



INTERNATIONAL CIVIL AVIATION ORGANIZATION

A United Nations Specialized Agency

Committee on Aviation Environmental Protection (CAEP)

Analysis on the estimation of CO₂ emissions reductions and costs expected to result from CORSIA

February 2019

Note – The updated analysis in this document was undertaken by CAEP's Global Market-Based Measure Technical Task Force (GMTF) and was presented to CAEP at its Eleventh Meeting (Montréal, Canada, 4-15 February 2019)

Background

- **This paper provides updates on the supplemental GMTF Analysis on the Estimation of the Costs and CO₂ Reductions Expected to Result from CORSIA** (based on the Assembly A39-3 Resolution),
- **This paper provides an;**
 - **Update of the assessment of CO₂ emissions reductions (i.e., environmental benefits) and costs from offsetting requirements expected to result from the CORSIA based on the Assembly A39-3 Resolution (Task 1),**
 - **Assessment of the potential costs from the implementation of the CORSIA Monitoring, Reporting and Verification (MRV) system and Registries (Task 2).**

Caveats and Disclaimer

- This paper provides a summary of the results of the technical analyses requested by GMTF,
- Modeling techniques and assumptions are customized (fit for purpose) to support GMTF requested analyses,
- Analyses include forecasts (i.e., CAEP/10 CO₂ emissions forecast) and assumptions that may vary and could be refined as more information on the implementation of CORSIA become available.

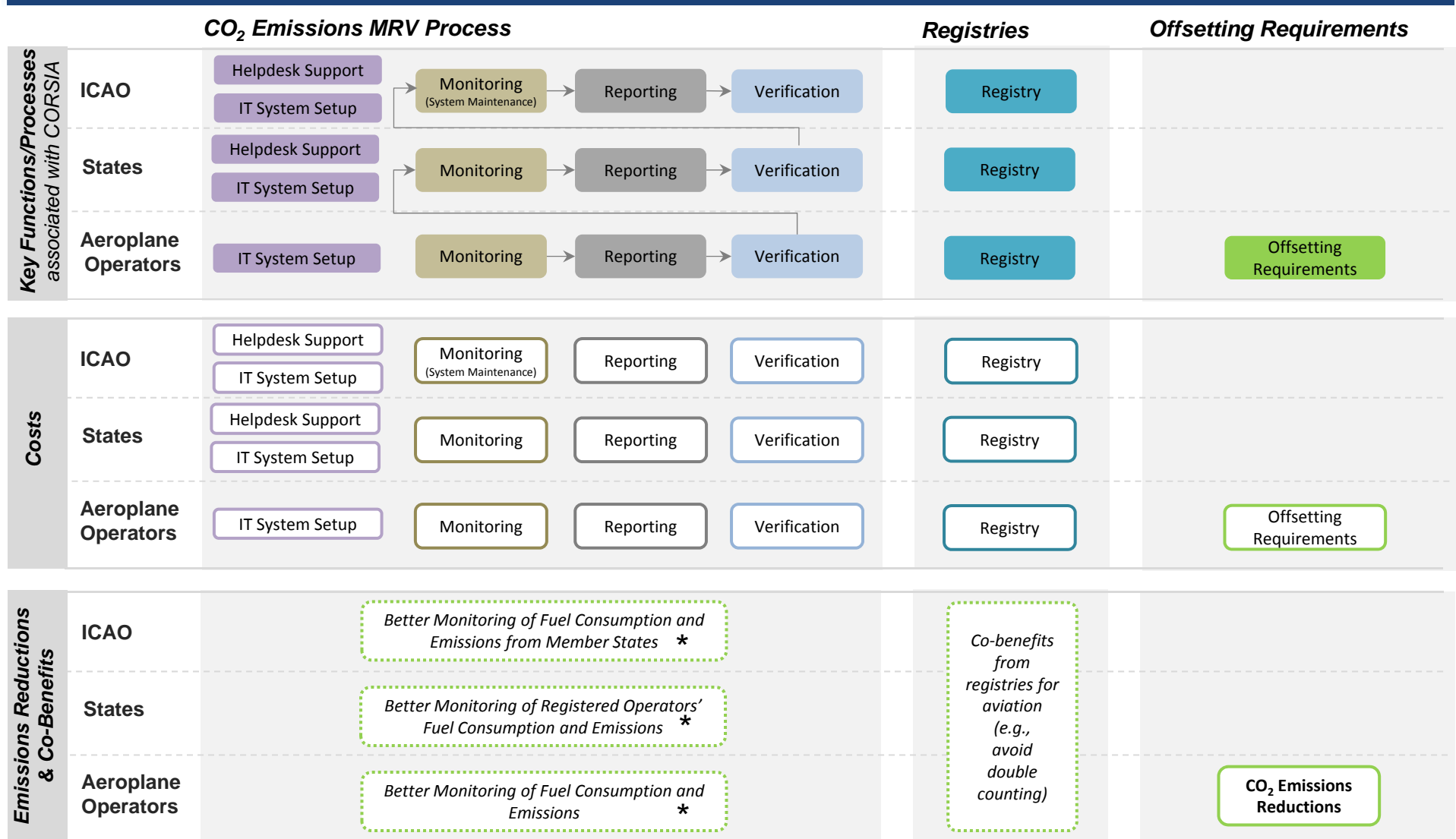
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- **High Level Approach for Estimating the Costs and CO₂ Reductions Expected to Result from CORSIA**
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Background

- **Mapped key functions and processes associated with the CORSIA to quantify and monetize the costs and emissions reductions as well as assess the non-quantified and non-monetized benefits and costs,**
- **Functions and processes relevant to the CORSIA include the CO₂ emissions Monitoring, Reporting and Verification (MRV) process that involves all three groups of stakeholders i.e.,**
 - **Aeroplane Operators,**
 - **States and**
 - **ICAO.**
- **All the functions are expected to results in compliance costs.**

Mapping of key functions and processes associated with CORSIA and identification of costs, emissions reductions and co-benefits



* Qualitative co-benefits (not quantified/assessed in this analysis)

Mapping of key functions and processes associated with CORSIA and identification of costs, emissions reductions and co-benefits (cont.)

- Functions associated with registries are also expected to result in implementation and compliance costs.
- Offsetting requirements and the resulting purchase/cancellation of Emissions Units is expected to result in:
 - (1) a cost to Aeroplane Operators resulting from the purchase/cancellation of Emissions Units and,
 - (2) a reduction in CO₂ emissions.
- MRV system for fuel consumption and CO₂ emissions can result in co-benefits for airlines such as better operational and performance data that can be used for operational, tactical and/or strategic planning. Co-benefits were considered qualitative and are not quantified (for the purpose of this analysis).

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Modelling Approach and Assumptions

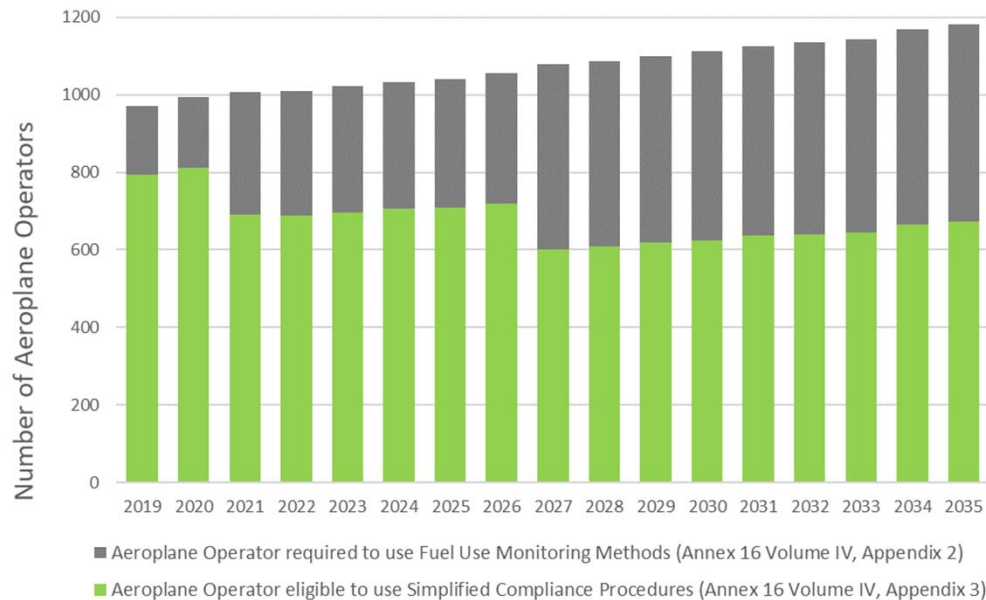
- **An MRV cost model -calibrated with relevant data- was developed to conduct a first order estimation of MRV and Registry costs.**
- **Modeling Approach:**
 - **Identify the scope of applicability of CORSIA i.e., the set of Aeroplane Operators that could be subject to MRV requirements (see Appendix),**
 - **Used a global aircraft registration database (with de-identified Aeroplane Operators) as a basis for the identification of Aeroplane Operators that could be subject to MRV requirements,**
 - **Assessed total expected cost of compliance with CORSIA between 2018 and 2035.**

Modelling Approach and Assumptions

- **Collected and developed assumptions for unit costs for Monitoring, Reporting, Verification and Registries for small and large Aeroplane Operators.**
- **Collected data from a number of sources including, but not limited to;**
 - **First order estimates based on GMTF MRV papers and processes,**
 - **Background research e.g., report from PwC cost of compliance with EU ETS ,**
 - **Input and feedback (i.e., possible review of initial assumptions) from Aeroplane Operators and aeroplane operator associations that are members of the GMTF,**
 - **Input and feedback from States participating in the GMTF,**
 - **Input and initial assumptions from ICAO.**

Background Statistics on Aeroplane Operators and States subject to Scope of Applicability of Annex 16 Volume IV

- Number of Aeroplane Operators subject to requirements of Annex 16 Volume IV scope of applicability ranges from approximately 960 to 1,100 in 2019 and 2035 respectively.
- Some Aeroplane Operators will be eligible to use Simplified Compliance Procedures.



- Approximately 150 States are expected to administer Aeroplane Operators subject to the requirements of Annex 16 Volume IV.

Assumptions for MRV and Registry Cost Model * for Aeroplane Operators and States

		Aeroplane Operators Eligible to Use Simplified Procedures				Aeroplane Operators (not eligible to use Simplified Compliance Procedures)			Units	References & Notes	
		Low	Mid	High		Low	Mid	High			
NRC**	IT System Setup	\$0	\$500	\$1,000		\$5,000	\$252,000	\$500,000	at implementation	Input from airlines and based on GMTF CERT functionality	
Recurring Costs	Aeroplane Operators	Monitoring (fixed)	\$1,000	\$1,500	\$1,650		\$2,000	\$6,000	\$10,000	per year	Estimated MRV costs for small emitters from EU ETS (Ref: PwC Report, Page 25)
		Monitoring (variable)	\$0	\$125	\$250		\$0	\$250	\$500	per aircraft per year	Ref: PwC Report, Page 20, 25 w/ airlines' input
		Verification***	\$2,500	\$7,600	\$12,500		\$5,900	\$17,700	\$29,400	per operator per year	Airlines' input and analyses from GMTF/13-WP/13.
		Reporting	\$1,055	\$2,205	\$3,355		\$1,500	\$3,250	\$5,000	per operator per year	
		Registry Costs				\$550				per operator per year	Registration costs for small and large emitters are similar, Ref: PwC Report, Page 20 (Subject to change for GMTF purposes pending GMTF/11 recommendations)
Recurring Costs	States	Monitoring Plans	\$1,000	\$1,700	\$2,400		\$2,000	\$2,600	\$3,200	per operator per year	PwC Report, Pg. 19 – 25
		Verification	\$1,500	\$2,300	\$3,100		\$2,500	\$3,750	\$5,000	per operator per year	PwC Report, Pg. 19 – 25
		Helpdesk Function	\$1,625	\$2,600	\$3,575		\$2,925	\$4,128	\$5,330	per operator per year	PwC Report, Pg. 19 – 25
							Low	Mid	High		
		Registry handling					10%	10%	10%	(of total cost to State) per year	Ref: PwC Report, Page 20
		Reporting					\$2,000	\$6,000	\$10,000	per year	
NRC**	IT System Setup					\$5,000	\$252,000	\$500,000	at implementation		

* First order estimates, subject to change as recommendations on design and implementation of CORSIA and CCR are finalized.

** NRC: Non-Recurring Cost.

*** Range of estimates for aeroplane operators not eligible to use simplified compliance procedures based on experience and input from airlines. Estimates for eligible operators based on this range and scaled down based on assumptions and recommendations from GMTF (i.e., GMTF/13-WP/13).

Assumptions for MRV and Registry Cost Model* (cont.) for ICAO

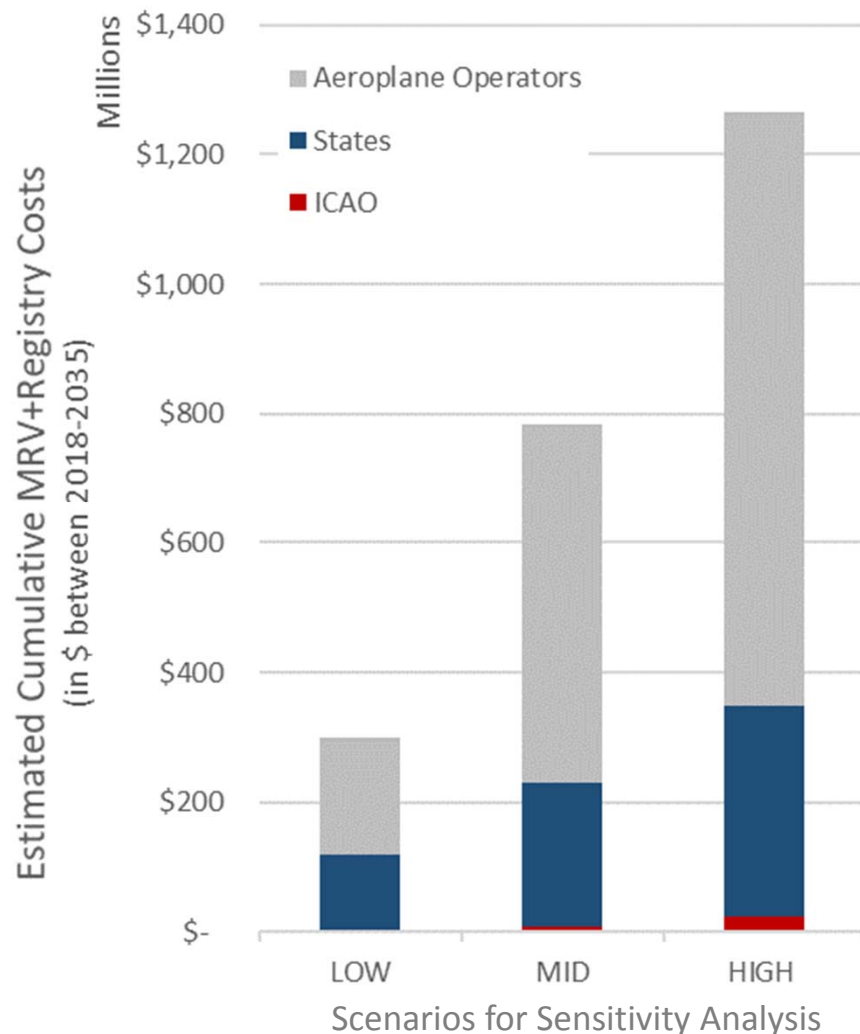
		2017-2019**			2020-2022 (and cycles through 2035)				Notes / Caveats
		Low	Mid	High	Low	Mid	High		
ICAO	CCR Development and Implementation***	\$100,000	\$1,000,000	\$5,000,000	\$100,000	\$1,000,000	\$2,000,000		Development, software licenses, and hosting. Potential cost for 2020-2022 onward could vary significantly based on variable operational cost and recommendations on additional features from CAEP and/or Council.
	External Reporting	NA	NA	NA	\$3,000	\$30,000	\$100,000	per triennium*	
	Data Integrity checks	\$1,000	\$10,000	\$100,000	\$3,000	\$30,000	\$300,000	per triennium*	Assume checks will start in 2019. Level will depend on the defined role of ICAO and the level of data being submitted (e.g., aggregated at a State level; aggregated at a route level; or per flight per AO).
	System Maintenance	\$50,000	\$100,000	\$250,000	\$100,000	\$250,000	\$500,000	per triennium*	Maintenance greatly depends on the type and complexity of the system chosen and IT platform.
	Helpdesk Function & Training	\$50,000	\$100,000	\$200,000	\$100,000	\$200,000	\$400,000	per triennium*	Assume operationalization in 2019 and that costs are higher at the end of a reporting period (i.e., low volume through much of the year with higher volume at the end of the year or reporting period).

* First order estimates, subject to change as recommendations on design and implementation of CORSIA and CCR are finalized.

** ICAO related estimated costs are presented per triennium in order to reflect ICAO budgeting cycles. Costs to States and Aeroplane Operators are presented on per year basis for simplicity.

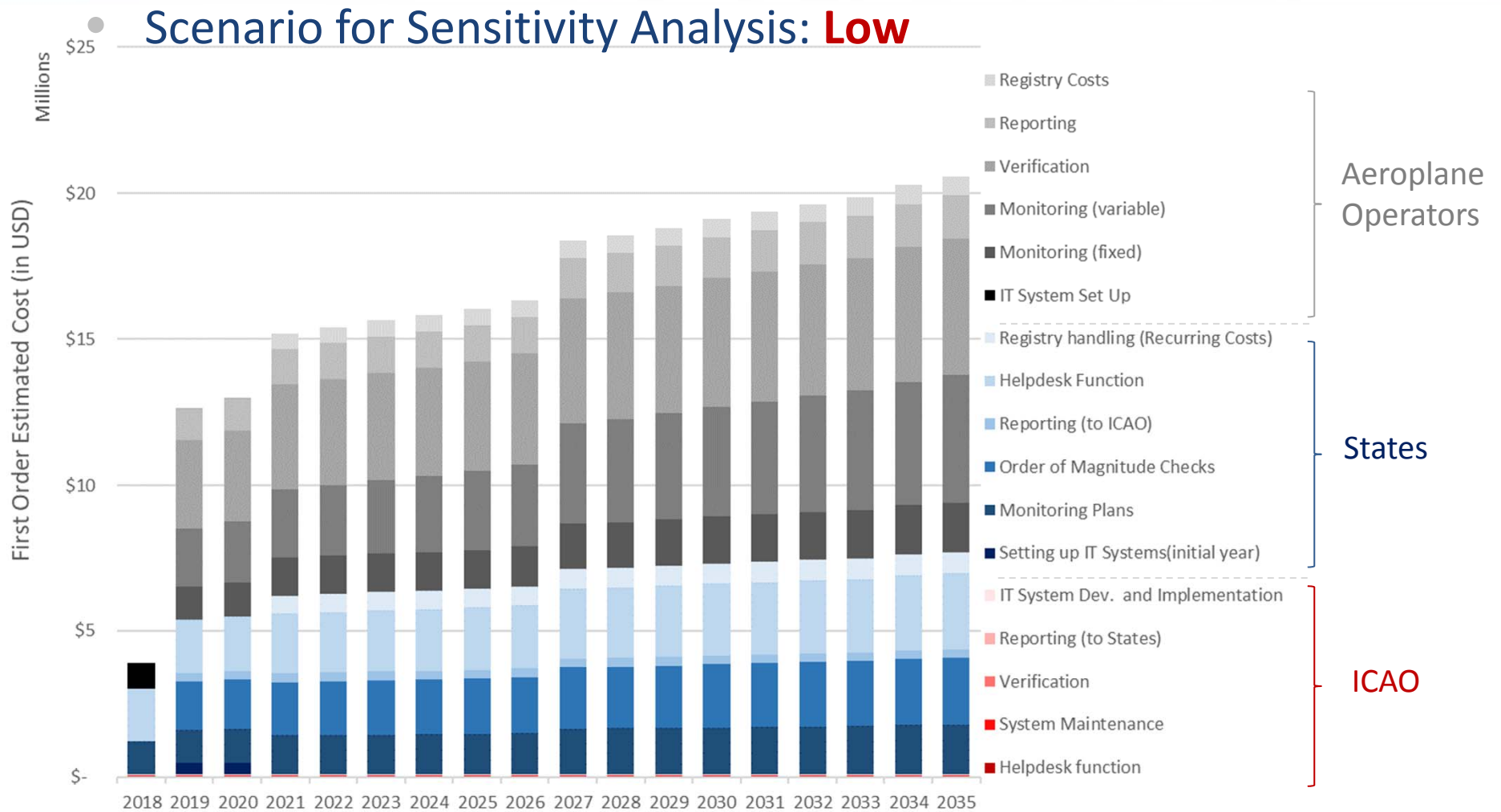
*** Estimates are considered first order estimates based on analyses from 2017 not necessarily reflective of actual/final cost of the developing and implementing the CCR. Actual costs will be based on outcome of the tendering process.

Estimated MRV and Registry Costs for ICAO, States and Aeroplane Operators

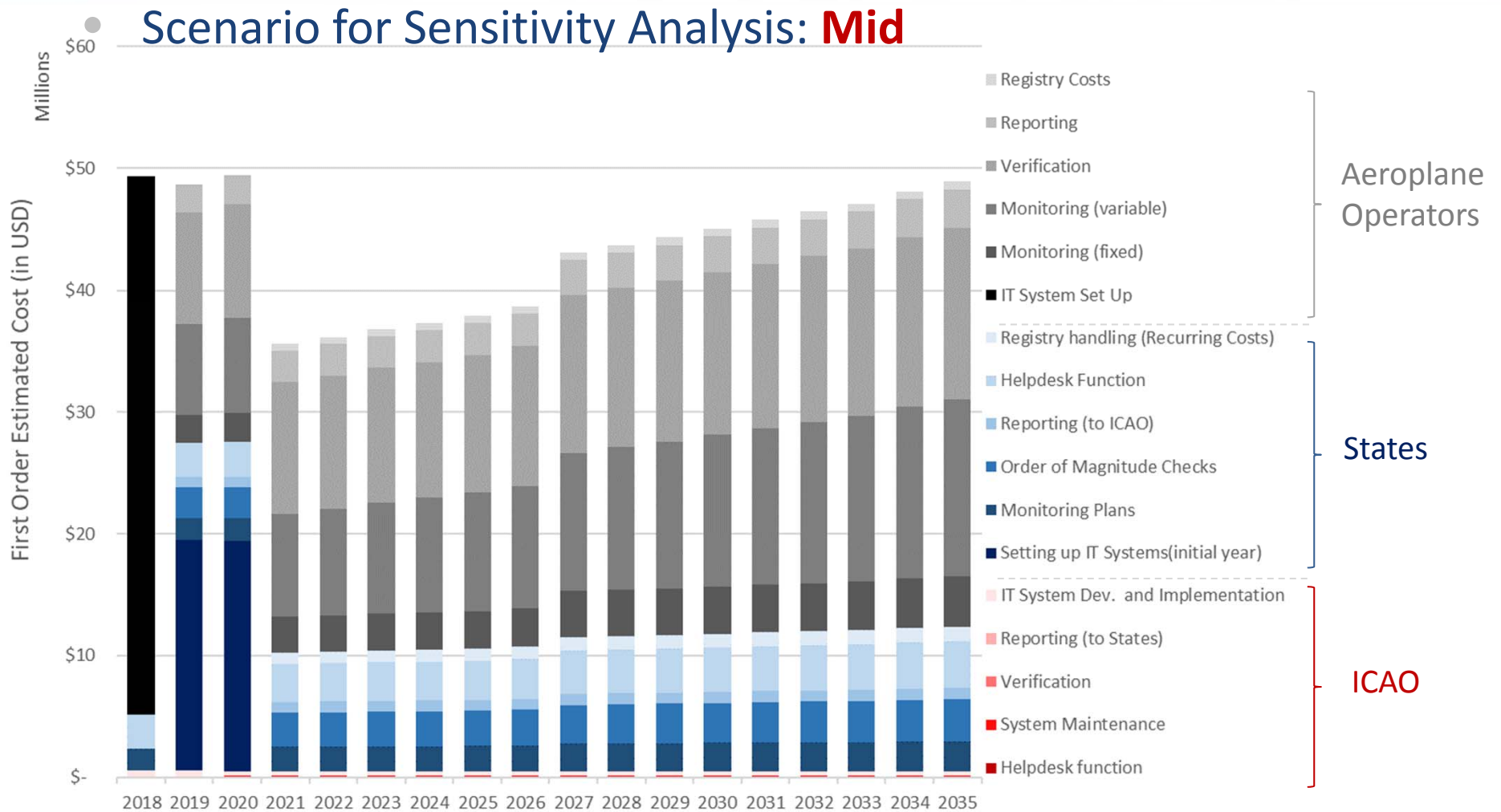


- Total costs for ICAO, States and Aeroplane Operators were estimated using the MRV+R cost model.
- Total MRV and Registry Costs for all Aeroplane Operators, States and ICAO could be approximately \$800 million USD from 2018-2035 (with a range from \$300 million to \$1.3 billion).

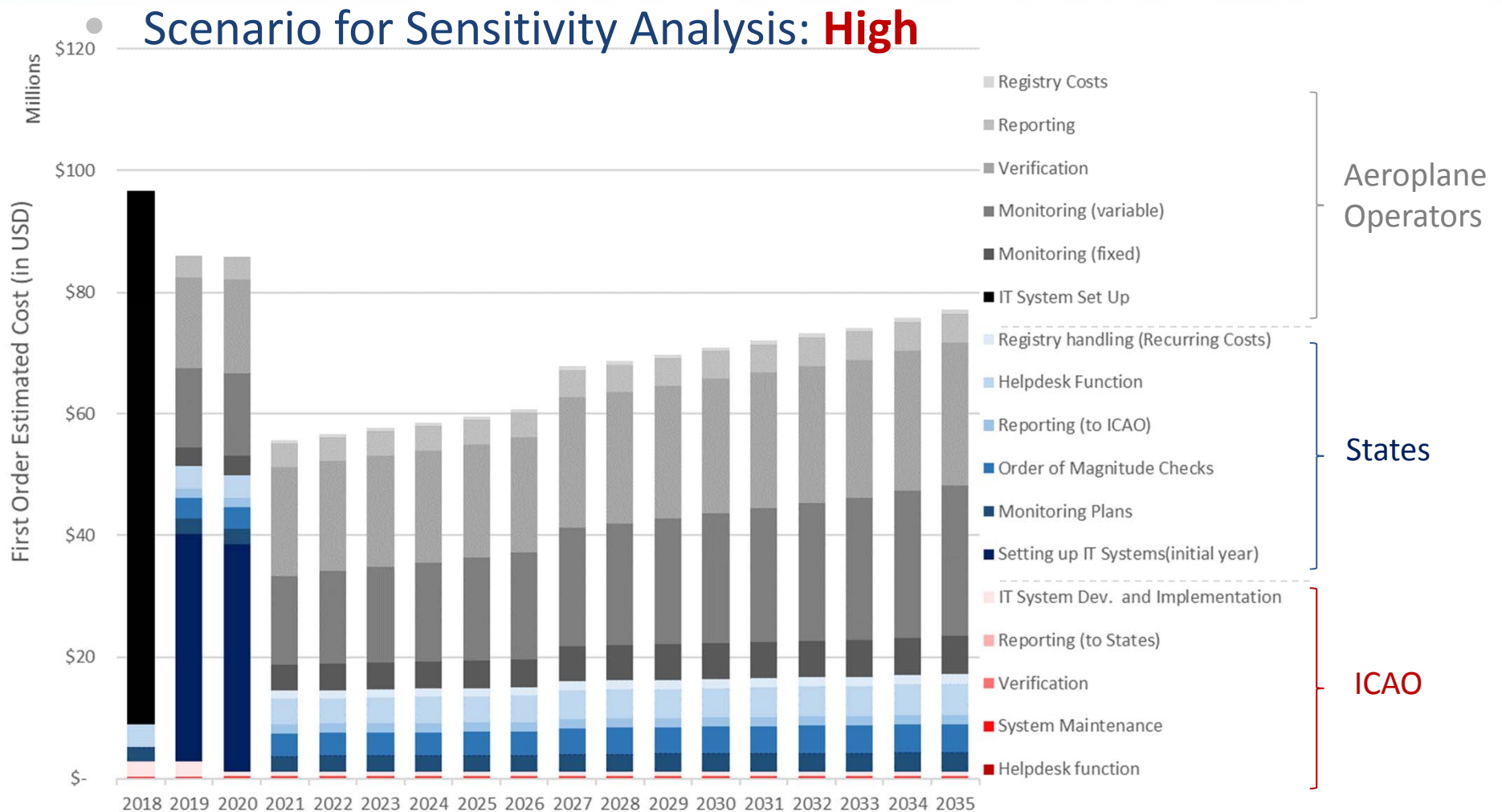
Evolution of Estimated MRV and Registry Costs for ICAO, States and Operators (2018-2035)



Evolution of Estimated MRV and Registry Costs for ICAO, States and Operators (2018-2035)

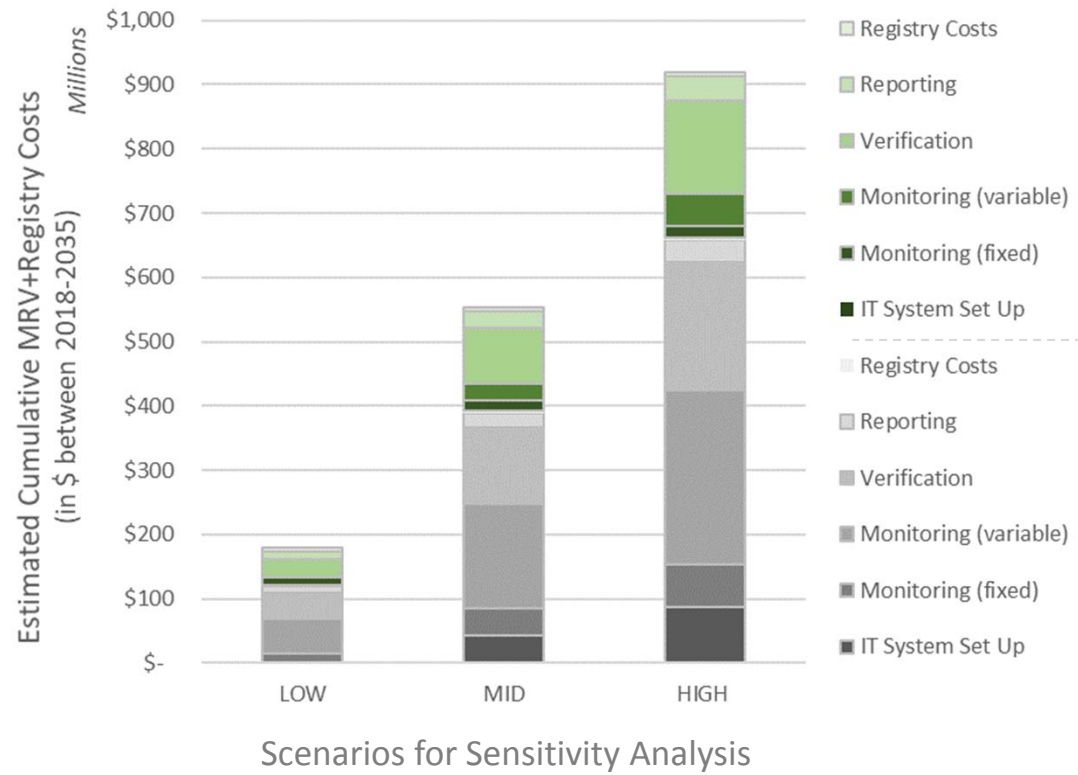


Evolution of Estimated MRV and Registry Costs for ICAO, States and Operators (2018-2035)



Estimated MRV and Registry Costs for Aeroplane Operators (by type of compliance procedures)

- Mid- and large-size Aeroplane Operators (not eligible to use simplified procedures) account for approximately 70% of total MRV and Registry Costs. AOs eligible to use simplified procedures account for the remaining 30%.
- Verification, Reporting and Monitoring are dominant costs for mid- and large-size AOs.
- Verification is the dominant cost for AOs eligible to use simplified procedures.



AOs eligible to use simplified procedures

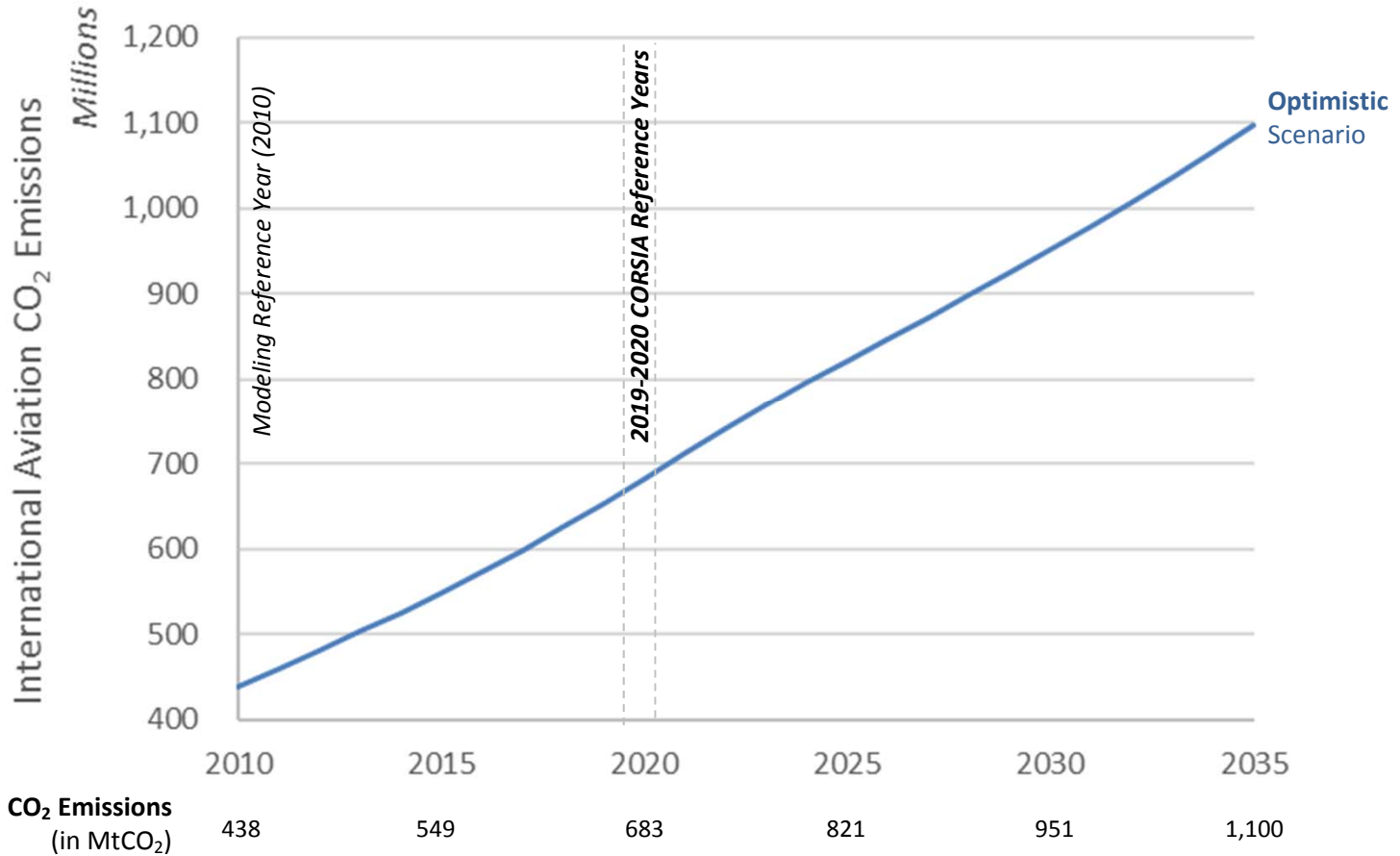
Mid- and large-size AOs (not eligible to use simplified procedures).

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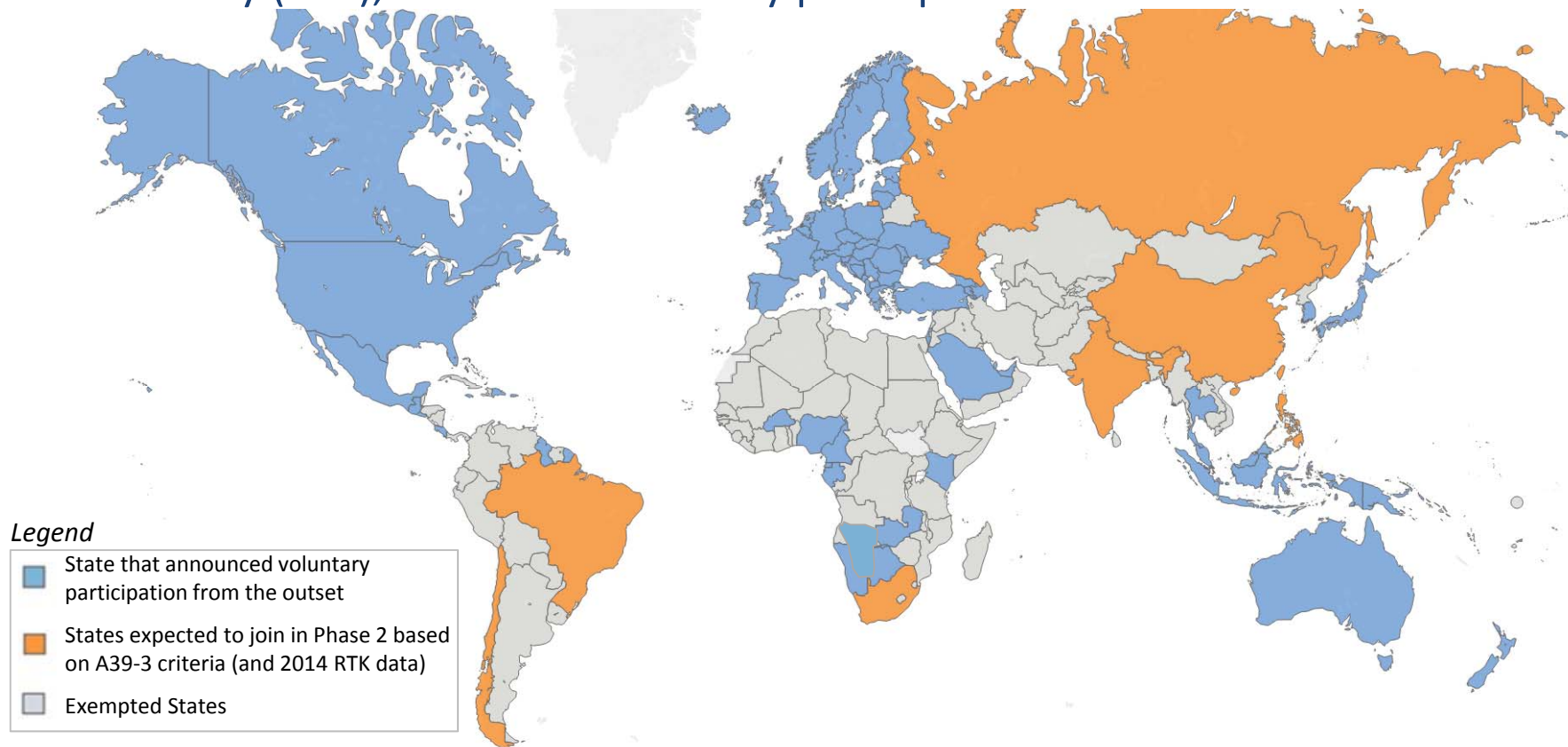
Global CO₂ Emissions from International Aviation

- International aviation CO₂ emissions between 2010 and 2035.



Phase In of States for Route Based Phased Implementation of CORSIA

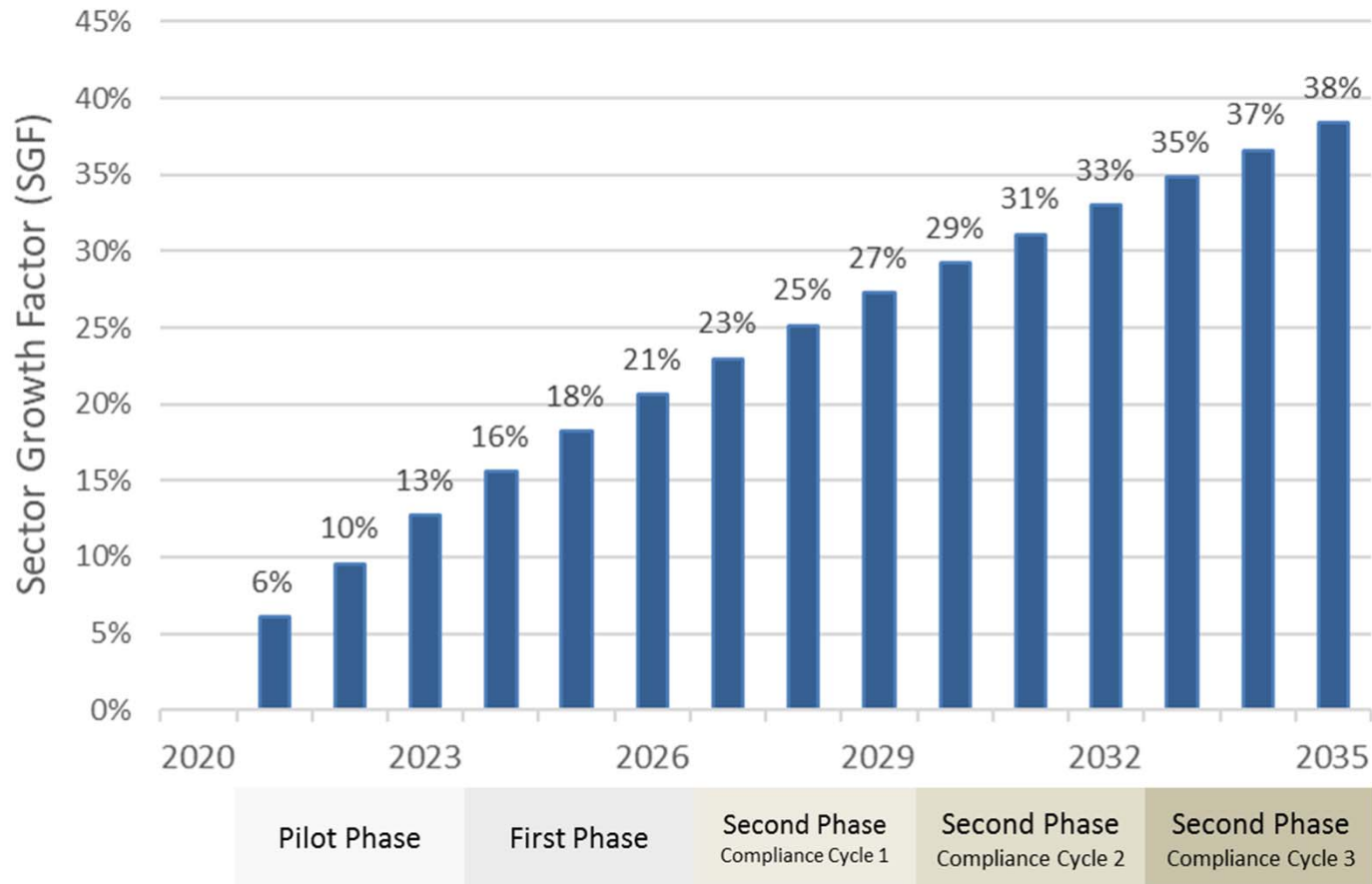
- As of 5 November 2018, 76 States, representing 75.96% of international aviation activity (RTK), intend to voluntarily participate in CORSIA from its outset.



Reference: ICAO, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), available at; <https://www.icao.int/environmental-protection/CORSIA/Pages/state-pairs.aspx>, last retrieved: 9 November 2018.

Estimated Sector Growth Factor (SGF) from 2021-2035

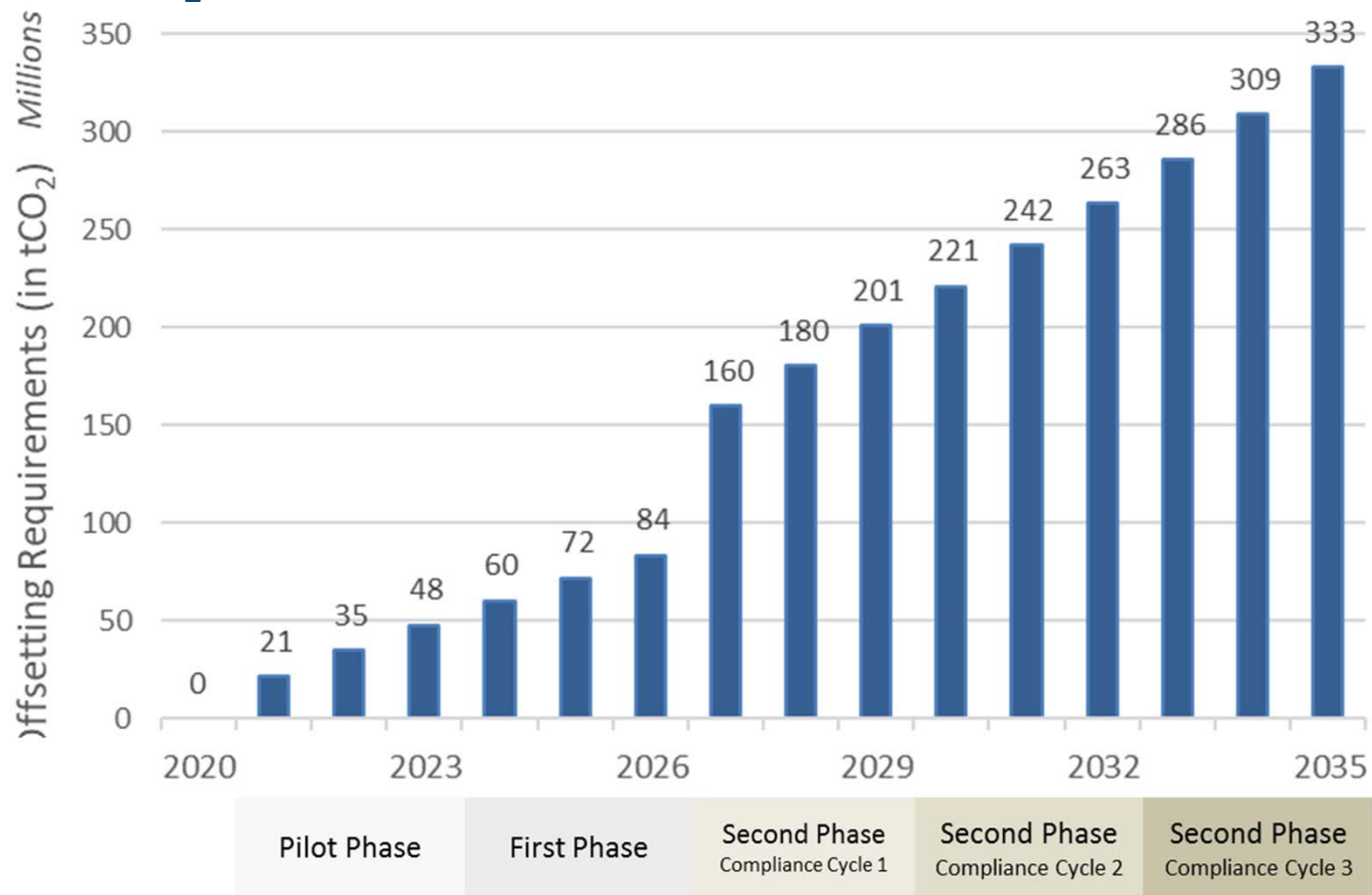
- Estimated Sector Growth Factor (SGF) from 2021 and 2035*.



* Note: Baseline emissions i.e., Average of annual sectoral CO₂ emissions between 2019 and 2020 covered by Annex 16 Volume IV, Chapter 3, 3.1 in the given year y (SEB,y) estimated at approximately 340 MtCO₂ from 2021-2026 and 540 MtCO₂ from 2027-2035.

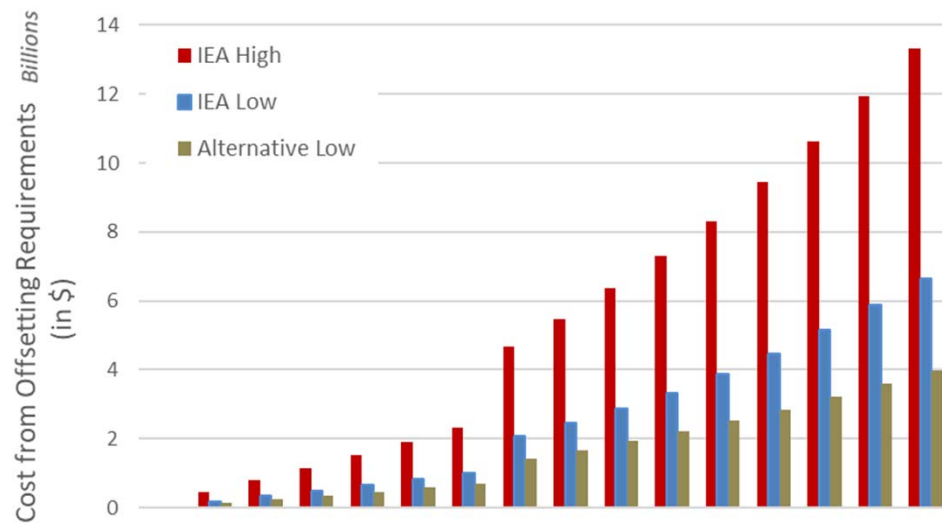
Quantities of Offsetting Requirements from 2021-2035 in tCO₂

- Total offsetting requirements are estimated to approximately 2.5 billion tonnes of CO₂ from 2021 and 2035.



Cost from Offsetting Requirements Resulting from Range of Scenarios

- Estimated cost from offsetting requirements based on CO₂ emissions to offset under CORSIA.
- Factoring high, low and alternative low forecasts of unit cost of carbon, the total cost from offsetting requirements between 2021 and 2035 were computed.



IEA WEO 2013 carbon price paths reflect allowance prices only.

The alternative low carbon price path takes into account a larger pool of emissions units with lower abatement costs.

Carbon Price Assumptions:

IEA High	20 \$/ton	33 \$/ton	40 \$/ton
IEA Low	8 \$/ton	15 \$/ton	20 \$/ton
Alternative Low*	6 \$/ton	10 \$/ton	12 \$/ton

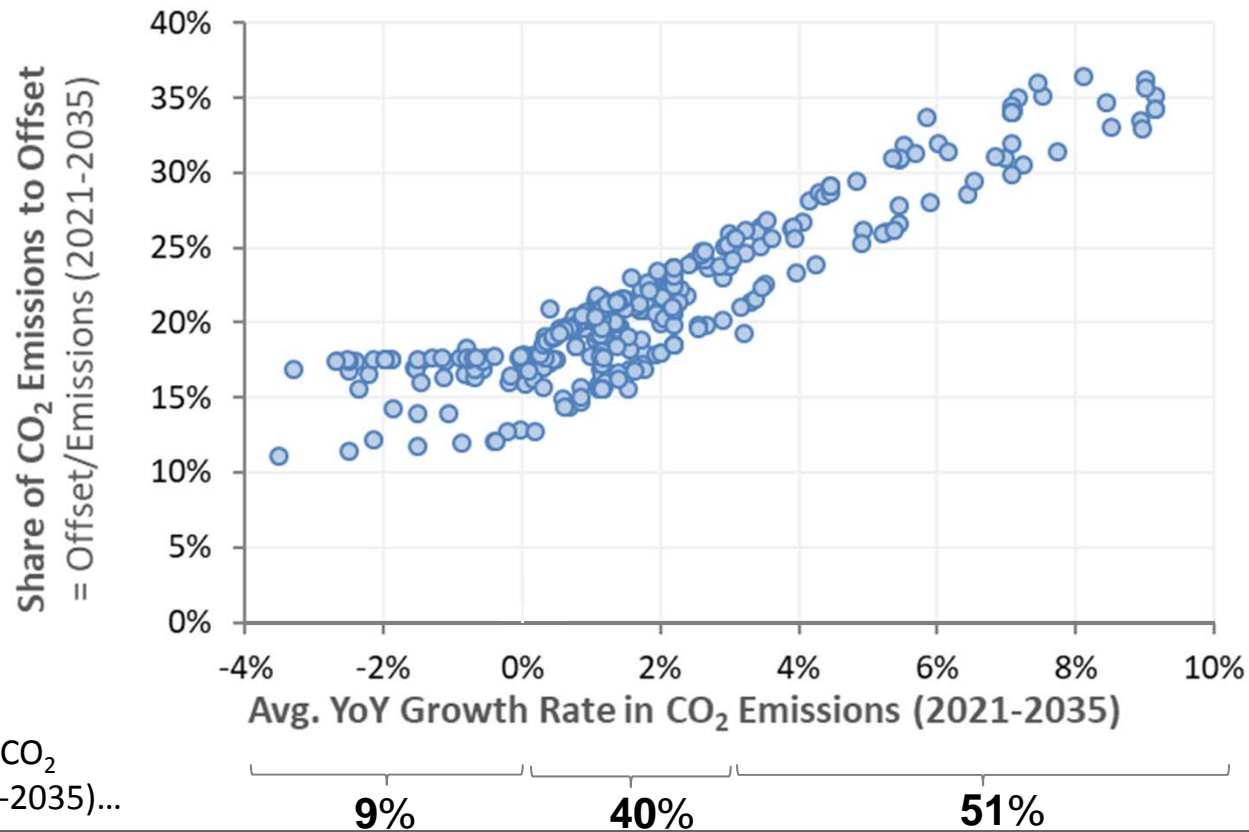
* Alternative low carbon price case

Distribution of Offsetting Requirements by Aeroplane Operators

- Distribution in share of CO₂ emissions to offset for various types of Aeroplane Operators (from slow to fast growing AOs)

Share of CO₂ Emissions to Offset by Aeroplane Operator (Cumulative 2021-2035):

Note: Each dot represents one Aeroplane Operator



Percent of Total CO₂
Emissions (2021-2035)...

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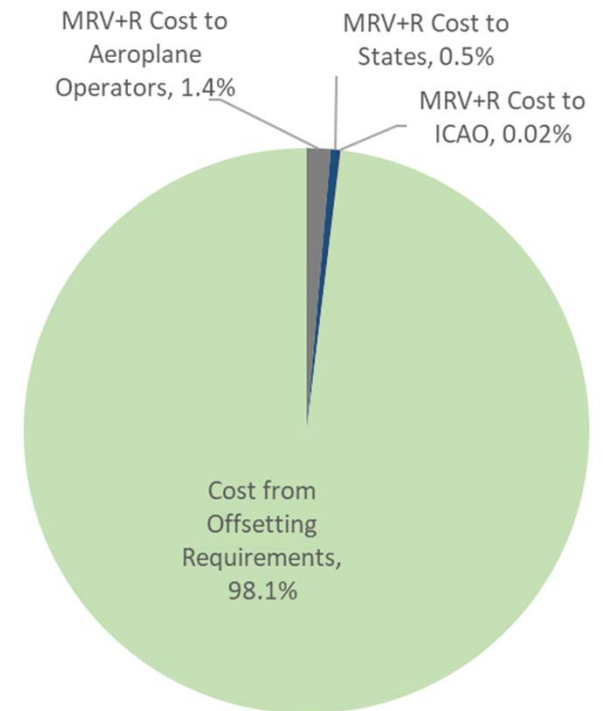
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Total Costs Expected to Result from CORSIA

- The vast majority of the total cost resulting from CORSIA is comprised of costs from offsetting requirements (i.e., 98.1%),
- MRV and Registry costs represent 1.4%, 0.5%, and 0.02% for Aeroplane Operators, States and ICAO respectively.
- Note: As observed and presented in several reports, the costs associated from CORSIA are expected to be manageable;
 - ICAO CAEP report*: “To put the total cost of offset obligations into context, the estimated costs could range from approximately 0.4% to 1.4% of total ICAO forecast revenues from international aviation in 2035.”
 - IATA paper (A39-WP/153).

* Reference: ICAO, CAEP-SG/20161-WP/16, Report on Assessment of Mechanisms for Distributing Offset Obligations in a Global Market-Based Measure (GMBM) for International Aviation prepared for the ICAO Environment Advisory Group (2014/2016).

Distribution of Costs Expected to Result from CORSIA (i.e., Offsetting Requirements, MRV and Registry Systems to AOs, States, and ICAO)



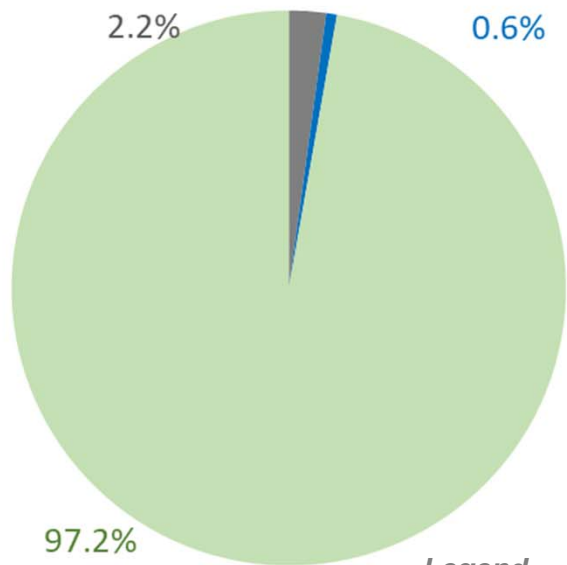
* Assumption: Costs from Offsetting Requirements and MRV+R based on Mid Scenarios

Distribution of Costs Expected to Result from CORSIA

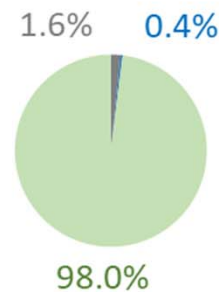
by groups of States according to Entry Phase into CORSIA i.e., Annex 16 Volume IV Chapter 3 Applicability

- Costs from Offsetting Requirements vs. Costs* from MRV+R are not uniformly distributed.

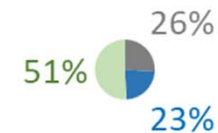
States that announced voluntary participation on the outset



States expected to join in Phase 2 based on A39-3 criteria (and 2014 RTK data)



States to and from which State pairs are not subject to Offsetting Requirements**



Legend

- Cost from MRV+R to Aeroplane Operators Registered in the State (2018-2035)
- Cost from MRV+R to States (2018-2035)
- Cost from Aeroplane Operators' Offset Requirements (2021-2035)

Note: Bubble size proportional to total cost from all AOs and States within category

** Note: Results split between States with Aeroplane Operators with and without Offsetting Requirements shown on next slide.

* For the purpose of analysis, data is reported by State. Data include; (1) MRV+R costs to Aeroplane Operators registered in the State, (2) MRV+R costs to the States, and (3) cost from offsetting requirements from Aeroplane Operators registered in the State.

Distribution of Costs Expected to Result from CORSIA

by groups of States according to Entry Phase into CORSIA i.e., Annex 16 Volume IV Chapter 3 Applicability (cont.)

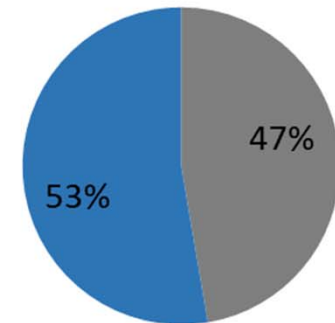
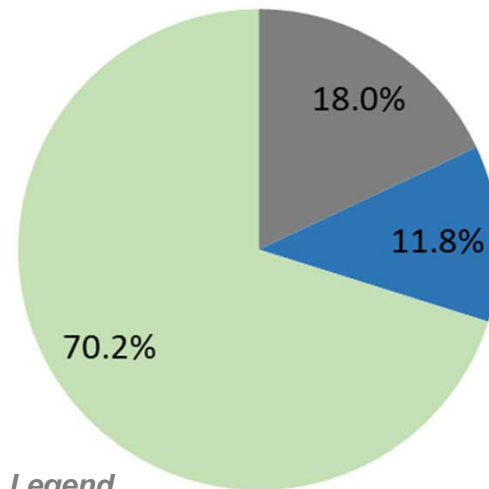
- Costs from Offsetting Requirements vs. Costs* from MRV+R are not uniformly distributed.

- Where Aeroplane Operators only fly on State pairs not subject to offsetting requirements, the Aeroplane Operators and their State of registration will only experience MRV related costs i.e., no offsetting requirements.

States to and from which State pairs are not subject to Offsetting Requirements

States with (one or more) Aeroplane Operators flying on State pairs subject to offsetting requirements

States with Aeroplane Operators NOT flying on State pairs subject to offsetting requirements



Legend

- Cost from MRV+R to Aeroplane Operators Registered in the State (2018-2035)
- Cost from MRV+R to States (2018-2035)
- Cost from Aeroplane Operators' Offset Requirements (2021-2035)

Note: Bubble size proportional to total cost from all States within category

* For the purpose of analysis, data is reported by State. Data include; (1) MRV+R costs to Aeroplane Operators registered in the State, (2) MRV+R costs to the States, and (3) cost from offsetting requirements from Aeroplane Operators registered in the State.

Summary of Observations

- Based on estimations of CO₂ reductions and Costs expected to result from CORSIA to Aeroplane Operators, States and ICAO, it is observed that;
 - The total offsetting requirements are estimated to be approximately 2.5 billion tonnes of CO₂ from 2021 and 2035,
 - The vast majority of the total cost resulting from CORSIA is comprised of costs from offsetting requirements (i.e., 98%). These costs represent a small fraction of total operating costs or revenue from international aviation,
 - MRV and Registry costs are borne by Aeroplane Operators, Member States and ICAO at 1.4%, 0.5%, and 0.02% of total cost from CORSIA respectively,
 - Comparison of costs from offsetting requirements vs. costs from MRV+R show non-uniform distribution of costs across categories of States.

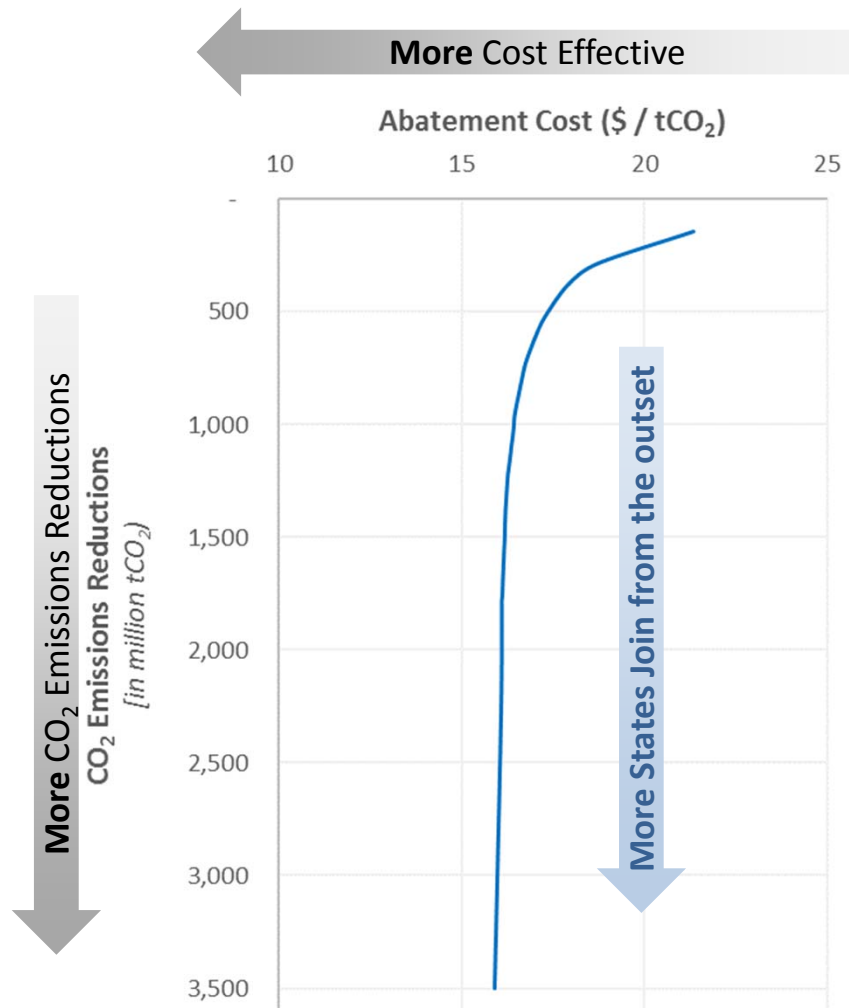
Cost Effectiveness Analysis

- A cost effectiveness analysis was conducted by combining total cost resulting from the policy (i.e., cost of compliance with MRV and registry requirements and cost from offsetting requirements) and comparing it to the policy outcome (i.e., reduction in CO₂ emissions for the international aviation sector).
- Ratio of total cost divided by reductions in CO₂ emissions measured in \$ / tCO₂ -also referred to as abatement cost- is the key metric for evaluating the cost effectiveness of policy alternatives.

Summary of Observations from Cost Effectiveness Analysis

- The more States join CORSIA from the outset*, the more cost effective CORSIA becomes i.e., lowest abatement cost and largest reductions in CO₂ emissions.

* through voluntary participation starting with the pilot phase.

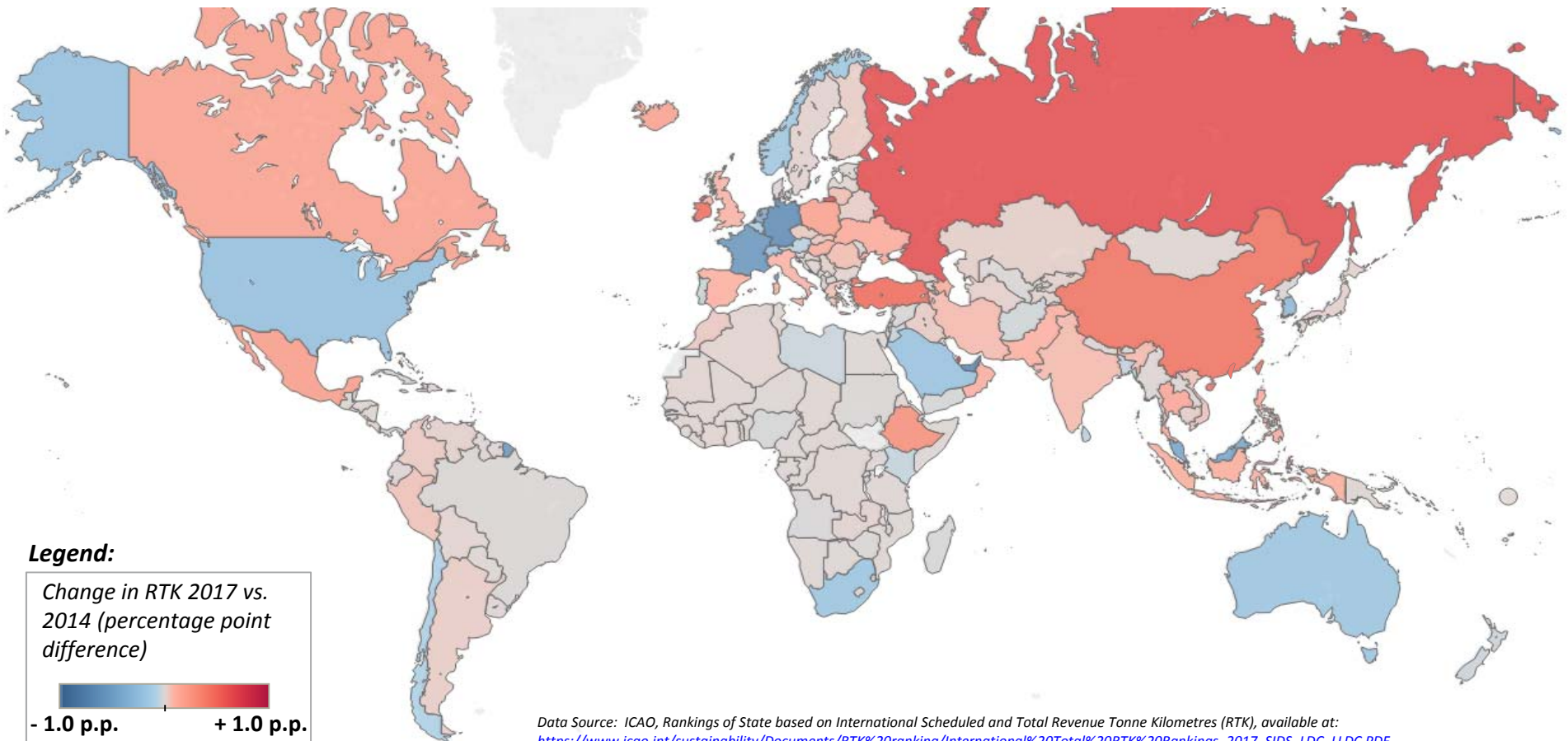


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Sensitivity Analysis Based on Recently Released 2017 RTK Data

- Percent of Total Revenue Tonne Kilometres (RTK) has changed slightly across States between 2014 and 2017.



Sensitivity Analysis Based on Newly Released 2017 RTK Data (cont.)

- For the majority of the States, the change in RTK between 2014 and 2017 does not change the Phase during which the State joins CORSIA for the purpose of Chapter 3 State Pairs (if it has not announced voluntary participation).
- A few States could be affected by the change in RTK Share. For example, using the 2017 RTK data to define the phased implementation of CORSIA (i.e., two States becoming Exempted) could reduce total offsetting requirements from 2021-2035 by approx. 1.5%.
- Note. – According the Assembly Resolution A39-3, the 2018 RTK data will be used to determine the addition of States to the Phase 2. The analysis of 2017 data is for information only and a reminder that assumptions of current analyses can change and be updated.



Appendix

Assumptions on Scope of Applicability

- Assumptions on scope of applicability based on draft Annex 16 Volume IV, Chapter 2 (MRV Requirements) and Chapter 3 (Offsetting Requirements)

Criteria	Metric/Threshold	MRV requirements	Offset Requirements	Simplified Procedures
Aircraft Size (MTOM) <i>Exemptions</i>	Aircraft with MTOM >= 5,700 kg	In Scope	In Scope*	
	Aircraft with MTOM < 5,700 kg	Outside of Scope	Outside of Scope	
International/ Domestic Operator	International flight(s)	In Scope	In Scope*	
	Domestic flights	Outside of Scope	Outside of Scope	
Purpose of Flight	Other than (below)	In Scope	In Scope*	
	Humanitarian, military, medical,	Outside of Scope	Outside of Scope	
Pilot and Phase I	P-P to and from exempted States	In Scope	In Scope*	
		In Scope	Outside of Scope	
Phase II	P-P and P-Phase II to / from exempted States	In Scope	In Scope*	
		In Scope	Outside of Scope	
Operator Size	CO ₂ Emissions >= 10,000 tCO ₂ from international flights	In Scope	In Scope*	
	CO ₂ Emissions < 10,000 tCO ₂ from international flights	Outside of Scope	Outside of Scope	

Note: Simplified procedures under discussion within GMTF MRV group could allow use of simplified (lower cost) compliance procedures for operators emitting less than a certain CO₂ emissions threshold.