INTERNATIONAL CIVIL AVIATION ORGANIZATION

*A United Nations Specialized Agency*

# ICAO Environment Advisory Group Meeting (EAG/15)
# January 20-21, 2016

**Agenda Item 1**

# Results of Technical Analyses by CAEP

Presented by ICAO CAEP

# Content

A. **Summary of Key Takeaways from Analyses**

B. **Analysis of Route-Based Approach**

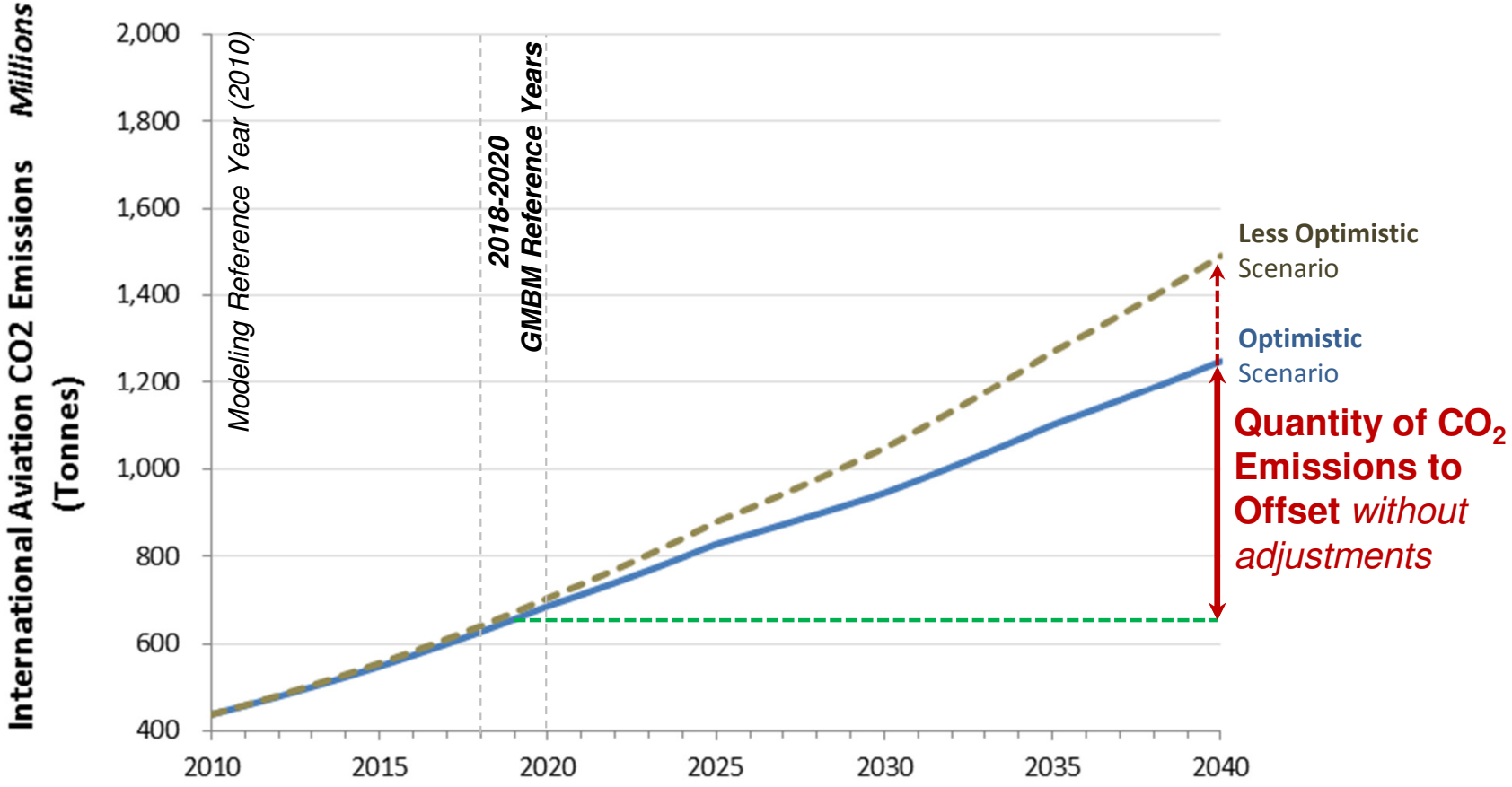
C. **Exploration of Data for Accumulative Emissions Approach**

D. **Comparison of Schemes**

*Note: This summary paper is supplemented by an Appendix that presents additional supporting material to the preliminary results of the technical analyses.*

# Global Emissions from International Aviation

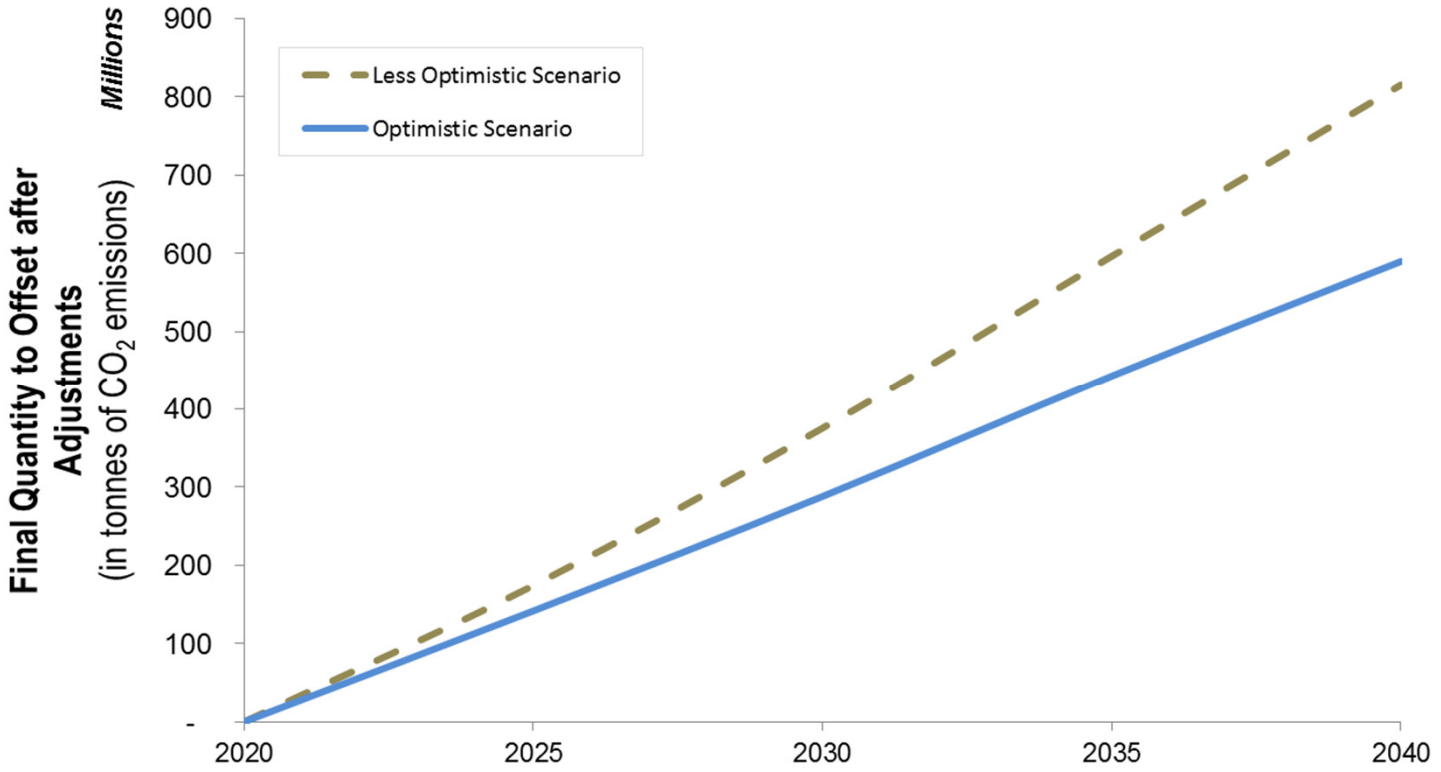
- International aviation $CO_2$ emissions between 2010 - 2040.




| International Aviation $CO_2$ Emissions (in Million tonnes) | 2010 | 2018-2020 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|
| Less Optimistic Scenario | 438 | 671 | 704 | 879 | 1,048 | 1,270 | 1,491 |
| Optimistic Scenario | 438 | 656 | 686 | 828 | 945 | 1,101 | 1,249 |

# $CO_2$ Emissions to be Offset

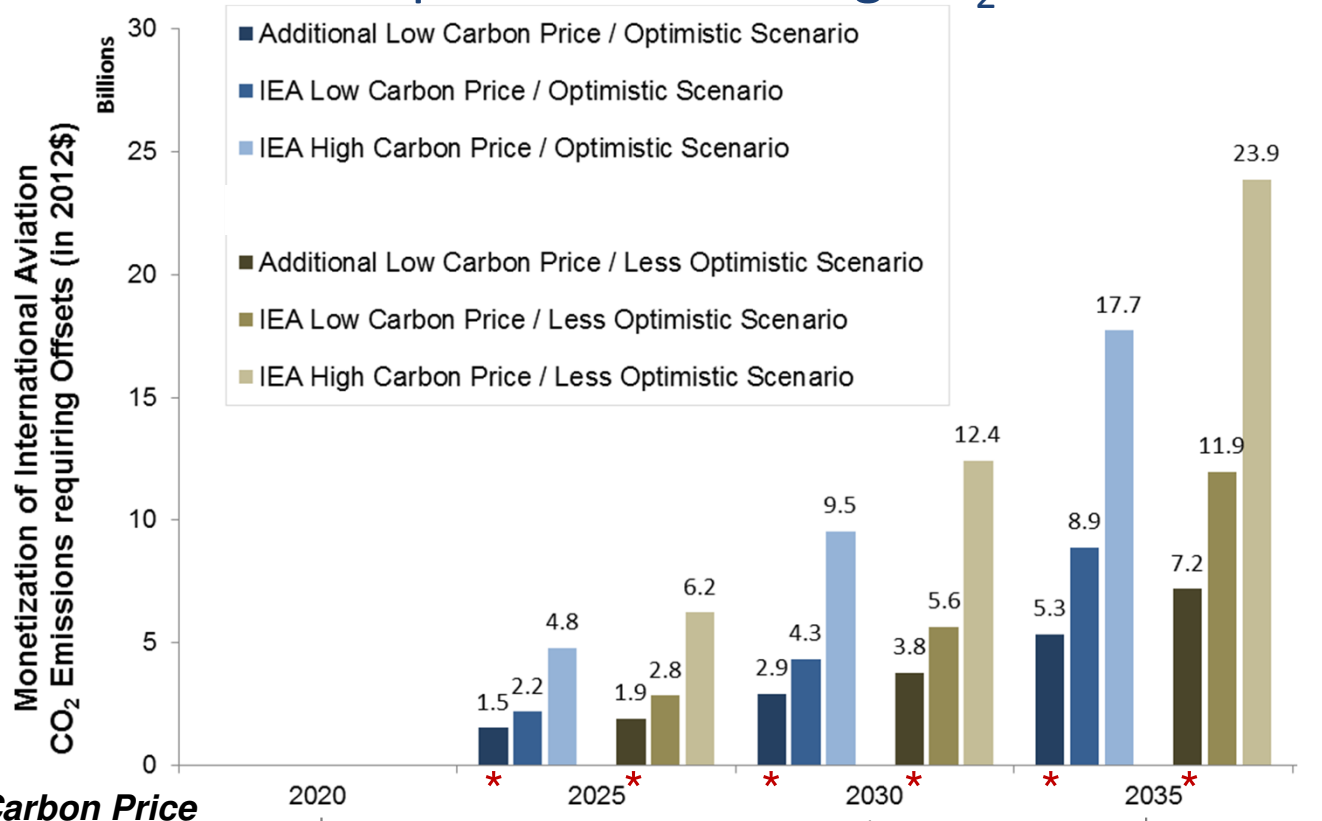
- Final quantity to offset after adjustments




| Final Quantity to Offset after adjustments (in Million tonnes of CO2 emissions) | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| Less Optimistic Scenario | - | 174 | 376 | 596 | 816 |
| Optimistic Scenario | - | 142 | 288 | 443 | 590 |

# Cost of Offsetting $CO_2$ Emissions from International Aviation

- Assumptions on unit carbon price are driving significant uncertainty in total cost impacts of offsetting $CO_2$ emissions from international aviation.




| ***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 |

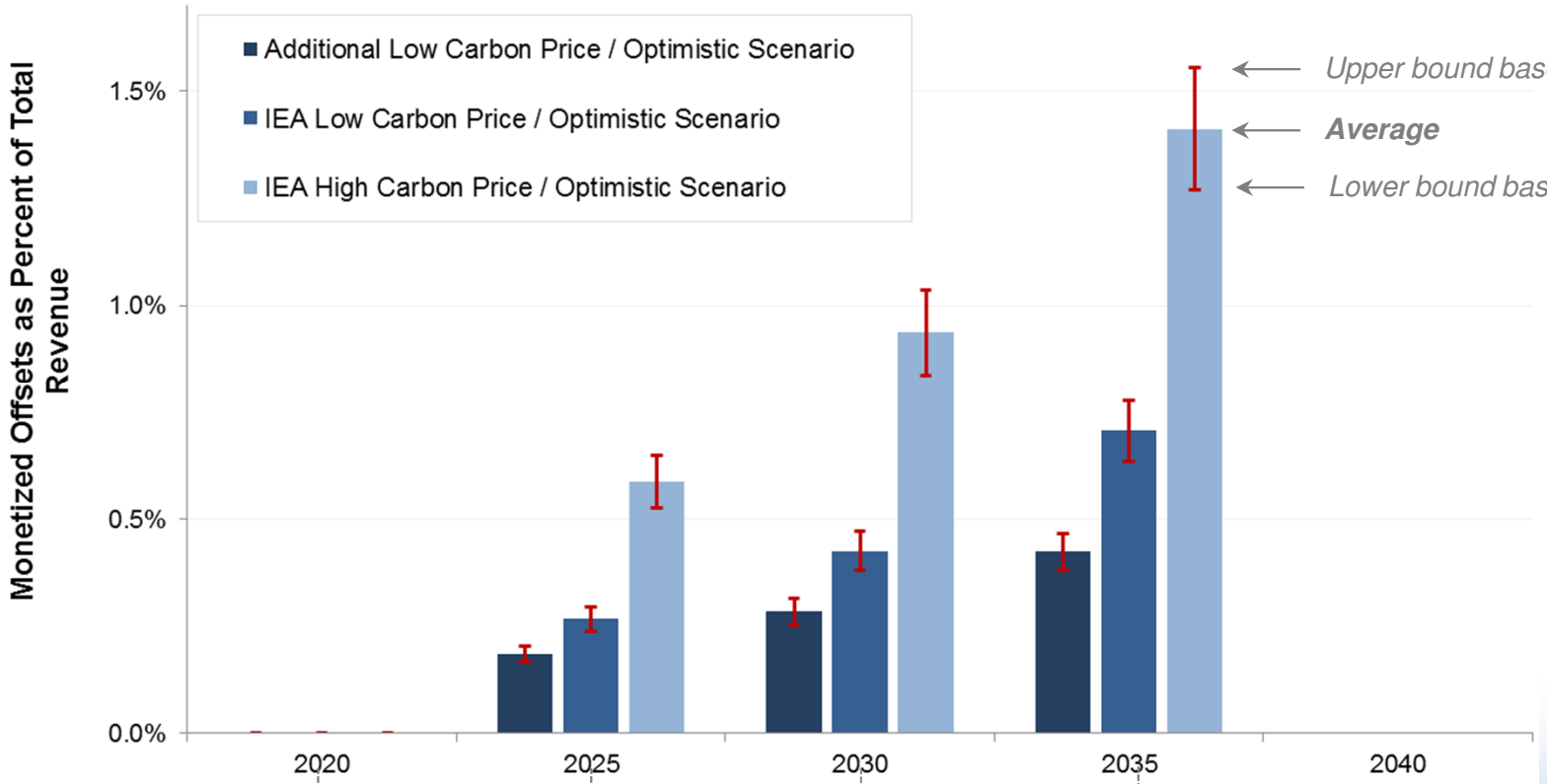
IEA WEO 2013 carbon price paths reflect allowance prices only.

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

* New case with alternative low carbon price

# Alternative Cost Metrics i.e., Cost as Percent of Total Revenue

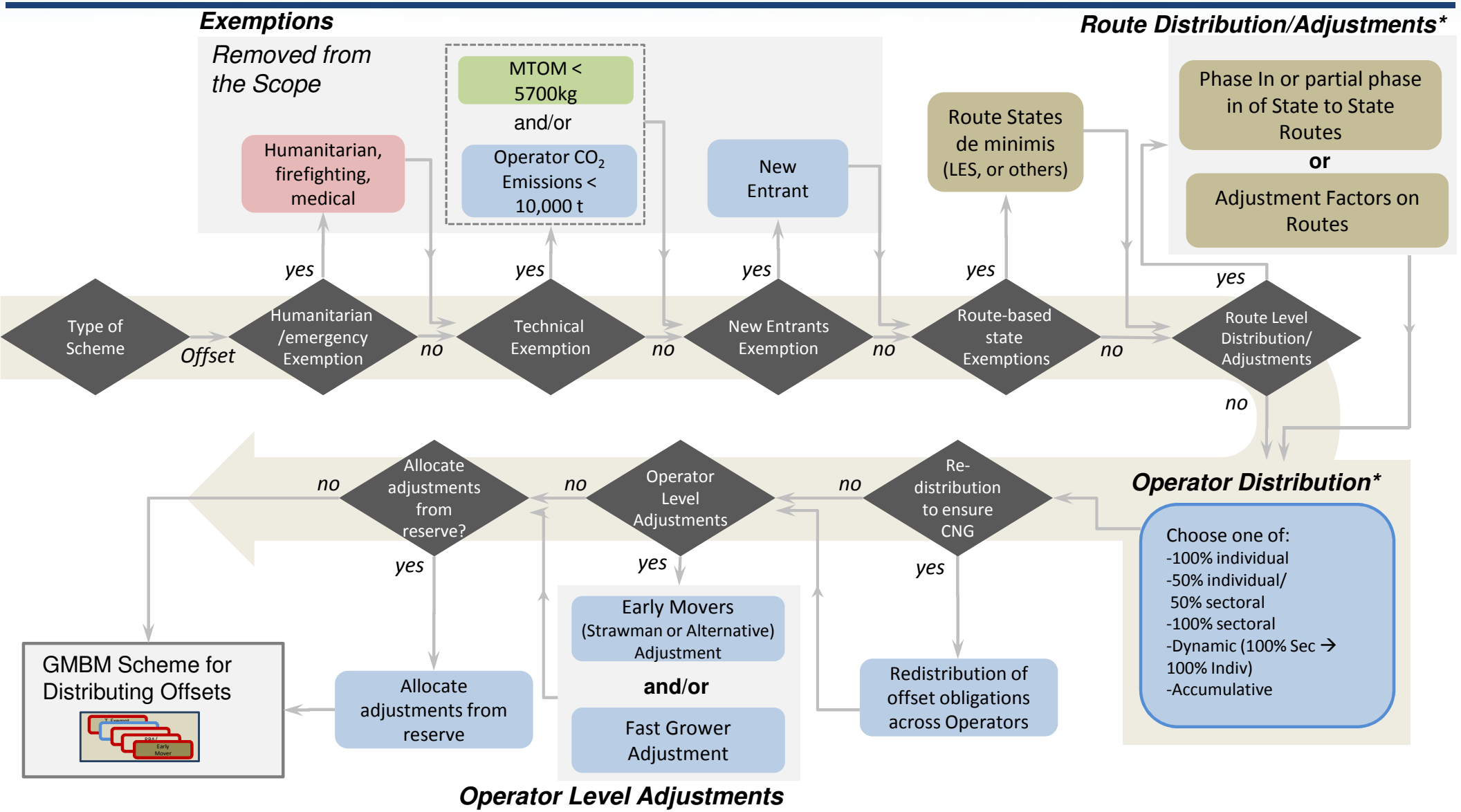
- CAEP computed relative cost to offset emissions from international aviation as percent of total revenue (based on ICAO and IATA forecasts).




| Revenue Forecast in 2012$ | 2020 | 2025 | 2030 | 2035 |
|---|---|---|---|---|
| ICAO | 716 $B | 864 $B | 1,090 $B | 1,330 $B |
| IATA | 579 $B | 734 $B | 917 $B | 1,140 $B |

***Note: ICAO and IATA Revenue Forecasts compared to Optimistic $CO_2$ Scenario (A38-WP/26 Scenario 9)***

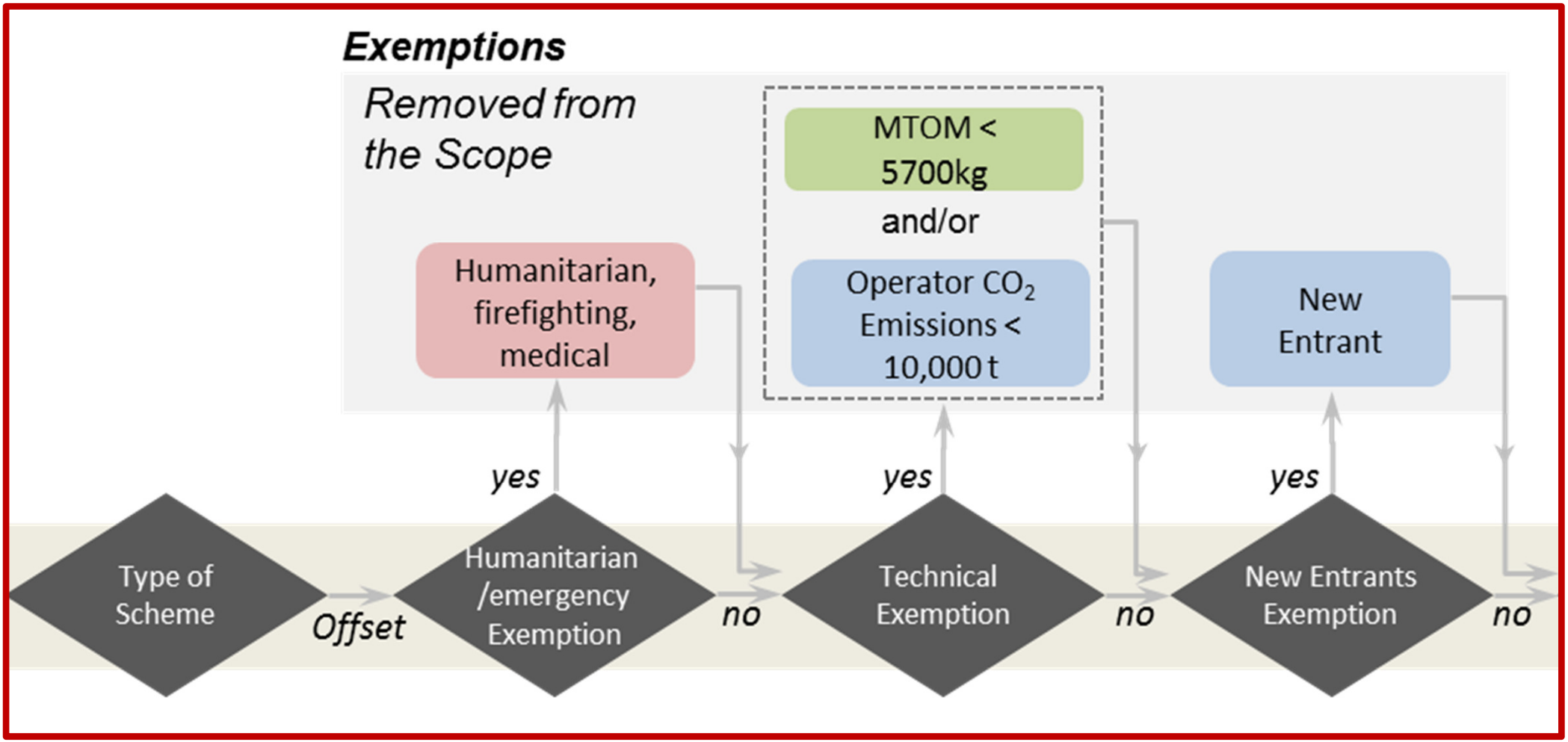
# Framework Illustrating Decisions on Offset Obligation Distribution Scheme




Legend: Operator Level | Flight Purpose Level | Route Level | Aircraft Level

*Other approaches possible. Chart reflects approaches specifically tasked by EAG

# Exemptions






Legend: Operator Level | Flight Purpose Level | Route Level | Aircraft Level

*Other approaches possible. Chart reflects approaches specifically tasked by EAG

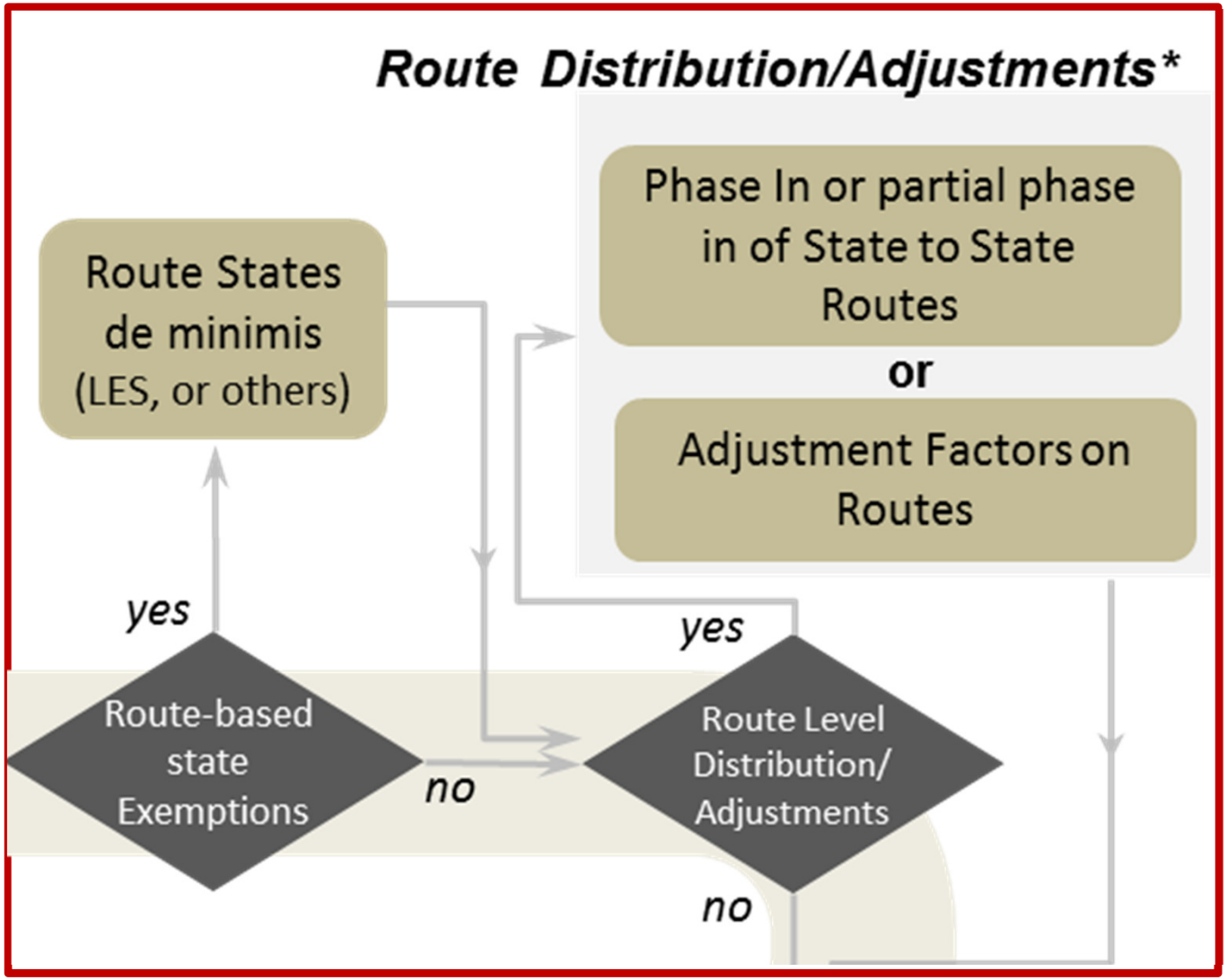
# Exemptions

- Data from 2010, shows that operators emitting less than **10,000 tonnes** of $CO_2$ per year accounted for 0.24%, though this could increase up to 3.1% as 2.9% of emissions likely from small emitters were not able to be attributed to specific operators.

- $CO_2$ emissions from aircraft with **MTOM < 5,700 kg** represented approximately 0.007% of total $CO_2$ emissions from international aviation

- A study by IATA of the contribution of **new entrants**, based on historical data concluded that new entrants on average represent 3% of total $CO_2$ emissions. CAEP expects that the contribution of new entrants may be less important than observed in the IATA study.

# Exemptions of Routes to and from Lowest Emissions States (LES)






Legend: Operator Level | Flight Purpose Level | Route Level | Aircraft Level

*Other approaches possible. Chart reflects approaches specifically tasked by EAG

# Exemptions of Routes to and from Lowest Emissions States (LES)

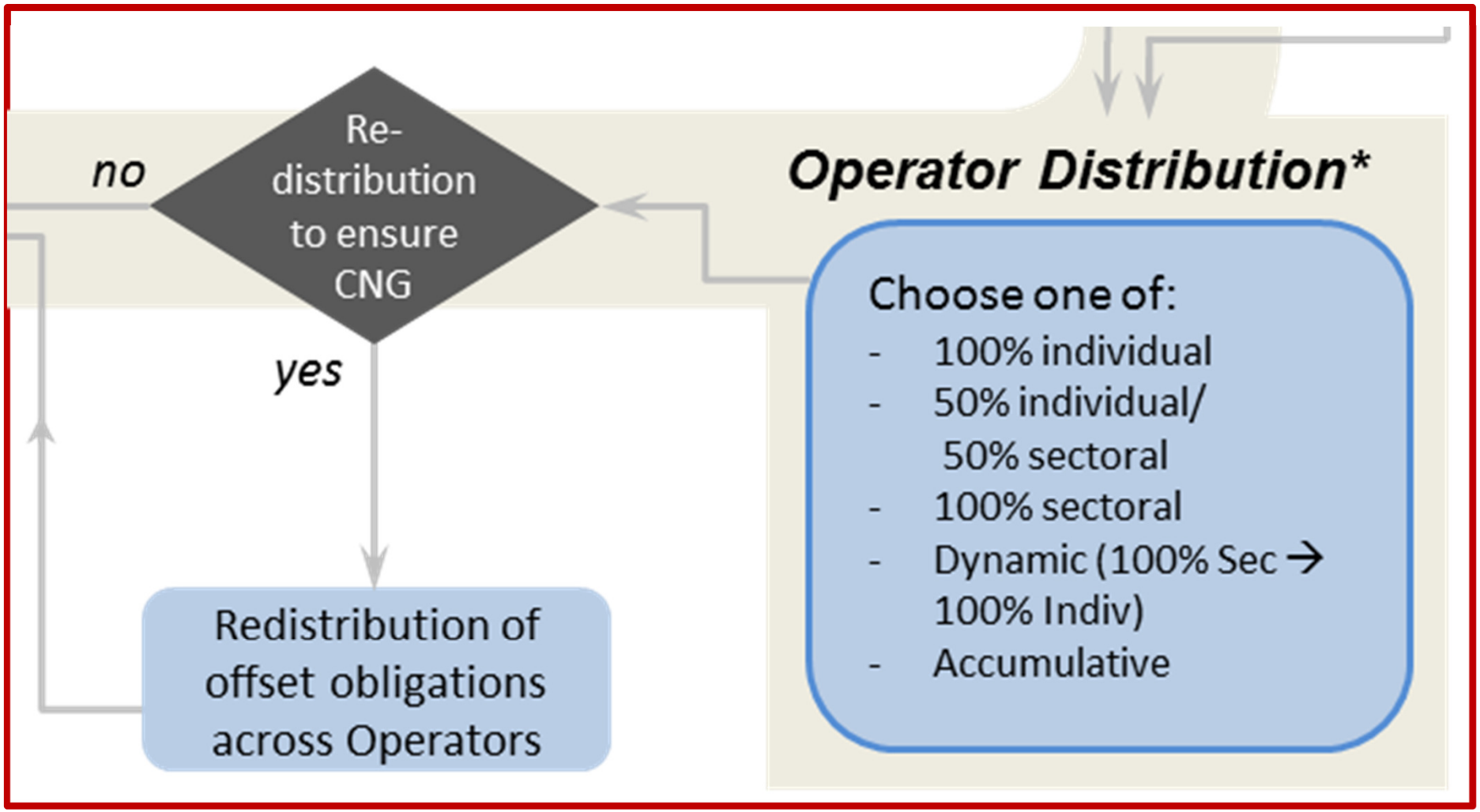
- The Strawman proposes to exempt flights to and from Lowest Emissions States (LES).
- CAEP estimated in 2020 exempting $CO_2$ emissions from flights to and from 97 of ICAO's States with the lowest emissions levels (from all arriving and departing international flights) would exempt approx. 5% of $CO_2$ emissions. Exemption of 117 and 129 LES would exempt approx. 10% and 15% of $CO_2$ emissions respectively.
- The ranking of State by international aviation emission levels is provided on the next slide. This list could be updated over time to reflect changes in the market for international civil aviation.

# Illustration: List of States in 2010

## *Ranked by increasing $CO_2$ emissions (from all international flights to and from individual States) with exemption thresholds*

| ICAO State Name | % CO2 Em. | Cumulative CO2 Em. | ICAO State Name | % CO2 Em. | Cumulative CO2 Em. | ICAO State Name | % CO2 Em. | Cumulative CO2 Em. | ICAO State Name | % CO2 Em. | Cumulative CO2 Em. | ICAO State Name | % CO2 Em. | Cumulative CO2 Em. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAURU | 0.0003% | 0.0003% | DJIBOUTI | 0.01% | 0.26% | LITHUANIA | 0.04% | 1.35% | LIBYA | 0.16% | 4.79% | ISRAEL | 0.5% | 16.1% |
| LESOTHO | 0.001% | 0.001% | MOZAMBIQUE | 0.02% | 0.28% | UGANDA | 0.04% | 1.39% | SENEGAL | 0.17% | 4.96% | NEW ZEALAND | 0.6% | 16.7% |
| SWAZILAND | 0.001% | 0.002% | REPUBLIC OF MOLDOVA | 0.02% | 0.29% | TAJIKISTAN | 0.05% | 1.44% | | | 5.00% | GREECE | 0.6% | 17.3% |
| BHUTAN | 0.001% | 0.003% | NICARAGUA | 0.02% | 0.31% | CAMEROON | 0.05% | 1.49% | IRAN (ISLAMIC REP.) | 0.18% | 5.15% | PHILIPPINES | 0.6% | 17.8% |
| GUINEA-BISSAU | 0.002% | 0.005% | MONGOLIA | 0.02% | 0.33% | ARMENIA | 0.05% | 1.54% | LEBANON | 0.19% | 5.34% | PORTUGAL | 0.6% | 18.4% |
| MICRONESIA (FED. STATES) | 0.002% | 0.006% | BURKINA FASO | 0.02% | 0.35% | CAMBODIA | 0.05% | 1.59% | CYPRUS | 0.19% | 5.52% | ARGENTINA | 0.6% | 19.1% |
| DEM. PEOPLE'S REP. KOREA | 0.002% | 0.008% | MARSHALL ISLANDS | 0.02% | 0.37% | KYRGYZSTAN | 0.05% | 1.64% | ROMANIA | 0.19% | 5.72% | INDONESIA | 0.7% | 19.7% |
| TIMOR-LESTE | 0.003% | 0.011% | PAPUA NEW GUINEA | 0.02% | 0.39% | URUGUAY | 0.06% | 1.70% | TUNISIA | 0.19% | 5.91% | QATAR | 0.9% | 20.6% |
| SAINT VINCENT &THE GREN. | 0.003% | 0.014% | CHAD | 0.02% | 0.41% | AZERBAIJAN | 0.06% | 1.76% | SRI LANKA | 0.20% | 6.11% | SAUDI ARABIA | 0.9% | 21.6% |
| SAO TOME AND PRINCIPE | 0.003% | 0.02% | PARAGUAY | 0.02% | 0.43% | IRAQ | 0.06% | 1.82% | JORDAN | 0.20% | 6.32% | EGYPT | 0.9% | 22.5% |
| PALAU | 0.004% | 0.02% | TOGO | 0.02% | 0.45% | SERBIA | 0.06% | 1.88% | ETHIOPIA | 0.22% | 6.53% | SWITZERLAND | 1.0% | 23.5% |
| TONGA | 0.004% | 0.03% | ALBANIA | 0.02% | 0.47% | TRINIDAD AND TOBAGO | 0.06% | 1.94% | UKRAINE | 0.22% | 6.75% | SOUTH AFRICA | 1.1% | 24.6% |
| SOLOMON ISLANDS | 0.004% | 0.03% | MONTENEGRO | 0.02% | 0.49% | GUATEMALA | 0.07% | 2.01% | PANAMA | 0.22% | 6.97% | BELGIUM | 1.1% | 25.6% |
| KIRIBATI | 0.005% | 0.03% | BENIN | 0.02% | 0.52% | MALTA | 0.07% | 2.08% | CUBA | 0.22% | 7.19% | MEXICO | 1.1% | 26.7% |
| SOMALIA | 0.005% | 0.04% | MYANMAR | 0.02% | 0.54% | CROATIA | 0.07% | 2.15% | CZECH REPUBLIC | 0.22% | 7.41% | MALAYSIA | 1.3% | 28.0% |
| BOTSWANA | 0.005% | 0.04% | HONDURAS | 0.03% | 0.57% | BAHAMAS | 0.07% | 2.22% | | | 7.50% | BRAZIL | 1.4% | 29.4% |
| COMOROS | 0.005% | 0.05% | SLOVENIA | 0.03% | 0.59% | EL SALVADOR | 0.07% | 2.29% | UZBEKISTAN | 0.23% | 7.6% | TURKEY | 1.5% | 30.9% |
| ERITREA | 0.006% | 0.06% | ZAMBIA | 0.03% | 0.62% | SUDAN | 0.07% | 2.37% | VENEZUELA (BOLIV. REP. | 0.23% | 7.9% | RUSSIAN FEDERATION | 1.7% | 32.6% |
| VANUATU | 0.006% | 0.06% | ZIMBABWE | 0.03% | 0.64% | BRUNEI DARUSSALAM | 0.08% | 2.44% | BANGLADESH | 0.25% | 8.1% | ITALY | 2.1% | 34.6% |
| GRENADA | 0.007% | 0.07% | NAMIBIA | 0.03% | 0.67% | | | 2.50% | LUXEMBOURG | 0.25% | 8.4% | INDIA | 2.1% | 36.8% |
| SAINT KITTS AND NEVIS | 0.007% | 0.08% | HAITI | 0.03% | 0.70% | LATVIA | 0.08% | 2.52% | KUWAIT | 0.30% | 8.7% | THAILAND | 2.1% | 38.9% |
| CENTRAL AFRICAN REP. | 0.007% | 0.08% | GEORGIA | 0.03% | 0.73% | FIJI | 0.08% | 2.59% | PAKISTAN | 0.31% | 9.0% | CANADA | 2.1% | 41.0% |
| BURUNDI | 0.008% | 0.09% | ESTONIA | 0.03% | 0.75% | NEPAL | 0.08% | 2.67% | NIGERIA | 0.31% | 9.3% | SINGAPORE | 2.2% | 43.2% |
| SIERRA LEONE | 0.008% | 0.10% | SURINAME | 0.03% | 0.78% | UNITED REP. OF TANZANIA | 0.08% | 2.75% | CHILE | 0.32% | 9.6% | REPUBLIC OF KOREA | 2.3% | 45.5% |
| LIBERIA | 0.008% | 0.11% | GABON | 0.03% | 0.81% | ICELAND | 0.09% | 2.83% | KAZAKHSTAN | 0.32% | 9.9% | NETHERLANDS | 2.3% | 47.8% |
| GUYANA | 0.008% | 0.11% | SEYCHELLES | 0.03% | 0.84% | BARBADOS | 0.09% | 2.93% | DOMINICAN REPUBLIC | 0.34% | 10.3% | AUSTRALIA | 2.4% | 50.2% |
| LAO PEOPLE'S DEM. REP. | 0.008% | 0.12% | SLOVAKIA | 0.03% | 0.87% | MALDIVES | 0.11% | 3.04% | PERU | 0.34% | 10.6% | SPAIN | 2.9% | 53.1% |
| BOSNIA AND HERZEGOVINA | 0.009% | 0.13% | BELARUS | 0.03% | 0.91% | SYRIAN ARAB REPUBLIC | 0.11% | 3.14% | MOROCCO | 0.34% | 10.9% | JAPAN | 3.7% | 56.8% |
| MALAWI | 0.010% | 0.14% | TURKMENISTAN | 0.03% | 0.94% | AFGHANISTAN | 0.11% | 3.26% | COLOMBIA | 0.34% | 11.3% | FRANCE | 3.7% | 60.6% |
| COOK ISLANDS | 0.010% | 0.15% | DEM. REP. OF THE CONGC | 0.03% | 0.97% | GHANA | 0.11% | 3.37% | KENYA | 0.34% | 11.6% | UNITED ARAB EMIRATES | 4.0% | 64.5% |
| EQUATORIAL GUINEA | 0.010% | 0.16% | SAINT LUCIA | 0.03% | 1.00% | BULGARIA | 0.12% | 3.49% | VIET NAM | 0.36% | 12.0% | GERMANY | 6.0% | 70.5% |
| SAMOA | 0.010% | 0.17% | ANTIGUA AND BARBUDA | 0.03% | 1.04% | ANGOLA | 0.13% | 3.61% | NORWAY | 0.36% | 12.3% | UNITED KINGDOM | 6.8% | 77.3% |
| GAMBIA | 0.010% | 0.18% | MALI | 0.03% | 1.07% | ALGERIA | 0.13% | 3.74% | FINLAND | 0.38% | 12.7% | CHINA | 8.1% | 85.4% |
| GUINEA | 0.010% | 0.19% | MADAGASCAR | 0.04% | 1.11% | COSTA RICA | 0.13% | 3.88% | BAHRAIN | 0.39% | 13.1% | UNITED STATES | 14.6% | 100.0% |
| BELIZE | 0.011% | 0.20% | COTE D'IVOIRE | 0.04% | 1.15% | JAMAICA | 0.13% | 4.01% | IRELAND | 0.42% | 13.5% | | | |
| MACEDONIA, FORM.REP.YUG | 0.011% | 0.21% | YEMEN | 0.04% | 1.19% | ECUADOR | 0.15% | 4.16% | POLAND | 0.46% | 14.0% | | | |
| MAURITANIA | 0.011% | 0.22% | CABO VERDE | 0.04% | 1.23% | HUNGARY | 0.16% | 4.32% | SWEDEN | 0.50% | 14.5% | | | |
| NIGER | 0.012% | 0.23% | BOLIVIA (PLUR. STATE OF) | 0.04% | 1.27% | MAURITIUS | 0.16% | 4.47% | DENMARK | 0.53% | 15.0% | | | |
| RWANDA | 0.013% | 0.25% | CONGO | 0.04% | 1.31% | OMAN | 0.16% | 4.63% | AUSTRIA | 0.53% | 15.6% | | | |

# Offset Obligation Distribution Schemes



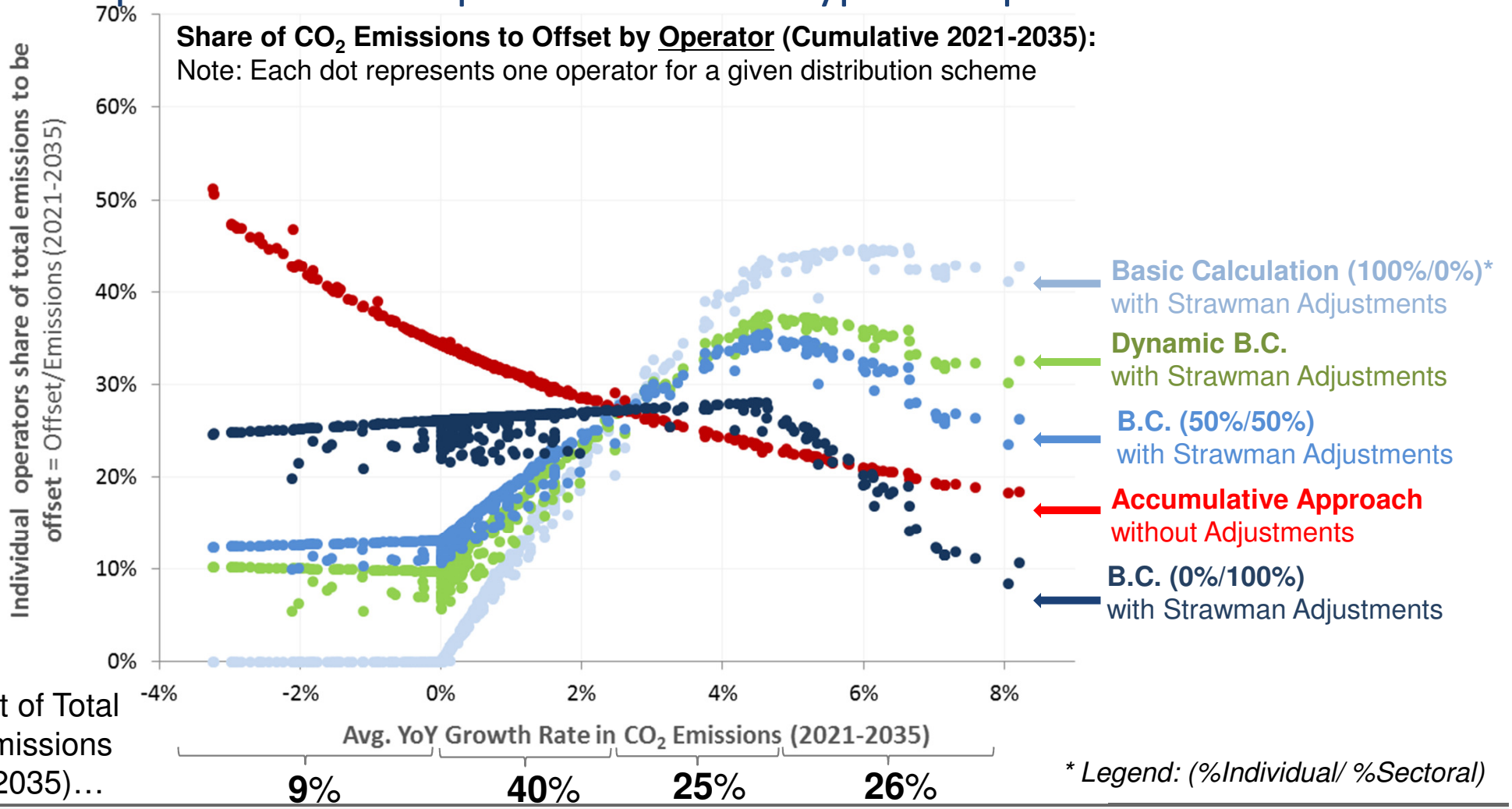



Legend: Operator Level | Flight Purpose Level | Route Level | Aircraft Level

*Other approaches possible. Chart reflects approaches specifically tasked by EAG

# Offset Obligation Distribution Schemes

- Trends in Share of $CO_2$ Emissions to Offset for Various Allocation Schemes capture potential cost impacts on various types of operators



# Route Based Approaches

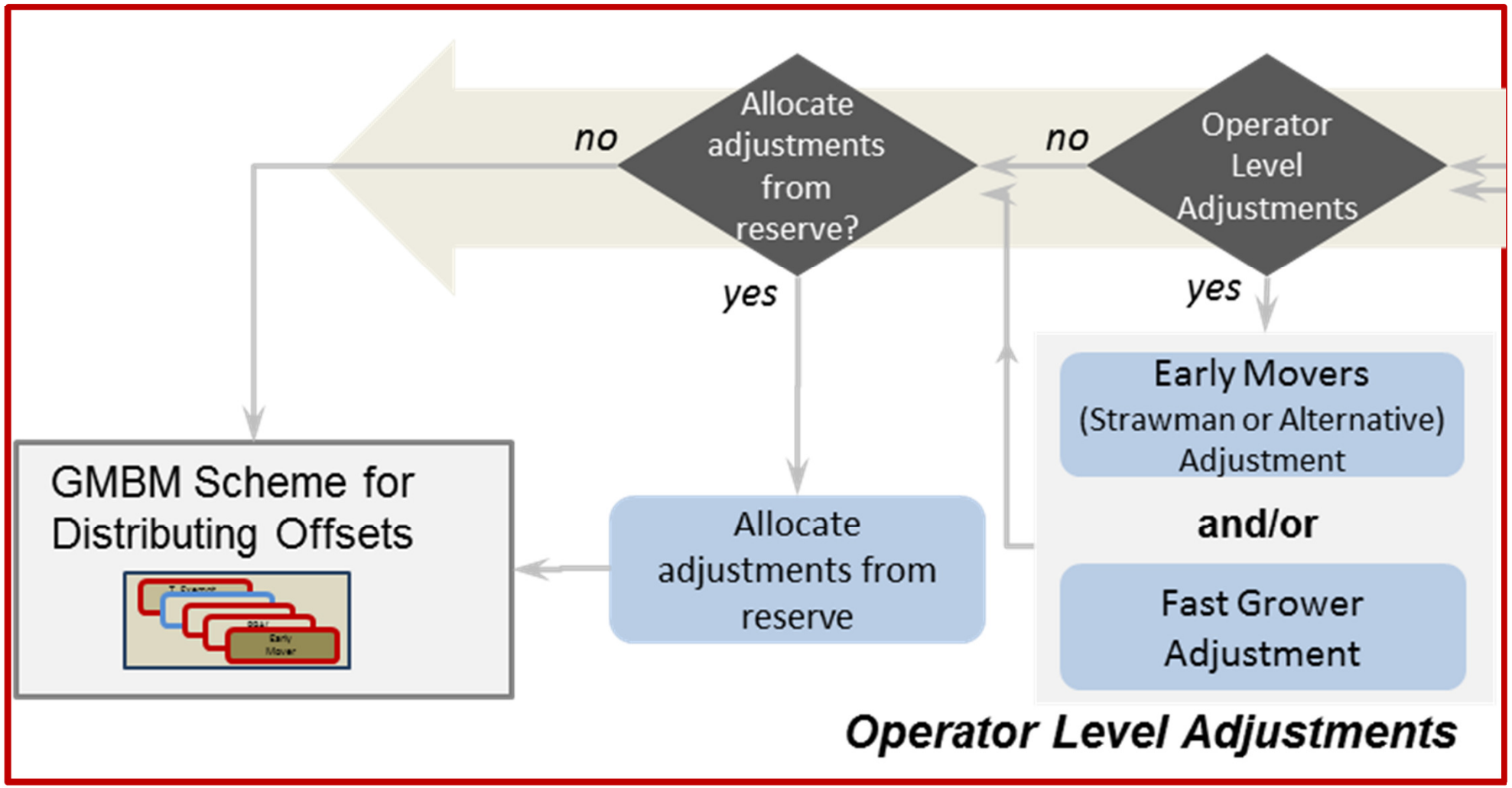
- CAEP has also evaluated route based approaches including; (1) gradual phase in of State pair routes where a fraction of the $CO_2$ emissions is temporarily exempted in the earlier years of implementation.
- $CO_2$ emissions coverage could range from 88% to 99% across various metrics and phase-in attribution profiles investigated.
- It was observed that the distribution of offset obligations is primarily driven by the choice of the operator allocation method (e.g. Basic Calculation %).
- The route based approach provides an additional adjustment by decreasing the share of emissions to offset for certain operators.
- Two alternative route based proposals were also identified.

# Redistribution

- Adding redistribution to a route based approach to improve performance against the global goal is feasible.

- Redistribution (1) may add complexity to the process for computing offsets and (2) may add uncertainty to the final quantities to offset.

# Operator Level Adjustments






*Legend:* Operator Level | Flight Purpose Level | Route Level | Aircraft Level

*Other approaches possible. Chart reflects approaches specifically tasked by EAG

# Operator Level Adjustments

- **Fast Grower** adjustments are allocated from the "reserve", i.e. the greater of the difference of the reference period emissions level and 2020 emissions or 3% of the total 2020 $CO_2$ emissions from international aviation.

- Adjustments from the reserve do not impact the achievement of the CNG 2020 goal.

- **Fast Growers** are operators whose individual emissions' growth rates is more than twice the average growth rate as depicted in page 14 by the kink in the lines above approx. 5% annual growth rate in $CO_2$ emissions.

# Operator Level Adjustments (cont.)

- **Early Mover** adjustments could be provided to operators whose individual fuel efficiency is more than 10% above the average fuel efficiency in the reference year (eligible from 2021 to 2025). ASG observed that EM adjustments are primarily assigned to operators conducting freight (only) operations.
- An analysis of an alternative Early Mover proposal submitted by IATA to EAG was also conducted. In addition to rewarding efficiency above average, the IATA proposal aims at recognizing efforts to improve efficiency at a rate greater than the average rate of improvement.
- The analysis showed that while more operators would qualify under the alternative approach, the average adjustment would be lower and the variation between operators less important than under the approach proposed in the Strawman.
- IATA proposed to not allocate the early mover adjustment from the reserve, this would impact the achievement of the global goal.

# B. Analysis of Route-Based Approach

## Tasks:

- Analyze alternative sequence of Lowest Emissions States, Operator Exemptions and Route Based Approach;
  - Separate LES Exemptions from the RBA/Phase In (i.e., Group D States) and apply the LES as an upstream step in the process for computing offset obligations (similar to Strawman implementation).
- Complete sensitivity of key results to changes to the threshold for the groups specified in WP/1 for each metric.
- Complete assessment of whether metrics and thresholds generate an incentive to reroute flights.

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

**For details and analyses in support of this section, see Appendix, pages 3-5**

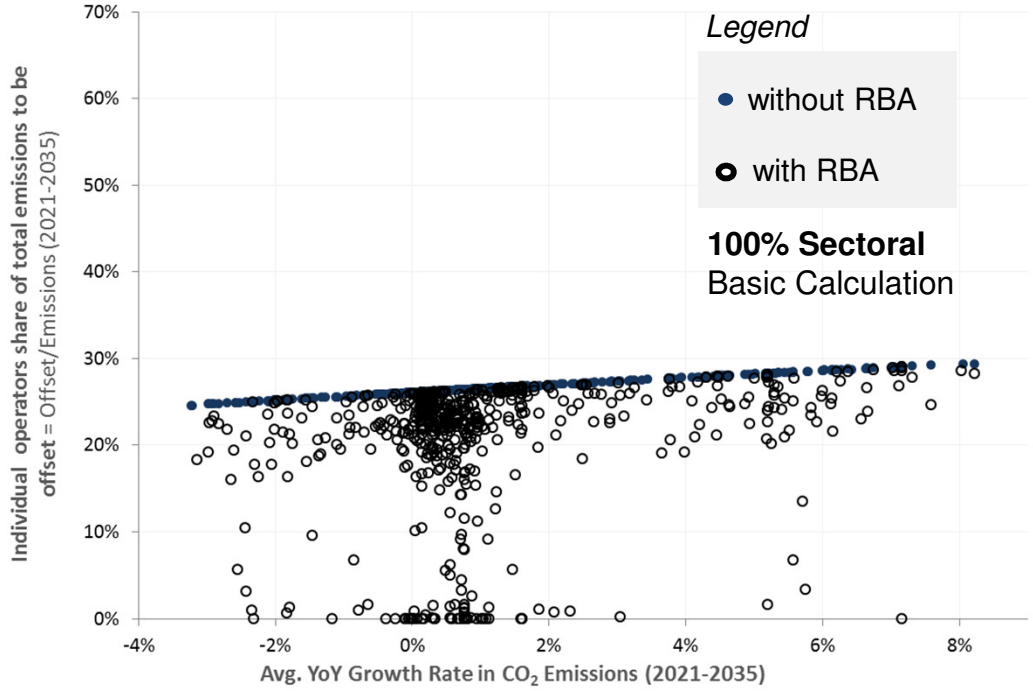
# Alternative Sequence of Lowest Emissions States, Operator Exemptions and Route Based Approach

- The effects of sequences of (1) LES, (2) Operator Level Exemptions and (3) Route Based Approach were discussed during the EAG/14 meeting.
- It was proposed that the LES exemptions could be extracted from the RBA Phase In (i.e., Group D States).
- CAEP developed an alternative model and implementation of Route Based Approach with Phase In, where;
  - (1) LES are applied upstream (similar to Strawman),
  - (2) Operator level exemptions i.e., 10,000t$CO_2$ are then applied,
  - (3) Route Based Approach Phase In for Groups of States A, B and C –without group D- are applied downstream as an adjustment (similar to EAG/12 analyses)

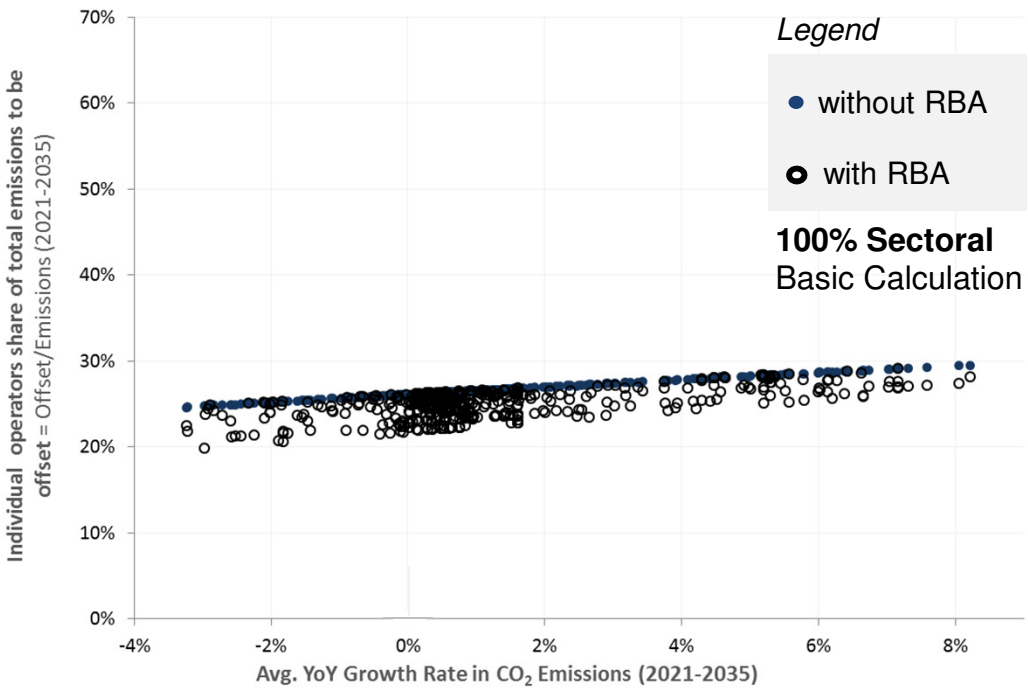
# Alternative Sequence of Lowest Emissions States, Operator Exemptions and Route Based Approach

- CAEP showed that an upstream application of LES and downstream application of RBA/Phase In is feasible.
- This approach results in an isolated effect of RBA/Phase In i.e., reductions in offset obligations solely due to RBA/Phase In.
- For sample illustrative metric/phase in profile, offset obligations are reduced on average by 5%. Maximum reduction reached 20% for some operators.

**Results of Prior Analyses** (EAG/13-14)




**Results of EAG/15 Analyses**



# B. Analysis of Route-Based Approach

## Tasks:

- Analyze alternative sequence of Lowest Emissions States, Operator Exemptions and Route Based Approach;
  - Separate LES Exemptions from the RBA/Phase In (i.e., Group D States) and apply the LES as an upstream step in the process for computing offset obligations (similar to Strawman implementation).
- Complete sensitivity of key results to changes to the threshold for the groups specified in WP/1 for each metric.
- Complete assessment of whether metrics and thresholds generate an incentive to reroute flights.

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

**For details and analyses in support of this section, see Appendix, pages 6-22**

# Sensitivity of Key Results to Changes to the Threshold for the Groups Specified in WP/1 for Each Metric

- Using Route Based Approach with Phase In approach as described in EAG/11-WP/1, CAEP conducted an analysis of the sensitivity of thresholds for defining groups of States i.e., Groups A, B, C and D.

- Thresholds were varied to (1) ***Less Inclusive*** scenario, (2) ***More Inclusive*** Scenario from the Baseline case that was presented at EAG/12.

- See Appendix for results for all metrics and threshold values.

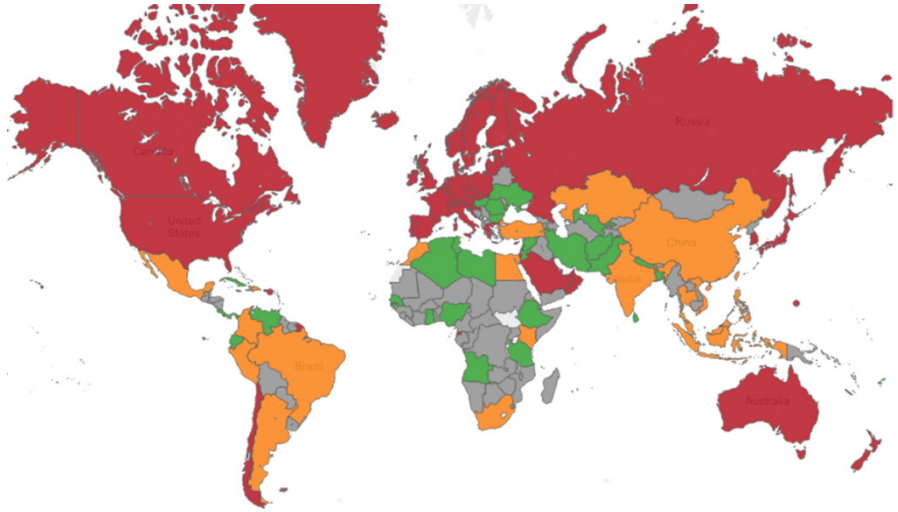
# *Illustration: Metric #1* $CO_2$ and GNI/Cap

*Note: GNI/Cap. based on Atlas Method*

| ICAO Member State | Less Inclusive | Baseline | More Inclusive | ICAO Member State | Less Inclusive | Baseline | More Inclusive | ICAO Member State | Less Inclusive | Baseline | More Inclusive | ICAO Member State | Less Inclusive | Baseline | More Inclusive |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTIGUA AND BARBUDA | A | A | A | UNITED ARAB EMIRATES | A | A | A | MALDIVES | C | C | B | MALI | D | D | D |
| AUSTRALIA | A | A | A | UNITED KINGDOM | A | A | A | SYRIAN ARAB REPUBLIC | C | C | B | MARSHALL ISLANDS | D | D | D |
| AUSTRIA | A | A | A | UNITED STATES | A | A | A | AFGHANISTAN | C | C | B | MAURITANIA | D | D | D |
| BAHAMAS | A | A | A | CHINA | B | B | B | NEPAL | C | C | B | MICRONESIA, FEDERATED STATES OF | D | D | D |
| BAHRAIN | A | A | A | INDIA | B | B | B | FIJI | C | C | B | MOLDOVA, REPUBLIC OF | D | D | D |
| BARBADOS | A | A | A | THAILAND | B | B | B | TANZANIA, UNITED REPUBLIC OF | C | C | B | MONGOLIA | D | D | D |
| BELGIUM | A | A | A | TURKEY | B | B | B | ALBANIA | D | D | D | MONTENEGRO | D | D | D |
| BRUNEI DARUSSALAM | A | A | A | MALAYSIA | B | B | B | ARMENIA | D | D | D | MOZAMBIQUE | D | D | D |
| CANADA | A | A | A | BRAZIL | B | B | B | AZERBAIJAN | D | D | D | NAMIBIA | D | D | D |
| CHILE | A | A | A | MEXICO | B | B | B | BELARUS | D | D | D | NICARAGUA | D | D | D |
| CROATIA | A | A | A | SOUTH AFRICA | B | B | B | BELIZE | D | D | D | NIGER | D | D | D |
| CYPRUS | A | A | A | EGYPT | B | B | B | BENIN | D | D | D | PALAU | D | D | D |
| CZECH REPUBLIC | A | A | A | INDONESIA | C | B | B | BHUTAN | D | D | D | PAPUA NEW GUINEA | D | D | D |
| DENMARK | A | A | A | ARGENTINA | C | B | B | BOLIVIA | D | D | D | PARAGUAY | D | D | D |
| EQUATORIAL GUINEA | A | A | A | PHILIPPINES | C | B | B | BOSNIA AND HERZEGOVINA | D | D | D | RWANDA | D | D | D |
| ESTONIA | A | A | A | KAZAKHSTAN | C | B | B | BOTSWANA | D | D | D | SAINT LUCIA | D | D | D |
| FINLAND | A | A | A | KENYA | C | B | B | BURKINA FASO | D | D | D | SAINT VINCENT AND THE GRENADINES | D | D | D |
| FRANCE | A | A | A | MOROCCO | C | B | B | BURUNDI | D | D | D | SAMOA | D | D | D |
| GERMANY | A | A | A | VIET NAM | C | B | B | CAMBODIA | D | D | D | SAO TOME AND PRINCIPE | D | D | D |
| GREECE | A | A | A | COLOMBIA | C | B | B | CAMEROON | D | D | D | SERBIA | D | D | D |
| ICELAND | A | A | A | PERU | C | B | B | CAPE VERDE | D | D | D | SEYCHELLES | D | D | D |
| IRELAND | A | A | A | DOMINICAN REPUBLIC | C | B | B | CENTRAL AFRICAN REPUBLIC | D | D | D | SIERRA LEONE | D | D | D |
| ISRAEL | A | A | A | PAKISTAN | C | C | B | CHAD | D | D | D | SOLOMON ISLANDS | D | D | D |
| ITALY | A | A | A | NIGERIA | C | C | B | COMOROS | D | D | D | SUDAN | D | D | D |
| JAPAN | A | A | A | BANGLADESH | C | C | B | CONGO, THE DEMOCRATIC REPUBLIC ( | D | D | D | SURINAME | D | D | D |
| KOREA, REPUBLIC OF | A | A | A | UZBEKISTAN | C | C | B | ` | D | D | D | SWAZILAND | D | D | D |
| KUWAIT | A | A | A | VENEZUELA | C | C | B | DJIBOUTI | D | D | D | TAJIKISTAN | D | D | D |
| LATVIA | A | A | A | PANAMA | C | C | B | EL SALVADOR | D | D | D | TOGO | D | D | D |
| LITHUANIA | A | A | A | CUBA | C | C | B | ERITREA | D | D | D | TONGA | D | D | D |
| LUXEMBOURG | A | A | A | UKRAINE | C | C | B | GABON | D | D | D | TURKMENISTAN | D | D | D |
| MALTA | A | A | A | JORDAN | C | C | B | GAMBIA | D | D | D | UGANDA | D | D | D |
| NETHERLANDS | A | A | A | SRI LANKA | C | C | B | GEORGIA | D | D | D | URUGUAY | D | D | D |
| NEW ZEALAND | A | A | A | ETHIOPIA | C | C | B | GRENADA | D | D | D | VANUATU | D | D | D |
| NORWAY | A | A | A | LEBANON | C | C | B | GUATEMALA | D | D | D | YEMEN | D | D | D |
| OMAN | A | A | A | TUNISIA | C | C | B | GUINEA | D | D | D | ZAMBIA | D | D | D |
| POLAND | A | A | A | ROMANIA | C | C | B | GUINEA-BISSAU | D | D | D | ZIMBABWE | D | D | D |
| PORTUGAL | A | A | A | IRAN, ISLAMIC REPUBLIC OF | C | C | B | GUYANA | D | D | D | CONGO | D | D | D |
| QATAR | A | A | A | SENEGAL | C | C | B | HAITI | D | D | D | COOK ISLANDS | D | D | D |
| RUSSIAN FEDERATION | A | A | A | LIBYAN ARAB JAMAHIRIYA | C | C | B | HONDURAS | D | D | D | DOMINICA | D | D | D |
| SAINT KITTS AND NEVIS | A | A | A | MAURITIUS | C | C | B | IRAQ | D | D | D | KOREA, DEMOCRATIC PEOPLE'S REPUB | D | D | D |
| SAUDI ARABIA | A | A | A | HUNGARY | C | C | B | KIRIBATI | D | D | D | MYANMAR | D | D | D |
| SINGAPORE | A | A | A | ANGOLA | C | C | B | KYRGYZSTAN | D | D | D | NAURU | D | D | D |
| SLOVAKIA | A | A | A | ECUADOR | C | C | B | LAO PEOPLE'S DEMOCRATIC REPUBLIC | D | D | D | SOMALIA | D | D | D |
| SLOVENIA | A | A | A | JAMAICA | C | C | B | LESOTHO | D | D | D | TIMOR-LESTE | D | D | D |
| SPAIN | A | A | A | ALGERIA | C | C | B | LIBERIA | D | D | D | TUVALU | D | D | D |
| SWEDEN | A | A | A | COSTA RICA | C | C | B | MACEDONIA, THE FORMER YUGOSLAV | D | D | D | | | | |
| SWITZERLAND | A | A | A | BULGARIA | C | C | B | MADAGASCAR | D | D | D | | | | |
| TRINIDAD AND TOBAGO | A | A | A | GHANA | C | C | B | MALAWI | D | D | D | | | | |

# *Illustration: Metric #1* $CO_2$ and GNI/Cap

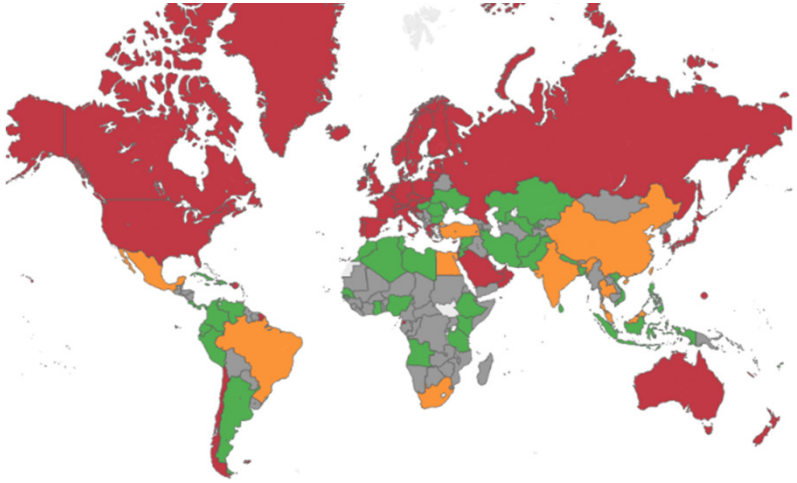
**Baseline** Scenario



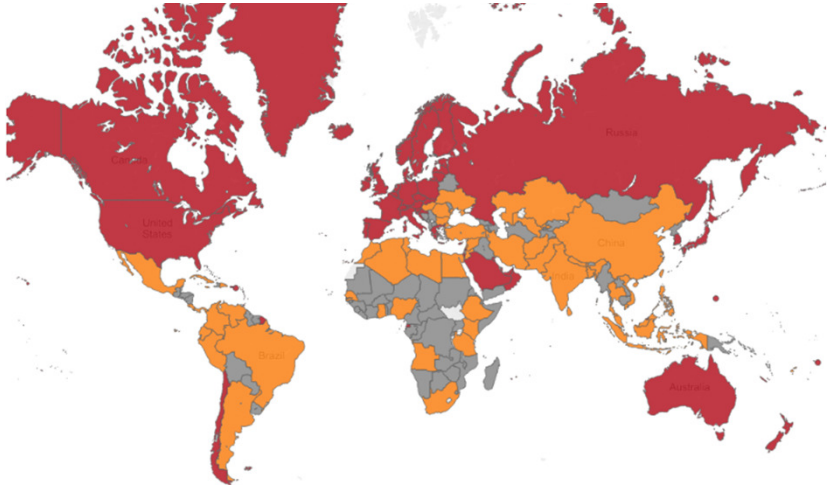
*Legend:*

- Group A
- Group B
- Group C
- Group D

**Less Inclusive** Scenario



**More Inclusive** Scenario

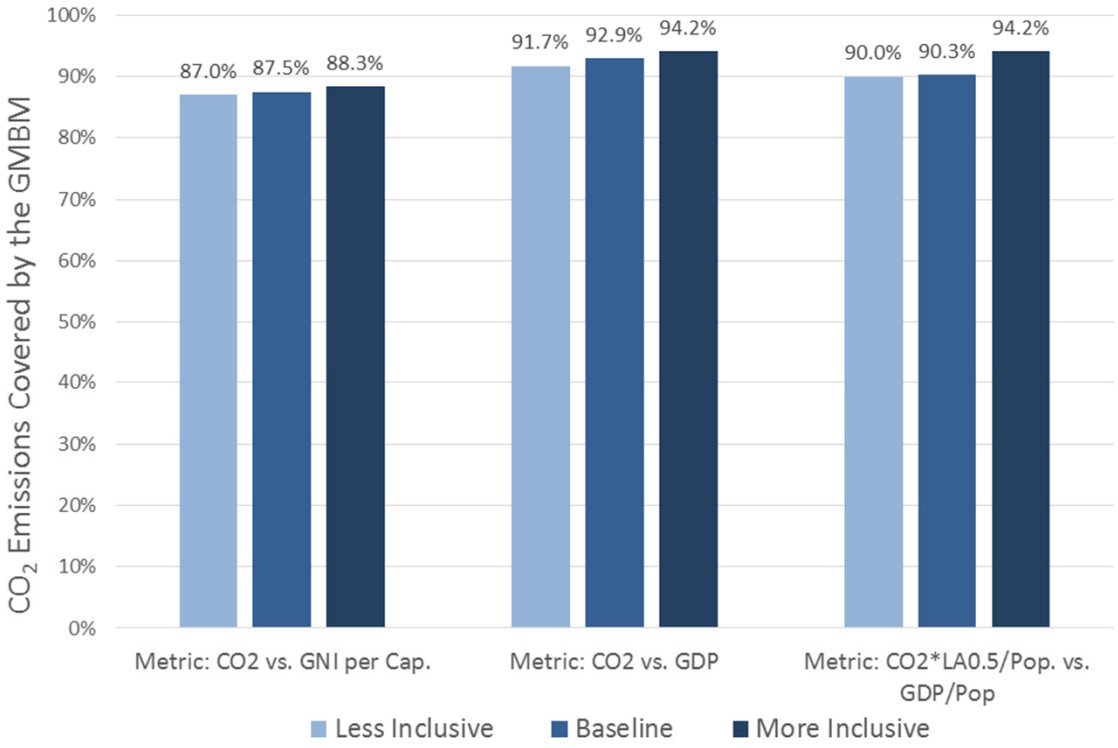


# Sensitivity of Key Results to Changes to the Threshold for the Groups Specified in WP/1 for Each Metric

- Changes in threshold values to determine groups of States generally has marginal influence on total $CO_2$ Emissions covered by the GMBM.
- Influence depends on metric (i.e., State rankings) and whether some large emitting States cross the thresholds.
- All operators (aggregated by their State of registration) experience a decrease/increase of offset obligations from the baseline case that can range from at most -11% to 14%.

**$CO_2$ Emissions Covered by the GMBM after RBA/Phase In**

for various Metrics and Grouping Thresholds



# B. Analysis of Route-Based Approach

## Tasks:

- Analyze alternative sequence of Lowest Emissions States, Operator Exemptions and Route Based Approach;
  - Separate LES Exemptions from the RBA/Phase In (i.e., Group D States) and apply the LES as an upstream step in the process for computing offset obligations (similar to Strawman implementation).
- Complete sensitivity of key results to changes to the threshold for the groups specified in WP/1 for each metric.
- Complete assessment of whether metrics and thresholds generate an incentive to reroute flights.

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

# Effects of Metrics and Thresholds on Incentive to Reroute Flights

- Route Based Approach with Phase In generally results in lower differences in relative costs* than some operator based approaches such as 100% individual or accumulative approach.
- As such, incentives to reroute flights from RBA/Phase In metrics and thresholds cannot be assessed in isolation but needs to consider the operator based scheme on which the RBA/Phase In is applied.
- See comprehensive assessment of market distortion in section D for results.

* For the purpose of the GMBM analyses, market distortion is measured solely by the difference in costs resulting from the GMBM offsets between two operators or across routes. It excludes considerations of existing market distortion due to other cost items, regulations, regional differences.

# C. Exploration of Data for Accumulative Emissions Approach

## Tasks:

- Further explore data for accumulative approach with alternative sources of data;
  - Summarize characteristics of historical databases investigated by CAEP to date.

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

# Summary of Characteristics of Historical Databases Investigated by CAEP to Date

- To provide a summary of characteristics of historical database, CAEP reviewed analyses of databases investigated to date.

- Captured the source and type of data, scope of coverage of databases and availability of historical data.

# Summary of Characteristics of Historical Databases Investigated by CAEP to Date

| | ICAO Form A | ICAO Form C | ICAO Form M | COD | OAG | U.S. BTS Form 41 | IEA Fuel Sales Data |
|---|---|---|---|---|---|---|---|
| **Source** | **Operators** | **Operators** | **Operators** | **Radar tracking system + published OAG schedules** | **Published schedules by (scheduled operators)** | **Operators** | **Fuel Suppliers** |
| **Type of Data** | **RTK** at operator level | **RTK** at operator-route level | **Fuel** | **Flight Origin-Destination** translated into fuel burn estimations using simulation models | **Flight Origin-Destination** translated into fuel burn estimations using simulation models | **RTK, Fuel** (purchases and uplift depending on database form). | **Fuel** |
| ***Scope of Coverage*** | Data for approx. 90 to 115 States. | Half of expected data/routes missing in 2010 | Low reporting of fuel burn by States | North America and Europe covered by radar data, rest of the world based on published schedules. Rest of world does not include cargo operations. | Published schedules worldwide. Does not include cargo operations. | U.S. carriers only | Deliveries of aviation fuels to aircraft for international aviation |
| ***Time series available*** | **1980-2012** (partial reporting for number of years) | **2010** *(analyzed)* | **Sample years** | **2010** | **1971-2014** (data from 1992 is available electronically) | **1991-2014** | **1971-2014** |

# D. Comparison of Schemes

## Tasks:

- Continue to analyze potential market distortion across schemes for distributing offset obligations.
- Complete the assessment of complexity of the schemes (illustrate and assess complexity against other dimensions of complexity e.g., monitoring/data collection, reporting/data sharing, computational, mitigation of missing data/reports, cost from MRV).
- Summary of Comparison of Schemes

**For details and analyses in support of this section, see Appendix, pages 24-37**

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

# Potential Market Distortion across Schemes for Distributing Offset Obligations: Approach

- CAEP used a multi-faceted approach to assess potential market distortion across schemes for distributing offset obligations;
  - (1) Computed and compared *cost of offsets relative to fuel costs* across all routes in the global international aviation network modelled (i.e., approx. 29,000 combinations of operators and State to State routes),
  - (2) Assessed and compared absolute cost of offsets vs. operating costs for sample markets,
  - (3) Conducted qualitative assessment/narrative for sample representative markets.

# Summary of Observations on Potential Market Distortion

## Effect of Distribution Schemes:

- Minimum difference in relative cost due to offsets across routes is achieved with 100% sectoral (all routes see the same impacts),
- Largest spread/differences in cost due to offsets observed for 100% individual and Accumulative Approach,
- The extent of market distortion is limited and directly related to the price of the offset

# Summary of Observations on Potential Market Distortion

## Impact on Specific Routes

- Cost differentiation amongst the different offsetting scheme on a route ranges from*
  - 0% to 4.2%** of fuel costs in 2025 at high offset price (1.2%** at low offset price)
  - 0% to 11.8%** in 2035 at high offset price (3.5%** at low offset price),
- Analysis shows that there are inequalities, but that the effects on the ticket prices are small (max ± 50 US$ for a business and ± 10 US$ for an economy ticket),
- The impact of the market distortion is relative to distance between the markets,
- Based on analyses of sample markets, difference in cost increase between two markets is expected to be on the order of a few dollars, which may not result in incentives for switching destinations.

* Percentage are expressed as offset cost versus fuel cost. Unit fuel cost : 3$/Gallon, Unit cost of Carbon 2025 (Low : 8, High : 27) 2035 (Low : 12, High : 40) **Differentiation and final percentage depends of the operator growth

# Summary of Observations on Potential Market Distortion (cont.)

## Effect of Route Based Approach (RBA) / Phase In

- Observed incremental effect of RBA/Phase In that results in reduction in offset obligations on partially exempted routes.

- Differentiation from Route Based Approach with Phase In can create a difference in cost between two passenger/cargo flow markets (same origins and destinations but connecting through different States).

# Summary of Observations on Potential Market Distortion (cont.)

## Effect of Least Emissions State (LES) Exemptions

- Market distortion can be introduced as a results of the fact that (1) the GMBM applies only for international aviation and (2) flights to and from the LES can be exempted,

## Effect of New Entrant Exemptions

- Similar to other adjustments/exemptions, New Entrant exemptions will create difference in costs (especially for schemes involving 100% sectoral approach).

# D. Comparison of Schemes

## Tasks:

- Continue to analyze potential market distortion across schemes for distributing offset obligations.
- Complete the assessment of complexity of the schemes (illustrate and assess complexity against other dimensions of complexity e.g., monitoring/data collection, reporting/data sharing, computational, mitigation of missing data/reports, cost from MRV).
- Summary of Comparison of Schemes

**For details and analyses in support of this section, see Appendix, pages 38-41**

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

# Background

- During the EAG/14 meeting, CAEP presented an initial assessment of the relative complexity associated with the process for computing offset obligations,
- The assessment was extended to other dimensions of complexity, including;
  - **Monitoring, Reporting, Verification (MRV)** i.e., minimum data required for computations of offset obligations vs. data expected to be available from GMBM MRV system
  - **Data gap filling process**
  - **Computational complexity.**

# Approach

- Developed a list of processes/actions by stakeholders, including Monitoring, Reporting, Verification and Computation of Offset Obligations.
- For each scheme for distributing offset obligations;
  - Identified types of data required to compute offset obligations,
  - Mapped exchange of data between stakeholders; (1) Operators, (2) States, (3) ICAO/Third Party.
  - Identified potential roles of stakeholders in the computation of obligations.
- Note: It was assumed that ICAO/Third Party computes final offset obligations based on information collected from States and Operators and communicate it back to States (who then communicate it to Operators).

# Summary of Assessment of Relative Complexity across Schemes

| Stakeholder | Approaches / Dimensions of Complexity Assessed | Basic Calc. (Ind.=100 %/ Sect.=0%) w/o Adjustments | Basic Calc. (0/100), (50/50), or Dynamic w/o Adjustments w/o LES | Basic Calc. (0/100), (50/50), or Dynamic w/ FG and EM Adjustments w/o LES | Basic Calc. (0/100), (50/50), or Dynamic w/o FG and EM Adjustments w/ LES | Basic Calc. (0/100), (50/50), or Dynamic w/ FG and EM Adjustments w/LES | Accumulative Approach w/o Adjustments w/o LES | Basic Calc. (0/100), (50/50), or Dynamic w/ RBA (EAG/11-WP/1) | Basic Calc. (0/100), (50/50), or Dynamic w/ RBA (EAG/11-WP/1) w/ Redistribution | Alternative RBA 1: EAG/12 Concept 5 | Alternative RBA 2: EAG/12 Concept 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Operators (MRV) | Minimum Data To Be Reported by Operator to State and ICAO | N/A* | Operator level $CO_2$ emissions | Operator level $CO_2$ emissions and RTK | Operator level $CO_2$ emissions and Route level CO2 Emissions | Operator level $CO_2$ emissions and RTK Route level CO2 Emissions | Operator level $CO_2$ emissions and RTK Historical CO2 Emissions | Operator level $CO_2$ emissions and RTK Route level $CO_2$ Emissions | Operator level $CO_2$ emissions and RTK Route level $CO_2$ Emissions | Operator level $CO_2$ emissions and RTK Route Level/ Historical CO2 Emissions | Operator level $CO_2$ emissions and RTK Route level $CO_2$ Emissions |
| | Availability of data from MRV | Data could be available from MRV | | | | | Not available from MRV | Data could be available from MRV | | Not available from MRV | Data could be available from MRV |
| | Complexity of data collection for the operator | Low | | Mid | | | N/A | Mid | | N/A | Low |
| ICAO/Third Party | Quantity of data needed for computations of offsets | 0 | 1600 – 16,000 | 6500 - 64000 | 76000 - 290000 | 78000 - 320000 | 3200 - 32000 | 6500 - 64000 | 78000 - 320000 | 71000 - 260000 | 75000 - 290000 |
| | Complexity of data gap filing process | N/A | Low | Mid | High | High | Mid | High | High | High | High |
| | Computations of Offsets | **No difference in computational complexity across schemes** *[CAEP analyses of EAG have shown feasibility of computations for all schemes]* | | | | | | | | | |

* Note: Operator level $CO_2$ emissions needed to compute offset obligations but no information from other operators needed/shared to compute offset obligations

# Assessment of Complexity of the Schemes: *Observations*

- Minimum data required to compute offset obligations are expected to be available from the GMBM MRV system, except for scheme that require historical data.

- Missing data/reports could create complexity. Consequences of missing data correlates with the amount of data required.

- No expected differences in computational complexity across schemes.

# D. Comparison of Schemes

## Tasks:

- Continue to analyze potential market distortion across schemes for distributing offset obligations.
- Complete the assessment of complexity of the schemes (illustrate and assess complexity against other dimensions of complexity e.g., monitoring/data collection, reporting/data sharing, computational, mitigation of missing data/reports, cost from MRV).
- Summary of Comparison of Schemes *(see Appendix B for details)*

**For details and analyses in support of this section, see Appendix, pages 42-45**

## Status:

**- Analytical Tasks Complete to the Best of CAEP's Ability**

# Conclusions

CAEP completed all analyses requested by EAG