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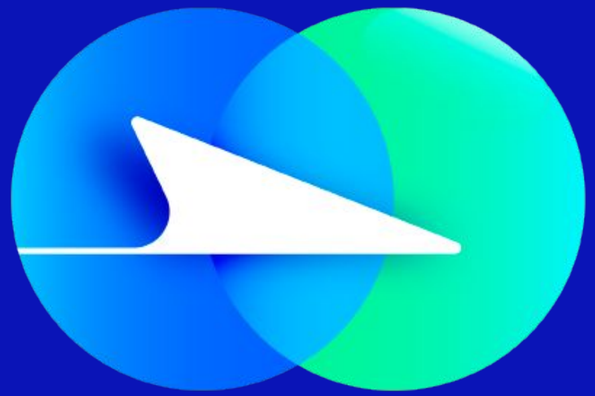

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Advancing Sustainable Aviation & Urban Air Mobility

Binding Quotas for Sustainable Aviation Fuels (SAF): Catalyzing Air Transport Decarbonization and a Global Hydrogen Economy

Dr. Stefan Kaufmann, Chairman TransHyDE 2.0 Initiative & Clean World Hydrogen Consulting

29–30 July 2025, Athens, Greece

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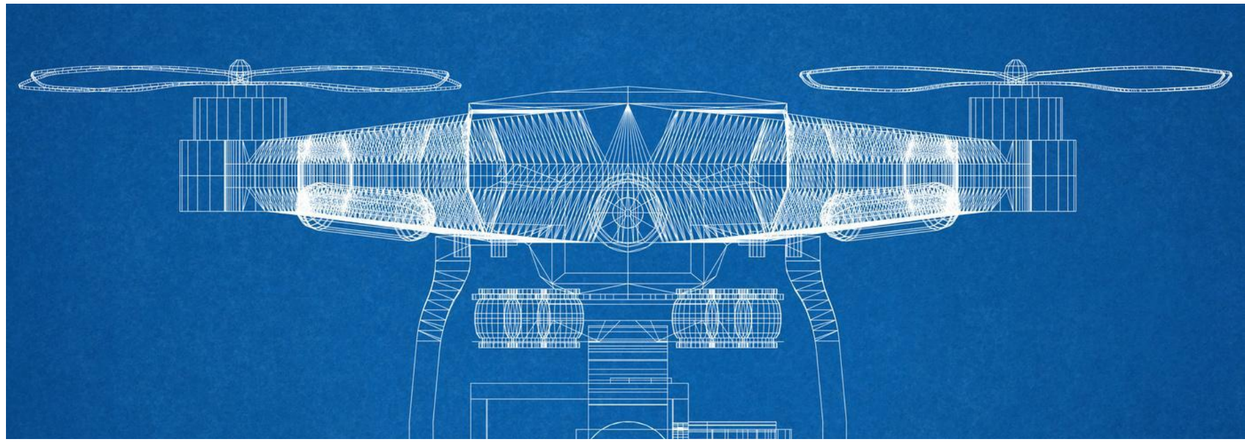
Introduction

- Aviation is a rapidly growing sector with significant carbon emissions, accounting for around 2.5% of global CO_2 emissions and a large share of transport-related GHGs.
- Sustainable Aviation Fuels (SAFs) - including biofuels and synthetic fuels from renewable hydrogen - are regarded as immediate enablers for decarbonization until zero-emission aircraft mature.
- Recent legislation has introduced binding quotas/mandates for SAF in major economies, fundamentally impacting global markets, technology, and cross-sectoral decarbonization.

How Binding Quotas Influence Air Transport Decarbonization



The Regulatory Push I

- The EU's ReFuelEU Aviation Regulation mandates progressive increases in SAF blends for all flights departing EU airports - from 2% in 2025, 6% by 2030, up to 70% by 2050.
- The UK mirrors the EU's approach, starting with 2% in 2025 and targeting 10% by 2030.

The Regulatory Push II

- The US, through the "Grand SAF Challenge" and the Infla-tion Reduction Act, initially used subsidies and tax incentives to stimulate SAF adoption, aiming for several billion liters annually by 2030. The Trump administration shifted the support approach from grants to tax-based incentives. The future of the „Grand SAF Challenge" is still open.

Impact on Market Dynamics

- Planning security provided by quotas stimulates both start-ups and large corporations to invest in SAF supply, infrastructure, and innovation
- Quotas trigger regional diversification of production, reducing dependence on traditional oil states and potentially creating millions of new green jobs worldwide.

Contribution to Decarbonization

- SAF quotas accelerate the development and scaling of production technologies, drive down costs, and foster innovation.
- By demanding clean blending, they force the industry to invest in hydrogen electrolysis, carbon capture, and feedstock innovation.

From Aviation to Shipping: Cross-Sectoral Learning

Shared Challenges

- Both aviation and maritime shipping are hard-to-abate sectors with entrenched fossil fuel infrastructure and slow technology adoption cycles.
- Economics of scale, drop-in compatibility, and global supply logistics are critical for both sectors.

Synergies and Learning Points

- Renewable jet fuel production can yield co-products for marine fuels, emulating integrated oil refineries' economies of scope.
- Policy frameworks for aviation serve as templates for shipping - e.g., fuel mandates increase demand certainty, driving supply investments and rapid cost reductions. IMO negotiations in London as best example.

Effects of Green Fuel Quotas on Global Markets

- Example: green ammonia: demand hubs in 2030: Europe (15 Mio t/year), Japan, Korea (5 Mio t/year)
- Projected global trade of green ammonia: 34 Mio t/year by 2030, 311 Mio t/year by 2050
- Transport and logistics costs for green ammonia and methanol are expected to be manageable, with $ 50 to 75 per tonne for intercontinental shipping.
- Green fuel quotas generate fierce global competition for cost-effective supply, especially for green ammonia and methanol, rewarding first-mover countries and firms.

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Competitiveness of Producing Countries

- Germany, Italy, and the US consistently top global competitiveness in green product exports, underpinned by diverse innovation ecosystems and supportive policy frameworks.
- China has rapidly improved capacity in solar, fuel cells, and green fuels, becoming a major player (f.e. Envision).
- India is on the way as well to produce very cost competitve derivatives like gren ammonia or green methanol. Main advantage: vertical integrated companies like Adani or Tata.
- Australia despite abundant resources, currently lags in green competitiveness due to limited value-added manufacturing and export capacity.

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Willingness to Pay

Insights from Shipping (Maersk)

- Maersk, a shipping sector leader, is actively contracting for green methanol and green ammonia, signaling a willingness to pay premiums to decarbonize fleet operations.
- Maersk requires 20 million tons/year green fuels, with major capital investments and long-term offtake agreements.
- The shipping sector overall is prepared to pay premium prices to meet climate targets, provided there is supply reliability and stable policy frameworks.
- Dual-fuel ships cost 10 to 15% more, but the decarbonization imperative justifies the expenditure for leading operators.

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Organizing Global Supply Chains

- Building out global supply chains for green fuels will require new infrastructure, harmonized standards, resilient logistics, and scale.
- Bunkering hubs (e.g., Singapore, Rotterdam) are transforming into early “green corridors” for methanol and ammonia, facilitating first-mover advantages and cross-sectoral integration.
- Coordination between ports, producers, and carriers is critical to secure competitive green fuel volumes and reduce risks of supply disruption.

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Political Frameworks and Industry Reaction

- Binding quotas and mandates - more effective than voluntary incentives - provide the planning certainty vital for market scaling.
- European Union and UK regulations directly oblige fuel suppliers; US mechanisms are more incentive-based but impactful.
- Industry reaction is mixed: While many welcome the clarity and market signal, others (e.g., Lufthansa) warn that current production cannot meet ambitious quotas quickly enough, stressing the need for further support, R&D, and international alignments.

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Technological Readiness: Fuel Cell Aircraft & Hydrogen

- SAFs are drop-in fuels, leveraging existing aircraft with little modification; hence, they are vital for medium-term decarbonization.
- Hydrogen aircraft and fuel cells are emerging but not yet commercially ready for large-scale, long-haul operations. Airbus, ZeroAvia, and others foresee first commercial hydrogen aircraft deployments in the 2030s, but substantial tech, infrastructure, and regulatory progress is still needed.
- For shorter regional routes, fuel cell propulsion is approaching viability and shows strong emissions reduction potential.

Prospects for Long-Haul Hydrogen Flights Before 2045

SAF

- Presently, SAF will likely remain the main decarbonization route for long-haul aviation through 2045 and beyond, with hydrogen solutions potentially achieving competitive scale in regional and short-haul applications earlier.

Hydrogen

- Long-haul hydrogen-powered flight on a global scale before 2045 faces significant feasibility barriers: technology maturity, aircraft certification, airport infrastructure, and the sheer scale of required green hydrogen supply.

Conclusions

- Binding SAF quotas are a powerful lever to accelerate air transport decarbonization and prime the development of a robust green hydrogen economy.
- Lessons from aviation regulation and markets are flowing into maritime shipping, fostering a broader decarbonization ecosystem through cross-sectoral learning, coordinated policy, and entrepreneurial risk-taking.
- The future global marketplace for SAF, green methanol, and ammonia will be shaped by the competitiveness of agile producing nations, proactive industry alliances (like Maersk), and the speed with which global supply chains can be organized around new political mandates and technology pathways.
- Achieving ambitious climate targets for air and sea transport will rely on sustained investment, international cooperation, and continuous innovation - on a scale not seen since the dawn of the jet age.

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Thank You for your Attention!

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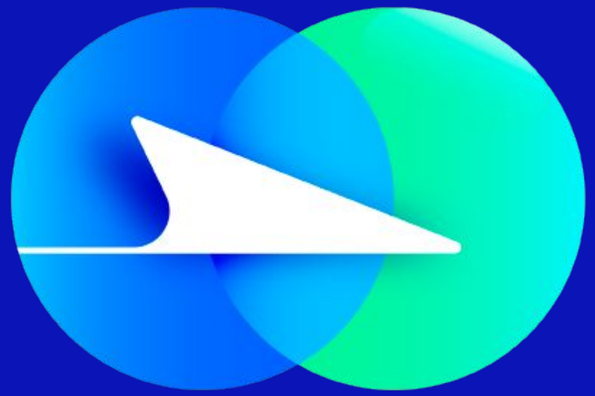

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