Fundamentals of SAF and the Role of Hydrogen in Decarbonizing Aviation

How to become SAF ready? How to make SAF happen?

SAF Training for ACI Africa & AFRAA

23.-25.04.2025, Arusha, Tanzania

Global Gateway

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An Agency of the European Union

Day 1 – Section 1:
Understanding the fundamentals of SAF and decarbonization of aviation

Topic

Part 1 –
Sustainable Aviation Fuel Fundamentals

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CBR Sustainability Partners

CEO & Founder

More than 15 years experience in the chemical process industry, large production infrastructure projects and technology development with focus on green transition of various industries via ClimateTech related innovation (renewable fuel, green chemistry, sustainability, environmental management systems, environmental certification, etc.)

Consulting Focus @ CBR Sustainability Partners

- Commercial project development and deal advisory (due diligences, etc.) of green energy, fuel and chemicals investments and production plant projects
- Renewable fuel and chemical regulatory, commercial and technology expertise

Education

- EMBA -Executive Master of Business Administration-, Kellogg School of Management at Northwestern University / WHU Otto Beisheim School of Management
- Diploma -International Business Studies-, University of Paderborn, Germany / École Supérieure de Commerce de Reims, Grande École / NEOMA Business School, France.

Day 1 – Section 1:
Understanding the fundamentals of SAF and decarbonization of aviation

Topic

Part 2 –
The Role of Hydrogen

Dr. Fabian Schmitt

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CBR Sustainability Partners

Technology Expert

Dr. Fabian Schmitt is a professional in green chemicals such as sustainable aviation fuels with profound knowledge in chemical conversion technologies with expertise in electrochemical processes, electrochemical and thermochemical conversion of carbon dioxide to produce base chemicals, as well as methanol and FT-synthesis.

Consulting Focus @ CBR Sustainability Partners

- Technology assessments, feasibility studies and techno-economic analysis in the field of renewable gases and liquids, hydrogen, Power-to-X, sustainable fuels (SAF) and green chemicals
- Expertise in regulatory policies with focus on renewable fuels, such as SAF
- Focus on renewable fuel production technologies, feedstock availabilities and CO_2 reduction potentials

Education

- PhD in Chemical Engineering, TU Darmstadt, Germany
- Master in Chemical Engineering, TU Darmstadt, Germany / Aalto University Espoo, Finland
- Bachelor in Chemistry, TU Darmstadt, Germany

Part 1

Sustainable Aviation Fuel Fundamentals

Recent headlines: A mix of confidence and uncertainty

Ncp| clgvEgrgdtcvgu I tcpf 'Qr gpkpi 'QhHggf qo 'Rkpgu'Hwgnu Rrcpv.'Vj g'Yqtnf)u Hktuv'Gvj cpqn'Vq Uwuvckpcdng Cxkcvkqp'Hwgn' Rtqf wevkqp Hcekrkv{'I qxgtpo gpv.'Eqtr qtcvg.'Cpf 'Eqo o wpkv{

Leaders Mark Historic Milestone as LanzaJet Launches Ground-breaking Next-Gen SAF Technology

chemicalonline.com; January 24, 2024

United Sustainable Flight Fund Invests in Heirloom to Scale Direct Air Capture

united.com; February 25, 2025

VIRGIN AUSTRALIA, QATAR AIRWAYS TEAM UP WITH RDA FOR ETJ FACILITY IN AUSTRALIA

NEWS BY FAYAZ HUSSAIN MARCH 28, 2025 0 PRINT THIS PAGE

World's first in-flight study of commercial aircraft using 100% sustainable aviation fuel show significant non-CO2 emission reductions

airbus.com; 06 June 2024

A (single-stage) catalyst for change

OXCCU's patented single-stage catalyst promises to lower the cost of PtL SAF, with the company's first demonstration plant about to commence operations.

Charlotte Bailey · August 29, 2024

Uniper halts development of SkyFuelH2 in Sollefteå

12 October 2024 by Alan Sherrard

Shell to temporarily pause on-site construction of European biofuels facility

2 Jul 2024

LONDON, UNITED KINGDOM, July 02, 2024: Shell Nederland Raffinaderij B.V., a subsidiary of Shell plc, is to temporarily pause on-site construction work at its 820,000 tonnes a year biofuels facility at the Shell Energy and Chemicals Park Rotterdam in the Netherlands to address project delivery and ensure future competitiveness given current market conditions.

Sustainable Aviation Fuel Takes Off at Heathrow

Heathrow Airport is accelerating its commitment to sustainability with the expansion of its Sustainable Aviation Fuel (SAF) incentive scheme for a fourth year.

By *Vedat Özgür Töre* / Published: January 11, 2025

EASA

Source: Various corporate press releases

SAF adoption

0.5 million

… flights with portion of SAF in the fuel mix

Ethiopian Airlines takes delivery of its 20th A350-900 powered by Sustainable Aviation Fuel (SAF)

Addis Ababa, 29 April 2023

AIR TRANSPORT

RAM's carbon neutral dream comes true with first eco flight

Royal Air Maroc launched the first eco-responsible flight between Casablanca and Dakar aboard a Boeing 787 on the sidelines of COP28 in Dubai.

Emirates world's first airline to operate A380 demonstration flight with 100% Sustainable Aviation Fuel

THIS STORY IS FROM MAY 4, 2023

Vistara operates the first Indian commercial airline flight with blended sustainable fuel

Manju V / TNN / May 4, 2023, 19:46 IST

SHARE AA FOLLOW US

Tata-SIA airline Vistara on Thursday became the first Indian carrier to operate a commercial domestic flight on a wide-body aircraft using sustainable aviation fuel (SAF). With a blend of 17 % SAF and 83 % conventional jet fuel, the airline operate ... Read More

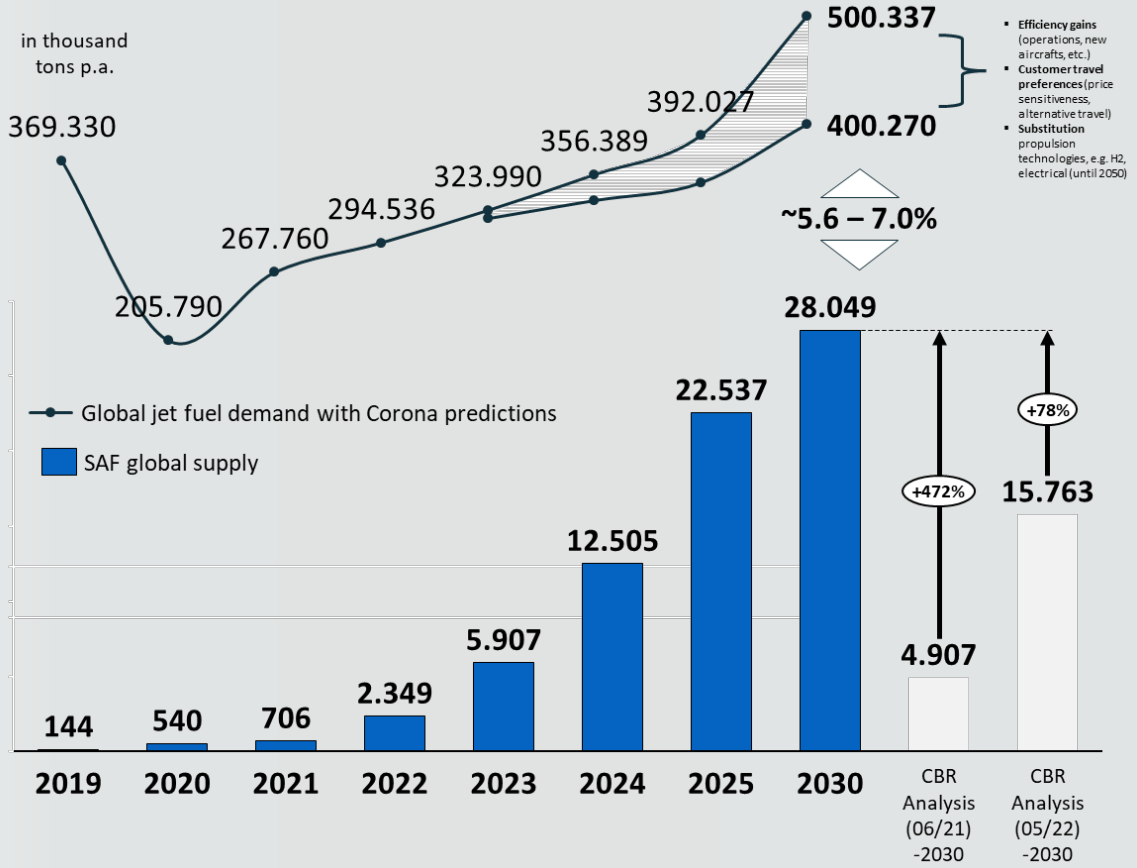
… ready-to-use as drop-in fuel!

Source: Various corporate press releases

SAF production

1 million

… tons of SAF produced in 2024



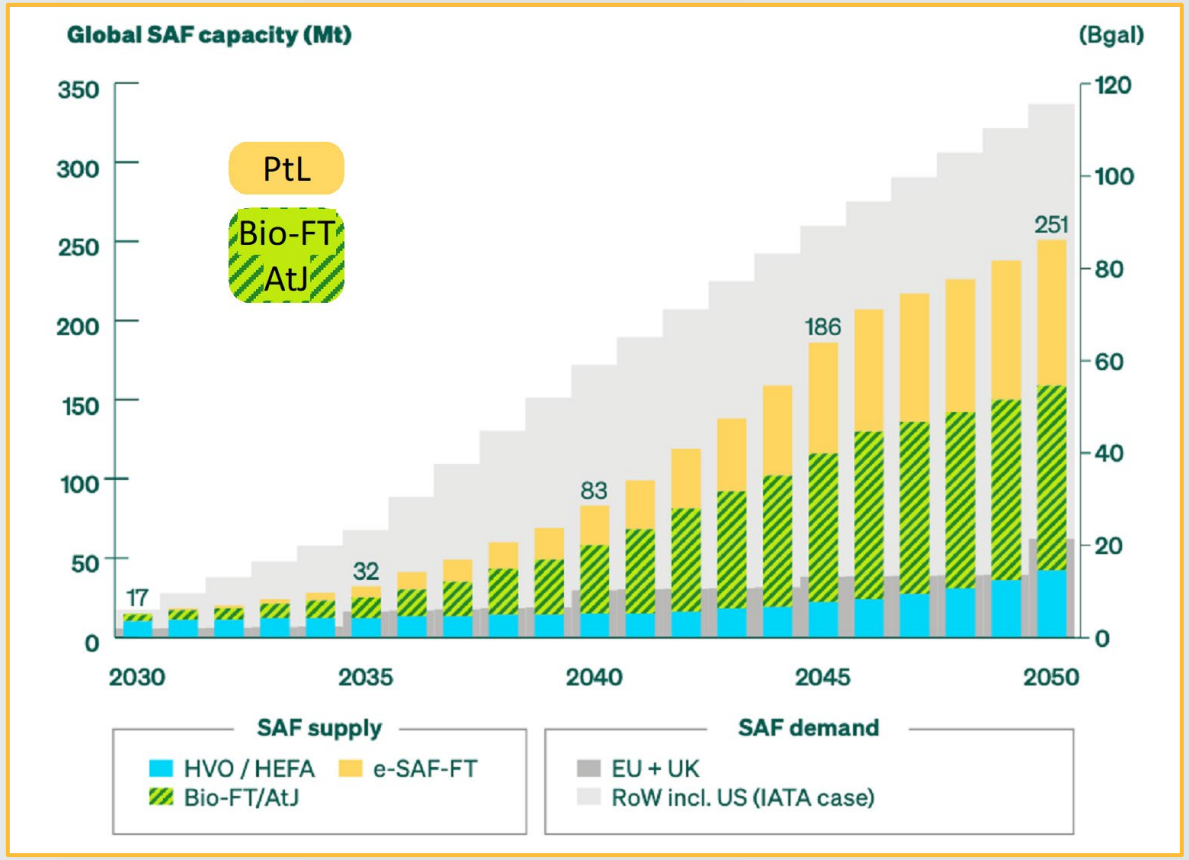
… with mature production technologies available!

Source: CBR Sustainability Partners, 2023

SAF demand

300 million

… tons of SAF demand expected by 2050



… requiring up to 6.500 plants to be build!

Source: SkyNRG, 2024

Project developers

150+

… SAF project developers identified

Non-exhaustive

… from legacy fuel to newly formed companies!

Feedstocks

48

CORSIA

… currently eligible under CORSIA

Exemplary

… fulfilling sustainability criteria for SAF!

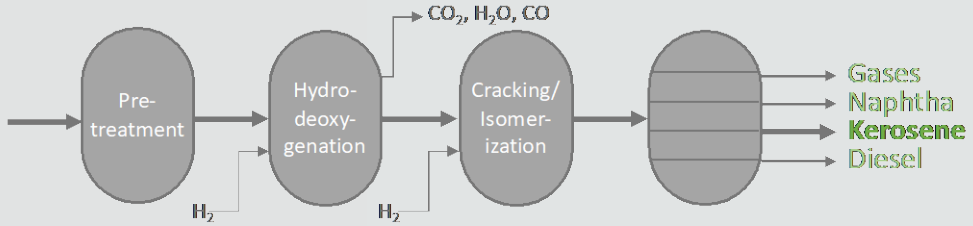
Source: ICAO

SAF technology pathways

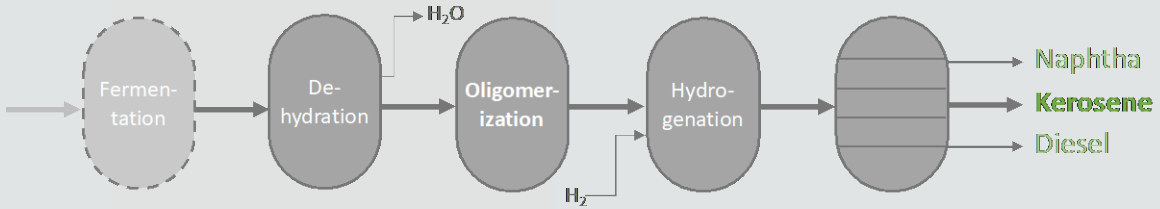
11 + 11

… ASTM approved and under evaluation

HEFA
Hydrotreated Esters and Fatty Acids

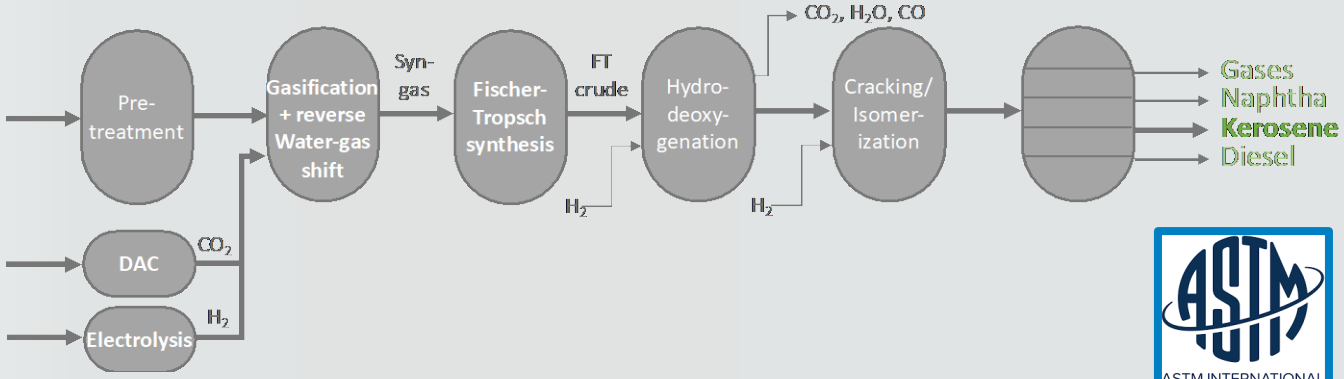


AtJ
Alcohol-to-Jet



BtL
Biomass-to-Liquid

PtL
Power-to-Liquid



ASTM INTERNATIONAL

… ensuring safe utilization of SAF!

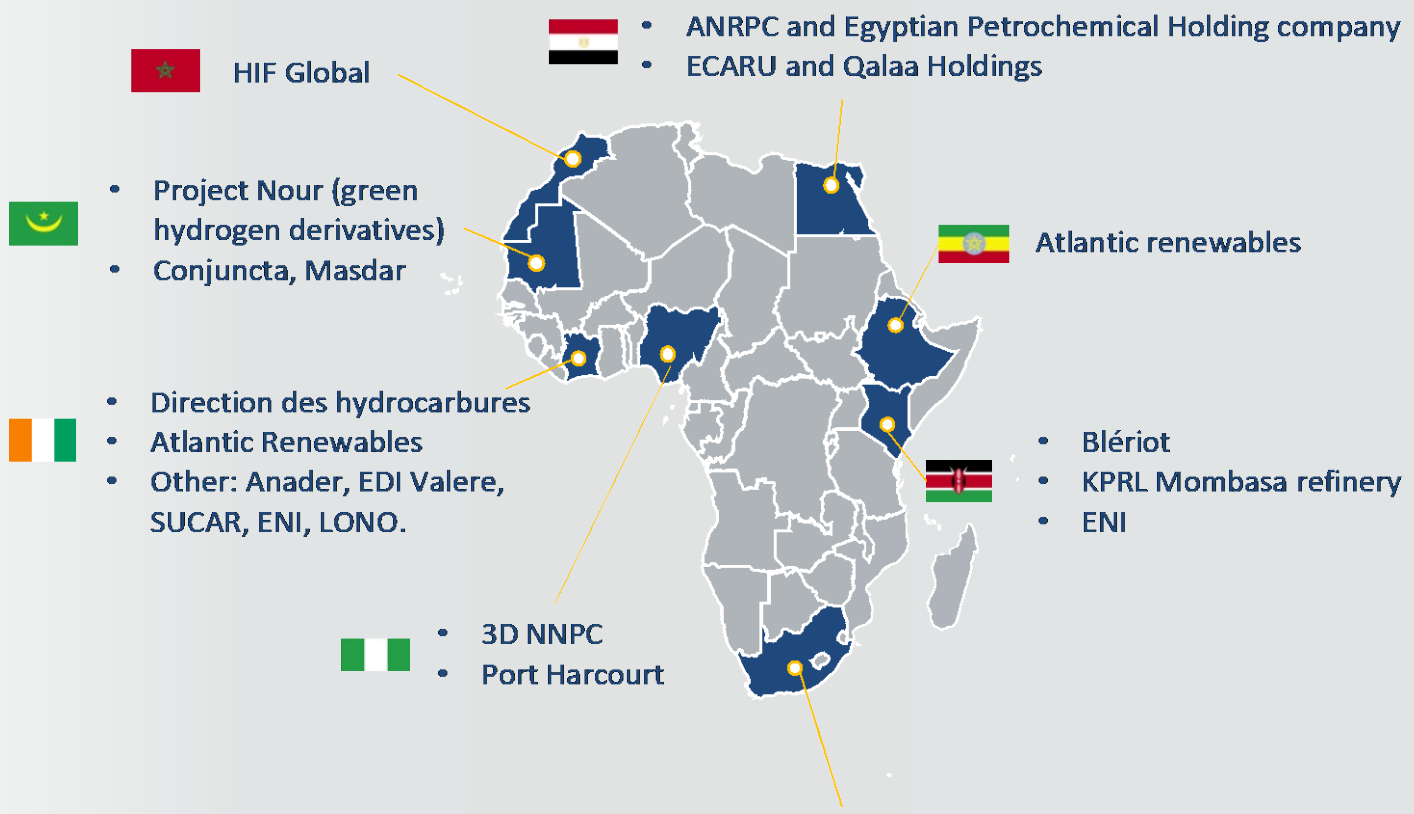
EASA

Simplified process diagrams. Only main steps are illustrated for categories of pathways

SAF facilities

458

Facility announcements globally



Non-exhaustive

… with around 17 African projects announced!

Investments

47.3 billion

… US Dollar investments announced

Non-exhaustive

… facilitating SAF ramp-up.

Source: Various corporate press releases

Offtake

53.8 billion

… liters offtake agreements committed

Non-exhaustive

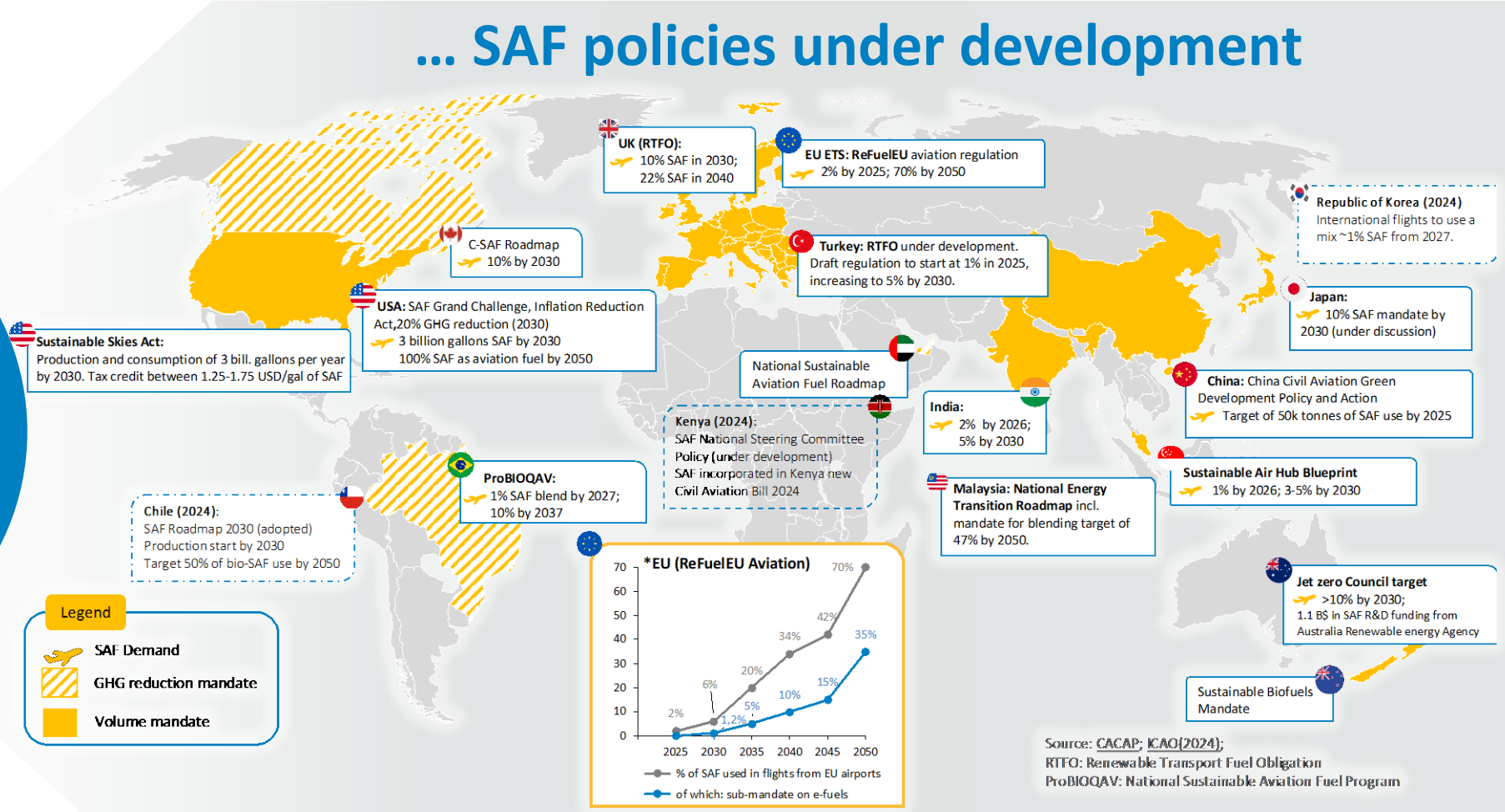
… facilitating SAF ramp-up.

Source: Various corporate press releases

Regulation

47

… SAF policies under development



… backing incentives, mandates and voluntary ambitions.

Source: CBR Sustainability Partners, 2023; ICAO, 2025

Airports

1. Strategy and Corporate Policies
2. Customer services and self-obligations, e.g. Scope 3 (SBTi)
3. Financial and capabilities exposure
4. SAF sourcing and engagement level intensity

Airports distributing SAF

Part of the core corporate strategy	Member of public-private consortium for SAF promotion	Advocating for policy incentives
Climate action through self-commitments (i.e. SBTi)	Partnerships to reduce GHG emission	Purchasing program for airlines of SAF subsidies
Equity stake in SAF production company	Investment in production plant	Committed funds for R&D
Dedicated mid-term corporate funds for SAF sourcing	SAF mid-term usage strategy	SAF offtake agreements

FRONTRUNNER — PROACTIVE — ACTIVE

… enabling SAF Through Multi-Stakeholder Collaboration!

Source: CBR Sustainability Partners, 2025

Airports distributing SAF

144

1. **Strategy and Corporate Policies**
2. **Customer services and self-obligations, e.g. Scope 3 (SBTi)**
3. **Financial and capabilities exposure**
4. **SAF sourcing and engagement level intensity**

Heathrow: Published Nature Positive Plan and announces an update to its sustainability strategy, (Heathrow 2.0), including SAF	Adelaide Airport: Formed a public-private partnership with Zero Petroleum and the South Australian government to produce up to 10 million litres of e-SAF.	Schiphol: Implemented an airport-led incentive scheme that supports airlines by reducing the price premium of SAF
Wellington Airport: Committed to SBTi, aiming for net-zero emissions by 2030. The airport has achieved a 27% reduction in net emissions since 2017	LAX: Introduced a full supply of blended Neste SAF to LAX by Signature Aviation.	brussels airport: Offered a financial incentive to all airlines, covering 80% of the additional cost of blended SAF, supported by the Belgian government
Paris Aéroport: Invested $20 million in SAF provider LanzaJet	Schiphol: Invested in the construction of Europe's first sustainable kerosene plant, built by SkyNRG	Düsseldorf Airport DUS: Partnered with Greenlyte Carbon Technologies to create world's first fully integrated DAC-to-SAF facility, producing 250 tons of SAF annually
Heathrow: Committed to a SAF incentive scheme funding to £86 million, aiming to achieve 3% SAF usage, 187,000t of aviation fuel	Hamburg Airport: Adapted its infrastructure to store SAF and is involved in projects aiming to produce low-carbon aviation fuel locally	Flughafen Zürich: Partnered with Synhelion, producing solar fuels. It will purchase 30,000 liters of solar diesel annually from Synhelion, starting in 2027

Strategic initiative: FRONTRUNNER — PROACTIVE — ACTIVE

Non-exhaustive

Enabling SAF Through Multi-Stakeholder Collaboration!

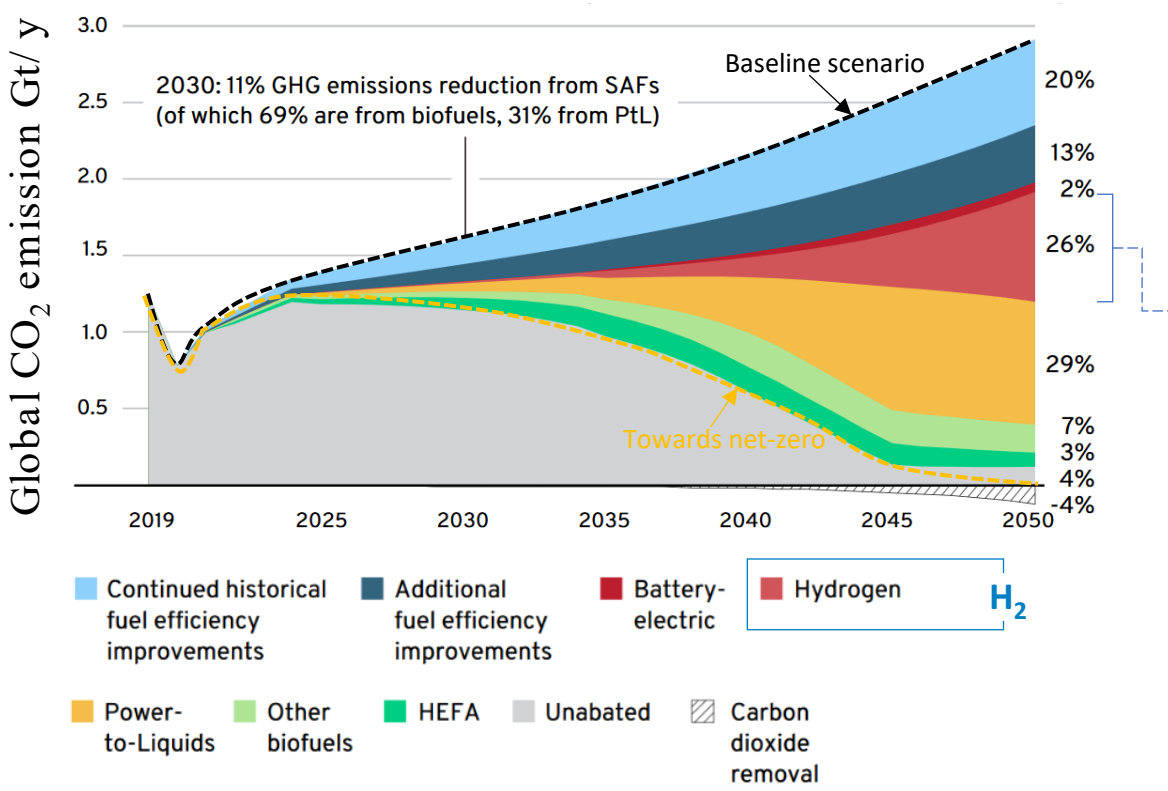
Source: CBR Sustainability Partners, 2025

Part 2

The Role of Hydrogen

- Fuel Alternative and Intermediate
- Similarities, Synergies, Policies

Battery, hydrogen and SAF:
Potentials for decarbonization of aviation as a hard-to-abate sector



	GHG reduction	Regional flight	Short haul	Medium/ long haul
Batteries	100%	✓		
H_2 Hydrogen	100%	✓	✓	
Sustainable aviation fuel (SAF)	70-99%	✓	✓	✓

- Hydrogen and batteries enable **carbon free air traffic**, however they are expected to be **limited to shorter flights.**
- Direct **hydrogen utilization** as aviation fuel will play an **increasing role** in decarbonization of the aviation sector.

Source: Mission Possible Partnership, Making net-zero aviation possible - An industry-backed, 1.5°C-aligned transition strategy, here the Optimistic Renewable Electricity scenario, WEF, 2022; CBR, 2023

Key aspects around Hydrogen and its energy properties, forming the basis for its application as and in aviation fuel.

Colours of Hydrogen

Grey
Fossil H_2 from natural gas (NG) reforming.
Black and brown for coal-based H_2.

Today: fossil H_2 ~95%

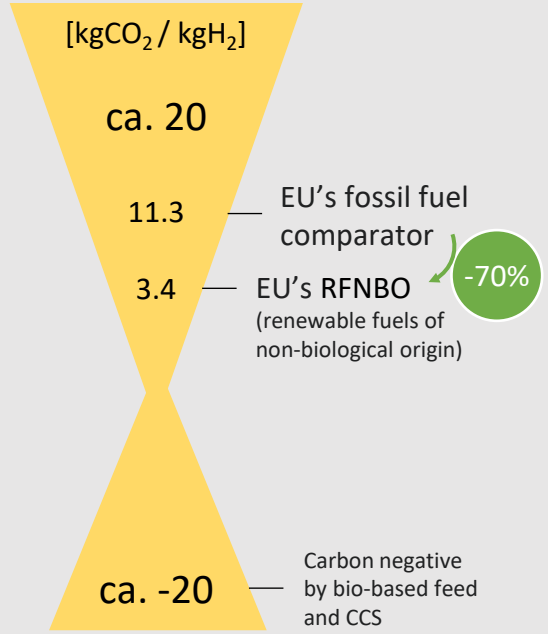
Blue
H_2 from NG reforming + carbon (CO_2) capture and storage.
Turquoise for NG pyrolysis and solid carbon removal.

Green
H_2 from electrolysis using regenerative electricity.
Pink for nuclear, yellow for sun powered hydrogen.

White
H_2 from geological sources.

Note: No international, standardized colour code. Definitions may vary.

Carbon intensity



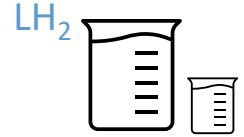
Emission values depending on feed, technology, transport and scope.

Energy content comparison H_2:Kerosene

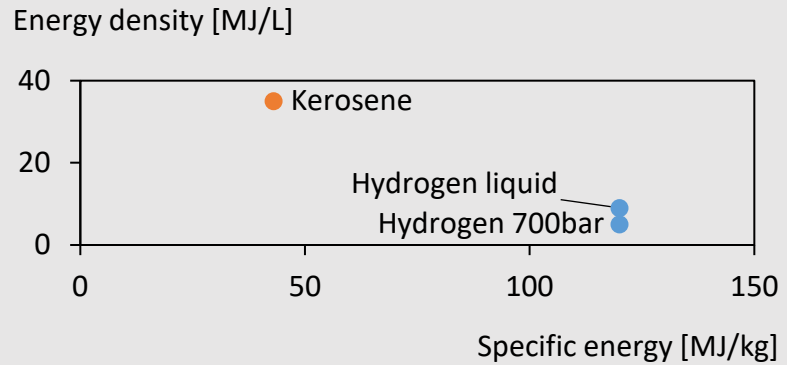
Specific energy
ratio 120 : 43 ≈ **3**

Mass per unit energy

Energy density
ratio 8.5 : 35 ≈ **0.24**

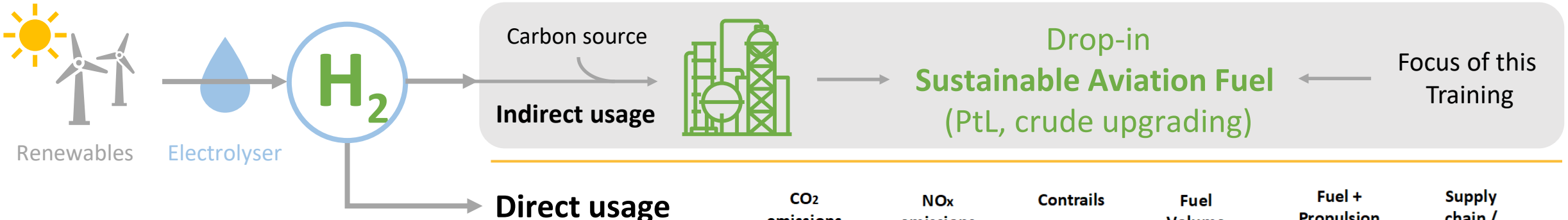


Volume per unit energy



- Carbon reduced, free and negative H_2 is produced from **renewables** and integration of **carbon removal** technologies.
- Emission depend on the **feed**, the applied **technology**, **transport** emissions, applied **calculation method** and the **scope** of analysis.
- H_2 is a **light-weight fuel** with a very **high specific energy**.

Hydrogen's role in decarbonization of aviation



Considerables:

- **Infrastructure** (airports)
- **Flexibility** (ground operations)
- Specific **energy** vs. energy density
- **Safety**:
  Leakage; Corrosiveness;
  Fire/Explosion protection;
  Crashworthiness
- Technology readiness level **TRL**
  (Fuel cell, H_2-engines)

Fuel cell electric

Colour code: benefit, neutral, critical

Source: EASA

History and developments of hydrogen in aviation

Airships
- Utilizing the low density of hydrogen for **buoyancy**
- Substituted by Helium due to severe safety concerns after Hindenburg disaster **1937**

Flight demonstrations
- Both, combustion and **fuel** cell electric
- Boeing, ZeroAvia and others
- First flights by Tupolev Tu-155 in **1988**

Hydrogen engines
- Intensive testing of modern turbines to adapt to combustion behaviour
- Rolls-Royce & easyJet
- Successful tests in **2022**

Future aircraft designs
- Airbus ZEROe
- Series of designs towards hydrogen utilization including airports as hydrogen hubs
- orig. planned for **2035**, **delayed**

Commercial activities:

February 18, 2025

ZeroAvia Announces First Sale of Standalone Electric Propulsion System

Jetcruzer International has signed an agreement to purchase ZeroAvia's 600kW electric propulsion system to power the next stage of its electric aircraft development

- Hydrogen plays a continuous role in aviation history and its future
- Intensive investigations for safe handling and commercial feasibility / no drop-in quality
- Integrated approaches for a hydrogen-based ecosystem

Integrated approaches:

Exemplary / Non-exhaustive
Source: dpa, Airbus, Rolls-Royce, ZeroAvia

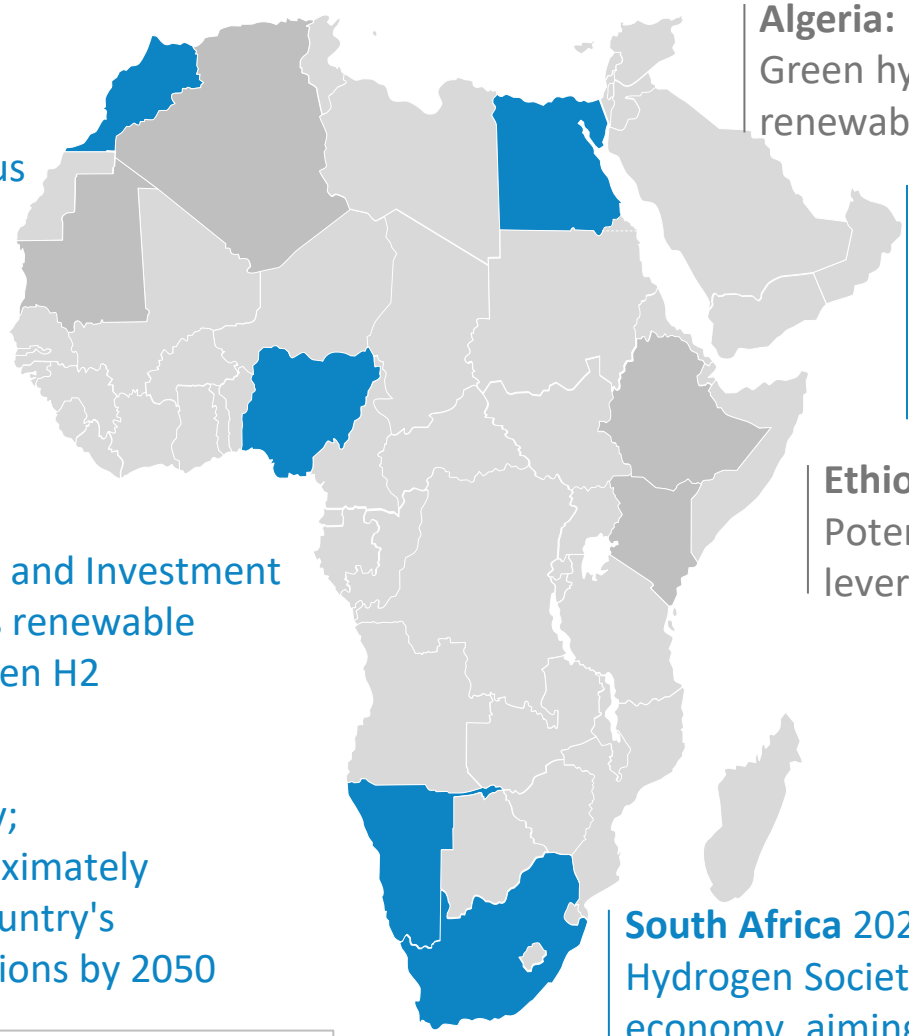
Ambitious national hydrogen strategies in place and in progresses, building the regulatory frameworks for a hydrogen economy

Morocco 2021:
3,500 GWh green Hydrogen by 2030; green ammonia production and exporting green hydrogen to countries with ambitious decarbonization goals

Mauritania
Green Hydrogen Initiatives, including the NOUR Project and the AMAN Project

Nigeria 2025:
Hydrogen Development and Investment Roadmap; leveraging its renewable energy potential for green H2

Namibia 2022:
Green Hydrogen and Derivatives Strategy; US$6 billion to the GDP and create approximately 80,000 jobs by 2030, aligning with the country's commitment to achieving net-zero emissions by 2050



Algeria:
Green hydrogen development, aiming to leverage its renewable energy potential and existing infrastructure

Egypt 2024:
National Strategy for Low-Carbon Hydrogen; focusing on developing infrastructure and policies to support hydrogen production and utilization

Ethiopia:
Potential for Green Hydrogen Development, leveraging renewable energy reyources

Kenya:
Green Hydrogen Integration Plans: Kenya plans to integrate green hydrogen into its domestic energy system, aiming for 100% renewable energy use by 2030

South Africa 2021:
Hydrogen Society Roadmap; integrate hydrogen into its economy, aiming to decarbonize various sectors and position the country as a global player;
Green Hydrogen Commercialisation Strategy

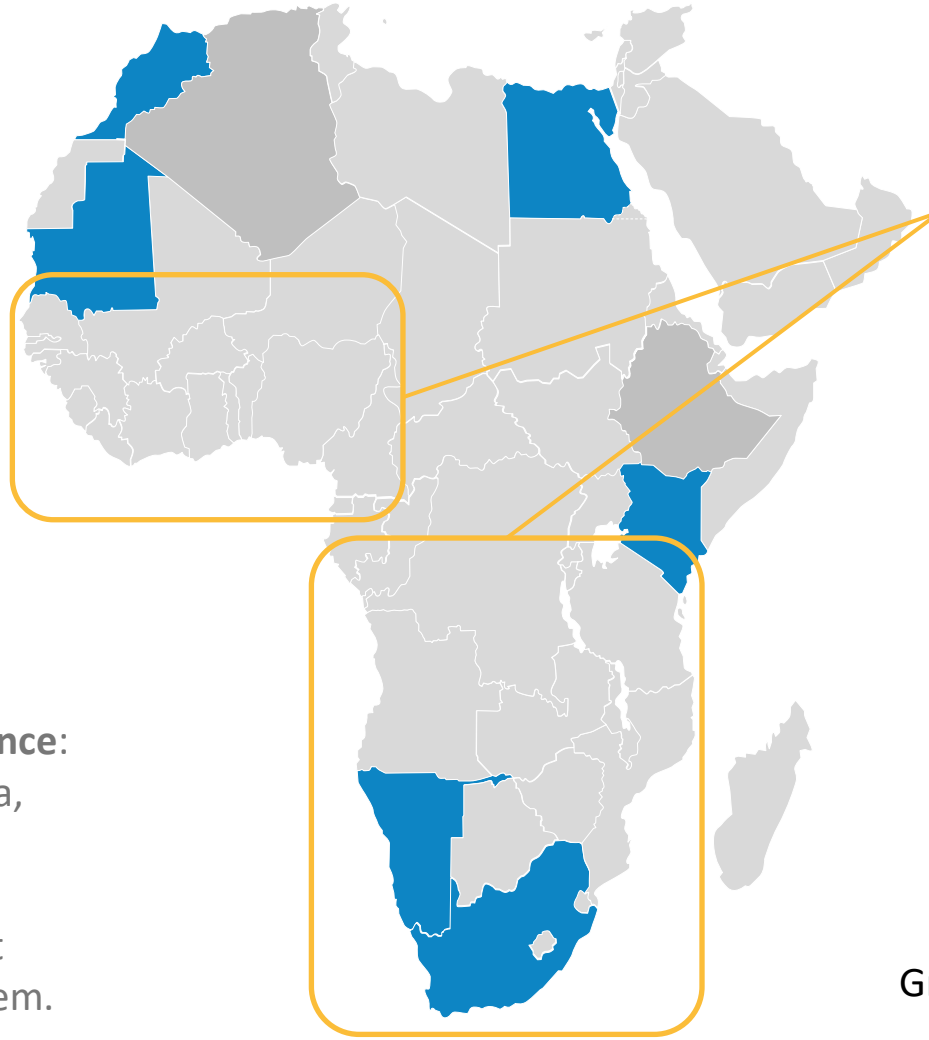
- Strategies *in place*
- Strategies *in progress*

EASA *Exemplary / Non-exhaustive*

Multiple studies attest large renewable hydrogen potentials – Continental and international projects are being pursued.

Africa Green Hydrogen Alliance (AGHA): Egypt, Kenya, Mauritania, Morocco, Namibia, and South Africa are aiming to intensify collaboration and accelerate the development of green hydrogen projects across the continent, focusing on public and regulatory policy, capacity building, financing, and certification needs.

African Hydrogen Partnership (AHP)



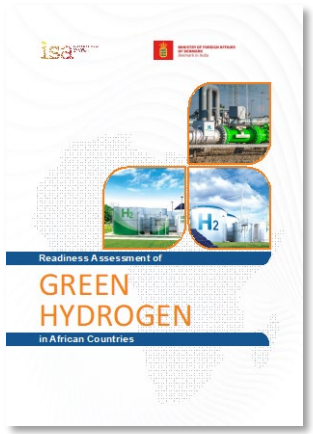
H_2Atlas-Africa exploring the H_2 production potentials in Sub-Sahara

JÜLICH Forschungszentrum

Bundesministerium für Bildung und Forschung

WASCAL West African Science Service Centre on Climate Change and Adapted Land Use

SASSCAL Southern African Science Service Centre for Climate Change and Adaptive Land Management



International Solar Alliance: Egypt, Morocco, Namibia, and Ethiopia are well-positioned to drive the development of a robust green hydrogen ecosystem.

South African Green Hydrogen Atlas

EASA

Exemplary / Non-exhaustive

Extensive infrastructure and investment needs to be met for a green hydrogen economy ramp up

1. Power

- Ramp-up of **renewable** electricity production from **solar, wind and hydro**
- Additional to increased electricity demand
- **Reliable** supply

2. Electrolyzer

- Deployment of **gigawatt-scale** electrolyzers (e.g., PEM, alkaline, SOEC)
- Incl. **grid connection** and water purification
- Facing **FOAK barriers** and power fluctuations

3. Storage

- Buffer production, ensure **supply reliability**
  - Compressed gas (350–700 bar)
  - Liquid hydrogen (-253°C)
  - Carriers (e.g., LOHC, ammonia)

4. Transport

- **Pipelines**: Retrofitting or building H_2 -specific pipelines
- **Trucking**: Cryogenic or pressurized trailers
- Ports & Shipping: **Export terminals** (ammonia, LOHC, LH_2)

5. End-use

- Plants, refineries, airports, steel & fertilizer **plants to be H_2 ready**
- Aircraft **fueling systems**
- Fuel cell / H_2 combustion **technology available**

Estimated investment requirements

from 2024 to 2030**:**

- **USD 100 billion** annually for emerging markets and developing countries (excluding China)
- USD 10 - 40 billion per year external financial support

Source: World Bank and OECD / IRENA, 2024

Major barriers:

- **Grid** capacity & stability: Reliable coupling of renewables and H_2
- **Nascent market & new technologies** require adjustment of risk-return-expectations
- **Bankability**: FOAK projects lack proven cash flows

Starting points:

- **Policy frameworks:** Provide plannability and incentives
- **Risk mitigation** tools: Insurance, guarantees / performance warranties, strategic partnering
- **Pricing and Offtake:** Contracts for Difference to bridge green premium (H2Global)

While large potentials are being attested and projects initiated, few have reached final investment decision.

PEM: Proton exchange membrane, SOEC: solid oxide electrolyzer cell, FOAK: First-of-a-kind, LOHC: Liquid organic hydrogen carrier

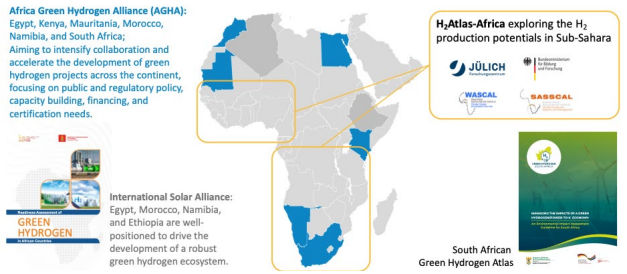
Key take-aways

SAF

- 0.5 Mio SAF flights
- 1 Mio tons production
- 300 Mio tons demand
- 120+ project developer
- 48 CORSIA feedstocks
- 11 ASTM pathways
- 458 facilities announced
- 47.3 Bln USD invests
- 53.8 Bln Liters offtage
- 47 policies under development
- 144 airports distributing SAF

- **Nascent market**, currently dominated by HEFA while new player enter market
- **Discoveries** to be made regarding regulations, technology maturity and costs
- **Partnerships** and **stakeholder engagement** key element

H_2



- **Increasing H_2 demand** across industries, including aviation
- **Direct use** and **intermediate** in SAF production, especially PtL
- H_2 **roadmaps ahead** of SAF
- **Same barriers** to overcome as SAF ramp-up

EASA
European Union Aviation Safety Agency

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easa.europa.eu/connect

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