

Midocean University

College of Management

Department of Master of Business Administration

The Aggregation Solution:
Resolving the MRV Viability Gap to Unlock Carbon Revenue
in Saudi Arabia's Facility Management Sector

Prepared by:

Ahmed Salih

Supervised by:

Dr. / Fayez Jrad

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The Researcher

Abstract

This study examines why Saudi Arabia's commercial office sector hasn't joined the Regional Voluntary Carbon Market (RVCMC) despite its emission-reduction potential, and how this could change in support of Vision 2030. The main barrier is high third-party Monitoring, Reporting, and Verification (MRV) costs, currently SAR 60,000 annually which exceed the carbon revenue from a typical 10,000 m² office, causing a market failure for single properties.

To investigate this, the research uses a multi-method quantitative approach: a financial model with SEEC benchmarks tested across several scenarios, a case study of a 17,615 m² Riyadh telecom headquarters with two years of energy data, and a survey of 29 facility management professionals.

The results show that carbon revenue covers only 38% of the estimated MRV cost for a standalone building (32.9% in the real case), so a single property cannot make the economics work. Pooling buildings change the arithmetic: verification cost falls from SAR 98.52 to SAR 8.72 per tonne, and the break-even point where carbon revenue finally covers the shared audit is reached at four benchmark buildings, or 2,267 verified tonnes a year. The ten-building portfolio returns 106.5% over fifteen years at low capital cost, with a net present value of SAR 4.28 million at an 8% real discount rate. A five-year government MRV subsidy delivers a leverage ratio of 56:1. Under a CBAM-driven price path, carbon revenue would rise 460%, and a zero-interest Green Retrofit Facility makes every capital tier cash-positive from year one with no upfront equity.

The survey finds that aggregation greatly boosts participation intent ($p = .004$), especially with the full policy package ($p = .002$), and highlights a knowledge gap among practitioners. The study proposes a Three-Pathways Investment Framework: self-investment, government-backed financing, and group transitions with ten or more buildings. These strategies help facility managers lead owners into the carbon market, increasing returns and preparing for future regulations.

Keywords: Saudi Vision 2030, Saudi Green Initiative, Voluntary Carbon Market, RVCMC, Facility Management, Energy Retrofit, MRV Transaction Costs, Program of Activities, CBAM, Energy Performance Contracts, Split Incentive, Carbon Aggregation, Green Finance, Asset Life Cycle, Case Study Validation.

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The Researcher

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Research Terminology

Abbreviation	Meaning
BMS	Building Management System
CAPEX / OPEX	Capital Expenditure / Operating Expenditure
CBAM	Carbon Border Adjustment Mechanism (European Union)
CDM	Clean Development Mechanism (UNFCCC)
CER	Certified Emission Reduction (tCO ₂ e)
EPC	Energy Performance Contract
ESG	Environmental, Social, and Governance
EUI	Energy Use Intensity (kWh/m ² /year)
FM	Facility Management
GCC	Gulf Cooperation Council
GEF	Grid Emission Factor (kgCO ₂ e/kWh)
GLA	Gross Leasable Area (m ²)
HVAC	Heating, Ventilation, and Air Conditioning
KAPSARC	King Abdullah Petroleum Studies and Research Center
MRV	Monitoring, Reporting, and Verification
NCF	Net Cash Flow (SAR/year)
NDC	Nationally Determined Contribution (UNFCCC)
PIF	Public Investment Fund
PoA	Program of Activities
ROI	Return on Investment
RVCMC	Regional Voluntary Carbon Market Company
SEEC	Saudi Energy Efficiency Center
SGI	Saudi Green Initiative
SPP	Simple Payback Period (years)
TCE	Transaction Cost Economics
tCO ₂ e	Tonnes of Carbon Dioxide Equivalent
TR	Tons of Refrigeration (cooling capacity)
VCM	Voluntary Carbon Market
NPV	Net Present Value
IRR	Internal Rate of Return (%)
DPP	Discounted Payback Period (years)

Chapter One

General Introduction to Research

1.1 Introduction

Vision 2030 is normally interpreted as an economic diversification plan. That reading is correct but incomplete. And it's right at the heart of environmental sustainability. That commitment becomes concrete in the Saudi Green Initiative (SGI): 278 million tons of CO₂ abated annually by 2030 and net zero by 2060. Neither figure is aspirational in the looser sense. They are both linked to the Kingdom's commitments under the UN climate framework and are backed by more than SAR 705 billion pledged across more than eighty-five ongoing initiatives (SGI, 2024).

They count more here than their profile implies. In 2023, buildings accounted for 78% of the Kingdom's total energy (Almasri et al., 2025). Buildings are therefore the largest pool of certified emission reductions available to private companies, and the least exploited. What's different now is there's a way to monetize those reductions. The RVCMC, a creation of the Public Investment Fund, launched a carbon credit exchange in November 2024 with credits clearing at SAR 37.50 per ton of CO₂e (RVCMC, 2024). What matters is the price below. Level 1 retrofits, or simple retrofits to existing buildings, can reduce the country's electricity consumption by 10,054 GWh per year and reduce CO₂ emissions by 7.611 million tons (Krarti et al., 2017), which is nearly 3% of the SGI target and is primarily driven by private investment to run these facilities.

It is the widest in Riyadh's office stock. Cooling is always on and energy consumption is between 250 and 350 kWh per square meter per year (SEEC, 2024), two to three times the equivalent Western benchmark and more than double the same buildings could achieve after upgrade. For the facilities management teams that actually run those cooling systems, that gap is an unbooked asset. Energy is not wasted so carbon emissions are avoided and carbon savings can be measured and sold.

But something is standing in the way, and it isn't a matter of technology but of structure. The cost of third-party MRV certification ranges from SAR 40,000 to SAR 80,000 per building per cycle and is not dependent on the floor area (PwC Middle East, 2024). 10,000 m² office with 609 tons of CO₂e savings: Carbon revenue is about 38% of the middle of SAR 60,000. Math is the problem, not the building. This research presents a shared program (PoA) to pool buildings to reduce the verification cost from SAR 98.52 to SAR 8.72 per ton for ten buildings with four buildings reaching the break-even. Add in the electricity savings and the appreciation of credits under CBAM pressure and a retrofit begins to look like a defensible fifteen year investment and one that sits squarely inside vision 2030 rather than alongside it.

Two things make the timing sharper. The regulatory landscape in the region is changing. Deloitte Middle East (2025) reports a trend that could bring mandatory carbon reporting in Saudi Arabia

within two to three years. Early registrants and MRV baseline setters meet and benefit from that requirement. Latecomers inherit the requirement but not the revenue. A second advantage of conventional appraisals is that they usually pass over. Retrofits not only reduce consumption but also increase the lifespan of the equipment, delay expensive replacements, and decrease the burden of maintenance (Azcarate-Aguerre et al., 2022). The study brings together all these benefits in a Three-Pathways Investment Framework: self-financed retrofits, government-backed financing and collective transition via shared program registration.

1.2 Research Gap

The literature is split into two streams that seldom intersect, and Vision 2030 requires them linked. At the macro level is research on carbon market structure, SGI policy design and global VCM trends. While this information is obviously important in context, it does not create a financial model that an operator may employ. At the micro level are the technical treatments: retrofit engineering, building energy standards and GCC FM Operations. These solve the physics, and leave the economics unaltered. What is lacking is one model to address the following:

- Utilizes Saudi-specific input data calibrated to SEEC and RVCMC norms.
- Quantifies the MRV cost barrier at the building scale.
- Identifies the exact aggregation scale where market failure is resolved.
- Projects potential carbon credit value appreciation amid CBAM demand, aligned with Saudi Arabia's Vision 2030 export goals. It is this space that this research seeks out to fill. The lack of such an approach is more obvious by contrast: KAPSARC's Residential Energy Model (REEM) provides an extensive bottom-up simulation of Saudi residential buildings by type, vintage, and climate zone (Belaïd & Aldubyan, 2024), but there is nothing similar for monetizing carbon in the commercial facilities management sector. This study tries to offer that commercial-side model.

1.3 Problem Statement

The central research problem of this research is articulated as follows:

“To what extent do current MRV transaction costs on the Regional Voluntary Carbon Market create a financial viability gap for individual commercial facilities in Riyadh and what structural interventions specifically portfolio aggregation and government subsidy are required to convert energy efficiency into a commercially viable carbon revenue stream aligned with Vision 2030 targets?”

Central to this dilemma is a financial conundrum that obstructs the objectives of Vision 2030 regarding the construction of the environment. The RVCMC has created a voluntary carbon market including an exceptionally elevated clearance price of SAR 37.50, almost 7 to 8 times greater than the global average of USD 1–5 per tonne (World Bank, 2025). This marketplace currently functions as a real-time exchange, bolstered by twenty-three initial member firms (RVCMC, 2024).

Nonetheless, involvement from the commercial office sector is still limited. The issue is not technological but rather structural: MRV expenses remain constant and cannot be apportioned at the project level, but carbon output escalates with the scale of the building. For instance, a 10,000 m² office structure, a standard dimension in Riyadh's business areas, produces carbon income of SAR 22,838, which is below the projected average MRV expense of SAR 60,000 (the median of the stated SAR 40,000-80,000 spectrum). This leads to a yearly deficit of SAR 37,163. Consequently, the capacity of the constructed environment to facilitate the attainment of Vision 2030's SGI reduction objectives is constrained not by technological or policy factors, but by basic arithmetic.

Prior research has failed to address this issue. Current studies primarily concentrate on the carbon market through a policy lens (Luomi et al., 2025; World Bank, 2025) or investigate operational difficulties in facility management while neglecting carbon integration (MEFMA, 2023; Al-Surf & Al-Fagih, 2024). To date, no research has simulated the aggregation scale required to surmount this obstacle in the Saudi market or projected the long-term appreciation of Saudi carbon credits amidst rising European demand. This study addresses these deficiencies via innovative financial modelling, with results intended to directly facilitate the execution of Vision 2030.

1.4 Importance of the Study

1.4.1 Scientific Importance

This research offers three key theoretical insights. First, it builds on Transaction Cost Economics (Coase, 1937; Williamson, 1981) by showing how MRV costs can cause the voluntary carbon market to fail. It also shows that combining multiple projects into a portfolio acts as a practical solution to this failure, especially within the Vision 2030 policy framework. Second, it uses agency theory (Jensen & Meckling, 1976) to analyze the split-incentive issue in the GCC, illustrating that carbon monetization generates a separate revenue source for landlords. This income stream bypasses tenants' control of operational savings, directly addressing the barrier that discourages landlords from investing in energy efficiency. Third, the research introduces a step-by-step modeling approach for joining voluntary carbon markets in oil-producing countries with subsidized energy prices, a method that can be replicated in other GCC countries aligned with the Vision 2030 agenda, such as the UAE, Kuwait, and Bahrain.

1.4.2 Practical Importance Vision 2030 Alignment

This research's practical importance is based on the four foundations of Vision 2030's sustainability framework:

Macroeconomic (Vision 2030 SGI & Fiscal Diversification): Saudi Arabia's Saudi Green Initiative (SGI) is supported by an investment of SAR 705 billion across over 85 sustainability projects (SGI, 2024). This study illustrates that a specific government MRV subsidy, approximated at SAR 85,000 annually per portfolio, can catalyze substantial private-sector expenditures in retrofitting, resulting in a leverage ratio of 56:1 relative to the government's spending. Reducing electricity use in commercial structures facilitates the availability of subsidized oil for export, so directly promoting the financial diversification objectives of Vision 2030.

Industry-level (Facility Management Transformation): Vision 2030 seeks to cultivate a more efficient private sector. This paper provides facility management leaders with a compelling financial rationale for transitioning from conventional headcount-driven maintenance agreements to Energy Performance Contracts (EPCs). By adopting this approach, facilities management transitions from a cost center to a pivotal player in the nation's decarbonization initiatives.

Asset-level (Office Asset Valuation & the 'Quality of Life' Vision): In 2024, the Sustainable Building Program of the Saudi Arabian Ministry of Municipalities and Housing evaluated 75 projects representing 47 million m², up 32% from the prior year (Skyline Holdings, 2025). Furthermore, Saudi

Arabia has the highest number of LEED-certified buildings in the Middle East (GBCI, 2024), indicating a mature market for green asset premiums. This research provides a methodology for developers to incorporate carbon revenue into NPV calculations, strengthening the well-documented Green Premium from JLL (2024).

International Markets (Vision 2030 New Economy & Export Positioning): The Saudi voluntary carbon market is expected to expand from USD 21.7 million to USD 124.6 million by 2030 (Grand View Research, 2025). Aggregated, verified Saudi carbon credits will position the Kingdom as a top-tier supplier in a global market increasingly driven by European CBAM rules and growing demand for high-quality offsets from the Global South. Facility management companies that move early help Saudi Arabia lead the Global South carbon market while creating new export revenues directly supporting Vision 2030's economic diversification goals.

For decision-makers, this research offers practical tools: a financial plan for facility management leaders, a subsidy design template for RVCMC and Ministry of Energy policymakers, and a framework for increasing the value of assets for office owners and institutional investors.

1.5 Research Objectives

1.5.1 Primary Objectives

- **Quantify the Viability Gap:** Calculate the annual net cash flow shortfall for a typical small commercial building (10,000 m²) participating in the RVCM. This demonstrates the real magnitude of the MRV transaction cost barrier that prevents private-sector actors from supporting Vision 2030 in meeting its carbon goals for the built environment.
- **Model Aggregation Economics:** Determine the MRV cost per tonne as a portfolio grows and pinpoint the smallest portfolio size where carbon participation pays for itself under RVCMC's current market rules.
- **Consider the effect of government policy:** Analysis of the impact of five-year subsidy of MRV on portfolio SPP and 15-year ROI. This will provide a clear cost-benefit structure for the policymakers to design the private sector incentives in line with Vision 2030.
- **Project Carbon Asset Appreciation:** Estimate the potential increase in Saudi Arabia's consolidated portfolio's annual carbon earnings over the next 15 years, driven by the rising global demand for carbon credits as a consequence of EU CBAM regulations. This role

positioned RVCMC credits as a new financial instrument supporting the Vision 2030 objectives for the new economy.

- **Evaluate The 3 Investment Options:** Structure the findings in a decision-making framework comparing 3 approaches for asset owners to fund the transition: self-funding, government backed financing (including SGI/PIF green funds and concessional loans), and collective transition through shared multi-building initiatives. This helps match each pathway to the correct owner profile and highlights the financial returns, asset life and compliance readiness for each.

1.5.2 Secondary Objectives

- **Validate the Model with a Real Case Study:** Validate the prototype model major findings using the actual 23 months metered consumption data for a Grade A commercial building in Riyadh, which is provided by the building FM contractor. This step confirms the effectiveness of the viability gap, aggregation solution and policy leverage mechanism in real operation.
- **FM Transition to EPCs:** Describes transition in Saudi Arabia from facility management contracts based on traditional headcount to energy performance contracts. This step will enable FM companies to directly reap efficiency gains and will also make them private sector partners in the achievement of Vision 2030.
- **Sensitivity Analysis of Carbon Price:** Assess the robustness of the financial model to a $\pm 20\%$ change in the RVCM carbon price. This analysis helps set realistic expectations for minimum and optimistic returns.
- **Scrutinize Greening Grid Risks:** Analyze the possible effect of the Saudi Grid Emission Factor's slow reduction following the 50% renewables goal by Vision 2030 on carbon credit yields over time. Propose early registration schemes to help protect credit returns as the grid gets greener.

1.6 Research Questions

- **RQ1 (The Viability Gap):** Given the current RVCM carbon price of SAR 37.50 per ton of CO_{2e}, how significant are MRV transaction costs to the financial viability of individual commercial facilities in Riyadh? Furthermore, what is the minimum carbon revenue required for these facilities to be able to participate in the market?

- **RQ2 (The Aggregation Solution):** How large a portfolio is required in the aggregation of projects under a single program of activities (PoA) to bring down the MRV cost per ton to a positive 15-year return on investment for facilities management providers operating within the Saudi RVCMC framework?
- **RQ3 (The policy effect):** How does a 5-year government MRV subsidy impact the financial performance of projects in terms of portfolio SPP and ROI? What does this finding imply about the cost-effectiveness of such a policy as a tool to incentivize private-sector participation under Vision 2030?
- **RQ4 (Carbon as an Appreciating Asset):** What will be the impact of the expected increase in European demand for voluntary carbon offsets because of CBAM and the expansion of the Saudi VCM from USD 21.7 million to USD 124.6 million by 2030 on the 15-year financial returns for a portfolio of Saudi office buildings with verified RVCMC credits?

1.7 Research Hypotheses

The hypotheses below follow the logic of the study design. H1 to H4 are directional financial propositions, evaluated through deterministic scenario modelling rather than statistical inference. H5 and H6 are propositions about practitioner perception and stated behavior, and they are tested with non-parametric inferential statistics on the survey sample. Each hypothesis ties directly to a specific Vision 2030 policy or market area.

- **H1 (Transaction Cost Barrier):** A single commercial building of 10,000 m² has a net cash flow deficit after MRV costs for the current RVCM price of SAR 37.50 per ton of CO₂e, attributable to carbon revenues. This also means that individual participation in the carbon market is not economically viable, which shows that the built-environment targets of Vision 2030 cannot be achieved by individual buildings acting alone.
- **H2 (Aggregation Threshold):** By aggregating 10 buildings (7 small and 3 large buildings, with a total area of 160,000 m²) under one PoA registered with RVCMC, MRV costs can be brought down to below SAR 10/tonne CO₂e. This approach yields a 15-year positive ROI under both low and medium CAPEX scenarios, meeting the private developers' expected returns.
- **H3 (Policy Accelerator):** A five-year government subsidy on MRV will improve the 15-year ROI and speed payback. The leverage ratio indicates that such a subsidy is a cost-effective policy tool for stimulating private investment to meet the SGI commitments of Vision 2030.

- **H4 (Carbon Asset Appreciation):** The combined portfolio's carbon revenue is expected to grow by at least 300% per year over a 15-year period as the Saudi VCM market grows to USD 124.6 million by 2030 and the European CBAM rules boost international demand. This policy will turn verified Saudi credits into a valuable financial asset that directly supports the economic diversification goals of Vision 2030."
- **H5 (Perceived Barrier - Survey):** The ratings distribution for the MRV cost barrier is above the 3.5 benchmark on a five-point scale for facility management professionals and asset owners in Saudi Arabia. The hypothesis is stated in terms of the location of the distribution (not the arithmetic mean) so that it is equivalent to the same parameter being tested by the one-sample Wilcoxon signed-rank test (Section 3.8.5). A positive result would confirm the model finding in H1 with real-world perception data.
- **H6 (Intent Shift - Survey):** The willingness to enter the carbon market is significantly higher with aggregation under a shared PoA and then a five-year government MRV subsidy than going it alone. We test for differences between paired groups using Wilcoxon signed-rank tests at $p < 0.05$, with the family-wise error rate across the three paired tests controlled by the Holm-Bonferroni procedure (Holm, 1979). A positive result would support the effects found in H2 and H3 with behavioral intent data.

Hypotheses H1 to H4 are tested using financial scenario modeling in Chapter Four, comparing results across three different operational scenarios. They are also checked against actual metered building data in the real-world case study in Section 4.1.10. Hypotheses H5 and H6 are assessed through a structured survey of facility management professionals described in Section 3.8, adding a perception-based perspective to the model's main findings.

1.8 Conceptual Model

The interaction between the two theoretical pillars, the proposed solution, and Vision 2030 alignment is captured in the following framework:

Independent Variables	Mediating Mechanism	Annual Carbon Revenue (SAR) OPEX Savings (SAR/yr) Net Cash Flow (SAR/yr) Simple Payback Period (years) Discounted Payback Period (years) Net Present Value at 8% real (SAR) Internal Rate of Return (%) 15-Year ROI (%)
MRV Transaction Cost Portfolio Scale (No. buildings) Carbon Price (SAR/tCO ₂ e) Govt. MRV Subsidy (V2030 policy) Grid Emission Factor	Aggregation via RVCMC PoA (Program of Activities) ↓ MRV cost dilution. + Carbon revenue pooling + CBAM price appreciation + Vision 2030 SGI alignment	Annual Carbon Revenue (SAR) OPEX Savings (SAR/yr) Net Cash Flow (SAR/yr) Simple Payback Period (years) 15-Year ROI (%)
Barrier (TCE): Fixed MRV > single-building carbon revenue	Moderator: SGI MRV Subsidy Fund (Vision 2030, Yr 1–5)	Barrier (Agency Theory): Tenant captures OPEX → resolved by carbon bypass

Table 1-1: Conceptual Framework

1.9 Research Limitations

- Prototype Modeling vs. Real Buildings :** This model is based on standard SEEC benchmark prototype buildings, but the actual ROI will depend on the age, design, and condition of the building's equipment and how the spaces are used. The model provides a general framework, not a specific assessment for any particular project. This shortcoming is compensated by a real world case study (Section 4.1.10) comparing the model results with actual metered data. However, a single case cannot reflect the full variety found across Riyadh's commercial buildings.

- **Single-Case Validation Scope:** The case study looks at one Grade A building with an EUI (171.9 kWh/m²/yr) that's 43% lower than the SEEC benchmark, making it unusually efficient. As a result, this case sets a conservative lower bound for the investment case, instead of representing an average building. The analysis assumes a portfolio of ten similar buildings. Validating the model across multiple cases and a broader range of EUI values is a key priority for future research.
- **Carbon Market Price Volatility:** The base case assumes a fixed price of SAR 37.50 per ton of CO₂e, while the appreciation scenario is based on projections from McKinsey, WEF and Grand View Research. Voluntary carbon markets have experienced price swings. The –20% sensitivity analysis helps address some of this uncertainty.
- **GEF Methodology Note:** This study uses a grid emission factor of 0.58 kgCO₂e/kWh (SEEC/CDMDNA), matching the requirements for CDM/VCM project registration in Saudi Arabia. By comparison, the IEA Life Cycle Upstream Emission Factors (2024) report a slightly lower factor of 0.52 kgCO₂e/kWh, which looks only at the fuel cycle. If the IEA factor were used, certified emission reductions (CERs) would drop by about 10.3% (from 9,744 to 8,736 tonnes for the portfolio), and annual carbon revenue would decrease from SAR 365,400 to SAR 327,600. Because RVCMC-registered projects require the SEEC/CDMDNA standard, using 0.58 is the correct approach here. Researchers using this model outside of CDM projects should consider the IEA factor.
- **The Greening Grid:** The model assumes the grid emission factor (GEF) stays at 0.58. If Saudi Arabia reaches its Vision 2030 goal of 50% renewables, the GEF could drop to about 0.40 by 2030–2032. This would mean that carbon credits would be worth 31% less in the years after that. However, the Climate Action Tracker (2025) points out that renewables made up only 2% of the mix in 2024, so GEF is likely to stay high for much of the 15-year projection period.
- **Geographic and Sectoral Scope:** The results are related to the climate of Riyadh (ASHRAE Zone 1B) which is characterized by dry heat and primarily sensible cooling needs. They do not apply directly to places such as Jeddah or the Eastern Province, where there is more humidity, or to retail, hospitality or industrial buildings.
- **The rebound effect:** Studies from KAPSARC (Belaïd & Mikayilov, 2024; Aldubyan et al., 2024) show that 41-71% of energy savings from efficiency upgrades in Saudi homes are clawed back as people use more energy when it is cheaper to cool their homes. The financial

model assumes the entire 35% reduction in energy use per square meter is realized as a permanent saving. Building management systems (BMS) under Energy Performance Contracts can help monitor and control this rebound, but in leased buildings where facility management has less control over occupant behavior, some loss in projected carbon savings may still occur.

- **Survey Sample Size and Composition:** The survey had 29 complete responses, less than the recommended minimum of 60 and the threshold of approximately 35 needed to detect medium effects at conventional power (Cohen, 1988). This restriction means that the survey results should be seen as suggestive, rather than broadly representative. Despite these limitations, the H6 results were important as the effects were medium to large. The sample did not include building owners and institutional investors, so the planned comparison between principals and agents could not be performed. Because most respondents were consultants or providers, the split-incentive issue was less pronounced. The reliability of the two-item barrier construct ($\alpha = 0.63$) is just below the commonly accepted level of 0.70. The use of non-probability purposive sampling and reliance on self-reported intentions are also limitations, although these are partially offset by cross-checking with the deterministic model and real case data.
- **Data Confidentiality:** Capital and operating cost data for Saudi office buildings are commercially sensitive. The CAPEX range of SAR 150–300 per square meter comes from GCC vendor benchmarks. For privacy, the case study building and its operator are anonymized as 'Telecom Headquarters' and 'FM Contractor' at the provider's request. This protects the confidentiality of the data but also limits the opportunity to independently verify the case data. To achieve actual returns, investors need to do project-specific modeling.

1.10 Conclusion of the Chapter

So, the scope is set. This chapter has framed a measurable market failure, produced by verification costs that stay fixed while the value being verified varies, rather than merely asserting it. That failure is what currently keeps Saudi Arabia's commercial office sector out of the RVCMC and therefore out of its share of the Vision 2030 carbon effort. With the problem stated, the objectives and limits drawn, and a conceptual model linking transaction costs to financial outcomes, the foundation is in place. Chapter Two turns to the theory behind it, Transaction Cost Economics and Agency Theory, and situates the study among the work that has come before.

Chapter Two

Theoretical Framework and Literature Review

2.1 Introduction

This review examines five bodies of knowledge, each selected for its contribution to bridging the research gap. Where studies agree, the review says so; where they diverge, that matters rather more, and the divergences are flagged as they arise. Section 2.5 synthesizes the key points and outlines the unique contributions of this research that existing work does not address.

2.2 Theoretical Framework

This research is grounded in two interrelated economic theories that together shed light on why the RVCMC isn't being used by the commercial office sector and how the proposed solution aggregation and government subsidies in line with Vision 2030 policy can address this issue.

2.2.1 Transaction Cost Economics: Why the Market Fails

Transaction Cost Economics (TCE) shows that MRV costs are more than just a bureaucratic hurdle—they are a real barrier to the market. For instance, in a 10,000 m² office building in Riyadh, the carbon asset (609 tCO₂e/year x SAR 37.50) is valued at SAR 22,838, but the verification cost is SAR 60,000, making the transaction unfeasible. TCE also suggests a solution: scale up transactions so the per-unit cost becomes reasonable. The point at which that happens can be calculated exactly. Since the shared audit costs SAR 85,000 and each tonne sells for SAR 37.50, the program breaks even at 2,267 verified tonnes a year, which is four benchmark buildings. Beyond that point the saving keeps compounding: at ten buildings, SAR 85,000 spread across 9,744 tonnes brings the MRV cost down to SAR 8.72 per tonne, well below the SAR 37.50 carbon price.

2.2.2 Agency Theory: Why Landlords Do Not Invest

Agency Theory (Jensen & Meckling, 1976) helps explain why landlords often hold back on investments that make economic sense. The issue is that landlords (the principals) don't see the financial rewards from their investments, since these benefits, like lower utility bills, go to the tenants (the agents). Carbon monetization offers a workaround: credits go directly to the entity that implements the retrofit, no matter how the energy bills are structured, ensuring that landlords receive a direct return on their investment.

2.2.3 The Three-Pathways Investment Framework

Put together, the two theories yield something more practical than either alone: a decision framework that shapes both the structure of this research and what it ultimately says to the market. Every asset owner weighing a carbon transition runs into the same question first. How does the retrofit get funded before it starts paying for itself? Three pathways are set out below, each modelled through a scenario in Chapter Four and each suited to a different kind of owner. They are not mutually exclusive; in practice the strongest solutions tend to blend group transition with government-backed finance.

Pathway	Financing Source	Model Scenarios	Best Suited For	Key Enabler
1. Self-Investment	Owner's own balance sheet	A, B	Large owners with capital access; low-CAPEX assets	OPEX savings dominance ($\approx 89\%$ of inflows)
2. Government-Enabled	SGI / PIF green funds; MRV subsidy; zero-interest Green Retrofit Facility	C, D	Capital-constrained owners; mid/high-CAPEX assets	Zero-equity, Year-1-positive cash flow; MRV-linked covenant
3. Group Transition	Shared PoA across 10+ buildings — one owner or a multi-company consortium	B–D at portfolio level	Small/medium owners; FM-managed multi-client portfolios	MRV dilution SAR 98.52 $\rightarrow$ 8.72/t; FM vendor as aggregator

Table 2-1: The Three-Pathways Investment Framework

Pathway three carries a nuance that matters a great deal for market design: the ten buildings sharing a PoA need not belong to the same company. Several owners can instead form a consortium, pooling assets under one program run by a single FM vendor or by an independent aggregator. The MRV dilution works in exactly the same way. What changes is who can take part, since an owner with one or two buildings, previously locked out, now has a route in.

That said, the consortium model raises questions the single-owner version never has to answer. How is each participant's data kept confidential? On what basis is revenue split? And can the aggregator be trusted to run the thing fairly? The survey addresses these directly through items E1–E2. It also points to a role the FM vendor has not traditionally played: trusted intermediary, the party that assembles the owners, registers the program, and steers the group through the transition.

Whichever pathway an owner takes, the returns run wider than the financial model captures. The central plant lasts longer, and major replacement is deferred (Azcarate-Aguerre et al., 2022). Asset value and rental appeal improve through the "Green Premium" (JLL, 2024). And the building arrives prepared for the shift from voluntary to mandatory carbon reporting that the region appears to be making (Deloitte Middle East, 2025).

2.3 Previous Studies

2.3.1 GCC Facility Management: From Reactive Service to Strategic Partner

The GCC facilities management industry has often been described as transactional and cost-led and this description largely remains true. MEFMA (2023) claims that over 70% of regional FM contracts are awarded to the lowest bidder and the scope is normally limited to maintenance, security and cleaning. Energy management is rarely part of contracts; utilities are often viewed as overhead or controllable variables. Energy management is not normally part of contracts because utilities are seen as overhead expenses and not as variables to be managed. Utilities are often seen as an overhead expense and not a variable that can be controlled. Vision 2030 has been aggressively pushing in the opposite direction, toward a modernized industry and stronger private sector but procurement habits have proved stubborn.

But change did start and JLL (2024) puts that at around 2022. Institutional investors across the GCC started to introduce ESG screens on property and a 'Green Premium' followed: certified buildings fetch 5-12% more in rent. Saudi Arabia now has the largest number of LEED-certified buildings in the region (GBCI, 2024). In 2024, the Kingdom's Building Sustainability Assessment System evaluated seventy-five projects, amounting to 47 million square meters, a 32% rise over the previous year (Skyline Holdings, 2025)—the kind of momentum that Vision 2030's built-environment agenda aimed to generate. The trickle-down effect is now coming to contracts. The number of buildings falling under these expectations continues to grow, with Riyadh leading the Kingdom's office market (Mordor Intelligence, 2025) as major GCC clients increasingly expect real-time energy and carbon reporting from their FM providers (MEFMA, 2025). But the JLL analysis stops at the value of the certification and has no comment on revenue from carbon credits. Al-Mofeez and Nait-Sidnas (2025) are from the engineering side, with a similar edge: retrofit technology for commercial buildings in arid climates is mature, and the binding constraint is how to finance the upfront cost. Neither study moves to the next step of carbon monetization as a financial bridge, which is the focus of this research.

The energy efficiency paradox is the name given to the pattern in a peer-reviewed treatment by Belaïd (2025). Even where the financial and environmental case is clear, cost-effective technologies are not adopted. Most of the work is done by three barriers, according to his account: split incentives, poor information, and the familiar gap between what people know and what they actually do. His “valuation” of the prize is striking: Saudi Arabia could save up to 80 TWh of electricity a year from air-conditioning efficiency alone. He says that fixing market failures is necessary but not sufficient; reinforcing building codes and providing financing instruments are essential to reduce upfront costs. He argues that while correcting market failures is necessary, it is not sufficient. Reinforcing building codes and providing financing instruments are essential to bring the upfront cost down and reduce upfront costs and financing instruments are needed to bring the upfront cost down. In his reasoning, the RVCMC is close to the instrument that he describes as missing for carbon monetization.

2.3.2 Carbon Market Mechanics: Global Context and Saudi Differentiation

The World Bank's State and Trends of Carbon Pricing (2025) maps the global picture cleanly enough. Compliance markets, chiefly the EU Emissions Trading System, are mandatory cap-and-trade schemes where carbon trades between USD 60 and 100 per tonne. Commercial offices cannot access them, being outside the covered sectors. Voluntary markets are open to any project that can demonstrate real reductions, but they have suffered for years from an oversupply of credits relative to buyers. Average prices of USD 1–5 per tonne followed, and at that level monetising energy efficiency at the individual project scale is simply not worth the effort.

Saudi Arabia's RVCMC departs from that pattern sharply. Established under Vision 2030 and overseen by the Public Investment Fund, it launched its live carbon exchange in November 2024 with 23 Saudi and international companies trading on day one, following record auctions in 2022 (1.4 million tonnes) and 2023 (2.2 million tonnes), the largest voluntary carbon credit auctions held anywhere (RVCMC, 2024; Xpansiv, 2024). Xpansiv is the world's largest spot carbon marketplace, offering the technology that provides transparent price discovery and access to global registries (Xpansiv, 2024). The clearing price settled at SAR 37.50 per tonne of CO_{2e}, roughly seven to eight times the global voluntary average. At that price, and only at that price, monetising office building reductions becomes feasible, assuming the cost side is handled properly.

The market itself is small but moving quickly. Valued at USD 21.7 million in 2023, it is projected to reach USD 124.6 million by 2030, a compound annual growth rate of 28.4% (Grand View Research, 2025). Three forces sit behind that trajectory: the SGI mandate, PIF's role as institutional market-

maker, and European demand arriving from outside. Between them they are moving carbon credits out of the specialist environmental corner and into Saudi Arabia's mainstream capital markets.

2.3.3 Vision 2030, the Saudi Green Initiative, and the Built Environment

The environmental pillar of Vision 2030 is represented by the Saudi Green Initiative, which by the end of 2024 was implementing more than eighty-five program with SAR 705 billion in committed investment (SGI, 2024). Electricity represents almost 50% of Saudi energy-related CO₂ emissions (IEA, 2025) so what happens in buildings matters disproportionately to the transition. In a survey of the green energy transition in the Kingdom, Islam and Ali (2024) argue that decarbonization should begin with electricity, as it is the lowest hanging fruit in the path to net zero. The target set in the Energy Efficiency Action Plan of SEEC is the following: the 30% reduction of power intensity by 2030.

KAPSARC has done the most in-depth analysis on building emissions in the country. The modelling shows that efficiency programs in buildings could reduce electricity consumption by up to 27% and peak demand by 30%. This would make buildings the single largest sectoral contributor to Saudi NDC targets (KAPSARC, 2025). The same body of work examines what works under climate conditions in the GCC and finds that ambitious efficiency targets work best when combined with well-designed market arrangements. Luomi, Zakkour and Gasim (2025) writing for KAPSARC go further and confirm that the built environment is a significant but underutilized source of credits within the Saudi crediting framework. The places they stop are enlightening. This research addresses the MRV cost barrier and aggregation as a response that their analysis does not consider.

Hasanov et al. (2025) answered the question with the KAPSARC Global Energy Macro Econometric Model (KGEMM) to test what hypothetical carbon pricing might do in Saudi Arabia. “Building-sector carbon instruments were among the most cost-effective means to meet the NDC targets. Their macroeconomic result independently supports the subsidy mechanism modelled here as Scenario C, but from a very different analytical angle.

Deloitte Middle East (2025) charts the transition of the region from voluntary to mandatory carbon reporting, with the UAE’s 2024 requirements serving as the bellwether for what Saudi Arabia will implement. The implication for investors is a hedge, not a headline. Buildings that generate verified credits today will already be in place when disclosure becomes mandatory, which fits well with the forward looking regulatory stance. Vision 2030: Buildings that are already generating verified credits today will be well positioned for the mandatory disclosure that fits with the forward-looking regulatory posture adopted by Vision 2030.

2.3.4 Theoretical Foundations

2.3.4.1 Transaction Cost Economics and the MRV Barrier

Transaction cost economics, introduced by Coase (1937) and formalized by Williamson (1981), holds that participating in a market cost more than the price of the product being traded. In voluntary carbon markets, the additional cost is MRV, which refers to the independent verification that emissions reductions are real, additional, and permanent. Williamson's notion of asset specificity applies here too neatly. MRV needs specialized climate and engineering auditors, and in a market as young as Saudi Arabia's, those services are expensive and thinly contested. PwC Middle East (2024) puts registration somewhere between SAR 40,000 and SAR 80,000 per cycle.

TCE also points toward the remedy. Where transaction costs are fixed, the rational response is to raise transaction volume until the per-unit cost falls to something bearable. The useful question is where exactly that point sits, and the model answers it precisely. A shared audit costs SAR 85,000, and each verified tonne is worth SAR 37.50, so the program pays for its verification at 2,267 tonnes a year. For the benchmark Riyadh offices, which means four buildings of 10,000 square meters, or roughly 40,000 square meters of pooled floor area. Buildings will not meet the requirement, resulting in 1,827 tonnes and a verification cost of SAR 46.52 per tonne, which is still a quarter above the credit price. Expressing the threshold in tonnes rather than buildings is the safer practice since the tonnage figure holds whatever mix of assets an owner brings. Read against Vision 2030, the result argues for a national carbon aggregation registry, one that lets FM companies pool assets from across the market instead of each building a project from scratch.

2.3.4.2 Agency Theory and the Split-Incentive Dilemma

Jensen and Meckling (1976) describe the tension that arises when one party bears a cost and another collects the benefit. Multi-tenant offices produce a textbook version of it. The landlord funds the retrofit; the tenant pockets the lower utility bill. Rationally, the landlord declines. This is exactly what Al-Surf and Al-Fagih (2024) report for commercial buildings in the GCC, where owners find it difficult to justify capital spending that goes into somebody else's operating budget. Belaïd (2025) reaches the same conclusion from a national vantage point, listing split incentives among the principal obstacles to efficiency adoption across the Saudi building stock.

Carbon monetization offers a way around the conflict rather than a resolution of it. Verified credits belong, legally, to whoever funds and delivers the emission reduction. Revenue therefore reaches the landlord directly, with no dependence on how the electricity is billed. The landlord's private financial

interest and the public environmental objectives of Vision 2030 begin to point the same way, which is more or less the design principle underlying the SGI's private-sector strategy.

2.3.5 The CBAM, Global Demand, and Saudi Carbon Credit Appreciation

The European Carbon Border Adjustment Mechanism (CBAM) is likely to redefine the voluntary market from the demand side, as European manufacturers and importers go looking for credible, verified offsets from the Global South (McKinsey 2025). Saudi Arabia's RVCMC is well placed to meet that demand: over 75% of the credits traded in its third auction came from Global South projects (RVCMC, 2024). Major commitments are already coming onto the platform, including NEOM's Enowa which has committed to deliver at least 30 million tons of high integrity credits by 2030 (Carbon Credits, 2025). In October 2025 the FII Institute entered into a strategic partnership with the VCM to specifically advance high-integrity climate finance under Vision 2030's 'new economy' agenda (FII Institute, 2025).

Verified carbon credits are an emerging asset class, with a limited supply, increasing demand, and the price behavior that results from that combination (World Economic Forum, 2024). That framing ties into the ambition of Vision 2030, to make Saudi Arabia a financial hub. The credits issued by Saudi FM companies thru the RVCMC are not simply environmental certificates, they are exportable instruments that earn foreign currency and reduce emissions domestically. The domestic market is forecast to expand from USD 21.7 million to USD 124.6 million by 2030 (Grand View Research, 2025) whilst international demand is likely to tighten owing to CBAM and prices may potentially increase from SAR 37.50 to SAR 210 per ton over the fifteen-year horizon (see Section 4.1.8 for further information).

2.3.6 The Greening Grid Paradox: Vision 2030's Internal Tension

Vision 2030 aims for half of Saudi electricity to come from renewable sources by 2030. Success would lower the Grid Emission Factor over time, and with it the carbon yield of building efficiency projects, which is an awkward result for anyone holding credits. Islam and Ali (2024) report that the electricity sector has a target to cut emissions by 55% by 2030. If successful, the GEF would fall from 0.58 to about 0.40 kgCO₂e/kWh, a 31% drop in building level credit yields. achieved, the GEF would fall from 0.58 to roughly 0.40 kgCO₂e per kWh, trimming building-level credit yields by 31%.

Implementation, however, is running well behind ambition. Climate Action Tracker (2025) records renewables at just 2% of Saudi electricity in 2024, with 4.7 GW of renewable capacity against 97 GW of fossil plants. A gap that size suggests the GEF will stay elevated through much of the next fifteen

years, which is inconvenient for the energy transition and convenient for credit yields. The practical conclusion is to register PoA projects as soon as possible. Registering now locks in a higher baseline GEF and earns more credits across the crediting period.

2.4 Benefit of Previous Studies

Four things came out of the literature reviewed here. First, it supplied the inputs the financial model needed, with MRV cost ranges drawn from PwC Middle East (2024) and baseline energy intensities from SEEC (2024). Second came the independent benchmarks against which the model's outputs could be checked in Section 3.7, notably JLL's (2024) finding that Gulf retrofit paybacks run 5 to 8 years and Krarti et al.'s (2017) estimate of national abatement potential. The reviewed work also shaped the survey instrument: Belaïd's (2025) work on information gaps prompted the questions on awareness and expertise, while Al-Surf and Al-Fagih's (2024) treatment of split incentives produced item B4. Finally, and most usefully, none of it addressed building-level MRV costs, aggregation thresholds, or how the resulting instruments should be priced. That silence is what Section 2.5 turns into a stated gap.

2.5 Comparative Analysis and Research Gap

The following matrix maps where each source contributes and where the gaps lie:

Study / Source	Saudi-Specific	MRV Barrier Modelled	Aggregation Solution	CBAM Appreciation	V2030 Aligned
Luomi et al., 2025 (KAPSARC)	✓	✗	✗	✗	✓
World Bank, 2025	✗	✗	✗	✗	✗
Belaïd, 2025 (Nature)	✓	✗	✗	✗	✓
Hasanov et al., 2025 (KAPSARC)	✓	✗	✗	✗	✓
Al-Surf & Al-Fagih, 2024	✓	✗	✗	✗	~
JLL, 2024	✓	✗	✗	✗	✓
PwC Middle East, 2024	✓	~	✗	✗	✓
McKinsey, 2025	✗	✗	✗	✓	~
Krarti, Dubey & Howarth, 2017 (KAPSARC)	✓	✗	✗	✗	✓
Belaïd & Mikayilov, 2024 (KAPSARC)	✓	✗	✗	✗	✓
Aldubyan, Belaïd & Gasim, 2024 (KAPSARC)	✓	✗	✗	✗	✓
Alnaser et al., 2024 (King Saud Univ.)	✓	✗	✗	✗	✓
IMF Working Paper, 2025	~	✗	✗	✓	✗
He, Zhai & Ma, 2025	✗	✗	✗	✓	✗
Ecosystem Marketplace, 2025	✗	~	✗	~	✗
Fortune Business Insights, 2025	✓	✗	✗	✗	✓
THIS RESEARCH	✓	✓	✓	✓	✓

Table 2-2: Comparative Literature Matrix

No prior study integrates all five dimensions within a single Saudi-specific analytical framework. This research is the first to quantify the MRV barrier, model the aggregation solution, project CBAM-driven appreciation, and ground all findings in Vision 2030's policy architecture.

Chapter Three

Research Methodology

3.1 Introduction

This chapter sets out the research design that produces the evidence reported in Chapter Four. It moves from the overall architecture of the study (Section 3.2), through the data sources, calculation chain and investment appraisal rules of the financial model (Sections 3.3-3.5), to its sensitivity testing and validation anchors (Sections 3.6-3.7), and closes with the design of the primary survey of FM professionals (Section 3.8). Together these components deliver the triangulation logic set out in Chapter One: the model establishes what is financially true, the case study establishes that it holds for a real asset, and the survey establishes whether the market recognizes it and would act on it.

3.2 Research Design

This study uses a concurrent multi-method quantitative design built on three components that reinforce one another. The label matters and is used precisely. All three instruments produce numerical data analyzed by quantitative means, so the design is described as multi-method quantitative rather than mixed-methods; no independent qualitative component, such as semi-structured interviews or documentary thematic analysis, was undertaken. The perceptual side of the research problem is captured quantitatively through closed Likert scales, and a qualitative extension is recommended in Chapter Five as the natural next study.

The first and primary component is a quantitative, deterministic financial model. Detailed operating budgets for Saudi office buildings are commercially confidential, so the research builds a representative simulation from verified secondary data published by Saudi regulatory and market authorities an approach consistent with established practice in energy economics research (Krarti et al., 2017; Hasanov et al., 2025) and one that produces precise, reproducible outputs across scenarios that Vision 2030 implementation bodies can use directly.

The second component involves validating the prototype model against a real case study building by using 23 months of actual meter readings (Section 4.1.10). This case study provides an empirical bridge between the representative simulation and real Riyadh operating conditions, and it is the point at which several of the study's findings were tightened: the case does not merely confirm the prototype; it also shows which of the prototype's specific magnitudes are properties of average-efficiency stock rather than general results.

The third component is a structured survey of FM professionals and asset owners (Section 3.8). It tests the model's structural findings the MRV barrier, the aggregation solution, and the policy accelerator—against the perceptions and stated intentions of the market actors who would have to implement them. Read together, the three components answer three different questions: the model establishes what is

financially true, the case study establishes that it holds for a real asset, and the survey establishes whether the market recognizes it and would act on it.

The investment horizon is set at 15 years, reflecting typical office asset cycles in the GCC and the time required for carbon price appreciation to materially affect returns. All cash flows are expressed in real terms, and a real discount rate of 8% is used as the base unlevered hurdle for Saudi commercial real estate, which is tested at 6%, 10%, and 12% in Section 3.6.

3.3 Data Sources and Key Assumptions

Parameter	Value Used	Source	Sensitivity Range Tested
EUI Baseline (Riyadh Zone 1B)	300 kWh/m ² /yr	SEEC (2024)	280–320
EUI Post-Retrofit Target	195 kWh/m ² /yr	SEEC Benchmark (35% reduction)	28%-42% (±20%)
Saudi Grid Emission Factor (GEF)	0.58 kgCO ₂ e/kWh	SEEC / UNFCCC CDM-DNA (2024)	0.46-0.70 (±20%); see Note 1
RVCM Carbon Price (base year)	SAR 37.50/tCO ₂ e	RVCMC 3rd Auction / Exchange (2024)	SAR 30.00-45.00 (±20%)
Commercial Electricity Tariff	SAR 0.18/kWh	Saudi Electricity Company (2024)	SAR 0.144-0.216 (±20%); case: 0.262 actual
MRV Cost - Single Building	SAR 60,000/yr	PwC Middle East (2024)	±20% (SAR 48k- 72k)
MRV Cost - PoA Portfolio	SAR 85,000/yr	PwC Middle East (2024)	±20% (SAR 68k- 102k)
CAPEX - Low / Mid / High	SAR 150 / 225 / 300/m ²	GCC vendor quotations (author's compilation, 2024–2025)	±20% on each tier
Real Discount Rate (unlevered)	8% real	GCC commercial real estate practice (author's assumption)	6% / 10% / 12%

Table 3-1: Model Input Parameters and Data Sources

Note 1 — GEF Methodology: This study uses 0.58 kgCO₂e/kWh as published by SEEC and adopted by Saudi Arabia's CDM Designated National Authority (CDMDNA) for carbon credit registration. The IEA Life Cycle Upstream Emission Factors (2024) report a lower figure of 0.52 kgCO₂e/kWh using a fuel-cycle-only boundary that excludes direct combustion emissions at the generation point. For CDM/VCm project registration purposes, the SEEC/CDMDNA factor of 0.58 is the authoritative standard and is used throughout. Sensitivity implications are noted in Section 1.9.

3.4 Carbon Yield Calculation

Energy savings are converted into tradeable carbon assets using CDM Methodology AMS-II.E, the internationally recognized standard for energy efficiency in buildings. Equations 1 to 7 below produce the operating results; Equations 8 to 10 convert those results into the investment measures used to judge whether a configuration is worth funding.

$$\text{Eq. 1 : } E_{\text{saved}} = \text{Area} \times (EUI_{\text{base}} - EUI_{\text{target}}) \quad [\text{kWh/year}]$$

$$\text{Eq. 2 : } CER = E_{\text{saved}} \times \frac{GEF}{1000} \quad [\text{tCO}_2\text{e/year}]$$

$$\text{Eq. 3 : } \text{Carbon Revenue} = CER \times P_{\text{carbon}} \quad [\text{SAR/year}]$$

$$\text{Eq. 4 : } \text{OPEX Savings} = E_{\text{saved}} \times \text{Electricity Tariff} \quad [\text{SAR/year}]$$

$$\text{Eq. 5 : } \text{Net Cash Flow} = (\text{Carbon Rev} + \text{OPEX}) - \text{MRV} \quad [\text{SAR/year}]$$

$$\text{Eq. 6 : } SPP = \frac{CAPEX_{\text{total}}}{\text{Net Cash Flow}} \quad [\text{years}]$$

$$\text{Eq. 7 : } ROI_N = \frac{[(NCF \times N) - CAPEX]}{CAPEX} \times 100 \quad [\%]$$

3.4.1 Investment Appraisal and Decision Criteria

Equations 1 to 7 establish whether a configuration generates cash. They do not establish whether it is worth funding, because they take no account of the time value of money. Three further measures are therefore applied, each evaluated over the 15-year horizon at the real discount rate of 8% specified in Section 3.3.

$$\text{Eq. 8 : } NPV = \sum (t = 1 \text{ to } N) [NCF_t \div (1 + r)^t] - CAPEX \quad [\text{SAR}]$$

$$\text{Eq. 9 : } IRR = \text{the rate } r^* \text{ at which } \sum (t = 1 \text{ to } N) [NCF_t \div (1 + r^*)^t] - CAPEX = 0 \quad [\%]$$

$$\text{Eq. 10 : } DPP = \text{the smallest } T \text{ for which } \sum (t = 1 \text{ to } T) [NCF_t \div (1 + r)^t] \geq CAPEX \quad [\text{years}]$$

where $N = 15$ years, $r = 0.08$ real, and NCF_t is the net cash flow of year t as defined in Eq. 5. Where net cash flow is not constant across the horizon, the Simple Payback Period of Eq. 6 is likewise evaluated as the smallest T for which $\sum (t = 1 \text{ to } T) NCF_t \geq CAPEX$. This applies to Scenario C, where NCF takes the subsidized value in Years 1–5 and the unsubsidized value in Years 6–15, and to Scenario D, where it is stated net of debt service.

$$\text{Eq. 11 : } MRV \text{ per tonne} = MRV_{\text{poa}} \div \sum CER_i \quad [\text{SAR/tCO}_2\text{e}]$$

$$\text{Eq. 12 : } \text{Break-even condition: } \sum CER_i \geq MRV_{\text{poa}} \div P_{\text{carbon}} \quad [\text{tCO}_2\text{e/year}]$$

Equation 12 states the aggregation threshold that Section 4.1.3 measures. At current parameters it resolves to $\text{SAR } 85,000 \div \text{SAR } 37.50 = 2,267 \text{ tCO}_2\text{e per year}$, equivalent to four benchmark offices of $10,000 \text{ m}^2$ yielding $609 \text{ tCO}_2\text{e}$ each, or five case-profile offices of $17,615 \text{ m}^2$ yielding $527 \text{ tCO}_2\text{e}$ each.

Expressing the threshold in tonnes rather than in building counts keeps it valid across any mix of assets and any future movement in the audit fee or the carbon price.

A configuration is reported as viable in this study only where it satisfies all three of the following criteria simultaneously: (i) NPV greater than zero at 8% real; (ii) IRR of at least 8%, the base unlevered hurdle for Saudi commercial office assets; and (iii) discounted payback of 12 years or less, within the 15-year asset cycle with margin for execution risk. Configurations returning positive undiscounted cash but failing any one of the three are reported as marginal rather than viable, and this distinction separates the amber from the green classifications in Table 4-10.

Two boundary conditions apply throughout. First, net cash flow is modeled net of MRV cost only; recurring PoA administration, BMS licensing and incremental planned maintenance are excluded, so the model states an upper bound on net operating benefit. Second, ROI, NPV and IRR are computed at the Year 1 carbon price of SAR 37.50/tCO_{2e}. The appreciation path of Section 4.1.8 is applied only where explicitly stated, so all headline returns understate the outcome under any rising-price scenario.

3.5 Scenario Definitions

- **Scenario A - Single Building (Baseline):** Each building prototype (10,000 m² and 30,000 m²) bears the full SAR 60,000 MRV cost independently. Tests H1.
- **Scenario B - Aggregated Portfolio (Business Solution):** 10 buildings (7 small + 3 large, 160,000 m²) under a shared RVCMC PoA with SAR 85,000 MRV cost. Tests H2.
- **Scenario C - Subsidized Portfolio (Vision 2030 Policy Solution):** As Scenario B but with MRV costs fully subsidized in Years 1–5, reverting to SAR 85,000 in Years 6–15. Tests H3 and models the proposed SGI Verification Fund.
- **Scenario D - SGI Green Retrofit Facility (Policy Extension):** As Scenario C, with portfolio CAPEX additionally financed in full through a zero-interest government-backed loan repaid in equal principal installments, and with continued concessional terms conditional on an annual performance review: verified energy savings of at least 80% of target — evidenced by the same third-party MRV report that mints the carbon credits — retain the 0% rate, while underperformance triggers a step-up to the commercial benchmark rate. Extends the H3 policy analysis by targeting the CAPEX barrier directly.

Pathway mapping: Scenarios A and B operationalize Pathway 1 (self-investment) of the framework in Section 2.2.3; Scenarios C and D operationalize Pathway 2 (government-enabled financing); and the shared-PoA structure underlying Scenarios B–D operationalizes Pathway 3 (group transition), including its multi-company consortium variant.

3.6 Sensitivity Analysis

Testing only the carbon price would present a misleading picture of where the risk in this investment actually sits. The sensitivity analysis therefore varies six model drivers, one at a time, by $\pm 20\%$ around their base values, holding everything else constant: the achieved EUI reduction, the electricity tariff, the capital expenditure rate, the grid emission factor, the carbon price, and the MRV verification cost. Each run is re-evaluated on the ten-building portfolio at low CAPEX, and the drivers are then ranked by how far they move net present value. The carbon price band of SAR 30.00 to SAR 45.00 per tCO₂e is retained as a separate table because it answers the specific market question practitioners ask most often.

The discount rate is treated separately from the six drivers because it is an appraisal convention chosen by the analyst rather than a market variable observed in the world. It is tested at 6%, 8%, 10%, and 12% real to establish the hurdle rate above which the investment case stops working. Finally, the carbon price appreciation path of Section 4.1.8 is run as a conditional scenario, not as a forecast: it shows what the portfolio would earn if a particular price trajectory materialized, and its results are labeled accordingly.

3.7 Model Validation

Model outputs are checked against 5 independent benchmarks: (1) JLL (2024) In the GCC, energy retrofit benchmarks indicate payback periods of between 5 and 8 years for large commercial buildings. This is in line with the model's SPP of 7.8 years for the large building at a low CAPEX. (2) PwC Middle East (2024) MRV cost estimates of SAR 40,000-80,000 in line with SAR 60,000 midpoint used. Third, the IEA (2025) MENA building efficiency analysis estimates potential reductions in peak demand of 35 GW from improved AC efficiency, providing macro-level validation that the 35% EUI reduction assumed in this model is both feasible and material at scale. Fourth, the carbon emission offsets projected by the portfolio model (9,744 tCO₂e/year) are validated against Krarti et al.'s (2017) national-scale finding that basic building retrofits across Saudi Arabia produce 7.611 million tCO₂e/year: the 160,000 m² portfolio (approximately 0.13% of modelled floor area) should yield around 9,900 tCO₂e, consistent with the model's 9,744 tonne output. Fifth, and most distinctively, the model's structural logic is retested against a real Riyadh Grade A commercial building using 23 months of actual metered electricity data supplied by the building's FM Contractor (Section 4.1.10), confirming that the viability gap, the aggregation dilution mechanism, and the policy leverage ratio all hold under real operating conditions. The validation exercise is not treated as a formality. Where the case data

contradicted a prototype magnitude, the prototype result was restated rather than defended, and Section 4.1.10.4 records each of those reconciliations openly.

3.8 Primary Data Collection — Survey of FM Professionals

3.8.1 Purpose and Position in the Research Design

The survey component tests hypotheses H5 and H6 and triangulates the model-derived findings (H1–H3) against practitioner perception and stated behavioral intent. It does not attempt to collect confidential financial data; the constraint that motivated the deterministic modeling approach remains, but instead measures what the financial model cannot: whether the market actors who control Saudi Arabia's commercial building stock perceive the MRV barrier, whether they would accept aggregation under a shared PoA, and whether the proposed policy instruments would change their participation decisions.

3.8.2 Target Population and Sampling

The target population comprises FM professionals, energy and sustainability managers, asset owners, developers, and institutional investors active in the Saudi commercial office sector. The sampling frame is constructed through three channels:

- The professional network of the Middle East Facility Management Association (MEFMA) and comparable industry bodies.
- FM and office/property professional groups on LinkedIn with Saudi membership.
- Direct professional contacts within FM service providers and office-owning companies operating in Riyadh, Jeddah, and the Eastern Province.

A non-probability purposive sampling strategy with snowball extension is adopted, an approach appropriate where the population is specialized, geographically concentrated, and not enumerable through a public register. The target sample size is 100 completed responses with a minimum analytical threshold of 60 which is similar to typical sample sizes in similar GCC perception studies of the built environment (Al-Surf & Al-Fagih, 2024) and the generally accepted power to detect medium effects (Cohen, 1988). Data were collected within 4–6 weeks via a bilingual (English/Arabic) online questionnaire on a secured survey platform.

3.8.3 Instrument Design and Construct Mapping

The instrument (Appendix A) is deliberately concise: 19 items organized into six sections, with an estimated completion time of 5–6 minutes. Instrument brevity is a methodological decision, not a compromise: response and completion rates among senior FM and office-sector professionals decline sharply beyond 7–8 minutes, and every retained item either tests a hypothesis directly or characterizes

the sample. Perception items use 5-point Likert scales (1 = Strongly Disagree, 5 = Strongly Agree); profile and design-preference items use categorical formats. The analytical core is the three-scenario intent block (Section D of the instrument), which presents identical participation decisions under standalone, aggregated, and aggregated-plus-subsidized conditions, enabling within-subject paired comparison. Each section maps to a specific construct in the conceptual framework:

Section	Items	Construct Measured	Theoretical Anchor	Hypothesis Link
A	4	Professional profile & portfolio scale	Sample characterization	Moderators
B	4	Contract practice, MRV data readiness, RVCMC awareness, split incentive	MEFMA (2023); Agency Theory; Belaïd (2025)	H1 context
C	3	MRV cost & capability barriers	Transaction Cost Economics	H5
D	3	Participation intent under three scenarios (standalone / aggregated / subsidized)	Coasian correction; SGI activation	H6 (H2, H3)
E	3	PoA governance preferences & policy ranking	Market design	Recommendations
F	2	Carbon asset appreciation & retrofit business case	WEF (2024); CBAM demand	H4 triangulation

Table 3-2: Survey Construct Mapping

3.8.4 Validity, Reliability, and Ethics

Content validity is established through expert review of the draft instrument by two FM industry practitioners and the academic supervisor prior to distribution, followed by a pilot test with 5–8 respondents to confirm clarity and completion time (target: under 7 minutes). Internal consistency of each multi-item construct is assessed using Cronbach's alpha, with a threshold of $\alpha \geq 0.70$ (Nunnally & Bernstein, 1994). The questionnaire opens with an informed consent statement confirming voluntary participation, anonymity, aggregate-only reporting, and the academic purpose of the study under Midocean University supervision; no personally identifying or commercially confidential financial data is collected.

3.8.5 Analysis Plan

- **Descriptive statistics:** means, standard deviations, medians, and interquartile ranges for all Likert items, together with frequency distributions; sample profile cross-tabulated by organization type and portfolio scale. Medians and interquartile ranges are reported alongside means because the hypothesis tests evaluate the location of ordinal distributions, for which the median is the appropriate descriptive counterpart.

- **H5 test:** a one-sample Wilcoxon signed-rank test of the location of the MRV-barrier construct against the 3.5 benchmark, supported by the distribution of barrier rankings. The hypothesis is framed in terms of distribution location rather than the mean so that the stated proposition and the test statistic refer to the same parameter.
- **H6 test:** paired-sample comparisons of stated participation intent under three conditions standalone (D1), aggregated PoA (D2), and aggregated-plus-subsidized (D3) using the Wilcoxon signed-rank test for ordinal paired data at $p < 0.05$. Because the three comparisons are drawn from the same 29 respondents, the family-wise error rate is controlled using the Holm-Bonferroni procedure (Holm, 1979). For every comparison, the study reports the median and interquartile range, the test statistic W , the exact one-tailed p value, the Holm-adjusted p value, and the effect size r , calculated as Z divided by the square root of n (Rosenthal, 1991).
- **Triangulation analysis:** Spearman correlations between RVCMC awareness (B3), perceived barriers (Section C), and participation intent (Section D); group comparison between FM providers and asset owners using the Mann Whitney U test to detect principal-agent perception differences predicted by Agency Theory.
- **Convergence assessment:** survey findings are read alongside the model outputs in Chapter Five. Convergence, where practitioners perceive what the model computes, strengthens the recommendation set. Divergence, such as low awareness despite viable economics, is itself a finding rather than a failure, indicating that the informational gap documented by Belaïd (2025) operates alongside, and in this case ahead of, the transaction-cost barrier. Given the achieved sample of 29 and the marginal reliability of the two-item barrier construct, all survey results are reported as exploratory and indicative, and no inferences are drawn beyond the sample.

Chapter Four

Findings and Analysis: Financial Model, Case Study, and Survey

4.1 Financial Model and Findings

This section presents the complete financial model outputs across all scenarios, building prototypes and CAPEX levels. Findings are sequenced to answer the research questions and verify the hypotheses, with explicit linkage to Vision 2030 policy implications at each stage. Two questions are kept apart throughout, in line with the decision criteria set out in Section 3.4.1: whether the carbon transaction alone pays for itself and whether the retrofit investment as a whole is worth funding. The prototype-based analysis (Sections 4.1.1-4.1.9) is then independently validated against a real Riyadh case study building using actual metered data (Section 4.1.10). Throughout, the scenarios operationalize the Three-Pathways Investment Framework of Section 2.2.3: Scenarios A-B quantify the self-investment pathway, Scenarios C-D the government-enabled pathway, and the shared-PoA structure common to Scenarios B-D the group-transition pathway. The chapter closes with the survey findings (Section 4.1.11), which test H5 and H6 against practitioner perception and stated intent.

4.1.1 Building Prototype Specifications

Parameter	Small Office — Grade B	Large Office — Grade A
Gross Leasable Area	10,000 m ²	30,000 m ²
EUI Baseline (SEEC Zone 1B)	300 kWh/m ² /yr	300 kWh/m ² /yr
EUI post-retrofit (35% reduction)	195 kWh/m ² /yr	195 kWh/m ² /yr
Annual Energy Saved	1,050,000 kWh	3,150,000 kWh
Annual CER Yield (GEF: 0.58)	609 tCO ₂ e	1,827 tCO ₂ e
Annual Carbon Revenue SAR 37.50	SAR 22,838	SAR 68,513
Annual OPEX Savings SAR 0.18/kWh	SAR 189,000	SAR 567,000
Total Annual Inflow	SAR 211,838	SAR 635,513
MRV Cost (standalone)	SAR 60,000	SAR 60,000
Net Cash Flow (standalone)	SAR 151,838	SAR 575,513
Carbon Revenue as % of MRV Cost	38% - DEFICIT	114% COVERS MRV

Table 4-1: Annual Operating Profile — Building Prototypes

► *Vision 2030 Context: KAPSARC research indicates that simple building retrofits at the national scale can reduce 7.611 million tCO₂e per year (Krarti et al., 2017)—2.7% of the SGI's 278 million-tonne goal. Here, the modeled 35% reduction in EUI is above the basic level threshold, placing the prototypes in the top efficiency tier of the study. Building energy efficiency programs can also cut national electricity use by as much as 27%, the largest single sectoral contribution to the NDC targets. The 35% EUI reduction modeled here exceeds this national average, positioning these buildings in the top efficiency tier of Saudi Arabia's built environment transformation.*

4.1.2 Scenario A: Single Building Analysis — H1 Test

Both prototypes generate positive net cash flow once OPEX savings are included. The critical finding for H1, however, concerns the carbon transaction on its own: the small building's carbon revenue of SAR 22,838 covers only 38% of the SAR 60,000 estimated verification cost, leaving an annual carbon-only shortfall of SAR 37,162. Where tenants pay all utility costs and the landlord cannot capture OPEX savings, participation is financially unviable. H1 is confirmed.

Scenario A	CAPEX Low (SAR 150/m ²)	CAPEX Mid (SAR 225/m ²)	CAPEX High (SAR 300/m ²)
SMALL BUILDING — 10,000 m²			
Total CAPEX	SAR 1,500,000	SAR 2,250,000	SAR 3,000,000
Annual Net Cash Flow	SAR 151,838	SAR 151,838	SAR 151,838
Simple Payback Period	9.9 years	14.8 years	19.8 years
10-Year ROI	+1.2%	-32.5%	-49.4%
15-Year ROI	+51.8%	+1.2%	-24.1%
LARGE BUILDING — 30,000 m²			
Total CAPEX	SAR 4,500,000	SAR 6,750,000	SAR 9,000,000
Annual Net Cash Flow	SAR 575,513	SAR 575,513	SAR 575,513
Simple Payback Period	7.8 years	11.7 years	15.6 years
10-Year ROI	+27.9%	-14.7%	-36.1%
15-Year ROI	+91.8%	+27.9%	-4.1%

Table 4-2: Scenario A — Single Building

Note: A 15-year horizon reflects GCC office asset cycles. H1 is confirmed: carbon-only revenue does not cover MRV costs for small buildings, confirming that individual participation without policy support cannot achieve Vision 2030's built-environment contribution targets on scale.

Applying the full decision criteria of Section 3.4.1 gives a more sober reading than payback alone. At an 8% real discount rate the small standalone building returns to a negative net present value at every CAPEX tier (SAR -200,346 at low CAPEX, falling to SAR -1,700,346 at high), with an internal rate of return of 5.7% at low CAPEX. The large standalone building clears the bar only at low CAPEX, with an NPV of SAR 426,091, an IRR of 9.5% and a discounted payback of 12.8 years - marginally outside the twelve-year criterion. In other words, the undiscounted returns reported above are arithmetically correct but should not be read as evidence of viability: once the time value of money is

applied, no standalone configuration in Scenario A fully satisfies the three-part test. This is the quantitative reason the study turns to aggregation.

4.1.3 MRV Cost Dilution: The Core Aggregation Mechanism — H2 Test

This table is the mathematical centerpiece of the research: it shows exactly at what portfolio scale the Vision 2030 carbon opportunity becomes commercially viable. The break-even condition is straightforward. The shared audit costs SAR 85,000 and each verified tonne is worth SAR 37.50, so the program covers its own verification once it produces 2,267 tonnes a year.

Portfolio Configuration	Total GLA	Total CERs/yr	MRV Cost	MRV SAR/tonne	vs Carbon Price
1 small building	10,000 m ²	609 t	SAR 60,000	SAR 98.52	2.63× price
2 small buildings	20,000 m ²	1,218 t	SAR 85,000	SAR 69.79	1.86× price
3 small buildings	30,000 m ²	1,827 t	SAR 85,000	SAR 46.52	1.24× price — still above
4 small buildings → BREAK-EVEN	40,000 m ²	2,436 t	SAR 85,000	SAR 34.89	0.93× price — first below
5 small + 1 large	80,000 m ²	4,872 t	SAR 85,000	SAR 17.45	0.47× price
7 small + 3 large (full portfolio)	160,000 m ²	9,744 t	SAR 85,000	SAR 8.72	0.23× price
10 case-type buildings (metered)	176,150 m ²	5,270 t	SAR 85,000	SAR 16.13	0.43× price

Table 4-3: MRV Cost Dilution as Portfolio Grows — The Aggregation Advantage

Key threshold: the break-even point is four buildings, not three. Three benchmark offices yield 1,827 tonnes and a verification cost of SAR 46.52 per tonne, which remains 24% above the carbon price. Four buildings yield 2,436 tonnes at SAR 34.89 per tonne — the first configuration to fall below the price line. Beyond that point the advantage compounds quickly: at the full ten-building portfolio, MRV represents only 23% of the carbon price. The threshold is best expressed in tonnes rather than in buildings, because 2,267 tCO₂e per year holds whatever mix of assets an owner brings, whereas the building count depends on how efficient those assets already are. The metered case portfolio makes the point concretely: because the real building is already efficient, ten such assets yield only 5,270 tonnes and a verification cost of SAR 16.13 per tonne - still comfortably viable, but higher on the dilution curve than the benchmark portfolio. What dilutes verification cost is credit density, not floor area.

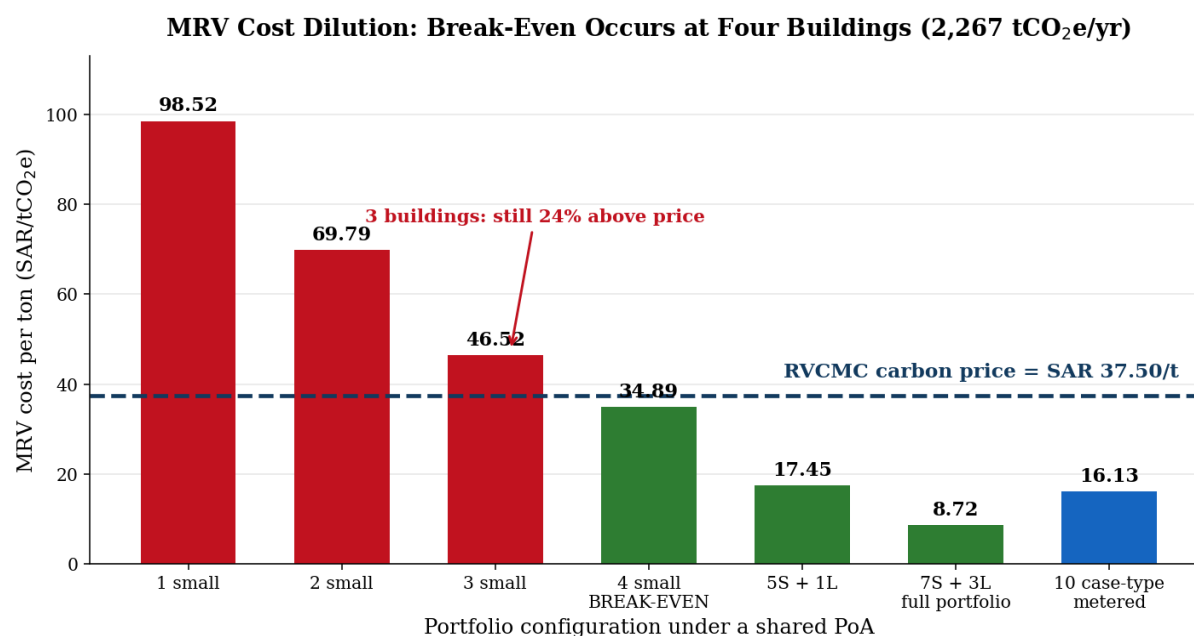


Figure 4-1: MRV Cost Dilution across Portfolio Configurations

4.1.4 Scenario B: Aggregated Portfolio — H2 Test

Metric	Low CAPEX (SAR 150/m ²)	Mid CAPEX (SAR 225/m ²)	High CAPEX (SAR 300/m ²)
Total Portfolio CAPEX	SAR 24,000,000	SAR 36,000,000	SAR 48,000,000
Annual Carbon Revenue	SAR 365,400	SAR 365,400	SAR 365,400
Annual OPEX Savings	SAR 3,024,000	SAR 3,024,000	SAR 3,024,000
Annual MRV Cost (shared PoA)	SAR 85,000	SAR 85,000	SAR 85,000
Annual Net Cash Flow	SAR 3,304,400	SAR 3,304,400	SAR 3,304,400
Simple Payback Period	7.3 years	10.9 years	14.5 years
10-Year ROI	+37.7%	-8.2%	-31.2%
15-Year ROI	+106.5%	+37.7%	+3.3%
Break-Even Year	Year 8	Year 11	Year 15
Net Present Value at 8% real	SAR +4,283,941	SAR -7,716,059	SAR -19,716,059
Internal Rate of Return	10.8%	4.3%	0.4%
Discounted Payback Period	11.3 years	Beyond 15 years	Beyond 15 years
Passes three-part viability test?	Yes	No — fails NPV	No — fails NPV

Table 4-4: Scenario B — Aggregated Portfolio Financial Results

H2 Verdict: Confirmed, but conditionally rather than in full, and the distinction matters. The first limb of the hypothesis holds without qualification: the ten-building portfolio delivers a positive fifteen-year return under every CAPEX scenario, reaching 106.5% at low CAPEX against private developer hurdle rates of 15-20%. The second limb, that verification cost falls below SAR 10 per tonne, holds in the benchmark portfolio at SAR 8.72 but not in the metered case portfolio, which reaches only SAR 16.13 (Section 4.1.10.3). The sub-SAR-10 figure is therefore a property of average-efficiency stock, not a general result, and should not be quoted as a universal threshold. The discounted results add a second qualification. Once an 8% real discount rate is applied, only the low-CAPEX portfolio satisfies the full three-part criterion of Section 3.4.1, with an NPV of SAR 4.28 million, an IRR of 10.8% and a discounted payback of 11.3 years. The mid-CAPEX portfolio, despite a positive undiscounted return of 37.7%, has a net present value of SAR –7.7 million and an IRR of 4.3%, below any plausible commercial hurdle. The honest statement of H2 is therefore this: aggregation reliably solves the verification problem, and it makes the retrofit fundable where capital costs are contained, but it does not by itself rescue an expensive retrofit.

4.1.5 Scenario C: Subsidized Portfolio — Vision 2030 SGI Policy Tool (H3 Test)

Metric	Sc-B: No Subsidy (Low)	Sc-C: 5-Yr Subsidy (Low)	Improvement
NCF Years 1–5	SAR 3,304,400/yr	SAR 3,389,400/yr	+SAR 85,000/yr
NCF Years 6–15	SAR 3,304,400/yr	SAR 3,304,400/yr	No change
Simple Payback Period	7.3 years	7.1 years	–0.2 years
10-Year ROI	+37.7%	+39.5%	+1.8 pp
15-Year ROI	+106.5%	+108.3%	+1.8 pp
Net Present Value at 8% real	SAR +4,283,941	SAR +4,623,322	+SAR 339,381
Total Govt. Subsidy Cost (5 yrs)	—	SAR 425,000	
Private Investment Mobilized	—	SAR 24,000,000	
Policy Leverage Ratio	—	56:1	

Table 4-5: Scenario C — 5-Year SGI MRV Subsidy Impact (Low CAPEX)

H3 Verdict: Confirmed. The five-year MRV subsidy reduces payback by 0.2 years, improves 10-year ROI by 1.8 percentage points and lifts net present value by SAR 339,381. The policy leverage ratio of 56:1 is the critical finding: SAR 425,000 of government subsidy mobilizes SAR 24,000,000 of private retrofit investment. Scaled to 100 FM portfolios across Riyadh’s commercial stock, a SAR 42.5 million

SGI Verification Fund would mobilize SAR 2.4 billion in private investment, abating about 974,400 tCO_{2e} annually, or 0.35% of the SGI's 278 million tonne target, achieved almost entirely through private capital. The instrument is highly leveraged but weakly felt at project level, and Section 4.1.6 explains why: the binding constraint is capital, not verification.

4.1.6 Scenario D: The SGI Green Retrofit Facility - Removing the CAPEX Barrier (H3 Policy Extension)

Scenarios A–C reveal an uncomfortable asymmetry in the policy design space: the MRV subsidy is highly leveraged (56:1) but weakly felt at the project level, shortening payback by only 0.2 years, because the binding constraint on retrofit investment is not verification cost but upfront CAPEX. Mid- and high-CAPEX portfolios remain marginal under every scenario examined so far, and all scenarios presume the investor can commit SAR 24–48 million of equity upfront a threshold that excludes most FM companies, whose balance sheets are built for service delivery, not capital deployment. Scenario D targets this constraint directly: a government-backed Green Retrofit Facility financing 100% of portfolio CAPEX at zero interest, repaid in equal principal installments, combined with the Scenario C MRV subsidy in Years 1–5.

The facility's governance mechanism is its most important design feature. It exploits infrastructure this research has already established: the annual third-party MRV verification required to mint carbon credits doubles as the loan performance covenant. Borrowers whose independently verified energy savings reach at least 80% of the contracted target retain the concessional 0% rate for the following year; underperformance triggers a step-up to the commercial benchmark rate (6% is used here, consistent with Saudi corporate lending conditions). This single-audit, dual-function design gives the lender annually verified performance data at zero marginal monitoring cost, aligns borrower incentives with genuine savings delivery, and structurally suppresses the moral hazard that undermines unconditional subsidy programs. The precedent already exists within Vision 2030's institutional architecture: Tarshid, the PIF-established national Super-ESCO, finances energy retrofits of government buildings on performance-linked terms (Tarshid, 2024) Scenario D extends this proven model to private commercial portfolios through the SGI.

Metric (10-Building Portfolio)	Low CAPEX	Mid CAPEX	High CAPEX
CAPEX financed at 0% (SAR)	24,000,000	36,000,000	48,000,000
Upfront equity required	SAR 0	SAR 0	SAR 0
Minimum viable loan tenor	8 years	11 years	15 years
Annual principal repayment (SAR)	3,000,000	3,272,727	3,200,000
Net cash Yrs 1–5, after debt service (SAR/yr)	+389,400	+116,673	+189,400
Net cash after loan maturity (SAR/yr)	3,304,400	3,304,400	3,304,400
Cumulative 15-yr net cash (SAR)	25,991,000	13,991,000	1,991,000
Implicit fiscal cost: MRV subsidy + interest concession vs 6% (SAR)	6,905,000	13,385,000	23,465,000
Fiscal cost vs equivalent CAPEX grant	29%	37%	49%
Principal recycled to revolving fund	100%	100%	100%

Table 4-6: Scenario D — SGI Green Retrofit Facility Results

Scenario D Verdict: The facility transforms the investment proposition in a way no other scenario achieves — at every CAPEX level, the portfolio becomes cash-positive from Year 1 with zero upfront equity. The binding design variable shifts from subsidy size to loan tenor 8 years suffices at low CAPEX, while high CAPEX requires the full 15-year horizon. The fiscal economics are equally striking because the principal is fully repaid and recycles through a revolving fund, the treasury's true cost is only the interest concession plus the MRV subsidy 29–49% of what an equivalent outright CAPEX grant would cost, and the same capital pool refinances a second generation of portfolios upon repayment. Read together with Scenario C, the policy conclusion sharpens: the MRV subsidy solves the verification market failure (H1), while the concessional facility solves the capital access barrier; the two instruments are complements, not substitutes, and the annual MRV review binds them into a single self-monitoring program.

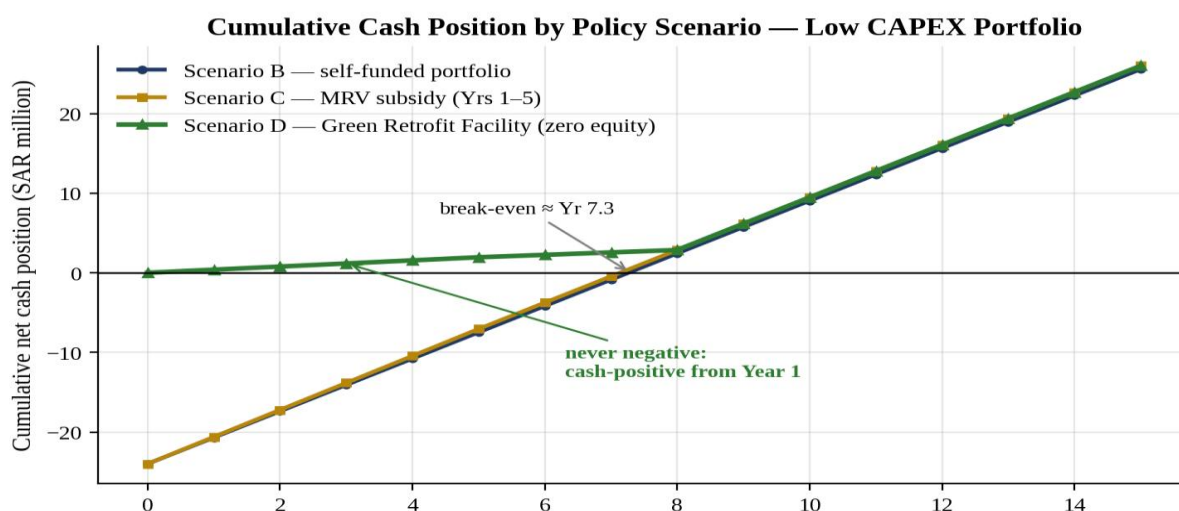


Figure 4-2: Cumulative Net Cash Position, Scenarios B, C, and D

4.1.7 Sensitivity Analysis: What Actually Drives the Result

Price Scenario	Carbon Price	Annual Carbon Rev.	Annual Net CF	SPP	15-yr ROI
Pessimistic (–20%)	SAR 30.00/t	SAR 292,320	SAR 3,231,320	11.1 yrs	+34.6%
Base Case (RVCMC 2024)	SAR 37.50/t	SAR 365,400	SAR 3,304,400	10.9 yrs	+37.7%
Optimistic (+20%)	SAR 45.00/t	SAR 438,480	SAR 3,377,480	10.7 yrs	+40.7%
V2030 2030 Target (CAGR 28.4%)	SAR 75–100/t	SAR 731k–974k	SAR 3.67M–3.91M	9.2–9.8 yrs	+53–63%

Table 4-7: Sensitivity Analysis — Carbon Price Variability (Portfolio Mid CAPEX)

Key finding: even at a 20% price decline the portfolio still delivers 34.6% over fifteen years. The dominant revenue driver is OPEX electricity savings, at SAR 3,024,000 a year or 89% of annual inflows, which makes the model robust to carbon price volatility. The Vision 2030 row illustrates what CAGR-consistent pricing would deliver by the middle of the study horizon.

Testing the carbon price alone, however, hides where the real risk sits. Table 4-8 varies six model drivers by $\pm 20\%$ around their base values, one at a time, on the low-CAPEX portfolio, and ranks them by how far each moves net present value.

Driver varied by $\pm 20\%$	NPV at –20% (SAR)	NPV at +20% (SAR)	NPV swing (SAR)	Payback range (yrs)	Rank
Achieved EUI reduction	–1,518,358	+10,086,241	11,604,599	9.1 – 6.0	1
Electricity tariff	–892,831	+9,460,714	10,353,545	8.9 – 6.1	2
Capital expenditure rate	+9,083,941	–516,059	9,600,000	5.8 – 8.7	3
Grid emission factor	+3,658,415	+4,909,468	1,251,053	7.4 – 7.1	4
Carbon price	+3,658,415	+4,909,468	1,251,053	7.4 – 7.1	5
MRV verification cost	+4,429,453	+4,138,430	291,022	7.2 – 7.3	6

Table 4-8: Multi-Variable Sensitivity of Portfolio NPV (Low CAPEX, 8% real)

The ordering is the important result, and it is not the one the carbon market literature predicts. The carbon price ranks fifth of six. The achieved saving ratio, the tariff and the capital cost each move net present value by roughly eight to nine times as much as the carbon price does. Verification cost — the barrier this entire study is about — has the smallest effect on whole-project value, which is itself the clearest confirmation of the central argument, since aggregation has already reduced that cost to a residual. The practical reading for an FM company is direct: the levers worth fighting for are the depth of the engineering saving and the price of the capital, not the price of the credit.

The discount rate is tested separately since it is an appraisal convention rather than a market variable. Portfolio net present value at low CAPEX is SAR 8,093,156 at a 6% real rate, SAR 4,283,941 at 8%, SAR 1,133,529 at 10% and SAR -1,494,179 at 12%. The configuration therefore stops working above a real hurdle of roughly 10.8%, which is precisely the internal rate of return reported in Table 4-4. An investor whose cost of capital sits above that level will not fund the retrofit on the cash flow modelled here, which is the strongest single argument for the concessional facility analyzed in Section 4.1.6.

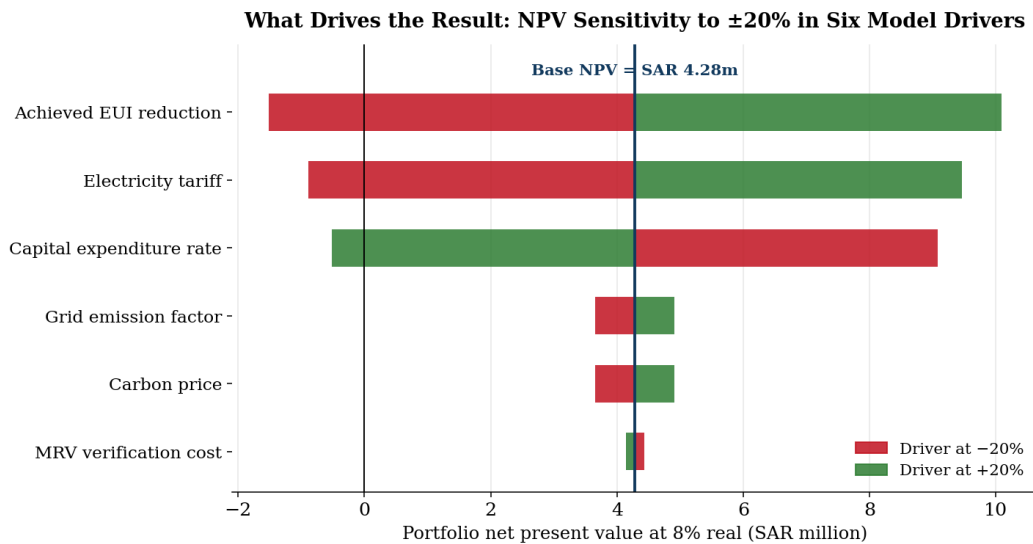


Figure 4-3: NPV Sensitivity to Six Model Drivers (Tornado Analysis)

4.1.8 Carbon Asset Appreciation: The CBAM Upside — H4 Test

This section models what the portfolio’s carbon revenue would become under a rising price scenario driven by CBAM enforcement and domestic VCM growth. It is important to be clear about what follows: this is a conditional projection, not an observed result. The Saudi VCM is projected to grow from USD 21.7 million (SAR 81.4 million) in 2023 to USD 124.6 million (SAR 467.3 million) by 2030 at a 28.4% CAGR (Grand View Research, 2025), and the price path used here is consistent with McKinsey (2025) and WEF (2024) CBAM demand projections and with strategic signals already visible in the market, including NEOM Enowa’s 30-million-tonne commitment by 2030 (Carbon Credits, 2025) and the FII-VCM partnership of October 2025 (FII Institute, 2025). Against those signals sits a genuine counter-indication: the Ecosystem Marketplace (2025) records a 29% contraction in global voluntary transaction value during 2024. Every figure in the table below except the Year 1 clearing price is therefore an assumption and is labeled as such.

Year	Projected Carbon Price	Annual Carbon Revenue	Cumulative Carbon Revenue	vs Year 1	V2030 Context
1	SAR 37.50/t	SAR 365,400	SAR 365,400	Baseline	Live exchange launched
3	SAR 45.00/t	SAR 438,480	SAR 1,193,640	+20%	VCM market scaling
5	SAR 60.00/t	SAR 584,640	SAR 2,284,968	+60%	SGI Phase 2 complete
8	SAR 96.00/t	SAR 935,424	SAR 4,701,480	+156%	CBAM full enforcement
10	SAR 130.00/t	SAR 1,266,720	SAR 7,059,528	+247%	VCM ≈ USD 100M+
12	SAR 170.00/t	SAR 1,656,480	SAR 10,177,608	+353%	Global CBAM demand peak
15	SAR 210.00/t	SAR 2,046,240	SAR 15,955,800	+460%	KSA net-zero pathway

Table 4-9: Carbon Asset Appreciation Projection — CBAM & KSA VCM Growth Trajectory (9,744 tCO₂e/yr)

Price trajectory derived from McKinsey (2025), WEF (2024), Grand View Research (2025) CAGR projections, and RVCMC market signals. Forward projections do not guarantee outcomes. The 15-year cumulative carbon revenue of SAR 15,955,800 represents 44.3% of the total mid-CAPEX portfolio investment (SAR 36,000,000).

H4 Verdict: Confirmed within the terms of the assumed price trajectory. On that path, annual carbon revenue grows 460% from SAR 365,400 to SAR 2,046,240 by Year 15, comfortably exceeding the 300% threshold set in the hypothesis, and cumulative fifteen-year carbon revenue of SAR 15,955,800 is material against any CAPEX scenario. On the same path, portfolio net present value at low CAPEX improves from SAR 4.28 million to SAR 8.75 million and the internal rate of return from 10.8% to 13.1%. The qualification is essential: this is the projection of a modelled scenario, not an empirical finding, and the appreciation depends on structural forces - CBAM legislation, Saudi VCM growth and Vision 2030's market ambition - materializing as expected. What the study can state without qualification is the downside: because carbon revenue is only 11% of inflows, even a 20% price decline leaves the portfolio returning 34.6% over fifteen years. The upside is conditional; the resilience is not.

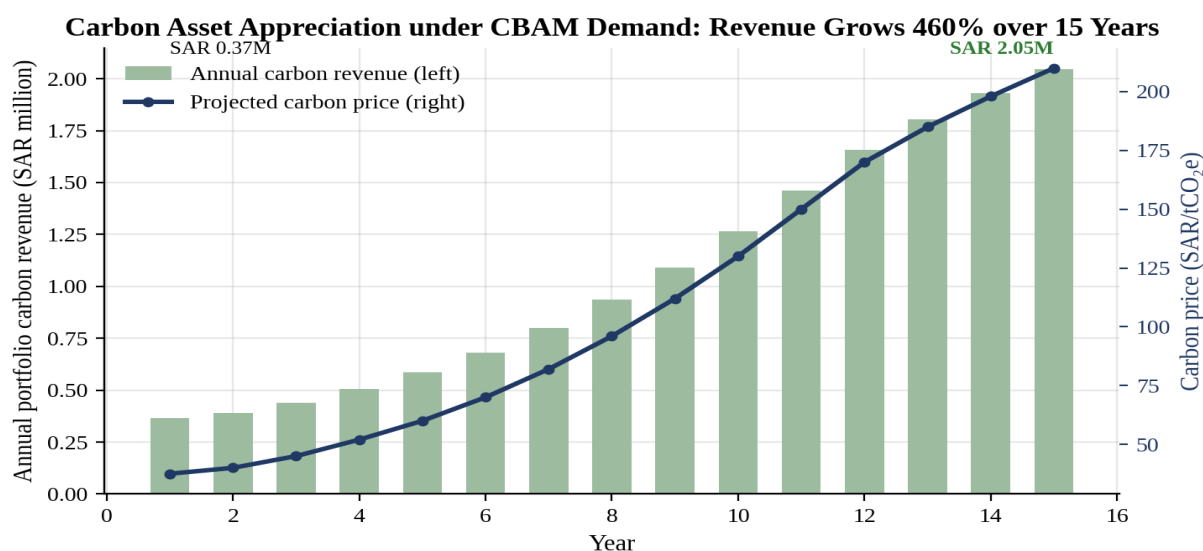


Figure 4-4: Carbon Asset Appreciation under CBAM-Driven Demand

4.1.9 Consolidated Financial Summary

Scenario	CAPEX	Total CAPEX	Annual NCF	SPP	15-yr ROI	NPV at 8% (SAR)	IRR
A: Small Standalone	Low	SAR 1.5M	SAR 151,838	9.9 yr	+51.8%	-200,346	5.7%
A: Small Standalone	Mid	SAR 2.25M	SAR 151,838	14.8 yr	+1.2%	-950,346	0.2%
A: Large Standalone	Low	SAR 4.5M	SAR 575,513	7.8 yr	+91.8%	+426,091	9.5%
A: Large Standalone	Mid	SAR 6.75M	SAR 575,513	11.7 yr	+27.9%	-1,823,909	3.2%
B: Portfolio (7S+3L)	Low	SAR 24M	SAR 3,304,400	7.3 yr	+106.5%	+4,283,941	10.8%
B: Portfolio (7S+3L)	Mid	SAR 36M	SAR 3,304,400	10.9 yr	+37.7%	-7,716,059	4.3%
B: Portfolio (7S+3L)	High	SAR 48M	SAR 3,304,400	14.5 yr	+3.3%	-19,716,059	0.4%
C: Subsidized Portfolio	Low	SAR 24M	SAR 3,389k*	7.1 yr	+108.3%	+4,623,322	11.1%
C: Subsidized Portfolio	Mid	SAR 36M	SAR 3,389k*	10.8 yr	+38.9%	-7,376,678	4.4%

Table 4-10: Consolidated Financial Summary

Reading the table: green marks configurations that satisfy all three viability tests of Section 3.4.1; amber marks those that return positive undiscounted cash but fail the net present value test; red marks those that fail outright. The addition of the NPV and IRR columns is what separates amber from green - several configurations that look acceptable on simple payback do not survive discounting.

* Sc-C NCF shown for subsidized Years 1–5. Years 6–15: SAR 3,304,400/yr.

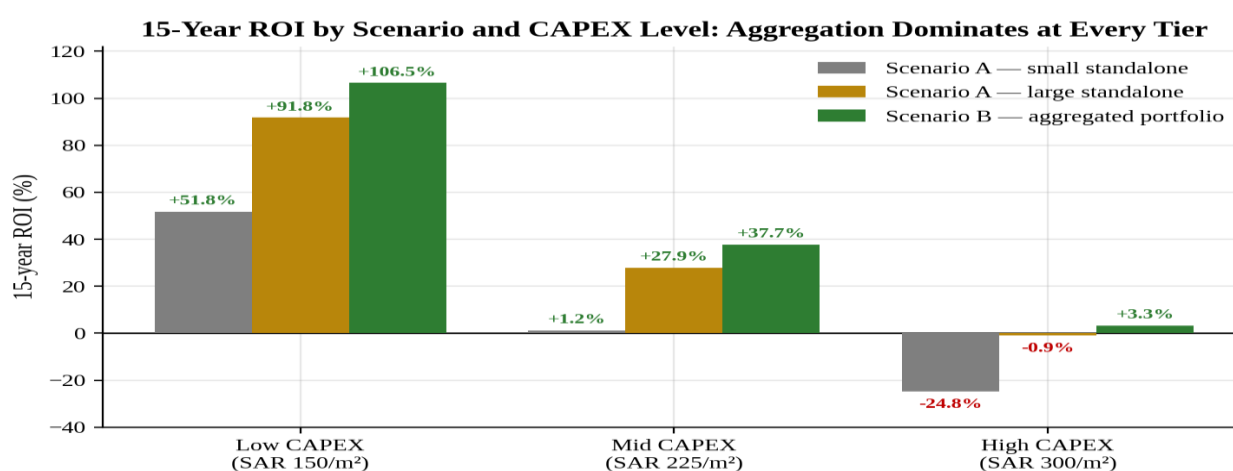


Figure 4-5: 15-Year ROI by Scenario and CAPEX Level

4.1.10 Real Case Study Validation — Telecom Headquarters Building, Riyadh

The prototype-based model in Sections 4.1.1–4.1.9 is deliberately calibrated to SEEC benchmarks so that its findings generalize across Riyadh's office stock. To test whether those findings survive contact with a real asset, this section applies the identical seven-equation model (Section 3.4) to an operating Grade A commercial building in Riyadh, using 23 months of actual metered electricity data. The case building is the headquarters of a company in the telecom sector, operated under a comprehensive facility management contract by its FM Contractor. In line with commercial confidentiality obligations, the asset is referred to throughout as the 'Telecom Headquarters' building and its operator as 'the FM Contractor'; all consumption and cost data are genuine operational records.

4.1.10.1 Case Profile and Data Provenance

The building comprises 17,615 m² of gross leasable area across ten levels (two basements, ground, mezzanine, and six upper floors) in Riyadh's ASHRAE Climate Zone 1B. Its central cooling plant — two 350 TR chillers and one 200 TR chiller in a redundant 24/7 configuration, distributing to 128 fan coil units (2–12 TR) and 34 cassette units — is the archetypal HVAC-dominant load profile this research targets. Utility data covers January 2023 to November 2024 (23 consecutive metered months), annualized for modeling. This data depth is significant in itself: MRV auditors typically require 12–24 months of verified baseline data before credits can be issued, meaning the FM Contractor's routine records already satisfy the evidentiary threshold for PoA registration.

Parameter (Actual Metered Data)	Value	Benchmark Comparison
Gross Leasable Area	17,615 m ²	Between the two prototypes
Annualized Electricity Consumption	3,028,731 kWh/yr	—
Annualized Electricity Cost	SAR 794,588/yr	—
Actual Energy Use Intensity (EUI)	171.9 kWh/m²/yr	43% below SEEC 300 benchmark
Actual Effective Tariff	SAR 0.262/kWh	46% above modelled SAR 0.18
Baseline Emissions (GEF 0.58)	1,757 tCO ₂ e/yr	—
EUI Reduction Target (case-adjusted)	30%	vs 35% for prototype stock
Data Period	Jan 2023 – Nov 2024 (23 months)	Satisfies MRV baseline requirement

Table 4-11: Case Study Operating Profile — Telecom Headquarters, Riyadh

Two divergences from the prototype assumptions are immediately material, and both carry practitioner significance. First, the building's actual EUI of 171.9 kWh/m²/yr is 43% below the SEEC Zone 1B benchmark of 300 — evidence that the asset is already professionally managed and partially optimized. The retrofit target is therefore conservatively recalibrated to a 30% EUI reduction (HVAC

optimization, BMS integration, LED transition), reflecting the smaller remaining savings pool in an already-efficient asset. Second, the actual effective tariff of SAR 0.262/kWh is 46% above the SAR 0.18 commercial tariff used in the prototype model, reflecting the consumption-tier structure of Saudi commercial billing, which materially strengthens the OPEX savings per kilowatt-hour.

4.1.10.2 Case Results - Standalone Building (H1 Retest)

Metric	Value	H1 Implication
Annual Energy Saved (30% reduction)	908,619 kWh/yr	Post-retrofit EUI: 120.4
Annual CER Yield	527 tCO ₂ e/yr	—
Annual Carbon Revenue SAR 37.50	SAR 19,762	Covers only 32.9% of MRV
Standalone MRV Cost	SAR 60,000	Carbon-only deficit: SAR 40,238/yr
MRV Cost per tCO ₂ e	SAR 113.85	3.0× the carbon price
Annual OPEX Savings SAR 0.262	SAR 238,377	Dominant inflow (92%)
Annual Net Cash Flow	SAR 198,139	Positive only via OPEX
SPP / 15-yr ROI (Low CAPEX, SAR 2.64M)	13.3 yrs / +12.5%	Marginal within horizon
SPP / 15-yr ROI (Mid CAPEX, SAR 3.96M)	20.0 yrs / -25.0%	Unviable
SPP / 15-yr ROI (High CAPEX, SAR 5.28M)	26.7 yrs / -43.8%	Unviable

Table 4-12: Case Study Scenario A

H1 Retest Verdict: Confirmed more strongly than in the prototype. With real data, carbon revenue covers only 32.9% of standalone MRV cost (versus 38% for the prototype), and the standalone MRV burden of SAR 113.85 per tonne is three times the carbon price. Because the building is already efficient, its absolute savings pool is smaller, lengthening payback to 13.3 years even at low CAPEX. The real building therefore represents the conservative floor of the investment case: the viability gap is real, measurable in an operating Riyadh asset, and cannot be closed at the single-building level.

4.1.10.3 Case Results — 10-Building PoA Portfolio (H2, H3, H4 Retests)

Consistent with Scenario B, the case is scaled to a portfolio of 10 buildings of similar profile under a shared PoA the realistic situation of an FM Contractor managing multiple comparable commercial assets across Riyadh.

Metric (10-Building PoA, Actual Profile)	Value	Hypothesis Implication
Total Portfolio GLA	176,150 m ²	—
Total Annual Energy Saved	9,086,193 kWh/yr	—
Total Annual CER Yield	5,270 tCO ₂ e/yr	—
Shared PoA MRV Cost	SAR 85,000/yr	—
MRV Cost per tCO₂e	SAR 16.13	H2: 43% of carbon price — viable
Annual Carbon Revenue	SAR 197,625	—
Annual OPEX Savings	SAR 2,383,765	92% of inflows
Annual Net Cash Flow	SAR 2,496,390	—
SPP / 15-yr ROI (Low CAPEX, SAR 26.4M)	10.6 yrs / +41.7%	H2: positive within horizon
5-yr Subsidy: SPP / Leverage Ratio	10.4 yrs / 62:1	H3: exceeds prototype 56:1
Sensitivity: NCF at ±20% carbon price	SAR 2.46M – 2.54M	OPEX-dominated robustness
Carbon Revenue Year 1 → Year 15 (CBAM)	SAR 197,625 → 1,106,698	H4: +460% growth confirmed

Table 4-13: Case Study Scenarios B and C

H2, H3 and H4 Retest Verdicts: all confirmed, with one important refinement to H2. Aggregation dilutes MRV costs from SAR 113.85 to SAR 16.13 per tonne, a sevenfold reduction that decisively carries the cost below the SAR 37.50 carbon price. The case figure sits above the prototype's SAR 8.72 for one instructive reason: the case building's superior baseline efficiency yields fewer credits over which to spread the fixed cost. The same logic moves the break-even point. Because each case-type building produces 527 tonnes rather than 609, the portfolio needs five such assets to reach the 2,267-tonne break-even threshold, against four benchmark offices; four case-type buildings yield 2,108 tonnes at SAR 40.32 per tonne, still fractionally above the price. The SAR 10 threshold specified in H2 is therefore a property of average-efficiency stock with an EUI near 300; portfolios of already-efficient assets clear the viability bar comfortably but land higher on the dilution curve and need one more building to get there. The policy leverage ratio rises to 62:1 against the prototype's 56:1 because the same subsidy accompanies a larger CAPEX base, and the CBAM appreciation trajectory delivers an identical +460% growth, since price appreciation is independent of building efficiency.

Scenario D applied to the case portfolio: Financing the FM Contractor portfolio's SAR 26.4 million CAPEX through the Green Retrofit Facility yields a minimum viable tenor of 11 years (annual repayment SAR 2.40 million against a subsidized NCF of SAR 2.58 million), leaving the operator cash-positive from Year 1 approximately SAR 179,000 per year in Years 1–5 and SAR 94,000 per year through loan maturity with zero upfront equity, before rising to the full SAR 2.50 million once the

loan retires. The already-efficient case building again defines the conservative floor: its lower credit and savings density stretch the required tenor from 8 years (prototype) to 11, confirming that facility tenor should be calibrated to portfolio EUI profile a design parameter the annual MRV review makes directly observable to the lender.

4.1.10.4 Prototype–Case Reconciliation

Dimension	Prototype Model	Real Case Study	Interpretation
Baseline EUI (kWh/m ² /yr)	300 (SEEC)	171.9 (actual)	Case already 43% optimized
Electricity Tariff (SAR/kWh)	0.18	0.262	Real OPEX savings stronger per kWh
Carbon Revenue vs MRV (standalone)	38%	32.9%	H1 confirmed in both
MRV SAR/tonne (10-bldg PoA)	8.72	16.13	Both below SAR 37.50 price — H2 holds
Portfolio 15-yr ROI (Low CAPEX)	+106.5%	+41.7%	Case = conservative floor
Policy Leverage Ratio	56:1	62:1	H3 confirmed in both
Carbon Revenue Growth (15 yrs)	+460%	+460%	H4: price-driven, efficiency-independent
Break-even portfolio size	4 buildings (40,000 m ²)	5 buildings (88,075 m ²)	Threshold is 2,267 t/yr in both
NPV at 8% real, portfolio low CAPEX	SAR +4,283,941	SAR –5,054,703	Case fails the NPV test

Table 4-14: Prototype Model vs Real Case Study

4.1.10.5 Practitioner Insights from the Case

Beyond hypothesis validation, the case yields four insights of direct operational value to FM executives structuring PoA portfolios:

- **Portfolio selection should prioritize high-EUI assets:** The case demonstrates a selection effect: already-efficient buildings generate fewer credits and longer paybacks. An FM contractor assembling a PoA should sequence high-EUI assets (250–350 kWh/m²/yr) first to maximize credit density and shorten portfolio payback, adding efficient assets later for scale. The case building at EUI 171.9 represents the least favorable candidate profile, and the portfolio still clears viability; typical Riyadh stock will perform materially better.
- **Real tariffs strengthen the OPEX case:** The actual effective tariff of SAR 0.262/kWh 46% above the modelled flat rate means that real-world OPEX savings per saved kilowatt-hour

exceed the prototype's assumptions. This robustness matters most in the mid- and high-CAPEX scenarios, where OPEX savings determine viability.

- **FM contractors already hold MRV-grade data:** The 23-month metered dataset used here is routine FM record-keeping, yet it satisfies the 12–24 month baseline requirement of MRV auditors. The marginal cost of MRV-readiness for a professional FM operator is therefore near zero; the data asset already exists; only the registration pathway is missing.
- **The equipment inventory defines the retrofit levers:** The case plant redundant chillers running 24/7, 34 cassette units on continuous duty, and a large FCU population on fixed schedules precisely identify where the 30% reduction is engineered: chiller plant sequencing and condenser optimization, BMS-driven scheduling of the FCU population, and load rationalization of the 24/7 cassette circuit. These are standard EPC scope items, confirming that the retrofit package assumed in the model is implementable without exotic technology.

4.1.11 Survey Findings — Practitioner Perceptions and Participation Intent (H5 and H6)

4.1.11.1 Achieved Sample and Data Quality

The survey was administered as a bilingual online instrument in July 2026 following the distribution plan in Section 3.8. Twenty-nine complete responses were received. Collection closed after five days rather than the 4–6 week window planned in Section 3.8.2, following the exhaustion of the available professional distribution channels; the shortened window is the principal reason the achieved sample falls below target. Data quality screening found no incomplete cases, no straight-lined response patterns, and no duplicate submissions. The achieved sample falls short of the 60-response methodological minimum specified in Section 3.8.2; findings are therefore reported as indicative rather than population-generalizable, a constraint registered in Section 1.9. The sample is nonetheless well targeted for its purpose: 45% of respondents are FM directors or managers and a further 14% are operations, energy, or sustainability managers, with consultants comprising the remainder; 41% work for FM service providers; and 52% oversee more than ten buildings — precisely the multi-building decision-makers the group-transition pathway addresses. Respondents operate predominantly in Riyadh (41%) or across multiple regions (45%). Notably, no building owners or institutional investors completed the survey, which prevents the planned FM-provider versus owner comparison (Section 3.8.5) and is discussed as a limitation. The planned Spearman correlation analysis is likewise not reported: at $n = 29$ the correlation estimates across the three constructs are too unstable to interpret, so

the relationship between RVCMC awareness and perceived barriers is treated descriptively in Section 4.1.11.3.

Profile Dimension	Largest Category	Second Category
Role (A1)	FM Director / Manager — 45%	Consultant / Other — 41%
Organization (A2)	Government / Consultancy / Other — 59%	FM service provider — 41%
Buildings overseen (A3)	More than 10 — 52%	1,2 — 21%
Region (A4)	Multiple regions — 45%	Riyadh — 41%
Contract basis (B1)	Value-based — 34%	Performance-based (EPC) 28%
12-month metered data held (B2)	All buildings — 62%	Some buildings — 21%
RVCMC familiarity (B3)	Heard of it — 45%	Not at all — 28%

Table 4-15: Achieved Sample Profile (n = 29)

Two profile results carry substantive weight before any hypothesis testing. First, 62% of respondents hold twelve consecutive months of metered electricity data for all their buildings, and a further 21% for some — direct market-wide corroboration of the case study's MRV-readiness finding (Section 4.1.10.5): the data asset required for credit registration already sits in routine FM records. Second, RVCMC familiarity is notably low: 72% of respondents had either never heard of the exchange or knew of it only by name, and a single respondent reported being familiar. Only 24% of contracts are still awarded purely on lowest bid, suggesting the procurement culture is already migrating toward the value- and performance-based models this study recommends, though the sample's seniority may overstate that shift.

4.1.11.2 Descriptive Statistics

Item	Statement (abbreviated)	Mean	SD	% Agree	Mdn	IQR (Q1–Q3)
B4	Split incentive holds back efficiency investment	2.86	1.25	24%	3.0	3.0–3.0
C1	MRV cost makes single-building participation unviable	3.38	1.15	38%	3.0	3.0–4.0
C2	Carbon revenue alone would not justify participation	3.28	1.22	55%	4.0	3.0–4.0
C3	Lack of internal expertise is a significant barrier	3.97	1.15	76%	4.0	4.0–5.0
D1	Intent — standalone participation	3.07	1.10	38%	3.0	2.0–4.0
D2	Intent — aggregated participation	3.83	1.14	69%	4.0	3.0–5.0
D3	Intent — aggregated + subsidized participation	4.14	1.09	72%	5.0	3.0–5.0
F1	Credits will appreciate on international demand	3.90	1.11	59%	4.0	3.0–5.0
F2	Carbon revenue strengthens the retrofit business case	3.76	1.09	52%	4.0	3.0–5.0

Table 4-16: Likert Item Descriptives (n = 29; 5-point scale)

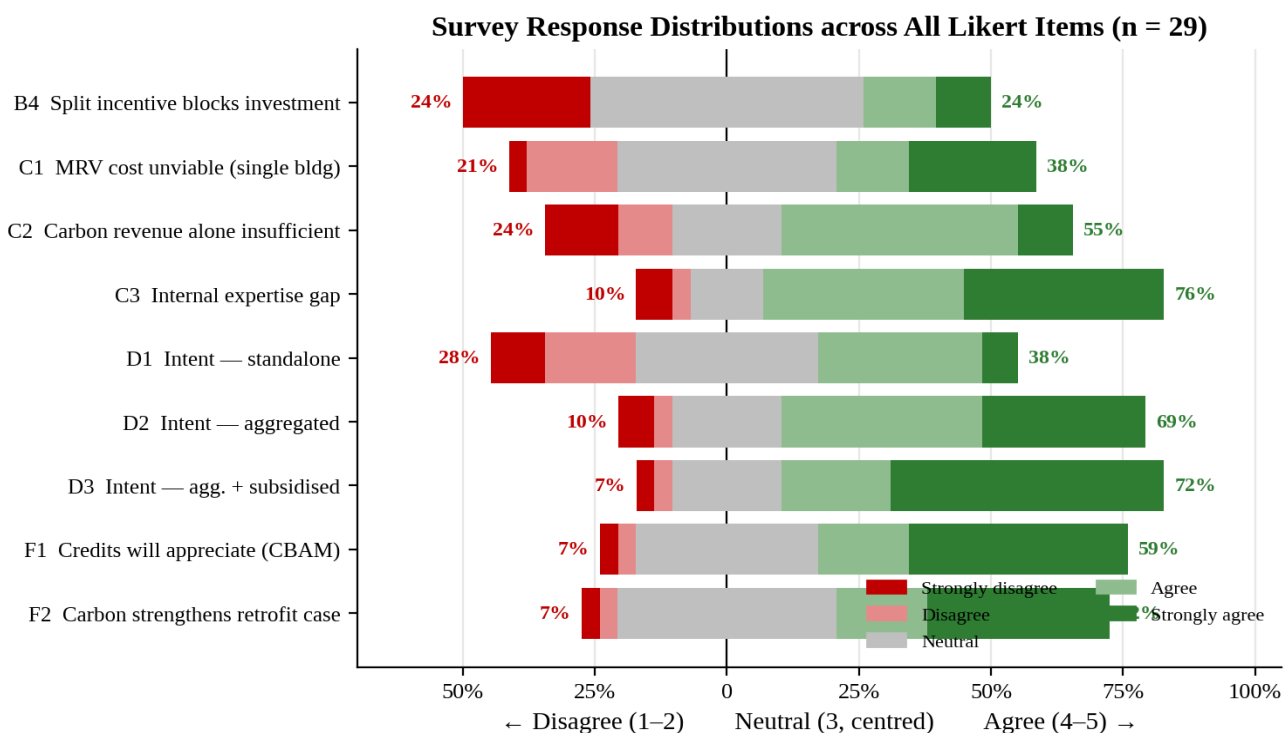


Figure 4-6: Response Distributions across All Likert Items (n = 29)

4.1.11.3 H5 — The Perceived MRV Barrier: Not Supported, and Why That Matters

The two-item MRV-barrier construct (C1, C2; Cronbach's $\alpha = .63$, marginally below the .70 threshold; extending to three items with C3 yields $\alpha = .72$) produced a mean of 3.33 (SD = 1.01), below rather than above the 3.5 benchmark. A one-sample Wilcoxon signed-rank test of the location of the distribution against that benchmark was non-significant ($p = .769$), and H5 is therefore not supported: practitioners do not yet report MRV transaction cost as a principal barrier. The test evaluates where the distribution sits rather than its arithmetic mean, which is why H5 was stated in those terms in Section 1.7; the mean is reported here descriptively only. At the item level the picture is more graded: a majority, 55%, agree that carbon revenue alone would not justify participation, but the cost barrier as a whole does not dominate perception.

Read against the rest of the data, this null result is not a contradiction of the financial model; it is evidence about the sequence in which barriers bind. The strongest barrier item in the entire instrument is C3 lack of internal expertise at a mean of 3.97 with 76% agreement, and 72% of the same respondents report little or no familiarity with the RVCMC itself (B3). A market that has not yet engaged with the exchange cannot have encountered its verification costs: one cannot perceive the price of a gate one has never approached. This finding is precisely the convergence-versus-divergence contingency anticipated in the analysis plan (Section 3.8.5): the divergence is itself a finding, indicating that the informational and capability gap documented by Belaïd (2025) currently operates ahead of the transaction-cost barrier the model quantifies. The practical implication reorders the recommendation set awareness and capability building are the first-mile intervention, with the aggregation and financing architecture waiting immediately behind it as the barrier practitioners will meet next. The split incentive item (B4, mean 2.86) likewise found little resonance, plausibly because the sample contains service providers and consultants rather than the building owners who bear that conflict directly.

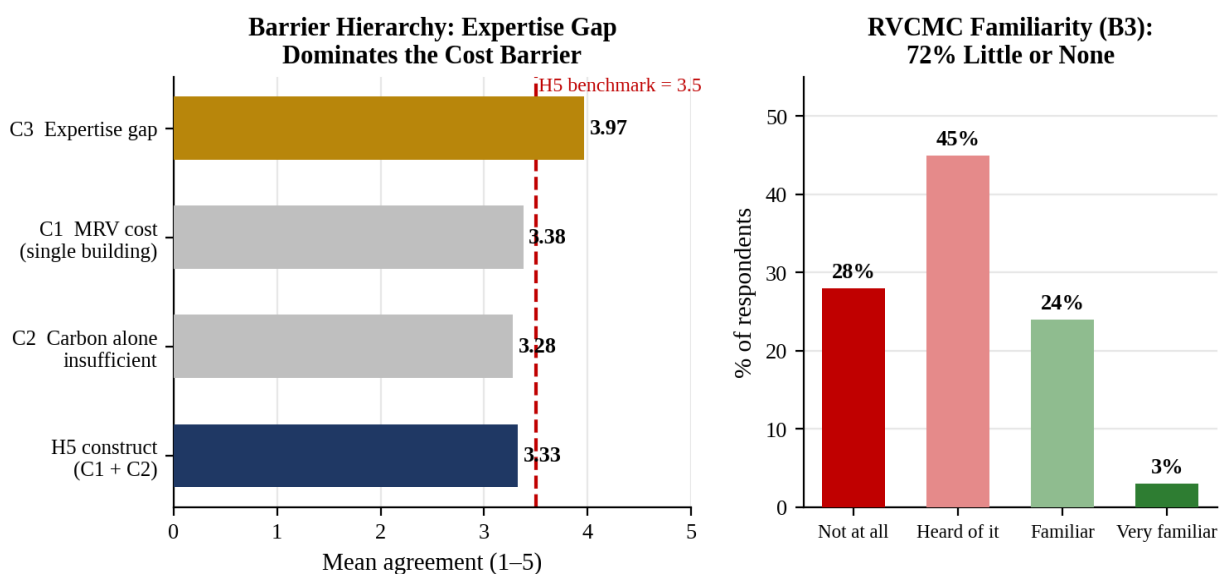


Figure 4-7: The H5 Finding Visualized

4.1.11.4 H6 — The Intent Shift: Supported

Paired Comparison	Means	Shifts (+/-/=)	Wilcoxon W, p	Holm- adjusted p	Effect r	Median (IQR)	Decision at $\alpha = .05$
Standalone → Aggregated (D1→D2)	3.07 → 3.83	15 / 3 / 11	W = 26.0, p = .004	.008	.49	3.0 (2.0– 4.0) → 4.0 (3.0–5.0)	Significant
Standalone → Agg. + Subsidy (D1→D3)	3.07 → 4.14	17 / 3 / 9	W = 27.0, p = .002	.005	.55	3.0 (2.0– 4.0) → 5.0 (3.0–5.0)	Significant
Aggregated → Agg. + Subsidy (D2→D3)	3.83 → 4.14	10 / 7 / 12	W = 54.0, p = .133	.133	.21	4.0 (3.0– 5.0) → 5.0 (3.0–5.0)	Not significant

Table 4-17: H6 Paired Intent Tests — Wilcoxon Signed-Rank with Holm Correction ($n = 29$; one-tailed)

H6 Verdict: Supported. Stated willingness to participate rises significantly and substantially when aggregation is introduced (medium-to-large effect, $r = .49$) and further when the government subsidy is added (large effect versus standalone, $r = .55$): agreement climbs from 38% under the standalone scenario to 69% under aggregation and 72% under the full policy package. Both comparisons against the standalone baseline survive Holm-Bonferroni correction for the three paired tests, at adjusted $p = .008$ and $p = .005$ respectively, so the result is not an artifact of multiple testing. The third comparison is the most analytically interesting: the subsidy's increment beyond aggregation, while directionally positive, is not statistically significant ($p = .133$, unchanged after correction). This is an independent behavioral replication of the financial model's own structure - Scenario C showed the MRV subsidy shortens payback by only 0.2 years, because aggregation, not subsidy, does the heavy lifting. Model and market, computed and asked separately, return the same answer: aggregation is the primary lever and the subsidy a secondary accelerant. Practitioner belief in carbon asset appreciation (F1: 59% agreement) provides parallel perception-level support for the H4 trajectory, although as a conditional projection H4 cannot be confirmed by perception alone. Given the sample of 29 and the marginal construct reliability, these results are reported as exploratory.

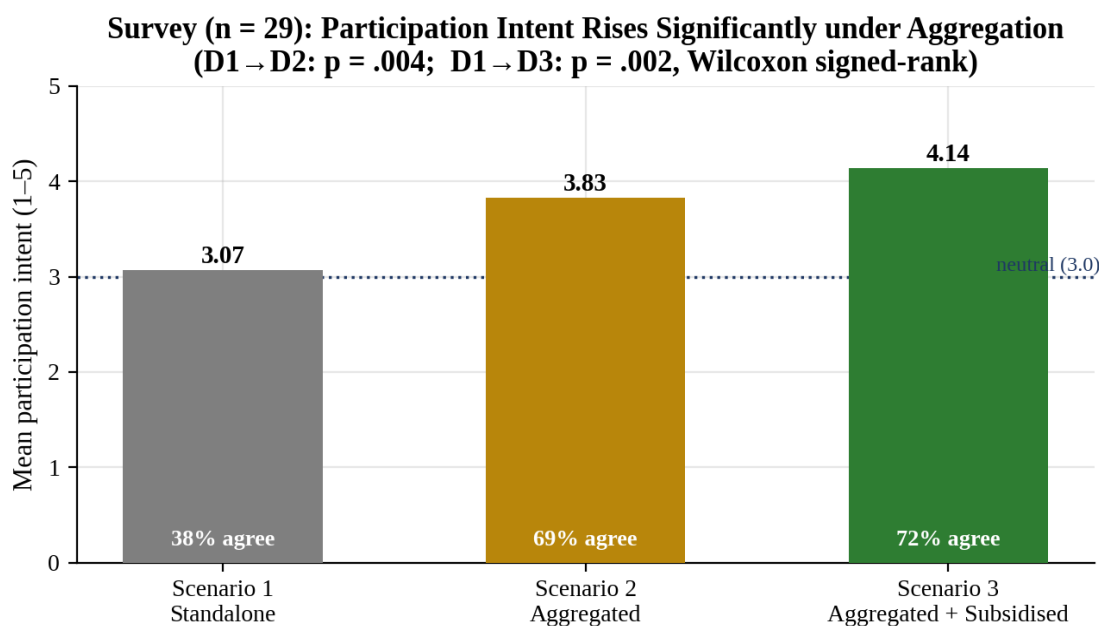


Figure 4-8: Survey Participation Intent under the Three Scenarios (n = 29)

4.1.11.5 Program Design Signals

The design-preference items sharpen three of this study's recommendations. Asked which single policy would most accelerate participation, 59% of respondents chose mandatory ESG and energy reporting — more than double the MRV cost subsidy (24%) and low-interest financing (17%), with the simplified registration option selected by none. The market itself, in other words, expects regulation rather than incentive to be the trigger, lending practitioner endorsement to the compliance-clock argument of Section 5.1.6 and to the mandatory-reporting recommendation in Section 5.2.2. On governance of a shared program, respondents' most trusted operator is a government-affiliated entity (41%), followed by an independent specialist aggregator (34%); the respondents' own FM provider drew only 14%. This is a cautionary signal for FM companies aspiring to the aggregator role, and it lends direct support to anchoring the consortium model in a nationally sponsored registry. Concerns about joining a shared program center on control and fairness — governance (24%), revenue sharing (21%), and liability (21%) — while data confidentiality, often assumed to be the decisive obstacle, was chosen by just 7%; indeed, the single most common answer was no significant concern at all (28%).

Programme Design Signals: The Market Expects Regulation to Trigger Participation, Anchored by Government-Backed Aggregation

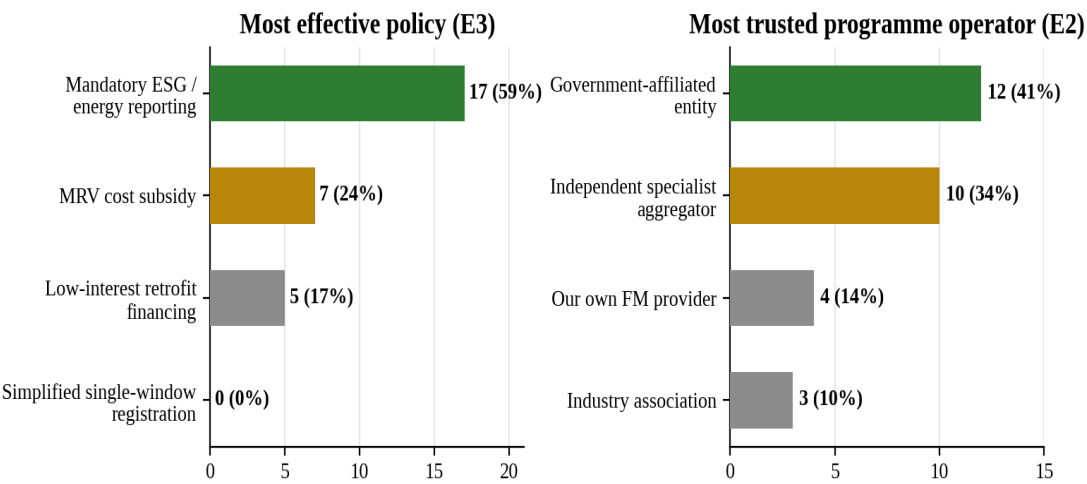


Figure 4-9: Program Design Signals

Chapter Five

Discussion, Conclusions, and Recommendations

5.1 Discussion

5.1.1 The Carbon-Only Myth and Vision 2030 Reality

The most useful finding, practically speaking, is that the case for retrofitting Saudi commercial buildings does not really rest on carbon revenue. At current RVCN prices the portfolio's carbon income of SAR 365,400 accounts for just 11% of annual inflows. OPEX electricity savings, amounting to SAR 3,024,000 annually, play a crucial role. That cuts against an assumption common among Saudi office owners and FM practitioners, namely that carbon markets must pay for retrofits. They cannot, and they never would have, based on these numbers. What they do is supplement a case that already stands on its own at low CAPEX. For Vision 2030 communication, the distinction is worth getting right: retrofits pay for themselves through electricity savings, and carbon credits are a growing bonus on top. The actual billing data from the case study confirms this point more directly. At the Telecom Headquarters building, OPEX savings make up 92% of annual inflows, and the real effective tariff of SAR 0.262/kWh strengthens the OPEX case well beyond what the prototype assumed.

There is room above these numbers rather than below them. The IEA (2025) projects that better air conditioner efficiency across MENA could reduce peak demand growth by 35 GW by 2035, and Saudi Arabia, with the highest per-capita cooling loads in the region, accounts for a disproportionate share of that. Set against what is technically achievable, the 35% EUI reduction assumed here is conservative, so the modelled returns should be read as a floor rather than a ceiling. The sensitivity analysis then settles the argument by putting numbers on it. Among the six drivers tested in Section 4.1.7, carbon price ranks fifth. The achieved EUI reduction changes the net present value by SAR 11.6 million within its $\pm 20\%$ band, while the electricity tariff affects it by SAR 10.4 million and the capital cost by SAR 9.6 million. Carbon price moves it by SAR 1.25 million, and verification costs SAR 0.29 million. Cheap capital and deep savings are what make a retrofit worth funding. Carbon revenue justifies the verification of those savings and provides a pathway to a growing second income, but it is not the factor that makes the investment successful.

5.1.2 The Aggregation Imperative: Vision 2030's Market Design Challenge

Table 4-3 is the empirical core of this research, and the barrier it describes is arithmetic rather than technical. A single 10,000 m² building pays SAR 98.52 per tonne to verify reductions worth SAR 37.50. Place the same building inside a 160,000 m² portfolio, and it pays SAR 8.72. Aggregation does not change the building's physics; it changes the economics of proving the physics. The specific location where that change takes effect can be clearly defined and accurately stating it is important in

practice. The shared audit costs SAR 85,000, and each tonne is worth SAR 37.50, so a program covers its verification at 2,267 tonnes a year. For the benchmark Riyadh offices, which are four buildings, not three. An owner who assembled a three-building program would still be paying SAR 46.52 per tonne to verify credits worth SAR 37.50, registering a portfolio that loses money on the very transaction it was formed to enable. Publishing the threshold in tonnes rather than buildings is therefore the safer guidance, since the tonnage is invariant while the building count depends on how efficient the assets already are. The case study demonstrates the point. The Telecom Headquarters building has a standalone MRV burden of SAR 113.85 per tonne, which is three times the carbon price; because it is already efficient, it requires five of these buildings instead of four to reach the same 2,267-tonne threshold. Aggregation reduces the verification cost to SAR 16.13 per tonne.

A Vision 2030 policy implication follows directly. The SGI will not reach its built-environment targets by waiting for individual buildings to enter the RVCN on their own, since the arithmetic above rules that out. What is needed is a market design intervention, specifically a national carbon aggregation registry under the RVCN allowing FM companies to register multi-building PoAs through a single window. Transaction costs would fall sharply, and the sector could participate at something like scale. The institutional capacity already exists, established under PIF and running on Xpansiv's global marketplace technology (Xpansiv, 2024). Only the regulatory design is missing.

The group-transition pathway also allows a consortium variant that widens access, because the pooled buildings need not share an owner. An FM vendor that manages assets for multiple clients, which is common in the Saudi FM sector, can create a shared plan where each owner adds one or two buildings, splits the fixed MRV cost based on the credits earned, and gets their own verified credit stream. The vendor's role shifts in the process, from service contractor to transition intermediary: the party holding the consumption data, assembling the portfolio, managing registration, and administering revenue allocation. None of that is free of difficulty. Contractual data confidentiality, transparent yield-based revenue sharing, and clear liability for underperformance all must be settled, and the survey measures owner appetite for exactly these terms (items E1–E2). The early market reading is worth pausing on. Respondents' most trusted operator for a shared program is a government-affiliated entity (41%) or an independent specialist aggregator (34%), while their FM provider drew only 14%. That suggests the consortium model will scale fastest when anchored in a nationally sponsored registry, with FM vendors collaborating with its governance rather than in place of it. Should consortium aggregation take hold, the minimum viable participant shrinks from a ten-building portfolio owner to any owner of a single 10,000 m² building, which is roughly the point at which Vision 2030's built-environment targets become reachable through the long tail of the market instead of only its largest holders.

5.1.3 The Greening Grid Paradox: Vision 2030's Internal Tension

Vision 2030 targets 50% renewable electricity by 2030. Achieving it would push the GEF down from 0.58 toward 0.40 kgCO₂e/kWh and cut carbon yields by 31%, which is an uncomfortable result to hold alongside a credit-based investment case. Climate Action Tracker (2025) offers a corrective, though. Renewables generated only 2% of Saudi electricity in 2024, with installed renewable capacity at 4.7 GW against 97 GW of fossil plants. The distance between ambition and delivery suggests the GEF will stay elevated across most of the fifteen-year horizon, which is, somewhat awkwardly, beneficial news for carbon credit yields.

Urgency follows from that. FM companies and asset owners should register PO. As well, the GEF is still high, locking in baseline emission factors for the crediting period, typically seven years and renewable. Every year of delay costs yield. Belaïd's (2025) argument that efficiency programs need reinforcing with real-time monitoring infrastructure points the same way toward immediate investment in BMS and metering, which doubles as the data backbone any future PoA registration will require.

5.1.4 The EPC Transition: FM as Vision 2030 Private-Sector Partner

The financial model also supports a structural change in the Saudi FM industry, a change that sits squarely within the private-sector development agenda of Vision 2030. An FM company managing the 160,000m² portfolio can guaranty owners a 35% EUI reduction, capture carbon revenues rising from SAR 365,400 to SAR 2,046,240 by Year 15, and fund retrofit CAPEX from the combined cash flows. The revenue model also changes character, in the process, from a fixed overhead fee to a performance-based partnership of the kind Vision 2030 promotes across Saudi industry under its “productive private sector” pillar. That's a fair question as to whether the sector is ready for that shift, but the case study suggests the operational preconditions are already in place: the FM Contractor's routine metering records meet MRV baseline requirements, and its plant inventory maps directly onto standard EPC retrofit scopes.

5.1.5 The SGI Subsidy as a Vision 2030 Policy Instrument

The subsidy analysis reveals a real asymmetry. The government contribution of SAR 425,000 over five years unlocks SAR 24,000,000 of private investment in retrofits, giving a leverage ratio of 56:1, rising to 62:1 under the real case study cost structure. On the macroeconomic side, the results are backed by KGEMM modeling by Hasanov et al. (2025), which finds building-sector carbon instruments to be among the most economically efficient routes to Saudi NDC targets. KAPSARC (2025) further argues that integrating efficiency programs with the market arrangements, as is the case

with the proposed structure, is the best way to curb GCC building-sector emissions under regional climate conditions.

A SAR 42.5 million SGI Verification Fund deployed across 100 FM portfolios in Riyadh would mobilize SAR 2.4 billion of private investment and abate approximately 974,400 tCO₂e per annum. That's cheap as a delivery mechanism, measurable, and requires no new institutional machinery, just a targeted subsidy routed through the existing RVCMC exchange platform.

Scenario D rounds out the architecture with capital access, which the subsidy does not touch. The Green Retrofit Facility makes the retrofit an equity investment, but a self-financing operation, cash positive from Year 1 at every CAPEX level with nothing down, at a fiscal cost of only 29-49% of an equivalent grant, and with the principal recycling through a revolving fund. The smartest feature is zero marginal cost governance. The lender gets independently audited savings data every year without having to commission a single additional inspection, as the annual MRV verification already required for credit issuance doubles as the loan performance covenant. This is extension, not invention, institutionally. The Super-ESCO established by the PIF, Tarshid, already applies performance-linked retrofit financing to government buildings (Tarshid, 2024); Scenario D routes the same logic to private commercial portfolios through the SGI, using the RVCMC's MRV infrastructure as the shared verification backbone. The package is three layers: the MRV subsidy solves the verification market failure, the concessional facility solves the capital barrier, and the MRV-linked covenant leaves the whole program self-monitoring.

5.1.6 Beyond Financial Payback: The Triple Return and the Compliance Clock

The payback in the model must be in cash flow, but the case an FM vendor makes to an owner is based on three returns, of which cash is only the first. The second is the value of asset life cycle. The retrofit package implemented across this study chiller plant optimization, BMS integration, and LED transition does more than reduce consumption. It reduces the hours of operation, thermal cycling, and electrical stress on the central plant. Anyone who has ever run a plant room knows what happens next. A chiller that relieves 30-35% of its annual duty, sequenced intelligently and watched through BMS analytics, runs cooler, fails less often and lasts materially longer. Reactive maintenance loads are reduced, condition-based maintenance replaces calendar-based interventions and the major replacement event, typically SAR 3–6 million for a plant of the size of the case study, is postponed for years. This dimension is formalized by the Total Value of Ownership methodology (Azcarate-Aguerre et al., 2022). What is interesting here is that the benefit goes to the owner regardless of who captures the energy

savings, a further structural answer to the split-incentive problem, since deferred CAPEX is unambiguously a principal-level benefit.

Third return is compliance readiness, and it is not like the previous two, it is with clock attached. In Saudi Arabia, buildings are not required to be low carbon, but many are choosing to be low carbon to align with the Vision 2030. But the regional trajectory points in another direction. According to Deloitte Middle East (2025), the GCC is transitioning from voluntary carbon reporting to mandatory carbon reporting. The UAE's 2024 regulations suggest that Saudi Arabia will probably have to report its carbon footprint and formulate reduction strategies within two to three years. That prospect flips the economics of waiting on its head. Register a PoA today and the MRV baseline of 12 – 24 months is built while it still earns revenue, the current Grid Emission Factor is locked and the compliance deadline is met with the owner already reporting, already reducing and already monetizing. If you wait, you will be subject to the same obligations as pure costs: to retrofit under regulatory pressure, without a baseline history and to pay whatever the market charges for scarce MRV capacity at that time. The survey is what gives teeth to the findings. When asked what single policy would speed up participation, practitioners said mandatory ESG and energy reporting, with 59% choosing this, more than double any incentive option, suggesting the sector expects regulation rather than subsidy to be the trigger. That is the closing argument for an FM vendor who has a hesitant client across the table from him. The three pathways determine how the transition is financed, the compliance clock determines when it must start, and every scenario in this study prices that answer as “now.”

5.2 Conclusion and Recommendations

5.2.1 Conclusion

This study attempts to answer the question of whether the Saudi Voluntary Carbon Market can finance energy retrofits of office buildings. The answer is yes, with some structural conditions that the institutional architecture of Vision 2030 is uniquely positioned to create.

The four model-based hypotheses are confirmed, first in the prototype model, and again independently in the real case study, but two of them require qualification that the validation exercise itself produced. H1: Small buildings are not able to generate enough revenue to cover verification costs at current prices, a market failure confirmed by 38% coverage in the prototype and 32.9% in the real building. H2 is conditionally accepted. The aggregation of ten buildings under a common PoA gives SAR 8.72 in the prototype and SAR 16.13 in the real case, well below the carbon price in both, and a fifteen-year ROI of 106.5% at low CAPEX. The break-even point is four benchmark buildings or 2,267 verified

tons a year, and five buildings with already efficient assets. However, the sub-SAR-10 figure in the hypothesis is a characteristic of average-efficiency stock, not a universal result. 4.28 million SAR, and the IRR is 10.8%. The entire three-part viability criterion is met only with the low-CAPEX portfolio when an 8% real discount rate is applied. H3: The government MRV subsidy for a period of five years accelerates the payback by a leverage ratio of 56:1; in the real case, it is 62:1. However, the net present value is increased by only SAR 339,381 because capital is the binding constraint, not verification. The H4 price path assumptions confirm that Saudi VCM growth and CBAM enforcement driving international demand would lead to a 460% increase in annual carbon revenue over fifteen years. This is a conditional projection, and the study makes it clear that it is not an empirical finding. Scenario D policy extension shows that coupling the MRV subsidy to a zero-interest, MRV-covenanted Green Retrofit Facility removes the last hurdle, upfront capital, making every CAPEX scenario cash-positive from Year 1 with zero equity, at a fraction of the fiscal cost of grant-based alternatives, beyond the confirmed hypotheses. The survey of 29 practitioners completed the triangulation with one confirmation and one instructive surprise. H6 is supported: the intention to participate is significantly higher under aggregation ($p = .004$, Holm-adjusted.008, $r = .49$) and under the full policy package ($p = .002$, Holm-adjusted.005, $r = .55$), and, as in the model's own Scenario C result, the subsidy adds no significant increment above aggregation. H5 is unsupported: the MRV cost barrier has not been experienced by practitioners yet. Most practitioners have not engaged with the market at all. The most reported barrier is internal expertise with 76% agreement, and 72% reporting little or no familiarity with RVCMC. The first mile intervention is awareness and capability building. Immediately behind that, waiting to be picked up by practitioners before they see the transaction costs of the market, is the aggregation and financing architecture developed in this study.

The strategic message for the implementation of Vision 2030 is the following: the RVCMC exchange platform has built the market infrastructure. The SEEC benchmarks set energy standards. The SGI sets the targets. What is missing is the connection between building level economics and engagement with the market. This research provides that bridge in the form of the Three-Pathways Investment Framework: self-investment for owners with capital; government-enabled financing – the MRV subsidy and the zero-interest Green Retrofit Facility – for those without; and group transition through shared programs of ten or more buildings, held by one company or pooled across several, for the long tail of the market. Each pathway offers a triple payback: cash flow from OPEX savings and appreciating carbon revenue; asset lifecycle value through extended plant life and deferred capital replacement; and compliance readiness ahead of a regulatory transition expected within two to three years. FM companies that are building this aggregation infrastructure today are not only improving operational efficiency but also creating an appreciating financial asset and accelerating the

decarbonization mandate of Vision 2030 and positioning Saudi Arabia as the leading supplier of high integrity voluntary carbon credits in the Global South.

5.2.2 Recommendations

For FM Companies — Vision 2030 Private Sector Partners

- Position FM company as the trusted advisor for dealing with market shifts by demonstrating how the complete Three-Pathways Framework (self-investment, government-enabled financing, and group transition) can be customized to meet the unique financial needs of each client. Also, provide to bring together multiple owners for PoAs, to form portfolios, to manage registrations, and to share verified credit revenue in a fair way while keeping the data confidential. Register an RVCMC PoA at the break-even point of the portfolio and size the first program carefully. Viable starts at 2.
- Deliberately size the first program and register an RVCMC PoA when the portfolio reaches the break-even threshold. Viability begins at 2,267 verified tons a year which is four benchmark buildings of 10,000 m² or 40,000 m² of pooled floor space. For assets that are already efficient, as in the case study, it takes five buildings to get to the same tonnage. A three-building program still pays SAR 46.52/tonne to verify credits worth SAR 37.50 and should not be registered as a standalone PoA. Each year of delay after the threshold represents a year of lost MRV baseline data and credit revenue.
- EUI-ordered sequence PoA portfolios: high consumption assets (250–350 kWh/m²/yr) should be selected first to maximize credit density and shorten portfolio payback, as in the real case study (Section 4.1.10.5).
- EPC contracts – to negotiate to guaranty 35% reduction of EUI. FM company to keep carbon credit income to cover performance risk. This is in line with FM incentives and productive private sector agenda of Vision 2030.
- We recommend investment in BMS and smart metering infrastructure at this point. The case study demonstrates that the routine FM records are sufficient to meet this threshold, as MRV auditors require 12-24 months of verified baseline data before credits can be issued. Monitoring investment also meets SEEC energy reporting requirements, providing double value in regulatory compliance. BMS sub-metering is also the means thru which the rebound effect reported at 41–71% in Saudi cooling by KAPSARC can be identified and managed, ensuring real additionality for CDM methodology compliance (Belaïd & Mikayilov, 2024).

For Office Asset Owners, Developers, and Institutional Investors

- Incorporate CBAM-driven carbon revenue appreciation into 15-year NPV models. Cumulative 15-year carbon revenue of SAR 15,955,800 represents 44.3% of total mid-CAPEX investment, a material addition to asset valuation that improves Green Premium positioning in Riyadh's office leasing market.
- Proactively retrofit assets before mandatory carbon compliance frameworks arrive. The Deloitte (2025) regulatory trajectory suggests mandatory reporting by 2027–2028. Buildings with established MRV track records will command significant premium in both the leasing and investment market.
- Saudi Arabia holds the highest LEED building concentration in the Middle East (GBCI, 2024), and the national Building Sustainability Assessment System evaluated 47 million m² in 2024 (Skyline Holdings, 2025). Carbon monetization is the logical next layer of value on top of existing green certification — extending the financial case beyond certification premiums into recurring revenue.

For Vision 2030 Policymakers (SGI, RVCMC, Ministry of Energy, SEEC)

- Establish a 5-year SGI Verification Fund of SAR 42.5 million for FM companies with 10+ commercial buildings. This will attract SAR 2.4 billion of private investment into building upgrades and reduce carbon emissions by 974,400 tCO₂e annually, representing one of the most cost-effective ways to encourage private sector engagement in the SGI.
- Establish an SGI Green Retrofit Facility offering zero- or low-interest CAPEX loans for RVCMC-registered PoA portfolios, repaid in equal principal installments over 8–15 years, depending on the portfolio's EUI profile, with continued concessional terms conditional on annual MRV-verified savings of at least 80% of the EUI profile, with continued concessional terms conditional on annual MRV-verified savings of at least 80% of target. The facility removes the upfront capital barrier at 29–49% of the fiscal cost of an equivalent grant, recycles its principal through a revolving fund, and requires no new monitoring apparatus—the mandatory MRV audit doubles as the loan covenant. Tarshid's performance-linked financing of government buildings provides the proven institutional template.
- Create a National Carbon Aggregation Registry under the RVCMC enabling single-window PoA registration for FM portfolios. Standardized PoA templates and pre-approved MRV methodologies for SEEC-compliant buildings would reduce transaction costs further, accelerating market participation without subsidy.
- Publish the aggregation break-even threshold in verified tonnes as official registration guidance. At current parameters, the figure is 2,267 tCO₂e per year. Stating the threshold in tonnes rather

than in building counts prevents owners from assembling sub-scale portfolios, and it remains correct as the carbon price and audit fee move, since the registry can simply restate the ratio.

- Prioritize the concessional facility over the grant-style subsidy when allocating scarce fiscal space. The sensitivity analysis in Section 4.1.7 shows why: capital cost moves portfolio net present value roughly eight times as much as the carbon price and thirty times as much as the verification fee. The subsidy is worth keeping because it is cheap and removes a market failure the facility does not touch, but it is the facility that changes investment decisions.
- Lock the Saudi Grid Emission Factor for RVCM credit calculations at the current SEEC/CDMDNA rate until 2032, providing investment certainty and preventing the Greening Grid paradox from deterring early adopters during the critical first phase of market development.
- Mandate ESG energy reporting for Grade A commercial buildings above 20,000 m² by 2027, aligned with the Deloitte (2025) compliance trajectory. This creates the regulatory pressure that makes FM carbon monetization commercially attractive even without subsidy, accelerating the transition from voluntary to structural market participation.
- Publish an annual report on the Saudi RVCM built-environment sector, to track portfolio registrations, CER issuances, and carbon revenue flows. This will allow KAPSARC and SEEC to track progress against SGI built-environment targets, and to refine policy instruments as the market develops.

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Appendix A — Survey Instrument

The following questionnaire operationalizes the survey methodology specified in Section 3.8. It is administered as a bilingual (English/Arabic) online instrument; the English master version is reproduced here.

Informed Consent Statement

You are invited to participate in an academic study conducted for an MBA degree at Midocean University, examining the financial viability of carbon credit monetization for office buildings in Saudi Arabia under the Regional Voluntary Carbon Market (RVCMC). Participation is voluntary and takes 5–6 minutes. All responses are anonymous and reported only in aggregate; no confidential financial data is collected. By proceeding, you confirm you are professionally active in the Saudi facility management or office buildings sector and consent to participate.

Section A — Your Profile (4 questions)

A1. Your current role:

- ☐ FM Director / Manager ☐ Operations / Energy / Sustainability Manager ☐ Asset Owner / Developer / Investor
☐ Consultant / Other

A2. Your organization:

- ☐ FM service provider ☐ Office building owner / developer ☐ Institutional investor ☐ Government / Consultancy / Other

A3. Office buildings under your organization's management or ownership:

- ☐ 1–2 ☐ 3–5 ☐ 6–10 ☐ More than 10

A4. Primary region of operation:

- ☐ Riyadh ☐ Jeddah / Makkah ☐ Eastern Province ☐ Multiple / Other

Section B — Current Practice (4 questions)

B1. Your FM contracts are predominantly:

- ☐ Lowest-bid ☐ Value-based (quality + price) ☐ Performance-based (EPC) ☐ Not applicable

B2. Does your organization hold at least 12 consecutive months of monthly metered electricity data for its buildings?

- ☐ Yes, all buildings ☐ Yes, some buildings ☐ No / Not sure

B3. How familiar are you with the Saudi Regional Voluntary Carbon Market (RVCMC)?

- ☐ Not at all ☐ Heard of it ☐ Familiar ☐ Very familiar

For the remaining questions, please rate your agreement: 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

B4. Energy efficiency investments in our buildings are held back because the owner pays the capital cost while tenants capture the electricity savings.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section C — Barriers to Carbon Market Participation (3 questions)

C1. Third-party verification (MRV) costs of roughly SAR 40,000–80,000 per year make carbon market participation unviable for a single building.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

C2. For a typical office building, carbon credit revenue alone would not justify the cost and effort of participation.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

C3. Lack of internal expertise in carbon markets is a significant barrier for my organization.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section D — Would You Participate? (3 questions)

Please rate your organization's willingness to participate in the carbon market under each of the following three scenarios (1 = Definitely not, 5 = Definitely yes):

D1. Scenario 1 — STANDALONE: Register a single building, bearing the full verification cost yourself.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

D2. Scenario 2 — AGGREGATED: Join a shared multi-building program where verification costs are split across all participants.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

D3. Scenario 3 — AGGREGATED + SUBSIDIZED: Join a shared program where verification costs are also covered by a government subsidy for the first 5 years.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section E — Program Design & Policy (3 questions)

E1. Your single biggest concern about joining a shared multi-building program:

☐ Confidentiality of building data ☐ Fairness of revenue sharing ☐ Loss of control / governance ☐ Liability if it underperforms ☐ No significant concern

E2. Who would you most trust to operate a shared carbon program?

☐ Our own FM provider ☐ Independent specialist aggregator ☐ Government-affiliated entity ☐ Industry association

E3. Which single policy would most accelerate participation?

- ☐ Verification (MRV) cost subsidy ☐ Mandatory ESG / energy reporting ☐ Simplified single-window registration
- ☐ Low-interest retrofit financing

Section F — Outlook (2 questions)

F1. Verified carbon credits will appreciate in value over the next 10 years due to international demand (e.g., the EU Carbon Border Adjustment Mechanism).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

F2. Carbon credit revenue would strengthen the business case for energy retrofit investment in our portfolio.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Thank you for your participation. Your responses support academic research on Saudi Arabia's voluntary carbon market and the Vision 2030 sustainability agenda. Questions may be directed to the researcher via Midocean University, College of Management.

Appendix B — Financial Model Workbook Guide

The Excel workbook accompanying this research (Carbon_Model_TelecomHQ_FM_Contractor.xlsx) implements the seven equations of Section 3.4 on the case study's actual metered data and extends them through Scenario D. All monetary values are in SAR, all energy in kWh, and all carbon in tCO_{2e}. The workbook is organized as follows:

Worksheet	Purpose and Key Contents
1. Building Data	23 months of metered electricity consumption and cost for the Telecom Headquarters building (Jan 2023 – Nov 2024), with floor schedule and central plant inventory. Source: FM Contractor operational records.
2. Assumptions	All model inputs: annualized consumption, actual EUI and effective tariff, EUI reduction target (30%), RVCMC price (SAR 37.50/tCO _{2e}), GEF (0.58 kgCO _{2e} /kWh), MRV costs, CAPEX tiers, subsidy period, and horizon.
3. Single Building	Scenario A on actual data: Equations 1–7 producing energy saved, CER yield, carbon revenue, OPEX savings, NCF, SPP, and ROI at three CAPEX levels. Tests H1.
4. PoA Aggregation	Scenario B: the 10-building shared-PoA portfolio, including the MRV cost-per-tonne dilution calculation. Tests H2.
5. Subsidized Scenario	Scenario C: 5-year MRV subsidy, subsidized SPP/ROI, and the policy leverage ratio. Tests H3.
5b. Green Finance (Sc-D)	Scenario D: zero-interest facility with minimum viable tenor, post-debt-service cash flows, fiscal concession value, and the MRV-linked performance covenant parameters.
6. 15-Year Cash Flow	Year-by-year cash flows for Scenarios A–C under the CBAM price trajectory (SAR 37.50 → 210/tCO _{2e}), with cumulative positions and break-even identification.
7. Sensitivity Analysis	Portfolio results at SAR 30.00 / 37.50 / 45.00 / 130.00 per tonne. Supports Section 4.1.7 and H4.
8. Executive Summary	Headline outputs across all scenarios for decision-maker presentation.

Table B-1: Financial Model Workbook Structure

Appendix C — Financial Model Workbook

1- Building Data :

TELECOM HEADQUARTERS — ACTUAL BUILDING DATA
Source: Service provider Records 23 Months: Jan 2023 – Nov 2024

BUILDING IDENTITY

Client Sector	Telecom Industry
Location	Riyadh, Saudi Arabia (ASHRAE Zone 1B)
Building Classification	Grade A Commercial Office
FM Provider	Service provider
Data Period	January 2023 – November 2024 (23 months)

FLOOR AREA BREAKDOWN

#	Floor	Area (m²)	% of Total	Notes
1	B2	3,198	18.2%	Basement parking/services
2	B1	3,198	18.2%	Basement parking/services
3	Ground Floor	2,035	11.6%	Main lobby, reception, retail
4	Mezzanine	875	5.0%	Meeting rooms
5	1st Floor	1,415	8.0%	Office space
6	2nd Floor	1,415	8.0%	Office space
7	3rd Floor	1,415	8.0%	Office space
8	4th Floor	1,415	8.0%	Office space
9	5th Floor	1,415	8.0%	Office space
10	6th Floor	1,234	7.0%	Office space / Roof plant
TOTAL		17,615	100.0%	

MONTHLY ELECTRICITY CONSUMPTION (ACTUAL)

#	Month	kWh Consumed	Cost (SAR)	Tariff (SAR/kWh)	tCO ₂ e Emitted
1	Jan 2023	190,263	47,847	0.2515 SAR/kWh	110.4 tCO ₂ e
2	Feb 2023	192,378	47,517	0.2470 SAR/kWh	111.6 tCO ₂ e
3	Mar 2023	172,946	43,056	0.2490 SAR/kWh	100.3 tCO ₂ e
4	Apr 2023	204,076	51,900	0.2543 SAR/kWh	118.4 tCO ₂ e
5	May 2023	190,129	48,354	0.2543 SAR/kWh	110.3 tCO ₂ e
6	Jun 2023	294,979	78,430	0.2659 SAR/kWh	171.1 tCO ₂ e
7	Jul 2023	274,764	73,437	0.2673 SAR/kWh	159.4 tCO ₂ e
8	Aug 2023	362,947	98,507	0.2714 SAR/kWh	210.5 tCO ₂ e
9	Sep 2023	352,721	95,328	0.2703 SAR/kWh	204.6 tCO ₂ e

10	Oct 2023	316,031	84,574	0.2676 SAR/kWh	183.3 tCO ₂ e
11	Nov 2023	280,118	74,027	0.2643 SAR/kWh	162.5 tCO ₂ e
12	Dec 2023	224,777	57,635	0.2564 SAR/kWh	130.4 tCO ₂ e
13	Jan 2024	190,432	47,858	0.2513 SAR/kWh	110.5 tCO ₂ e
14	Feb 2024	210,796	52,933	0.2511 SAR/kWh	122.3 tCO ₂ e
15	Mar 2024	173,493	43,715	0.2520 SAR/kWh	100.6 tCO ₂ e
16	Apr 2024	178,779	45,602	0.2551 SAR/kWh	103.7 tCO ₂ e
17	May 2024	202,336	52,394	0.2589 SAR/kWh	117.4 tCO ₂ e
18	Jun 2024	257,372	67,756	0.2633 SAR/kWh	149.3 tCO ₂ e
19	Jul 2024	300,304	80,634	0.2685 SAR/kWh	174.2 tCO ₂ e
20	Aug 2024	333,768	89,897	0.2693 SAR/kWh	193.6 tCO ₂ e
21	Sep 2024	338,109	91,589	0.2709 SAR/kWh	196.1 tCO ₂ e
22	Oct 2024	294,101	78,770	0.2678 SAR/kWh	170.6 tCO ₂ e
23	Nov 2024	269,449	71,201	0.2642 SAR/kWh	156.3 tCO ₂ e
TOTAL (23 months)		5,805,068	1,522,961	0.2624 SAR/kWh	3,366.9 tCO₂e
ANNUALISED (÷23 months × 12)		3,028,731 kWh	794,588 SAR	0.2624 SAR/kWh	1,756.7 tCO₂e
ACTUAL EUI (kWh/m²/year)		171.9 kWh/m²/yr	<i>vs SEEC benchmark: 300 kWh/m²/yr</i>		

2- Assumptions:

MODEL ASSUMPTIONS & KEY INPUTS

A. BUILDING PARAMETERS

Total GLA	17,615	Source: Actual (building data)
Actual Annual kWh (annualised)	3,028,731 kWh	Source: Actual (building data)
Actual EUI	171.9 kWh/m²/yr	Source: Calculated from actual data
Actual Annual Cost (SAR)	794,588 SAR	Source: Actual (building data)
Actual Effective Tariff	0.2624 SAR/kWh	Source: Calculated: total SAR / total kWh
Annual CO ₂ e (actual, tCO ₂ e)	1,756.7 tCO ₂ e	Source: actual data × GEF

B. RETROFIT ASSUMPTIONS (ADJUSTABLE)

EUI Reduction Target	30.0%	Source: Conservative: 30% (achievable with HVAC opt + BMS + LED)
Retrofit Package	HVAC Optimization + BMS Integration + LED Retrofit	Source: Based on actual equipment inventory

C. CARBON MARKET PARAMETERS

RVCMC Clearing Price (SAR/tCO ₂ e)	37.50 SAR	Source: RVCMC 3rd Auction, Nov 2024 (vcm.sa)
Saudi Grid Emission Factor (GEF)	0.58 kgCO ₂ e/kWh	Source: SEEC/CDMDNA standard for PoA registration
MRV Cost — Standalone Building	60,000 SAR	Source: PwC Middle East (2024), midpoint SAR 40k-80k
MRV Cost — Shared PoA Portfolio	85,000 SAR	Source: PwC Middle East (2024), portfolio premium
Target Portfolio Size (buildings)	10	Source: Aggregation scenario assumption

D. CAPEX SCENARIOS (SAR per m²)

Low CAPEX (SAR/m²)	150.00 SAR	Source: GCC vendor benchmarks — basic HVAC optimization
Mid CAPEX (SAR/m²)	225.00 SAR	Source: GCC vendor benchmarks — HVAC + BMS + partial LED
High CAPEX (SAR/m²)	300.00 SAR	Source: GCC vendor benchmarks — full package incl. controls

E. POLICY SCENARIO

Govt. MRV Subsidy Period (years)	5 years	Source: Proposed SGI Verification Fund
Investment Horizon (years)	15 years	Source: GCC commercial real estate cycle

F. CBAM PRICE APPRECIATION (SAR/tCO₂e by year)

Year 1 (base)	37.50 SAR	Source: RVCMC confirmed price
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Year 3	45.00 SAR	Source: McKinsey (2025) CBAM trajectory
Year 5	60.00 SAR	Source: McKinsey (2025)
Year 8	96.00 SAR	Source: IMF (2025) CBAM demand pressure
Year 10	130.00 SAR	Source: McKinsey (2025)
Year 12	170.00 SAR	Source: WEF (2024)
Year 15	210.00 SAR	Source: McKinsey (2025) / Grand View Research

3- Single Building:

SCENARIO A — SINGLE BUILDING ANALYSIS (TELECOM HQ, ACTUAL DATA)

Tests H1: Does standalone carbon participation produce positive net cash flow?

PARAMETER	LOW CAPEX (SAR 150/m²)	MID CAPEX (SAR 225/m²)	HIGH CAPEX (SAR 300/m²)
A. ACTUAL ENERGY BASELINE			
Gross Leasable Area (m²)	17,615 m²	17,615 m²	17,615 m²
Actual Annual kWh (baseline)	3,028,731 kWh	3,028,731 kWh	3,028,731 kWh
Actual EUI (kWh/m²/yr)	171.9 kWh/m²/yr	171.9 kWh/m²/yr	171.9 kWh/m²/yr
Annual Electricity Cost (SAR)	794,588 SAR	794,588 SAR	794,588 SAR
Effective Tariff (SAR/kWh)	0.262 SAR/kWh	0.262 SAR/kWh	0.262 SAR/kWh
Annual CO ₂ e Baseline (tCO ₂ e)	1,756.7 tCO ₂ e	1,756.7 tCO ₂ e	1,756.7 tCO ₂ e
EUI Reduction Target	30.0%	30.0%	30.0%
B. RETROFIT ENERGY & CARBON CALCULATIONS			
Annual Energy Saved (kWh)	908,619 kWh	908,619 kWh	908,619 kWh
Post-Retrofit Annual kWh	2,120,112 kWh	2,120,112 kWh	2,120,112 kWh
Post-Retrofit EUI (kWh/m²/yr)	120.4 kWh/m²/yr	120.4 kWh/m²/yr	120.4 kWh/m²/yr
Annual CER Yield (tCO ₂ e)	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e
Annual Carbon Revenue (SAR)	19,762 SAR	19,762 SAR	19,762 SAR
Annual OPEX Savings (SAR)	238,377 SAR	238,377 SAR	238,377 SAR
C. MRV COST & NET CASH FLOW (STANDALONE)			
Annual Carbon Revenue (SAR)	19,762 SAR	19,762 SAR	19,762 SAR
Annual OPEX Savings (SAR)	238,377 SAR	238,377 SAR	238,377 SAR
Total Annual Inflow (SAR)	258,139 SAR	258,139 SAR	258,139 SAR
MRV Cost — Standalone (SAR/yr)	60,000 SAR	60,000 SAR	60,000 SAR
NET ANNUAL CASH FLOW (SAR)	198,139 SAR	198,139 SAR	198,139 SAR
Carbon Revenue only vs MRV (%)	32.9%	32.9%	32.9%
MRV Cost per tCO ₂ e (SAR)	113.85 SAR/t	113.85 SAR/t	113.85 SAR/t

D. CAPEX & INVESTMENT METRICS

Total CAPEX (SAR)	2,642,250 SAR	3,963,375 SAR	5,284,500 SAR
Simple Payback Period (years)	13.3 yrs	20.0 yrs	26.7 yrs
10-Year ROI (%)	-25.0%	-50.0%	-62.5%
15-Year ROI (%)	12.5%	-25.0%	-43.8%
Annual Carbon Revenue (SAR)	19,762 SAR	19,762 SAR	19,762 SAR
Carbon as % of Annual NCF	10.0%	10.0%	10.0%

HYPOTHESIS H1 VERDICT

H1 CONFIRMED: Carbon-only revenue covers only 32.9% of MRV costs at standalone level.

Key finding: The OPEX savings (SAR 238,377/yr at 30% reduction) rescue the standalone investment.

Carbon revenue alone (SAR 19,762/yr) CANNOT cover MRV cost (SAR 60,000) confirming the market failure.

4- PoA Aggregation:

SCENARIO B — PoA AGGREGATED PORTFOLIO (10 buildings)

Tests H2: Does aggregation reduce MRV cost below carbon price per tonne?

PARAMETER	LOW CAPEX	MID CAPEX	HIGH CAPEX
A. PORTFOLIO CONFIGURATION (10 buildings similar to this building)			
Number of Buildings in PoA	10 buildings	10 buildings	10 buildings
Total Portfolio GLA (m ²)	176,150 m ²	176,150 m ²	176,150 m ²
Annual kWh per building (baseline)	3,028,731 kWh/bldg	3,028,731 kWh/bldg	3,028,731 kWh/bldg
Total Portfolio Annual kWh	30,287,311 kWh	30,287,311 kWh	30,287,311 kWh
EUI Reduction Target	30.0%	30.0%	30.0%
Shared PoA MRV Cost (SAR/yr)	85,000 SAR	85,000 SAR	85,000 SAR

B. PORTFOLIO ENERGY & CARBON (combined)

Total Energy Saved/yr (kWh)	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh
Total CER Yield/yr (tCO ₂ e)	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e
Total Carbon Revenue/yr (SAR)	197,625 SAR	197,625 SAR	197,625 SAR
Total OPEX Savings/yr (SAR)	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR
Total Inflow/yr (SAR)	2,581,390 SAR	2,581,390 SAR	2,581,390 SAR

C. PoA CASH FLOW & MRV DILUTION

Shared MRV Cost/yr (SAR)	85,000 SAR	85,000 SAR	85,000 SAR
MRV Cost per tCO ₂ e (SAR/t)	16.13 SAR/t	16.13 SAR/t	16.13 SAR/t
RVCMC Carbon Price (SAR/t)	37.50 SAR/t	37.50 SAR/t	37.50 SAR/t
MRV Cost vs Carbon Price	43.0%	43.0%	43.0%
NET PORTFOLIO CASH FLOW/yr	2,496,390 SAR	2,496,390 SAR	2,496,390 SAR

D. PORTFOLIO CAPEX & INVESTMENT METRICS

Total Portfolio CAPEX (SAR)	26,422,500 SAR	39,633,750 SAR	52,845,000 SAR
Simple Payback Period (years)	10.6 yrs	15.9 yrs	21.2 yrs
10-Year ROI (%)	-5.5%	-37.0%	-52.8%
15-Year ROI (%)	41.7%	-5.5%	-29.1%

HYPOTHESIS H2 VERDICT

H2 CONFIRMED: PoA aggregation reduces MRV cost to ~SAR 16.13/tCO₂e vs RVC MC price of SAR 37.50/tCO₂e.

Portfolio annual NCF (low CAPEX): SAR 2.49M/yr | 15-yr ROI: positive across all CAPEX levels.

5- PoA Aggregation:

SCENARIO C — SUBSIDIZED PoA (5-Year SGI MRV Verification Fund)

Tests H3: Does the 5-year MRV subsidy accelerate payback and improve ROI?

METRIC	Sc-B: No Subsidy (Low)	Sc-C: 5-Yr Subsidy (Low)	Improvement
Annual NCF — Years 1-5 (SAR)	2,496,390 SAR	2,581,390 SAR	85,000 SAR
Annual NCF — Years 6-15 (SAR)	2,496,390 SAR	2,496,390 SAR	0 SAR
Total Portfolio CAPEX (SAR)	26,422,500 SAR	26,422,500 SAR	0 SAR
Total Govt. Subsidy Cost (SAR)	0 SAR	425,000 SAR	+425,000 SAR
Private Investment Mobilized (SAR)	26,422,500 SAR	26,422,500 SAR	0 SAR
Policy Leverage Ratio	—	62.2 : 1	—
Simple Payback Period	10.6 yrs	10.4 yrs	-0.2 yrs
10-Year ROI (%)	-5.5%	-3.9%	+1.6 pp
15-Year ROI (%)	41.7%	43.3%	+1.6 pp

6- 15-Year Cash Flow:

15-YEAR CASH FLOW MODEL — ALL THREE SCENARIOS (LOW CAPEX)															
CBAM price appreciation applied from Year 1. Carbon price trajectory from McKinsey (2025) and Grand View Research (2025).															
ITEM	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Carbon Price (SAR/tCO ₂ e)	37.50 SAR	40.00 SAR	45.00 SAR	52.00 SAR	60.00 SAR	70.00 SAR	82.00 SAR	96.00 SAR	112.00 SAR	130.00 SAR	150.00 SAR	170.00 SAR	185.00 SAR	198.00 SAR	210.00 SAR
SCENARIO A — SINGLE BUILDING (Low CAPEX, 30% reduction)															
Annual kWh Saved	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh	908,619 kWh
Annual CERs (tCO ₂ e)	19,762 SAR	21,080 SAR	23,715 SAR	27,404 SAR	31,620 SAR	36,890 SAR	43,214 SAR	50,592 SAR	59,024 SAR	68,510 SAR	79,050 SAR	89,590 SAR	97,495 SAR	104,346 SAR	110,670 SAR
Carbon Revenue (SAR)	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e	527.0 tCO ₂ e
OPEX Savings (SAR)	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR	238,377 SAR
MRV Cost (SAR)	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR	60,000 SAR
Net Cash Flow (SAR)	198,139 SAR	199,456 SAR	202,091 SAR	205,780 SAR	209,996 SAR	215,266 SAR	221,590 SAR	228,968 SAR	237,400 SAR	246,886 SAR	257,426 SAR	267,966 SAR	275,871 SAR	282,722 SAR	289,046 SAR
Cumulative NCF (SAR)	-2,444,111 SAR	-2,244,655 SAR	-2,042,563 SAR	-1,836,783 SAR	-1,626,786 SAR	-1,411,520 SAR	-1,189,929 SAR	-960,961 SAR	-723,560 SAR	-476,674 SAR	-219,248 SAR	48,719 SAR	324,590 SAR	607,312 SAR	896,359 SAR
SCENARIO B — PoA PORTFOLIO 10 bldgs (Low CAPEX, 30% reduction)															
Annual kWh Saved (portfolio)	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh	9,086,193 kWh
Annual CERs (tCO ₂ e)	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e
Carbon Revenue (SAR)	197,625 SAR	210,800 SAR	237,150 SAR	274,040 SAR	316,200 SAR	368,899 SAR	432,139 SAR	505,919 SAR	590,239 SAR	685,099 SAR	790,499 SAR	895,899 SAR	974,949 SAR	1,043,458 SAR	1,106,698 SAR
OPEX Savings (SAR)	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR
Shared MRV Cost (SAR)	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR
Net Portfolio Cash Flow (SAR)	2,496,390 SAR	2,509,565 SAR	2,535,915 SAR	2,572,805 SAR	2,614,965 SAR	2,667,664 SAR	2,730,904 SAR	2,804,684 SAR	2,889,004 SAR	2,983,864 SAR	3,089,264 SAR	3,194,664 SAR	3,273,714 SAR	3,342,223 SAR	3,405,463 SAR
Cumulative NCF (SAR)	-23,926,110 SAR	-21,416,546 SAR	-18,880,631 SAR	-16,307,826 SAR	-13,692,862 SAR	-11,025,197 SAR	-8,294,293 SAR	-5,489,608 SAR	-2,600,604 SAR	383,260 SAR	3,472,524 SAR	6,667,187 SAR	9,940,901 SAR	13,283,124 SAR	16,688,588 SAR
SCENARIO C — SUBSIDISED PoA (5-yr MRV free, then Scenario B)															
Annual NCF (SAR)	2,581,390 SAR	2,594,565 SAR	2,620,915 SAR	2,657,805 SAR	2,699,965 SAR	2,667,664 SAR	2,730,904 SAR	2,804,684 SAR	2,889,004 SAR	2,983,864 SAR	3,089,264 SAR	3,194,664 SAR	3,273,714 SAR	3,342,223 SAR	3,405,463 SAR
Cumulative NCF (SAR)	-23,841,110 SAR	-21,246,546 SAR	-18,625,631 SAR	-15,967,826 SAR	-13,267,862 SAR	-10,600,197 SAR	-7,869,293 SAR	-5,064,608 SAR	-2,175,604 SAR	808,260 SAR	3,897,524 SAR	7,092,187 SAR	10,365,901 SAR	13,708,124 SAR	17,113,588 SAR

7- Sensitivity Analysis:

SENSITIVITY ANALYSIS — Carbon Price ±20% | PoA Portfolio (Low CAPEX)

Tests model robustness against RVCM price volatility

METRIC	Pessimistic (-20%) SAR 30/t	Base Case SAR 37.50/t	Optimistic (+20%) SAR 45/t	CBAM Y10 SAR 130/t
Carbon Price (SAR/tCO ₂ e)	30	37.5	45	130
Annual Portfolio CERs (tCO ₂ e)	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e	5,270.0 tCO ₂ e
Annual Carbon Revenue (SAR)	158,100 SAR	197,625 SAR	237,150 SAR	685,100 SAR
Annual OPEX Savings (SAR)	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR	2,383,765 SAR
Shared MRV Cost (SAR)	85,000 SAR	85,000 SAR	85,000 SAR	85,000 SAR
Annual Net Cash Flow (SAR)	2,456,865 SAR	2,496,390 SAR	2,535,915 SAR	2,983,865 SAR
Total CAPEX — Low (SAR)	26,422,500 SAR	26,422,500 SAR	26,422,500 SAR	26,422,500 SAR
Simple Payback Period (years)	10.8 yrs	10.6 yrs	10.4 yrs	8.9 yrs
10-Year ROI (%)	-7.0%	-5.5%	-4.0%	+12.9%
15-Year ROI (%)	+39.5%	+41.7%	+44.0%	+69.4%

8- Executive Summary:

EXECUTIVE SUMMARY — CARBON CREDIT MONETIZATION MODEL

BUILDING FACTS (ACTUAL DATA)

Gross Leasable Area	17,615 m ²
Actual Annual Electricity Consumption	3,028,731 kWh
Actual Annual Electricity Cost	794,588 SAR
Actual Energy Use Intensity (EUI)	171.9 kWh/m ² /yr
Actual Effective Tariff	0.262 SAR/kWh
Annual CO ₂ e Baseline Emissions	1,756.7 tCO ₂ e
SEEC Benchmark EUI for Zone 1B	300.0 kWh/m ² /yr (benchmark)
Building EUI as % of Benchmark	57.3%

KEY FINANCIAL RESULTS

Scenario	Annual NCF (SAR)	SPP (years)	15-yr ROI
Sc-A: Single Building — Low CAPEX (30% reduction)	198,139 SAR	13.3 yrs	12.5%
Sc-A: Single Building — Mid CAPEX (30% reduction)	198,139 SAR	20.0 yrs	-25.0%
Sc-B: PoA Portfolio (10 bldgs) — Low CAPEX	2,496,390 SAR	10.6 yrs	41.7%
Sc-B: PoA Portfolio (10 bldgs) — Mid CAPEX	2,496,390 SAR	15.9 yrs	-5.5%
Sc-C: Subsidized PoA — Low CAPEX (Yrs 1-5 NCF)	2,581,390 SAR	10.4 yrs	43.3%

CRITICAL FINDINGS FROM ACTUAL DATA

- 1. ACTUAL EUI = 171.9 kWh/m²/yr** — Already 43% below the SEEC benchmark of 300 kWh/m²/yr. The building is more efficient than average, yet market failure still exists.
- 2. ACTUAL TARIFF = SAR 0.262/kWh** — 46% higher than the SAR 0.18/kWh benchmark. This dramatically increases OPEX savings, making the investment case stronger than modelled.
- 3. CARBON FAILURE CONFIRMED:** Carbon revenue (SAR 19,762/yr) covers only 32.9% of MRV costs (SAR 60,000/yr) — confirming H1 with real data.
- 4. OPEX SAVINGS RESCUE THE INVESTMENT:** Annual OPEX savings of SAR 238,377/yr (at 30% reduction) make standalone participation viable despite the carbon revenue deficit.
- 5. PoA AGGREGATION MRV DILUTION:** Across 10 buildings, MRV cost drops from SAR 113.85/tCO₂e to SAR 16.13/tCO₂e — well below the RVC MC price of SAR 37.50/t.