Scenario quantification - approach and assumptions (excerpt)

- **Local Air Quality**
- **Landing Charge** (ULS)
- **Kerosene to Hydrogen fleet rollover** (RPP)
- **Noise**
- **Others**
  - **Profitability in aviation**
  - **Comparison and ranges of assumptions made in other studies**

Local air quality – approach for quantification

Around 65 cities are selected world wide
with a slight emphasis on the larger airports on the western hemisphere.

For these cities (or airports) NLR quantified the average change in:

- fuel consumption
- carbon dioxide CO2
- water (vapour) H2O
- nitrogen oxides NOx

and

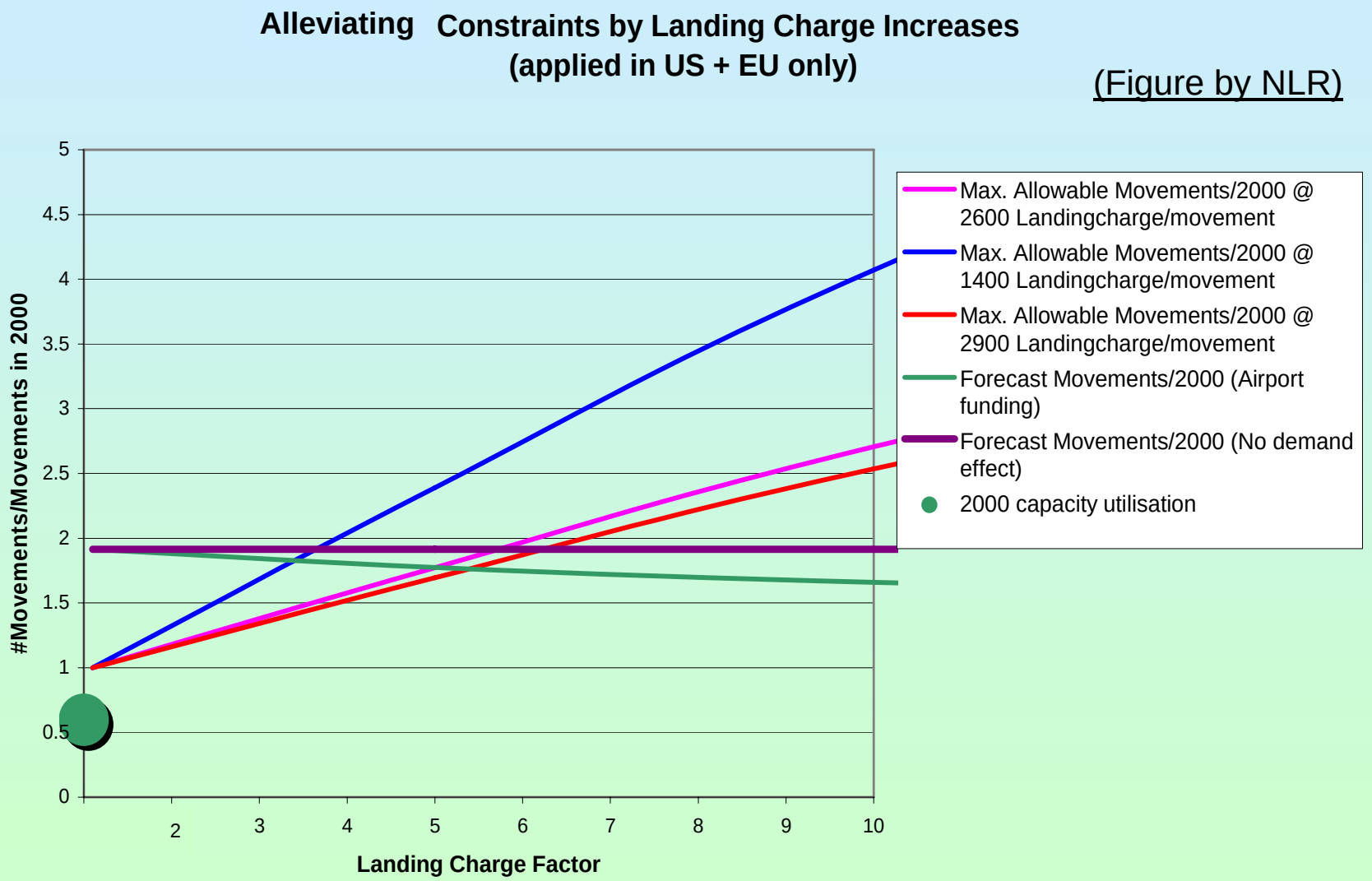
- unburned carbon hydroxides CxHy
  (expressed in an emissions factor as an indicator for the aviation contribution to the local air quality)

Approach to determine landing charge to finance infrastructure constraints in “Unlimited Skies”

- Conditions
  - High traffic volume, # flights
  - Capacity Inventory and short term Forecast (EUROCONTROL)
  - Assumption: constraints in EU + US)
  - Long Lead times: 20+ years
  - Consider AC & ATM Technology: Derive max. Growth factors
    - 1.5 @ larger airports (> 200k)
    - 5.8 @ smaller airports (< 200k)

- Strategy
  - Calculate # flights changes
  - Select type of charge: Landing charges
    - # flight related
    - drive to high capacity aircraft
    - various levels
  - Calculate infrastructure costs
    - Max. versus required capacity: margin?
    - Need for new runways
    - Transform Landing Charge revenues into new Runways: amortisation, investment etc.
  - Select Landing Charge level

Alleviating Constraints by Landing Charge Increases (applied in US + EU only)



(Figure by NLR)

Scenario fitting: Constraints - Example Airports

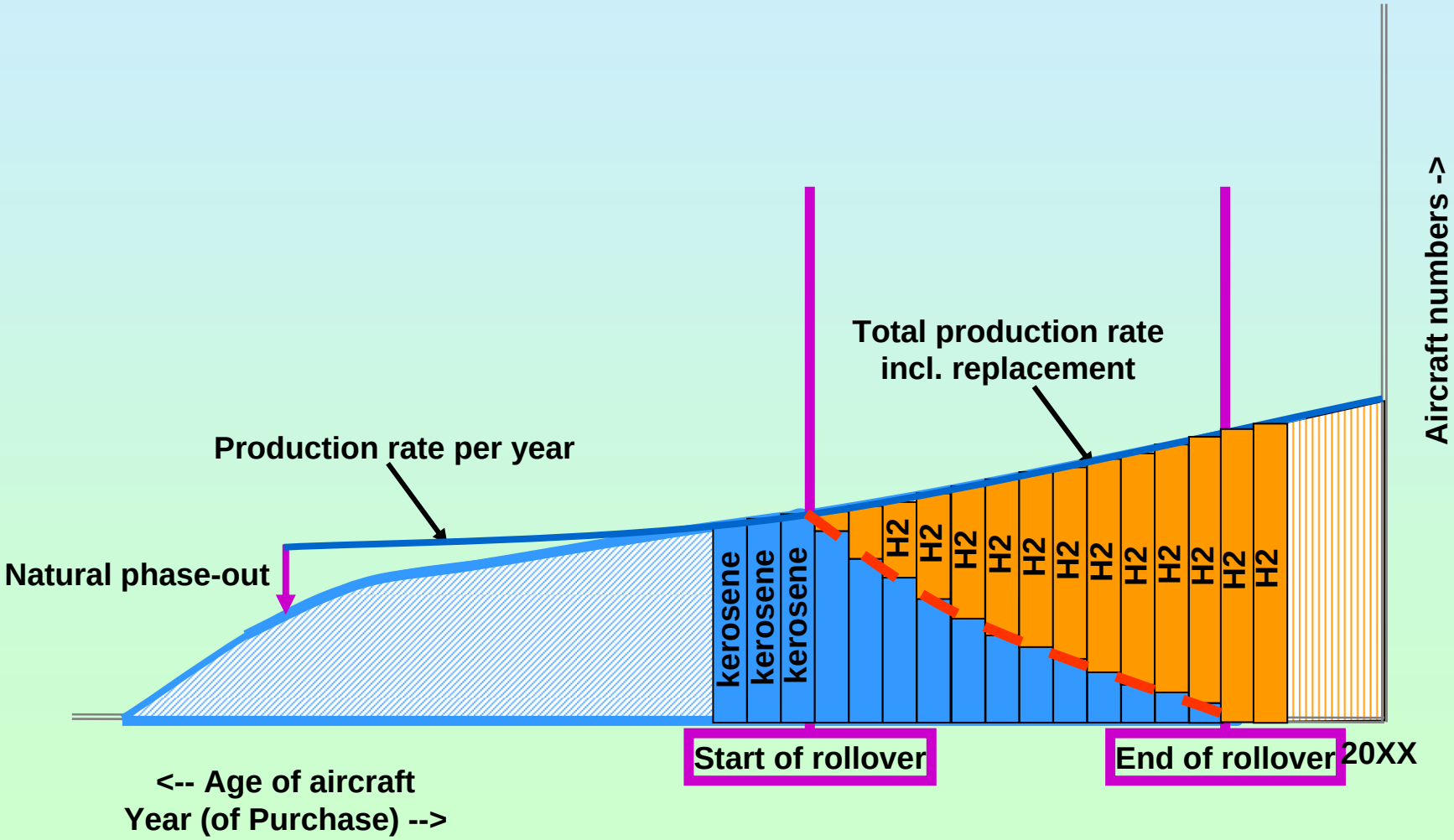
- **Storylines indicate very high Aviation Growth**
- **(Major) Airports severely Constrained (Noise / Capacity)**
  - Capacity Inventory and short term Forecast (EUROCONTROL)
  - Consider AC & ATM Technology: Derive max. Growth factors
  - Define Government Actions & Responses (incl. lead time)
  - AERO runs and match

IATA Region	Growth factor	
	(airports > 200 k)	(airports < 200 k)
EU	1.5	5.8
US	1.6	6.0

Approach to assess the accelerated Kerosene to Hydrogen fleet rollover in “Regulatory Push&Pull”

- **Assumed fleet aspects**
  - Single fuel infrastructure
  - Single fuel engine technology
  - 10 year roll-over (Fractured World)
  - No retrofitting

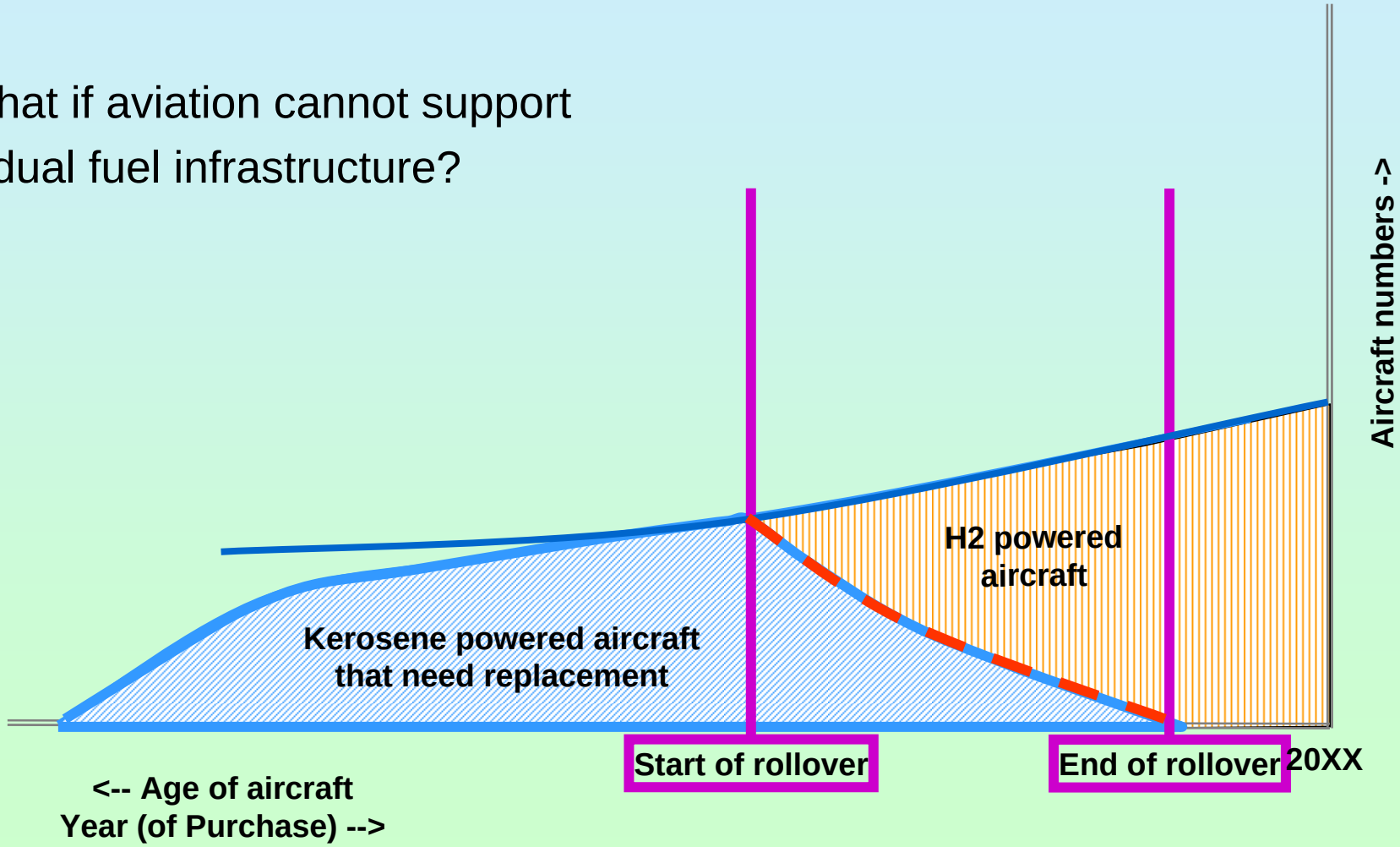
Fleet roll-over, dual infrastructure



Fleet roll-over, dual infrastructure

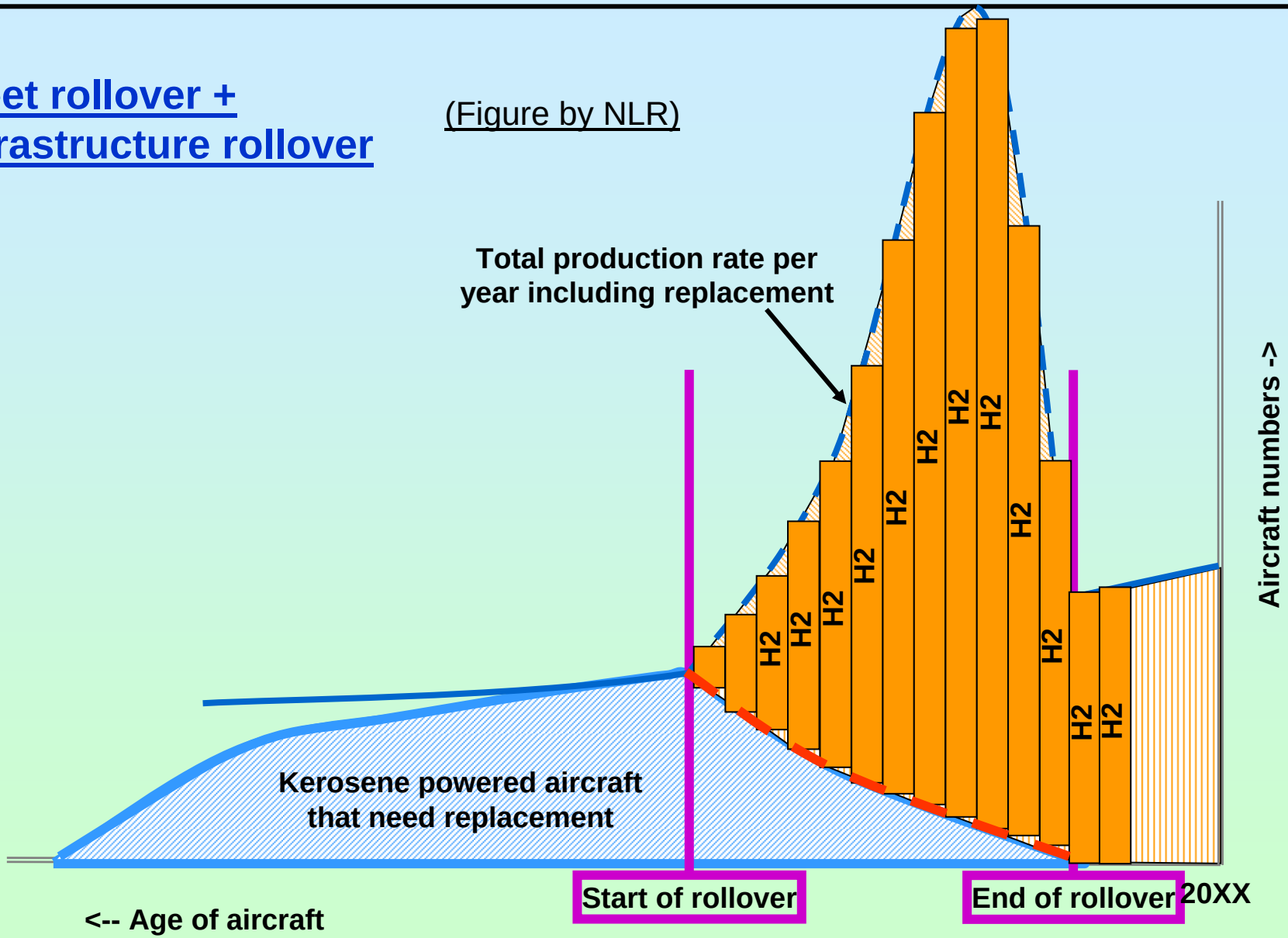
(Figure by NLR)

What if aviation cannot support
a dual fuel infrastructure?



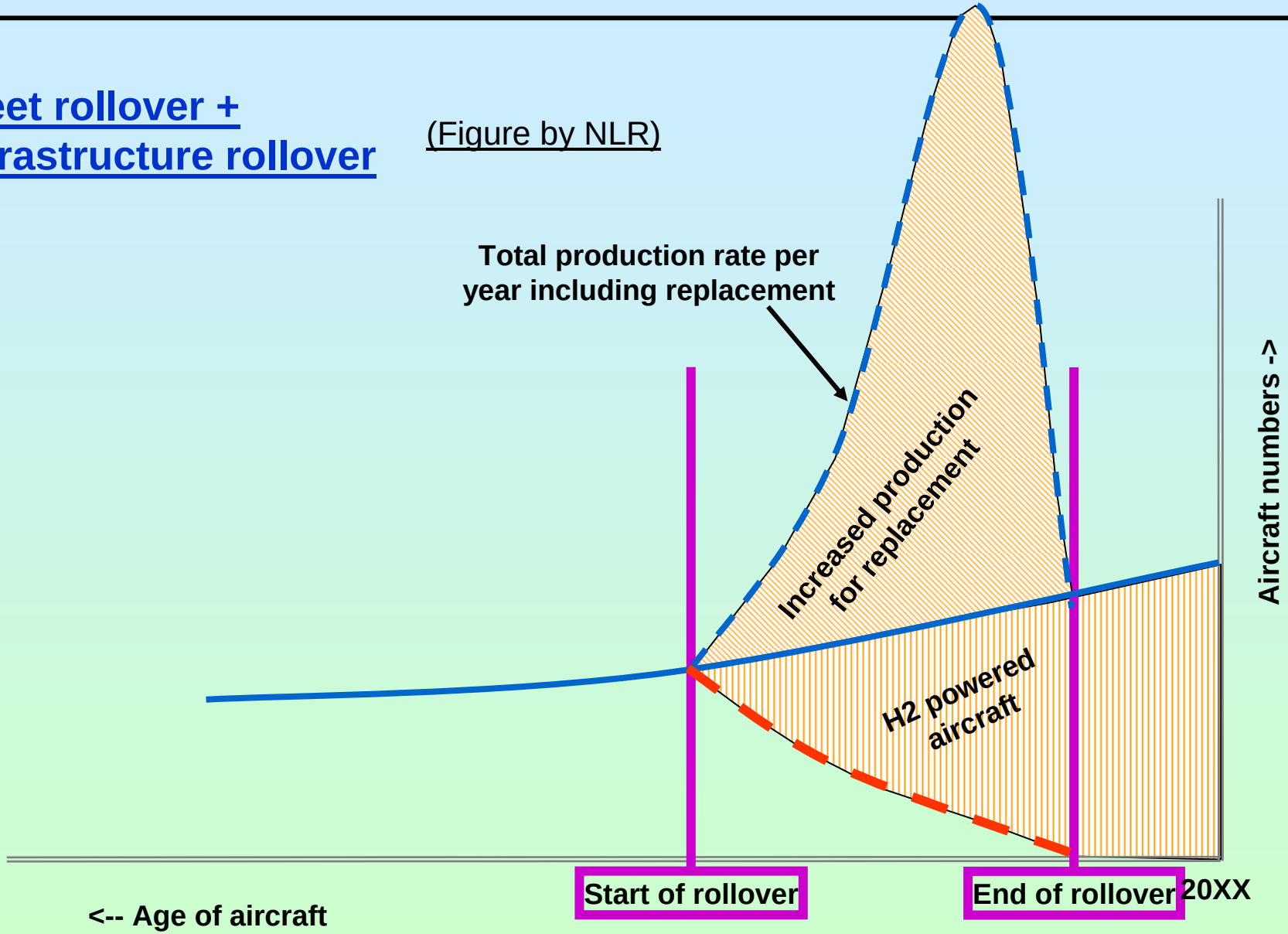
Fleet rollover + infrastructure rollover

(Figure by NLR)



Fleet rollover + infrastructure rollover

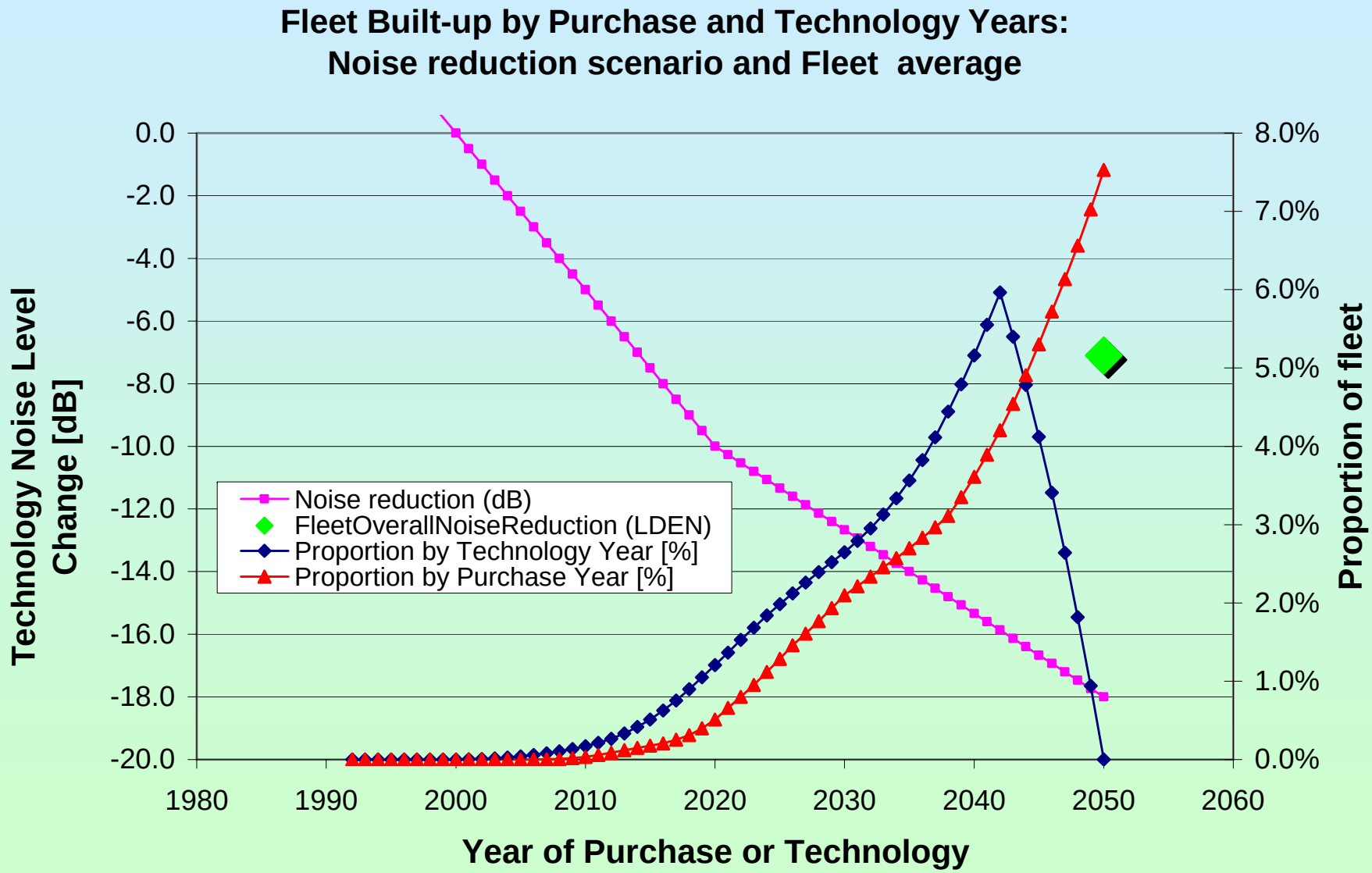
(Figure by NLR)



Possible Consequences of Fleet + Infrastructure rollover

- High costs of buy out (old aircraft)
  - Lower (no) residual value
  - Capital loss
- Accelerated introduction of new aircraft
  - High demand, high aircraft new prices
  - New technology, higher new prices
  - Airline financed
- Aircraft-Engine manufacturing
  - New technology introduction
  - Very high production volume (over short period)
  - Loss of capital (old production lines)
  - High investments and loss of capital (production lines volume)
- Airline favourable scenario
  - Maintaining high traffic volume
  - Government compensates early retirement

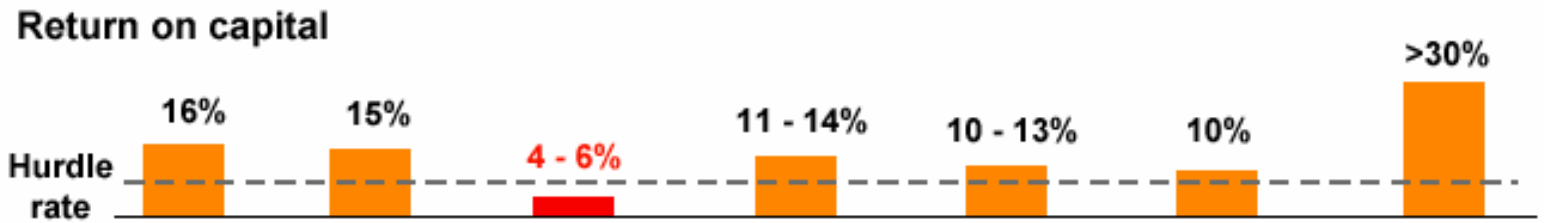
Noise Assessment



Key aviation aspects	Unlimited Skies	Regulatory Push & Pull	Fractured World	Down to Earth
Kerosene to hydrogen		2040-2050		
Security	+ 4$/pax	8$/pax	+ 4$/pax EU,NA: + 8$/pax	B: + 4$ / pax L: + 6$ / pax
New airports	Landing charges	Landing charges		Landing charges
Crew numbers	Minimum	Default + 1	Interregional: +1 Intraregional: Def	Default
Crew salaries	GDP/capita 0.5% / year	GDP/capita	GDP/capita +0.3% / year	+0.7% / year
Profit levels	2020: 8% 2050: 5%	2020: 5% 2050: 3%	2020: 2 - 5% 2050: 2 - 4%	2020: 2% 2050: 2%
ATM efficiency (default charges)	0.9 … 0.95	0.9 … 0.95	EU,NA: 0.9...0.95 others: 1.0	0.9 … 0.95
New Aircraft prices	Tech driven + 0.25 GDP/capita	Tech driven + 0.25 GDP/capita	Tech driven + 0.25 GDP/capita	Tech driven + 0.25 GDP/capita
Oil pricing 2050	uniform	70% world 30% local	30% world 70% local	uniform
Volume costs 2050	25% lower	10% lower	20% lower	25% lower
Maintenance costs	0.5*GDP/capita - 0.25% / year	0.5*GDP/capita	+0.5*GDP/capita (until 2020): +1.5% / year	+1.5% / year (up to 2020)
Interregional traffic	Default	Default	* 0.3 between fractured worlds	Default

Airlines and Service Providers in the Value Chain

2 major companies serve 100 % of the market	2 companies serve 45 % of the market	> 1,500 airlines compete globally	< 3 competitors at deregulated airports	2 companies serve 40 % of the market	„Natural monopolies“	4 companies worldwide



Airlines (and others) Return on capital 1992-1996

Source: McKinsey Study of 1998 (ROIC 1992 – 1996)

Ranges of assumptions for the scenario year 2020 made in different studies

Scenario Drivers	Maximum	Source	CONSAVE Scenarios				Minimum	Source
			High Growth		Fractured World	Down to Earth		
			Unlimited Skies	Regulatory Push&Pull				
Population [billion]	8.0	UN 2002	7.5		8.2	7.5	7.1	UN 2002
Economic growth rates (p.a.)	3.9%	IPCC SRES A1	3.9%	3.8%	2.3%	3.3%	2.0%	International Energy Outlook - Scenario C (EIA 2001)
World GDP-mer (trillion $)	58	International Energy Outlook 2003	57	56.4	40	53	40	Global Energy Perspectives - B
Energy use [EJ]	730	International Energy Outlook - Scenario B (EIA 2001)	700	610	600	580	430	Faktor 4-Szenario
Ratio of global oil production (1990=1)	1.7	US DoE 1999	1.3		2.2	1.5	0.9	Global Energy Perspectives - C
Crude oil price (1990=1)	no value found		1.5	2	4	2	1	U.S. Department of Energy 2001
Zero-carbon energy rate	27%	Global Energy Perspectives - C	15%	20%	regional differences	20%	20%	Global Energy Perspectives - A
Air Transport Demand Index (1990=1)	3.3	CAEP/4 - FESG Report 4, 1998 - Fe	3.2	2.6	2.0	1.9	2.2	CAEP/4 - FESG Report 4, 1998 - Fc
Fuel Efficiency Change	-20%	Scientific Advisory Board of the German Ministry of Transport	-10 to -20% below 2000 level (0.75% reduction p.a.)		2020: -10 to -20% below 2000 level (-0.75% p.a.); N.America: -2% p.a. after 2020; Eurasia & Far East: -1% p.a.	+10% c.f. 2000 levels (+0.5% increase p.a.)	12% below 1999 levels	IPCC 1999
LTO NOx Levels	50% below CAEP/2 levels	IPCC 1999	45% of 2000		N.America - gradual increase to 2x 2000 levels (+11.5% p.a.); Eurasia & Far East - maintain 2020 tech levels; Middle East - 2010 to 2020 aircraft mean levels; Subcontinent, Unaligned Regions - post-2000 aircraft mean levels	30% of 2000	4% below CAEP/2 levels	IPCC 1999
Noise Reduction	- 10 dB	Scientific Advisory Board of the German Ministry of Transport	10 dB reduction by 2020				-4dB'	Based on 2.2x traffic increase to keep current noise levels
Fleet Lifespan (in years)	35	IPCC 1999	<30	<25	NAmerica, Eurasia, Far East <20; All other regions >30	<20	25	IPCC 1999
Aircraft Size Growth	1% per year	Airbus 2003	large		large	large	0,2% per year (until 2015)	ICAO 2004
CO2 Emissions [billion kg pa]	300	IPCC 1999 - Scenario Ecb	906.5	748.9	622.6	624.9	850	IPCC 1999 - Scenario Eeh

Ranges of assumptions for the scenario year 2050 made in different studies

Scenario Drivers	Maximum	Source	CONSAVE Scenarios				Minimum	Source
			High Growth		Fractured World	Down to Earth		
			Unlimited Skies	Regulatory Push&Pull				
Population [billion]	12.8	UN 2002	8.7		11.3	8.7	7.4	UN 2002
Economic growth rates (p.a.)	3.9%	IPCC SRES A1	3.9%	3.8%	2.3%	3.3%	1.2%	IPCC IS92c
World GDP-mer (trillion $)	196	Shell 2001	180	174.6	82	136	72.8	Global Energy Perspectives - B
Energy use [EJ]	1121	Shell - Spirit of the Coming Age	1350	1100	970	810	434	Faktor 4-Szenario
Ratio of global oil production (1990=1)	2.6	Global Energy Perspectives - A 1	2.2		1.7	1.5 - 1.8	0.8	Global Energy Perspectives - C 2
Crude oil price (1990=1)	no value found		2	4	8	4	no value found	
Zero-carbon energy rate	43%	Global Energy Perspectives - C1	33%	40%	regional differences	30%	27%	Global Energy Perspectives - A 2
Air Transport Demand Index (1990=1)	21.0	EDF Scenario IS92e High (Eeh)	10.4	7.2	3.4	2.0	3.9	CAEP/4 - FESG Report 4, 1998 - Fc
Fuel Efficiency Change	50% below 1999 levels	IPCC 1999	2020: -10 to -20% below 2000 level (-0.75% p.a.), -1.5% p.a. after 2020		2020: -10 to -20% below 2000 level (-0.75% p.a.); N.America: -2% p.a. after 2020; Eurasia & Far East: -1% p.a.	2020: +10% c.f. 2000 levels (+0.5% p.a.), -1% p.a. after 2020	30% below 1999 levels	IPCC 1999
LTO NOx Levels	70% below CAEP/2 levels	IPCC 1999	35% of 2000		N.America - gradual increase to 2x 2000 levels (+11.5% p.a.); Eurasia & Far East - maintain 2020 tech levels; Middle East - 2010 to 2020 aircraft mean levels; Subcontinent, Unaligned Regions - post-2000 aircraft mean levels	80% below CAEP/2 levels	10% below CAEP/2 levels	IPCC 1999
Noise Reduction	Possibly close to background levels outside airport	Silent Aircraft Project	10 dB reduction by 2020, further 8dB by 2050		10 dB reduction by 2020, further 3 to 8 dB by 2050 according to region	10 dB reduction by 2020, further 10dB by 2050	6dB	Based on 3.9x traffic increase to keep current noise levels
Fleet Lifespan (in years)	35	IPCC 1999	<30	<25	NAmerica, Eurasia, Far East <20; All other regions 30+	<20	25	IPCC 1999
Aircraft Size Growth	no value found		large		regional: NAmerica, Eurasia - large growth; Middle East, Subcontinent, Far east, Unaligned Regions - no change	large	no value found	
CO2 Emissions [billion kg pa]	230.6	ICAO CAEP/4 FESG 1998 Scenario Fc1	2441.6	1653.8	955	719.4	1975	IPCC 1999 - Scenario Eeh