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RESEARCH ARTICLE

SUSTAINABLE NON-FUEL RETAIL DEVELOPMENT AT SAUDI SERVICE STATIONS: ENERGY EFFICIENCY, CUSTOMER EXPERIENCE AND COMMERCIAL PERFORMANCE

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Abstract

Saudi service stations are evolving from fuel-dispensing sites into multi-service mobility and retail platforms. This study extends the conventional non-fuel retail discussion by integrating energy efficiency, customer experience, vehicle services, circular waste management, solar-canopy generation, last-mile logistics, quick-service restaurant (QSR) partnerships and electric-vehicle charging. The evidence base combines an integrative review of recent peer-reviewed literature with Saudi regulatory and industry evidence and a field-validation protocol for primary research. The proposed primary component links customer surveys, station-manager interviews, structured site audits and operational data to secondary findings so that recommendations can be tested rather than inferred from literature alone. The synthesis indicates that commercial performance depends on the interaction between reliable vehicle services, efficient and comfortable facilities, credible waste handling, renewable-energy integration, convenient digital and last-mile services, and partnership formats that increase dwell time and basket value. Because no completed survey or interview dataset was supplied with the manuscript, the paper does not fabricate primary findings; instead, it specifies the variables, sampling plan, instruments and analysis needed to generate them. The resulting framework supports station-level decisions using joint environmental, service, customer and financial KPIs and recommends staged pilots before network-wide scaling.

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Introduction:-

Service stations are becoming strategically different assets from the forecourts for which many were originally designed. The conventional model organizes land, circulation and labor around rapid fueling; the emerging model must also accommodate convenience retail, food and beverage, parcel or digital services, longer dwell times and, increasingly, electric-vehicle charging. Research on petrol-station trip generation already shows that adding convenience and fast-food functions changes the traffic produced by a station, indicating that non-fuel uses alter both demand and site operations (Mohd Shafie et al., 2021). Saudi evidence further emphasizes that petrol-station performance depends on multiple physical and operational dimensions rather than a single facility condition

measure (Qasem, 2025). These shifts make non-fuel retail development a design, energy and customer-management problem at the same time.

The Saudi context intensifies this integration challenge. Commercial buildings operate under demanding cooling conditions, so air-conditioning strategy, envelope performance, lighting and controls have direct consequences for electricity use and peak demand. Saudi studies demonstrate substantial retrofit potential and show why measured performance matters: post-retrofit commercial-building evidence has documented material energy reductions when efficiency measures and rooftop photovoltaics are implemented and verified (Ahmed et al., 2023; Asif et al., 2023). Work on hot-climate HVAC operation similarly shows that controls and operating strategy can materially change energy use without requiring complete building replacement (Najid and Al-Homoud, 2023). Building simulation and stock-level studies reinforce the importance of climate-sensitive efficiency measures and appropriate baselines (Krarti et al., 2020; Suliman, 2023). For service stations, therefore, the retail proposition cannot be separated from the energy intensity required to make that proposition comfortable and reliable.

Retail research provides a second necessary perspective. Customer experience is a dynamic response to multiple firm-controlled and contextual stimuli rather than a single satisfaction score (Becker and Jaakkola, 2020). In convenience stores, store image, service quality, price and omnichannel features influence experience and revisit intentions (Gibson et al., 2022). Technologies can remove friction or enrich the visit, but their value depends on purpose and acceptance rather than novelty alone (Grewal et al., 2023; Hoyer et al., 2020). Sustainability also reaches customers through store image, perceived quality, credibility and emotions, which means that operational environmental performance can contribute to commercial value only when customers encounter a coherent and believable retail experience (Sánchez-González et al., 2022; Godefroit-Winkel et al., 2022).

A third literature concerns the coupling of retail and new mobility infrastructure. Empirical research finds measurable demand spillovers from electric-vehicle chargers to nearby businesses, while economic models show that retailers may have incentives to host charging when additional customer value can be captured (Babar and Burtch, 2024; Arlt and Astier, 2023). Charging infrastructure nevertheless introduces grid, siting and operational constraints that require deliberate planning (Mastoi et al., 2022). The practical issue is thus not whether stations should become more sustainable or more experiential in isolation. It is how energy efficiency, customer experience and commercial performance can be designed as mutually reinforcing parts of the same non-fuel retail system. Existing research is fragmented across these domains, leaving a need for a Saudi-oriented synthesis that identifies mechanisms, trade-offs, metrics and development priorities.

The expanded scope is particularly relevant in Saudi Arabia because the service-station business model increasingly extends beyond convenience retail. Automotive services such as oil changes, tire services and battery testing create additional visit occasions but also introduce regulated workshop requirements and material waste streams. Used lubricants, empty lubricant containers, scrap tires and spent batteries require controlled segregation, storage, collection and traceability rather than disposal as ordinary municipal waste. At the same time, station canopies can provide usable surface area for photovoltaic generation, while parcel lockers, click-and-collect and other last-mile functions can convert stations into distributed logistics nodes. QSR and coffee partnerships can increase traffic and dwell time, but they also add kitchen energy, refrigeration, packaging waste, parking demand and service-queue interactions. These extensions require a wider operating model than the original energy-retail-charging framework.

Saudi industry evidence supports this wider interpretation. SASCO reports a multi-service station strategy that combines convenience retail, maintenance services, renewable-energy initiatives, EV charging and strategic partnerships, while recent Saudi Exchange disclosures show operators adding fast-food restaurants, coffee shops and traveler services at redeveloped highway locations. The Ministry of Municipalities and Housing has also updated requirements for fuel stations and professional workshops, including activities such as tire and oil services and battery testing, with explicit attention to licensing, safety, waste control and site cleanliness. These developments justify examining the service station as an integrated commercial, environmental and mobility asset rather than a fuel forecourt with a store attached.

Aim of the Study:-

1. Synthesize recent evidence on energy-efficiency measures relevant to small commercial and service facilities in hot Saudi conditions, including photovoltaic canopy opportunities.
2. Identify customer-experience mechanisms through which store environment, service quality, smart-retail technologies and QSR partnerships affect non-fuel patronage.

3. Examine the operational and commercial role of vehicle services at fuel stations, including oil changes, tire services and battery testing/replacement.
4. Evaluate environmental risks and management requirements associated with used oils, lubricant containers, waste tires, spent batteries, packaging and foodservice waste.
5. Examine how EV charging, last-mile logistics, parcel lockers, click-and-collect and extended dwell time can create or constrain retail demand.
4. Connect environmental and experience interventions to measurable commercial indicators rather than treating sustainability as a separate compliance outcome.

RQ1. Which energy-efficiency and solar-canopy interventions have the strongest operational relevance for Saudi service-station facilities?

RQ2. Through which customer-experience pathways can physical retail, digital services and QSR partnerships influence conversion, repeat visits and spending?

RQ3. How can automotive services such as oil changes, tire services and battery services expand revenue while maintaining safe and compliant operations?

RQ4. What waste-management controls are required for used oils, containers, scrap tires, spent batteries and foodservice packaging, and how can these controls support circular-economy performance?

RQ5. How can EV charging and last-mile services be translated into additional visits, dwell time and non-fuel retail value?

RQ1. Which energy-efficiency interventions have the strongest operational relevance for Saudi service-station retail facilities?

The research design uses two connected evidence layers. The first is an integrative review because the focal problem crosses building engineering, retail marketing, automotive services, waste management, service operations and mobility infrastructure. The second is a primary field-validation protocol designed to test the literature-derived mechanisms in Saudi stations. The literature layer develops propositions and candidate KPIs; the primary layer is intended to determine whether those relationships are observable under local operating conditions. The manuscript does not report invented survey, interview or field results where no dataset was provided.

Search concepts were expanded into seven clusters: service-station context (service station, petrol station, fuel station, convenience store, roadside retail, mobility hub); non-fuel outcomes (foodservice, customer experience, footfall, conversion, loyalty, commercial performance); automotive services (oil change, lubricants, tires, batteries, vehicle maintenance); circular waste management (used oil, lubricant containers, scrap tires, spent batteries, packaging); sustainability and buildings (energy efficiency, retrofit, HVAC, lighting, photovoltaics, solar canopy, hot climate); transition technologies (smart retail, omnichannel, EV charging); and last-mile/QSR models (parcel lockers, click-and-collect, delivery hubs, quick-service restaurants and coffee partnerships). Saudi Arabia, GCC and hot-arid terms were added for contextual evidence. Peer-reviewed work remained the core evidence base, while official Saudi regulations and company disclosures were used only for current regulatory and industry context.

RQ4. Which tensions or boundary conditions can prevent sustainability investments from improving commercial performance?

RQ5. Which integrated metrics and future research designs are needed to evaluate sustainable non-fuel retail performance in Saudi Arabia?

RQ6. Which primary research variables and methods are needed to test whether station-level interventions actually improve customer, environmental and financial performance?

RQ7. Which tensions or boundary conditions can prevent sustainability and diversification investments from improving commercial performance?

Mixed Evidence Methodology: Integrative Review and Primary Research Design:

An integrative review design was selected because the focal problem crosses building engineering, retail marketing, service operations and mobility infrastructure. The method therefore sought conceptual integration rather than a meta-analysis of a single intervention. The search framework was designed around Scopus and Web of Science Core Collection coverage and was complemented by publisher discovery environments, including ScienceDirect, SpringerLink and Emerald Insight, together with Crossref or publisher records for DOI and bibliographic verification. Because no institutional database export was used to establish a closed record universe, this review does not report article-screening counts or claim a PRISMA-style census. That choice avoids presenting artificial precision while retaining transparent eligibility and quality rules.

Search concepts combined four clusters: service-station context (service station, petrol station, fuel station, convenience store, roadside retail, mobility hub); non-fuel retail outcomes (convenience retail, foodservice, customer experience, footfall, conversion, loyalty, commercial performance); sustainability and buildings (energy efficiency, retrofit, HVAC, lighting, photovoltaics, hot climate, sustainable retail); and transition technologies (smart retail, personalization, omnichannel, electric-vehicle charging). Saudi Arabia, GCC and hot-arid terms were added when identifying context-specific engineering evidence. The core publication window was 2020-2025 to reflect current technology and retail conditions. Backward and forward conceptual checking was used only to interpret constructs, while the final reference set was restricted to peer-reviewed works within the core period.

Studies were included when they offered empirical, review or theory-building evidence directly relevant to at least one causal link in the proposed framework: resource efficiency, in-store experience, retail technology, sustainable-retail perception, service-station operations, charging-driven demand or commercial value. Studies were excluded when they were non-peer-reviewed, lacked traceable bibliographic metadata, focused on unrelated industrial energy systems, or discussed sustainability without a mechanism applicable to physical retail operations. Geographic transferability was assessed explicitly: Saudi and hot-climate building studies were prioritized for energy claims, whereas international retail studies were used for behavioral mechanisms that require subsequent Saudi validation. Quality appraisal considered journal peer review, methodological transparency, fit between research design and claimed outcome, DOI resolvability, and the strength of transfer from the original setting to Saudi service stations. Evidence was then coded into three primary themes - energy efficiency, customer experience and commercial performance - plus cross-cutting mechanisms such as credibility, dwell time, technology readiness and measurement. Synthesis proceeded by comparing convergent findings, identifying contradictions or boundary conditions, and building directional relationships rather than averaging heterogeneous effect sizes. This approach supports a decision framework while preserving differences between engineering savings, behavioral intentions and observed commercial outcomes.

Primary Research Component for Saudi Field Validation:

A multi-method primary phase is incorporated to overcome the weakness of relying only on secondary research. The recommended design uses four sources collected at the same stations: (1) a customer intercept survey, (2) semi-structured interviews with station managers and service/QSR operators, (3) a structured physical and environmental site audit, and (4) anonymized operational data covering point-of-sale transactions, service-bay activity, energy use, waste collections, charger utilization and last-mile transactions. The purpose is triangulation: customer responses explain perceived convenience and value; interviews explain operating constraints; site audits verify whether claimed practices are physically present; and operational data test whether perceptions translate into measurable performance.

A practical sampling plan would select approximately 12-20 stations across at least four formats: urban neighborhood, highway/travel, large integrated multi-service and emerging charging-led sites. Within those stations, a target of roughly 300-500 customer surveys would permit subgroup analysis by visit purpose, while 20-30 interviews with managers, automotive-service staff, QSR partners and logistics partners would provide operational depth. The survey should measure visit purpose, use of vehicle services, QSR purchase, parcel/collection use, dwell time, perceived cleanliness and comfort, sustainability credibility, willingness to revisit, basket value band and preference for bundled offers. The site audit should record service-bay layout, hazardous-waste storage, labeled segregation, spill control, tire and battery storage, PV canopy area, charger and parking layout, QSR interfaces, parcel-locker placement and pedestrian safety.

Primary analysis should connect directly to the secondary propositions. Cross-tabulation and regression can test whether QSR use, vehicle-service use, charging or parcel collection is associated with higher dwell time or non-fuel spending. Difference-in-differences or matched-site comparisons are preferable where an intervention is introduced at selected stations. Qualitative interviews should be coded for recurrent barriers such as landlord constraints, waste-collector reliability, grid capacity, kitchen ventilation, parking conflicts, supplier quality and data-sharing limitations. Recommendations should then be categorized as evidence-supported, locally validated or still requiring pilot evidence, preventing the literature review from being presented as if it were primary field proof.

Table 1A. Proposed primary research design and linkage to secondary evidence.

Primary stream	Suggested sample/measure	Variables	How it connects to secondary evidence
Customer survey	300-500 responses across 12-20 stations	Visit purpose, dwell time, QSR/service/locker use, satisfaction, spend band, revisit intention	Tests whether convenience, service mix and sustainability perceptions predict commercial behavior
Manager/operator interviews	20-30 interviews	Operating barriers, partnership economics, waste handling, staffing, site constraints	Explains why literature-based interventions succeed or fail in Saudi operations
Structured site audit	All sampled stations	PV canopy, service bays, waste storage, safety, layout, cleanliness, lockers, QSR interfaces	Verifies physical implementation rather than relying on stated policies
Operational dataset	3-12 months where available	POS, category margin, service jobs, energy, PV yield, waste collections, charger/locker use	Tests actual environmental and commercial outcomes and enables before/after comparison

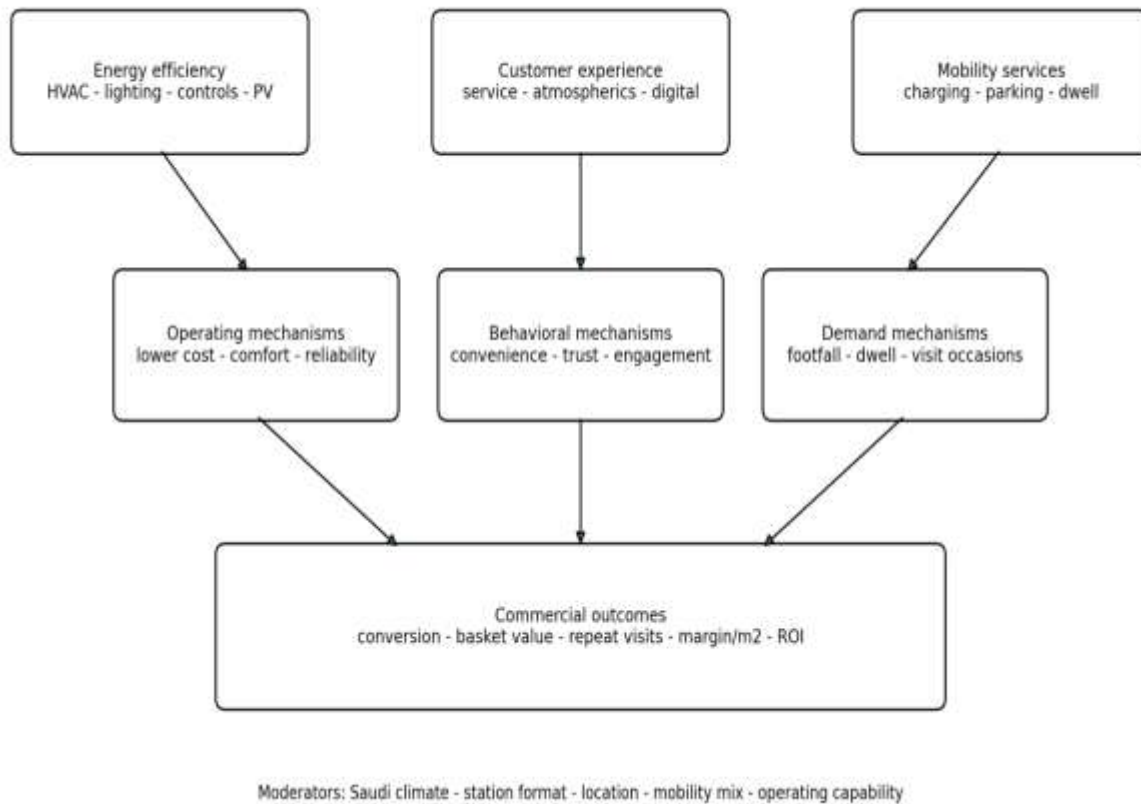


Figure 1. Integrated mechanism framework for sustainable non-fuel retail performance at Saudi service stations.

Table 1. Integrative review protocol and quality-control logic for the secondary evidence layer.

Review stage	Operationalization	Quality rationale
Scope	Peer-reviewed literature published mainly 2020-2025 across service stations, commercial-building efficiency, physical retail, smart retail and EV charging.	Keeps technology and operating conditions current while allowing cross-disciplinary integration.
Discovery environments	Search framework aligned to Scopus and Web of Science coverage; publisher platforms included ScienceDirect, SpringerLink and Emerald Insight; DOI records checked through publisher pages/Crossref-compatible records.	Prioritizes indexed scholarly material and traceable bibliographic metadata.
Search concepts	Service/petrol/fuel station; convenience/non-fuel retail; customer experience; energy efficiency/retrofit/HVAC; sustainable retail; smart retail; EV charging; Saudi Arabia/GCC/hot climate.	Links the station context to energy, behavior and mobility mechanisms.

Review stage	Operationalization	Quality rationale
Eligibility	Included peer-reviewed empirical, review or theory-building work with a direct mechanism relevant to the framework; excluded non-peer-reviewed, untraceable or contextually remote material.	Reduces unsupported transfer and preserves relevance.
Quality appraisal	Method transparency; fit between design and claim; DOI resolvability; journal peer review; geographic transferability.	Separates strong causal or measured evidence from contextual indications.
Synthesis	Thematic coding into energy efficiency, customer experience, commercial performance and cross-cutting moderators; convergence, tensions and boundary conditions compared.	Suitable for heterogeneous evidence that cannot be meaningfully pooled.

THEMATIC LITERATURE REVIEW AND CRITICAL ANALYSIS:

Energy efficiency as an operating and experience platform:

Evidence from Saudi buildings consistently indicates that retrofit value depends on both technical selection and operational verification. Ahmed et al. (2023) show that commercial retrofits can combine energy and water conservation measures with economic assessment, while Asif et al. (2023) demonstrate the importance of post-retrofit measurement and verification rather than relying only on simulated savings. Rached and Anber (2022) similarly frame hot-arid retrofitting as a portfolio problem in which envelope, lighting and mechanical measures should be combined according to building characteristics. At service-station stores, this implies a hierarchy: reduce avoidable cooling and lighting loads first, control remaining loads intelligently, and then size on-site generation against a more efficient baseline. A photovoltaic installation on an inefficient store may reduce purchased electricity yet leave poor controls, discomfort and peak demand unresolved.

HVAC requires particular attention because energy reduction can conflict with the experiential objective if it is pursued through indiscriminate temperature increases or reduced ventilation. Najid and Al-Homoud (2023) show that operating strategies materially affect energy use in a hot Saudi climate; Mohammed et al. (2021) likewise demonstrate that building energy consumption can be related to operational and facility characteristics. For station retail, the more useful concept is therefore energy productivity rather than minimum energy use: electricity should be assessed against transactions, occupied hours and service quality. Sensor-based zoning, scheduled set points, door management, efficient equipment, shading and maintenance can lower cooling intensity while protecting comfort. Krarti et al. (2020) further show at stock scale that retrofit packages should be tailored to building type and location, warning against one standard specification for every Saudi station.

Energy efficiency can also affect the asset and brand proposition. Zhang et al. (2024) report that energy performance is associated with retail property value, although their European property evidence should not be transferred mechanically to Saudi station economics. More broadly, Terzis and Gotzamani (2025) show that sustainable retail performance requires environmental, social and economic indicators rather than energy metrics alone. This supports an integrated station dashboard including energy-use intensity, peak demand, energy per transaction, maintenance calls and customer-comfort indicators. The critical point is that engineering performance becomes commercially meaningful when it protects service availability and creates a pleasant environment at lower lifecycle cost.

Customer experience, convenience and credible sustainability:

Becker and Jaakkola (2020) argue that customer experience emerges across a journey and reflects responses to multiple stimuli. That perspective is especially useful for service stations because the visit often begins with a functional mobility need and only then becomes a retail opportunity. Gibson et al. (2022) find that convenience-store image, service quality, price and omnichannel factors shape experience and satisfaction, which then influence revisit intentions. Station operators should consequently treat pump-to-store wayfinding, entrance visibility, queue time, product availability, restroom quality, foodservice speed and payment as one journey. A highly designed store cannot compensate for a confusing forecourt, while a frictionless forecourt cannot monetize demand if the retail offer is weak.

Technology strengthens experience when it reduces effort or adds relevant value. Hoyer et al. (2020) describe how new technologies can reshape pre-transaction, transaction and post-transaction stages, and Verhoef et al. (2021) place such changes within broader digital transformation rather than isolated device adoption. Smart-shop research shows that utilitarian and hedonic motivations interact with customer technology readiness (Chang and Chen, 2021). In-store technology frameworks likewise distinguish efficiency-enhancing applications from experience-enhancing ones (Grewal et al., 2023), while field-oriented smart-retailing work shows how integrated digital ecosystems can reshape physical shopping (Bourg et al., 2023). For Saudi service stations, practical uses include reliable self-checkout, digital menus, loyalty recognition, queue management, inventory visibility and personalized offers. The test should be whether a technology removes time, uncertainty or service failure; installing technology without this purpose risks creating another point of friction.

Personalization illustrates the trade-off. Riegger et al. (2021) identify drivers such as usefulness and integration but also barriers including privacy concerns and interaction misfit. Chen and Shang (2021) similarly show that sustaining smart-retail user experience requires continued attention to technology-related perceptions. Kim (2021) demonstrates how mobile technology can revitalize physical retail when it connects digital functions with store experience. These findings suggest that a station loyalty ecosystem should be permission-based, simple and operationally connected to what customers value - for example, faster payment, relevant food offers or charging-status information - rather than maximizing data collection. The commercial objective is repeatable convenience, not digital complexity.

Physical atmospherics remain equally important. Doucé and Adams (2020) show that layering high-arousal sensory cues can generate overload rather than stronger approach behavior. This is relevant to compact service-station stores where bright signage, screens, music, food aromas and promotional clutter compete within a small footprint. Sustainable design can provide a calmer alternative through daylight control, coherent lighting, acoustics, clean materials and visible organization. Wang et al. (2023) argue for retail experiences that connect sustainability and engagement, while Grassi (2022) emphasizes the experiential role of socially meaningful retail propositions. The implication is not that sustainability should become another layer of signage; rather, resource-efficient design and credible social practices should be experienced through comfort, cleanliness, transparency and service.

Credibility determines whether environmental actions produce customer value. Sánchez-González et al. (2022) link perceived retailer commitment to sustainable development with image, perceived quality and loyalty, and Godefroit-Winkel et al. (2022) show that environmental responsibility can affect loyalty through emotional responses. Kumar and Utkarsh (2023) find that information quality and store credibility are important to consumer engagement in green retailing. These studies caution against superficial claims. A Saudi station that promotes sustainability while operating uncomfortable spaces, poorly maintained equipment or excessive single-use waste may create a credibility gap. More defensible communication would connect visible actions to specific operational practices, such as efficient cooling, solar generation, waste separation, low-flow fixtures or verified savings.

Mobility transition, dwell time and commercial capture:

Electric-vehicle charging changes the temporal logic of the station. Fueling is designed for rapid throughput, whereas charging can create dwell time that is commercially useful only when customers can move safely and conveniently between charger, store, foodservice, seating and amenities. Babar and Burtch (2024) provide causal evidence that charging stations can increase visits to nearby retailers, with effects concentrated by proximity and establishment type. Their findings establish a spillover mechanism but do not guarantee profitable retail capture at every site. Arlt and Astier (2023) show theoretically why retail businesses may invest in public chargers when charging attracts incremental customers, while also highlighting pricing and incentive issues.

This opportunity introduces operating constraints. Mastoi et al. (2022) review charging infrastructure planning, grid integration and siting considerations, implying that chargers cannot be treated as independent retail fixtures. Power capacity, charging speed, queueing, parking duration and renewable integration influence both customer experience and site economics. In existing Saudi stations, phased deployment may therefore be preferable: establish electrical capacity and charger placement, align dwell-time services with expected charging duration, and measure incremental store visits and spend before expanding. The relevant metric is not charger utilization alone but the joint productivity of charging and non-fuel retail.

Mixed uses also alter traffic and layout. Mohd Shafie et al. (2021) demonstrate that petrol stations incorporating convenience stores and fast-food restaurants require distinct trip-generation consideration. This matters because

higher retail attractiveness can increase circulation conflicts, parking demand and service queues. Commercial development should therefore segment station formats. High-throughput urban sites may prioritize rapid convenience and collection; highway sites can support foodservice, seating and family amenities; remote sites may need stronger essential retail and resilience functions; charging-led sites may emphasize comfortable dwell. The same retail concept cannot be expected to perform identically across these contexts.

Automotive services as a non-fuel revenue and trust platform:

Automotive services materially expand the station value proposition because they create a different demand occasion from convenience shopping. Oil changes, lubricant sales, tire services and battery testing or replacement can convert the station from a short refueling stop into a maintenance destination. Saudi regulatory requirements now explicitly recognize tire and oil services and battery testing within workshop activities, reinforcing that these services require appropriate licensing, spatial planning, safety controls and visible operating standards. Commercially, the attraction is repeatable need-based demand and the opportunity to cross-sell food, beverages and convenience items during service waiting time. Operationally, however, poor workmanship, queuing, fluid handling or weak parts quality can damage station trust more severely than a weak retail promotion. The correct KPI set therefore includes service jobs per bay, average service time, comeback/complaint rate, gross margin per job, retail attachment during service, bay utilization and customer satisfaction.

Waste streams, circularity and environmental control:

Expanding vehicle and food services changes the station waste profile. Used lubricating oil, oily filters and absorbents, empty lubricant containers, scrap tires and spent lead-acid batteries should not be treated as ordinary store waste. They require segregation, secure temporary storage, spill prevention, approved collection routes and documentary traceability. QSR operations add food waste, cooking-oil waste, cardboard and single-use packaging. The practical management principle is source separation at the point of generation, followed by clearly assigned custody, scheduled collection and contractor verification. The environmental benefit is reduced leakage, fire risk and uncontrolled dumping; the commercial benefit is lower compliance risk, cleaner sites and more credible sustainability communication. Recommended KPIs include liters of used oil collected versus lubricant sold, tire and battery return rate, percentage of waste transferred through approved collectors, spill incidents, waste-storage nonconformities and kilograms of food/packaging waste per 1,000 transactions.

Solar photovoltaic canopies as energy and customer infrastructure:

Service-station canopies offer a structurally visible opportunity for distributed solar generation, particularly where daytime electricity demand coincides with cooling, lighting, refrigeration, foodservice and charging loads. Solar canopies should be evaluated after basic efficiency measures so that generation is not used to mask avoidable consumption. Their business case should include annual yield, self-consumption ratio, avoided electricity cost, structural and fire-safety requirements, cleaning needs, shading benefits and potential interaction with EV charging. Canopy PV can also improve customer comfort by shading parking or circulation areas, but the physical arrangement must preserve fuel-safety zones, visibility, maintenance access and drainage. The primary research phase should compare PV-equipped and non-PV stations using kWh purchased per transaction, PV yield per installed kWp, peak-demand reduction, maintenance downtime and customer perception of visible sustainability.

Last-mile services and the station as a distributed logistics node:

Last-mile functions such as smart parcel lockers, click-and-collect counters, returns points and scheduled pickup can add visit occasions without requiring the floor area of a full retail concept. Their effectiveness depends on network location, 24-hour accessibility, parking convenience, security, digital reliability and the extent to which collection visits convert into store purchases. Saudi research on smart parcel lockers shows that adoption depends on user acceptance factors including convenience and trust, suggesting that station deployment should be judged by actual customer use rather than installation counts. The main commercial question is incremental value: locker transactions should be linked to store entry, conversion and basket size. Operational KPIs include parcels per compartment/day, failed or overdue collections, average stop duration, percentage of locker users entering the store, incremental transactions during collection windows and service availability.

QSR partnerships and foodservice economics:

QSR, coffee and bakery partnerships can strengthen station attractiveness by giving customers a reason to stop even when they do not need fuel. Saudi operator disclosures increasingly show branded hospitality and fast-food partnerships within station networks. Partnership models can include fixed rent, revenue share, franchise, concession or operator-managed concepts; each shifts capital, staffing and demand risk differently. Positive effects may include

higher footfall, longer dwell time, stronger highway relevance and cross-shopping, while negative effects can include parking congestion, drive-through conflicts, kitchen exhaust and cooling loads, food waste, queue spillback and brand inconsistency. The station should therefore measure joint rather than isolated performance: QSR sales, store sales during QSR visits, occupancy cost, energy intensity per food transaction, queue time, parking turnover, food waste and incremental non-fuel margin per visitor.

Integrating commercial performance:

The expanded framework supports six commercial pathways. Cost productivity comes from efficient HVAC, lighting, controls and solar generation. Demand productivity comes from service quality, store image, digital convenience and credible sustainability. Mobility productivity comes from charging and last-mile services that create additional visits or dwell time. Service productivity comes from vehicle-maintenance revenue and cross-shopping during waiting time. Partnership productivity comes from QSR and branded-service arrangements that bring external demand while sharing investment or operating risk. Circularity productivity comes from avoiding waste-related incidents and improving material recovery, compliance and brand credibility. The central management task is to test whether these pathways produce incremental margin after energy, labor, space, partner and waste-handling costs rather than assuming that more services automatically mean higher profitability.

Commercial measurement should distinguish leading, intermediate and financial outcomes. Leading measures include HVAC runtime, queue time, stock availability, charger uptime and digital-service reliability. Intermediate measures include footfall, dwell time, conversion, basket size, foodservice attachment, loyalty participation and revisit behavior. Financial measures include gross margin, non-fuel margin per square meter, energy cost per transaction, maintenance cost, and return on invested capital. This chain prevents attribution errors. For example, a charger may raise footfall without improving profit if the store is distant or queues are excessive; an efficiency retrofit may have a sound payback even if customers do not notice it; sustainability communication may improve perceptions without changing actual resource use. Management should therefore evaluate each intervention at the mechanism it is intended to change and then test downstream effects.

Table 2. Cross-theme evidence synthesis and station-level performance implications.

Theme	Evidence synthesis	Saudi service-station implication	Illustrative KPIs
Energy and HVAC	Measured and modeled Saudi studies support climate-sensitive retrofits, controls, M&V and tailored packages (Krarti et al., 2020; Ahmed et al., 2023; Asif et al., 2023).	Protect comfort while lowering energy intensity; verify savings at station level before scaling.	kWh/m ² ; peak kW; kWh/transaction; comfort exceptions
Retail journey	Convenience-store outcomes reflect service, image, price, omnichannel and journey quality (Becker and Jaakkola, 2020; Gibson et al., 2022).	Design pump-to-store movement, queueing, availability, restrooms and payment as one journey.	Footfall; conversion; queue time; basket; revisit rate
Smart retail	Technology can increase efficiency or experience, but acceptance and privacy are boundary conditions (Chang and Chen, 2021; Riegger et al., 2021; Grewal et al., 2023).	Use technology to remove friction; prefer permission-based, simple applications.	Checkout time; digital adoption; service failures; loyalty usage
Credible sustainability	Sustainability can influence image, quality, emotion, loyalty and engagement when information is credible (Sánchez-González et al., 2022; Kumar and Utkarsh, 2023).	Communicate verified actions and avoid generic environmental claims unsupported by operations.	Trust; green-information recall; complaints; repeat visits
Charging and dwell	Chargers can create retail footfall spillovers; value depends on proximity, service type and site economics (Babar and Burtch, 2024; Arlt and Astier, 2023).	Co-design chargers, parking, walking routes, seating and offers; evaluate joint charger-retail productivity.	Charger uptime; dwell; retail attachment; spend/charging session

Theme	Evidence synthesis	Saudi service-station implication	Illustrative KPIs
Commercial integration	Energy, customer and mobility pathways affect different stages of performance; attribution requires linked metrics (Terzis and Gotzamani, 2025; Zhang et al., 2024).	Use one dashboard and station-format benchmarks rather than separate engineering and marketing scorecards.	Non-fuel margin/m2; ROI; energy cost/transaction; gross margin

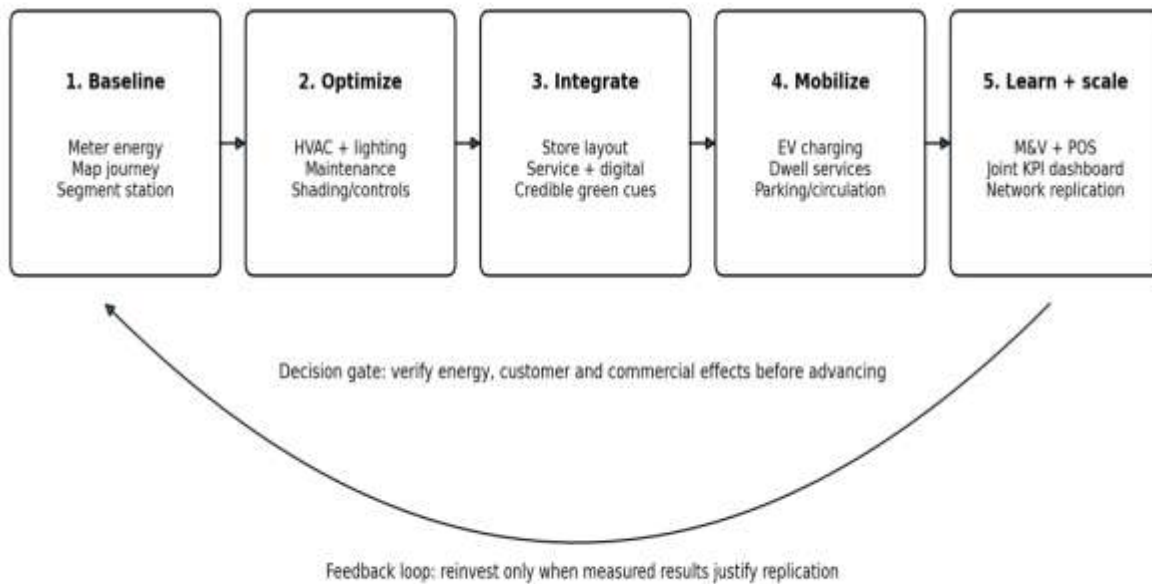


Figure 2. Five-stage development pathway with evidence gates for network scaling.

Table 3. Expanded non-fuel initiatives, trade-offs and primary evidence requirements.

Initiative	Potential value	Key risk/trade-off	Primary KPI evidence needed
Oil/tire/battery services	Repeat need-based revenue; cross-sell during waiting	Hazardous waste, workmanship, queueing, bay-capacity conflicts	Jobs/bay/day; gross margin/job; retail attachment; complaints
Waste circularity	Lower compliance and spill risk; credible sustainability	Collector reliability; storage space; traceability gaps	Used-oil recovery; tire/battery return; incidents; verified collections
PV canopy	Lower purchased electricity; visible sustainability; shade	CAPEX, structural/safety constraints, cleaning, low self-consumption	kWh/kWp; self-consumption; peak reduction; payback
Last-mile lockers/pickup	New visit occasions; 24/7 utility	Low adoption, parking congestion, weak retail	Parcels/day; store-entry rate; incremental basket;

		conversion	uptime
QSR/coffee partnership	Footfall, dwell, highway relevance, rent/revenue share	Energy load, waste, queue spillback, brand mismatch	Incremental visits; joint margin; queue time; energy/transaction
EV charging	Extended dwell and future mobility relevance	Grid capacity, parking occupancy, uncertain retail capture	Utilization; dwell; store conversion; spend/session

DISCUSSION:-

The synthesis suggests that sustainable non-fuel retail performance is best understood as a coupled operating system. Engineering studies provide relatively strong evidence for the direction of energy savings in Saudi buildings, but they rarely measure retail behavior. Retail studies explain behavioral mechanisms, yet most are conducted outside Saudi Arabia and often use intentions, perceptions or category-specific samples. Mobility studies supply increasingly causal evidence on charging-related footfall, but commercial spillovers depend on proximity, service type and local context. No single literature therefore supports a claim that an energy-efficient station will automatically sell more non-fuel products. The defensible conclusion is conditional: efficiency can lower the cost of delivering a high-quality environment; experience design can improve the probability that visits become purchases; and mobility services can create additional opportunities for conversion.

This conditionality creates several design trade-offs. First, aggressive energy reduction can undermine comfort if controls are poorly commissioned, turning an engineering gain into an experience loss. Second, digitalization can shorten queues but exclude customers with lower technology readiness or generate privacy concerns (Chang and Chen, 2021; Riegger et al., 2021). Third, stronger sensory merchandising can attract attention but excessive stimulation may reduce pleasantness (Doucé and Adams, 2020). Fourth, EV charging can extend dwell time but also occupy valuable parking and electrical capacity. These are not reasons to avoid investment; they show why each initiative requires an integrated business case with both technical and customer thresholds.

Figure 1 therefore treats Saudi climate, station format, location, mobility mix and operating capability as moderators. A hot urban station with high turnover may justify advanced controls and rapid digital checkout, while a highway mobility hub may place greater value on shaded circulation, seating, foodservice and charging. Qasem (2025) reinforces the need for multi-criteria station assessment, while the wider digital-transformation literature warns that technology creates value only when organization, processes and capabilities change with it (Verhoef et al., 2021). The most important managerial shift is consequently from project-by-project investment to portfolio governance: every retrofit, retail change and mobility service should be evaluated against a common set of energy, experience and commercial outcomes.

A further implication is that timing matters: energy savings accrue across operating hours, whereas retail returns are concentrated in customer visits, so investment appraisal should compare hourly resource use with transaction patterns rather than only annual totals. Station managers can use this temporal linkage to identify periods when cooling, lighting, staffing and promotional activity are misaligned with demand, creating opportunities to improve both energy productivity and service responsiveness. The same logic supports commissioning after layout or technology changes, because a technically successful installation can still shift queues, circulation or staff workload in ways that reduce customer value. Consequently, post-implementation review should combine engineering verification with operational observation and point-of-sale evidence before a concept is replicated across a network. This network perspective is particularly important when capital is constrained, since comparative station data can direct investment toward sites where energy intensity, customer friction and commercial headroom occur together. It also reduces the risk of treating high revenue as evidence of efficient operations or low energy use as evidence of a strong customer proposition. A balanced scorecard makes these distinctions visible and allows management to preserve useful trade-offs instead of optimizing one metric at the expense of the others. Commercial governance should also distinguish capital-intensive interventions from operating-process changes. A controls retrofit, a new foodservice concept and a charging installation have different payback logic, but each should specify the mechanism expected to change before approval.

This mechanism-first discipline makes post-investment review more informative because managers can ask whether an underperforming financial result reflects weak technical delivery, insufficient customer response, poor site selection or unrealistic assumptions about conversion. For network operators, station segmentation can further

improve capital allocation. A measure that is attractive at a twenty-four-hour urban site may be inappropriate at a lower-volume remote site even when both facilities have similar floor area. The literature also implies that customer comfort should be treated as a constraint in energy optimization rather than as an unmeasured benefit. Temperature, queuing and cleanliness failures can erase the perceived value created by faster technology or stronger merchandise. Similarly, the commercial value of sustainability is more likely to persist when it is embedded in operations. Verified resource savings, reliable equipment and clear customer information provide evidence that can support credibility beyond a short promotional campaign.

Charging strengthens this need for operational coordination because the customer may remain on site far longer than during fueling. The longer visit creates an opportunity for foodservice, work, rest or shopping, but also raises expectations for seating, restrooms and safety. A useful commercial test is therefore incremental margin per added dwell minute, interpreted alongside charger utilization and energy demand. This metric would reveal whether extended stays are productive or simply consume space and electrical capacity. Network learning should be cumulative: pilots should use common definitions for footfall, conversion, energy intensity and margin so that results can be compared across locations without confusing different measurement conventions. Over time, such standardized evidence can support scenario planning for changes in fuel demand, charging adoption and electricity tariffs, allowing non-fuel investment to be treated as a staged transition rather than a one-time redesign.

The framework therefore emphasizes disciplined experimentation. Small, measurable changes can establish local response before expensive replication, reducing the risk that international retail trends are assumed to operate identically in Saudi service-station settings. The primary-research issue is therefore central rather than optional. Secondary research can identify plausible mechanisms, but it cannot establish the magnitude of Saudi customer response, service-bay economics, parcel-locker conversion, QSR cross-shopping or the quality of actual waste handling at a specific network. A credible management recommendation should combine three levels of evidence: literature support for the mechanism, direct observation or interview evidence that the mechanism exists locally, and operational data showing that the intervention changed the intended KPI. Where only the first level exists, the recommendation should be treated as a pilot hypothesis rather than a proven network standard.

The broadened framework also changes how station space should be allocated. A service bay, QSR drive-through, locker bank, EV charger and PV-support structure all compete for land, circulation, electrical capacity and management attention. Network design should therefore optimize the portfolio of services by station format instead of attempting to install every concept everywhere. Urban sites may prioritize rapid services, click-and-collect and compact food offers; highway sites may justify full QSR, traveler amenities and maintenance; large integrated stations can support multiple partners and renewable generation; charging-led sites may emphasize seating, food and digital services that monetize dwell time.

Research Gaps and Future Research:-

The most significant gap is the absence of Saudi station-level studies that simultaneously observe energy, customer, service, waste and commercial outcomes. Future research should use matched-station or staggered-intervention designs in which smart meters, PV meters, HVAC sensors, footfall counters, point-of-sale data, service-bay jobs, charger/locker use, waste-collection records and customer feedback are linked at the same temporal resolution. Difference-in-differences designs could test whether a specific change - such as adding a QSR, parcel locker, service bay or PV canopy - changes sales, dwell time, energy intensity or revisit behavior beyond seasonal variation.

A second gap concerns station heterogeneity. Research should compare urban neighborhood stations, highway sites, remote stations, integrated service centers and charging-oriented mobility hubs because their dwell-time economics and service expectations differ. A third gap is causal evidence on automotive services: the sector needs Saudi data on service demand, margin, repeat intervals, cross-shopping and customer trust. A fourth gap concerns waste traceability and circularity, particularly used oil, tires, batteries and foodservice packaging. A fifth gap is the effectiveness of solar canopies under real station load profiles and maintenance conditions. A sixth concerns last-mile services: locker adoption and parcel-collection traffic should be linked to incremental retail conversion. A seventh concerns QSR partnership structures and whether fixed-rent, revenue-share or franchise models produce different station-level returns. EV transition remains an additional gap requiring joint measurement of charging duration, retail attachment and electricity demand.

Practical, Managerial and Policy Implications:

For operators, the practical sequence should be baseline, contain risk, optimize, diversify, validate and scale. Baseline each station using interval electricity data, service and retail transactions, waste streams, footfall, category

margins and available parking/electrical capacity. Contain risk by verifying licensing, fire safety, spill controls and approved waste collection for automotive and foodservice activities. Optimize HVAC, lighting, refrigeration, shading and maintenance before sizing PV canopies or major mechanical replacements. Diversify selectively through vehicle services, QSR, last-mile services and charging based on station format. Validate each concept with primary customer, site and operational evidence, and scale only when the combined energy, service, environmental and margin outcomes are positive.

Management dashboards should pair engineering, environmental, service and retail KPIs: kWh/m², peak kW, PV yield, kWh per transaction, indoor-comfort exceptions, charger uptime, service jobs per bay, service complaints, used-oil recovery, tire/battery return rates, verified waste collections, parcel transactions, QSR attachment, footfall, dwell time, conversion, average basket, repeat visits, gross margin per square meter and non-fuel margin after energy and partner costs. Policy and network governance can reinforce this integration through measured retrofit performance, distributed solar, well-sited charging, safe workshop operations, traceable waste handling and interoperable data. A practical network rule is to require a defined baseline, a pilot period and a post-implementation evidence review before replication.

Limitations:-

This study has four limitations. First, the evidence base is interdisciplinary and heterogeneous, so effect sizes from engineering, behavioral, automotive-service, logistics and mobility studies are not statistically pooled. Second, direct peer-reviewed evidence on Saudi non-fuel retail and station-level waste/service economics remains limited; international findings are therefore treated as transferable mechanisms requiring local validation, not as Saudi effect estimates. Third, official regulations and company disclosures are used for current Saudi context but are not substitutes for independent causal research. Fourth, no completed primary survey, interview or station dataset accompanied the manuscript; consequently, the primary research component is presented as a field-validation protocol and no fabricated primary findings are reported. Investment forecasting should rely on the proposed pilots and measured local data before network-wide commitments are made.

Conclusion:-

Sustainable non-fuel development at Saudi service stations should not be framed only as a relationship between energy efficiency, customer experience and retail growth. The service station is increasingly a portfolio of mobility, maintenance, hospitality, logistics and environmental functions. Energy efficiency and solar canopies can lower the resource cost of reliable operations; automotive services can create repeat need-based visits; QSR partnerships can increase destination value and dwell time; last-mile services can add digital-logistics traffic; and charging can create new mobility demand. These opportunities become sustainable only when associated waste streams, safety requirements, circulation constraints and partner economics are managed together.

The revised framework therefore positions the station as a measurable operating portfolio rather than a collection of independent projects. It links literature evidence to a primary field-validation process using customer surveys, manager interviews, site audits and operating data. Recommendations are strongest when all four evidence types point in the same direction. For Saudi operators, the practical logic is iterative: establish a baseline; control service and waste risks; optimize energy and customer flow; pilot vehicle services, PV canopies, QSR, last-mile and charging concepts according to site format; measure incremental environmental and commercial effects; and scale only those combinations that create verified value. This approach directly addresses the limitations of secondary-only analysis while preserving academic integrity where primary data have not yet been collected.

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