A Multi-Criteria Decision-Making Framework for Strategic Entry into Energy Service Markets: Integrating SWOT, AHP and TOWS with an Application to the Telecommunications Industry

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Abstract

This study presents a framework for prioritizing strategic actions for a telecommunications operator considering entry into Iran's energy services market. Geometric aggregation of 690 pairwise judgments from 15 experts yielded the following SWOT priorities, in descending order: opportunities (0.380255), strengths (0.264294), threats (0.226549), and weaknesses (0.128902). O1 and S4 received the highest global weights. SO1 ranked first under all four baseline scoring rules. When the SWOT dimension weights were varied one at a time, SO1 ranked first by raw score in all 24 scenarios and by mean factor weight in 18 of the 24 scenarios. A separate sensitivity analysis of local factor weights showed that SO1 retained the highest raw score in 119 of 120 scenarios. The Business Model Canvas and implementation roadmap present design proposals for subsequent feasibility assessment. [Reviewer 2, Comments 1.4, 2.1, and 1.7]

Keywords: multi-criteria decision making; AHP; SWOT; weighted TOWS; sensitivity analysis; digital energy services.

1. Introduction

Power systems are shifting from centralized, asset-oriented structures toward distributed, service-oriented, and digitally coordinated architectures. Decarbonization is increasing the value of flexible resources, while digitalization enables their observation, forecasting, coordination, and commercialization. Consequently, value creation in the energy sector increasingly extends beyond the sale of electricity or equipment to include data-enabled services, flexibility, optimization, and continuing customer relationships.

Telecommunications operators are important adjacent actors because they possess nationwide communication infrastructure, IoT/M2M platforms, data centers and cloud services, billing systems, enterprise sales channels, large customer bases, and data-analytics capabilities. Technological proximity alone, however, does not constitute a successful entry strategy. ESCO services, demand response, and aggregation also depend on energy-domain expertise, contracting capabilities, measurement and verification, settlement mechanisms, data access, and market rules.

The empirical context of this study is Iran. A telecommunications operator considering entry into an emerging electricity market must evaluate market opportunities together with internal capability readiness, regulatory and investment risks, and dependence on complementary partners. The central problem is therefore not merely technology selection, but the reconfiguration of telecommunications capabilities within a regulated energy ecosystem.

From an industrial-engineering perspective, the research gap is the absence of a quantitative and traceable decision chain that converts SWOT-based environmental diagnosis into defensible weights, strategic actions, and implementation outputs. Many SWOT applications remain descriptive, while in hybrid approaches strategy scores may be influenced by the number of supporting factors. This study addresses that gap by integrating AHP, weighted TOWS, and a complementary normalization rule, and applies the framework to telecommunications entry into the energy-service market.

This study addresses four decision questions:

1) What is the relative importance of the SWOT dimensions and factors in cross-sector entry into energy-service markets?

2) Which factors have the highest global priorities after combining group and local weights?

3) What do raw and normalized TOWS scores reveal about the robustness and sensitivity of strategic actions?

4) How can the quantitative decision output be translated into a traceable implementation configuration without conflating expert data with managerial design judgments?

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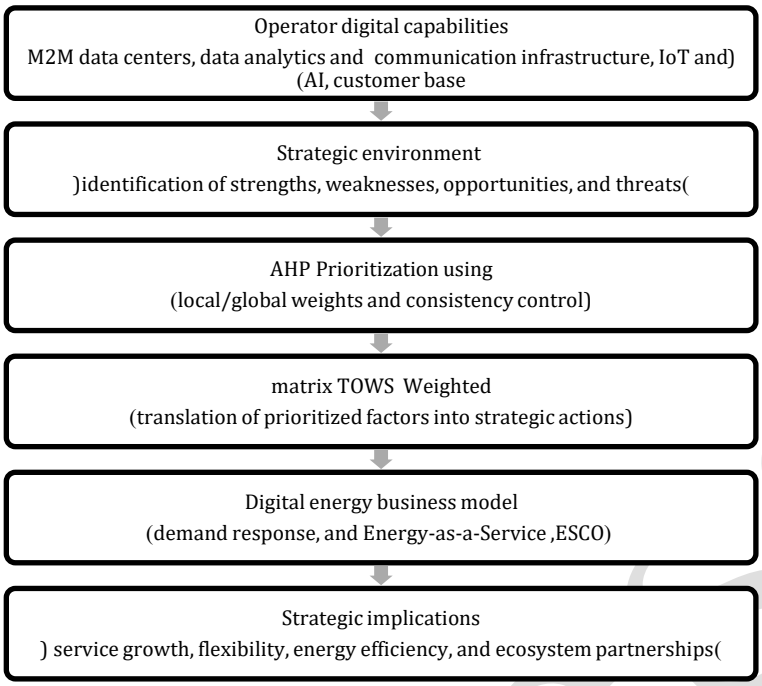


Fig.1. Integrated conceptual framework for telecommunications entry into digital energy services

2. Literature Review and Theoretical Background

2.1. Digital Transformation and the Emergence of Smart Energy Services

Digital transformation is shifting the traditional electricity industry from a predominantly centralized, asset-based system toward a data-driven, distributed, and service-oriented ecosystem. Smart meters, the Internet of Things (IoT), cloud computing, big data, and artificial intelligence have expanded the capacity for real-time monitoring, demand forecasting, demand-side management, and optimization of energy-system performance. In this environment, value creation is no longer confined to energy or equipment sales; data, flexibility, analytics, and continuing services have also become sources of value.

Siuta-Tokarska et al. [1] show that digitalization can drive the redesign of energy-sector business models. Hiteva and Foxon [2] further argue that digital energy-service models must simultaneously address value creation for users and for the energy system, and that a value gap may arise between these objectives. Wang et al. [3] emphasize the complementary roles of artificial intelligence, smart metering, IoT, and grid management in the energy transition. Digital transformation in the electricity sector should therefore be understood not merely as technological change, but as the joint redesign of technology, ecosystem relationships, and business logic.

2.2. Energy Service Companies and the Transition toward Service-Oriented Models

Energy service companies (ESCOs) are an important mechanism for moving from the simple sale of energy toward performance-based services. ESCO offerings may include energy audits and optimization, performance monitoring and measurement, energy management, and savings-based contracts. Cagno et al. [4] show that ESCO services vary in service scope, financing arrangements, risk allocation, and customer relationships. Cebekhulu et al. [5], in a systematic review of ESCO research, likewise highlight persistent challenges related to market development, contractual models, and institutional conditions.

At the same time, servitization has expanded energy offerings toward digital services, data analytics, demand management, and continuing customer support. Brown et al. [6] describe this transition as a shift from selling energy toward delivering final energy services. Iria and Soares [7] propose an Energy-as-a-Service model for prosumer aggregators. From this perspective, telecommunications entry into the energy market does not necessarily require immediate transformation into a fully integrated traditional ESCO; an alternative path is to begin with asset-light digital services and subsequently complement them through partnerships or the development of specialized energy capabilities.

2.3. Demand Response, Aggregation, and Flexibility-Based Models

The expansion of distributed energy resources and smart grids has increased the importance of demand response and flexibility aggregation. In such models, an aggregator coordinates small resources or loads as a portfolio so that they can participate in energy and ancillary-service markets. Okur et al. [8] show that the viability of aggregator business models depends on the joint consideration of operational and financial factors. Martín-Martínez et al. [9] further emphasize actor relationships, technical architecture, and deployment arrangements in aggregator models.

This domain overlaps substantially with telecommunications capabilities because broad connectivity, data management, continuing customer relationships, and digital platforms can support consumption-data collection, resource coordination, and flexibility services. These capabilities, however, do not substitute for energy-domain expertise, baseline determination, measurement and verification, performance-based contracting, or lawful access to electricity markets. Digital capabilities must

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therefore be assessed together with complementary energy-sector capabilities.

2.4. Telecommunications Capabilities for Entry into Energy-Service Markets

Telecommunications operators have increasingly evolved from connectivity providers into broader digital-infrastructure and service providers. Communication networks, IoT and M2M platforms, data centers and cloud services, data analytics and artificial intelligence, billing systems, and access to large customer bases constitute resources that may be redeployed in adjacent industries. Banda et al. [10] identify vertical markets, including energy, as potential diversification paths for mobile network operators. Lee and Kim [11], through the KT-MEG case, demonstrate that combining telecommunications, IoT, big data, and AI capabilities can support the development of an energy-management business.

Technological proximity to the energy sector is nevertheless insufficient for successful entry. Performance-based services require expertise in energy auditing, contract-risk management, measurement and verification, interaction with electricity companies, and regulatory requirements. The strategic issue is therefore not simply the identification of a telecommunications operator's digital assets, but how those resources can be reconfigured and missing capabilities complemented through partnerships with ESCOs, electricity companies, and other ecosystem actors.

2.5. Business Models and Cross-Sector Capability Reconfiguration

From a theoretical perspective, telecommunications entry into energy services can be viewed as cross-sector capability reconfiguration: resources developed in telecommunications are redeployed in an adjacent industry to create new value. Teece [12] emphasizes that technology alone does not guarantee value creation and capture; firms require a coherent logic for value proposition, value delivery, and value capture. Accordingly, connectivity, IoT, and AI become energy-sector advantages only when they are connected to specific services, target customers, key partners, and implementable revenue mechanisms.

In this study, the Business Model Canvas [13] is used as a managerial translation of the AHP–TOWS results rather than as an independent empirical validation layer. It links the prioritized strategic actions to the logic of value creation, delivery, and capture through the nine BMC components. The relationships among the operator's digital capabilities, the SWOT environment, AHP priorities, TOWS actions, and BMC components are therefore kept traceable. Accordingly, the BMC elements reported in this study should be interpreted as implementation design implications derived from the decision model.

2.6. Methodological Gap and Positioning of the Present Study

Weihrich [14] introduced TOWS as a tool for strategic matching. Kurttila et al. [15] combined AHP and SWOT to quantify factor priorities, and Kajanus et al. [16] compared multicriteria decision support methods in SWOT analysis. The present study applies these established methods to telecommunications operators' entry into the energy services market. Its contribution lies in assessing the consistency of the aggregated matrices, documenting the links between SWOT factors and strategic actions, reporting support scores normalized by the number of linked factors, and examining how action rankings respond to alternative scoring rules. The Business Model Canvas provides a managerial interpretation of the results, with the proposed design choices subject to feasibility assessment. [Reviewer 1, Comment 1]

The literature reveals four related but largely separate research streams: digital transformation and energy business models; ESCOs and energy servitization; demand response, aggregators, and flexibility models; and telecommunications business-model development and entry into vertical markets. Despite their relevance, these streams rarely provide a unified decision architecture for cross-sector entry.

The literature offers limited guidance on how telecommunications operators can reconfigure their digital capabilities, prioritize opportunities and constraints, and translate those priorities into strategic actions and business model design proposals. Studies published in IJIEPR illustrate how expert judgment and robustness assessment have been used in industrial engineering. Examples include fuzzy AHP for prioritizing resilience capabilities [17], fuzzy AHP–TOPSIS for supplier selection [18], AHP–ISM with sensitivity analysis for industrial strategy development [19], and AHP–SMART–ILP for project portfolio selection [20]. The present study applies this approach to telecommunications operators' entry into the energy services market by examining how alternative scoring rules and sensitivity scenarios affect the ranking of strategic actions. [Reviewer 2, Comment 2.3]

Evidence from Iran also confirms the importance of the institutional context. Saebi et al. [21] designed and implemented a competitive day-ahead demand-response framework using operational experience from Khorasan Regional Electricity Company, illustrating a transition from traditional demand-side management toward market-oriented mechanisms. Jafari [22] likewise emphasizes institutional and external conditions in the development of ESCOs in Iran.

From an industrial-engineering methodology perspective, recent IJIEPR studies also show that complex strategic and industrial problems are increasingly addressed through hybrid MCDM frameworks and robustness checks. Published studies in the journal have used Fuzzy AHP-TOPSIS for supplier selection, AHP-ISM for supply-chain strategy development, and hybrid AHP-SMART-ILP approaches for portfolio selection. These studies reinforce the value of combining structured expert judgment with explicit robustness analysis rather than relying on a single point ranking.

Accordingly, this study proposes an integrated decision architecture for telecommunications entry into digital energy services. SWOT diagnoses internal and external factors, AHP quantifies their relative importance, weighted TOWS translates priorities into strategic actions, and the Business Model Canvas converts these actions into a value-creation, delivery, and capture logic. The principal contribution is the traceability of this chain and the explicit robustness controls applied to the strategy scores.

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Tab.1. Analytical synthesis of selected studies and positioning of the present study

Study	Domain and approach	Finding relevant to this study	Gap relative to the present study
Weihrich (1982) [14]	TOWS for matching strategic factors	Systematically matches internal strengths and weaknesses with external opportunities and threats to formulate strategic alternatives.	Provides the basis for strategic matching. Empirical AHP weighting and telecommunications entry into the energy sector fall outside its scope.
Kurttila et al. (2000) [15]	AHP–SWOT (A'WOT) applied to forest certification	Uses AHP to quantify SWOT priorities and compare the relative importance of strategic factors.	Establishes a precedent for combining AHP and SWOT. The present study uses this established approach.
Kajanus et al. (2012) [16]	SWOT combined with multiple-criteria decision support (MCDS) in natural resource management	Reviews AHP, SMART, and SMAA-O as alternative methods for eliciting preferences in SWOT analysis.	Highlights the range of available methods and the importance of testing how results depend on the choice of preference elicitation and scoring methods.
Lee and Kim (2020) [11]	Telecom digital energy; KT-MEG case study	AI, IoT, and big data can jointly support an operator energy-management business.	Single case; no prioritization framework or explicit translation from strategy to BMC.
Hiteva and Foxon (2021) [2]	Digital energy services; business-model analysis	Value creation and capture for users and the energy system depend on technological, institutional, and ecosystem arrangements.	Does not examine telecommunications entry or strategic prioritization.
Okur et al. (2021) [8]	Aggregation and flexibility; operational/financial review	Aggregator business models depend on coordination of operational and financial considerations.	Telecommunications entry and strategic-factor prioritization are outside the study scope.
Cagno et al. (2022) [4]	ESCO services; service-characterization framework	ESCO configurations vary by service scope, financing, risk allocation, and customer relationship.	Does not assess telecom digital capabilities or prioritize entry factors.
Żmija and Żmija (2022) [1]	Energy-sector digitalization; drivers and business models	Digitalization drives business-model change and new value-creation directions.	Does not focus on telecommunications entry or the translation of capabilities into entry strategies.
Brown et al. (2022) [6]	Energy-service business models; interviews/workshops	Energy services represent a shift from selling energy toward delivering final services and performance.	Primarily residential/European context; telecommunications entry is not examined.
Singh et al. (2022) [23]	Energy servitization; review/business-model analysis	Service-oriented models and startup participation create new energy value propositions.	No quantitative framework specific to telecommunications operators.
Banda et al. (2022) [10]	5G operator business models; review	Vertical markets, including energy, are potential diversification paths for mobile operators.	Does not operationalize the conversion of telecom capabilities into an energy-service model.
Iria and Soares (2023) [7]	Energy-as-a-Service; techno-economic model/simulation	EaaS can create new revenue logic and customer relationships between aggregators and prosumers.	Focuses on aggregators rather than the telecommunications entry pathway.
Cebekhulu et al. (2024) [5]	ESCO market and research; systematic review	Market, contractual, policy, and service-development barriers remain prominent in ESCO research.	Does not focus on capability reconfiguration by an adjacent actor such as a telecom operator.
Martín-Martínez et al. (2024) [9]	Aggregator business models; technical design/deployment	Actor relationships and technical architecture are decisive for aggregator deployment.	European context; telecom capability reconfiguration is not examined.
Wang et al. (2025) [3]	AI and energy transition; comprehensive review	AI, IoT, and smart metering play complementary roles in forecasting, demand management, and grid intelligence.	Technology-oriented review; does not provide an entry architecture or operator business model.
Singh et al. (2025) [24]	Demand-side energy services; provider perspective	Regulation, market design, and service design are important for demand-side service development.	No link to telecom capabilities or TOWS/BMC.
Biancardi and Staffell (2025) [25]	Electricity-sector innovation; interviews/strategic analysis	Regulation, collaboration, and innovation capabilities shape the changing role of electricity actors.	Focuses on incumbent grid actors rather than a telecommunications entrant.
Present study	Telecommunications entry into digital energy services; SWOT-AHP, weighted TOWS, and BMC	Links digital capabilities and environmental conditions to priorities, strategic actions, and a business model.	Requires future validation with independent stakeholders, field pilots, and techno-economic analysis.

3. Materials and Methods

This is an applied, multi-stage decision study. The methodological architecture comprises four layers: (1) identification and structuring of factors using SWOT; (2) quantification of their relative importance using group AHP; (3) translation of global weights into strategic actions using weighted TOWS, with control for sensitivity to the number of supporting factors; and (4) translation of the decision output into an implementation configuration. Expert-derived AHP data are separated from model-derived TOWS scores and managerial design outputs to preserve reproducibility and traceability.

The decision-maker is the strategy team of a telecommunications operator in Iran. The objective is to assess the relative strategic importance of 20 internal and external factors and prioritize the proposed strategic responses for

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further feasibility assessment. The study focuses on strategy formulation and prioritization. [Reviewer 1, Comment 2]

3.1. Identification and Consolidation of SWOT Factors

The SWOT factors were selected by synthesizing the literature on energy services, energy service companies (ESCOs), smart grids, demand response, and telecommunications operators' capabilities [1,2,3,4,5,6,7,8,9,10,11,12,21,22] and by reviewing their relevance to the Iranian context. Five factors were retained in each SWOT dimension. Complete records of the original screening process were unavailable for this reconstruction.

To document the final set, each factor was linked to the rationale for market entry and to its conceptual basis in the reviewed literature. Its distinction from closely related factors was also documented. Appendix H reports the results of this retrospective audit for all 20 factors. Available records provide only partial documentation of the initial list of candidate factors, the factors that were excluded, and the original voting procedure. [Reviewer 2, Comment 1.2]

Table 3 presents the final set of 20 factors used in the AHP analysis.

Each of the 15 experts (E01–E15) provided 46 pairwise judgments. Appendix B lists their areas of expertise.

Based on the primary area of expertise recorded in Appendix B, the panel comprised four experts in telecommunications, three in energy and ESCOs, three in digital technology, two in finance and energy economics, two in regulation, and one in project and change management. For each pairwise comparison, each expert received an equal weight of 1/15 in the geometric mean. This approach avoids assigning expertise-specific weights without a documented basis. Because the groups differed in size, their aggregate contributions reflected the number of experts in each group. The effect of panel composition was examined by excluding one expertise group at a time. [Reviewer 2, Comment 1.3]

Tab.2. Data Structure

Component	Reported specification
Number of experts	15
Pairwise comparisons per expert	46
Number of pairwise comparison ratios	690

Tab.3. Strategic SWOT factors

Strengths	Weaknesses
S1. Nationwide communication infrastructure and broad access network for deploying energy-management equipment S2. Capability to develop IoT and M2M platforms for monitoring and controlling energy consumption S3. Access to data centers and capability to process large-scale energy-consumption data S4. Data-analytics and AI capability for energy-demand forecasting S5. Access to a large residential, industrial, and organizational customer base	W1. Limited operational experience with Energy Performance Contracting W2. Limited specialist knowledge of energy auditing and consumption optimization W3. High initial-investment risk in ESCO projects W4. Lack of a clear revenue model for energy-management services W5. Complexity of coordination with multiple electricity-sector actors
Opportunities	**Threats**
O1. Growth of the energy-efficiency and ESCO market O2. Development of smart grids and digitalization of the energy sector O3. Increasing demand for consumption management among industrial customers O4. Opportunity to provide Demand Response services O5. Opportunity for operators to provide Energy-as-a-Service	T1. Immaturity of the national ESCO regulatory framework T2. Structural dominance of electricity companies in the energy market T3. Risk of long payback periods for ESCO projects T4. Competition from specialized energy-service companies T5. Legal constraints on operator entry into electricity markets

The calculations used 690 pairwise comparison ratios recorded in the original response data. Each of the 15 respondent IDs had six comparisons across the SWOT dimensions and ten comparisons within each group of five factors. A reciprocal comparison matrix with ones on the diagonal was constructed for each respondent and each section. The choice of the first or second factor determined the direction of preference, and the corresponding ratio was encoded as an integer intensity from 1 to 9 or its reciprocal [26,27]. For each pairwise comparison, the 15 recorded ratios were aggregated using the geometric mean. The data file contained all required comparisons.

$$a_{ij}^{G} = \left(\prod_{k=1}^{15} a_{ij}^{(k)} \right)^{\frac{1}{15}}$$

In the aggregation formula, a_{ij}^{k} denotes the pairwise comparison ratio of factor i to factor j in the matrix of expert k. The index k ranges from 1 to 15, and the exponent (1/15) is applied to the product of all 15 ratios. [Reviewer 2, Comments 2.4 and 1.3]

The normalized principal eigenvector of each group comparison matrix yielded either the weights of the SWOT dimensions or the local weights of the factors within a dimension. The consistency index (CI) and consistency ratio (CR) were calculated using the following equations.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

The consistency index (CI) and consistency ratio (CR) were defined following Saaty [26,27]. The random index (RI) was 0.90 for (4 × 4) matrices and 1.12 for (5 × 5) matrices. [Reviewer 2, Comment 2.4]

The CR threshold was 0.10. Each factor's global weight was calculated by multiplying its local weight by the weight of its corresponding SWOT dimension. The TOWS calculations and sensitivity analyses used unrounded values. Weights and scores were rounded to six decimal places for reporting.

$$w_i^{global} = w_g^{SWOT} \times w_i^{local}$$

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The common criterion for pairwise comparisons was the relative strategic importance of each factor in prioritizing market-entry actions. For weaknesses and threats, a higher weight indicates greater importance of addressing the factor. Appendix A presents the 46-item questionnaire template for future data collection.

S3 represents data storage and processing infrastructure, whereas S4 represents the ability to draw insights from data and make forecasts. W3 captures the operator's exposure to financing requirements and capital commitments, whereas T3 captures the risk of long payback periods as an external characteristic of the ESCO project market. T1 concerns regulatory maturity, T2 concerns the market power of incumbent utilities, and T5 concerns legal restrictions on market participation. O4 and O5 represent external opportunities in demand response and energy as a service (EaaS). The operator's actions to pursue these opportunities are defined separately. Some interdependencies among the factors may remain. Conventional hierarchical AHP assumes that the factors are sufficiently separable and leaves network feedback effects outside the model, which limits causal interpretation of the resulting priorities. [Reviewer 1, Comment 4]

3.2. Group AHP, Weighted TOWS, and Robustness Assessment

Following the TOWS logic introduced by Weihrich [17], actions were developed by cross-matching prioritized factors: SO actions use strengths to exploit opportunities; WO actions use opportunities to compensate for weaknesses; ST actions use strengths to address threats; and WT actions reduce vulnerabilities and threats simultaneously. These actions are analytical outputs of the model rather than independent expert votes. For each action, the raw score was calculated as the sum of the global weights of its associated factors. Because an additive score may increase with the number of mapped factors, a normalized score was also calculated by dividing the raw score by the number of supporting factors. Comparing the two measures provides a structural robustness check on dependence of the result on mapping breadth.

Let A denote the set of distinct factors linked to a strategic action and w_i the global weight of factor i. The raw score is $\sum_{i\in A} w_i$, and the mean score is $\frac{1}{|A|}\sum_{i\in A} w_i$. The raw score measures total support and is useful for comparing actions of similar scope. The mean score measures average support per linked factor and is useful when the aim is to reduce the influence of the number of links. Both scores treat each factor–action link as binary while allowing the factors themselves to have different weights. Assigning weights to reflect the strength of individual links would require independent data. When the rankings differ, both are reported so that the scoring rule can be selected according to the screening objective. [Reviewer 2, Comment 1.5]

Tab.4. Consistency indicators for the aggregated AHP matrices

Matrix	λ_{max}	CR
Four SWOT dimensions	4.0002	0.000074
Strengths (S)	5.0031	0.000705
Weaknesses (W)	5.0011	0.000265
Opportunities (O)	5.0026	0.000585
Threats (T)	5.0011	0.000253

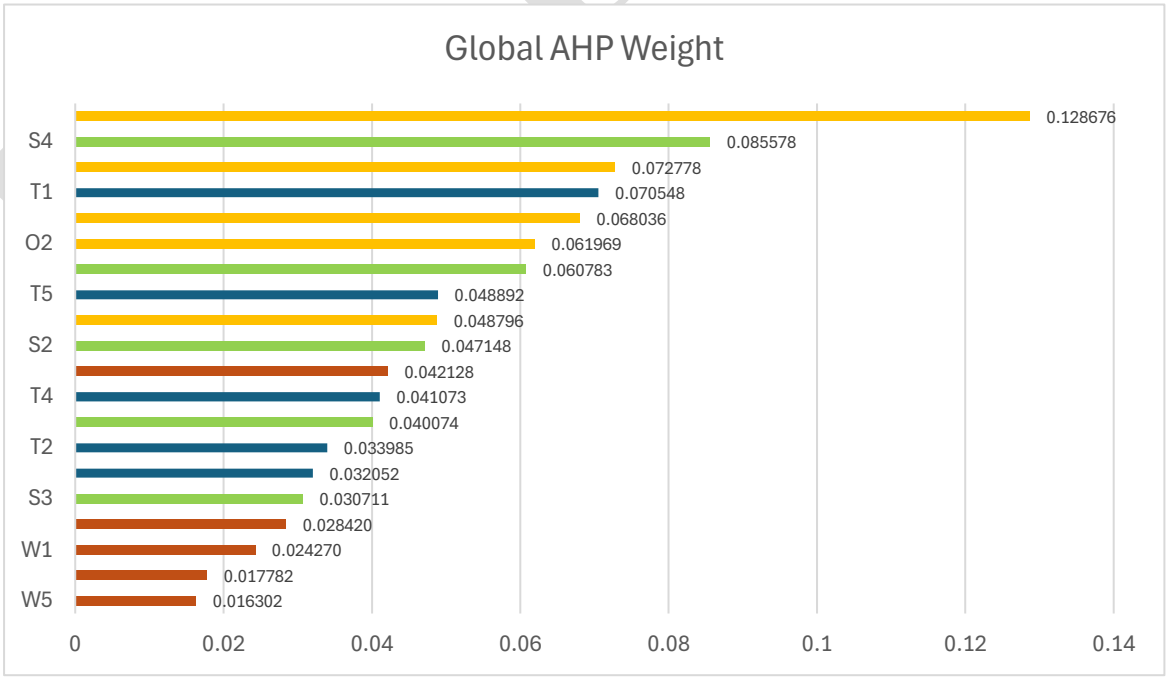


Fig.2. Global priorities of strategic factors for telecommunications entry into digital energy services

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4. Results

The mapping of each TOWS action was reviewed to assess how the action would leverage a strength, capitalize on an opportunity, address a weakness, or mitigate a threat. For example, ST4 illustrates how technology can support regulatory monitoring and compliance. Tables 12 and 13 document the factor–action links and provide the conceptual rationale for those links. The TOWS score indicates the support an action receives from its linked factors and can guide managerial attention. Comparisons across quadrants should be interpreted in light of the scoring rule used.

The five group comparison matrices were obtained by taking the geometric mean of the pairwise comparison ratios recorded for the 15 experts.

Tab.5. Aggregated Pairwise Comparison Matrix for SWOT Dimensions

Factor	S	W	O	T
S	1	2.0157	0.6988	1.1801
W	0.4960	1	0.3391	0.5590
O	1.4309	2.9483	1	1.6887
T	0.8473	1.7888	0.5921	1

Tab.6. Aggregated Pairwise Comparison Matrix for Strengths

Factor	S1	S2	S3	S4	S5
S1	1	1.2944	1.9247	0.7376	1.4986
S2	0.7725	1.0000	1.5276	0.5808	1.1268
S3	0.5195	0.6545	1	0.3310	0.8027
S4	1.3556	1.7214	3.0209	1	2.1519
S5	0.6672	0.8874	1.2457	0.4646	1

Tab.7.Aggregated Pairwise Comparison Matrix for Weaknesses

Factor	W1	W2	W3	W4	W5
W1	1	1.3928	0.5654	0.8705	1.4586
W2	0.7179	1	0.4203	0.6083	1.1486
W3	1.7686	2.3789	1	1.4586	2.5688
W4	1.1486	1.6437	0.6855	1	1.7006
W5	0.6855	0.8705	0.3892	0.5879	1

Tab.8.Aggregated Pairwise Comparison Matrix for Opportunities

Factor	O1	O2	O3	O4	O5
O1	1	2.1111	2.7640	1.8234	1.7214
O2	0.4736	1	1.2030	0.9117	0.9117
O3	0.3617	0.8312	1	0.7236	0.6597
O4	0.5484	1.0968	1.3819	1	0.9117
O5	0.5808	1.0968	1.5157	1.0968	1

Tab.9. Aggregated Pairwise Comparison Matrix for Threats

Factor	T1	T2	T3	T4	T5
T1	1	2.1277	2.1596	1.7686	1.3928
T2	0.4699	1	1.0472	0.8247	0.7236
T3	0.4630	0.9548	1	0.7725	0.6421
T4	0.5654	1.2125	1.2944	1	0.8540
T5	0.7179	1.3819	1.5572	1.1709	1

The dataset contains 690 pairwise comparison ratios from 15 experts and lists the 46 comparisons. Section 3.2 presents the five group comparison matrices. For each comparison, the ratios were aggregated using the geometric mean. The principal eigenvector of each matrix was then normalized, and each local weight was multiplied by the weight of its corresponding SWOT dimension. The scores were calculated using the mapping in Table 7 and the scoring rules in Section 4. Tables J1 and J2 summarize expert-level consistency and group-level agreement, respectively. The reported values are rounded. [Reviewer 2, Comment 1.1]

Table 8 reports the weights and ranks of the SWOT dimensions. Opportunities rank first with a weight of 0.380255, followed by strengths (0.264294), threats (0.226549), and weaknesses (0.128902). O1(ESCO market growth) and S4 (data analytics and artificial intelligence) have the highest global weights, at 0.128676 and 0.085578, respectively.

Tab.8. SWOT-dimension weights and ranks

SWOT dimension	Weight	Rank	Interpretation
Opportunities	0.3802	1	External growth and digital-energy opportunities dominate.
Strengths	0.2642	2	Existing digital assets provide strategic leverage.
Threats	0.2265	3	Regulation and market structure remain important constraints.
Weaknesses	0.1289	4	Capability gaps matter, but have lower relative influence.

Table 9 reports the local and global weights of the strategic factors.

Tab.9. Local and global weights of strategic factors

Code	Strategic factor	Group	Local weight	Global weight
O1	ESCO market growth	Opportunity	0.338395	0.128676
S4	Data analytics and artificial intelligence	Strength	0.323797	0.085578
O2	Smart-grid development	Opportunity	0.162967	0.061969
O4	Demand response	Opportunity	0.178922	0.068036
O5	Energy-as-a-Service	Opportunity	0.191391	0.072778
S1	Nationwide communication infrastructure	Strength	0.229983	0.060783
T1	Regulatory immaturity	Threat	0.311402	0.070548

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Code	Strategic factor	Group	Local weight	Global weight
O3	Industrial demand for consumption management	Opportunity	0.128325	0.048796
S2	IoT/M2M capability	Strength	0.178394	0.047148
S5	Large customer base	Strength	0.151627	0.040074
W3	Initial-investment risk	Weakness	0.326820	0.042128
T2	Dominance of incumbent electricity actors	Threat	0.150011	0.033985
T4	Competition from specialized ESCOs	Threat	0.181298	0.041073
T5	Legal entry constraints	Threat	0.215811	0.048892
S3	Data-center/big-data capacity	Strength	0.116200	0.030711
W1	Limited ESCO-contract experience	Weakness	0.188279	0.024270
W4	Lack of a clear revenue model	Weakness	0.220478	0.028420
T3	Long-payback risk	Threat	0.141478	0.032052
W2	Limited specialist energy knowledge	Weakness	0.137951	0.017782
W5	Coordination complexity	Weakness	0.126471	0.016302

Table 8 reports the weights and ranks of the SWOT dimensions. Opportunities rank first with a weight of 0.380255, followed by strengths (0.264294), threats (0.226549), and weaknesses (0.128902). O1 and S4 have the highest global weights, at 0.128676 and 0.085578, respectively.

Reaggregation of the recorded pairwise comparison ratios yielded local weights of 0.162967, 0.178922, and 0.191391 for O2, O4, and O5, respectively. Multiplying these local weights by the weight of the Opportunities dimension yielded global weights of 0.061969, 0.068036, and 0.072778, respectively. The data underlying the current version yield distinct weights for these three factors, which were reported as equal in the previous version. [Reviewer 2, Comment 1.6]

SO1 and SO2 rank among the top three actions under both the raw and mean scoring rules. WO1 moves from fifth by raw score to second by mean score after normalizing for the number of linked factors. These results support exploring digital services alongside partnerships with energy service companies (ESCOs) and power sector stakeholders.

SO1 ranks first by both raw score (0.236608) and mean score per linked factor (0.078869). WO1 has a mean score per linked factor of 0.076473. These scores measure the relative support that the mapped factors provide for each action.

In this study, the business model is treated as an implementation output derived from AHP-TOWS rather than as a co-equal layer of the decision model. Its role is to show how prioritized factors and actions can be translated into customer segments, value propositions, partners, activities, and proposed revenue streams.

Tab.10. Weighted TOWS strategic actions and sensitivity to the number of supporting factors

Code	Strategic action	Related factors	Raw score	Normalized score
SO1	IoT-based energy-management platform using nationwide communication infrastructure to exploit ESCO market growth	S1, S2 + O1	0.236608	0.078869
SO2	Data- and AI-driven demand-response services for industrial customers	S4 + O3, O4	0.202410	0.067470
SO3	Energy-as-a-Service for the operator customer base	S5 + O5	0.112852	0.056426
SO4	Big-data-based energy-management system in a smart-grid environment	S3, S4 + O2	0.178257	0.059419
SO5	IoT-based monitoring and control of industrial energy consumption	S2, S5 + O3	0.136019	0.045340
WO1	Partner with specialized ESCOs to compensate for limited operational ESCO experience	W1 + O1	0.152946	0.076473
WO2	Develop energy-auditing expertise through participation in smart-grid projects	W2 + O2	0.079751	0.039876
WO3	Develop savings-based revenue models through Energy-as-a-Service	W4 + O5	0.101198	0.050599
WO4	Joint industrial demand-management projects to reduce investment risk	W3 + O3	0.090924	0.045462
WO5	Telecommunications-electricity consortium for demand-response services	W5 + O4	0.084338	0.042169
ST1	Use communication infrastructure to reduce entry costs and compete with specialized ESCOs	S1 + T4	0.101856	0.050928
ST2	Data-driven energy-management services to reduce dependence on incumbent electricity-market structures	S4 + T2	0.119562	0.059781
ST3	Energy-as-a-Service model to reduce exposure to long payback periods	S5, S4 + T3	0.157703	0.052568
ST4	Digital energy-management platform to address legal entry constraints	S2, S3 + T5	0.126751	0.042250
ST5	Leverage the operator customer base to strengthen its competitive position against ESCOs	S5 + T4	0.081147	0.040573
WT1	Stage entry into the ESCO market through pilot projects	W1, W3 + T3	0.098449	0.032816
WT2	Initially focus on software-based energy management without heavy capital investment	W3, W4 + T3, T5	0.151491	0.037873
WT3	Partner with electricity distribution companies to reduce regulatory and legal exposure	W5 + T1, T5	0.135742	0.045247

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Code	Strategic action	Related factors	Raw score	Normalized score
WT4	Use small industrial projects to limit financial risk	W3 + T3	0.074180	0.037090
WT5	Collaborate with existing ESCOs to address knowledge gaps and competitive pressure	W1, W2 + T4	0.083125	0.027708

Table 11 presents the proposed Business Model Canvas and its AHP-TOWS basis.

Tab.11. Proposed Business Model Canvas and AHP-TOWS basis

Business Model Canvas component	Proposed configuration	AHP-TOWS basis
Customer segments	Industrial and organizational customers, customers with load-management potential, and subsequently selected digital-energy-service customers.	O3, O4, and O5; SO2 and SO5.
Value proposition	Intelligent consumption monitoring and analytics, AI-based forecasting and optimization, demand response, Energy-as-a-Service, and integrated IoT-Energy services.	S4 (0.085587), O4 (0.068036) and O5 (0.072778); SO2, SO3, and SO4.
Channels	Digital platform and dashboard, enterprise sales and direct contracting, enterprise service panel/API, and collaboration with electricity distribution companies.	S1 and S2; SO1 and SO4.
Customer relationships	Subscription- or performance-based contracts, dashboards and periodic reporting, dedicated industrial account management, and specialist support.	O5; SO3; continuing and outcome-oriented service logic.
Revenue streams	Share of energy savings, platform subscriptions, demand-response fees, EaaS, and analytics/consulting services; profitability of these options was not measured in this study.	O1, O4, and O5; SO1-SO3.
Key resources	Communication network and IoT, data centers and cloud infrastructure, data/AI team, customer base, and sales network.	S1-S5, especially S4 and S1.
Key activities	Energy-management platform development, consumption-data analytics, monitoring, IoT integration, demand-response pilots, and energy-service contract management.	SO1, SO2, and SO4; staged implementation pathway.
Key partners	Electricity distribution companies, specialized ESCOs, equipment/IoT suppliers, and regulatory bodies.	WO1 and WT3; addresses operational-experience gaps and regulatory requirements.
Cost structure	Platform development and maintenance, IoT and metering equipment, data/cloud processing, specialist energy and data personnel, integration, and operations.	W3 and T3; WT1, WT2, and WT4.

Table 12 traces strategic evidence to the business model.

Tab.12. Traceability from strategic evidence to the business model

SWOT evidence	Global weight	Strategic implication	Business-model component	Managerial action
O1 ESCO market growth	0.128676	Enter through scalable energy services	Value proposition / Revenue streams	Implement a limited industrial pilot with measurable savings
S4 AI and data analytics	0.085578	Differentiate through analytics-based services	Key resources / Value proposition	Develop forecasting, anomaly detection, and energy optimization
O4 Demand response	0.068036	Develop flexibility-coordination services	Value proposition / Key partners	Partner with an electricity company/aggregator for a DR pilot
O5 Energy-as-a-Service	0.072778	Move from selling connectivity toward outcome-oriented services	Revenue streams / Customer relationships	Design subscription- or performance-based contracts
S1 Nationwide connectivity	0.060783	Use telecom infrastructure as an enabling platform	Key resources / Channels	Integrate IoT connectivity with metering and control architecture
T1 Regulatory immaturity	0.070548	Prefer staged, partnership-based entry	Key partners / Risk governance	Use pilots/regulatory sandboxes and explicit data-governance agreements

Table 13 presents the staged implementation roadmap.

Tab.5. Staged implementation roadmap

Stage	Primary objective	Illustrative actions	Proposed KPI	Primary risk
1. Capability validation	Build technical and institutional readiness	Energy-data architecture; electricity-company/ESCO partnership; industrial pilot selection	Pilot-data access; partner agreement; model accuracy	Data access and interoperability
2. Controlled entry	Validate customer value and operational delivery	Energy analytics; monitoring; demand-response pilot; performance measurement	Verified savings; DR response; customer retention	Regulatory and contractual risk
3. Platform scaling	Expand EaaS and multi-customer coordination	Subscription/performance contracts; portfolio optimization; automated platform	Recurring revenue; portfolio MW; service margin	Capital risk and ecosystem dependence

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Figure 3 presents the proposed telecommunications architecture for digital energy services.

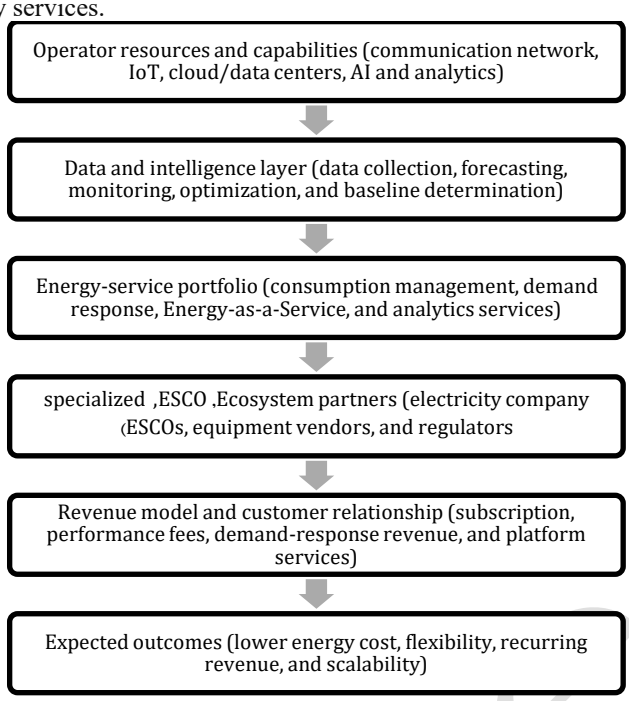


Fig.3. Proposed telecommunications architecture for digital energy services

The raw sum rewards the breadth of the factors mapped to an action. Dividing the sum by the number of factors measures their average salience and may favor actions mapped to fewer factors. Neither measure provides an unbiased estimate of expected value. These two rules should be treated as alternative descriptive perspectives. Establishing that the choice of an action is robust requires further evidence. The current analysis varies dimension weights by ±5%, ±10%, and ±20% and covers only one source of uncertainty. It does not test uncertainty in the mappings or individual judgments, alternative nonadditive aggregation methods, or simultaneous changes in parameters. [Reviewer 1, Comment 10]

To examine structural robustness, the results were recalculated using the reference weights for four scoring rules and 24 one-at-a-time scenarios that varied the dimension weights. These tests do not constitute a comprehensive analysis of mapping uncertainty, regulatory feasibility, or implementation costs.

The top three actions are SO1, SO2, and SO4 under the additive score, SO1, SO2, and WO1 under the square-root count penalty, SO1, WO1, and SO2 under the mean per linked factor, and SO1, WO1, and SO2 under the dimension-balanced mean. SO1 ranks first under all four rules, and the subsequent ranks depend on the scoring rule.

Using the same mappings for the 20 actions and the same reference global weights, four deterministic scoring rules were compared. (1) Additive support is the sum of the weights of the linked factors. (2) Count-penalized support is that sum divided by the square root of the number of linked factors. (3) Mean support is that sum divided by the number of linked factors. (4) Dimension-balanced mean is the unweighted average of the within-dimension means for the dimensions represented in each action. These measures reflect different aggregation assumptions. They do not represent independent expert judgments or economic returns.

4.1. Robustness, Traceability, and Reproducibility Analysis

The 690 recorded pairwise comparisons were used to construct 75 individual comparison matrices. The consistency ratios (CRs) ranged from 0 to 0.034981, with all values below 0.10. Appendix J provides details on consistency and rank agreement.

Each SWOT dimension weight was varied one at a time by ±5%, ±10%, and ±20%. The weights of the other three dimensions were adjusted in proportion to their baseline weights, while the local factor weights were held constant. By raw score, the top three actions were SO1, SO2, and SO4 in 23 scenarios and SO1, SO2, and WO1 in one scenario. By mean score per linked factor, the top three actions were SO1, WO1, and SO2 in 17 scenarios, WO1, SO1, and SO2 in six scenarios, and SO1, ST2, and WO1 in one scenario. Table 11 and Appendix Ch provide the details.

Tab.6. Summary of sensitivity analysis for SWOT-dimension weights

Perturbed dimension	Change range	Highest raw-score actions	Normalized-score pattern	Interpretation
S	±5%, ±10%, ±20%	SO1, SO2, SO4 (5 scenarios) and SO1, SO2, WO1 (1 scenario)	WO1, SO1, SO2 (3 scenarios) and SO1, WO1, SO2 (3 scenarios)	Ranking of the Top Three Actions Across Six Scenarios
W	±5%, ±10%, ±20%	SO1, SO2, SO4 (6 scenarios)	SO1, WO1, SO2 (5 scenarios) and WO1, SO1, SO2 (1 scenario)	Ranking of the Top Three Actions Across Six Scenarios

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Perturbed dimension	Change range	Highest raw-score actions	Normalized-score pattern	Interpretation
O	±5%, ±10%, ±20%	SO1, SO2, SO4 (6 scenarios)	SO1, WO1, SO2 (3 scenarios), WO1, SO1, SO2 (2 scenarios), and SO1, ST2, WO1 (1 scenario)	Ranking of the Top Three Actions Across Six Scenarios
T	±5%, ±10%, ±20%	SO1, SO2, SO4 (6 scenarios)	SO1, WO1, SO2 (6 scenarios)	Ranking of the Top Three Actions Across Six Scenarios

In the leave-one-expertise-group-out analysis, the ratios for each pairwise comparison were reaggregated using the judgments of the remaining experts. Across all six cases, O ranked first among the SWOT dimensions, O1 ranked first among the factors, and SO1 ranked first by raw score. Under the mean score per linked factor, WO1 ranked first when either the telecommunications group or the finance and energy economics group was excluded. Kendall's coefficient of concordance, reported in Appendix J, ranged from 0.413383 for threats to 0.724031 for the SWOT dimensions. The exclusion analysis is descriptive. The small and unequal group sizes preclude drawing conclusions about systematic differences across areas of expertise. [Reviewer 2, Comment 1.3]

In a separate analysis, each of the 20 local weights was varied one at a time by ±5%, ±10%, and ±20%. The other local weights within the same group were adjusted in proportion to their baseline shares, while the weights of the four SWOT dimensions were held constant. Across the 120 scenarios, O1 ranked first overall in every case, and S4 ranked second in 118 cases. SO1 ranked first by raw score in 119 scenarios and by mean score per linked factor in 115 scenarios. Under the mean scoring rule, WO1 ranked first in four scenarios and SO2 in one. Appendix Kh summarizes the results. [Reviewer 2, Comment 1.4]

The presence of S4 and S5 in multiple actions creates potential for overlap and synergy among those actions. The ranking tables identify candidates for subsequent feasibility screening. Determining an optimal subset or implementation sequence requires a separate portfolio model. Before recommending joint implementation, such a model should explicitly account for resource budgets, legal admissibility, interdependencies, and complementarities. [Reviewer 1, Comment 9]

Tab 15. Structural Traceability of the 20 TOWS Factor-to-Action Mappings

Action	Factor Codes
SO1	S1, S2, O1
SO2	S4, O3, O4
SO3	S5, O5
SO4	S3, S4, O2
SO5	S2, S5, O3
WO1	W1, O1
WO2	W2, O2
WO3	W4, O5
WO4	W3, O3
WO5	W5, O4
ST1	S1, T4
ST2	S4, T2
ST3	S5, S4, T3
ST4	S2, S3, T5
ST5	S5, T4
WT1	W1, W3, T3
WT2	W3, W4, T3, T5
WT3	W5, T1, T5
WT4	W3, T3
WT5	W1, W2, T4

Tab 16. Conceptual Review of Potentially Ambiguous Factor-to-Action Mappings

Action and Source Factor Codes	Mechanism-Based Rationale	Limitations and Required Verification
ST4 — S2, S3 + T5	IoT/M2M capabilities (S2) and data center and big data processing capacity (S3) can support auditable measurement, access control, monitoring, and data reporting on a digital energy management platform. These capabilities can facilitate compliance-related operations under the legal entry restrictions represented by T5.	Digital infrastructure alone cannot remove licensing restrictions or confer the right to participate in a regulated energy market. ST4 is interpreted as a response that facilitates compliance or relies on partnerships, subject to legal review.

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Action and Source Factor Codes	Mechanism-Based Rationale	Limitations and Required Verification
WO1 — W1 + O1	Partnering with a specialized energy service company (ESCO) can provide the operational expertise in energy performance contracting that the operator lacks (W1) and enable it to serve growing demand for ESCO services (O1).	WO1 is an opportunity-driven approach to acquiring capabilities. A successful contract and partner availability would need to be verified separately.
WT5 — W1, W2 + T4	Collaborating with an existing ESCO can address both limited experience with ESCO contracting (W1) and limited specialized energy expertise (W2), while reducing exposure to competition from established ESCOs (T4).	WT5 is a defensive response aimed at reducing risk and closing capability gaps, whereas WO1 is primarily driven by market growth. A single partnership could support both actions, so they should be counted as one project if implemented through that partnership.
ST3 — S5, S4 + T3	Access to customers (S5) and analytics capabilities (S4) can support low-cost customer acquisition and help design services that make cash flows more predictable in the face of long payback periods (T3).	Using the energy-as-a-service (EaaS) label alone cannot shorten the payback period. Cash flow modeling is required.
WT2 — W3, W4 + T3, T5	A software-first deployment can limit upfront capital exposure (W3) and enable testing of the revenue model (W4) under long payback periods and legal entry restrictions (T3 and T5).	Lower investment in physical assets alone cannot guarantee regulatory approval or commercial viability.

Tab 17. Potentially Overlapping or Complementary Strategic Actions

Overlapping or Complementary Actions	Relationship	Implications for Implementation
WO1 and WT5	Substantial overlap. Both rely on an ESCO partnership, but WO1 seeks to capitalize on an opportunity, while WT5 aims to reduce risk.	A single ESCO partnership program may cover both actions. Avoid double-counting costs and benefits.
SO4, SO1, and SO5	The actions share digital monitoring infrastructure, IoT capabilities, and a data platform. SO4 adds smart grid analytics, and SO5 adds industrial monitoring.	Consider a shared modular platform with distinct service packages.
WO5, SO2, and WT3	Demand response services may require a power utility or distribution partner and may need to comply with market rules.	Assess partnership arrangements and regulatory requirements before deploying the service.
WT2, WT1, and WT4	All three emphasize lower-risk entry through a pilot, an initially software-based scope, or a smaller industrial contract.	Treat these as alternative designs for controlling risk. Each can be considered independently, with no prescribed sequence.
WO3, SO3, and ST3	All three concern energy as a service (EaaS) and service monetization. WO3 addresses weaknesses in the revenue model, and ST3 addresses exposure to long payback periods.	Evaluate the actions jointly using unit economics and contract design.

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The mappings were reviewed conceptually for consistency with their respective TOWS quadrants and for the plausibility of the proposed mechanisms. ST4 concerns regulatory monitoring and compliance. WO1 and WT5 can build on a shared partnership framework with an energy service company (ESCO).

4.2. Interpretation of the Decision-Model Output

The TOWS results do not support presenting a single strategy as the uniquely "best" option. SO1 has the highest raw score, whereas WO1 becomes marginally highest after normalization by the number of factors. The appropriate interpretation is therefore an SO-oriented configuration complemented by partnership strategies that supply specialized energy capabilities.

In this configuration, communication infrastructure, IoT, and data analytics are used to exploit market opportunities, while partnerships with specialized ESCOs and electricity companies address gaps in operational experience, energy auditing, measurement and verification, and regulatory requirements.

4.3. Implementation Recommendations Derived from the Results

The following implementation recommendations are directly derived from the prioritized factors and TOWS actions and are proposed as pathways for field testing:

- Develop an IoT-based energy-management pilot using the operator's communication infrastructure (S1, S2, and SO1).
- Develop AI-based analytics, forecasting, and consumption-anomaly detection services (S4).
- Implement a demand-response pilot for industrial customers in partnership with an electricity company or aggregator (O4 and SO2).
- Gradually design Energy-as-a-Service offerings and subscription- or performance-based contracts after technical and legal validation (O5).
- Partner with specialized ESCOs to complement capabilities in energy auditing, energy performance contracting (EPC), measurement and verification, and to reduce the operational-experience gap (WO1).
- Use limited pilots and, where feasible, regulatory sandbox arrangements to manage T1-related risk before scaling.

The action code and proposed mechanism are first identified from Tables 10 and 15. A direct link to a Business Model Canvas component is recorded only when the action description explicitly identifies the function of that component. For example, in SO1, developing an energy management platform is linked to a key activity, while using communications infrastructure is linked to a key resource. In WO1, the ESCO is identified as a key partner, while the contractual structure and revenue-sharing arrangements require separate assessment. Table 11 records the supporting code, the rationale for the mapping, and whether the link is direct or inferred. Design choices without direct support are recorded as managerial hypotheses. [Reviewer 1, Comment 12] [Reviewer 2, Comment 1.7]

The proposed phased, relatively asset-light entry pathway reflects an additional managerial feasibility screening step that accounts for capital exposure, regulatory uncertainty, and capability gaps. The pilot and risk-reduction actions (WT1, WT2, and WT4) rank below several SO actions by raw TOWS score. The proposed sequence is therefore a conditional recommendation for field testing. Establishing an optimal entry sequence would require analysis beyond the AHP rankings. [Reviewer 1, Comment 11]

Tab 18. Leading Actions Under Alternative Scoring Rules and Implications for Ranking

Scoring Rule	Rank 1	Rank 2	Rank 3	Top Five Actions in Rank Order
Raw sum	SO1	SO2	SO4	SO1, SO2, SO4, ST3, WO1
Square-root count penalty	SO1	SO2	WO1	SO1, SO2, WO1, SO4, ST3
Mean per linked factor	SO1	WO1	SO2	SO1, WO1, SO2, ST2, SO4
Dimension-balanced mean	SO1	WO1	SO2	SO1, WO1, SO2, SO4, ST2

Tab 19. Scores for All 20 TOWS Actions Under Four Alternative Scoring Rules

Action	Raw Sum	Mean per Linked Factor	Square-Root Count Penalty	Dimension-Balanced Mean	Ranks (Raw / Mean / Square Root / Balanced)
SO1	0.236608	0.078869	0.136606	0.091321	1 / 1 / 1 / 1
SO2	0.202410	0.067470	0.116861	0.071997	2 / 3 / 2 / 3
SO3	0.112852	0.056426	0.079798	0.056426	11 / 6 / 7 / 6
SO4	0.178257	0.059419	0.102917	0.060057	3 / 5 / 4 / 4
SO5	0.136019	0.045340	0.078531	0.046204	7 / 11 / 8 / 10
WO1	0.152946	0.076473	0.108149	0.076473	5 / 2 / 3 / 2
WO2	0.079751	0.039876	0.056393	0.039876	19 / 16 / 18 / 15
WO3	0.101198	0.050599	0.071558	0.050599	13 / 9 / 13 / 8
WO4	0.090924	0.045462	0.064293	0.045462	15 / 10 / 14 / 11
WO5	0.084338	0.042169	0.059636	0.042169	16 / 14 / 15 / 13
ST1	0.101856	0.050928	0.072023	0.050928	12 / 8 / 12 / 7
ST2	0.119562	0.059781	0.084543	0.059781	10 / 4 / 6 / 5
ST3	0.157703	0.052568	0.091050	0.047439	4 / 7 / 5 / 9
ST4	0.126751	0.042250	0.073180	0.043911	9 / 13 / 11 / 12
ST5	0.081147	0.040573	0.057380	0.040573	18 / 15 / 16 / 14
WT1	0.098449	0.032816	0.056840	0.032625	14 / 19 / 17 / 19
WT2	0.151491	0.037873	0.075746	0.037873	6 / 17 / 10 / 17
WT3	0.135742	0.045247	0.078371	0.038011	8 / 12 / 9 / 16
WT4	0.074180	0.037090	0.052453	0.037090	20 / 18 / 19 / 18
WT5	0.083125	0.027708	0.047992	0.031049	17 / 20 / 20 / 20

Under baseline conditions, SO1 ranks first under all four scoring rules. The rankings of the remaining actions vary with the scoring rule.

5. Discussion

The dominance of opportunities and the high weight of O1 indicate that entry logic depends more on the development of the energy-service market than on technology ownership alone. This finding is consistent with ESCO literature emphasizing market conditions, contractual arrangements, and institutional environments in energy-service development [4,5]. In Iran, Jafari [14] likewise highlights the importance of external factors and institutional infrastructure for ESCO development. Digital assets are therefore enabling conditions, but are not sufficient on their own to establish an energy-service business.

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The higher priority of S4 relative to S1 indicates that the operator's advantage lies not only in connectivity but also, and more importantly, in its ability to convert data into forecasting, optimization, and decision support. This interpretation is consistent with digital-energy studies emphasizing the synergy of AI, IoT, and data in demand management and grid intelligence [3], and with the KT-MEG case, which demonstrates how telecommunications and analytics capabilities can underpin an energy-management business [11].

The equal weights of O2, O4, and O5 suggest that smart grids, demand response, and EaaS can be viewed as a complementary opportunity cluster. Evidence from Iran on market-oriented demand-response design also indicates the feasibility of moving from traditional demand-side management toward more competitive mechanisms (Saebi et al., 2022). In this configuration, the smart grid provides the technical infrastructure, demand response provides a mechanism for monetizing flexibility, and EaaS provides the logic for recurring service relationships with customers.

The TOWS results further reinforce an ecosystem-based entry logic. WO1 indicates that partnerships with existing ESCOs can compensate for the operator's limited specialist energy experience, while SO1, SO2, and SO4 continue to emphasize the exploitation of the operator's digital capabilities. Capability-led entry and capability completion through partnership are therefore complementary logics.

Compared with prior studies, the added value does not lie merely in combining several tools. ESCO studies have largely focused on service structures, contracts, and market barriers; aggregator studies on technical and financial architectures; and telecommunications research on diversification and vertical markets. This study connects these streams in a single decision chain and shows how a capability or opportunity is translated, through a specific TOWS action, into a business-model component. The main methodological contribution is therefore traceability from evidence to design, rather than a claim of inherent superiority for SWOT, AHP, or BMC individually.

The importance of T1 indicates that regulation is a boundary condition for the entire business model. Data access and ownership, interoperability, baseline determination, measurement and verification, cybersecurity, customer consent, settlement, and revenue sharing should be clarified before performance-based or flexibility services are scaled.

This boundary condition is particularly important in Iran. Existing evidence on day-ahead demand response shows that movement toward market-oriented mechanisms is feasible, but the design of participation rules and interaction with electricity companies remains decisive. Iranian ESCO literature also emphasizes legal and institutional infrastructure. Accordingly, rather than assuming unrestricted operator access to the electricity market, the proposed pathway treats staged entry, partnerships with authorized actors, and testing of data, settlement, and measurement mechanisms as prerequisites for scaling.

5.1. Interpretation of Weighted TOWS and Decision Robustness

The difference between raw and normalized scores reveals an important methodological issue: in hybrid SWOT-MCDM models, a strategy linked to more factors may receive a higher score partly because of mapping breadth. Reporting both measures makes this effect visible and prevents the model output from being presented as an apparently definitive ranking. In the present application, the relative stability of SO1, SO2, and SO4 across both measures, together with the prominence of WO1 after normalization, supports a capability-led configuration complemented by partnerships.

5.2. Proposed Implementation Pathway

A three-stage implementation pathway is proposed. Stage 1 prioritizes capability validation, establishment of an energy-data architecture, and partnership formation with an electricity company or ESCO. Stage 2 focuses on controlled entry through energy analytics, monitoring, demand response, and measurement and verification. Stage 3 scales services toward subscription- or performance-based EaaS contracts and multi-customer coordination. Proposed indicators include data availability, partnership agreements, analytical-model performance, verified savings, demand-response performance, customer retention, recurring revenue, and service margin. These indicators are managerial proposals and should not be interpreted as empirically validated performance thresholds.

5.3. Research Contributions

This study offers three contributions. First, methodologically, it provides a traceable SWOT-AHP-TOWS chain that converts qualitative diagnosis into global weights and comparable actions, while simultaneous reporting of raw and normalized scores reveals the effect of the number of supporting factors. Second, empirically, the framework is applied to a real cross-sector decision problem at the telecommunications-energy boundary involving internal capabilities, market opportunities, investment risk, and regulatory constraints. Third, managerially, the quantitative model output is translated into an implementation configuration and business model without conflating this design layer with the expert-derived AHP data. Although The study documents each step of the analysis, from pairwise comparison ratios to global weights, action scores, and sensitivity scenarios. Under baseline conditions, the same action ranks first across all four scoring rules, while the lower ranks vary by rule. Linking the actions to the components of the Business Model Canvas shows how the results inform hypotheses for service design. [Reviewer 2, Comments 1.4 and 1.7]

6. Managerial Implications and Industrial Application

For a telecommunications operator, entry should begin with relatively asset-light services such as energy analytics, monitoring, and optimization. Demand response can then be tested through controlled pilots and, if customer value is demonstrated and regulatory conditions permit, expanded toward EaaS and recurring contracts. Partnerships with ESCOs and electricity companies should explicitly define data governance, cybersecurity, measurement and verification, ownership of the customer relationship, revenue sharing, and operational responsibilities.

For policymakers and electricity-sector institutions, digital energy-market development requires clear rules for data access and interoperability, customer authorization, cybersecurity, demand-response participation, baseline determination, measurement and verification, settlement, and value sharing. Pilots and regulatory sandboxes can be used to assess

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operational feasibility and governance requirements before large-scale deployment.

Data availability: The questionnaire structure and respondent-level AHP data may be provided as supplementary material only where the original raw questionnaires are available, enabling reproduction of geometric-mean aggregation and weight calculations. Expert-identifying information should not be disclosed.

To enhance reproducibility of the AHP component, the pairwise-comparison structure, geometric-mean aggregation rule, weight-extraction method, CR threshold, and aggregated matrices are explicitly reported. The quantitative results reported in the article should therefore be reconstructable from the aggregated matrices. Any respondent-level analysis should be presented as empirical evidence only if the original raw questionnaires are available.

To assess structural sensitivity of the TOWS scores, both raw and factor-count-normalized scores were reported and a one-at-a-time sensitivity analysis of SWOT-dimension weights was performed at ±5%, ±10%, and ±20%. These checks show that the main strategic pattern is not dependent on a single scoring formulation or modest changes in dimension weights. They do not, however, replace a full uncertainty analysis of individual pairwise judgments or simultaneous multi-parameter perturbations.

To reduce the limitation arising from incomplete documentation of the original SWOT-factor screening stage, a retrospective traceability audit was conducted. Each of the 20 final factors was checked against three criteria: direct relevance to telecommunications entry into digital energy services, conceptual non-overlap with other factors, and independent evaluability within the AHP structure. The conceptual origin of each factor was also compared with the reviewed literature and the internal-capability/external-environment logic. This audit assesses the coherence of the final 20-factor set but is not interpreted as a substitute for historical records of excluded candidates or initial voting.

The consistency ratio (CR) measures the internal consistency of a comparison matrix. The agreement measures in Appendix J describe the similarity of rankings across expert profiles.

In the one-at-a-time sensitivity analysis, SO1 ranked first by raw score in all 24 scenarios and by mean score per linked factor in 18 of the 24 scenarios. These results depend on the recorded pairwise comparison ratios, the factor–action mappings, and the range of scenarios tested.

The retrospective audit of the final factor set in Appendix H explains how the internal and external factors relate to the market-entry decision and clarifies the boundaries between closely related factors. It distinguishes among S2, S3, and S4, between W3 and T3, and among T1, T2, and T5 to avoid double counting. The audit draws on the final factor set and the existing literature. Reconstructing the original screening process would require the original records. [Reviewer 2, Comment 1.2]

7. Limitations and Future Research

The main limitations are the 15-member expert panel, the single-country Iranian context, the static nature of SWOT, the non-causal structure of AHP and TOWS, and the dependence of weights on panel composition. The one-at-a-time sensitivity analysis evaluates stability under ±5% to ±20% changes in dimension weights, but it does not cover all sources of uncertainty, simultaneous interactions among weights, or uncertainty in individual judgments. Future research may employ multi-parameter or probabilistic sensitivity analysis, fuzzy methods, comparisons with TOPSIS/VIKOR/BWM, and validation using independent panels and industries.

Sensitivity to changes in dimension weights and local factor weights was tested separately using a one-at-a-time approach. The tests did not examine simultaneous changes in weights, uncertainty in the pairwise judgments themselves, or changes in the factor-to-action mappings. [Reviewer 2, Comment 1.4]

The priorities depend on the conditions prevailing at the time, including the regulatory and economic context. The invitation log in Data records the first invitation on May 3, 2025, and the receipt of completed responses from May 5 to 17, 2025. Of the 18 invitations, 15 yielded complete responses, corresponding to a completion rate of 83.3%. Appendix B presents the expert profiles, and Appendix J reports the consistency and agreement measures.

8. Conclusions

This study developed a traceable SWOT-AHP-weighted TOWS framework for evaluating telecommunications entry into digital energy-service markets. The results show that opportunities carry the greatest decision weight, while ESCO market growth and data-analytics/artificial-intelligence capability are the most influential global factors. The weighted-TOWS analysis identifies a stable capability-led strategic core centered on IoT-enabled energy management, data- and AI-driven demand response, and smart-grid-oriented analytics. At the same time, factor-count normalization highlights the importance of partnership-based entry, particularly collaboration with specialized ESCOs, as a means of complementing limited energy-domain capabilities. The one-at-a-time sensitivity analysis confirms that the main raw-score strategic pattern remains stable across the tested perturbations, although normalized scores are more sensitive to changes in opportunity weights. The proposed Business Model Canvas and staged roadmap translate these decision-model outputs into managerial implementation implications rather than independent empirical validation. For practice, the findings support a staged, relatively asset-light entry path that begins with monitoring, analytics, optimization, and controlled industrial pilots before broader Energy-as-a-Service scaling. Future research should validate the framework with independent panels, richer uncertainty analysis, alternative MCDM methods, and field evidence on technical and financial performance.

Opportunities received the highest weight among the SWOT dimensions, and O1 and S4 received the two highest global factor weights. Under baseline conditions, SO1 ranked first under all four scoring rules. In the one-at-a-time sensitivity analysis of dimension weights, SO1 ranked first by raw score in all 24 scenarios and by mean score per linked factor in 18 of the 24 scenarios. When local factor weights were varied, SO1 ranked first under these two rules in 119 and 115 of the 120 scenarios, respectively. The Business Model Canvas and implementation roadmap provide hypotheses for subsequent feasibility assessment. [Reviewer 2, Comments 1.4, 2.1, and 1.7]

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Appendix A. AHP Questionnaire

This questionnaire elicits expert judgments on the potential entry of a telecommunications operator into Iran's energy services market. Its purpose is to determine the relative importance of internal and external factors for this decision. There are no right or wrong answers.

Respondent code: ..... Date: .....

Area of expertise: ..... Position or professional role: .....

Years of relevant experience: ..... Educational qualification: .....

Please leave your name and contact details blank. If responses need to be reviewed, follow-up will be arranged separately using the respondent code.

Response Instructions

For each row, consider which factor is more strategically important for the operator's entry into Iran's energy services market and by how much. Select the first or second factor and record the intensity. If both are equally important, select Equal and record an intensity of 1.

For weaknesses and threats, assess the importance of the issue and the need to address it in the entry decision. A higher importance rating indicates a greater need for attention. Desirability and profitability are outside this rating. Apply the same decision criterion when comparing the four SWOT dimensions.

Intensity	Meaning
1	Equal importance
3	Moderate preference
5	Strong preference
7	Very strong preference
9	Extreme preference
2, 4, 6, and 8	Intermediate values between adjacent intensities

If you have insufficient information, select that option only and leave the intensity blank. Use Equal only when you judge both factors equally important. The selection of the first or second factor indicates the direction of preference, so you can enter the intensity directly without writing a fraction or reciprocal.

Worked Example

If you judge data analytics capability to be strongly more important than access to customers, select First and record an intensity of 5. This example illustrates how to respond. Use your own judgment when assessing the study factors.

Part 1. Comparison of the Four Strategic Dimensions

Which factor is more strategically important for the entry decision, and by how much?

Item	First Factor	Second Factor	Response
1	Internal strengths of the telecommunications operator	Internal weaknesses of the telecommunications operator	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
2	Internal strengths of the telecommunications operator	External opportunities in the energy services market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
3	Internal strengths of the telecommunications operator	External threats in the energy services market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
4	Internal weaknesses of the telecommunications operator	External opportunities in the energy services market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
5	Internal weaknesses of the telecommunications operator	External threats in the energy services market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
6	External opportunities in the energy services market	External threats in the energy services market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

Part 2. Comparison of Strengths

Which factor is more strategically important for the entry decision, and by how much?

Item	First Factor	Second Factor	Response
7	Nationwide communications infrastructure and an extensive access network for deploying energy management equipment	Capability to develop IoT and M2M platforms for monitoring and controlling energy consumption	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
8	Nationwide communications infrastructure and an extensive access network for deploying energy management equipment	Access to data centers and the capacity to process large-scale energy consumption data	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

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Item	First Factor	Second Factor	Response
9	Nationwide communications infrastructure and an extensive access network for deploying energy management equipment	Data analytics and artificial intelligence capabilities for forecasting energy demand	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
10	Nationwide communications infrastructure and an extensive access network for deploying energy management equipment	Access to a large residential, industrial, and institutional customer base	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
11	Capability to develop IoT and M2M platforms for monitoring and controlling energy consumption	Access to data centers and the capacity to process large-scale energy consumption data	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
12	Capability to develop IoT and M2M platforms for monitoring and controlling energy consumption	Data analytics and artificial intelligence capabilities for forecasting energy demand	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
13	Capability to develop IoT and M2M platforms for monitoring and controlling energy consumption	Access to a large residential, industrial, and institutional customer base	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
14	Access to data centers and the capacity to process large-scale energy consumption data	Data analytics and artificial intelligence capabilities for forecasting energy demand	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
15	Access to data centers and the capacity to process large-scale energy consumption data	Access to a large residential, industrial, and institutional customer base	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
16	Data analytics and artificial intelligence capabilities for forecasting energy demand	Access to a large residential, industrial, and institutional customer base	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

Part 3. Comparison of Weaknesses

Which factor is more strategically important for the entry decision, and by how much?

Item	First Factor	Second Factor	Response
17	Limited operational experience with energy performance contracting	Limited expertise in energy auditing and energy consumption optimization	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
18	Limited operational experience with energy performance contracting	High upfront investment risk in ESCO projects	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
19	Limited operational experience with energy performance contracting	Lack of a clear revenue model for energy management services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
20	Limited operational experience with energy performance contracting	Complexity of coordinating with multiple stakeholders in the power sector	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
21	Limited expertise in energy auditing and energy consumption optimization	High upfront investment risk in ESCO projects	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
22	Limited expertise in energy auditing and energy consumption optimization	Lack of a clear revenue model for energy management services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
23	Limited expertise in energy auditing and energy consumption optimization	Complexity of coordinating with multiple stakeholders in the power sector	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
24	High upfront investment risk in ESCO projects	Lack of a clear revenue model for energy management services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
25	High upfront investment risk in ESCO projects	Complexity of coordinating with multiple stakeholders in the power sector	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
26	Lack of a clear revenue model for energy management services	Complexity of coordinating with multiple stakeholders in the power sector	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

Part 4. Comparison of Opportunities

Which factor is more strategically important for the entry decision, and by how much?

Item	First Factor	Second Factor	Response
27	Growth of the energy efficiency and ESCO markets	Smart grid development and digitalization of the energy sector	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

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Item	First Factor	Second Factor	Response
28	Growth of the energy efficiency and ESCO markets	Growing demand for energy consumption management among industrial customers	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
29	Growth of the energy efficiency and ESCO markets	Opportunity to offer demand response services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
30	Growth of the energy efficiency and ESCO markets	Opportunity for telecommunications operators to offer energy as a service (EaaS)	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
31	Smart grid development and digitalization of the energy sector	Growing demand for energy consumption management among industrial customers	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
32	Smart grid development and digitalization of the energy sector	Opportunity to offer demand response services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
33	Smart grid development and digitalization of the energy sector	Opportunity for telecommunications operators to offer energy as a service (EaaS)	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
34	Growing demand for energy consumption management among industrial customers	Opportunity to offer demand response services	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
35	Growing demand for energy consumption management among industrial customers	Opportunity for telecommunications operators to offer energy as a service (EaaS)	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
36	Opportunity to offer demand response services	Opportunity for telecommunications operators to offer energy as a service (EaaS)	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

Part 5. Comparison of Threats

Which factor is more strategically important for the entry decision, and by how much?

Item	First Factor	Second Factor	Response
37	Underdeveloped national regulatory framework for ESCOs	Structural dominance of electric utilities in the energy market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
38	Underdeveloped national regulatory framework for ESCOs	Risk of long payback periods for ESCO projects	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
39	Underdeveloped national regulatory framework for ESCOs	Competition from specialized energy service companies	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
40	Underdeveloped national regulatory framework for ESCOs	Legal restrictions on telecommunications operators entering the electricity market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
41	Structural dominance of electric utilities in the energy market	Risk of long payback periods for ESCO projects	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
42	Structural dominance of electric utilities in the energy market	Competition from specialized energy service companies	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
43	Structural dominance of electric utilities in the energy market	Legal restrictions on telecommunications operators entering the electricity market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
44	Risk of long payback periods for ESCO projects	Competition from specialized energy service companies	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
45	Risk of long payback periods for ESCO projects	Legal restrictions on telecommunications operators entering the electricity market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information
46	Competition from specialized energy service companies	Legal restrictions on telecommunications operators entering the electricity market	□ First □ Equal □ Second Intensity: ..... □ Insufficient information

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Appendix B. Expert Profiles by Area of Expertise

ID	Area of Expertise	Position	Degree	Years of Experience
E01	Telecommunications strategy	Strategy Manager	Master's degree	18
E02	Telecommunications business development	Business Development Manager	MBA	14
E03	Telecommunications network infrastructure	Network Operations Supervisor	Master's degree	12
E04	Digital transformation in telecommunications	Digital Transformation Manager	Master's degree	10
E05	Energy services and ESCOs	ESCO Operations Manager	Master's degree	16
E06	Energy efficiency	Energy Management Specialist	Master's degree	12
E07	Energy services markets	Market Development Supervisor	MBA	9
E08	Data analytics and artificial intelligence	Analytics Manager	Master's degree	11
E09	IoT and smart systems	IoT Solutions Architect	Master's degree	9
E10	Digital systems architecture	Enterprise Architect	Master's degree	8
E11	Finance and investment	Investment Manager	MBA	15
E12	Energy economics	Project Appraisal Analyst	Master's degree	12
E13	Energy regulation	Energy Policy Advisor	Doctorate	19
E14	Telecommunications regulation	Regulatory Affairs Specialist	Master's degree	13
E15	Project and organizational change management	Transformation Program Manager	Master's degree	11

P1. Recruitment Protocol

The recruitment protocol template specifies purposive selection based on at least five years of relevant experience and coverage of telecommunications, energy, digital technology, investment, and regulation.

P2. Invitation Log

Invitation ID	Invitation Date	Status	Response Date
01	2025-05-03	Complete response	2025-05-05
02	2025-05-03	Complete response	2025-05-12
03	2025-05-03	Complete response	2025-05-07
04	2025-05-03	Complete response	2025-05-14
05	2025-05-04	Complete response	2025-05-10
06	2025-05-04	Complete response	2025-05-17
07	2025-05-04	Complete response	2025-05-12
08	2025-05-04	Complete response	2025-05-07
09	2025-05-05	Complete response	2025-05-15
10	2025-05-05	Complete response	2025-05-10
11	2025-05-05	Complete response	2025-05-17
12	2025-05-05	Complete response	2025-05-12
13	2025-05-06	Complete response	2025-05-08
14	2025-05-06	Complete response	2025-05-15
15	2025-05-06	Complete response	2025-05-10
16	2025-05-06	No response	—
17	2025-05-07	No response	—
18	2025-05-07	Withdrew	2025-05-12

T1. TOWS Evaluation Form

This section illustrates how to record evaluations of 20 strategies against three criteria. It provides 60 illustrative records and 180 scores generated using seed 20261104. The AHP–TOWS calculations in this version exclude these scores.

T2. Evaluation Form for Each Strategy

Field	Required Response
Strategy code	SO1–SO5, WO1–WO5, ST1–ST5, WT1–WT5
Proposed mapped factor codes	Copy the codes exactly from the approved TOWS traceability table.
Conceptual fit	1 = indefensible, 2 = weak, 3 = somewhat defensible, 4 = defensible, 5 = fully defensible
Causal mechanism	In one or two sentences, explain how the factor facilitates the action or mitigates the issue.

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Field	Required Response
Missing or unsuitable factor	Specify the factor codes or enter “None.”
Overlap or complementarity	Where applicable, specify the codes of the other actions.
Recommendation	Retain, revise, or remove the mapping.
Confidence	Low, moderate, or high

T3. Priority Cases for Validation

Strategy	Validation Focus	Potential Issue to Test
ST4	Do technology, data, and IoT capabilities mitigate the stated regulatory threat?	Technical monitoring alone cannot secure legal authorization.
WO1	Does an ESCO partnership capitalize on the market opportunity while closing an internal capability gap?	Potential duplication with the defensive partnership strategy WT5.
WT5	Does the partnership mitigate the associated weaknesses and threats?	May involve the same operational initiative as WO1 and require a distinct rationale.
SO1 / SO4 / SO5	Distinguish closely related digital platform or market development actions.	Potential portfolio overlap and shared prerequisites.

T4. TOWS Scoring Summary

Illustrative Record ID	Number of Strategies	Mean Across Three Criteria
01	20	3.217
02	20	3.533
03	20	3.633

Appendix Th. Consistency of Aggregated Matrices and Interpretation of TOWS Mappings [Reviewer 1, Comments 6 and 7]

Th1. Group Consistency and Rank Agreement

The five group CR values for the SWOT dimensions, strengths, weaknesses, opportunities, and threats were 0.000074, 0.000705, 0.000265, 0.000585, and 0.000253, respectively. Appendix J reports individual consistency and rank agreement separately.

Appendix J. Consistency and Agreement of Expert Judgments

The 690 judgments were used to construct one 4 × 4 and four 5 × 5 reciprocal matrices for each expert profile. The consistency index was calculated as CI = $(\lambda_{max} - n)/(n - 1)$, and the consistency ratio as CR = CI/RI. The random index (RI) was 0.90 for matrices of order 4 and 1.12 for matrices of order 5.

Table J1. Consistency Ratios by Expert ID

Expert ID	SWOT Dimensions	Strengths	Weaknesses	Opportunities	Threats
E01	0.003838	0.034981	0.021566	0.011660	0.000000
E02	0.001540	0.017316	0.005601	0.012387	0.002960
E03	0.003838	0.000000	0.020433	0.012373	0.012373
E04	0.016970	0.004429	0.016642	0.018179	0.013821
E05	0.022462	0.021566	0.017316	0.021566	0.015356
E06	0.000000	0.012448	0.017481	0.013084	0.013084
E07	0.007637	0.000000	0.002223	0.012373	0.010233
E08	0.022462	0.016642	0.012692	0.004429	0.013084
E09	0.000000	0.003698	0.005890	0.000000	0.017316
E10	0.007637	0.008115	0.012373	0.004136	0.017481
E11	0.000000	0.015926	0.005423	0.012373	0.013084
E12	0.009146	0.010233	0.012387	0.002223	0.013084
E13	0.022462	0.018986	0.006647	0.002960	0.012082
E14	0.000000	0.002960	0.021011	0.017316	0.002960
E15	0.007637	0.021892	0.013084	0.013084	0.021566

All 75 matrices had a CR below 0.10. The values ranged from 0.000000 to 0.034981.

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Table J2. Summary of Consistency Ratios and Descriptive Measures of Rank Agreement

Section	Min. CR	Mean CR	Max. CR	Count < 0.10	Kendall's W	Mean Spearman Correlation
SWOT dimensions	0.000000	0.008375	0.022462	15	0.724031	0.706674
Strengths	0.000000	0.012613	0.034981	15	0.706960	0.690022
Weaknesses	0.002223	0.012718	0.021566	15	0.564612	0.534868
Opportunities	0.000000	0.010543	0.021566	15	0.647312	0.621104
Threats	0.000000	0.011899	0.021566	15	0.413383	0.401014

For each section, individual weights were derived from the principal eigenvector and ranked from highest to lowest. Weights were rounded to 12 decimal places to identify ties, which were assigned average ranks. Kendall's W was computed with a correction for ties. Mean Spearman correlation was calculated across expert pairs with defined correlations. In the threats section, one expert assigned equal ranks to all factors, so 14 undefined correlations were excluded from the 105 pairs. These figures are descriptive. The analysis reports neither p-values nor claims of statistical generalizability.
The agreement measures describe the similarity of the individual rankings recorded within this expert group.

Appendix Ch. Details of the 24 Sensitivity Scenarios

Dimension	Weight Change	Top Three Actions by Raw Score	Top Three Actions by Mean Score per Linked Factor
S	-20%	SO1, SO2, WO1	WO1, SO1, SO2
S	-10%	SO1, SO2, SO4	WO1, SO1, SO2
S	-5%	SO1, SO2, SO4	WO1, SO1, SO2
S	+5%	SO1, SO2, SO4	SO1, WO1, SO2
S	+10%	SO1, SO2, SO4	SO1, WO1, SO2
S	+20%	SO1, SO2, SO4	SO1, WO1, SO2
W	-20%	SO1, SO2, SO4	SO1, WO1, SO2
W	-10%	SO1, SO2, SO4	SO1, WO1, SO2
W	-5%	SO1, SO2, SO4	SO1, WO1, SO2
W	+5%	SO1, SO2, SO4	SO1, WO1, SO2
W	+10%	SO1, SO2, SO4	SO1, WO1, SO2
W	+20%	SO1, SO2, SO4	WO1, SO1, SO2
O	-20%	SO1, SO2, SO4	SO1, ST2, WO1
O	-10%	SO1, SO2, SO4	SO1, WO1, SO2
O	-5%	SO1, SO2, SO4	SO1, WO1, SO2
O	+5%	SO1, SO2, SO4	SO1, WO1, SO2
O	+10%	SO1, SO2, SO4	WO1, SO1, SO2
O	+20%	SO1, SO2, SO4	WO1, SO1, SO2
T	-20%	SO1, SO2, SO4	SO1, WO1, SO2
T	-10%	SO1, SO2, SO4	SO1, WO1, SO2
T	-5%	SO1, SO2, SO4	SO1, WO1, SO2
T	+5%	SO1, SO2, SO4	SO1, WO1, SO2
T	+10%	SO1, SO2, SO4	SO1, WO1, SO2
T	+20%	SO1, SO2, SO4	SO1, WO1, SO2

Appendix H. Retrospective Traceability Audit of the 20 Final Factors [Reviewer 2, Comment 1.2]

Code	Concept	Related Literature	Relevance and Distinction from Related Factors
S1	Communications network and coverage	[10, 11]	Network assets for connecting equipment, distinct from the application platform in S2.
S2	IoT and M2M platform	[3, 11]	Equipment monitoring and control, distinct from data processing in S3.
S3	Data centers and data processing	[3, 11]	Storage and processing capacity, distinct from the inference and forecasting in S4.
S4	Data analytics and artificial intelligence	[3, 11]	Forecasting and optimization supported by the infrastructure in S3.
S5	Customer base	[10, 11]	Commercial access to customers, distinct from the technical coverage in S1.
W1	Limited ESCO operating experience	[4, 5]	Track record of executing contracts and projects, distinct from the specialized knowledge in W2.
W2	Limited specialized energy knowledge	[4, 5]	Energy auditing and technical expertise, distinct from the operating experience in W1.
W3	Operator investment exposure	[4, 7]	The operator's capital commitment, distinct from the project payback horizon in T3.
W4	Unestablished revenue model	[4, 6, 7]	The operator's revenue generation mechanism, distinct from capital allocation in W3.
W5	Coordination complexity	[8, 9]	The operator's readiness to coordinate, distinct from the structural power of incumbents in T2.

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Code	Concept	Related Literature	Relevance and Distinction from Related Factors
O1	ESCO market growth	[4, 5, 22]	Growth in the market for services and performance contracts, distinct from industrial demand in O3.
O2	Smart grid development	[3, 21]	External infrastructure for measurement and interaction, distinct from the demand response mechanism in O4.
O3	Industrial demand for consumption management	[4, 21]	Industrial customers' needs, distinct from the opportunity to supply demand response in O4.
O4	Demand response development	[8, 21]	Opportunity to provide flexibility services, distinct from the infrastructure in O2 and service contracting in O5.
O5	Energy as a service	[6, 7]	Opportunity for a service-based contracting model, distinct from the flexibility product in O4.
T1	Regulatory immaturity	[21, 22]	Overall maturity and clarity of the rules, distinct from legal eligibility for entry in T5.
T2	Structural dominance of electric utilities	[8, 9, 21]	The power of incumbent utilities, distinct from commercial competition from ESCOs in T4.
T3	Long project payback period	[4, 5]	The project payback horizon, distinct from the operator's capital commitment in W3.
T4	Competition from specialized firms	[4, 5, 22]	Competitive pressure from ESCOs, distinct from the structural power of utilities in T2.
T5	Legal restrictions on entry	[21, 22]	Conditions under which the operator may legally participate, distinct from overall regulatory maturity in T1.

Appendix Kh. Supplementary Tests of Panel Composition and Local Factor Weights [Reviewer 2, Comments 1.3 and 1.4]

Expertise Group Excluded	Excluded	Remaining	Top Dimension	Top Factor	Top Action by Raw Score	Top Action by Mean Score
Telecommunications	4	11	O	O1	SO1	WO1
Energy and ESCOs	3	12	O	O1	SO1	SO1
Digital technology	3	12	O	O1	SO1	SO1
Finance and energy economics	2	13	O	O1	SO1	WO1
Regulation	2	13	O	O1	SO1	SO1
Project and change management	1	14	O	O1	SO1	SO1

Summary of the 120 One-at-a-Time Local Weight Scenarios [Reviewer 2, Comment 1.4]

Measure	Frequency
O1 ranked first overall	120 of 120
S4 ranked second overall	118 of 120
Top action by raw score	SO1 in 119 scenarios and SO2 in 1 scenario
Top action by mean score per linked factor	SO1 in 115 scenarios, WO1 in 4, and SO2 in 1
Order of the top three actions by raw score retained	118 of 120
Order of the top three actions by mean score retained	115 of 120

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