Constrained Scenarios on Aviation and Emissions
The CONSAVE 2050 Project

Presentation at the 2006 AERODAYS

Date/Place: 20th of June 2006 in Vienna

Topics

a) CONSAVE 2050 Scenario work
b) Scenario storylines
c) Some main quantification results

Ralf Berghof, Co-ordinator
DLR (German AEROSPACE Center)

CONSAVE 2050 - Homepage: www.dlr.de/consave

Partners and their roles/inputs

The project (“Accompanying measure”, EC funded) with quantifications up to the year 2050, started in September 2002 and was finished end of July 2005

Partner Institutions:	Role/Input
DLR German Aerospace Center	Co-ordinator, Aviation Scenarios, System Analysis
IIASA Inter. Institute for Applied System Analysis, Vienna/AT (IPCC-Author)	Background Scenarios incl. Global Developments/Assumptions
NLR Netherlands Aerospace Laboratory	Calculation (AERO-Model), Aviation Development/Assumptions
MVA, GB	AERO-Model Enhancements
QinetiQ, (former DERA), GB	Aviation Technology Development/Assumptions
DLH, German Lufthansa	**Stakeholder-Inputs** by Advisory Committee
Airbus	Additional Data for Scenarios Calculation

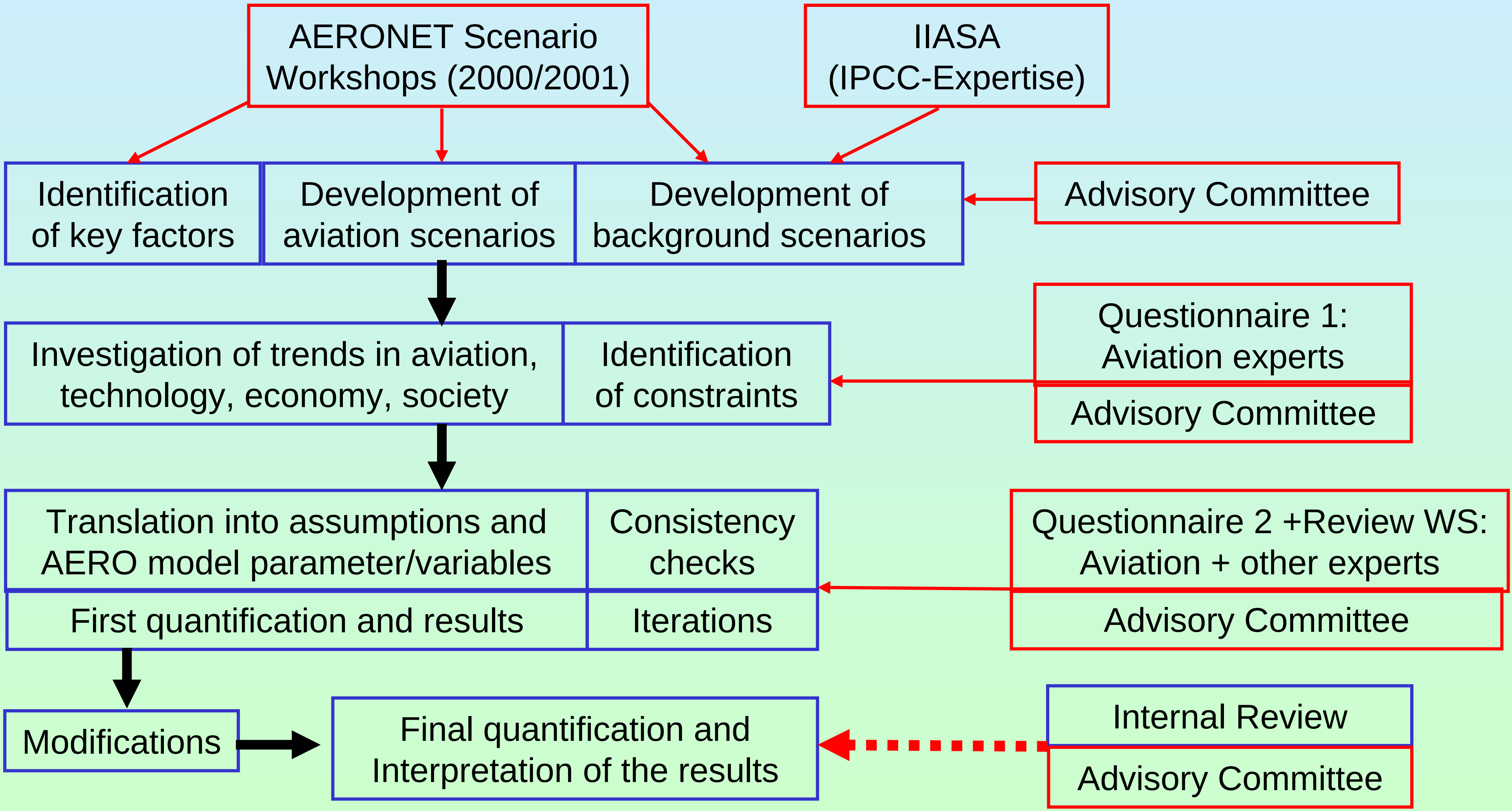
Key features of the project

- Goal was to design **a representative set of robust quantitative scenarios of aviation and emissions** with focus on the time horizon year 2050, an intermediate view to year 2020, and an outlook to year 2100 (esp. relevant for climate models).
- The project foresees explicitly and as its most important and innovative topic, the **development of constrained scenarios.** Most recent information from IPCC/SRES/2000 on assumptions for the development of population growths, economy, and other areas frame-setting for the development in aviation were used.

with special consideration of

- Society: population, policy, energy availability/consumption/price, customer preferences, globalisation/regionalisation.
- Impacts: demand, fuel consumption, noise and emissions (global, local), fleet, costs, airline profitability, infrastructure requirements, employment
- Sub-scenarios: Hydrogen, Fuel tax, Level of Landing Charges for financing additional runways, Saturation, Elasticities

Working process + external inputs



Comparison of scenario philosophies

(from ACARE/ASTERA, CONSAVE and EUROCONTROL)

Scenarios	Goal	Focus	Considered Trends	Results
ACARE/ASTERA	Vision 2020	Technology requirements	Technology	High Level Target Concepts
CONSAVE	Orientation knowledge, IPCC input (emissions)	Aviation system constraints	Economy, Technology, Ecology, Aviation, Society	Quantification of impacts, sub-scenarios on constraints
EUROCONTROL	Infrastructure planning	Airport movements	Economy, Aviation	demand forecast

Resume:
The scenario exercises are dealing with similar assumptions and different goals.
They deliver different added values and represent compatible & synergetic activities.

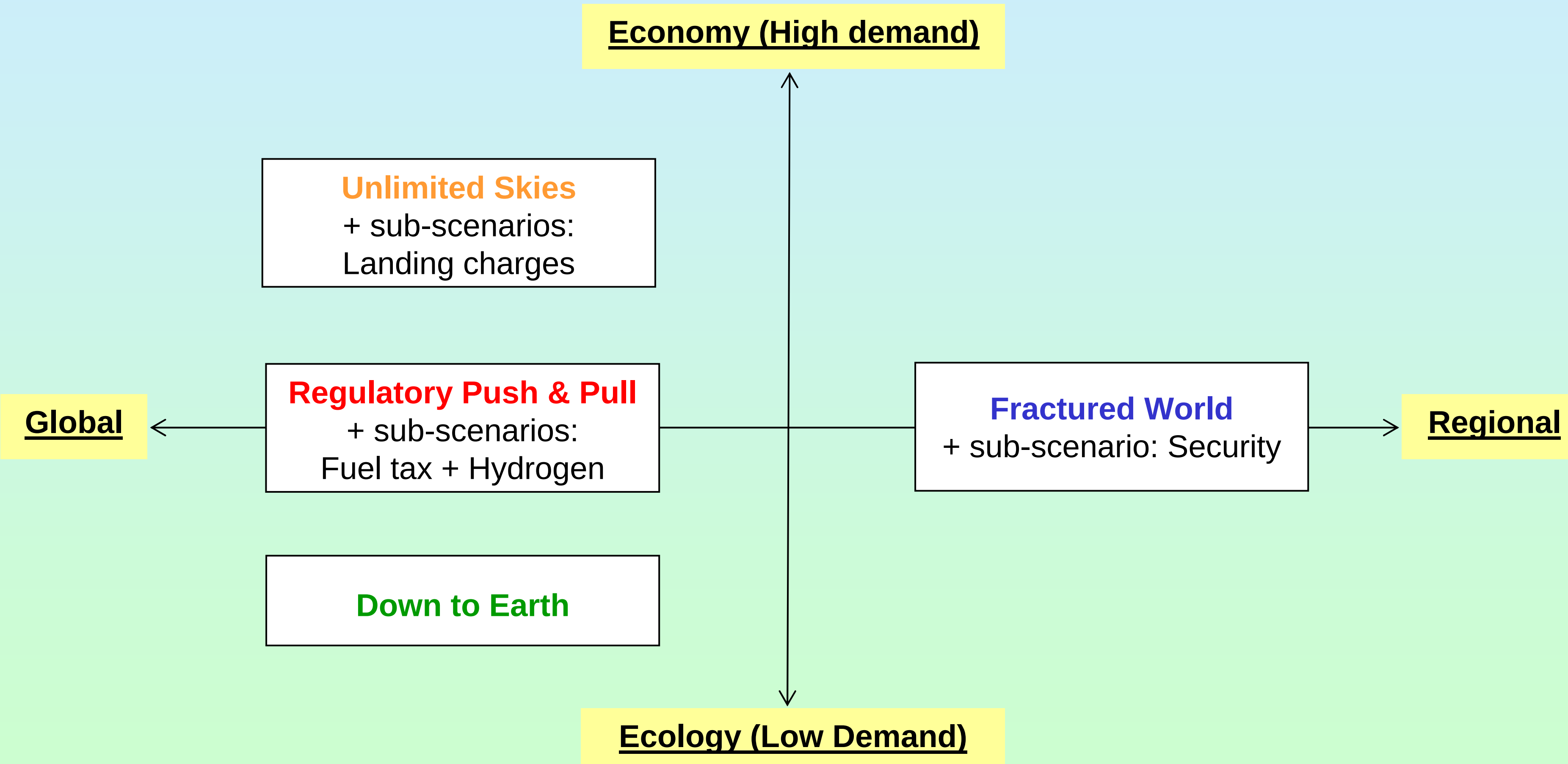
Focussing on Constraints

Trying to include developments in the world and the societies, which could turn out as limits to growth for aviation, the project foresees explicitly and as it's most important and innovative topic, the development of **constrained** scenarios.

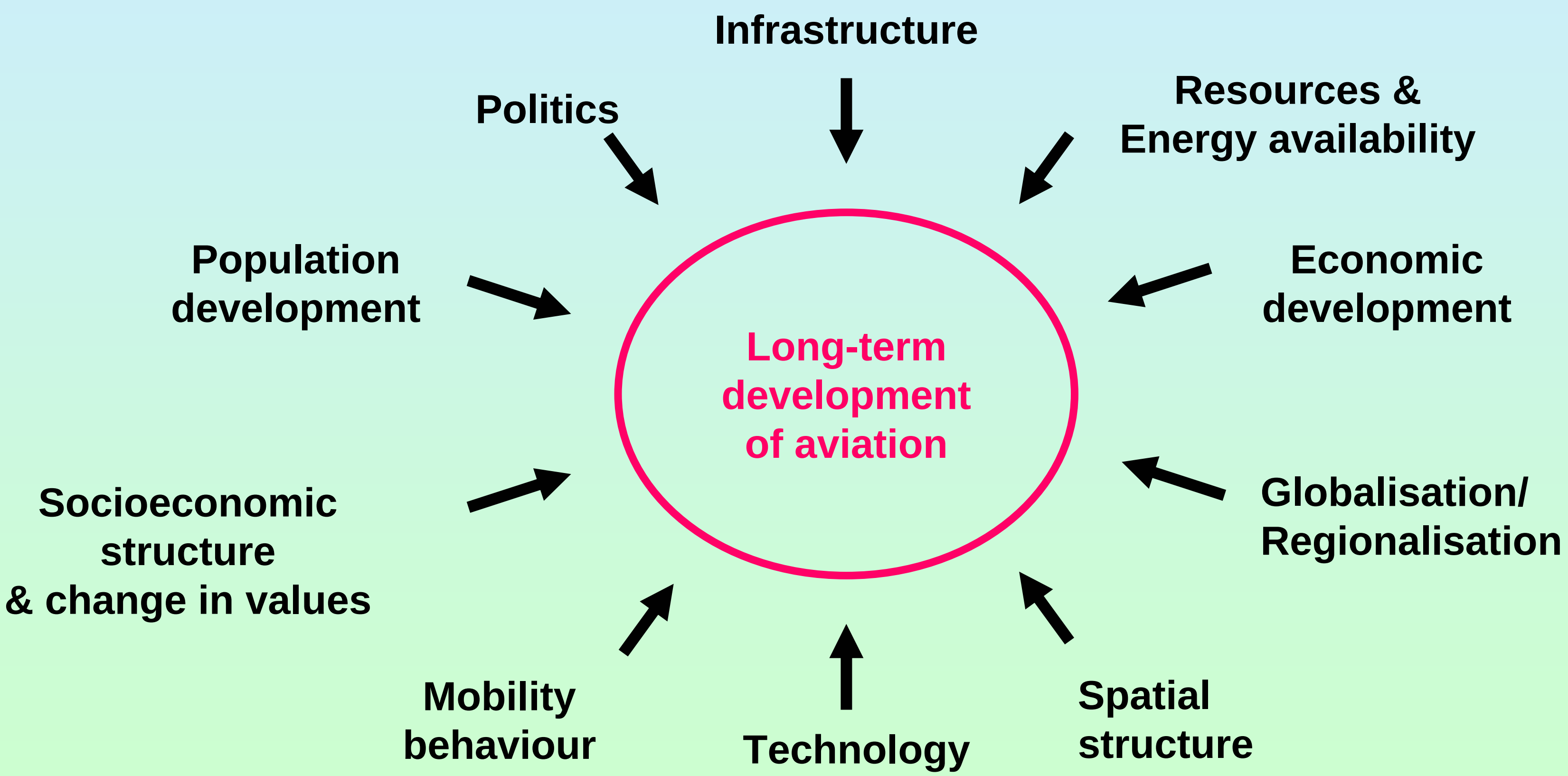
Four scenarios were designed with alternative "philosophies", focussed on specific challenges and constraints.

High growth 1	**Unlimited Skies (ULS)**	Infrastructure constraints: Limits to airports and runways
High growth 2	**Regulatory Push & Pull (RPP)**	Climate problem: Environmental Regulation
Low growth 1	**Fractured World (FW)**	Fragmentation: Block Building and Autarky
Low growth 2	**Down-to-Earth (DtE)**	Value Change: Regional Lifestyle + Slow Mobility

Scenario Structure Overview



Factors of influence for the long-term development of aviation, taken into account for the quantification



Drivers (Environment, Energy, Technology):

	Unlimited Skies	Regulatory Push & Pull	Fractured World	Down to Earth
Environment	no catastrophic change	significant change; main problems 2052-2058	little change	some alarming, but no catastrophic change
Energy availability	available	available	depending to regions; scarcity after 2050 expected	available, scarcity after 2050 expected
Peak of world oil production (incl. artificial oil)	2080	2050	2020	2020
Energy use / EJ	1350	1100	970	810
Energy price (1990 = 1)	2	4	8	4
Technology development	dynamism of technological innovation is broad-based; communication and transportation growth		heterogeneous, partly incompatible, interchange problems	rapid diffusion of post-fossil technologies - no solution for noise reduction

Drivers (Policy, People):

	Unlimited Skies	Regulatory Push & Pull	Fractured World	Down to Earth
Political development	market philosophy	emission regulations	regional differences	pollution sources tightly controlled
Citizen preferences	global orientation, pragmatic solutions	regulatory approach in environmental issues	autarky, regional orientation	environmental and safety concerns
Customers values	convenient and flexible service and mobility	cheap and environmental ly okay	security concerns	stigmatisation of "fast" and international patterns

Key air transport assumptions 1/2

2050 Scenario Assumptions	Unlimited Skies	Regulatory Push & Pull	Fractured World	Down to Earth
Aircraft technology	new very large aircraft available	ULS (slower) + introduction of hydrogen powered ac	different standards	NOx optimized ac
Safety & Security	high standards	high standards (regulation)	high effort for security	high standards
Market Development	deregulation, strong competition	controlled liberalisation, medium competition	dominance of national carriers	decrease in the number of airlines

Key air transport assumptions 2/2

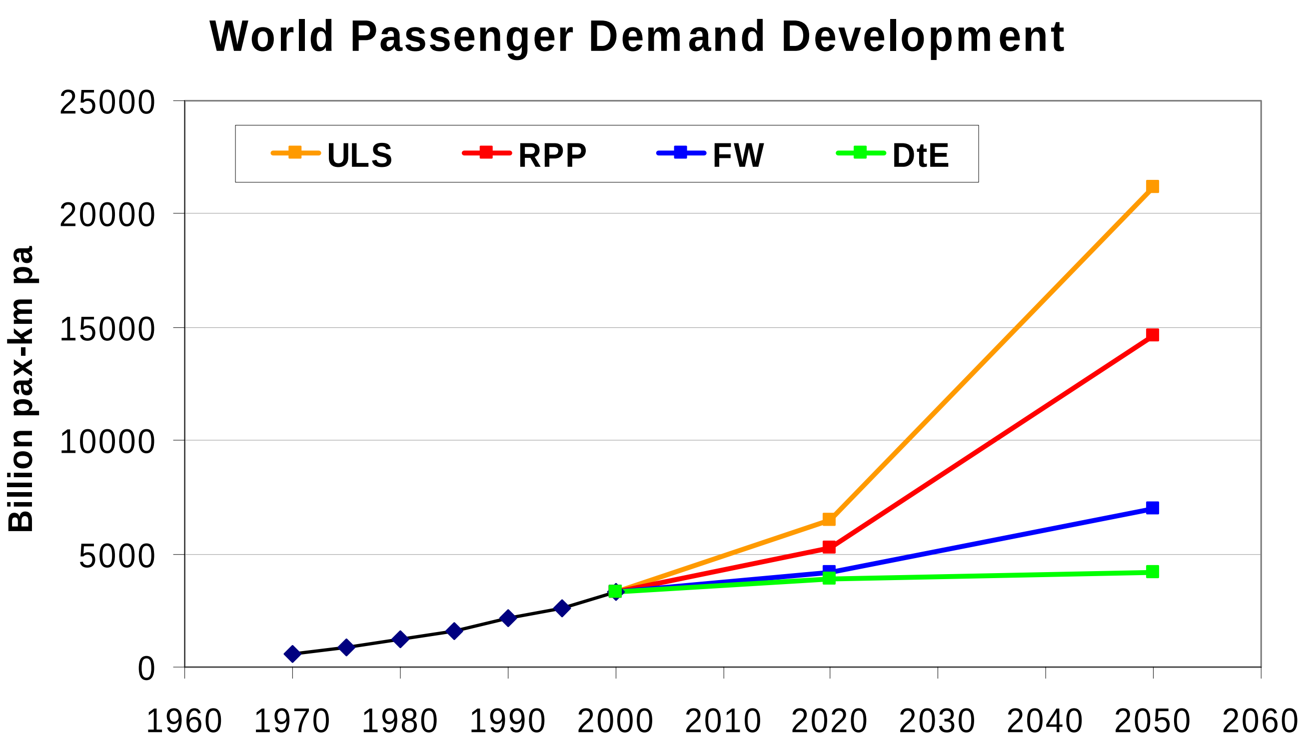
2050 Scenario Assumptions	Unlimited Skies	Regulatory Push & Pull	Fractured World	Down to Earth
Air transport supply & demand	Very high increase	High increase	Low growth in interregional flights	Decrease
Airport & ATM Capacity	Constraints	Capacity regulated	Depending to regions	No constraints, but low profitability
Aviation Costs	Lower specific costs	Lower specific costs	Higher (security & standards)	Higher specific costs

Range of quantification results

Quantification results for the four scenarios are available for the following categories:

- **Air traffic demand**
- Effects on typical European airports
- Movements and fleet
- **Local air quality around airports,** Noise
- Fuel consumption, **global emissions**
- Costs and effects on airlines
- **Impacts of Fuel Tax, Local Charges and Hydrogen Fleet**

Comparison of the total passenger demand



Average Annual Growth

	2020 v 2000	-	2050 v 2000
ULS	3.4%	-	3.8%
RPP	2.4%	-	3.0%
FW	1.1%	-	1.5%
DtE	0.9%	-	0.5%

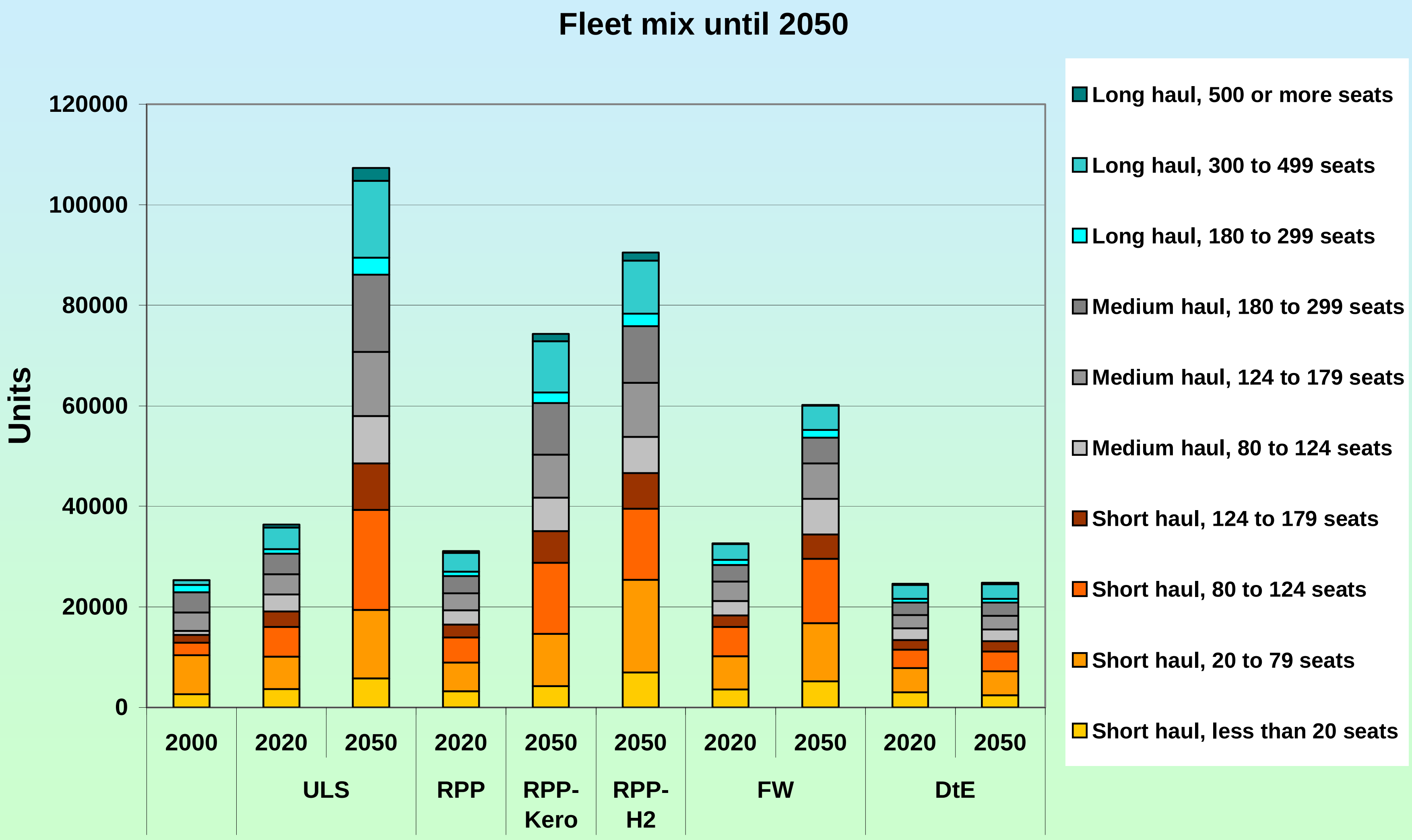
Total Growth

2020/2050 as a multiple of 2000

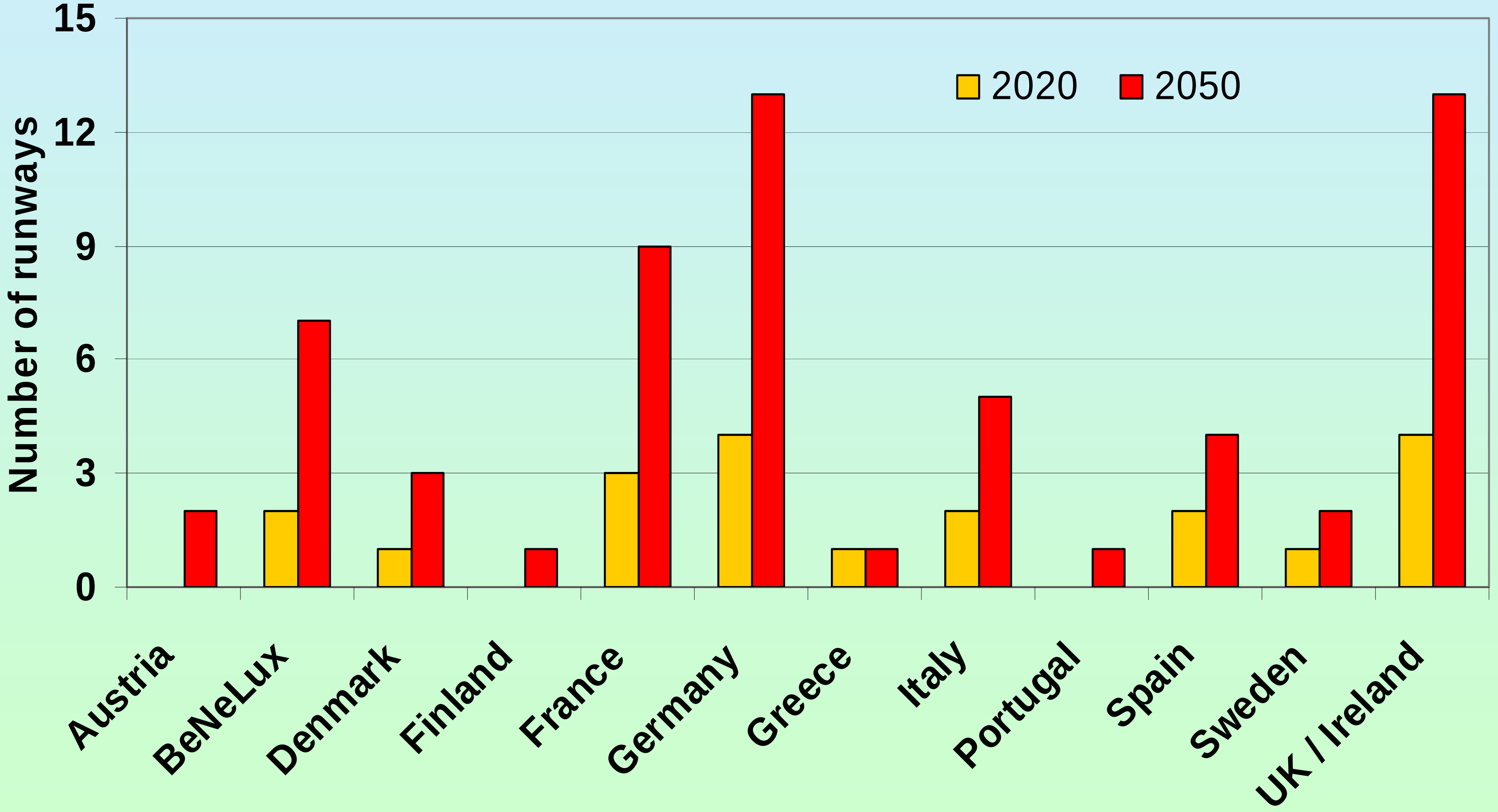
ULS	2.0	-	6.3
RPP	1.6	-	4.4
FW	1.3	-	2.1
DtE	1.2	-	1.3

Highest growth in Scenario **ULS** with 6505 billion pax-km p.a. in 2020 and 21185 billion pax-km p.a. in 2050 - Corresponding growth rate p.a. 3.4% (2020) and 3.8 % (2050) - Scenario **RPP**: 2.4% (2020) and 3.0% (2050)

Fleet mix development for different scenarios



Unlimited Skies - Additional Runway Requirements in Europe



Conclusions for demand

- Different scenario assumptions result in a wide range of imaginable long term developments in travel demand until 2050.
- The "**Unlimited Skies**" scenario yields a high increase in air trips per capita all over the world.
- However, this demand growth will lead to regional infrastructure constraints (primarily in the EU & US; capacities lag behind demand).
- The "**Regulatory Push & Pull**" scenario corresponds with high demand growth, too; aviation is not sustainable with the measures applied, but still a profitable business.
- In the scenario "**Fractured World**" travel demand will only increase within the various world regions and "friendly blocks" (with acceptable profitability).
- In "**Down to Earth**" regional travel will be preferred by customers, mainly by Train/Cars, in consequence of life style changes - aviation is not a profitable business.

Conclusions related to local air quality

• In **Unlimited Skies**, local air quality obviously worsens. Apparently, the increase in air traffic cannot be compensated by the technology advances as introduced in the fleet.

• In **Regulatory Push & Pull** with the all kerosene powered fleet scenario, local air quality obviously worsens, but at a lower pace than the **Unlimited Skies**. Also obvious, application of a kerosene tax (of the order of 10 % of the kerosene price) has only a small effect: Airlines and demand responses to taxes of this level are quite small.

• In the **Regulatory Push & Pull sub-scenario** with the kerosene to hydrogen fleet roll-over, shows a remarkably different situation, because the fleet is quite young, hence incorporating the latest technology. On the other hand, aviation is not financially sustainable. Even if only the costs of new aircraft are born by the airlines (infrastructure costs are not taken into account), the aviation industry is faced with heavy losses, even if they have sought the best possible position in fare levels.

Emission share of civil aviation for different scenarios

CO2 emissions: Share of civil aviation	2000	2020	2050
ULS	1.82%	2.27%	3.11%
RPP – kerosene	1.82%	1.99%	3.68%
RPP – cryoplane	1.82%	1.99%	0.17%
FW	1.82%	1.48%	1.64%
DtE	1.82%	1.86%	2.23%

NOx emissions: Share Of civil aviation	2000	2020	2050
ULS	2.12%	2.31%	2.50%
RPP – kerosene	2.12%	1.90%	2.45%
RPP – cryoplane	2.12%	1.90%	0.42%
FW	2.12%	1.53%	1.60%
DtE	2.12%	1.31%	0.85%

Remark:

It should be noted that some uncertainties in these figures result from the fact that the scenario assumptions from IPCC/SRES are very close to those for the CONSAVE scenarios, but completely identical only in respect of the dominant aspects GDP and population.

Conclusions related to measures

Landing Charges (increase factor 3/2020 – 6/2050, to finance additional infra-structure, causing higher ticket prices, slightly lower demand and reduced movements with bigger airplanes) might work with acceptable losses for aviation business - with positive effects on noise. => *Market approach works in aviation*

Reduced emissions by fleet innovations will be overcompensated by demand growth in **Unlimited Skies** and **Regulatory Push & Pull** - but significant emission reductions probably with hydrogen (not considering uncertainties with respect on possible effects on contrail and cirrus cloud formation).

But: A significant reduction of CO_2 emissions (~10%) via fuel tax (2 US$/kg) or a quick introduction of hydrogen powered aircraft (rollover 8-10 years) reduces strongly the profitability of aviation business.

Main conclusions

Overall scenario results show, that

- Main scenario related results look plausible and are in line with different forecasts. The probability for a correct handling of interdependencies seems therefore to be high => *a good sign for the scenario approach*;

- Technological improvements will be overcompensated by demand in three scenarios (*not in* **Down to Earth**), causing environmental pressure on local and global level;

- Infrastructure enhancements and noise emissions can be successfully targeted with landing charges;

- Fuel tax (2 US$/kg) is not an appropriate measure to tackle CO2 emissions;

- The introduction of hydrogen powered aircraft is expansive but reduces CO2 & NOx. Government needs to compensate early retirement of kerosene powered aircraft?

Final remarks:

More Project information is available:
CONSAVE 2050 - Homepage: www.dlr.de/consave
And over the project co-ordinator: Ralf.Berghof@dlr.de

Thank you for your attention

ULS-Measure Landing Charge for Financing Infrastructure (Start 2020)

Remark: **A landing charge increase by a factor of 3 to 6 is required to accommodate all air traffic in the US and EU using additional infrastructure.**

Data:

ULS Landing charge	**Demand** billion pax-km pa			**Fleet** number of aircrafts			**Movements** 1000 mov pa			**NOx** million kg pa		
	2000	**2020**	**2050**	**2000**	**2020**	**2050**	**2000**	**2020**	**2050**	**2000**	**2020**	**2050**
ULS (charge factor 1.1)	3308	6505	21185	18988	34790	105570	393.6	608.3	1607.6	2227.9	3494.5	7312.6
ULS (charge factor 10)	3308	6505	20874	18988	34790	102250	393.6	608.3	1383.2	2227.9	3494.5	7262.9
ULS (charge factor 20)	3308	6505	20554	18988	34790	100200	393.6	608.3	1226.5	2227.9	3494.5	7186.2

Assessment for Engineers:

ULS Landing charge	Reduction compared to "no measure"			
	Demand	**Aircraft**	**Movements**	**NOx**
ULS (charge factor 10)	1.5%	3.1%	14.0%	0.7%
ULS (charge factor 20)	3.0%	5.1%	23.7%	3.0%

Assessment for Regulators:

ULS Landing charge	Measure Efficency				Profitability in	
	Demand	**Aircraft**	**Movements**	**NOx**	**2020**	**2050**
ULS (charge factor 1.1)					8.14%	6.88%
ULS (charge factor 10)	2.1%	4.7%	22.5%	1.3%		5.24%
ULS (charge factor 20)	4.3%	7.6%	38.1%	3.3%		4.20%

RPP-Measure Fuel Tax for Reducing Emissions (Start 2020) and RPP-Measure Introduction of Hydrogen Fleet (Start 2040)

Data:

RPP Fuel Tax and Hydrogen	**Demand** billion pax-km pa			**Fleet** number of aircrafts			**NOx** million kg pa			**CO2** billion kg pa		
	2000	**2020**	**2050**	**2000**	**2020**	**2050**	**2000**	**2020**	**2050**	**2000**	**2020**	**2050**
RPP (Kerosene/no tax)	3308	5284	14636	18988	29278	74346	2228	2871	4914	531	749	1654
RPP (1$/kg)			14259			68114			4650			1563
RPP (2$/kg)			13884			63575			4419			1485
RPP Hydrogen 2040			13886			67957			1382			76

Assessment for Engineers:

RPP Fuel Tax	Reduction compared to "no measure"			
	Demand	**Aircraft**	**CO2**	**NOx**
RPP (1$/kg)	2.6%	8.4%	5.5%	5.4%
RPP (2$/kg)	5.1%	14.5%	10.2%	10.1%
RPP Hydrogen	5.1%	8.6%	95.4%	71.9%

Assessment for Regulators:

RPP Fuel Tax	Measure Efficency				Profitability in	
	Demand	**Aircraft**	**CO2**	**NOx**	**2020**	**2050**
RPP (Kerosene/no tax)					5.05%	4.35%
RPP (1$/kg)	4.0%	13.8%	10.0%	12.9%		1.01%
RPP (2$/kg)	8.0%	23.9%	18.7%	24.2%		-0.72%
RPP Hydrogen	8.0%	14.2%	174.4%	172.9%		-3.99%