AI-Driven ESCO for Decarbonization of the Residential and Commercial Sector

Background

According to the National Greenhouse Gas Emission Inventory Report (國家溫室氣體排放清冊報告), Taiwan's residential and commercial sector greenhouse gas emissions reached 57.553 million metric tons of CO_2 equivalent in 2023, of which approximately 86% comes from indirect emissions generated by electricity consumption. Under the Taiwan Carbon Reduction Action Plan (臺灣總體減碳行動計畫), the residential and commercial sector must reduce emissions by 20.222 million metric tons by 2030 compared to 2023, representing a 35% reduction target. Current primary carbon reduction strategies include improving equipment energy efficiency, strengthening building energy management, and lowering electricity carbon emission factor through the energy sector's power structure transformation. However, over-reliance on declining electricity carbon emission factor would constrain carbon reduction progress to the pace of energy sector transformation, reducing the residential and commercial sector's resilience and controllability in carbon reduction independently. Therefore, more proactive and concrete measures have become necessary to ensure direct reduction of building energy demand and continuous energy efficiency improvement, thereby strengthening the robustness of carbon reduction efforts.

In this context, Taiwan's commercial sector currently implements the Energy Service Company (ESCO) policy, guiding commercial service industries to adopt energy-saving solutions as an important pathway for deep carbon reduction. Simultaneously, the government promotes electric commercial vehicle programs to improve the usage environment for low-carbon transportation. However, traditional ESCO still faces limitations in energy efficiency assessment accuracy, data governance, and long-term benefits tracking.

To address these challenges, promoting the "AI-ESCO" model will be the key direction for the next phase. By integrating AI technology into ESCO services, significant improvements can be achieved in energy consumption diagnostics, equipment scheduling, and energy management efficiency and precision, strengthening investment returns. This not only enables commercial facilities to be more intelligent in energy management but also helps accumulate data, gradually establishing comprehensive energy usage baselines through field demonstration projects, providing reliable evidence for subsequent application expansion. Furthermore, AI technology can be extended to logistics and warehousing industries, further amplifying cross-sector carbon reduction synergies.

Global Outlook and Domestic Progress

1. Global Outlook

1.1 Characteristics of International AI-Driven ESCO at Different Stages

AI-driven ESCO evolves through four stages: Stage 1 uses IoT and data governance for energy data collection and cleaning; Stage 2 applies discriminative AI like YOLO to identify personnel/equipment status for dispatching and fault diagnosis; Stage 3 employs predictive AI with MPC and reinforcement learning to forecast demand, alert peaks, and optimize control; Stage 4 leverages generative AI agents for real-time recommendations, fault explanations, and autonomous management.

1.2 International Logistics Combined with AI

Internationally, three core nodes—upstream supply chain, warehousing, distribution—integrate advanced AI and energy technologies to create quantifiable demonstration cases for policy and industry promotion. Upstream sections deploy predictive AI systems for real-time monitoring and big data analysis, forecasting energy demand/load variations to automatically adjust production lines and facilities, reducing peak consumption and losses; industrial parks add large-scale storage, renewables, and off-peak pricing for energy independence and grid resilience. Warehousing integrates discriminative AI for automated cargo identification, classification, and inventory management to cut manual energy use; BIM/AI digital twins optimize design-construction-operation lifecycle efficiency with low-embodied-carbon principles, while cold-chain adds AI energy dispatch, defrost recovery, and solar PV for balanced efficiency/resilience. Distribution adopts evolutionary route optimization algorithms for dynamic, low-energy paths based on traffic/weather/orders, slashing emissions/costs; cold-chain features temperature monitoring with end-to-end tracking; fleets electrify rapidly with smart off-peak charging systems, paralleled by storage/charging infrastructure to handle digitalization demands and ensure grid stability/operational continuity.

2. Domestic Progress

2.1 Domestic ESCO Policies

Taiwan currently promotes ESCO primarily through subsidy policies, including the "Commercial Service Industry Energy-Saving Equipment Subsidies" (商業服務業節能設備補助) from the Ministry of Economic Affairs' Administration of Commerce and the "Energy Efficiency Performance Guarantee Demonstration and Promotion Subsidies" (節能績效保證示範推廣補助) from the Ministry of Economic Affairs' Energy Administration. Both require achieving at least 10% energy-saving rates. However, most current programs primarily focus on hardware replacement or high-efficiency equipment deployment. To address this limitation, energy management technology driven by IoT and AI can establish sustainable, continuously optimizable smart energy-saving mechanisms.

2.2 Domestic Logistics Net-Zero Related Policies

In logistics, Taiwan's current policies have addressed vehicle electrification. The transportation sector carbon reduction flagship plan includes electric commercial vehicle subsidies, offering 500,000 NTD to 750,000 NTD in subsidies for heavy-duty trucks, light commercial vehicles, and intelligent charging management systems. Additionally, the "Electric Commercial Vehicle Smart Operations Demonstration Program" (電動商用車智慧運營驗證計畫) promoted by the Ministry of Economic Affairs includes two types of support: first, vehicle development, providing subsidies for vehicle research and development combined with deployment of intelligent dispatching and electric power replenishment systems in domestic logistics fields; second, operations development, verifying domestic and international electric vehicles and energy management platforms through field testing, accumulating practical experience in logistics net-zero.

Current policies have provided incentives for electric logistics vehicles. Future policies anticipate introducing AI technology into the logistics industry, improving overall logistics efficiency through intelligent warehouse management and renewable energy integration.

Goal for Residential and Commercial Sector (2030)

Carbon Reduction of 20.22 million metric tons CO_2e (**35% reduction**) by 2030, however emissions increased by 0.2% in 2023 compared to the baseline year.

Existing ESCO Subsidy Programs

Administration of Commerce: Commercial Industry Energy-Saving Equipment Subsidies

Replace energy-intensive equipment and introduce systematic energy-saving improvement programs

Administration of Energy: Energy Performance Guarantee Demonstration and Promotion Subsidies

Through the **ESCO model**, encourage enterprises to collaborate with energy technology service providers

+ Large-scale equipment replacement has been implemented for years, with equipment efficiency significantly improved; however, **subsequent replacement projects face diminishing marginal energy-saving potential.**
+ Future **data center** demand is expected to exceed projections, **potentially increasing overall electricity consumption in the residential-commercial sector.**
+ Achieving the 35% carbon reduction target under existing plans presents high difficulty; **AI technologies can be introduced to further enhance equipment efficiency.**

Recommended Solutions

- Propose the establishment of a **data collection and management platform** to gather and integrate de-identified operational data.
- Introduce **building AI energy management systems** for data collection and automated control mechanisms.

Strategic Planning Frameworks

Key technology items that could be considered for deployment include a data collection and management platform, an AI-based energy management system for warehousing, and an AI-based energy management system for logistics.

Commercial facilities such as department stores, hypermarkets, and convenience stores typically operate large-scale refrigeration and air-conditioning systems that consume substantial amounts of energy and thus offer significant decarbonization potential. At the same time, the scale of warehouse facilities has expanded rapidly, making them a major source of energy use.

2026 - Policy Enhancement :
Rolling revisions to existing subsidies through special tariff budgets

2027-2030 - Phase II Net-Zero Technology Potential Technology Program:
AI-Driven ESCO for Decarbonization of the Residential and Commercial Sector

AI-ESCO Subsidies and Platform Establishment Program

- **Provide AI performance reports:** Estimate the projected improvement ratio in energy use efficiency after AI implementation through AI technology
- **Achieve sustained energy-saving effects for at least one year**, or provide equivalent proof
- **Achieve energy-saving rate of 3% or higher** (if only equipment replacement, energy-saving rate shall be 25%, with short-term data collection)
- **Establish a data collection and management platform** to store operational data obtained through ESCO subsidies

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❶ AI-ESCO Adoption and Energy Baseline Development for Commercial Facilities and Warehouses

- Through subsidies for AI-ESCO deployment in commercial facilities and warehousing operations, **collect field data for advanced applications and policy formulation.**
- **Strengthen AI technologies of AI-ESCO service providers.**

❷ Pilot Demonstrations at Transportation Hubs

- Through **pilot implementation of AI-ESCO in transportation hubs**, collect field data and deployment experience to replicate and scale successful cases.

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❸ Linking Energy-Intensive Industry Data to Building Certification for Decarbonization

- **Existing Buildings:** Integrate with energy-saving obligations and reporting requirements for major electricity consumers, as well as green building certification, with **data uploaded to the Administration of Commerce's self-built data platform.**
- **New Buildings:** Require data upload to cloud platforms as a mandatory item for smart building certification applications.
- **Data Integration:** **Link operational data from energy-heavy industries holding smart building certifications** to revise certification levels and establish building electricity baselines.

Target for 2028: Administration of Commerce collaborates with the Ministry of the Interior and Administration of Energy.

Strategy 1: AI-ESCO Adoption and Energy Baseline Development for Commercial Facilities and Warehouses

Commercial facilities can deploy energy management systems that leverage real-time monitoring and automated control mechanisms to adjust electricity consumption patterns and enhance energy efficiency, whereas warehouses should be encouraged to adopt state-of-the-art energy efficiency technologies that, through data integration and AI-driven automatic controls, deliver both energy savings and carbon-reduction benefits while improving operational performance.

To establish an energy-management foundation for commercial and warehousing facilities, an AI-driven ESCO subsidy mechanism can be introduced to support the deployment of energy management systems and data acquisition, and to consolidate operational energy-use data from businesses into the data management platform developed by the Administration of Commerce. This will allow the accumulation of baseline emissions data, serving as a basis for future policy development and performance evaluation.

In parallel, efforts should be made to strengthen AI capabilities among ESCO providers so that they can offer integrated AI-ESCO services, thereby facilitating industrial upgrading and amplifying overall decarbonization benefits.

Strategy 2: Pilot Demonstrations at Transportation Hubs

Transport hubs, including railway and metro stations, ports, airports, and their associated commercial complexes, serve as key nodes of public transport. They exhibit both high energy-consumption intensity and high passenger throughput, and because they are predominantly under public-sector control, they are well suited to function as demonstration sites for cross-functional technology applications.

For the pilot measures, existing facilities and equipment, passenger-flow monitoring, environmental sensing, online ticketing, and ERP systems can be interconnected using IoT and big data technologies to build the foundation for model training and forecasting. Building on this, a predictive AI-based energy management system can be introduced to anticipate energy demand and perform dynamic scheduling, achieving automated control and optimal allocation of energy resources. To ensure robust energy-saving outcomes, hubs should be required to maintain stable energy-saving performance for at least one year and to implement data-transparency mechanisms. Relevant data can be uploaded and integrated via a platform developed by the Administration of Commerce or via smart management cloud platforms managed by the Energy Administration or the Architecture and Building Research Institute, thereby forming an evidence base for policy review and subsequent scaling-up.

Strategy 3: Linking Energy-Intensive Industry Data to Building Certification for Decarbonization

Current green building and intelligent building certification schemes primarily focus on the design and construction stages prior to the issuance of use permits, with relatively limited requirements for energy-use monitoring during the operational phase. This can lead to discrepancies between actual operational energy performance and the original design targets. Meanwhile, energy-heavy industries are required by regulation to implement energy-saving measures annually and to report operational energy-use data to the Energy Administration, creating an important data source on energy consumption.

To enhance policy coherence and the value of data utilization, it is advisable to link the operational data reported by energy-heavy industries with the energy-performance benchmarks embedded in building rating systems. By integrating these data sets, policymakers can identify gaps between actual energy use and design standards, adjust rating criteria and evaluation mechanisms accordingly, and progressively establish a national baseline for energy consumption in the operational phase of buildings.

In addition, for newly constructed buildings, it would be advisable to mandate the uploading of operational-phase energy-use data to a designated platform as one of the prerequisites for obtaining intelligent building certification. This would gradually strengthen data transparency and accountability, while supplying large-scale datasets to support AI model training and future energy-efficiency policy design.

Potential Benefits

By establishing an AI-driven energy service (ESCO) model, this initiative seeks to enhance real-time energy-saving control and electricity-use data collection systems for commercial facilities and large transport hubs in the residential and commercial sectors, thereby building a baseline electricity-use database and a performance-tracking mechanism for energy-saving outcomes in these sectors. Once these mechanisms and demonstration projects are in place, they can help large electricity users in Taiwan accelerate progress towards achieving an annual energy-saving rate improvement of 1–1.5%, in line with the “Deep Energy Saving and Carbon Reduction Flagship Program” (深度節能減碳旗艦計畫) objectives on service-sector energy-saving incentives and data governance. This will constitute a key milestone in advancing low-carbon and smart transitions in the residential and commercial sectors.

References

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