concrete elements (e.g., 100 mm of concrete) or concrete with **high embodied carbon** (≥ ~250 $kgCO_2/m^3$), then GFRC can deliver net savings (e.g., Scenario A with 100 mm @ 250 kg/m³ gives ~568 t saved across the airport). But that requires project-level proof that GFRC fully displaced that concrete volume.

3. **The original archived mass (50 t total fibers over 82,300 m²) produced a tiny GFRC per-m² emission (~0.44 kg/m²)** because that record likely listed *only* the fiberglass grid mass (50 t), not complete GFRC panel system mass. Using that mass-only approach yields a conservative embodied GFRC value (36.2 t CO_2-eq total), and **avoids** the large GFRC-per-m² emissions produced when we assume full-system weights of 25–34 kg/m².

4. **Takeaway:** whether GFRC reduces embodied carbon depends entirely on:

- the **actual GFRC system mass** installed per m² (not just fiber mass),
- the **thickness and embodied carbon of the concrete** it replaced,
- the **LCA system boundary** (does the replacement include structural backing, anchors, transport, installation?). See Arup/ICE guidance. (Arup, circularecology.com)

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

This chapter interprets the pilot study's findings on the use of Glass Fiber Reinforced Concrete (GFRC) in Abuja's built environment, as assessed through archival data analysis. The discussion compares the environmental performance, cost implications, and barriers identified in the previous Chapter (RESULTS AND FINDINGS) with literature benchmarks and the expectations set out in the methodology. The conclusions are drawn from both the conservative emissions estimate and the alternative scenario analysis, while the recommendations point toward practical actions for stakeholders and future research directions.

DISCUSSION OF KEY FINDINGS

ENVIRONMENTAL PERFORMANCE

The conservative estimate for Nnamdi Azikiwe International Airport's GFRC application — based solely on the recorded 50 tonnes of fiberglass grid — resulted in **36.2 t CO_2-eq** in cradle-to-gate embodied emissions (≈0.44 kg/m²). This is substantially lower than the stadium's reported *savings* of 1.88 kg/m², highlighting how reported outcomes are sensitive to how GFRC mass is defined and whether the full panel system is included.

The **alternative scenario analysis** revealed that, under realistic GFRC system mass assumptions (25–34 kg/m²), savings can swing from positive to negative depending on the baseline concrete thickness and carbon intensity. When GFRC replaces thin, low-carbon concrete (e.g., 50 mm @ 180 kgCO_2/m³), embodied emissions can be higher than the baseline. Conversely, when it replaces thicker or higher-carbon concrete (e.g., 100 mm @ 250 kgCO_2/m³), significant savings are possible — up to ~568 t CO_2-eq across the airport area.

This aligns with existing LCA studies on façade systems, which stress that GFRC's environmental benefit is context-dependent, often requiring thin lightweight construction, reduced material transport impacts, and displacement of relatively carbon-intensive conventional assemblies (Formglas, n.d.; Climatiq, n.d.; IStructE, 2022).

COST IMPLICATIONS

Archival records indicate that the GFRC costs for the stadium ($5.50/m²) and airport ($1.69/m²) are far below many international market averages (often $17–$279/m²). This could reflect local sourcing, economies of scale, or partial reporting (e.g., omitting certain installation costs). While low cost strengthens GFRC's adoption potential in Abuja, the discrepancy complicates direct comparisons with international benchmarks and calls for more detailed cost breakdowns in future documentation.

BARRIERS TO ADOPTION

Three consistent barriers emerged from the pilot analysis:

1. **Incomplete documentation** — especially missing baseline material quantities and unclear GFRC system weights.
2. **Technical variability** — differences between structural GFRC, cladding panels, and membrane systems make cross-project comparisons challenging without standardized LCA boundaries.
3. **Market perception and training gaps** — although not formally measured here, commentary from archival sources and literature suggests that limited local familiarity with GFRC detailing and installation remains a constraint.

CONCLUSIONS

1. GFRC has the potential to deliver notable embodied carbon savings in Abuja's building sector, but benefits are not guaranteed; they are highly sensitive to system mass, replacement context, and baseline material properties.

2. Archival data, while useful for initial scoping, often lacks the level of detail required for robust life-cycle comparisons — particularly for structural applications like the airport runway system.

3. Reported costs for GFRC in Abuja are substantially lower than many global benchmarks, which may indicate procurement advantages or incomplete reporting; either case warrants further investigation.

RECOMMENDATIONS

For Industry Stakeholders

- **Mandate comprehensive material reporting** — Include full system masses, mix designs, and precise baseline material quantities in project documentation.

- **Target GFRC where displacement potential is high** — Focus use on applications replacing thicker, higher-carbon concrete elements for maximum environmental benefit.

- **Develop local training modules** — Equip contractors and design professionals with technical knowledge on GFRC fabrication, installation, and maintenance.

For Policy Makers

- **Incentivise low-carbon materials** — Offer procurement preference or tax benefits for projects with documented embodied carbon reductions verified by LCA.

- **Standardise LCA requirements** — Require consistent system boundaries in embodied carbon reporting for all public projects.

For Future Research

- **Expand the building sample** — Include at least 5–10 projects with full GFRC and baseline concrete documentation to improve statistical reliability.

- **Integrate operational performance data** — Pair embodied carbon data with energy use, maintenance costs, and durability metrics for a holistic sustainability profile.

- **Conduct product-specific EPD analysis** — Source Environmental Product Declarations for locally used GFRC to replace generic emission factors.

CLOSING STATEMENT

The pilot analysis confirms that GFRC can contribute to Abuja's sustainable construction goals, but only when applied under conditions that maximise displacement of carbon-intensive materials and minimise its own embodied emissions. The methodology applied here, especially the sensitivity range introduced in the Chapter– RESULTS AND FINDINGS, provides a practical framework for evaluating these conditions. Scaling this approach to a larger, better-documented sample could provide the evidence base needed for policy adoption and broader industry uptake.

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