ICAO Long Term Aspirational Goal (LTAG) Review

Presented to: CAAFI Webinar

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Date: October 11, 2022

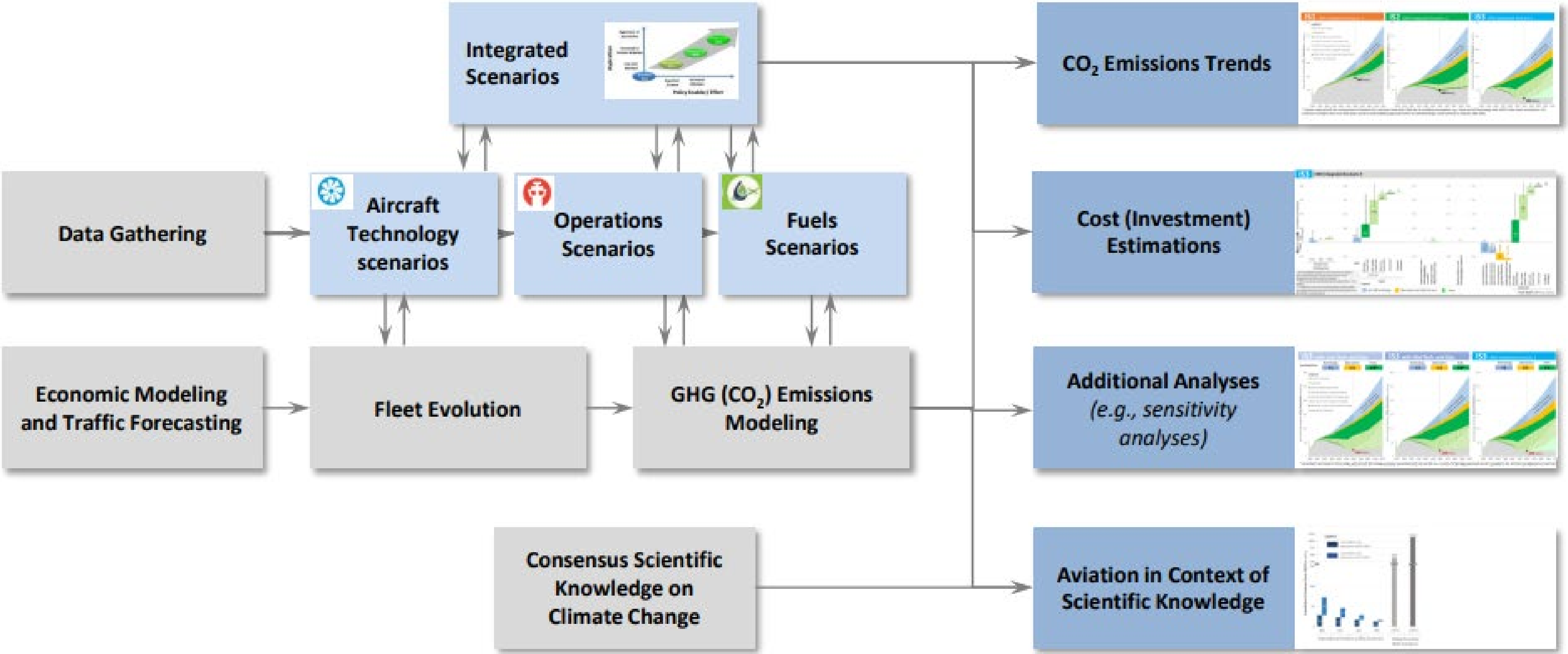
Federal Aviation Administration

Introduction

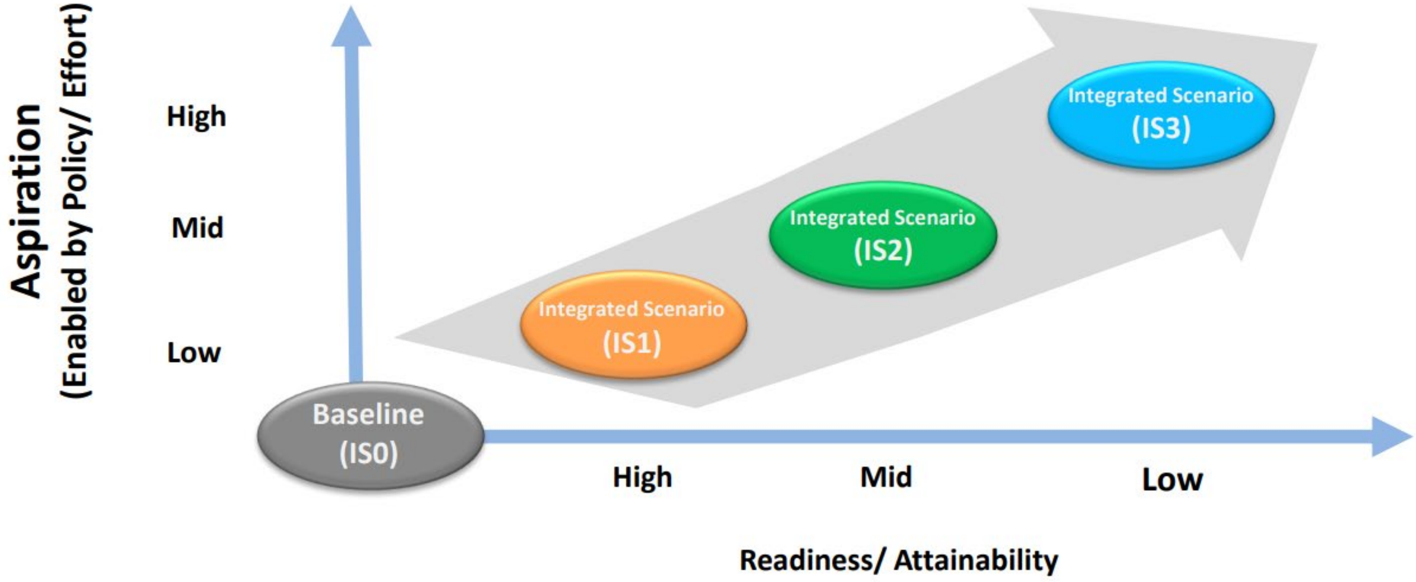
- **2020**: ICAO CAEP announces effort to assess feasibility of a long-term aspirational goal (LTAG) for ***CO2 emissions*** from ***international*** aviation
  - FAA led most technical areas (technology, fuels, operations, scenarios) in assessment of CO_2 emissions for future scenarios
  - Leveraged multiple analysis efforts across U.S. government:
    - **Fuels**: ASCENT 01 & 52 and Argonne National Lab
    - **Technology**: ASCENT 64
    - **Ops**: U.S. input informed by FAA (NextGen, ASCENT)
    - **Integration**: Volpe (using AEDT)
    - **Cost**: Philippe Bonnefoy (Blue Sky)
- **March 2022**: CAEP Steering Group approved final LTAG Report (icao.int)

ICAO: International Civil Aviation Organization
CAEP: Committee on Aviation Environmental Protection

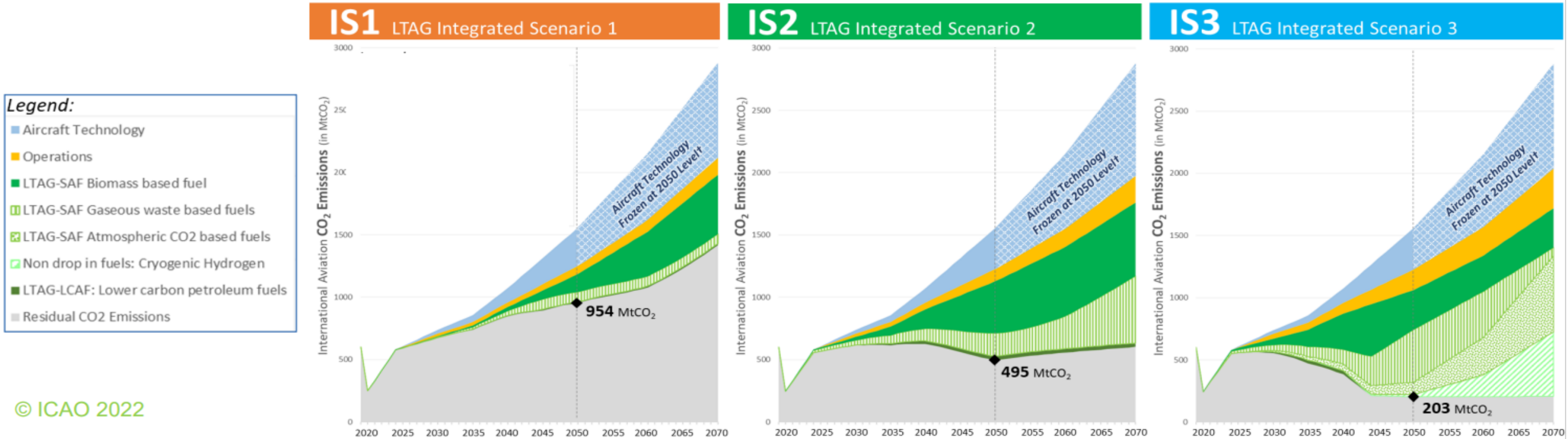
Methodology



Scenarios


Aspiration
(Enabled by Policy/ Effort)
High
Mid
Low
Baseline
(IS0)
Integrated Scenario
(IS1)
Integrated Scenario
(IS2)
Integrated Scenario
(IS3)
High
Mid
Low
Readiness/ Attainability

High Level Results



Metrics	IS1	IS2	IS3
CO_2 Emissions in 2050 after Reductions	**≈950 $MtCO_2$** in 2050 (*160% of 2019 CO_2 emissions*)	**≈500 $MtCO_2$** in 2050 (*80% of 2019 CO_2 emissions*)	**≈200 $MtCO_2$** in 2050 (*35% of 2019 CO_2 emissions*)
Reduction in 2050 from the Baseline	**39% total** through: Technologies - 20%, Operations - 4%, Fuels - 15%	**68% total** through: Technologies - 21%, Operations - 6%, Fuels - 41%)	**87% total** through: Technologies - 21%, Operations - 11%, Fuels - 55%
Cumulative residual Emissions from 2020 to 2070	23 $GtCO_2$ (2020 to 2050) 23 $GtCO_2$ (2051 to 2070)	17 $GtCO_2$ (2020 to 2050) 11 $GtCO_2$ (2051 to 2070)	12 $GtCO_2$ (2020 to 2050) 4 $GtCO_2$ (2051 to 2070)

15

Source: LTAG Task Group Final Report - Slides

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Technology Modeling

Forecast and Scenarios input

Scenario/Operations

Demand Forecast

Aircraft Retirements

Replacements Schedule

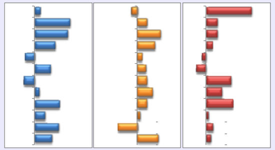
New Product / Upgrade Availability

Vehicle Analysis

Vehicle Performance Characteristics

Technologies

Benefit
Applicability
Availability

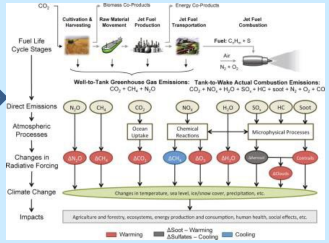


ICAO CAEP Working Group input

External input

Fuel input

Alternative Fuels

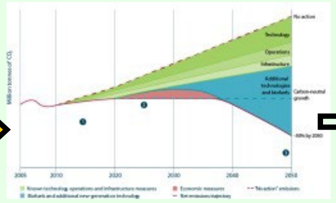


Fleet Analysis

FB/Operation
Total Ops
Total FB

Modeling

Fleet Impact



Deliverable
Assess alternatives and provide recommendations to LTAG-TG Leadership

Technology Improvements

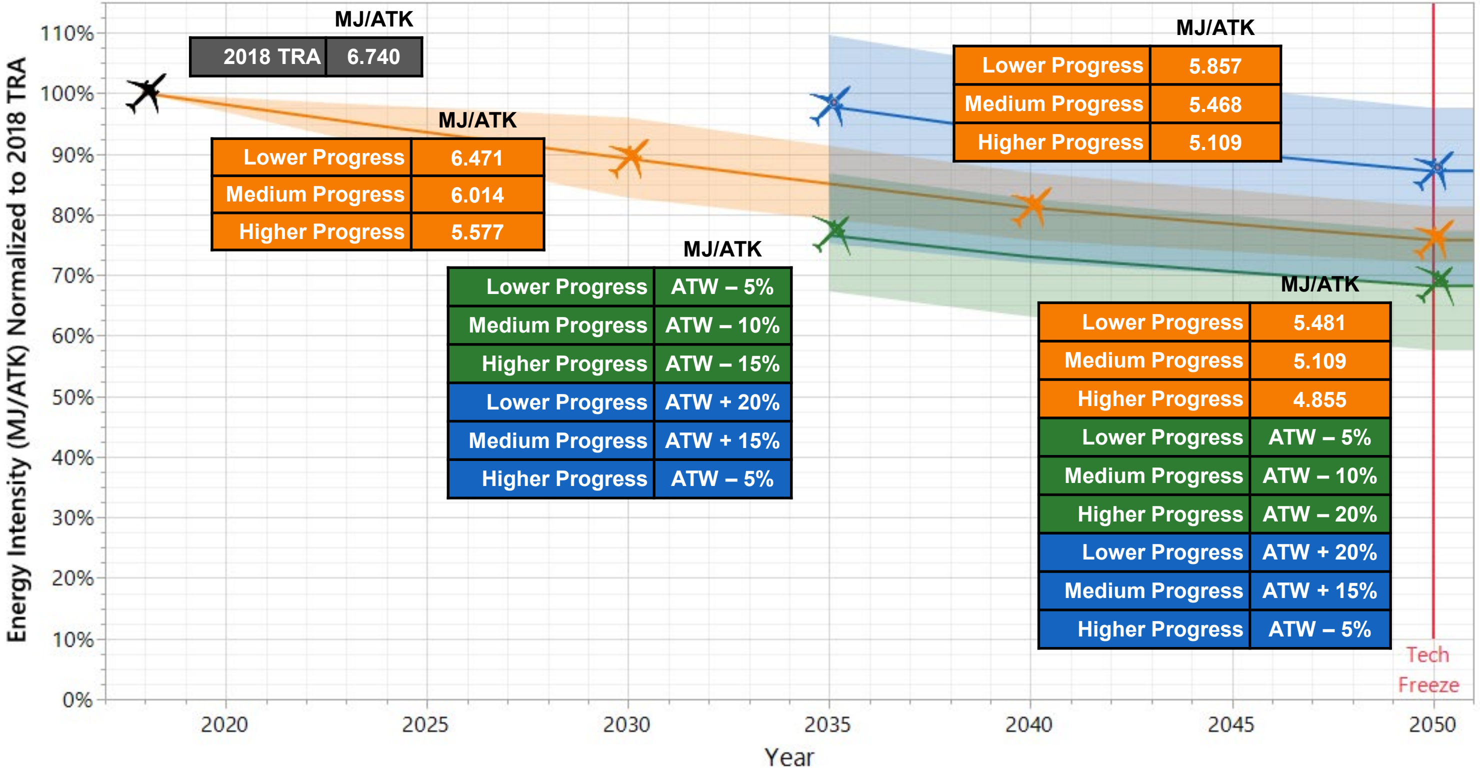
Aerodynamics
- Excrescence Reduction
- Flow Control: HLFC / NLF, Riblets
- Active CG Control
- Advance Wingtip Devices
- MDAO – Configuration Integration

Structures / Materials
- Advanced Metallic Technologies
- Advanced Composite Technologies
- Optimized Local Design
- Multifunctional Design/Materials
- Advanced Load Alleviation
- Nacelle Improvements

Systems
- More Electric A/C (replacement of various pneumatic systems with electrical equivalents)
- Adaptive ECS (Filtration and reconfiguration)

Propulsion
- Advanced Propulsion System
  - Higher OPR
  - Lower FPR
  - Component Weight Reductions
  - Component Efficiency Improvements

Narrow Body Energy Trend



Technology Summary

- **Conventional Tube and Wing aircraft: <u>incremental improvements</u> in fuel consumption**
  - Not enough to meet the 2050 goal on their own

- **Technology and concept alternatives are available for each vehicle class:** business jets, turboprops, regional jets, narrow and wide bodies

- **Advanced concept aircraft: <u>step changes</u> in energy use**
  - Lifecycle carbon reduction benefits for non-drop-in fuels depend heavily on production methods
  - Advanced concepts require <u>significant R&D</u> and <u>flight demonstration programs</u>
  - Technical capability and maturity advances are necessary <u>**but not sufficient**</u> without infrastructural and regulatory considerations

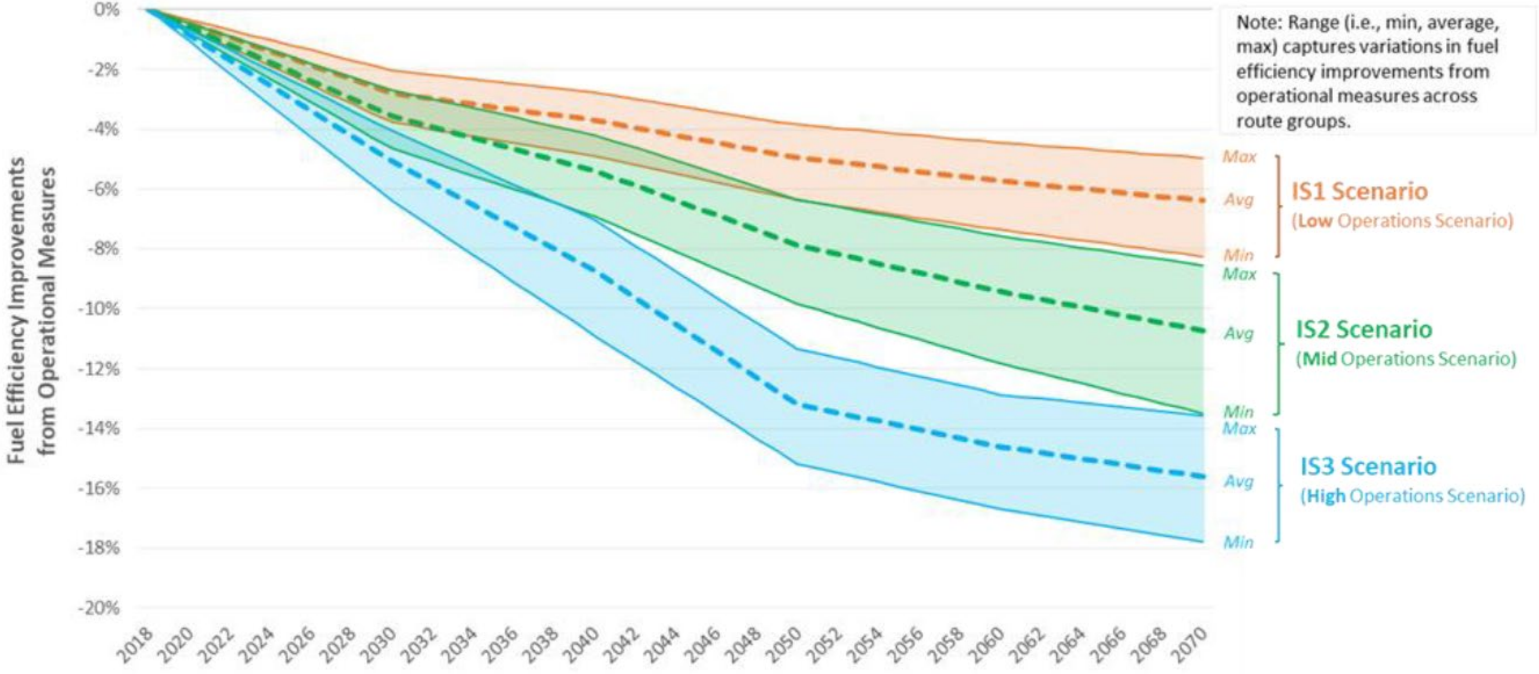
Progress Level	Narrow Body Energy Intensity Relative to 2018 TRA							
	2018	2030	2035		2040	2050–2070		
Lower Progress		96.01%	86.8%	110%	86.9%	81.32%	77.3%	97.6%
Medium Progress	100%	89.22%	76.6%	97.8%	81.1%	75.80%	68.2%	87.2%
Higher Progress		82.74%	67.3%	75.2%	75.8%	72.03%	57.6%	68.4%

Operations Scenarios

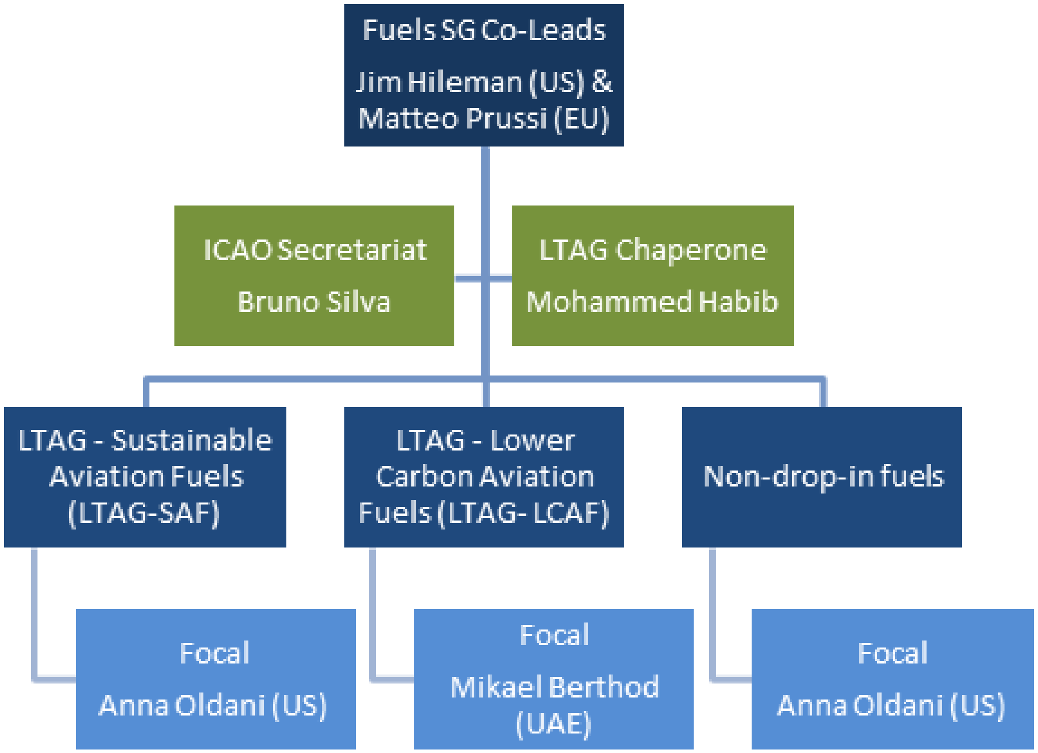
	MDG/FESG Baseline	LTAG-TG Scenarios		
	Integrated Scenario 0 (IS0)	Integrated Scenario 1 (IS1)	Integrated Scenario 2 (IS2)	Integrated Scenario 3 (IS3)
		Decreasing readiness and attainability. Increasing aspiration. →		
General Description	Projection of current technologies available in base year (through fleet renewal). No additional improvements from tech, ops and fuels. No systemic change – e.g. infrastructure changes to accommodate growth only.	**Low / nominal** Current (c. 2021) expectation of future available tech, ops efficiencies, fuel availability, costs. Includes expected policy enablers for technology, ops and fuels. **Low systemic change** – no substantial infrastructure changes.	**Increased / further** Approx. mid-point. Faster rollout of future tech, increased ops efficiencies and higher fuel availability. Assumes increased policy enablers, therefore decreased costs for technology, ops and fuels. **Increased systemic change** – limited infrastructure changes.	**Aggressive / speculative** Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs. Assumes max policy enablers for tech, ops and fuels. **High, internationally aligned systemic change** e.g. significant and broad change to airport and energy infrastructure.
Operations (O)	No emissions reductions from operations after 2025 (implementation of ASBU blocks 0 and 1)	**Low CO2 reduction from Operations** Conservative assumptions about rate and extent of implementation of operational measures, based on reduced/slower investment in ground and airborne systems and technologies. Low rate of ASBU element deployment to optimise HFE, VFE and GFE	**Mid CO2 reduction from Operations** Emissions reductions and operational efficiencies in line with existing "Rules of Thumb" developed by WG2 and new "Rules of Thumb" developed by LTAG OPS for new measures. Medium rate of ASBU element deployment to optimise HFE, VFE and GFE, Low rate of operational measure deployment to optimise IFE and AFE	**High CO2 reduction from Operations** Aggressive assumptions about rate and extent of implementation of operational measures, based on higher/accelerated investment in ground and airborne systems and technologies. High rate of ASBU element deployment to optimise HFE, VFE and GFE, Medium rate of operational measure deployment to optimise IFE and AFE

Source: "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions." International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

Operations Summary



Fuels Sub-Group



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Fuels Process

Fuel Categorization

- Carbon source
- Drop-in / non drop-in

Scenario Definition

- IS1/F1, IS2/F2, IS3/F3
- Expectation on available technologies
- Fuel availability - readiness, attainability

Fuels Analyses

- Examined each fuel category
- Used scenario definitions
- Fuel production potential
- Lifecycle GHG saving
- Economics and infrastructure issues

Unconstrained Scenarios

- Combined all fuel types from fuels analyses
- Production potential and life cycle GHG values
- Volume > demand

Constrained Scenarios

- Combined all fuel types from fuels analyses
- Production potential and life cycle GHG savings
- Volume <= demand
- Evaluated based on final MDG/Tech fuel use data

Fuels Categorization

Drop-in

Fuel Category	Fuel Name	Carbon source in fuel feedstock	Research Lead
LTAG - Sustainable Aviation Fuels (LTAG-SAF)	Biomass-based fuel	Primary biomass products and co-products	WSU/ FTG TPP
	Solid/liquid waste-based fuels	By-products, residues, and wastes	WSU/ FTG TPP
	Gaseous waste-based fuels	Waste CO/CO_2	MIT/ ANL
	Atmospheric CO_2-based fuels	Atmospheric CO_2	MIT/ ANL
LTAG - Lower Carbon Aviation Fuels (LTAG-LCAF)	Lower carbon petroleum fuels	Petroleum	ADNOC/ Aramco

Non drop-in

Fuel Category	Fuel Name	Carbon source in fuel feedstock	Research Lead
Non drop-in fuels	Electricity	Not applicable	MIT
	Liquefied gas aviation fuels (ASKT)	Petroleum gas, "fat" natural gas, flare gas, and propane-butane gases	Russia
	Cryogenic hydrogen	Natural gas, by-products, non-carbon sources	MIT

Fuels Scenarios

	MDG/FESG Baseline	LTAG-TG Scenarios		
	Integrated Scenario 0 (IS0)	Integrated Scenario 1 (IS1)	Integrated Scenario 2 (IS2)	Integrated Scenario 3 (IS3)
General Description	Projection of current technologies available in base year (through fleet renewal). No additional improvements from tech, ops and fuels. No systemic change – e.g. infrastructure changes to accommodate growth only.	**Low / nominal** Current (c. 2021) expectation of future available tech, ops efficiencies, fuel availability, costs. Includes expected policy enablers for technology, ops and fuels. **Low systemic change** – no ***substantial*** infrastructure changes.	**Increased / further** Approx mid-point. Faster rollout of future tech, increased ops efficiencies and higher fuel availability. Assumes increased policy enablers for technology, ops and fuels. **Increased systemic change** – limited infrastructure changes.	**Aggressive / speculative** Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs. Assumes max policy enablers for tech, ops and fuels. **High, internationally aligned systemic change** e.g. significant and broad change to airport and energy infrastructure.
Fuels (F)	No emissions reductions from low-carbon fuels (e.g. SAF).	**Low GHG reduction from Fuels (LTAG-SAF and LTAG-LCAF)**	**Mid GHG reduction from Fuels (LTAG-SAF and LTAG-LCAF)**	**High GHG reduction from Fuels (LTAG-SAF, LTAG-LCAF and non-drop-in fuels)**
		ASTM Intl develop methods to approve use of alternative jet fuels at blend levels above 50%.	ASTM Intl develop methods to approve use of 100% Synthesized Jet Fuel in existing aircraft and engines without any modification. This enables use of 100% SAF in all existing and new aircraft. (spans IS2 and IS3)	
		Ground transportation and aviation have level playing field with respect to alternative fuel use.	Electrification of ground transportation leads to increased availability of SAF as ground transport uses more electricity and less renewable fuels.	Economy-wide deep decarbonisation. Extensive electrification of ground transportation and widespread availability of renewable energy.
		Low incentives for LTAG-SAF/LTAG-LCAF production.	Increased incentives lead to reduced LTAG-SAF/LTAG-LCAF fuel cost for users.	Large incentives lead to widespread use of low GHG fuels for aviation.
		Technology evolution **enables use of waste (CO/CO_2) gases for LTAG-SAF, feedstock from a variety of settings** (e.g., oilseed cover crops), and **use of blue/green hydrogen** for LTAG-SAF/LTAG-LCAF production.	Technology evolution **enables widespread use of waste gases for LTAG-SAF, increased feedstock availability**, and **widespread use of blue/green hydrogen for LTAG-SAF/LTAG-LCAF** production. **Carbon Capture Utilization and Storage (CCUS) is in use**.	Technology evolution **enables widespread use of atmospheric CO2 for LTAG-SAF, further increases in feedstock availability, widespread use of CCUS**, and sufficient H2 exists to **enable use of cryogenic H2 use in aircraft**.
				Infrastructure developed to enable **use of non-drop-in fuels at airports** around globe

Source: "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions." International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

Fuels Scenario – F1

Low / nominal
Current (c. 2021) expectation of future available tech, ops efficiencies, fuel availability, costs.
Includes expected policy enablers for technology, ops and fuels.
Low systemic change – no ***substantial*** infrastructure changes.

Low GHG reduction from Fuels (LTAG-SAF and LTAG-LCAF)

ASTM Intl develop methods to approve use of alternative jet fuels at blend levels above 50%.

Ground transportation and aviation have level playing field with respect to alternative fuel use.

Low incentives for LTAG-SAF/LTAG-LCAF production.

Technology evolution **enables use of waste (CO/CO_2) gases for LTAG-SAF, feedstock from a variety of settings** (e.g., oilseed cover crops), and **use of blue/green hydrogen** for LTAG-SAF/LTAG-LCAF production.

	MDG/FESG Baseline	…G Scenarios	
	Integrated Scenario 0 (IS0)	…Scenario 2 (IS2)	Integrated Scenario 3 (IS3)
General Description	Projection of current technologies available in base year (through fleet renewal). No additional improvements from tech, ops and fuels. No systemic change – e.g. infrastructure changes to accommodate growth only.	…re tech, increased ops …er fuel availability. …policy enablers for … fuels. …**change** – limited …es.	**Aggressive / speculative** Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs. Assumes max policy enablers for tech, ops and fuels. **High, internationally aligned systemic change** e.g. significant and broad change to airport and energy infrastructure.
Fuels (F)	No emissions reductions from low-carbon fuels (e.g. SAF).	**…from Fuels …-LCAF)**	**High GHG reduction from Fuels (LTAG-SAF, LTAG-LCAF and non-drop-in fuels)**
		…methods to approve use of 100% Synthesized Jet Fuel in existing aircraft and … modification. This enables use of 100% SAF in all existing and new aircraft.	
		…und transportation leads …ility of SAF as ground … electricity and less	Economy-wide deep decarbonisation. Extensive electrification of ground transportation and widespread availability of renewable energy.
		… lead to reduced LTAG- … cost for users.	Large incentives lead to widespread use of low GHG fuels for aviation.
		…n **enables widespread use** …**TAG-SAF, increased** …**ty**, and **widespread use of** …**n for LTAG-SAF/LTAG-** …**rbon Capture Utilization** … **is in use**.	Technology evolution **enables widespread use of atmospheric CO2 for LTAG-SAF, further increases in feedstock availability, widespread use of CCUS**, and sufficient H2 exists to **enable use of cryogenic H2 use in aircraft**.
			Infrastructure developed to enable **use of non-drop-in fuels at airports** around globe

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Fuels Scenario – F2

	MDG/FESG Baseline	Scenarios	
	Integrated Scenario 0 (IS0)	Integrated Scenario 2 (IS2)	Integrated Scenario 3 (IS3)
General Description	Projection of current technologies available in base year (through fleet renewal). No additional improvements from tech, ops and fuels. No systemic change – e.g. infrastructure changes to accommodate growth only.	…tech, increased ops …fuel availability. …licy enablers for …uels. …ange – limited …s.	**Aggressive / speculative** Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs. Assumes max policy enablers for tech, ops and fuels. **High, internationally aligned systemic change** e.g. significant and broad change to airport and energy infrastructure.
Fuels (F)	No emissions reductions from low-carbon fuels (e.g. SAF).	…om Fuels …LCAF)	**High GHG reduction from Fuels (LTAG-SAF, LTAG-LCAF and non-drop-in fuels)** … and … aft. Extensive electrification of ground transportation and widespread availability of renewable energy. Large incentives lead to widespread use of low GHG fuels for aviation. Technology evolution **enables widespread use of atmospheric CO2 for LTAG-SAF, further increases in feedstock availability, widespread use of CCUS**, and sufficient H2 exists to **enable use of cryogenic H2 use in aircraft**. Infrastructure developed to enable **use of non-drop-in fuels at airports** around globe

Increased / further
Approx mid-point.
Faster rollout of future tech, increased ops efficiencies and higher fuel availability.
Assumes increased policy enablers for technology, ops and fuels.
Increased systemic change – limited infrastructure changes.

Mid GHG reduction from Fuels (LTAG-SAF and LTAG-LCAF)

ASTM Intl develop methods to approve use of 100% Synthesized Jet Fuel in existing aircraft and engines without any modification. This enables use of 100% SAF in all existing and new aircraft.

Electrification of ground transportation leads to increased availability of SAF as ground transport uses more electricity and less renewable fuels.

Increased incentives lead to reduced LTAG-SAF/LTAG-LCAF fuel cost for users.

Technology evolution **enables widespread use of waste gases for LTAG-SAF, increased feedstock availability**, and **widespread use of blue/green hydrogen for LTAG-SAF/LTAG-LCAF** production. **Carbon Capture Utilization and Storage (CCUS) is in use.**

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Fuels Scenario – F3

	MDG/FESG Baseline Integrated Scenario 0 (IS0)	Integrated Scenario	Integrated Scenario 3 (IS3)
General Description	Projection of current technologies available in base year (through fleet renewal). No additional improvements from tech, ops and fuels. No systemic change – e.g. infrastructure changes to accommodate growth only.	**Low / nominal** Current (c. 2021) expectation of available tech, ops efficiencies, f availability, costs. Includes expected policy enabler technology, ops and fuels. **Low systemic change** – no ***subst*** infrastructure changes.	**Aggressive / speculative** Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs. Assumes max policy enablers for tech, ops and fuels. **High, internationally aligned systemic change** e.g. significant and broad change to airport and energy infrastructure.
Fuels (F)	No emissions reductions from	**Low GHG reduction from Fuels** alternative jet fuels at blend leve Ground transportation and aviat playing field with respect to alter use. Low incentives for LTAG-SAF/LT production. Technology evolution **enables u** **(CO/CO_2) gases for LTAG-SAF, fe** **a variety of settings** (e.g., oilsee and **use of blue/green hydroger** SAF/LTAG-LCAF production.	**High GHG reduction from Fuels (LTAG-SAF, LTAG-LCAF and non-drop-in fuels)** % Synthesized Jet Fuel in existing aircraft and of 100% SAF in all existing and new aircraft. Economy-wide deep decarbonisation. Extensive electrification of ground transportation and widespread availability of renewable energy. Large incentives lead to widespread use of low GHG fuels for aviation. Technology evolution **enables widespread use of atmospheric CO2 for LTAG-SAF, further increases in feedstock availability, widespread use of CCUS**, and sufficient H2 exists to **enable use of cryogenic H2 use in aircraft**. Infrastructure developed to enable **use of non-drop-in fuels at airports** around globe

ASTM Intl develop methods to approve use of 100% Synthesized Jet Fuel in existing aircraft and engines without any modification. This enables use of 100% SAF in all existing and new aircraft.

Aggressive / speculative
Maximum possible effort: tech rollout, ops efficiencies, fuel availability, costs.
Assumes max policy enablers for tech, ops and fuels.
High, internationally aligned systemic change e.g. significant and broad change to airport and energy infrastructure.

High GHG reduction from Fuels (LTAG-SAF, LTAG-LCAF and non-drop-in fuels)

Economy-wide deep decarbonisation. Extensive electrification of ground transportation and widespread availability of renewable energy.

Large incentives lead to widespread use of low GHG fuels for aviation.

Technology evolution **enables widespread use of atmospheric CO2 for LTAG-SAF, further increases in feedstock availability, widespread use of CCUS**, and sufficient H2 exists to **enable use of cryogenic H2 use in aircraft**.

Infrastructure developed to enable **use of non-drop-in fuels at airports** around globe

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Fuels Analyses – LTAG-SAF-FTG

Category	Fuel Name	Suffix
LTAG-SAF	Biomass	-FTG
	Solid/liquid	
	Gaseous waste CO2	-CO2
	Atmospheric CO2	-DAC

LTAG-SAF-FTG lifecycle analysis relied on FTG work examining SAF production projections and associated GHG emissions reductions

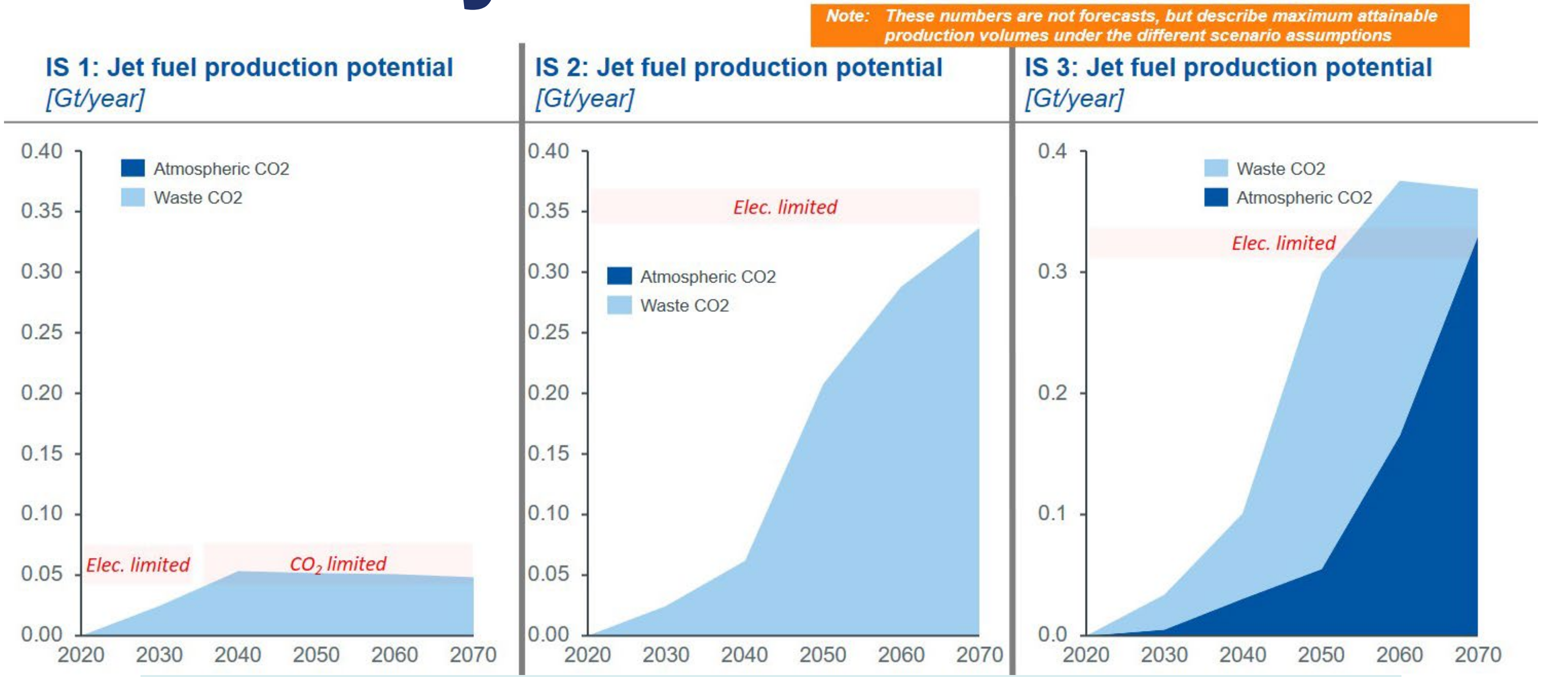
ICAO_LTAG_Report_AppendixM5_AttachmentA.pdf

Factor	F1 (2035/2050/2070)	F2 (2035/2050/2070)	F3 (2035/2050/2070)
cover crops	limited/moderate/moderate	moderate/high/total	high/high/total
green H2	limited/moderate/moderate	moderate/high/high	moderate/high/total
renewable electricity	limited/moderate/high	moderate/high/high	moderate/high/total
CCUS	no/limited/limited	limited/moderate/high	moderate/high/total
waste gases	limited/limited/moderate	moderate/moderate/high	moderate/high/total
atmospheric gases	no/no/no	no/no/no	limited/moderate/high

LTAG-SAF Lifecycle Value (biomass, solid/liquid waste based) [g CO_{2eq}/MJ_{SAF}]

Time	F1	F2	F3
2035	29.00	26.38	24.23
2050	30.91	26.55	24.67
2070	30.12	24.49	21.14

Fuels Analyses – LTAG-SAF-CO2



LTAG-SAF-CO2/DAC production and lifecycle analysis relied on ANL/MIT work to understand future resource availability and technology development

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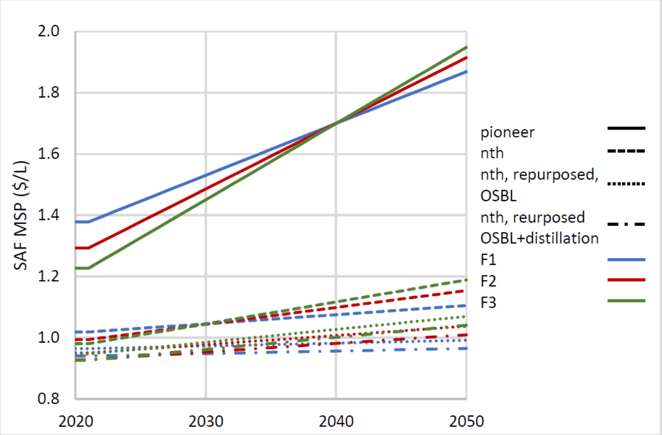
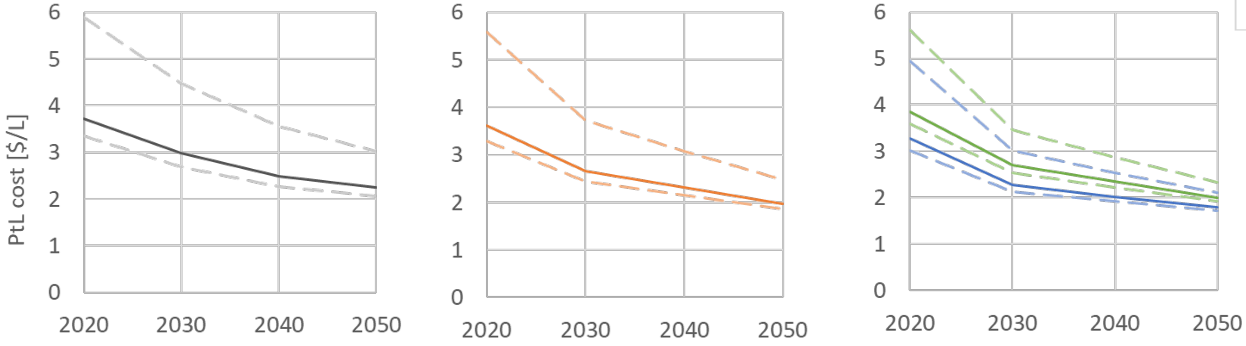
Fuels Analyses – Costs

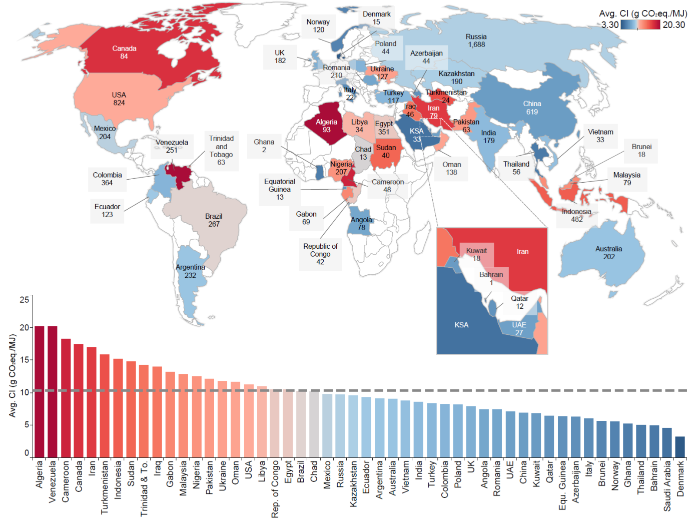
LTAG-SAF cost analyses varied depending on fuel category

- For existing fuel technologies, nth plant modeling reflects learning curve and economies of scale improvements over time
- For novel/ pioneer technologies, additional assumptions on technology improvements were reviewed with available literature



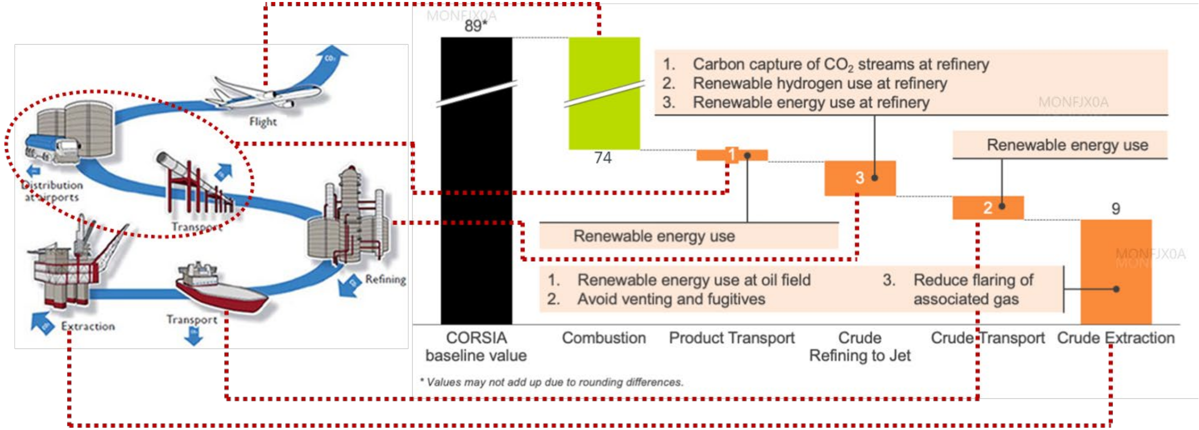


Fuels Analyses – LTAG-LCAF



Global Refinery Crude Intake Carbon Intensity

Jet Fuel Supply Chain & Carbon Intensity Mitigation Strategies



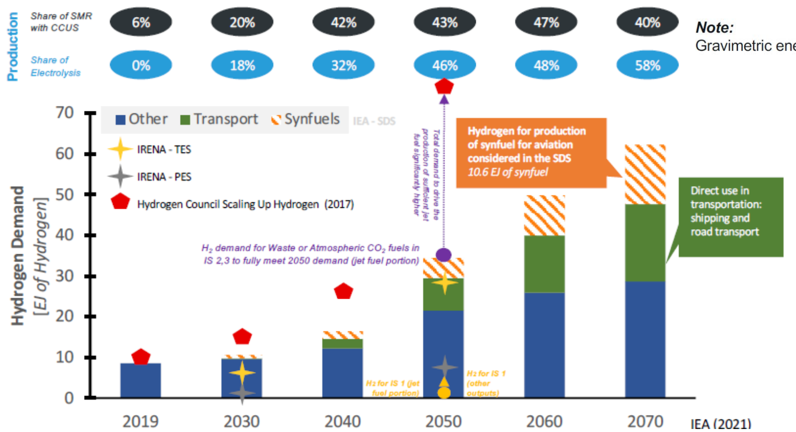
Fuels Analyses – H2

IEA Energy Technologies Perspectives (2020)
Sustainable Development Scenario (SDS): Required changes to the energy system and use to meet UN Sustainable Development Agenda goals (reach global net-zero CO_2 emissions by 2070)

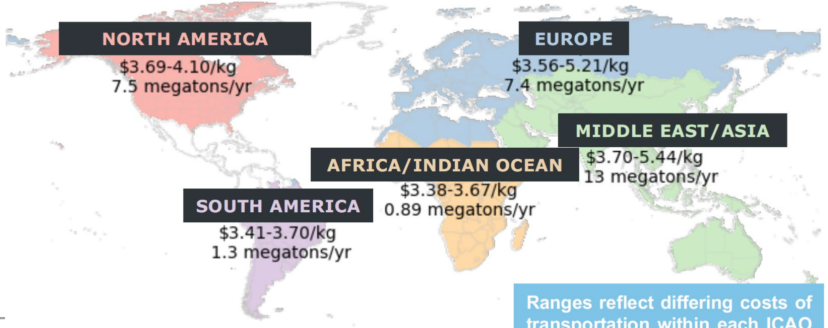
IRENA scenarios (blue and green hydrogen only)
Planned Energy Scenario (PES) based on current energy plans and other targets (as of 2019)
Transforming Energy Scenario (TES): ambitious scenario consistent with <2C warming

Hydrogen Council
Hydrogen forecast, Scale Up Hydrogen

Global Hydrogen Supply and Demand 2019 – 2070
IEA SDS, IRENA PES/TES, Hydrogen Council forecast



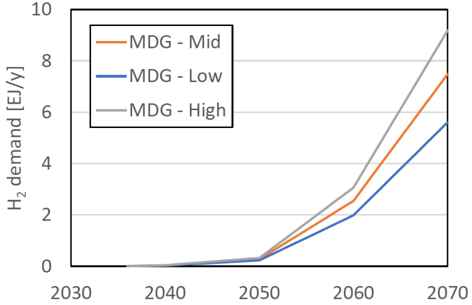
Cost of LH_2 at Airport



Ranges reflect differing costs of transportation within each ICAO Region from optimal electricity generation locations to airports

Note:
Gravimetric energy density of LH_2 ~3 times higher than Jet-A

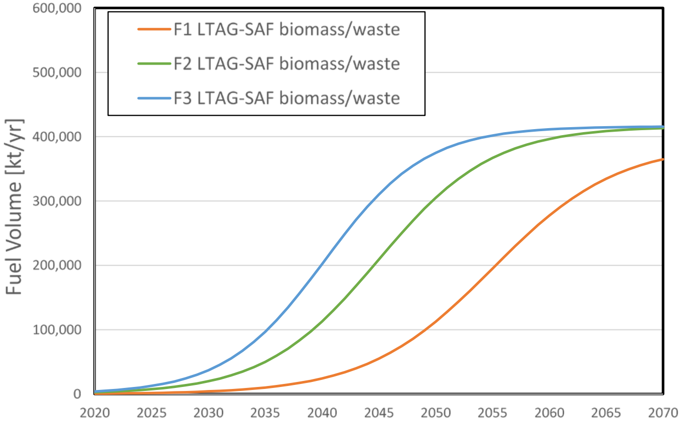
F3 H_2 demand for ACA-T3 aircraft

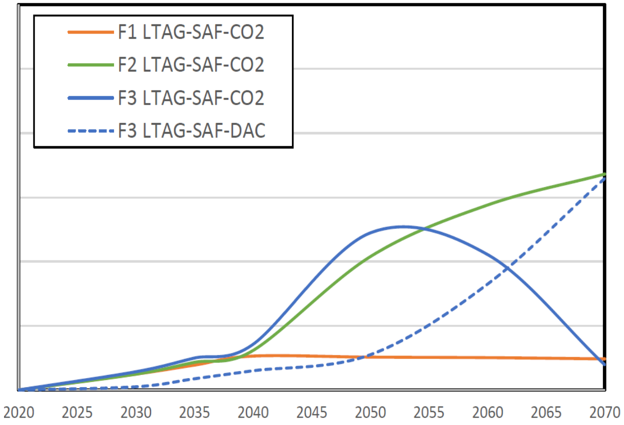


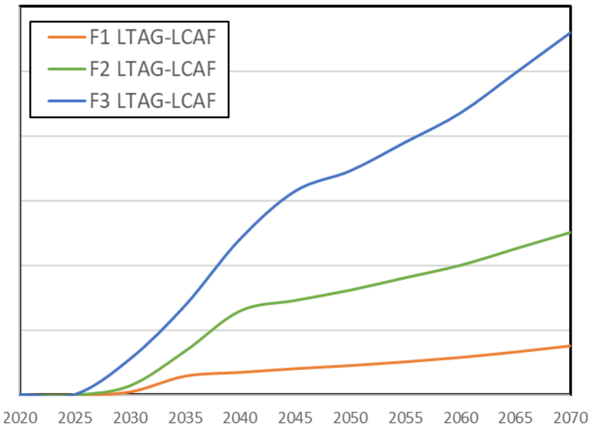
Source: "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions." International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

Unconstrained Scenarios

Drop-in Fuels







LTAG-SAF biomass/waste relied on FTG TPP group market diffusion modeling, extending analysis to 2070 with feedstock availability per CAEP/10 Fuel Production Assessment

LTAG-SAF waste/atmospheric CO2 relied on ANL/MIT resource availability and technology development

LTAG-LCAF relied on expert bottom-up and top-down analyses of possible integration of GHG mitigation technologies under the scenarios

Source: "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions." International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

Constrained Scenarios

Process

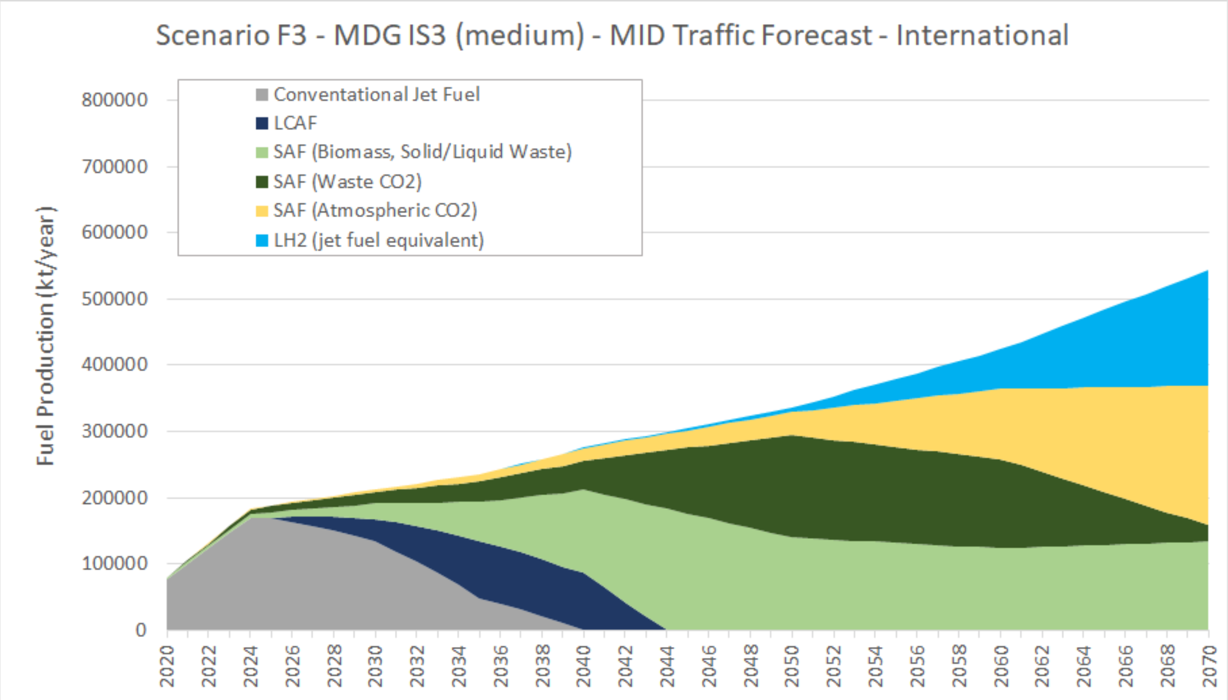
Category	Fuel Name	Suffix
LTAG-SAF	Biomass Solid/liquid	-FTG
	Gaseous waste CO2	-CO2
	Atmospheric CO2	-DAC
LTAG-LCAF	Lower carbon petroleum fuels	

Fuel Order per Scenario with Selection Criteria					
F1	MSP [$/L]	F2	Marginal Abatement Cost [$/kg $CO2e_{red}$]	F3	Lifecycle [gCO2e/MJ]
LTAG-LCAF	0.52	LTAG-SAF-FTG	<1	LTAG-SAF-DAC	8-13
LTAG-SAF-FTG	0.9-2	LTAG-LCAF	<1	LTAG-SAF-CO2	13-16
LTAG-SAF-CO2	~2.5	LTAG-SAF-CO2	4.3	LTAG-SAF-FTG	21-24
LTAG-SAF-DAC	N/A	LTAG-SAF-DAC	N/A	LTAG-LTAG-LCAF	80.1

Source: "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions." International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

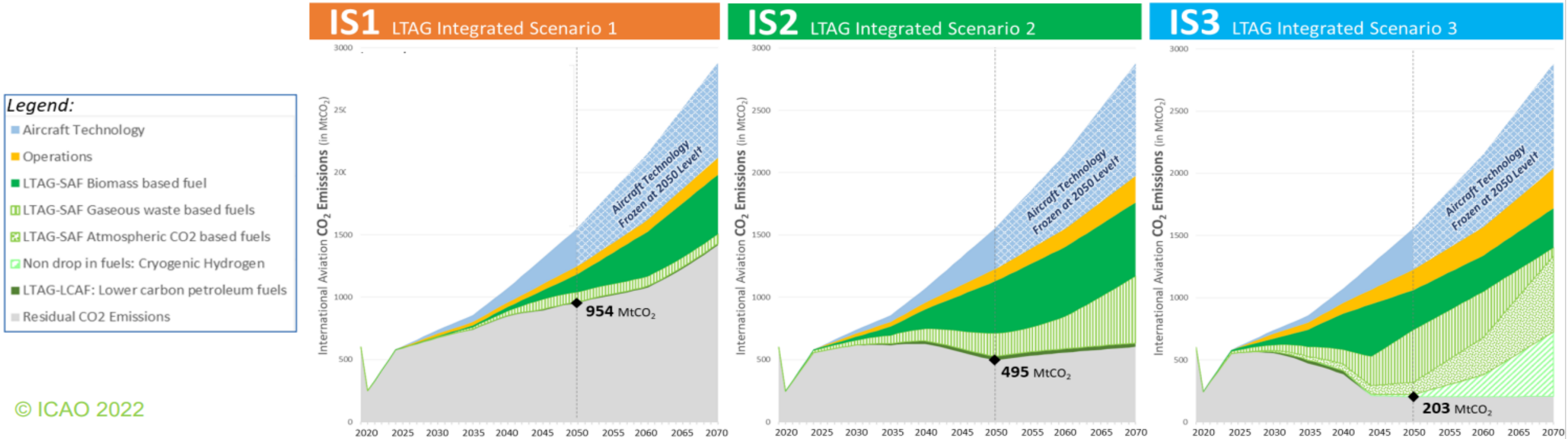
Constrained Scenarios

Results



Source: “Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation CO2 Emission Reductions.” International Civil Aviation Organization. March 2022. Available: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

High Level Results



Metrics	IS1	IS2	IS3
CO_2 Emissions in 2050 after Reductions	**≈950 $MtCO_2$** in 2050 *(**160%** of 2019 CO_2 emissions)*	**≈500 $MtCO_2$** in 2050 *(**80%** of 2019 CO_2 emissions)*	**≈200 $MtCO_2$** in 2050 *(**35%** of 2019 CO_2 emissions)*
Reduction in 2050 from the Baseline	**39% total** through: Technologies - 20%, Operations - 4%, Fuels - 15%	**68% total** through: Technologies - 21%, Operations - 6%, Fuels - 41%)	**87% total** through: Technologies - 21%, Operations - 11%, Fuels - 55%
Cumulative residual Emissions from 2020 to 2070	23 $GtCO_2$ (2020 to 2050) 23 $GtCO_2$ (2051 to 2070)	17 $GtCO_2$ (2020 to 2050) 11 $GtCO_2$ (2051 to 2070)	12 $GtCO_2$ (2020 to 2050) 4 $GtCO_2$ (2051 to 2070)

15

Key Takeaways

- Although scenarios show potential for **substantial CO_2 reductions**, **none achieve carbon neutrality by 2050** (only in-sector measures considered)
- **Drop-in fuel, particularly SAF, plays largest role in reducing CO_2** followed by aircraft technology and operations
- Obtaining these CO_2 reductions from SAF will require the **most significant investments of the three categories**

Path Forward

- **LTAG Task Group's final report has been published**
  - Full report is available to the public at: https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx
- This work represented a **bottom-up feasibility assessment of a long-term aspirational goal**
  - Many thanks to the ASCENT community for its contributions
- The top-down policy aspects of this decision, informed by the analysis, led to the **adoption of a Long Term Aspirational Goal for Net Zero CO2 Emissions at the recent 41st ICAO Assembly**