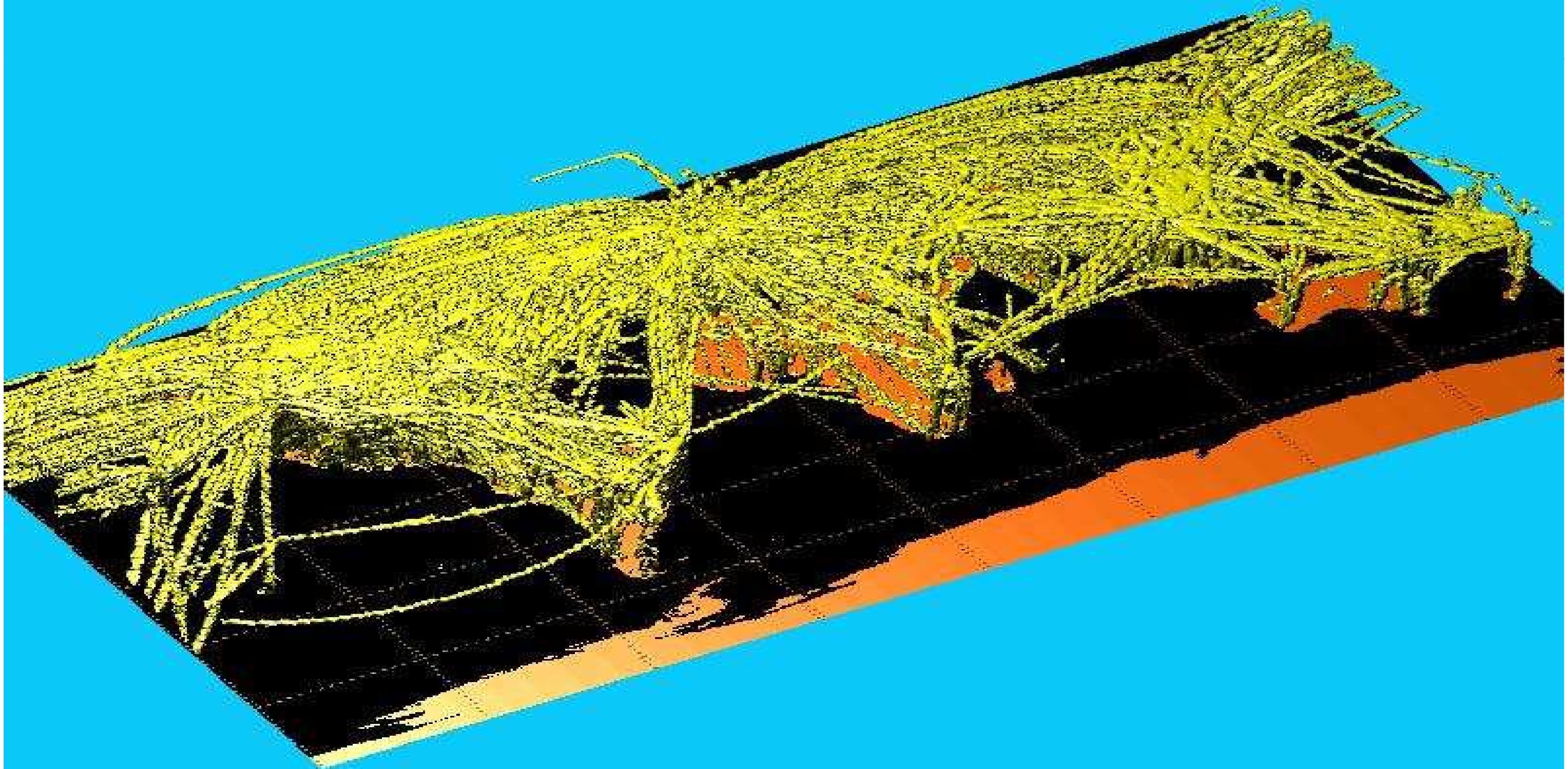
Technology Developments and Aviation Growth to 2050
Demand, Targets, Technology, Fuels and Market-Based Measures

Chris Eyers
QinetiQ

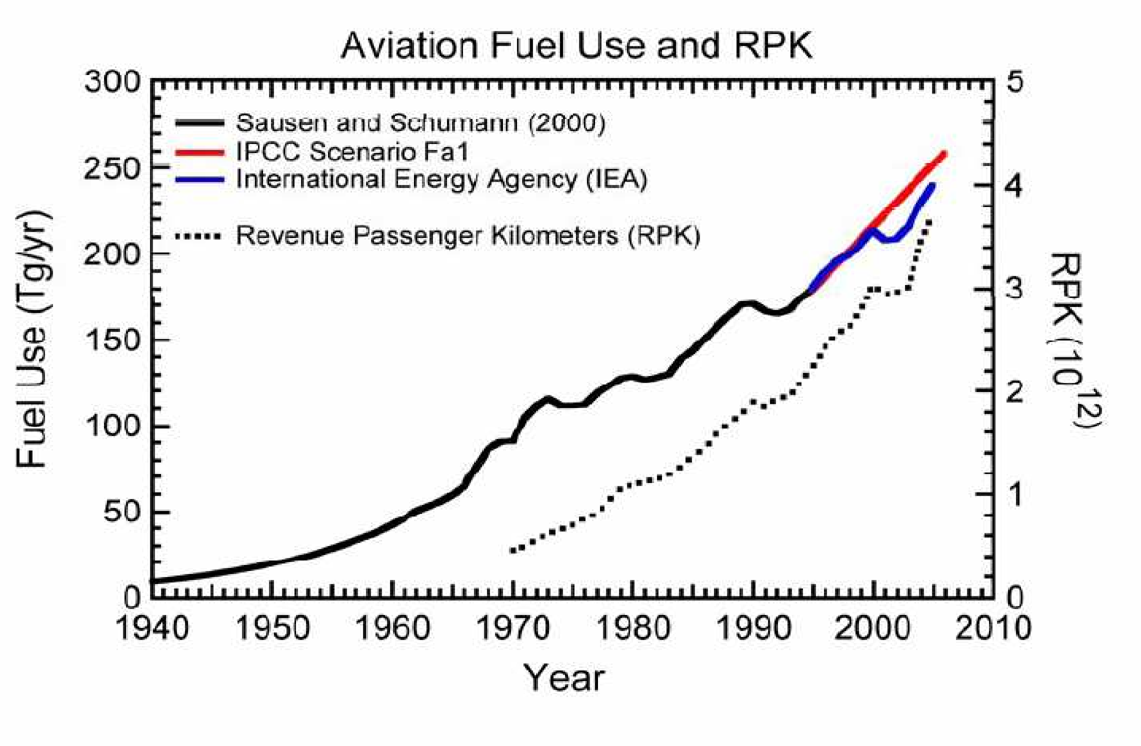
Brussels
26 Mar 2010



1
Demand

1 Demand History

- 4-5% per year
- “delayed“ by external factors:
  - Recessions
  - Wild card events
- Historically, “delay” is partially recovered

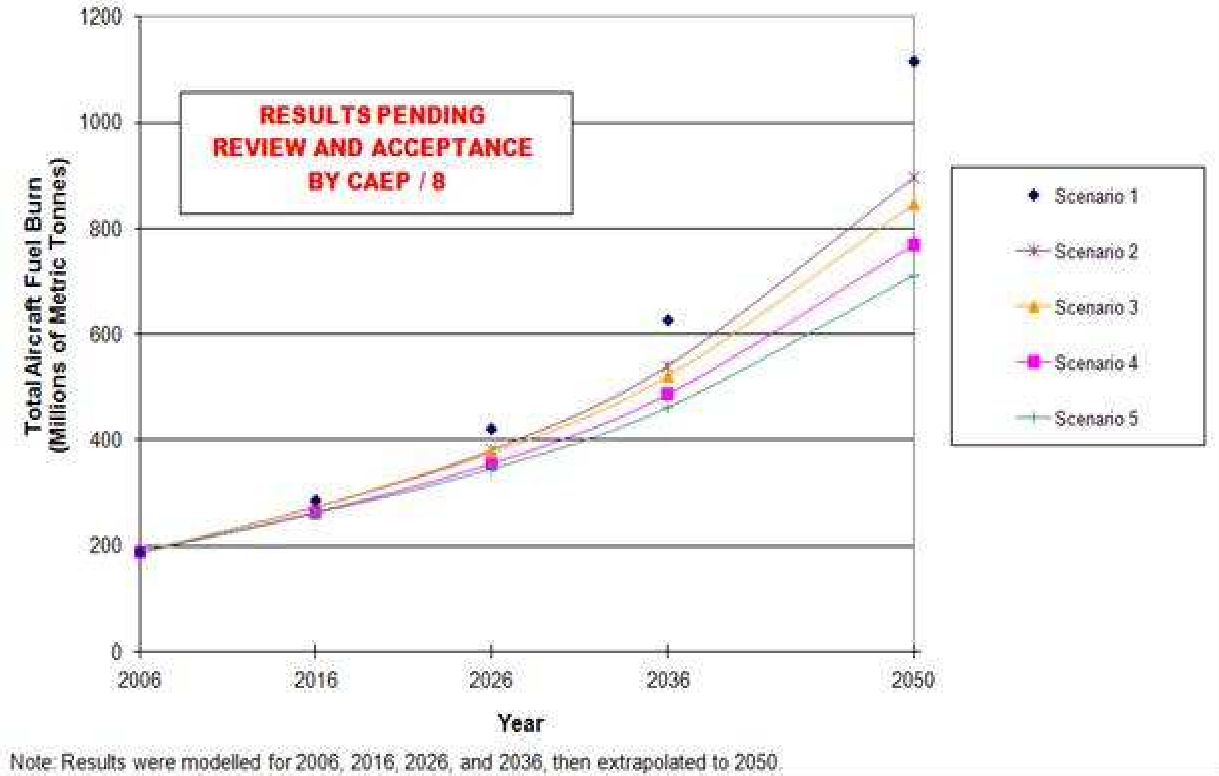


Lee et al, Aviation and Global Climate Change in the 21st Century

1 Forecasts and Projections - CAEP

Scenario 1 is a CAEP "BAU-type" projection including moderate technology and operational improvement

Other scenarios include technology and operational improvements



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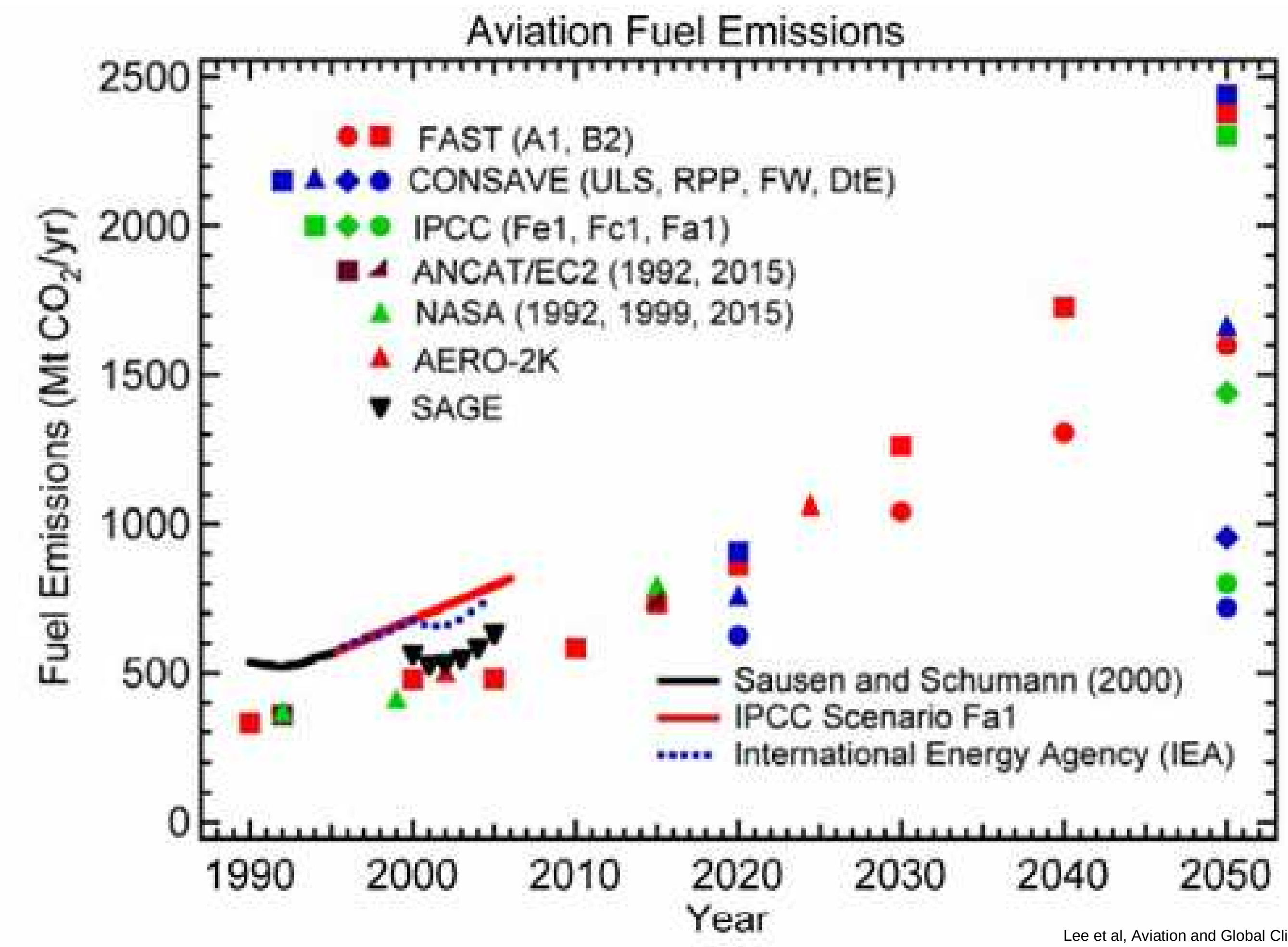
1 Forecasts and Projections - Others



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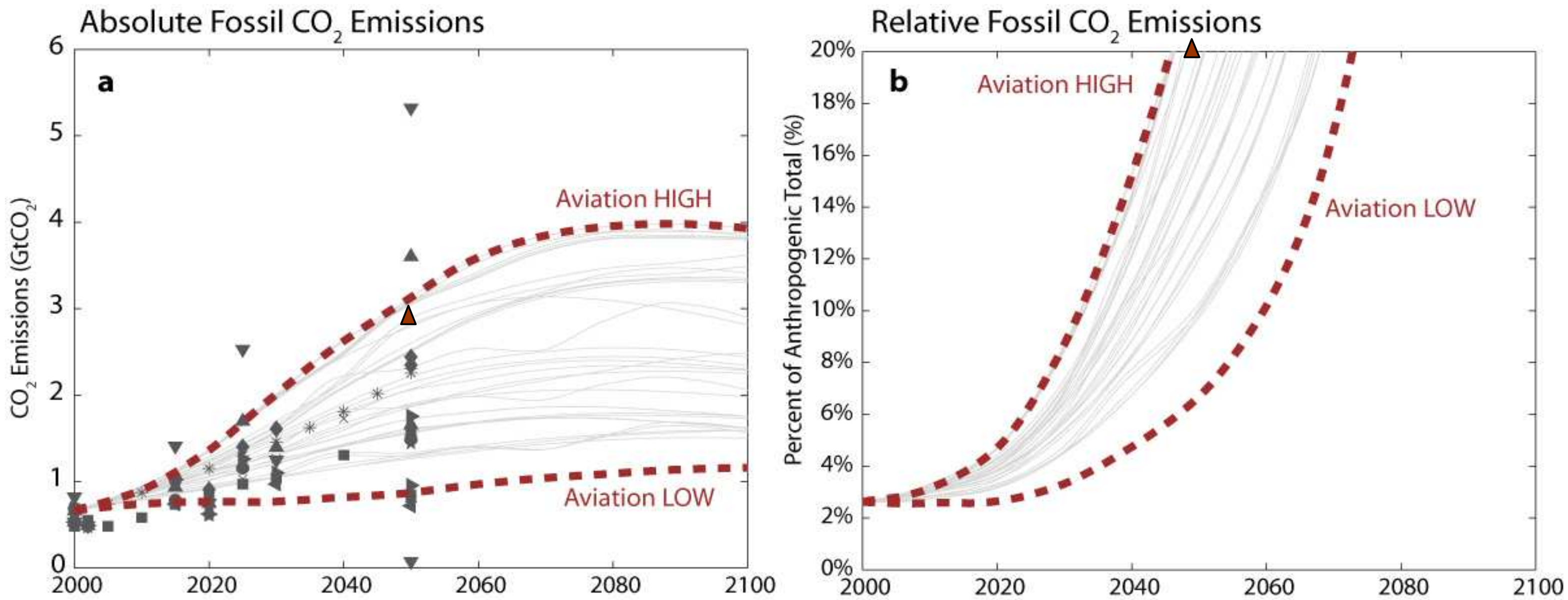
1 Forecasts and Projections - Others

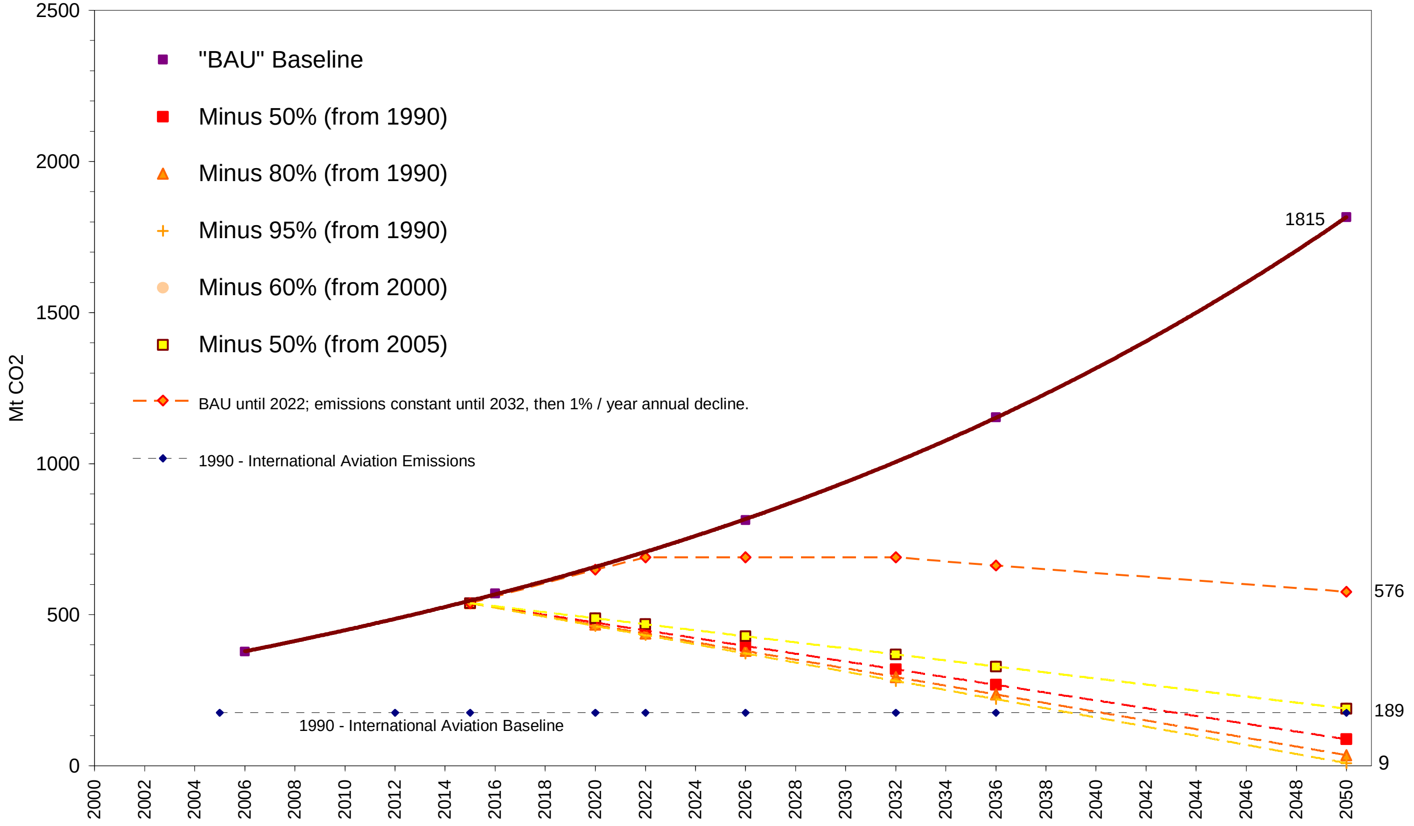


Future total aviation emissions and their effects in the context of a carbon constrained world. Fossil CO_2 emissions of derived aviation scenarios (lines) lie within the range of scenarios in the literature. The relative share of global all-sector fossil CO_2 emissions rises continuously from around 2% to beyond 20% as early as 2050 (b). Baseline scenarios from this report are superimposed for 2050.

Lee et al, Aviation and Global Climate Change in the 21st Century

2
Targets

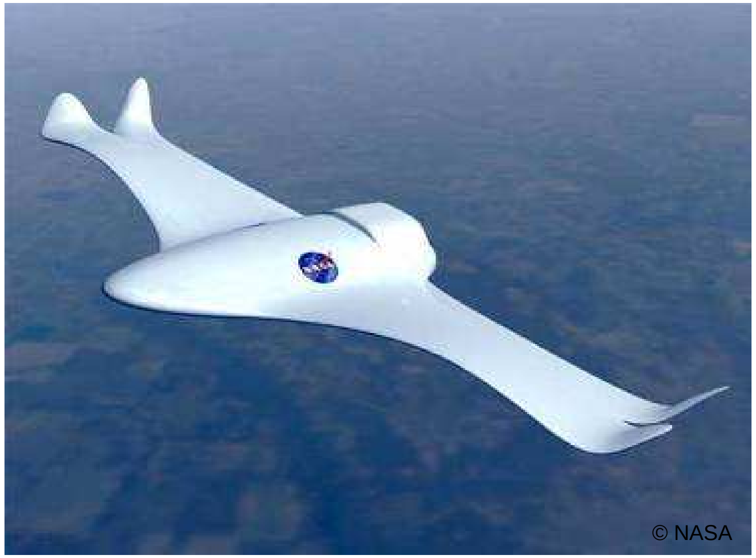
2 Targets – Non Sector Specific



BAU Baseline International Commercial Aviation Emissions Projections compared with non-Sector Specific Emissions Reduction Targets (Note: excludes domestic aviation)

3

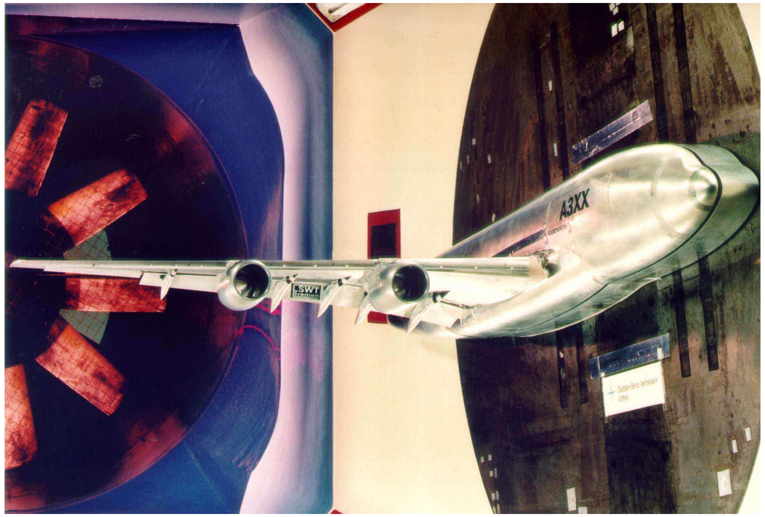
Abatement Options



3

Technology Options

- Evolutionary Airframe and Engine
- Radical Airframe and Engine
- Fuels
- ATM and Ops



3 Evolutionary Airframe Technology

Technology	Potential Aircraft CO_2 improvement	Earliest Availability	Retro - fit?	Key Technical Barriers
Winglets	1-2%	Now	Y	New – none Retrofit benefit is application dependent, leasing
Riblets	1-2%	2015-2020	Y	New – dev and certification Retrofit is application dependent, leasing
Laminar Flow (wings)	10-20%	Now -2020	N	Manufacturing costs, maintenance costs
Laminar Flow (Nacelles)	1%	Now	Y	As Laminar flow wings but with less significance.
Lighter Materials (Composites)	10-20%	Now	N	Certification, manufacturing, repair, recycling
Active Airframe Health Monitoring	Up to 12%	2015-2025	N	Development test and evaluation costs, certification.
TOTAL	**20-30%**	**By 2025**		
Retrofit	2-5%			

c.f. ACARE Target 20%

3 Evolutionary Engine Technology

Technology	Potential Aircraft CO_2 improvement	Earliest Availability	Retro-fit?	Key Barriers
OPR, Materials, Cooling	3-5%	Now-2020	Y	None
Compressor and Turbine Aero	3-5%	Now-2020	Y	None
TOTAL	**6-10%**	**By 2020**	**Y**	
Geared Turbofan	12-15%	2013-2020	N	Dev risk for larger gearboxes
GRAND TOTAL	**20%**	**By 2020**		
Retrofit by Module Replacement	*0.5-1%*	*Now*		
Retrofit by new engine to 10 year old airframe	*5-7.5%*	*Now*		

c.f. ACARE Target 20%

3

Technology options

- Evolutionary Airframe and Engine
- Radical Airframe and Engine
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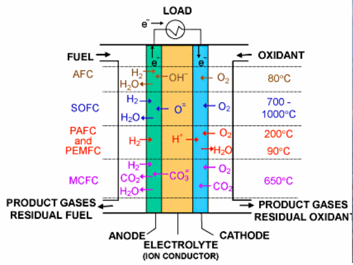

3 Radical Concepts

Technology	Potential Aircraft CO_2 improvement	Earliest Availability	Retro-fit?	Key Barriers
UDF Powered Aircraft	15% (Single Aisle 25-30%)	2015	N	Blade containment, certification, noise, maintenance
Blended Wing Body	20%	2025	N	Social, market, infrastructure, safety/certification
Distributed Engines	<0.5%	2050	N	Complexity, certification
Airships	Up to 50%	2015	N	Slow, infrastructure, weather
Unmanned Aircraft	2-3%	2035	N	Acceptance, safety, ATM
Morphing Structure and Control	5%	2030	N	Airworthiness/safety
Supersonic and Hypersonic Transport	2-5 x worse	Now/2050	N	Certification, acceptance, infrastructure, noise
Fuel Cells	100%	2050+	N	CURRENTLY NO PRACTICAL TECHNOLOGY AVAILABLE – cell and motor too heavy
Solar Power	100%	2050+	N	CURRENTLY NO PRACTICAL TECHNOLOGY AVAILABLE – cells and motor too heavy
Nuclear Power	100%	2050+	N	CURRENTLY NO PRACTICAL TECHNOLOGY AVAILABLE – reactor, motor and shielding too heavy, safety
TOTAL	**30%**	**2025**		
Retrofit	*Nil*			

© easyJet – ecoJet design

Unducted Fan Powered Aircraft

15%

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Blended Wing Body

20%

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Distributed Power

<0.5%

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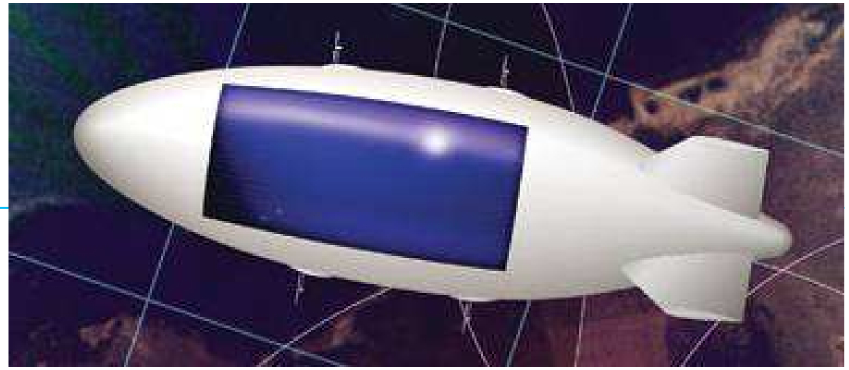

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Airships

50%

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Unmanned Aircraft

2-3%

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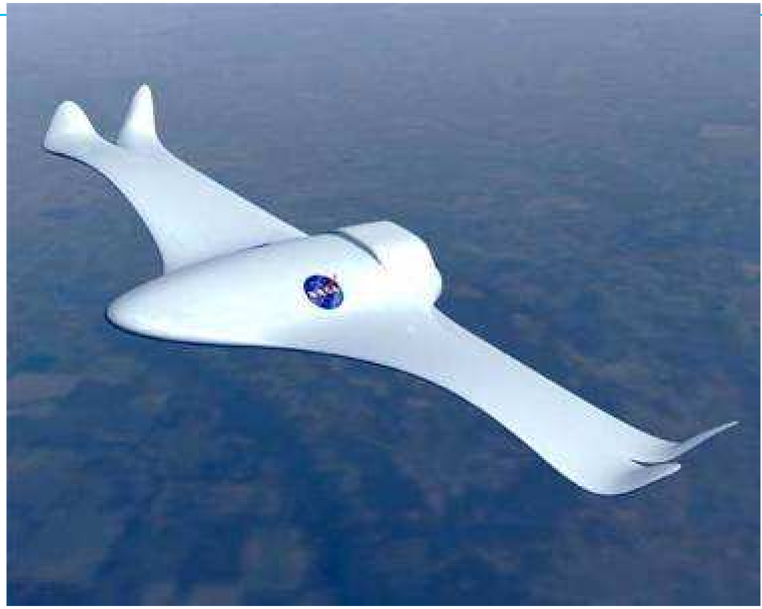

Morphing Structure and Control

Up to 5%

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Hypersonic Aircraft Model © A2 – Reaction Engine

Supersonics and Hypersonics

2-5 times worse

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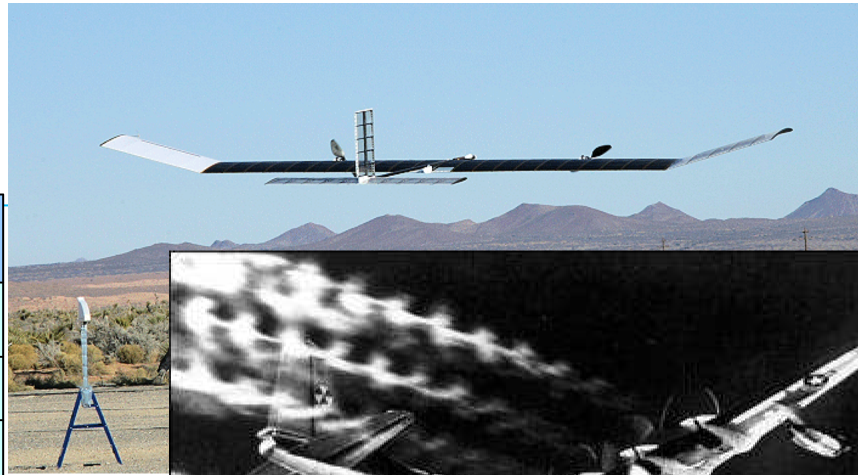

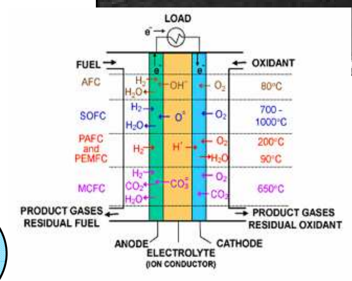

Fuel Cells, Solar, Nuclear

100% - but not practical

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TOTAL	**30%**	**2025**		
Retrofit	*Nil*			

- Radical Concepts Summary
  - Perhaps 30% reduction while still flying “fast” (but not faster) by 2025
  - This excludes the evolutionary improvements, where they are applicable
  - Further step change “fast” technology not yet apparent
  - Flying slower is a different ball game

3

Technology options

- Evolutionary Airframe and Engine
- Radical Airframe and Engine
- Fuels
- ATM and Ops

3 Alternative Fuels

Technology	Potential Aircraft CO_2 improvement	Earliest Availability	Retro-fit?	Key Barriers
Kerosene "Drop-in" Replacement	±1%	Now (small scale) 2015 (large scale)	Y	Proof of supply suitability (spec), supply
Bio-ethanol, bio-diesel, bio-methanol etc	Worse	Now	N	CURRNTLY NO REASON TO DEVELOP THESE FOR AVIATION
Hydrogen	100%	2025	N	Infrastructure, new aircraft, climate impact
TOTAL	**-**			
Retrofit	±1%			

Production CO_2 is the issue

3

Technology Options

- Evolutionary Airframe and Engine
- Radical Airframe and Engine
- Fuels
- ATM and Ops

3 Aircraft Operations

Technology	Potential Aircraft CO_2 improvement	Earliest Availability	Retro-fit?	Key Barriers
OPERATIONS				
Ground towing	Up to 2%	2010s	N	Aircraft design, airport capacity
(Stop) Tankering	0.5%	Now	Y	Turn round time
Cabin dead weight reduction	<1%	Now	Y	Brand image, public expectation
Optimum stage length	Up to 7%	2015-2040	N	New fleet , extended journey time, more airports, increased LTO risk and noise
Formation flight	1%	2020s	N	Coordination, risk
Load factor maximisation	6% Max 1-3% feasible	Now	Y	Timetabling, frequency
Point-to-point	Possibly up to 5%	2015-2035	N	Smaller planes, airport size shift, route frequency
AIR TRAFFIC MANAGEMENT				
System delays and imperfect trajectories	3-5%	2020	N	System improvements already funded in parallel with capacity increase research
TOTAL	**Up to 25%**	**2030**		
Retrofit	*4%*			

c.f. ACARE Target 10%

4

Drawing some lines in the sand

4 A View on Potential CO_2 Reductions from Combining Technologies

	% CO_2 reduction	Total	Timescales
Evolutionary technology	Airframe 20%-30% + Engine 20%	**45%**	2025
Radical Technology	30% + Evolutionary	**55%**	2025+
Fuels	-	**-**	-
Ops	20%	**20%**	2030
ATM	3-5%	**3-5%**	2020

4 A View on Potential CO_2 Reductions from Combining Technologies

	% aircraft CO_2 reduction	Total	Timescales	Reduction realisation by		
				Encouragement	Insistence	Revolution
Evolutionary technology	Airframe 20%-30% + Engine 20%	**45%**	2025	22%	35%	45%
Radical Technology	30% + Evolutionary	**55%**	2025+	27%	45%	55%
Fuels	0%	0%	-	0%	0%	0%
Ops	20%	**20%**	2030	2%	5%	20%
ATM	3-5%	**3-5%**	2020	3%	5%	5%
TOTALS	**Evolutionary Tech**			**25%**	**40%**	**60%**
	Radical Tech			**30%**	**50%**	**65%**

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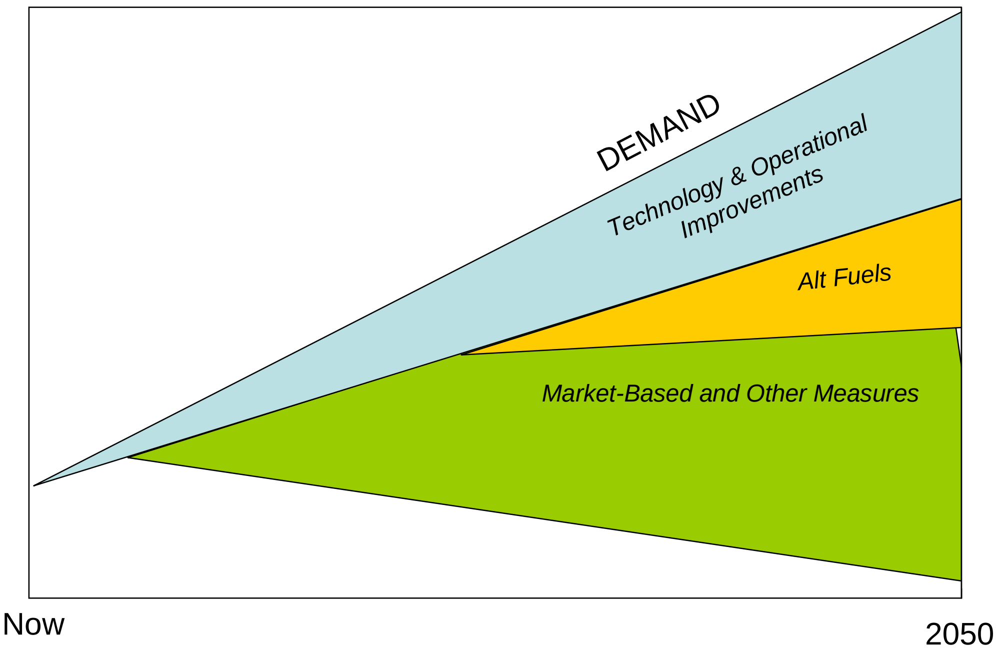
	% aircraft CO_2 reduction	Total	Tim…			
Evolutionary technology	Airframe 20%-30% + Engine 20%	**45%**				
Radical Technology	30% + Evolutio…					
Fuels	0%	0%				
Ops	20%	**20%**	2030	2%		20%
ATM	3-5%	**3-5%**	2020	3%	5%	5%
TOTALS	**Evolutionary Tech**			**25%**	**40%**	**60%**
	Radical Tech			**30%**	**50%**	**65%**

Bio-Fuels and Hydrogen offer well-to-wake CO_2 abatement

5
Future Scenarios

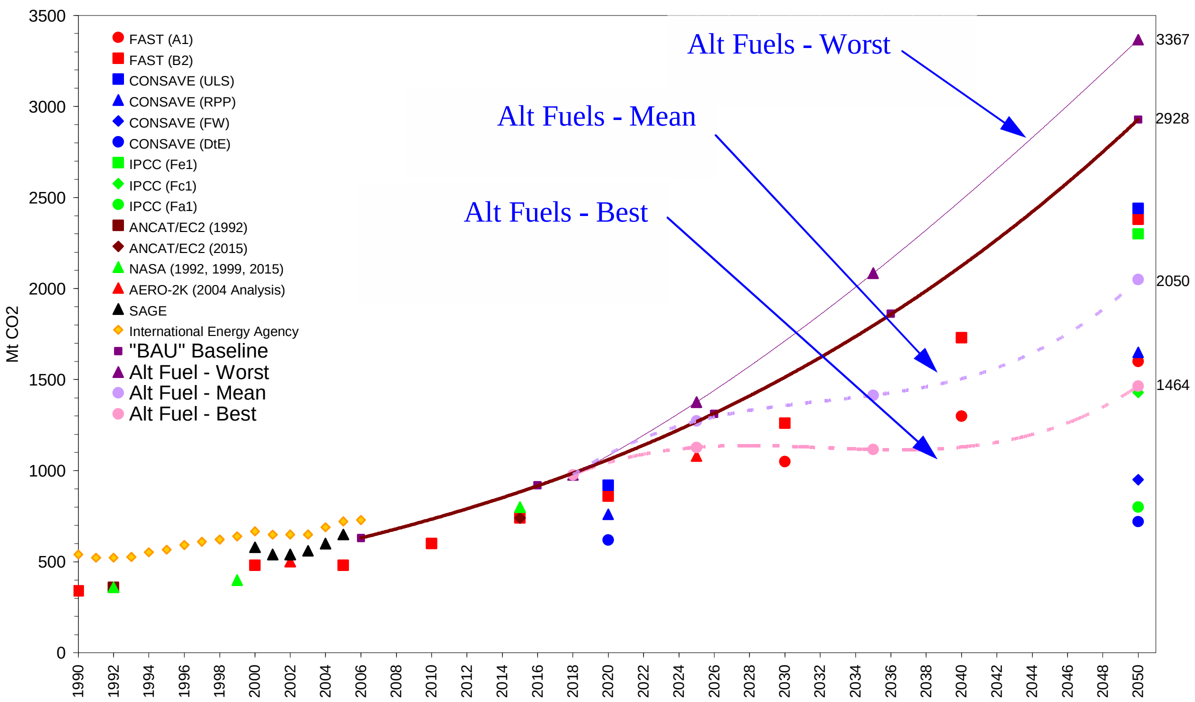
5 Aviation Road Map

- Technology & Ops
- Alternative fuel supply sources
- Market-based measures



5 Alternative Fuel Supply Scenarios

- Highly uncertain



5 Combining Assumptions into Scenarios

- 4 selected scenarios
  - BASELINE
  - BLUE SKIES
  - GREEN – Fuel
  - GREEN - Technology

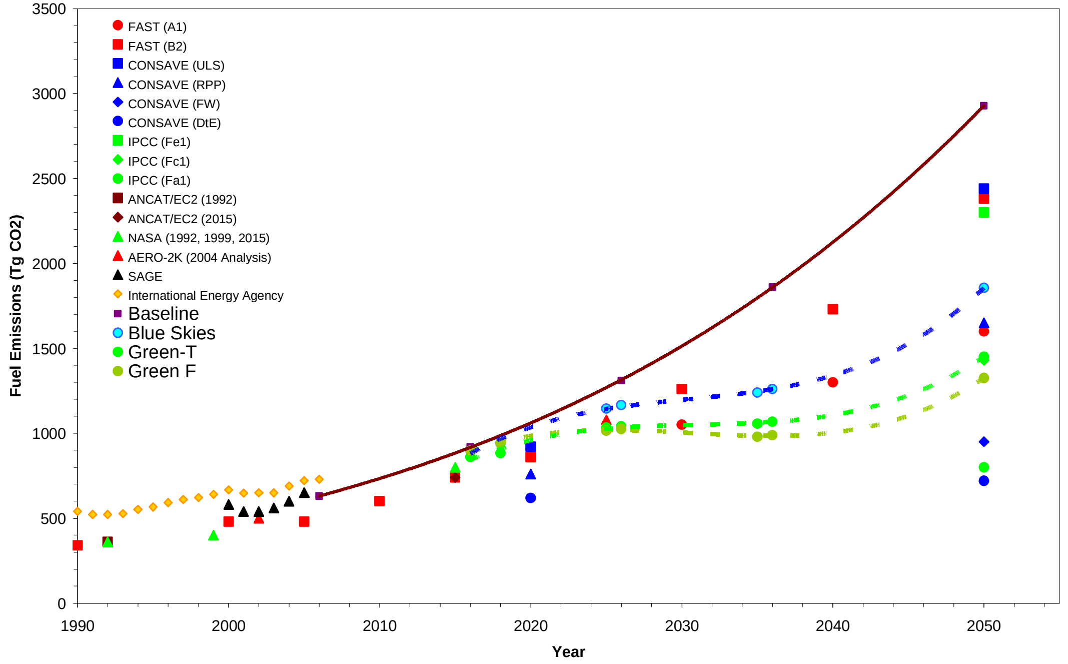
Scenario Map, showing combined tech/ops/alt fuel scenarios B= Blue Skies, G-T = Green Skies (technology/ops), G-F = Green Skies (alt fuels option)

Technology Scenario	**Operations Scenario**	**Alt Fuel Scenario**			
		None	**Worst**	**Mean**	**Best**
Tech freeze	Tech freeze	(C)			
IPCC1999	BAU Baseline	(L)			
BAU Baseline	BAU Baseline	Grey Skies BAU BASELINE SCENARIO (C)	(C)	(C)	(C)
BAU Baseline	Advanced	(L)			
Advanced	Advanced	(C)		Blue Skies (C)	Green-Fuel (C)
Highly Advanced	Highly Advanced	(C)		Green-Tech (C)	

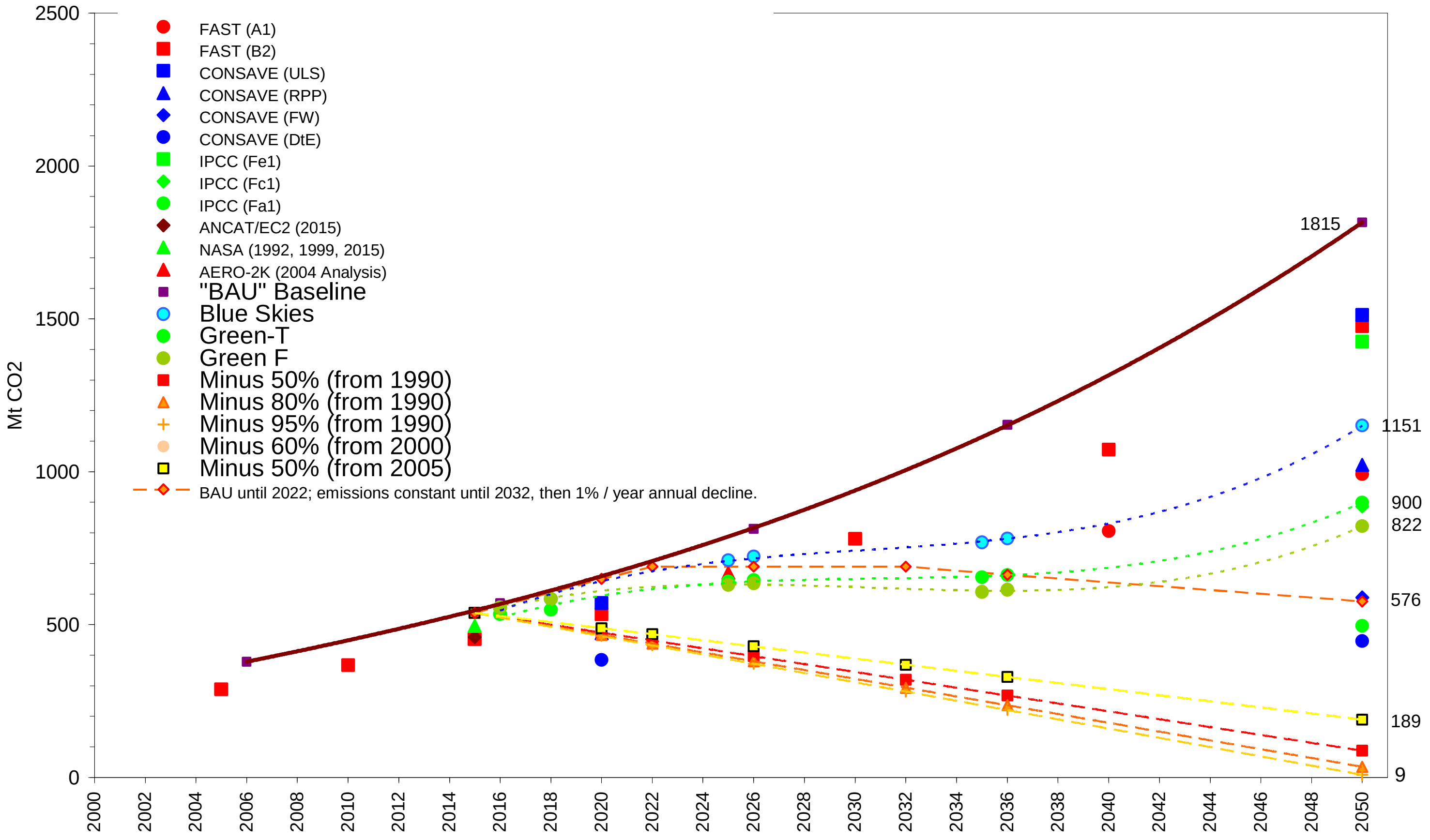
5 Alternative Technology, Operations and Alt Fuel Scenarios

These "optimistic" scenarios suggest that even with the most optimistic technology + operations + fuel improvements;

- Annual CO2 grows to 2025
- May stabilise to2035
- Will increase unless alt fuel sources improbably successful



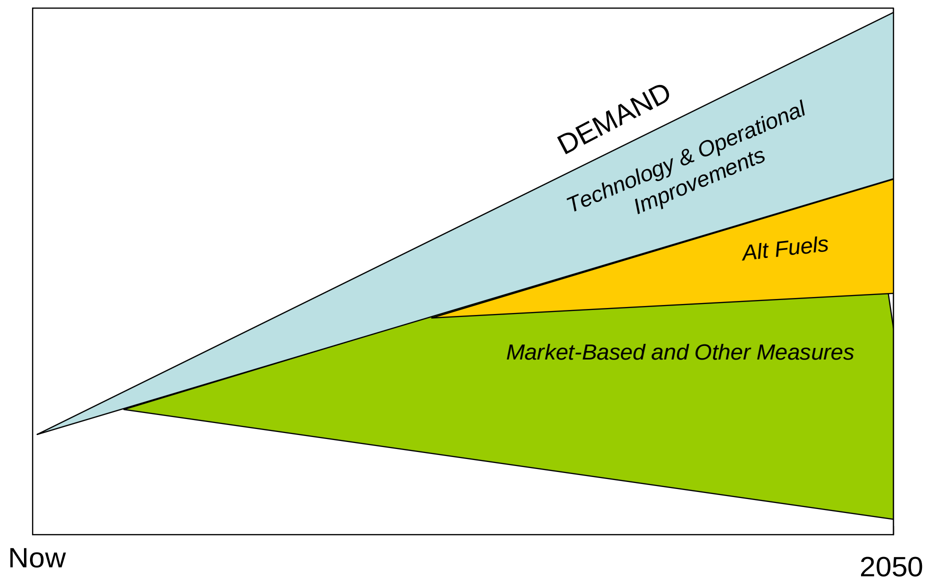
5 Scenarios vs Potential International Aviation Targets



5 Market Based measures

Market Based Measures

- Demand reduction or “offset” type
- Large impact needed to meet potential targets
- Needs work to determine what is equitable or most effective in economic, societal and environmental terms
- I make no predictions

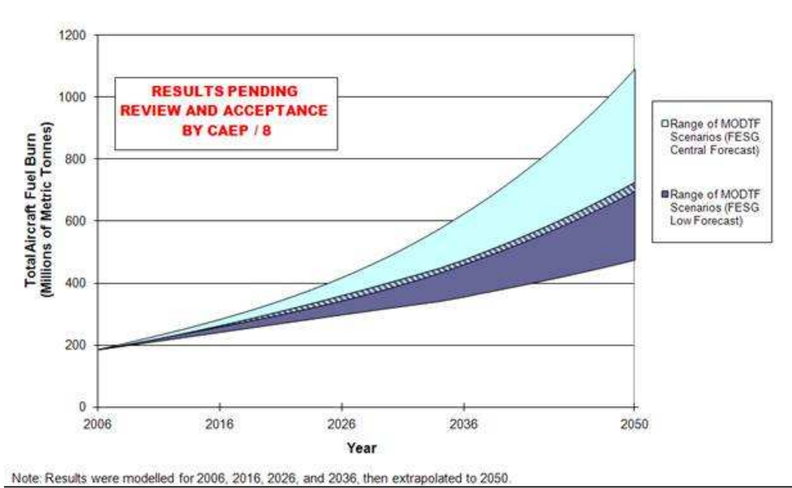


6
and finally ……………..

6 The current recession

Will aviation recover from the current recession?

- ICAO CAEP – maybe/maybe not
- Historically
  - partial recovery of delay
  - return to previous growth rate
- **Bigger question**
  - **What is the ultimate growth constraint?**
  - **I don't know**



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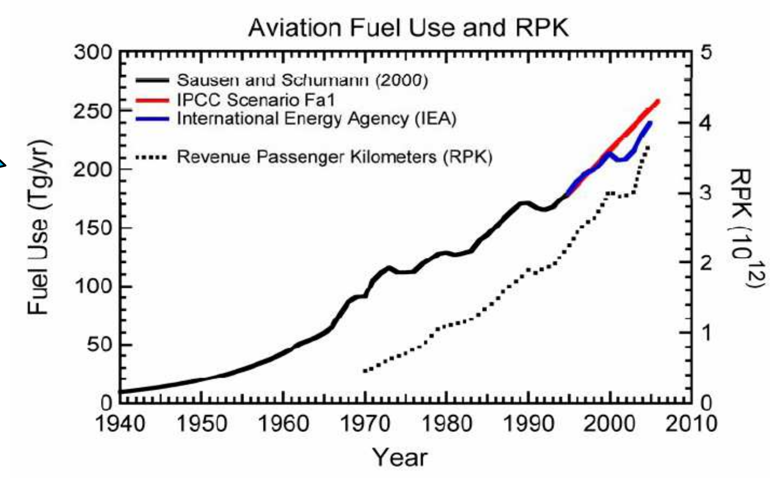

Unreferenced data available at: http://www.theccc.org.uk/reports/aviation-report/supporting-research