VIEWPOINT

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CAPTURING VALUE FROM SUSTAINABLE GROUND OPERATIONS

How airports can lead — and profit from — the decarbonization push

As the aviation sector accelerates its sustainability agenda, airports are uniquely positioned to lead the decarbonization of ground operations. This Viewpoint explores how electrification, APU-OFF, and ENGINE-OFF solutions can reduce emissions and unlock new value. Airports have the tools to go beyond regulatory compliance, turning sustainability into value creation by rethinking roles, business models, and investments to drive environmental impact and competitive advantage.

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THE GREEN AVIATION IMPERATIVE

Global aviation faces a defining moment. Climate pressure is intensifying, regulations are tightening, and stakeholder expectations — from passengers to investors — are rapidly evolving. Fortunately, actors across the aviation value chain are not limited to reactive compliance. In fact, they have a unique opportunity to turn sustainability into competitive advantage.

Two levers for "greening" aviation are within reach:

1. **Electrification of ground operations and transportation** — offering a fast, tangible route to lower emissions and cleaner mobility
2. **Adoption of sustainable aviation fuels (SAF)** — currently the only scalable solution for decarbonizing medium- and long-haul flight

Looking forward, two more levers are expected to reshape the landscape:

1. **(Hybrid-) electric aircraft.** These are poised to enter commercial service in the near future and could transform short-haul and regional routes.
2. **Hydrogen propulsion.** This is still in early stages and faces significant barriers, but it could become a (very) long-term option for deep decarbonization of long-haul aviation.

GLOBAL AVIATION FACES A DEFINING MOMENT

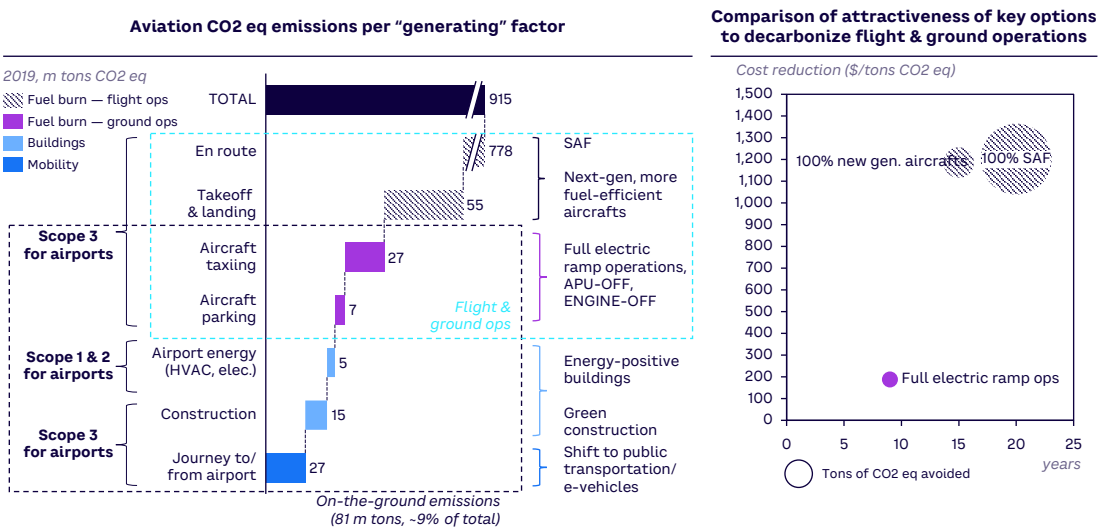
The race to net zero has begun, and the frontrunners will be companies that act early, align strategically, and invest wisely, being first movers in capturing value from greenification.

ELECTRIFICATION OF GROUND OPERATIONS

Electrification of ground operations and transportation is a practical and impactful starting point for aviation's decarbonization journey (see Figure 1). Two factors make this a high-priority area:

1. **High contribution to emissions reduction.** Ground operations and landside mobility can account for up to 30% of total airport-site emissions.
2. **Cost-effectiveness.** Electrifying these activities provides immediate environmental benefits at a relatively low investment level, especially when compared to long-term, higher-complexity solutions still under development.

Figure 1. Greening options



Source: Arthur D. Little, IATA

TO CAPTURE THE FULL VALUE OF ELECTRIFICATION, THE SECTOR MUST GO BEYOND TECHNICAL READINESS

Several electrification opportunities are available and technically mature, with the potential to reduce emissions and lower operational costs. They include:

- **Electric ground support equipment (eGSE)** — replaces diesel-powered vehicles with zero-emission alternatives
- **Gate-handling electrification** — enables APU-OFF operations through fixed electrical ground power (FEGP) and preconditioned air (PCA)
- **ENGINE-OFF taxiing** — uses systems such as TaxiBot to reduce fuel burn on the ground

These solutions offer a mix of environmental and economic returns, from immediate savings on fuel and maintenance to longer-term gains in emissions performance. However, their deployment comes with distinct challenges:

- Capital investment requirements and variable payback periods
- Infrastructure readiness and spatial constraints
- Operational complexity and the need for regulatory coordination

To capture the full value of electrification, the sector must go beyond technical readiness. This will require:

- Coordinated planning across stakeholders (airports, handlers, airlines, authorities)
- Clear allocation of roles and responsibilities
- Tailored business models that reflect the incentives and constraints of each actor in the ecosystem

eGSE: A scalable & accelerating transition

eGSE is gaining momentum across the aviation sector, as major ground handlers shift from diesel-powered assets to electric baggage tractors, belt loaders, ground power units (GPUs), and more. This transition is already delivering tangible benefits, including:

- Reduced fuel consumption and associated CO2 emissions
- Lower maintenance costs and reduced noise pollution
- Improved working conditions for airside personnel

Barriers remain, however, particularly for smaller airports that lack the financial resources (or access to dedicated funding) needed for fleet renewal and charging infrastructure deployment. In many cases, these airports operate their own ground-handling services, which makes the investment burden even heavier (considering eGSE is roughly 20% more expensive than internal combustion engines GSE today, with almost similar maintenance cost) and decentralizes procurement decisions.

Despite these challenges, the electrification of the global GSE fleet is projected to accelerate significantly in the coming decade. Today, eGSE represents less than 20% of the global installed base (~38,000 units). Meeting the decarbonization targets set by airports, public authorities, and handlers will require this number to quadruple by 2035, reaching an estimated 60% electric fleet (~200,000 units). Achieving this target will hinge on:

- Accelerating fleet-replacement cycles
- Increasing the share of eGSE in new equipment purchases, which is expected to exceed 50% of annual sales beginning in 2028

Market projections suggest a compound annual growth rate of about 9% between 2023 and 2035, with an inflection point anticipated around 2027/2028.

Penetration rates are forecast to reach approximately 35% by 2024, 60% by 2031, and 75% by 2035. The transition will be driven primarily by light and basic motorized GSE, which are simpler to electrify and typically have faster turnover cycles. These segments are expected to account for 80% of all eGSE sales by 2030 and up to 90% by 2035.

APU-OFF: A proven strategy for emissions & cost reduction

APU-OFF strategies aim to replace use of the aircraft's auxiliary power unit while at the gate with FEGP and PCA systems provided by the airport. This shift significantly reduces fuel burn, CO2/NOx (nitrogen oxides) emissions, and noise pollution during aircraft turnaround operations.

For airlines, APU-OFF adoption results in tangible cost savings and enhanced sustainability. For airports, it improves local environmental performance and supports compliance with airport carbon-accreditation programs. Estimated savings range from US $58-$290 per turnaround, depending on the aircraft type, with narrow bodies yielding lower-end benefits and wide bodies achieving the greatest impact.

The main barrier to adoption lies with remote stands, where infrastructure coverage is limited. PCA systems are now installed at more than 55% of contact stands, but mobile solutions cover less than 20% of remote positions — a critical infrastructure gap. A promising response is the deployment of "combo" units: mobile systems that combine a 400 Hz power supply and high-performance PCA. These units are specifically designed to extend APU-OFF capabilities to remote stands, without the need for extensive fixed infrastructure.

This technology is mature and already deployed at scale. For example, more than 200 combo units are in operation across more than 20 airports in Latin America, serving airlines such as Azul, LATAM, Gol, Sky, Aeromexico, and Viva Aerobus.

THE MAIN BARRIER TO ADOPTION LIES WITH REMOTE STANDS, WHERE INFRASTRUCTURE COVERAGE IS LIMITED

Adoption is expanding into India (IndiGo) and Japan. The business is highly profitable for both the APU-OFF service provider and the airlines, as value from reduced fuel consumption is shared between both parties. For narrow-body aircraft, considering a minimum 50 kg of jet fuel burn savings per turnaround, that means about $40 in savings per turnaround, or $80,000-$100,000 in savings a year.

Broader uptake depends on four key enablers:

1. Infrastructure readiness at both contact and remote stands
2. Cross-stakeholder coordination between airlines, airports, and ground handlers
3. Gate equipment standardization
4. Well-structured incentives to support adoption and behavioral change

ENGINE-OFF taxiing: A breakthrough in ground-movement efficiency

ENGINE-OFF solutions represent a major innovation in the decarbonization of airside operations, letting aircraft taxi without engaging their main engines as a way to reduce emissions, fuel consumption, and noise.

TaxiBot, a semi-autonomous, tow-bar-less towing vehicle that lets pilots taxi aircraft directly from the cockpit without using engines, has emerged as one of the most mature solutions. Fully integrated with airport control systems, it significantly reduces fuel burn, engine wear, and CO2 emissions during taxi. When deployed at scale, TaxiBot operations have the potential to cut millions of tons of CO2 annually while improving local air quality and minimizing noise pollution near terminal areas.

ENGINE-OFF SOLUTIONS REPRESENT A MAJOR INNOVATION IN THE DECARBONIZATION OF AIRSIDE OPERATIONS

Despite its relatively high acquisition cost (typically $1.7-$2.3 million per unit), the business case is compelling. A single unit can manage up to 7,000 movements per year, with net savings ranging from $17-$69 per movement, depending on aircraft type and airport configuration. Nevertheless, adoption remains currently limited, largely due to:

- Operational complexity and the need for alignment with airside procedures
- The need to integrate with air traffic control (ATC) and ground-handling routines
- Uncertainty around investment and ownership models

Enabling ENGINE-OFF operations at scale also requires adaptation of airport procedures and regulatory frameworks, particularly for departures. Coordination with the home airline and ATC is essential to align routing, scheduling, and turnaround times. In some cases, service roads, apron logistics, and control tower staffing must be adjusted to allow the swift return of GSE units from the runway to avoid delays or operational inefficiencies.

Ultimately, widespread deployment will depend on answering the following three questions:

1. Who should invest in the system?
2. Who should operate it?
3. How should the value be captured and shared across stakeholders, including airlines, airports, handlers, and control towers?

TURNING TARGETS INTO ACTION

Regulation is a central force accelerating the electrification of airport ground operations. The EU's Fit for 55 package is funneling billions into sustainable infrastructure, from charging systems to fixed electrical ground power and transition planning. At the same time, ICAO (International Civil Aviation Organization) and IATA (International Air Transport Association) are tightening global mandates, aligning the industry around net zero objectives. But the real challenge is turning targets into action. Poorly structured incentives and fragmented implementation risks can slow progress — or worse, overload an already capital-intensive sector.

The difference between compliance and value creation will come down to governance. Leaders like the EU, US, UK, and Singapore are setting the pace, but many others will need targeted support to build coherent, execution-ready regulatory frameworks.

THE TECHNOLOGY IS READY, ADOPTION MUST CATCH UP

The technology to decarbonize ground operations is no longer experimental. Solutions such as eGSE, APU-OFF procedures, and ENGINE-OFF systems are technically mature and in use across major global hubs, proving their reliability and operational viability. Regulatory momentum is creating a strong push toward decarbonization, but adoption remains slow due to:

- CAPEX requirements
- Fragmented stakeholder responsibilities
- Lack of enabling infrastructure

Business opportunities lie in the gap between maturity and adoption. However, turning opportunities into scalable, value-generating systems requires investment, alignment, and focused execution.

BUSINESS OPPORTUNITIES LIE IN THE GAP BETWEEN MATURITY AND ADOPTION

Fortunately, the ecosystem to support adoption is in place, both financially and operationally. Financing levers include:

- Green loans and sustainability-linked credit lines, provided by development banks and commercial institutions
- Blended finance programs that combine public grants (e.g., EU CEF [Connecting Europe Facility], national recovery plans) with private capital
- Leasing models and pay-per-use contracts, reducing up-front CAPEX and aligning cost with use
- Public-private partnerships, which are particularly effective for cross-tenant or infrastructure-heavy investments

On the operational side, a mature network of specialized partners is active at regional and global levels. Companies such as TCR, AES, HiSERV, and AirRail offer integrated electrification solutions from eGSE fleets and charging infrastructure to full-service maintenance models, helping airports and handlers accelerate deployment while minimizing operational risk.

AIRPORTS HOLD THE KEYS TO STRATEGIC LEADERSHIP

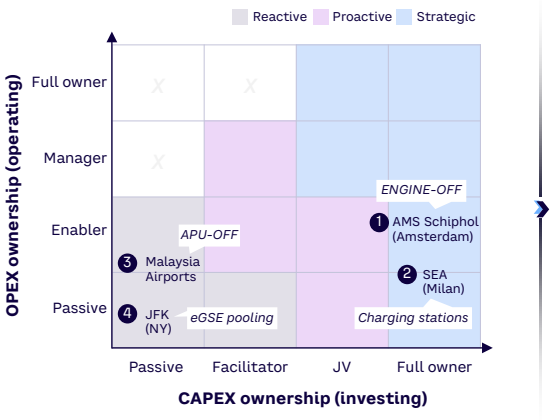
Among aviation players, airports are uniquely positioned to manage the complexity of the green transition. They control the core levers required to enable change, including master planning, space allocation, grid coordination, and infrastructure deployment. This positions airports to overcome friction points that often slow adoption so they can move faster and more coherently than fragmented stakeholders.

In contrast, airlines and ground handlers are typically limited to tactical, localized decisions, primarily shaped by Scope 1 emission targets and constrained investment capacity:

- Airlines are increasingly pressuring their ground partners to offer e-enabled services as part of their own decarbonization strategies.
- Ground handlers are beginning to invest in eGSE and related capabilities, but they frequently lack the capital or infrastructure autonomy to scale independently.

Figure 2 illustrates how airports can position themselves along a spectrum of engagement in green ground operations — from reactive compliance to proactive enablement to fully strategic orchestration. To take a more strategic stance, starting by asking, "How do we want to position ourselves in enabling the energy transition on our premises?"

Figure 2. Airports' positioning on green ground operations



REACTIVE

- No commercial model or monetization logic defined
- Provides physical space on request & allows access to airside
- Reacts to third-party investment proposals & accepts external equipment deployment (e.g., chargers, PCA units)

PROACTIVE

- Commercial model based on long-term leases or concessions to operators or utilities
- Drives allocation of dedicated zones for assets & provides grid access & capacity planning
- Facilitates funding access & sets operational guidelines

STRATEGIC

- Use electrification to drive non-aero revenue growth & branding differentiation, implementing pay-per-use models or bundled service pricing, monetizing across stakeholders
- Owns & manages assets (e.g., charging hubs, ENGINE-OFF solutions, combo units)
- Participates in energy markets (e.g., grid balancing, flexibility)

Source: Arthur D. Little

With this approach in mind, airports have the opportunity to capture value — provided they are willing to redefine their role. By embracing new business models, they can shift from passive landlords to strategic actors by:

- Offering energy as a service or green GSE as a service to tenants
- Monetizing infrastructure through leasing, joint ventures, or ownership
- Participating in grid balancing or flexibility markets and/or electricity production to unlock new revenue streams
- Using electrification as a brand differentiator to attract sustainability-driven airlines

Electrification of ground operations represents the first wave of aviation's energy transition — a proving ground for airports to test their infrastructure readiness, organizational agility, and commercial innovation.

ELECTRIFICATION OF GROUND OPERATIONS REPRESENTS THE FIRST WAVE OF AVIATION'S ENERGY TRANSITION

Those that act now will be structurally better prepared for the second wave, including aircraft electrification

But capitalizing on this opportunity requires more than deployment; it demands strategic orchestration (see Figure 3). Airports must define how they make investments, manage operations, and share value across stakeholders. These foundational elements will determine whether airports simply enable the transition — or lead it.

Figure 3. Greening initiative building blocks

Source: Arthur D. Little

CONCLUSION

AIRPORTS AT THE HEART OF THE TRANSITION

SUSTAINABILITY BECOMES A LEVER TO GROW NON-AERO REVENUES AND DIFFERENTIATE COMPETITIVELY

As infrastructure owners and ecosystem orchestrators, airports are uniquely positioned to shape the transition to electric ground operations. Airlines and handlers are under significant external pressures, but airports can choose how to respond:

1. **Reactively** — by accommodating demand
2. **Proactively** — by enabling infrastructure and setting requirements
3. **Strategically** — by creating new business models like energy provision or GSE as a service

This shift requires moving beyond compliance — sustainability becomes a lever to grow non-aero revenues and differentiate competitively. As aviation ground operations become increasingly asset-intensive, the competitive landscape is shifting — and airports are now closer than ever to becoming the driving force behind their decarbonization.

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