An Economist Approach to Sustainable Aviation

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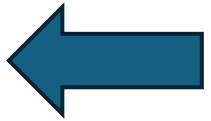
Agenda for this talk

- SUSTAINABILITY AND CLIMATE CHANGE
- EU policy on intra EU aviation
  - Role of ETS – does it work
  - Role of SAF's – does an ambitious blending mandate make sense?
- CORSIA
  - What policies are accepted for stabilizing emissions?
  - Who will participate?
- FUEL EFFICIENCY POLICIES

“Sustainable” – no 0/1 concept – we need to focus on 1 dimension and check whether we do ok for the other dimensions

	LOCAL	GLOBAL
IMPACT	At level of city, region, country	At world level
EXAMPLES	Noise Local air pollution	CLIMATE CHANGE Sea pollution
GOVERNANCE	City, region, country, EU	International organisations



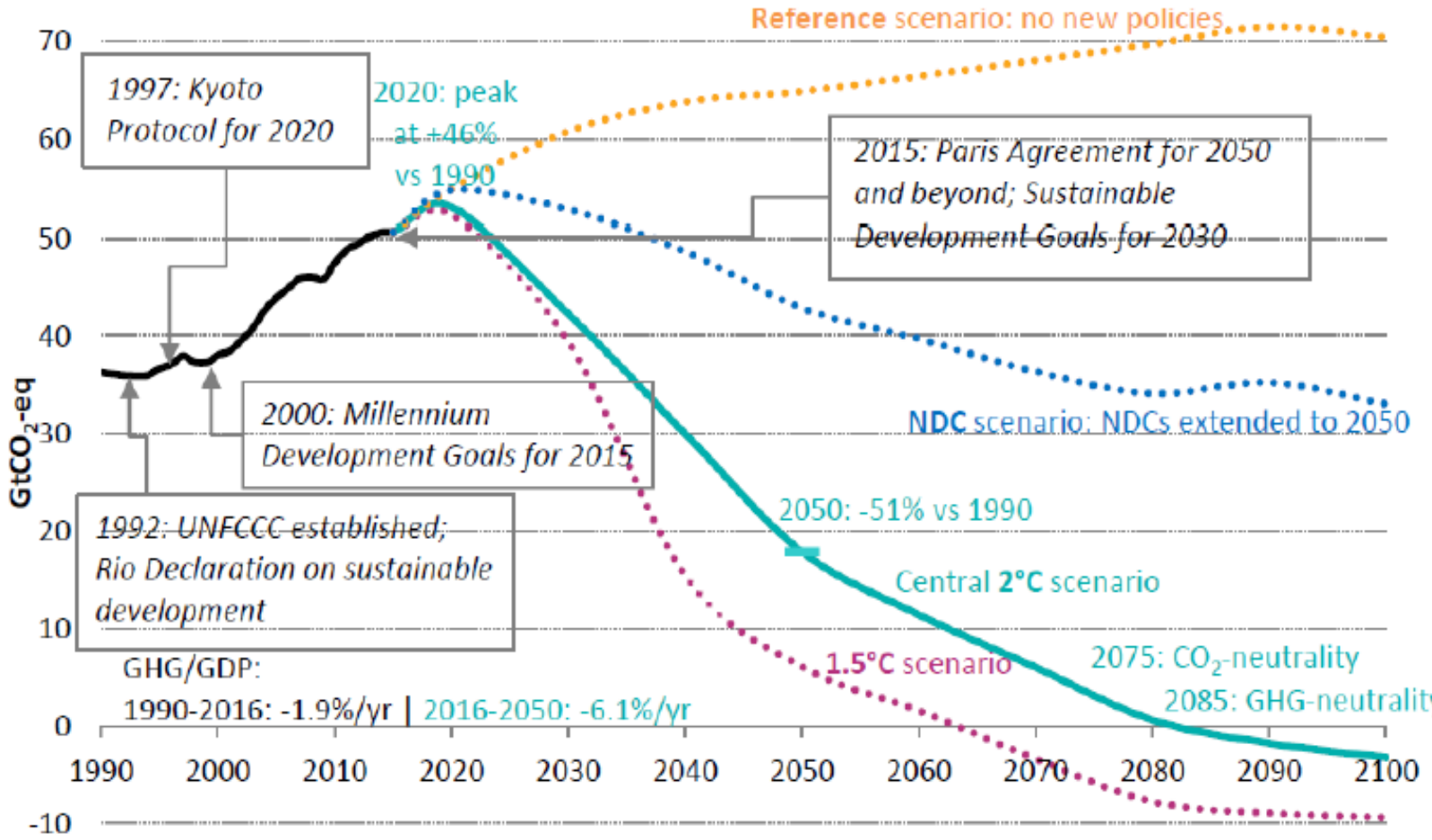
What is the problem?

- Europe is very ambitious:
  - GreenhouseGas (GHG) emissions - 55% in 2030 rather than -40%
  - ZERO net GHG emissions in 2050
- Emissions in Transport keep growing and sector is accused “of not doing its fair share”
- We see calls for urgent action by pressure groups and by governments
- Here: What makes (economic) sense – using a very broad brush?

World Climate Dilemma:

limited climate agreements and green paradox

GHG Emissions per year



GREEN PARADOX:
Whenever only part of the World reduces oil use,
It will be used by the rest Of the world
Compare it to road congestion

National Commitments are Limited
"Commitments" are "promises"
Prisoners dilemma
Costs are for you, benefits are for the others
Compare it to congestion on the road

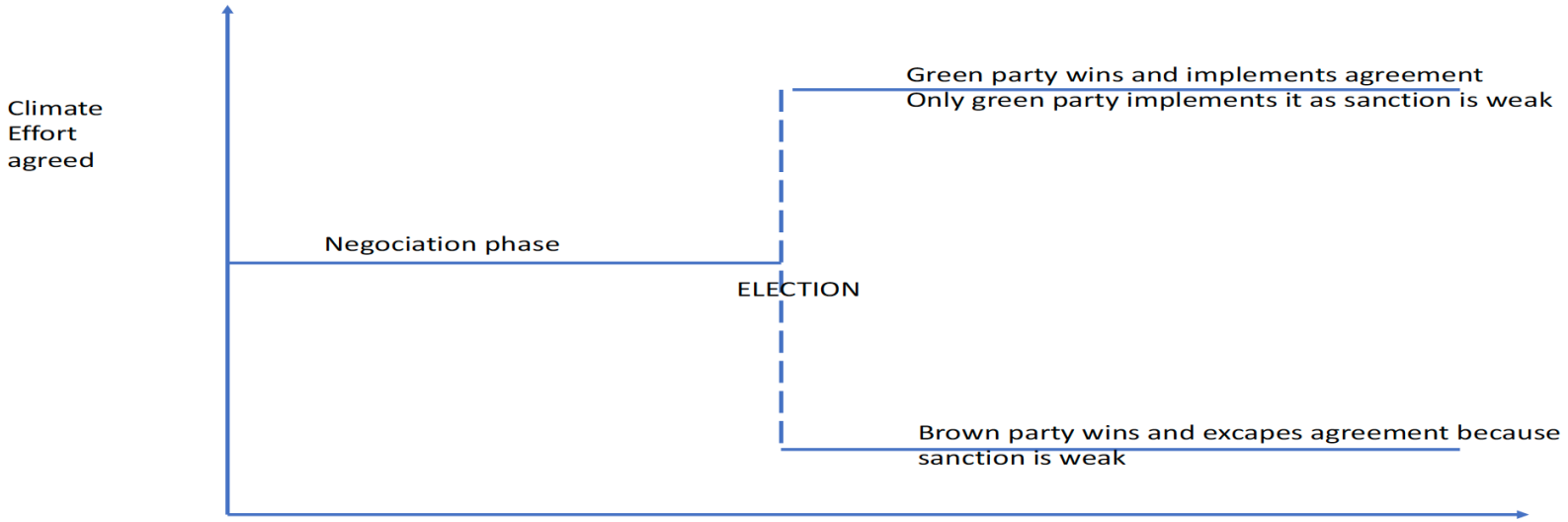
Note: The NDC scenario assumes that the global average rate of decarbonisation implied by the NDCs in 2020–2030 is maintained over 2030–2050. This report mainly describes the central 2°C scenario.

Source: Poles-JRC 2018

Some political economy: Climate is a world public good, action needed BUT…

- Ambitious international agreements (Paris 2015) – 0 net emission in 2050
- But only very modest action in the world
- Why do we still see “ambitious” international agreements?
  - Role of international agreements for local policy purposes (Battaglini and Harstad, JPolEcon 2020)

International agreements that are not enforced is equilibrium for brown and green parties



Agreements that are signed promise a lot and this gives options for

a) Brown incumbents not to comply with the agreement when they are re-elected
b) Green incumbents to comply with the ambitious agreement when they are re-elected
   But they will limit their commitments such that they still need to be re-elected

What do we see?

- USA: stop and go
  - Obama signs Paris agreement and promises action
  - Trump withdraws from Paris and invests in new fossil fuel production
  - Biden re-enters Paris agreement and starts active climate policy with industrial policy component
  - Trump/Biden…
- China: limited climate policy with strong industrial policy component
  - Photvoltaic, electric cars, wind power..
- EU: strongest and consistent climate policy
  - will be forced to stress industrial policy
  - Scale back somewhat ambitions because of opposition of populist parties

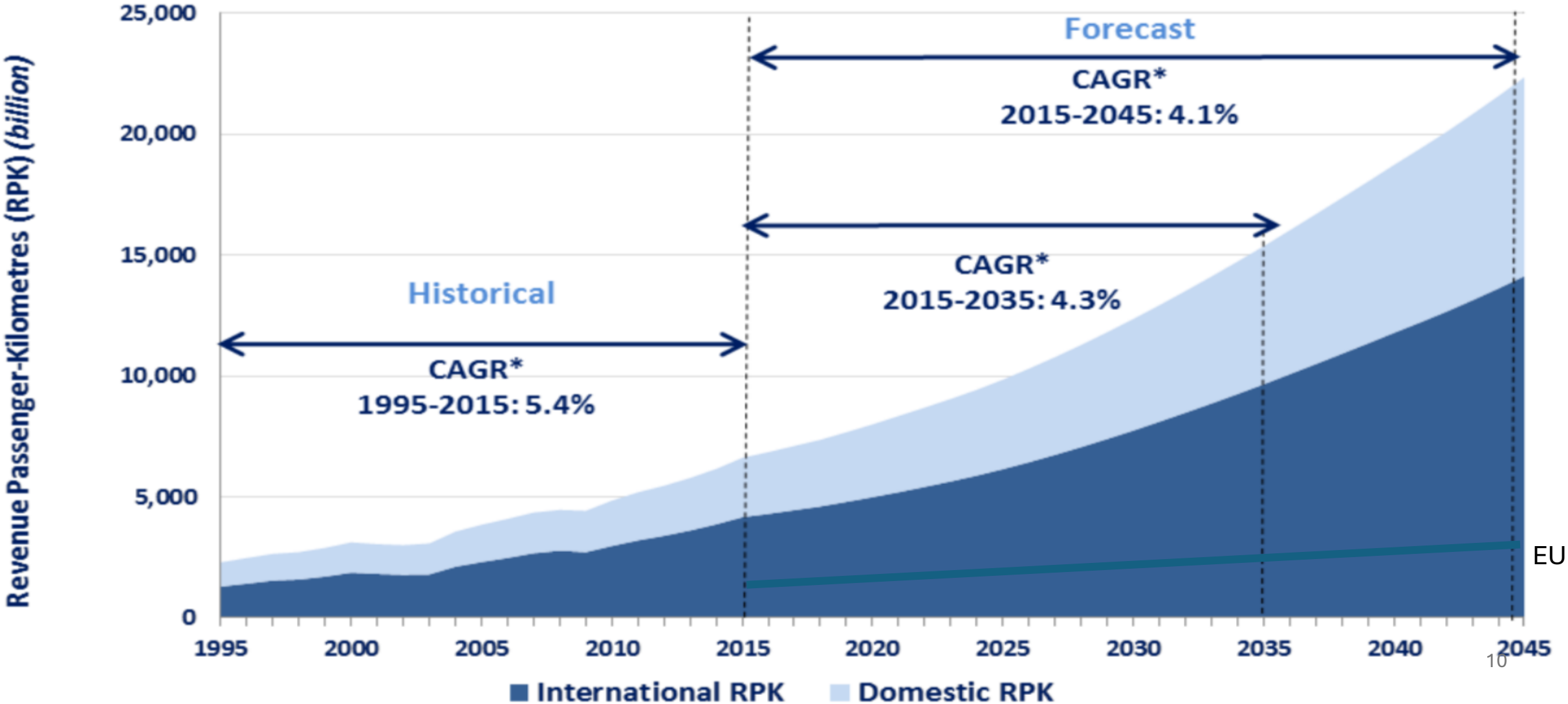
Aviation is a fashionable Climate Topic…

- “Flygscam” : we should feel guilty when we fly…
- Intra EU: use HSR instead of flying
- “Flights are too cheap, the Ryanairs are the probleem”

Aviation activity growth in the world

(source: ICAO 2018)

Strong growth expected outside EU and US due to economic growth



EU share

Aviation CO2 emissions	Within EU	EU to ROW ROW= Rest of World	ROW to ROW	Within ROW country
WHERE (sum=100%)	14%	22% growing	>16% growing	<48 growing
Int Agreem	Paris	Corsia	Corsia	Paris
Policies	EU-ETS SAF (Fuel eff)	Offsets (SAF) (Fuel eff)	Offsets (SAF) (Fuel eff)	….
Issues	EU-ETS SAF target?	Offset price SAF efficiency? Participation?	Offset price Participation?	……
Extra issue	Non – CO2 gasses count for 1,7 times more global warming than CO2 (Lee, et al. 2021)			

Aviation: small (3%) but growing part of total emissions worldwide

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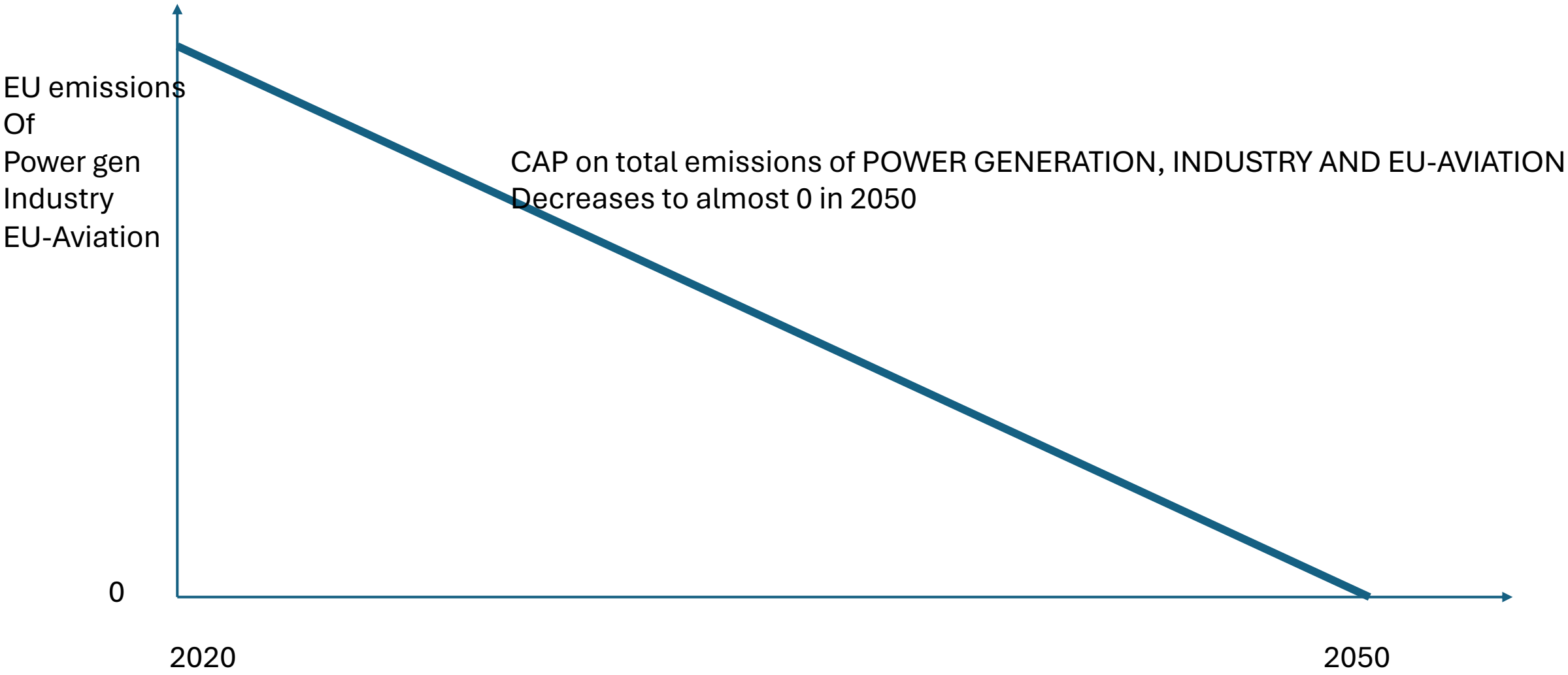
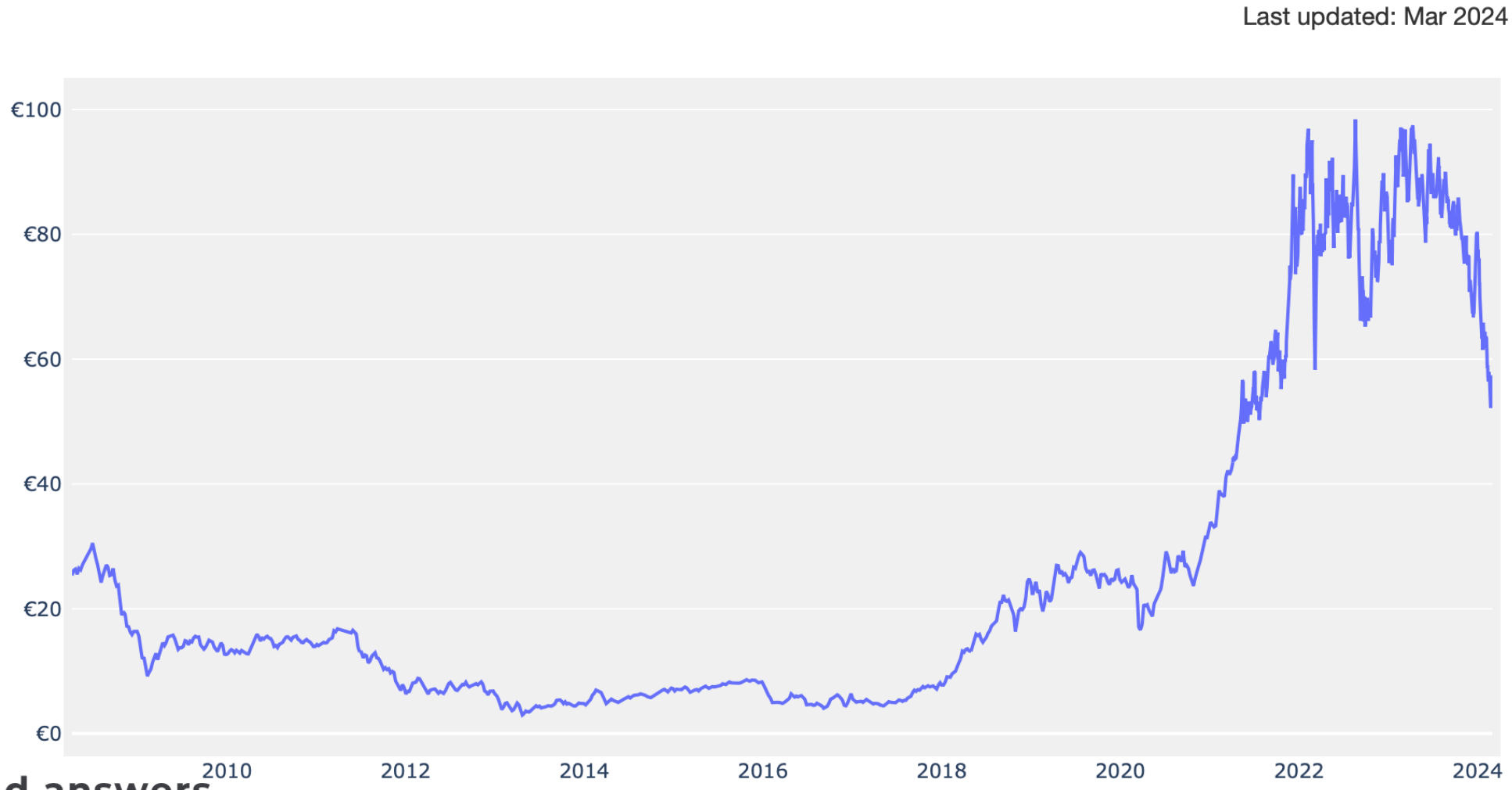
EU climate policy



European Emission Trading system as crucial instrument

- It is a global bubble for emissions of 3 sectors: electricity generation, industry and intra-EU aviation that decreases progressively to net ZERO
- Emission permits are partly grandfathered (distributed for free in function of past emissions)
- Emission permits are tradeable (among sectors) and are bankable (can be used in later periods – hedging possible)
- Emitters with emission abatement costs lower than permit price will sell to high cost emitters
- Equilibrium price signals the marginal abatement cost in the three sectors

EU ETS prices



Source: Sandbag economics

EU-ETS is important and not well understood

- QUIZ (for European politicians)
  - if I replace my flight Brussels to Vienna by a train journey, will this increase or decrease emissions of CO2 in Europe?
  - Answer is
    - Flying emits per passenger 100 g CO2/pkm so for 1000 km it means 0,1 ton CO2
    - Electric trains need electricity and this requires a little bit of CO2 so may be 0,01 ton CO2
  - But both are part of the ETS system, so net additional CO2 emissions are ZERO, discouraging flying within the EU is pointless for climate reasons
    - Exception: other GHG gasses at high altitude (Nox, ozone, factor 1,7..)

Strong empirical evidence that ETS works for aviation

Fageda and Teixido (2022) analyze empirically the effects of the EU-ETS that applies to intra EU aviation. They show

- that the emission permits, also when they are grandfathered, work: they reduce emissions

- the effect is larger for routes where an alternative (rail) exists

- a larger effect on the low-cost airlines (Easy-Jet and Ryanair…) .

Design of empirical study of Fageda et al (2022)

- Analyze the difference in emissions in 2013-2016 between routes
  - Departing in EU and arriving in EU (“treated”)
  - Departing in EU and arriving in Europe (but not in EU) (“not treated”)
- Observation at the airline-route level :

  , the total number of seats, frequencies, aircraft size, distance flown, the operating airline and the aircraft type
- Using diff in diff method (panel data correcting for common factors in treated and non-treated observations)

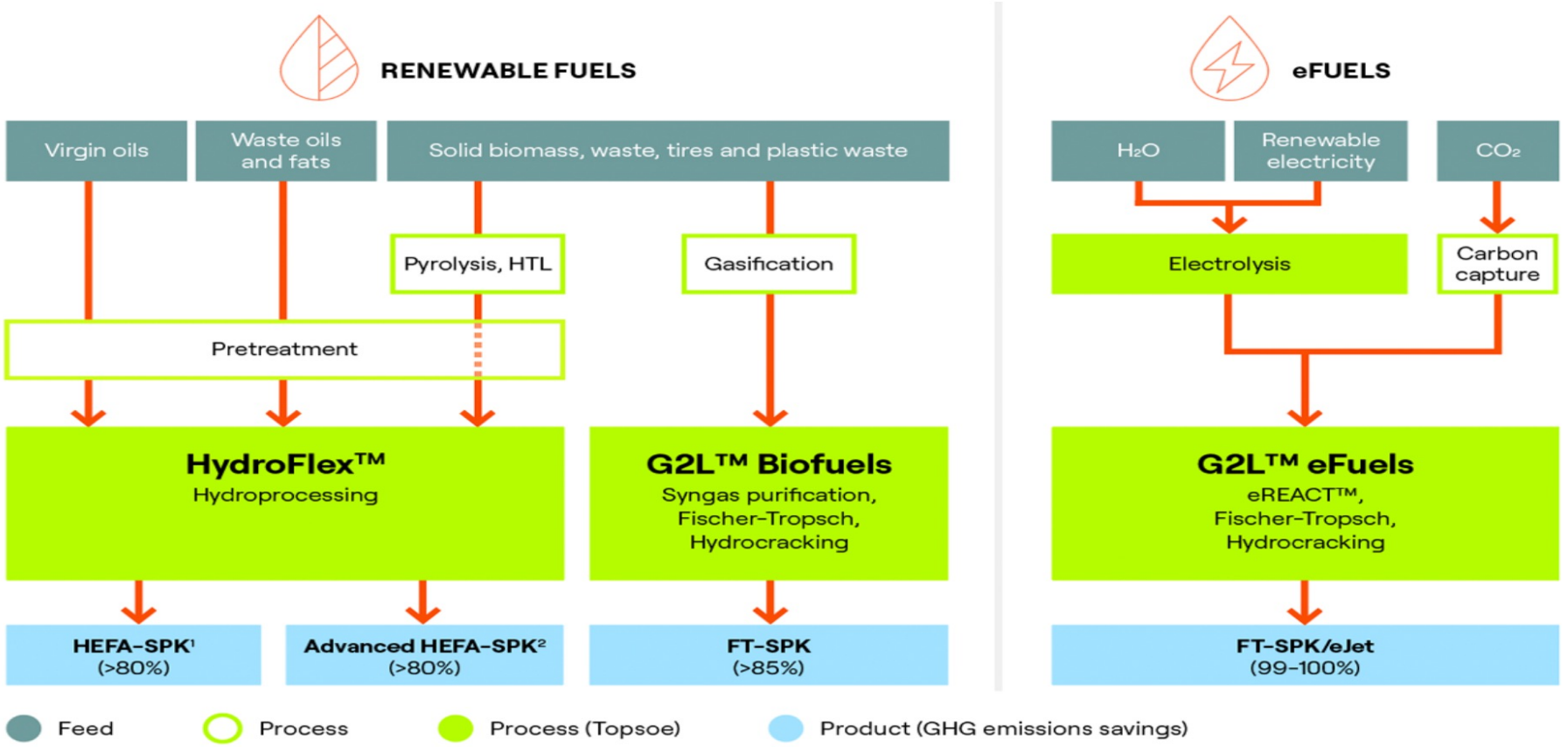
Routes within ETS and outside ETS

Notes: This map shows countries in the European Economic Area-EEA (in blue) and other countries sampled (in yellow). Treated routes are those flying *within* the EEA countries.

Fig. 2. Map with EEA countries and control countries.

2. EU: use more SAF's – what SAF's?

Source picture: Topsoe A/S



Net emissions up to 80%, cheaper but limited capacity

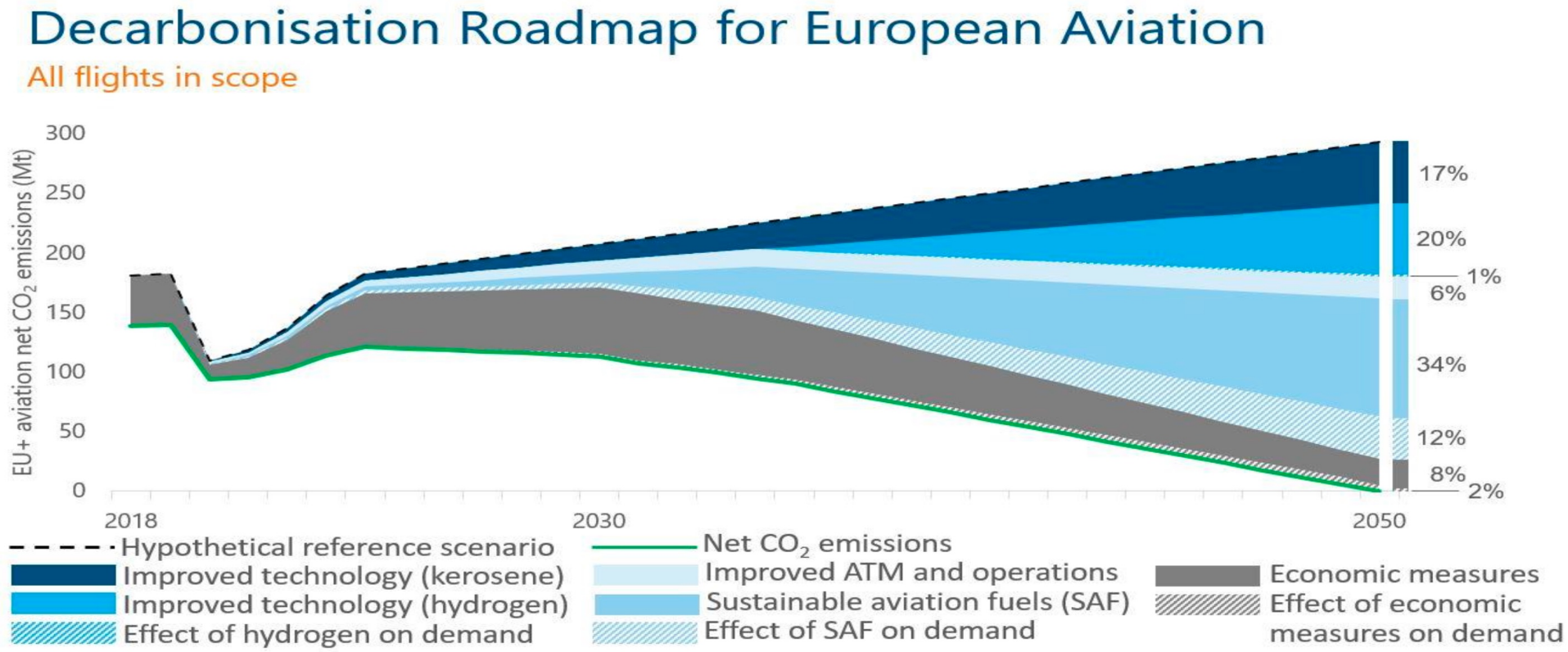
Net emission 15% but very expensive

2. EU: are drop-in Sustainable Aviation Fuels (SAF) the way to reduce emissions by 60% in 2050?

- SAF fuels comply with sustainability criteria (no food substitution and no biodiversity degradation) – they are not carbon free but emit only 15 to 80% of CO2 from kerosene (see Mayeres et al paper)
- They are “drop-in” so can use current aircraft technology and distribution infrastructure
- Two types
  - bio material that is converted into liquid fuels (costs 1,5 to 4 times the price of kerosene and supply is limited)
  - E-fuels: based on captured C02 combined with green Hydrogen (costs 3 to 6 times the price of kerosene

How does the aviation sector expect to reduce intra-EU emissions to almost zero ?
- a consultancy view from SEO

REDUCING CO2



Source: Destination 2050.

seo • amsterdam economics

SAF blending mandates 2 to 63% in 2050

- Argument PRO: “this is needed to arrive at carbon neutral aviation in 2050 and to make sure aviation does its fair share. The current prices of kerosene (including ETS permit costs) are insufficient to pay for the supply costs of SAF”.
  - Technological progress: yes but we have already experience with blending biofuels for cars, so potential is limited
- A blending mandate is in fact a tax on kerosene used to subsidize SAF
- Argument contra:
  - it is much more costly in welfare terms than letting the ETS prices do their job, certainly if one includes the CO2 emitted in the processing of the SAF’s (15 to 80%)

SAF – blending argumentation Contra

- As EU-ETS Permit prices will increase to reach NET ZERO emissions in 2050,
  - Permit prices will be a stimulus for SAF but also for more fuel efficient aircrafts and decreasing flight activity
  - Pure R&D subsidies for SAF may be useful
  - Other techological options will appear – negative carbon options (Carbon Capture Storage)…and can compensate aviation emissions
- Conclusion: There are cheaper policies around than the blending mandates: let EU permit prices do their job

Example of Blending mandate

Biofuel costs 100 % more than kerosene

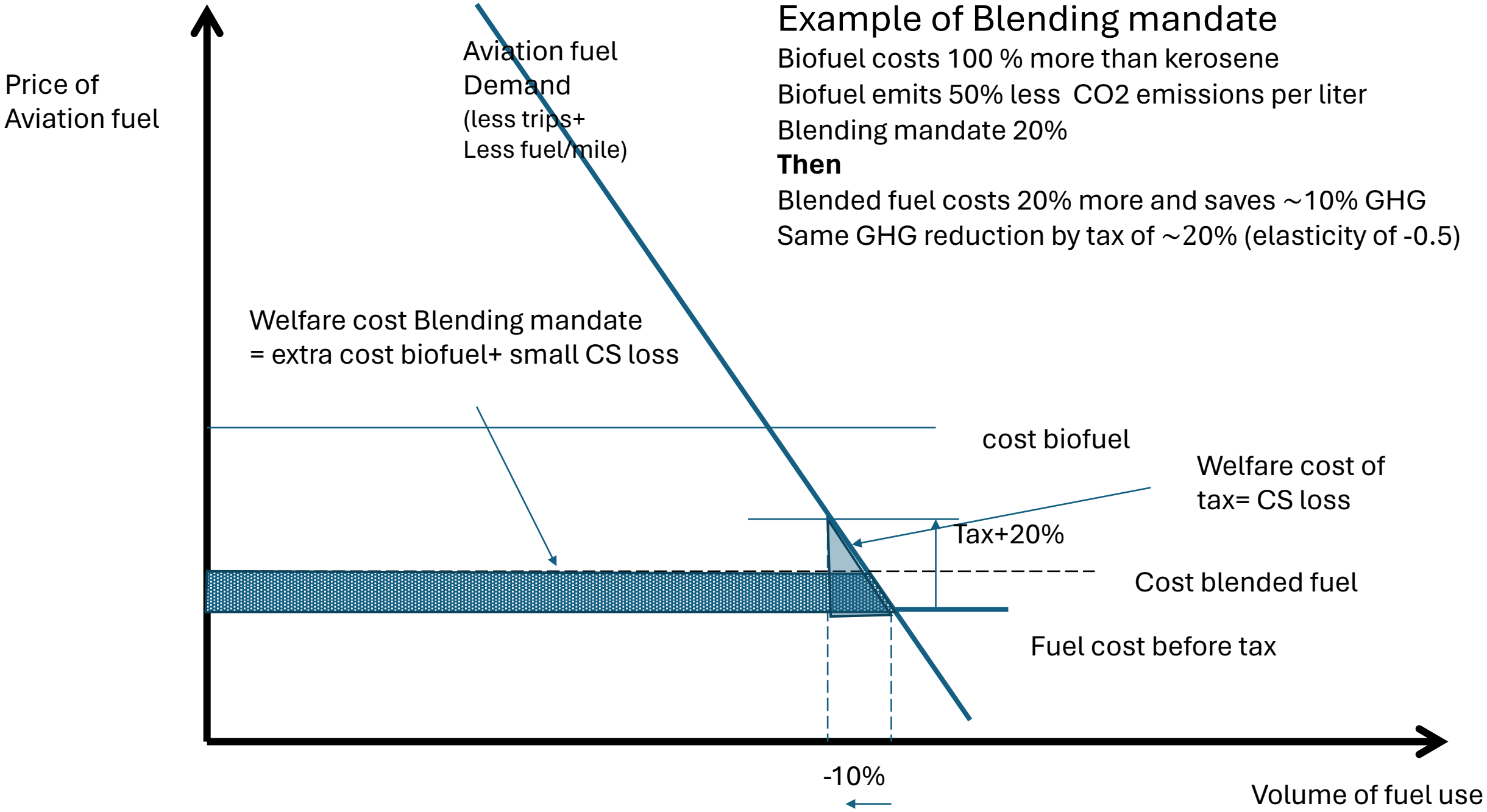
Biofuel emits 50% less CO_2 emissions per liter

Blending mandate 20%

Then

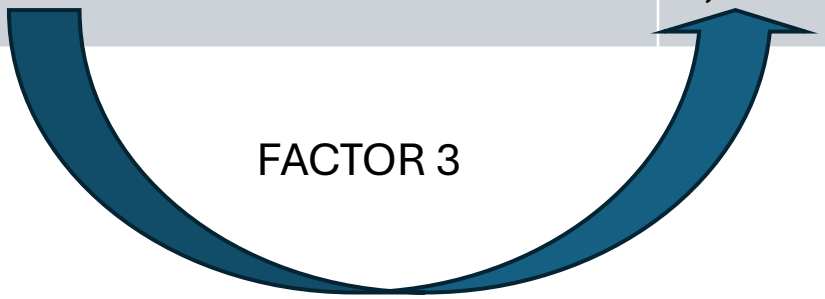
Blended fuel costs 20% more and saves ~10% GHG

Same GHG reduction by tax of ~20% (elasticity of -0.5)



Why the aviation sector prefers SAF's

Fuel price elast =-0.5 Extra production cost SAF that is carbon neutral =100%	18% blending rate	Permit price of 100 € =50,8% higher fuel price
Emission reduction	-25,4%	-25,4%
Fuel price for airlines	+18%	+50,8%
Consumer surplus	-0,172	-0.44
Tax or permit revenues	0	+0,38
Gross Welfare cost	0,17	0,06



Derivation of the relative cost-efficiency expressions for SAF blending policies

.Setting initial fuel quantity for aviation $q°=1$ and kerosene fuel price $p_e=1$, aprice elasticity of fuel demand (in absolute value) ϵ (sum of flight volume reduction effects and more efficient airplane effects) and using an additional cost of SAF of n, a relative emission of carbon of $\beta(<1)$ for SAF, we have for a blending rate l_m:

The price of blended fuel becomes

$$p = (1 - l_m)p_e + l_m(1 + n)p_e = (1 + l_m\, n)\, p° \qquad \text{A.9}$$

The emission reduction of the blending mandate consists of two parts. First via reduction of kerosine consumption that results from the price increase = $\epsilon\, l_m\, n$

And second via the use of biofuels with relative emission β equals the share of biofuels times the emission reduction per unit of fuel times the remaining fuel use = $l_m\,(1-\beta)(1-\epsilon\, l_m\, n)$

The same total reduction of emissions by a simple fuel tax or permit price on non-blended kerosine requires a fuel tax t* of

$$t^* = (1/\epsilon)\{\epsilon\, l_m\, n + l_m(1 - \beta)(1 - \epsilon\, l_m\, n)\} \qquad \text{A.10}$$

The welfare cost of the reduction of emissions via a blending mandate equals consumer surplus loss due to higher fuel cost

$$(1 - 0{,}5\,\epsilon\, l_m\, n)\, l_m\, n \qquad \text{A.11}$$

While the welfare cost of a fuel tax achieving the same reduction of emissions

$$0{,}4\, t^{*2} \qquad \text{A.12}$$

2. How can Aviation reduce its carbon emissions in the EU?

- What is the objective? Reduce aviation CO2 emissions to 0 in 2050?
  - NO – the objective is to reduce total EU-emissions to net 0 in 2050
- This will be achieved in different ways:
  - Less flights
  - More fuel efficient flights (better aircrafts)
  - Less carbon intensive fuels
  - Compensating emissions reductions (Carbon Capture and Storage..)
- Stimulated by
  - EU permit price
  - Subsidies for R&D

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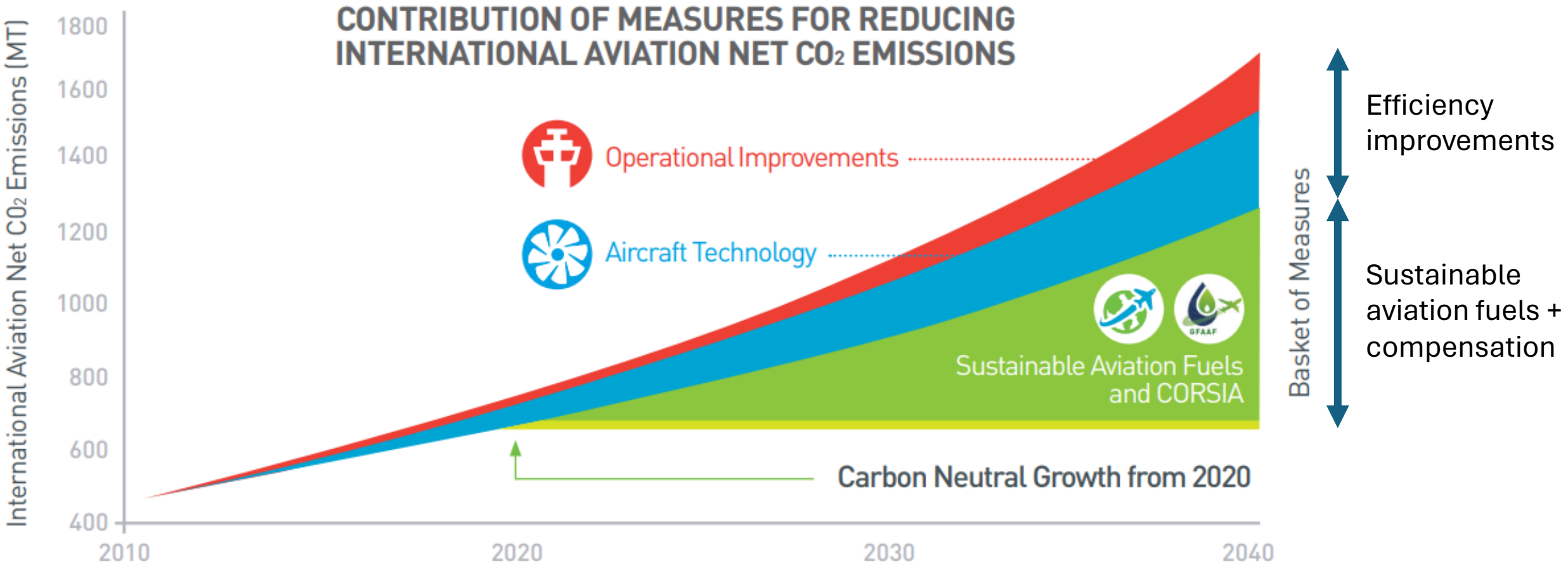
Aviation: small (3%) but growing part of total emissions worldwide

3. CORSIA – agreement: will it work – 1 ?

- CORSIA agreement: any 2 signatories promise to stabilize emissions on their bilateral flights
- “signed” by many countries – still to be operationalized by most countries
- International agreements that are not enforced can give stop and go national policies

INTERNATIONAL CIVIL AVIATION ORGANIZATION view on HOW to stabilise emissions



ICAO – civil aviation forum (2018) “Corsia brochure”
https://www.icao.int/environmental-protection/Documents/CorsiaBrochure_8Panels-ENG-Web.pdf

3. CORSIA – agreement: will it work -2?

- CORSIA agreement: any 2 signatories promise to stabilize emissions on their bilateral flights
- Agreement on HOW to stabilize emissions on bilateral flights?
  - By “Offsets”(compensation for aviation emissions in another sector of the economy)
    - not yet well specified, there are offsets on the market for less than 10 €/ton of CO2 ?
    - Offsets raise the question of additionality: are they a real additional effort not yet covered by other climate policy commitments?
  - By SAF’s: but criteria are very weak: SAF’s need to realize minimum savings of CO2 of only 10%, (Criteria 1.1 of CORSIA) – this means a SAF fuel that saves in net terms only 10% of emissions count for 100% compensation
  - this means “anything goes”.. and the EU “signed” but does not agree with these criteria – will make up its mind in 2027

When will a country join CORSIA?

Country A will always join country B in the CORSIA agreement if its own marginal climate damage d_A is larger than or equal to half of the price of the offset

The benefits of participation are increasing in the growth rate of air transport activity if the marginal damage d_A is larger or equal than half of the price of the offset.

National Climate damage assumption (OECD , 2021,“revealed “ climate tax or permits) only EU, USA, Japan and Canada would join CORSIA

ASSUMPTION	CO2 damage €/ ton
EU	28,2
US	13,2
China	5,4
India	7,8
Australia	12
UAE	0,3
Russia	4,2
Canada	20,4
Japan	14,4

ASSUMPTION	Offset price of 31 €/ton CO2

		Country B									
		Australia	Brazil	Canada	China	EU28	India	Japan	Russia	USA	UAE
Country A	Australia			-0.20	-12.74	-0.44	-0.51	-1.11		-1.49	-6.05
	Brazil			-1.94		-35.06				-53.02	-8.87
	Canada	3.19	1.00		35.62	38.34	3.60	3.56		112.12	2.80
	China	-56.04		-46.34		-123.83	-26.30	-135.49	-47.15	-60.07	-38.05
	EU28	3.68	44.27	79.88	215.53		77.18	84.57	99.92	419.47	165.96
	India	-1.53		-2.70	-19.17	-32.68		-3.39	-12.71	-10.33	-91.00
	Japan	0.82		0.58	8.51	3.97	0.20		0.58	9.34	0.34
	Russia			0.00	-53.73	-59.23	-19.96	-5.83		-4.24	-16.62
	USA	1.07	-2.23	-4.53	4.14	0.00	-1.14	84.97	0.03		-2.60
	UAE	-42.52	-9.07	-5.82	-60.18	-157.12	-196.76	-8.63	-23.24	-52.86	

Table 7: Net gain or loss for a country in Mill €/ year in 2040 from participating in CORSIA, given an offset price of 31 euro/ton CO2

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4. More efficient airplanes: market dominated by duopoly

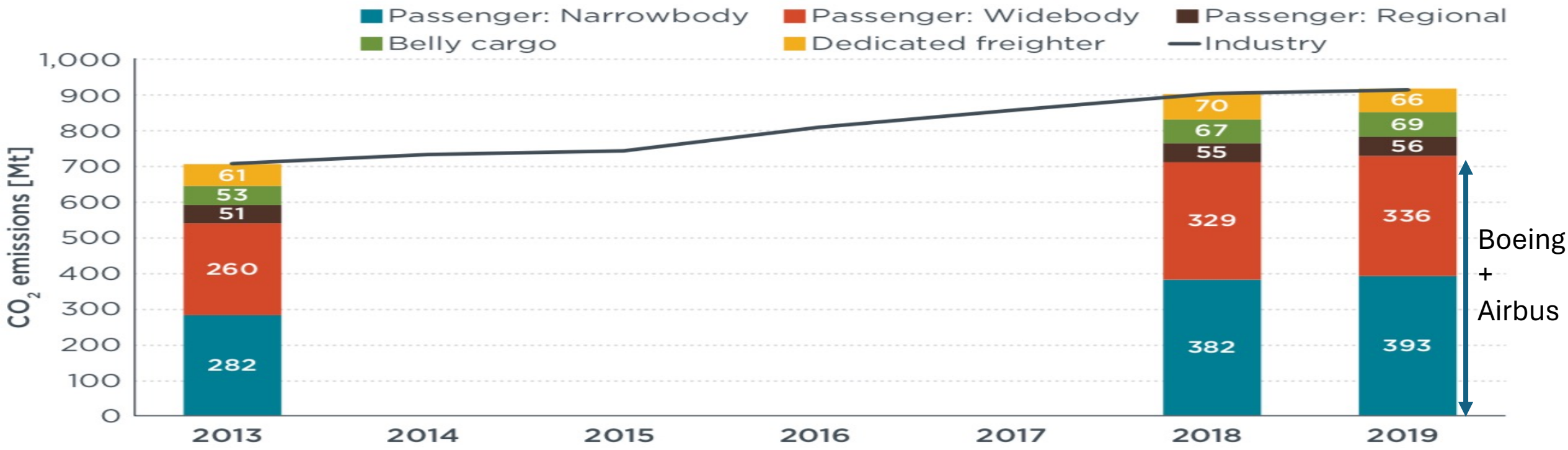
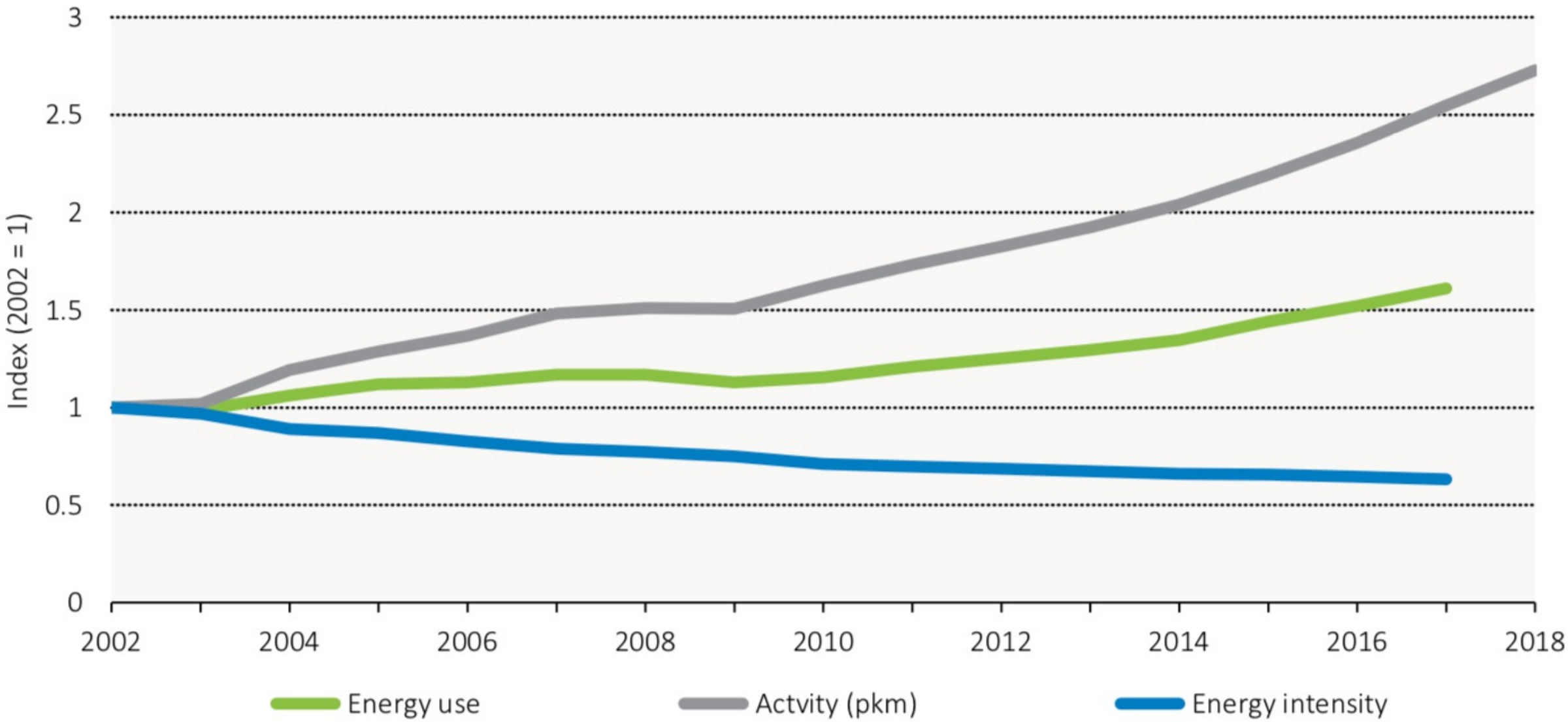


Figure ES-1. CO_2 emissions by operations and aircraft class in the three analyzed years.

- Manufacturing of (large) airplanes is dominated by duopoly of Boeing (45%) and Airbus (45%)
- Setting a much stricter efficiency standard in Europe, Airbus may lose market share to Boeing (USA), but cooperation may work

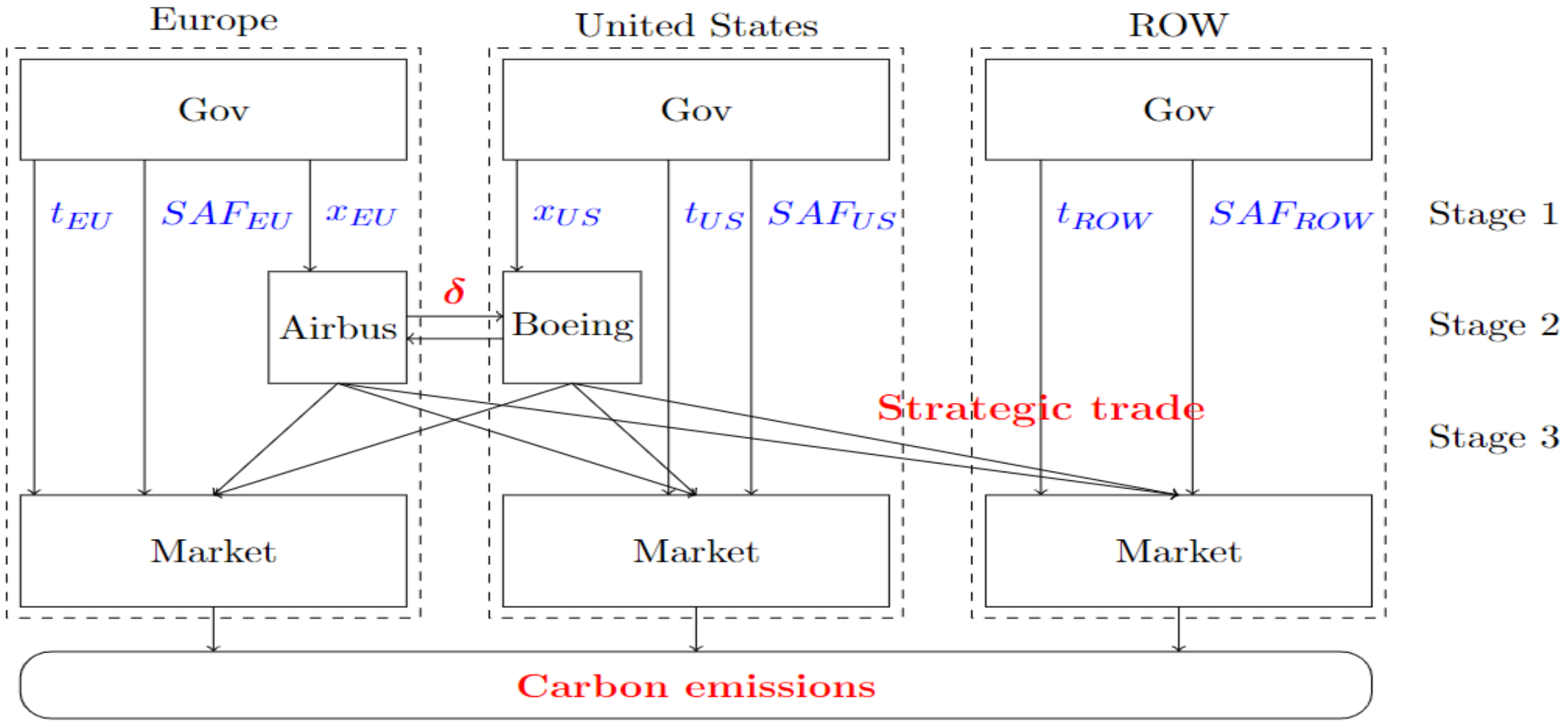
Figure 1. Change in energy use, activity and energy intensity of passenger air transport, 2002-18



Source: Adapted from IEA (2018a); IEA (2020a); ICAO (2019a).

x= Investment in R&D
T= permit price or tax

World aviation model overview



Model characteristics

- 3 regions (Europe, United States, and Rest of the World),
- 3 decision stages
  - Stage 1: government policy
  - Stage 2: producer R&D effort x
  - Stage 3: producer output
  - Competitive air transport markets buy aircrafts
- 3 inefficiencies in red (R&D spillovers δ, strategic trade, and externality of carbon emissions)
- 8 policy instruments in blue: 3 taxes, 3 SAF blending rates, 2 efficiency standards.

Table 2. Policy instruments and the resulting demand, emissions, and welfare for five cases: no policy instruments, no cooperation, EU-US cooperation without ROW changing its domestic tax, EU-US cooperation with ROW changing its domestic tax, and finally worldwide cooperation.

		No instruments (1)	No coop (2)	EU-US cooperation ROW fixed (3)	EU-US cooperation ROW reaction (4)	World coop (5)
Fuel tax t_{ROW}	€/l	0	0.19	0.19	0.37	0.05
Fuel tax t_{EU}, t_{US}	€/l	0	0.16	-0.32	-0.32	0.05
Efficiency x_{EU}, x_{US}	%	6.5	10.9	13.0	13.0	21.1
Demand EU/US	Tpkm/y	2.04	1.86	2.51	2.51	2.10
Demand ROW	Tpkm/y	5.11	4.54	4.59	3.99	5.21
Relative emissions	%	100	85	92	85	86
Total welfare	B€/y	62.5	69.1	66.9	65.9	73.4
Welfare EU/US	B€/y	35.9	31.5	33.6	30.3	33.8
Welfare ROW	B€/y	-9.2	6.1	-0.3	5.2	5.9
CS EU/US	B€/y	20.8	17.3	31.4	31.4	21.7
CS ROW	B€/y	52.0	41.1	42.0	31.8	54.2
PS EU/US	B€/y	45.7	34.6	47.8	42.7	36.7
Tax revenue EU/US	B€/y	0	5.9	-15.8	-15.8	1.8
Tax revenue ROW	B€/y	0	17.5	17.3	29.2	4.4
Damages EU/US	B€/y	30.6	26.2	29.8	27.9	26.4
Damages ROW	B€/y	61.3	52.5	59.5	55.9	52.7

More efficient aircrafts: insights

- A unilateral efficiency standard (EU imposes fuel efficiency and subsidizes R&D for fuel efficiency) can be useful as indirect instrument to reduce aviation emissions in the WORLD if the rebound effect is limited.

- Rebound effect can be limited if the ROW has a reasonable carbon permit price

Summing up on Sustainable aviation

- Within EU: go for lowest cost of emission reduction in the economy: ETS
  - Adjust requirement for aviation to 1,7 CO2 permits for aviation to account for contrails etc.
  - Emission permit systems allow to achieve a nation-wide target at lowest cost
  - Could very well be paying for carbon capture and storage
- Extra EU : CORSIA is at present mainly window dressing
  - Quality criteria for SAF's and offsets are not acceptable
- Airline industry
  - fuel (carbon) efficiency is incentivized by
  - High carbon and permit prices – mainly at EU level and this is insufficient
  - Potential for subsidy-fuel efficiency deals for Airbus-Boeing
- SAF- industry
  - Production dispersed over many countries
  - Not sure whether SAF blending mandata will work

Sources

Overall EU policy in transport sector

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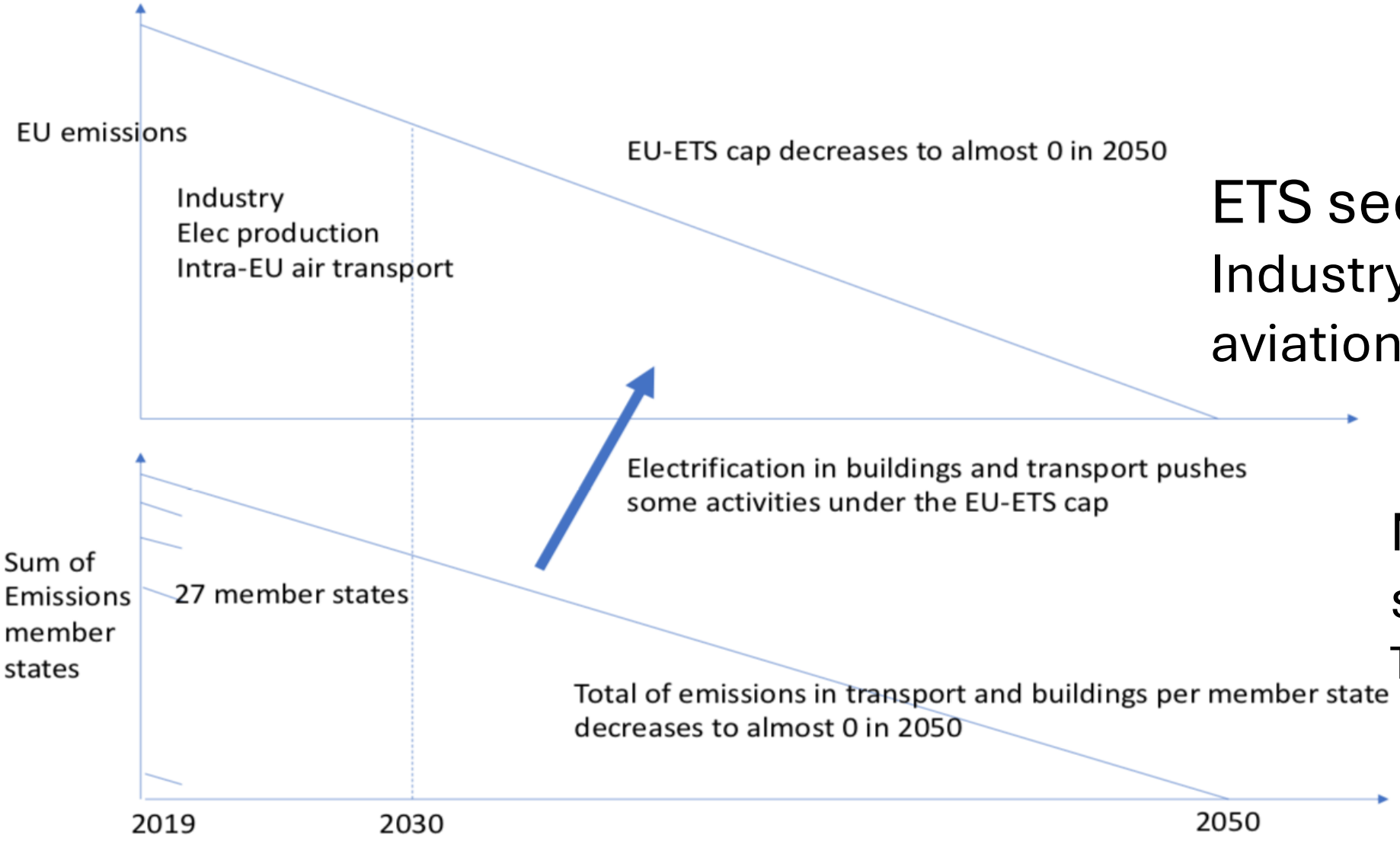
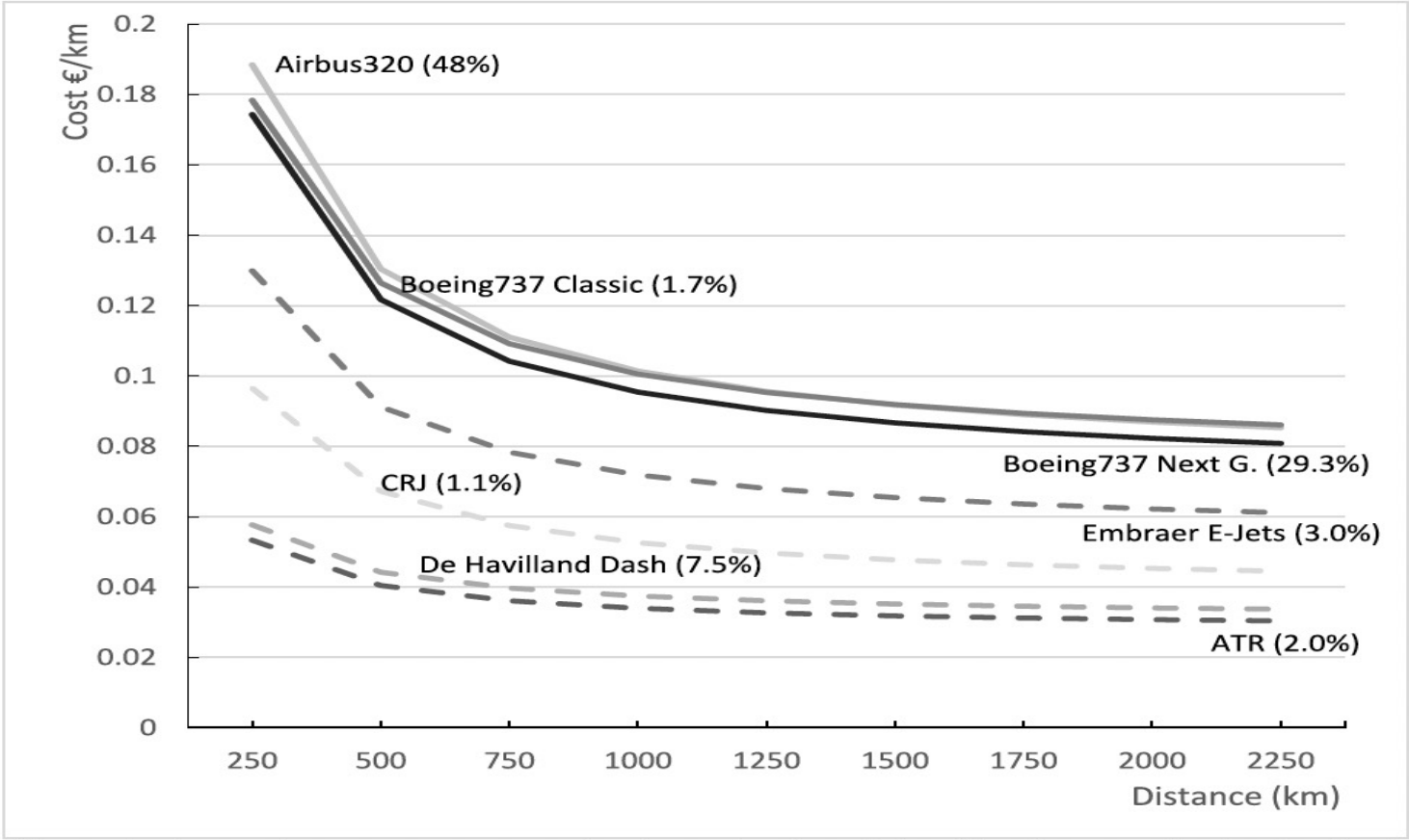
Structure EU climate policy



ETS sectors
Industry, Electr, EU aviation

Non- ETS sectors
Transport

Emissions for departure are important and this means that short haul flights emit more on average per flightkm



Notes: This graph shows the average cost per km by main aircraft families (in parenthesis, the % of flights in intra-European routes in 2016). Solid lines plot mainline jets, with capacities between 150-180, and dashed lines plot regional jets, with smaller capacities and used mainly on shorter distances and connecting flights. Notice that 77% of flights are operated with the Airbus 320 family (this includes A318, A319, A320 and A321) and Boeing 737 Next Generation family (B737-600/700/800/900).

Fig. 1. Carbon costs per km at average carbon price (2013–2016) by aircraft family.

Source:
Fageda et al 2020

More flights intra EU but Emissions of Flights outside the EU are more important than intra EU