Industry Perspective on Fuel and Environmental Challenges for Aviation

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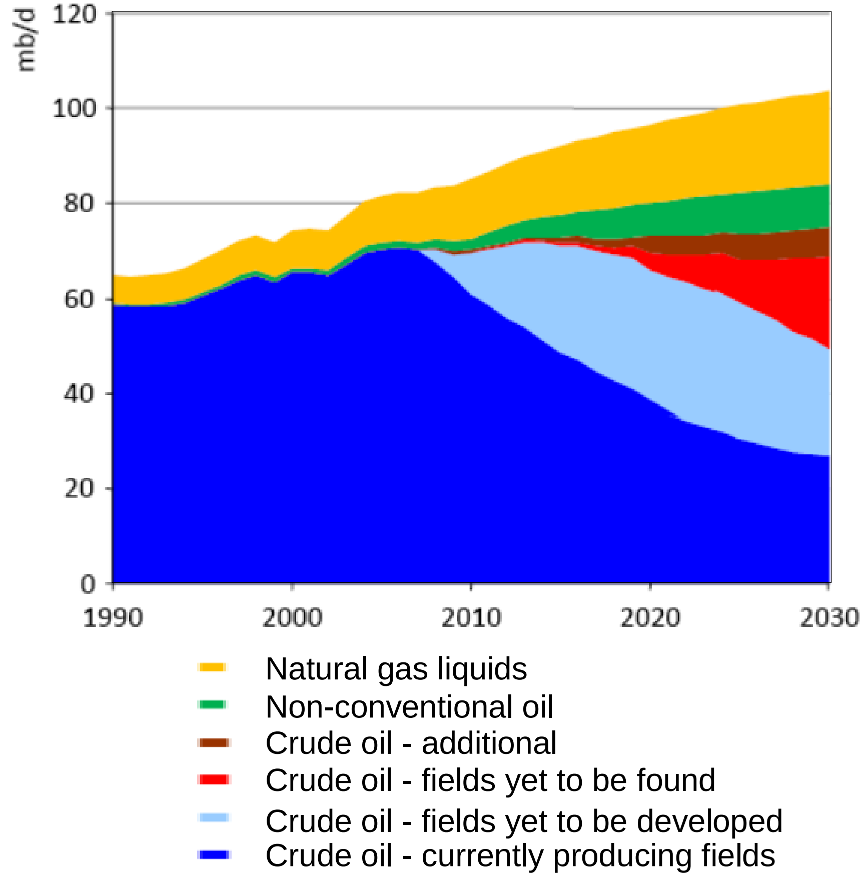
OUTLINES

- Fuel & environmental challenges
- Mitigation strategies
- Exploring & approval process for alternative fuels
- Impact of PM emissions on climate & health
- PM regulatory process & measurement methodology development
- PM experience and concerns with alternative fuels
- Conclusions

ENERGY & ENVIRONMENTAL CHALLENGES FOR TRANSPORTATION

- Depleting fuel supply & increasing demand
- High fuel costs
- Global warming & increasing carbon foot-print

WORLD OIL PRODUCTION TRENDS



Production reaches 104 mb/d in 2030, requiring 64 mb/d of gross capacity additions – six times the current capacity of Saudi Arabia – to meet demand growth & counter decline

Source: Lew Fulton, IEA, “Energy Futures and Air Travel”, ICAO Workshop on Aviation and Alternative Fuels, 10 Feb 2009.

ENVIRONMENTAL CHALLENGES FOR AVIATION

CO, VOC, NOx, Smoke, ICAO Regulations, Landing Fee Surcharges, Health Effects

ICAO Regulations, Health Effects

Local Air Quality

Community Noise

Cadmium, Mercury, Solvents, Health Effects

Hazardous Materials

Water Quality

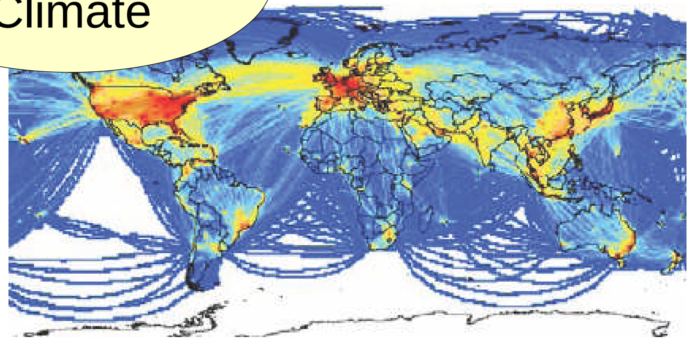
Health Effects, Regulations

Fuel Availability

Global Climate

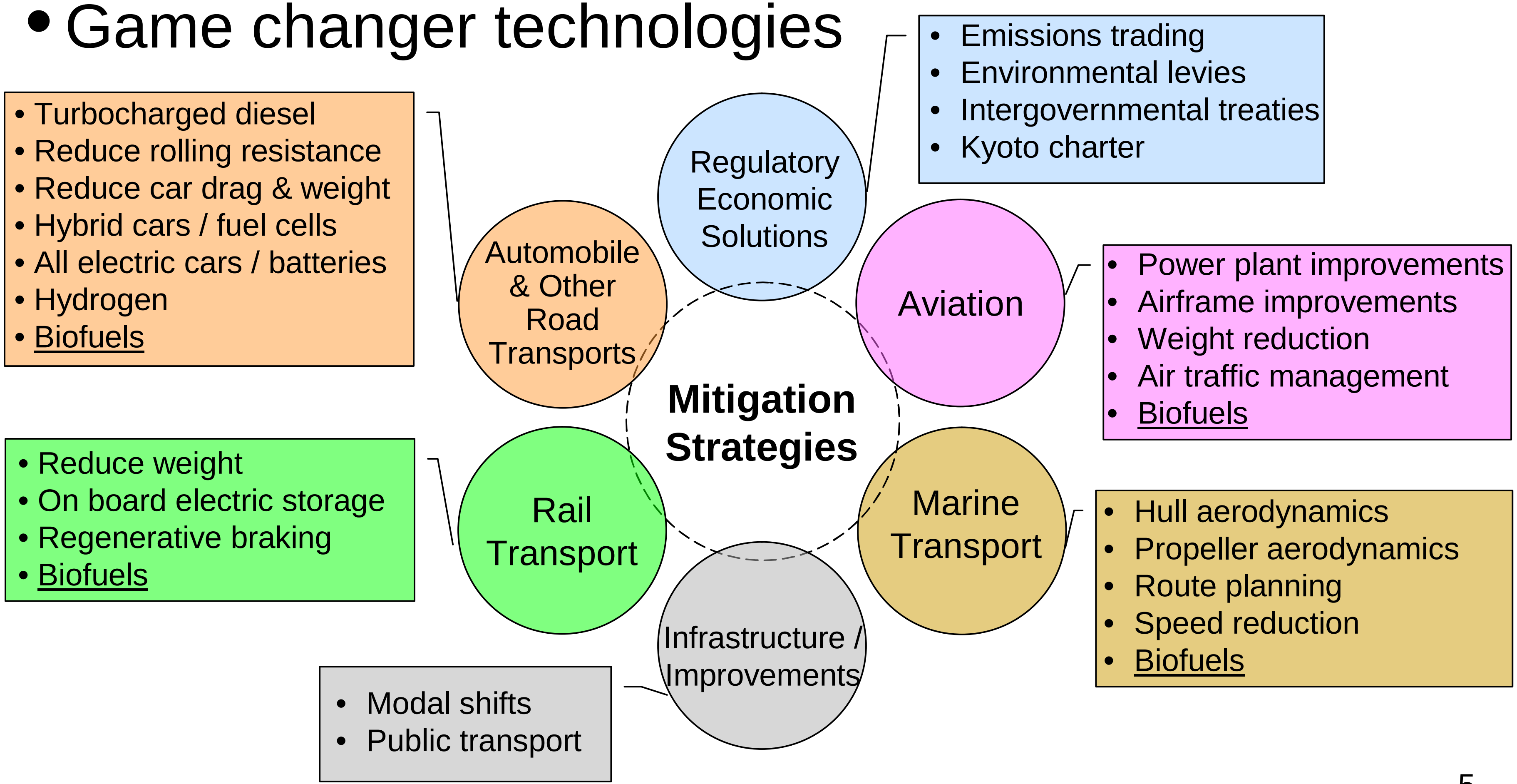
Price / Demand
Alternative Fuels

Greenhouse Gases
Ozone Depletion
Cruise NOx

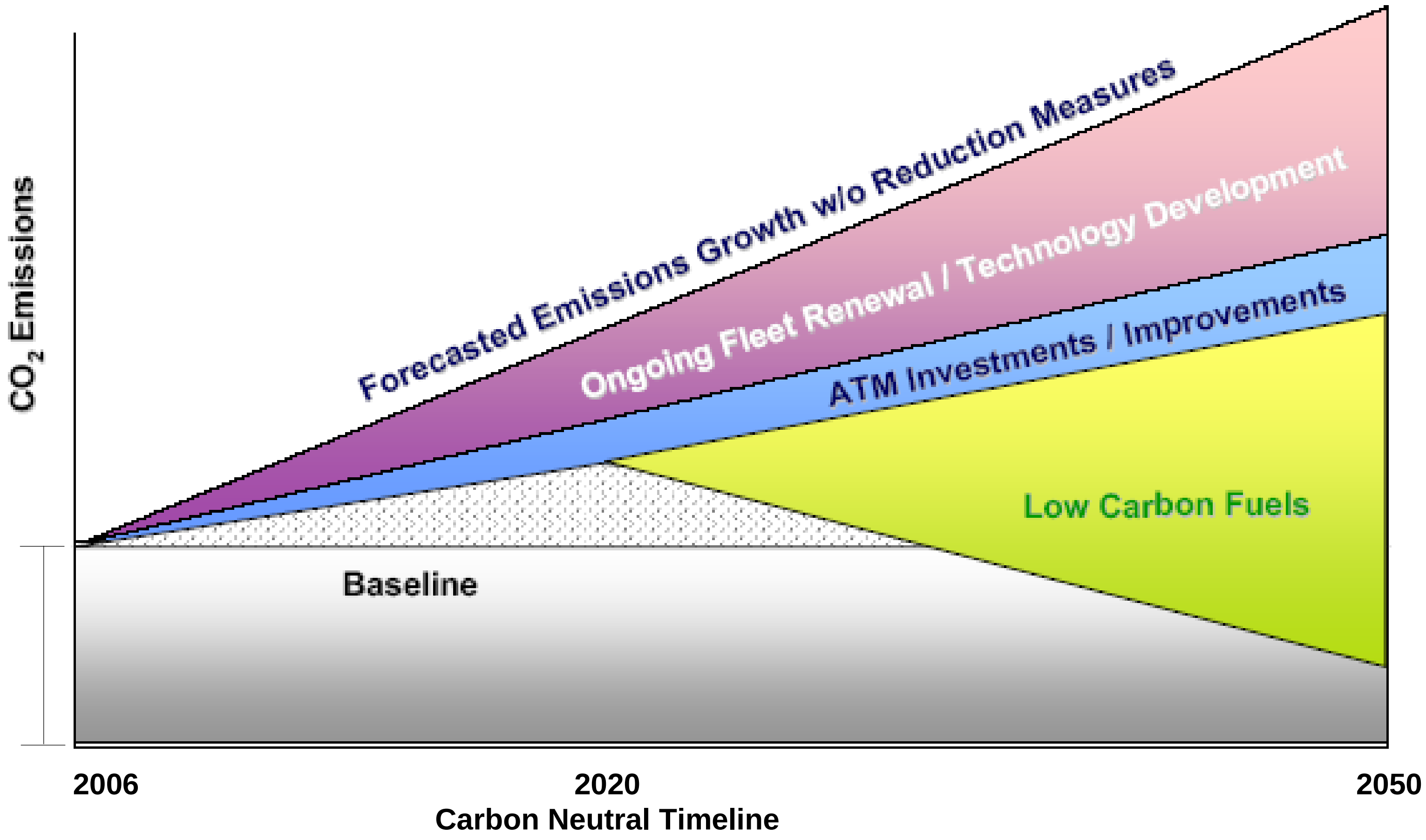


CLIMATE MITIGATION METHODOLOGIES FOR TRANSPORATION

- Improve energy efficiency of designs
- Improve operational methods & maintenance
- Game changer technologies

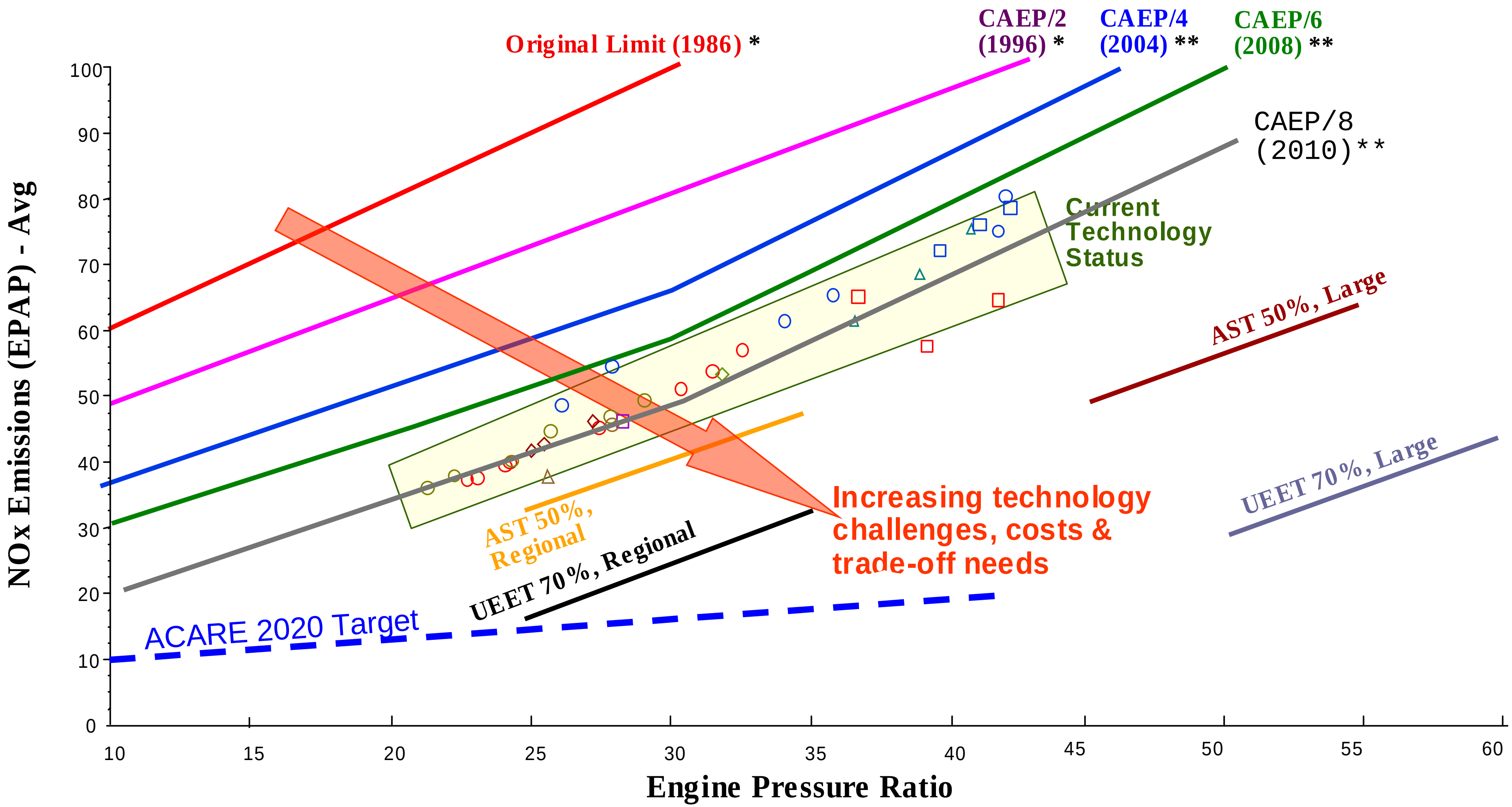


MITIGATION STRATEGIES FOR AVIATION CARBON FOOTPRINT



Source: Paul Steele, Dir. Aviation Environment, IATA, Exec. Dir. ATAG, “Why We Need Alternative Fuels”, ICAO Workshop on Aviation and Alternative Fuels, 10 Feb 2009.

NOx TECHNOLOGY STANDINGS vs REGULATIONS



* For turbofan engines exceeding 6000 lb thrust only

** Correction for thrust down to 6000 lb with no additional stringency

EXPLORING SUSTAINABLE BIOSTOCKS

Image: Boeing

Generation 1: Sugar cane, corn, vegetable oil – compete with food chain

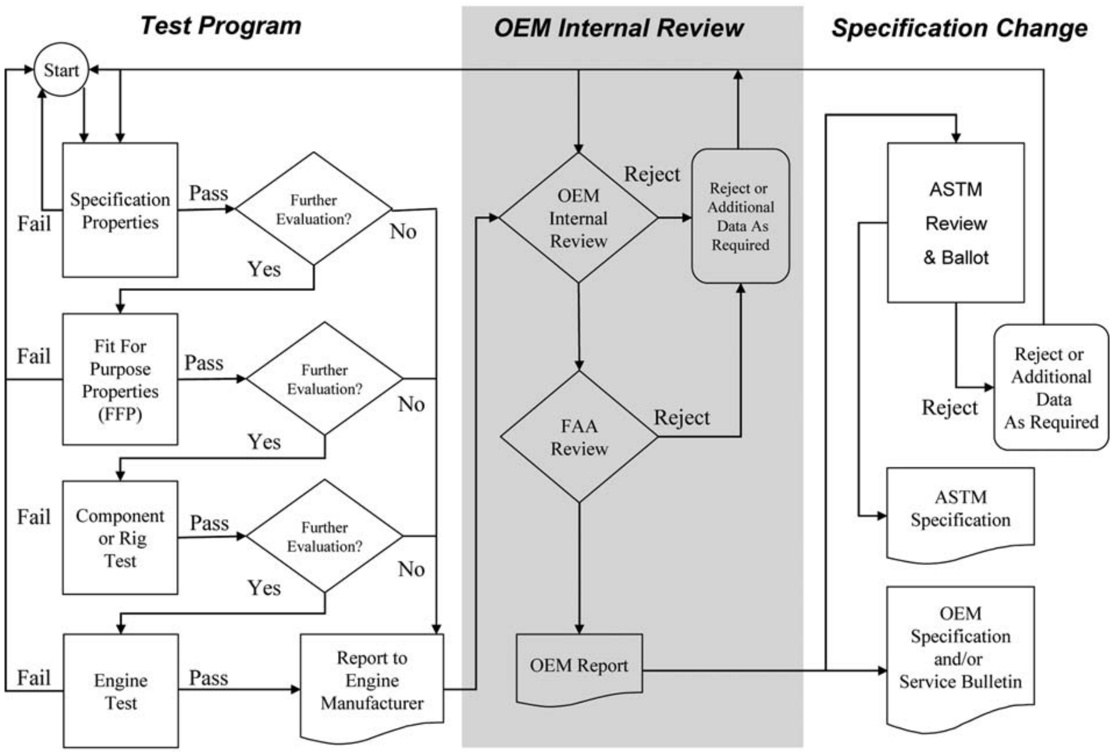
Generation 2: Jatropa, camelina, babasu, halophytes – non-food crops, desert land usage, etc.

Generation 3: Algae, cellulosic biostock – high yield feedstock, not competing with food chain or water

Source: Dr. Lourdes Maurice, FAA Office of Environment & Energy, “Alternative Fuels R&D – A U.S. Perspective”, ICAO Workshop: Aviation and Alternative Fuels, 11 Feb 2009.

ENGINE MANUFACTURERS' ROLE IN AND REQUIREMENTS OF ALTERNATIVE FUELS

ASTM D4054 Overview –
Fuel and Additive Approval Process



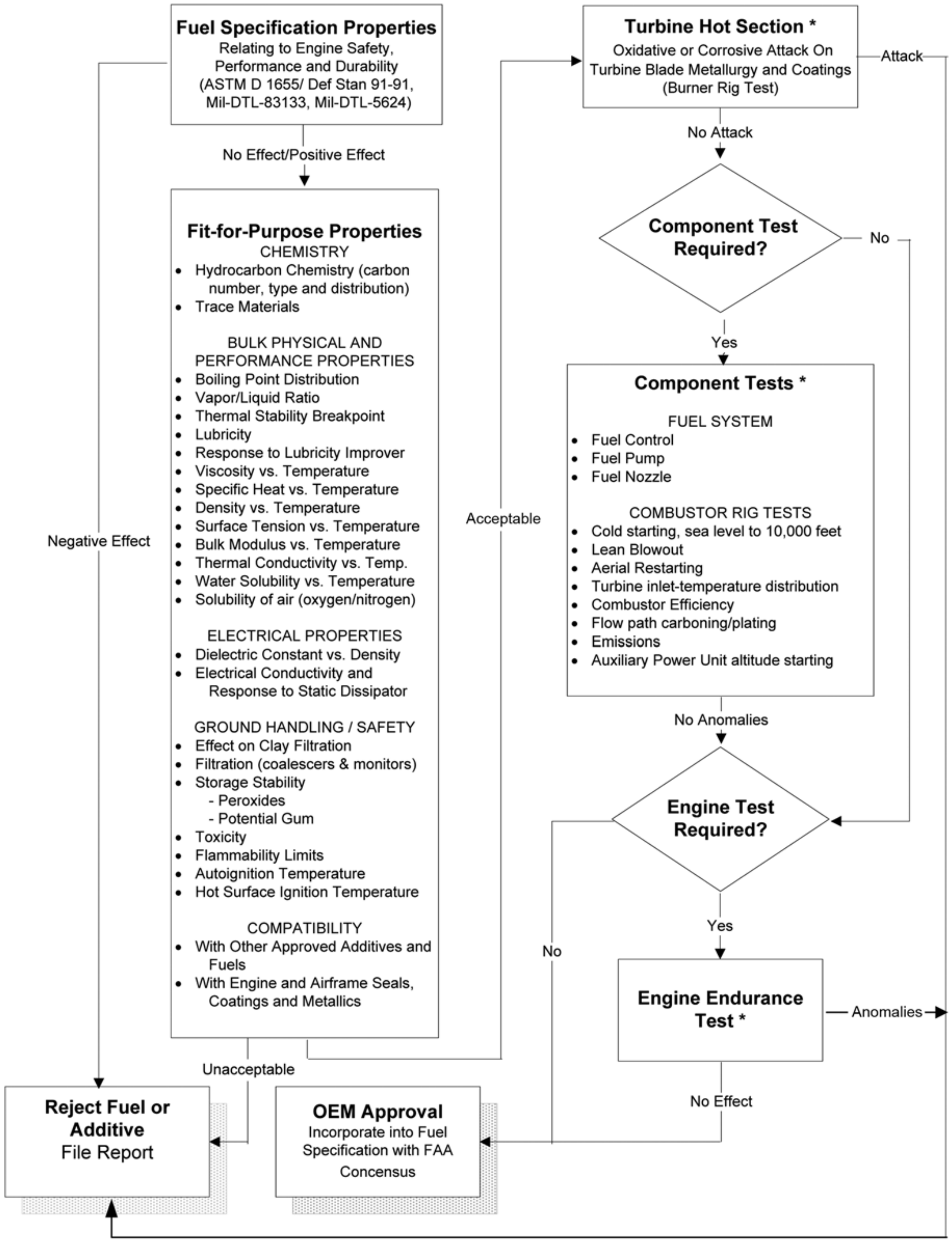
Validate Alternative Fuels

- Support customer initiatives
- Evaluate impact on the engine
- Provide a timely and cost-effective path for approval and field use.

OEM Requirements

- High energy content
- Drop-in capability
- No negative impact on engine safety, durability and performance.

ASTM D4054 Test Program



CANADA-INDIA BIOFUEL TECHNOLOGY PROGRAM 2010 - 2013

Pratt & Whitney Canada
A United Technologies Company

RYERSON UNIVERSITY

UNIVERSITÉ LAVAL

McGill

NRC·CNRC
Aerospace/Aérospatiale

Biofuels
- Biojet (algae)
- Additives
- Materials
- Modelling
- Rig & Engine Tests

Funding from :
P&WC
MDEIE
CRIAQ
ISTP
NRC

Biofuel Suppliers

Properties
- Comparison to Aviation Fuel Spec. ASTM D1655
- Identify Fit-for-purpose tests: ASTM D4054
- Biofuels Modeling

Properties , Economics, Application Issues

2010 Program Starts

2011 Biofuel Properties

2012 Fit-for- purpose Tests
Component Tests
Modelling

2013 Engine Validation

Biofuel Certification

Infotech
Creating Business Impact

IndianOil

Funding from :
P&WC
Infotech
Oil Companies
GITA

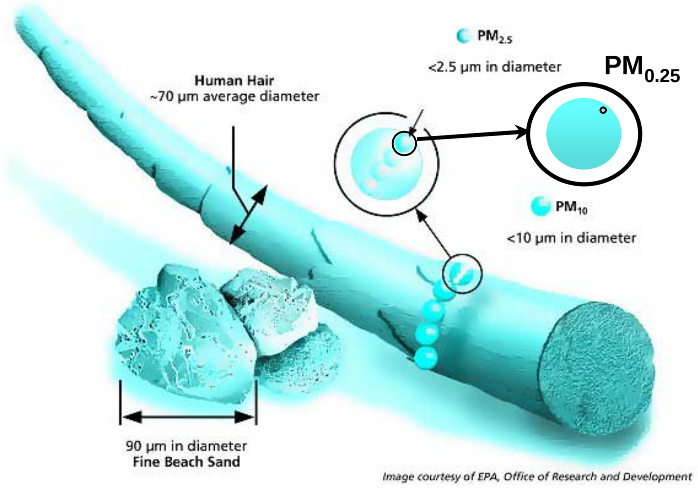
Biofuels
- Biojet (jatropha)
- Bioethanol, Biobutanol
- Additives
- Component tests
- Supplier input
- Modelling

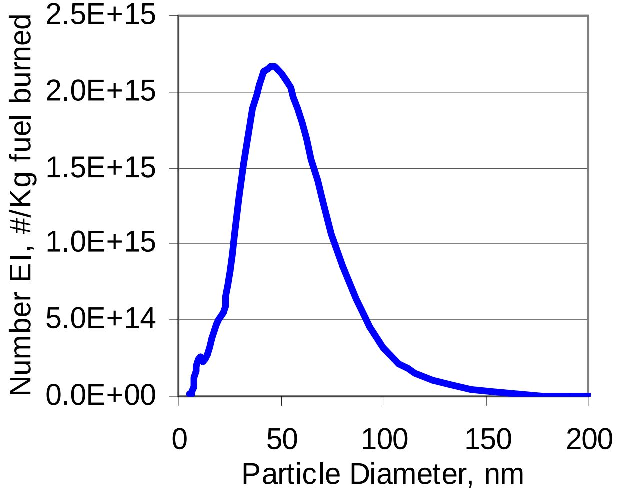
What are Aviation PM emissions and why are they of concern?

How can we reduce these emissions

What are PM emissions from Aviation?

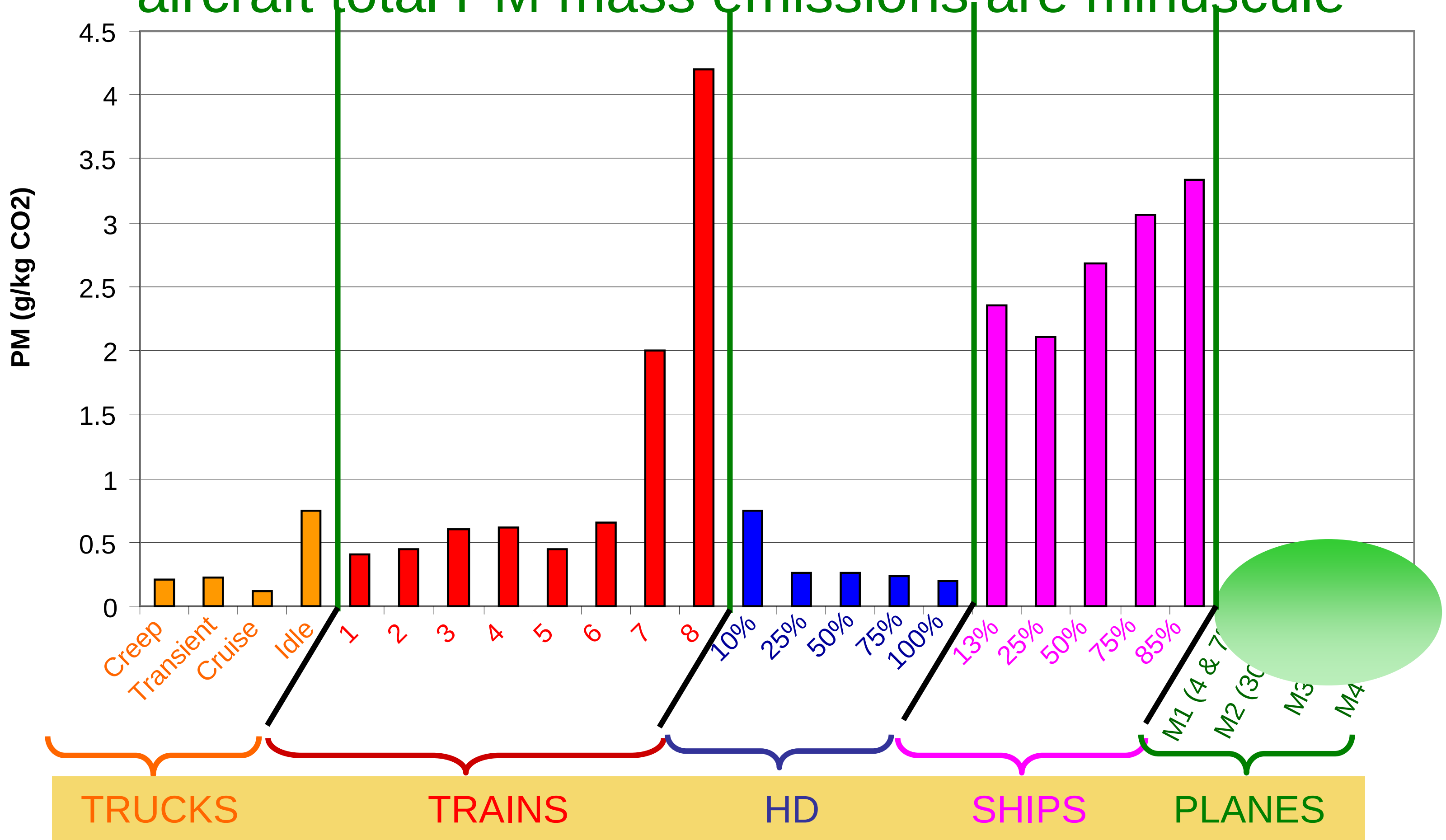
- "Particulate matter", $PM_{2.5}$ and PM_{10}, is a complex mixture of extremely small soot particles and liquid droplets.
- Most of aviation PM emissions are smaller than 0.25 μm (250nm)
- Mass, number and size distribution of PM emissions are important for Local Air Quality, human health, and the global environment
  - Aircraft engines produce very large number of very small particles
  - Emission indices of PM emissions from aircraft tested
    - EI_{mass} = ~ 0.4 g/kg fuel burned
    - EI_{number} = ~1 $X10^{16}$ /kg fuel burned





Aircraft PM mass emissions are small as compared to other sources

PM emissions from aircraft consists of very tiny particles, aircraft total PM mass emissions are minuscule



Data courtesy Prof. Wayne Miller, UC Riverside

Aircraft PM number emissions may be significant as compared to other sources

- Aircraft PM mass emissions are insignificant as compared to other mobile sources because size of particles emitted by aircraft engines is much smaller than other sources
- Large number of very tiny particles emitted by aircraft engines may have a significant health and climate impact than other sources

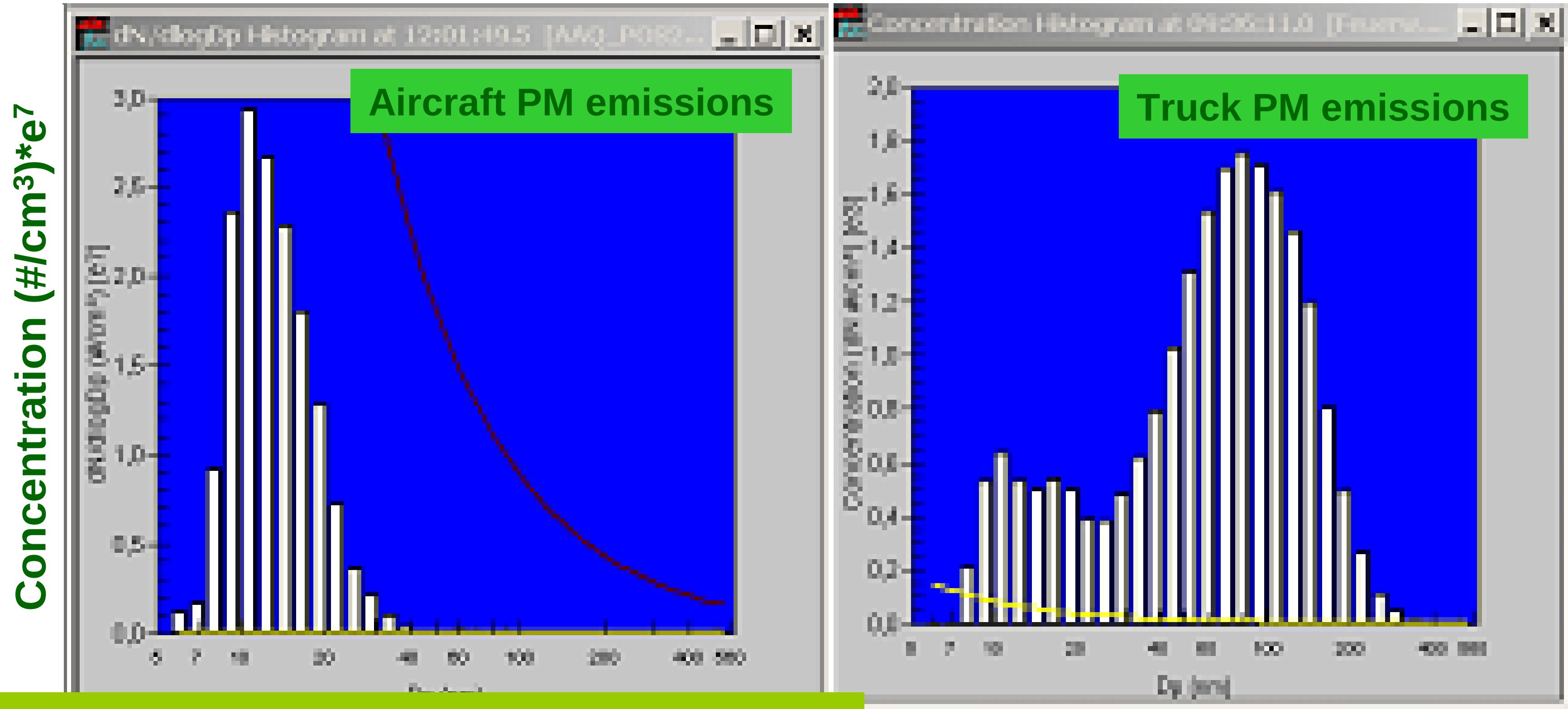
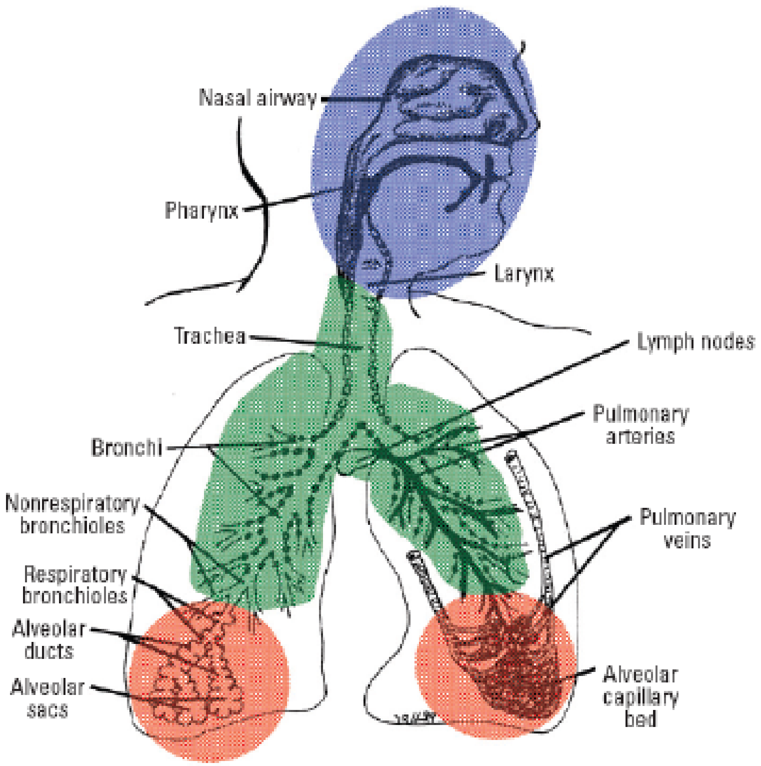
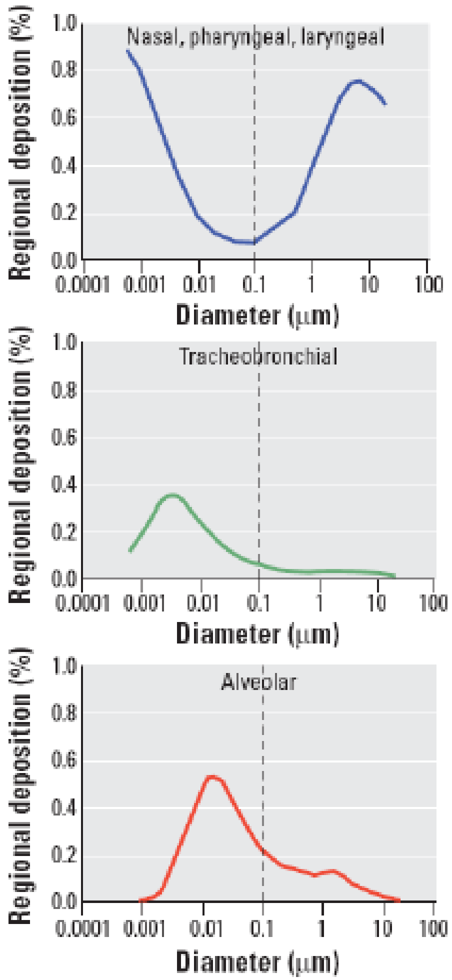


Chart courtesy Theo Rindlisbacher, Swiss FOCA

Human Health – Impact of PM on The Respiratory system





Cleaning mechanisms

Dissolution / leaching of soluble matter in the humid environment of the respiratory system.

Physical translocation of non-volatile, insoluble particulate matter.

Removal from alveolar region by interaction with macrophages.

(Oberdörster et al., 2005)

Chart courtesy Andreas Petzold, DLR

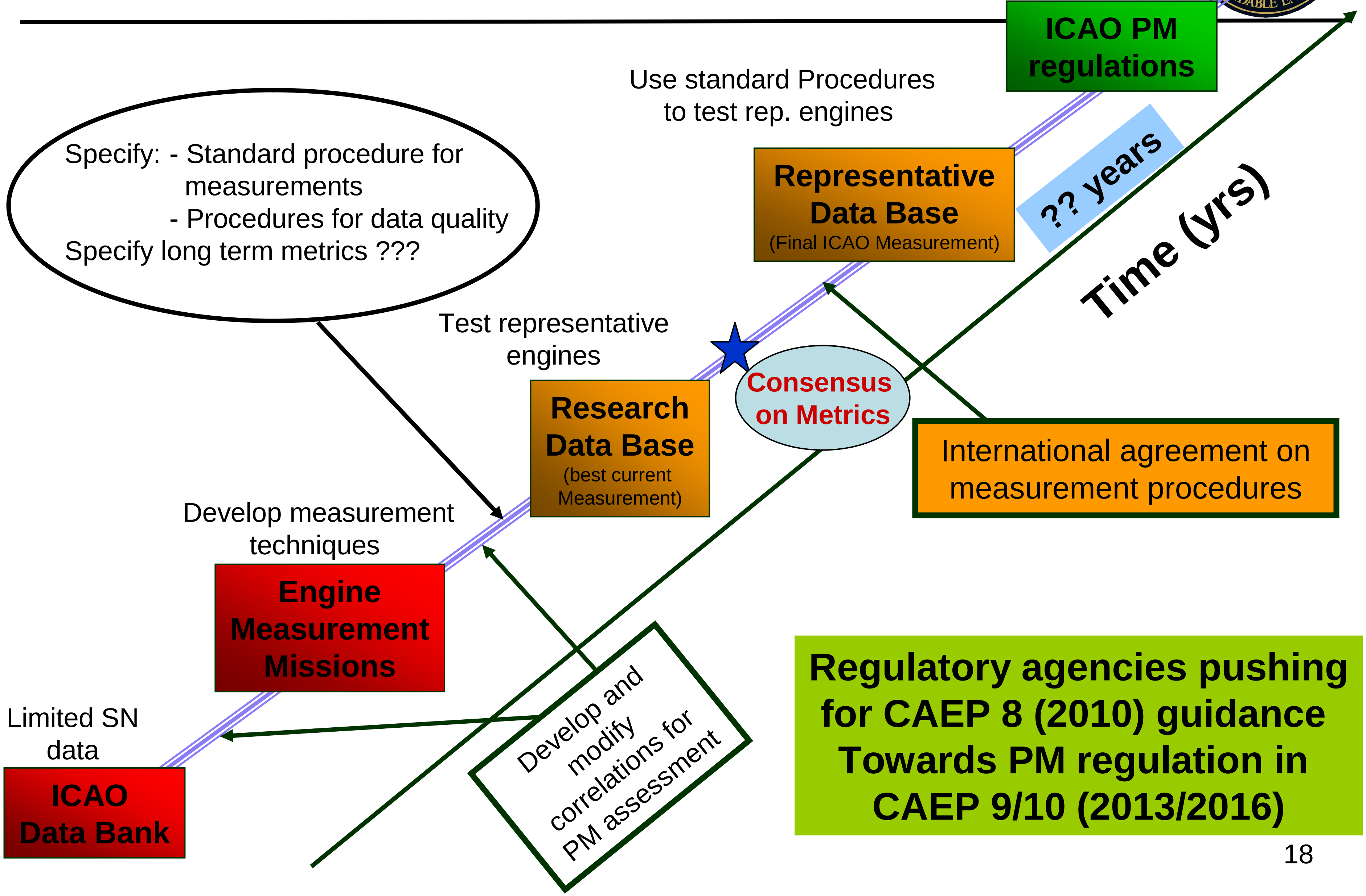
PM Impact Analysis: Large uncertianty on impact on Atmosphere and Climate

Aircraft emit particles and generate contrails under certain conditions. Contrails may transform into persistent contrails and further into cirrus clouds, causing additional cirrus cloud cover.

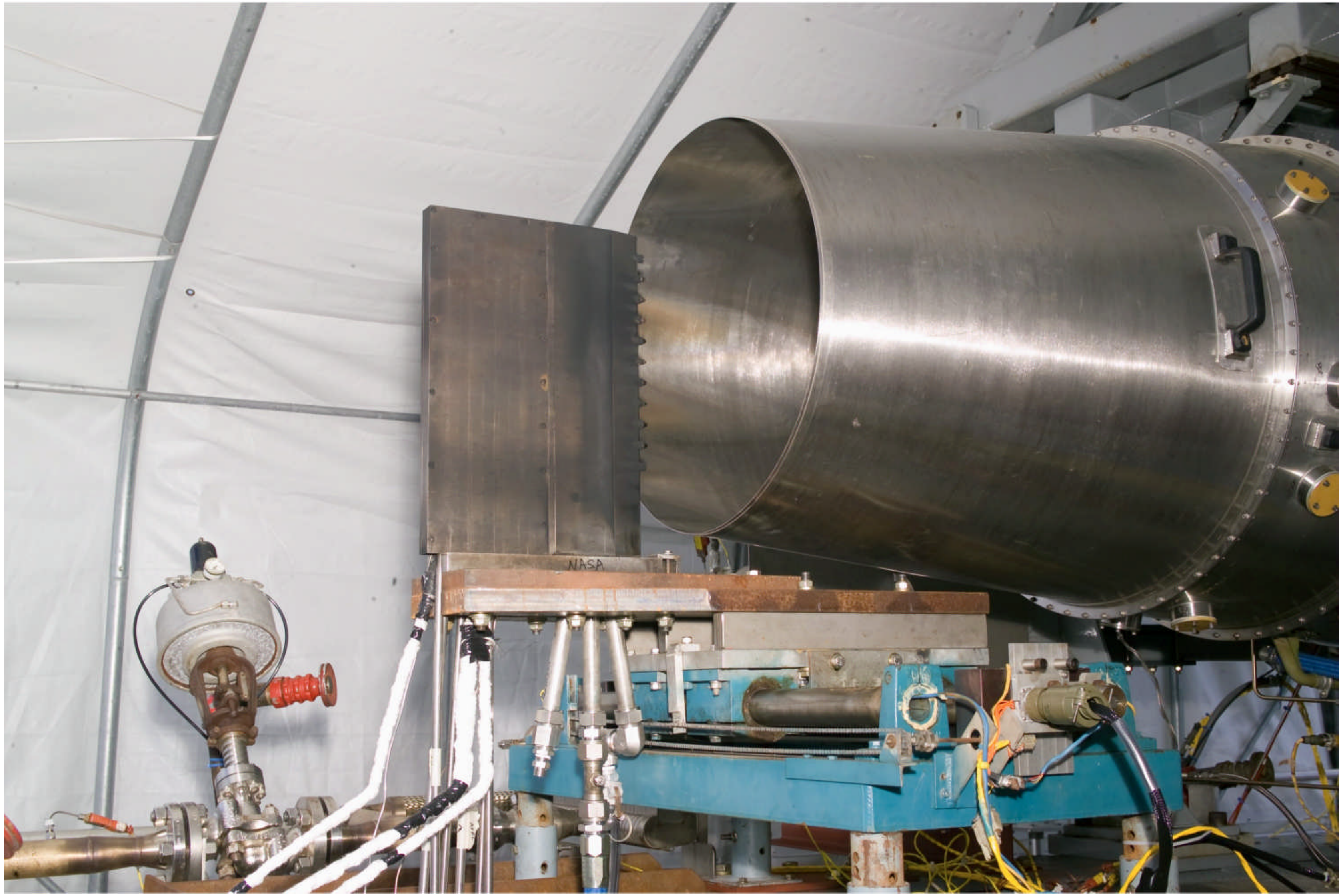
Particles emitted from aircraft may generate additional cirrus clouds in otherwise cloud free regions of the atmosphere.

Chart courtesy Andreas Petzold, DLR

Establish PM standards and regulations



Reduction in PM emissions with Alternative Fuels



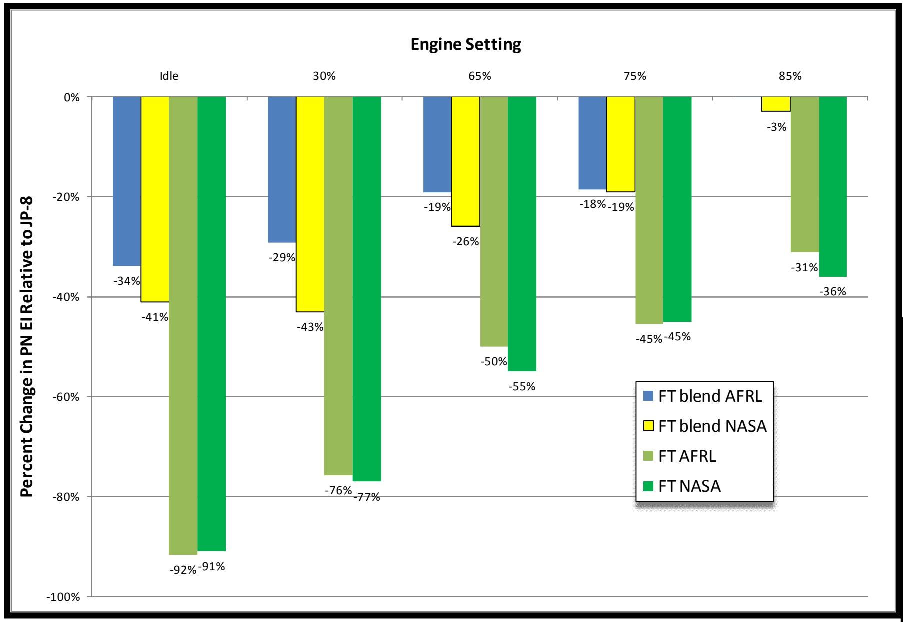
Engine and gaseous emissions data indicates similarities between the fuels tested

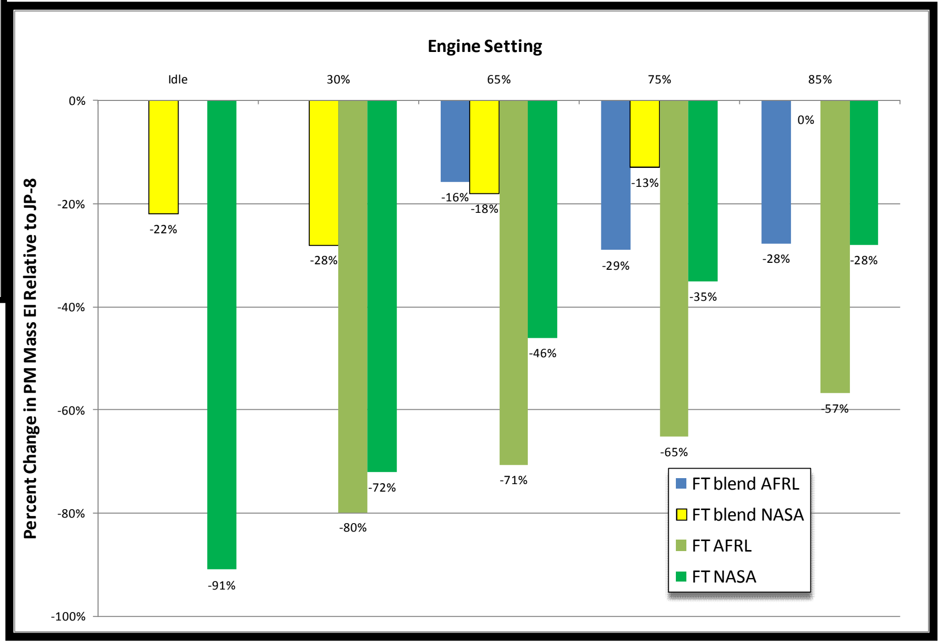
	RATIO - Blend/JP8				RATIO – FT100%/JP8			
Thrust (Rotor Speed N1)	Fuel flow	NOx	CO	SO_2	Fuel flow	NOx	CO	SO_2
LOW (2200)	0.999	0.97	0.95	0.50	0.985	0.97	0.90	0.05
INTERMEDIATE (4500)	1.00	0.98	NA	0.54	0.982	0.97	NA	0.1
HIGH (5750)	0.995	1.0	NA	0.54	0.978	0.98	NA	0.1

- Negligible impact on NOx
- Negligible UHC at all power conditions for both fuels
- SO_2 emissions indicate Sulfur content of the blend to be around 50% of JP8 while for 100% FT fuel a value of 0.1% indicates contamination
- ~2% fuel flow benefit with 100% synthetic fuel can be attributed to the higher heat content of synthetic fuel

Negligible differences in gaseous emissions & performance as expected due to similarity in the physical properties of the fuels (like heating value, specific gravity)

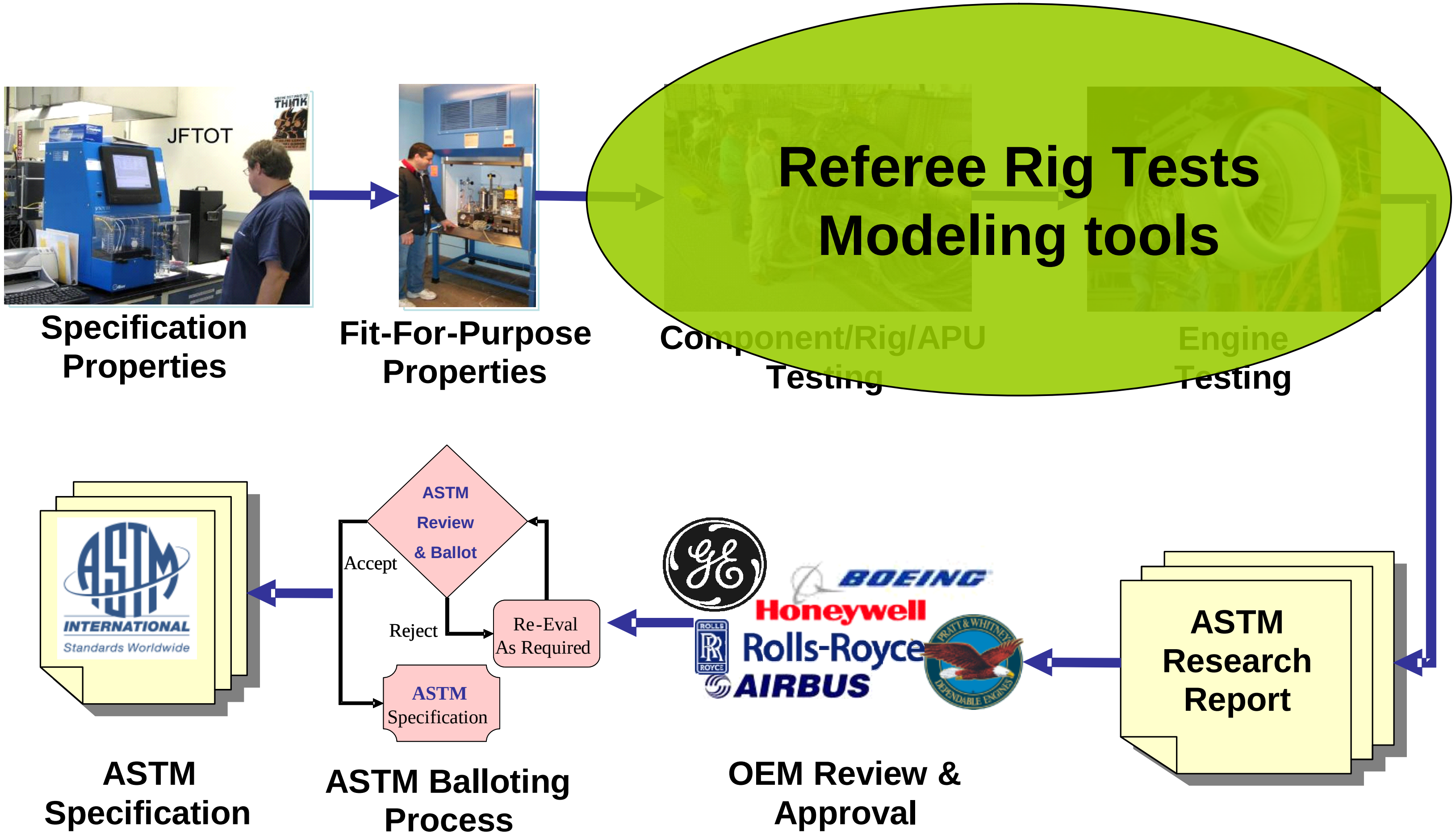
Alternative fuel reduces PM Emission Index





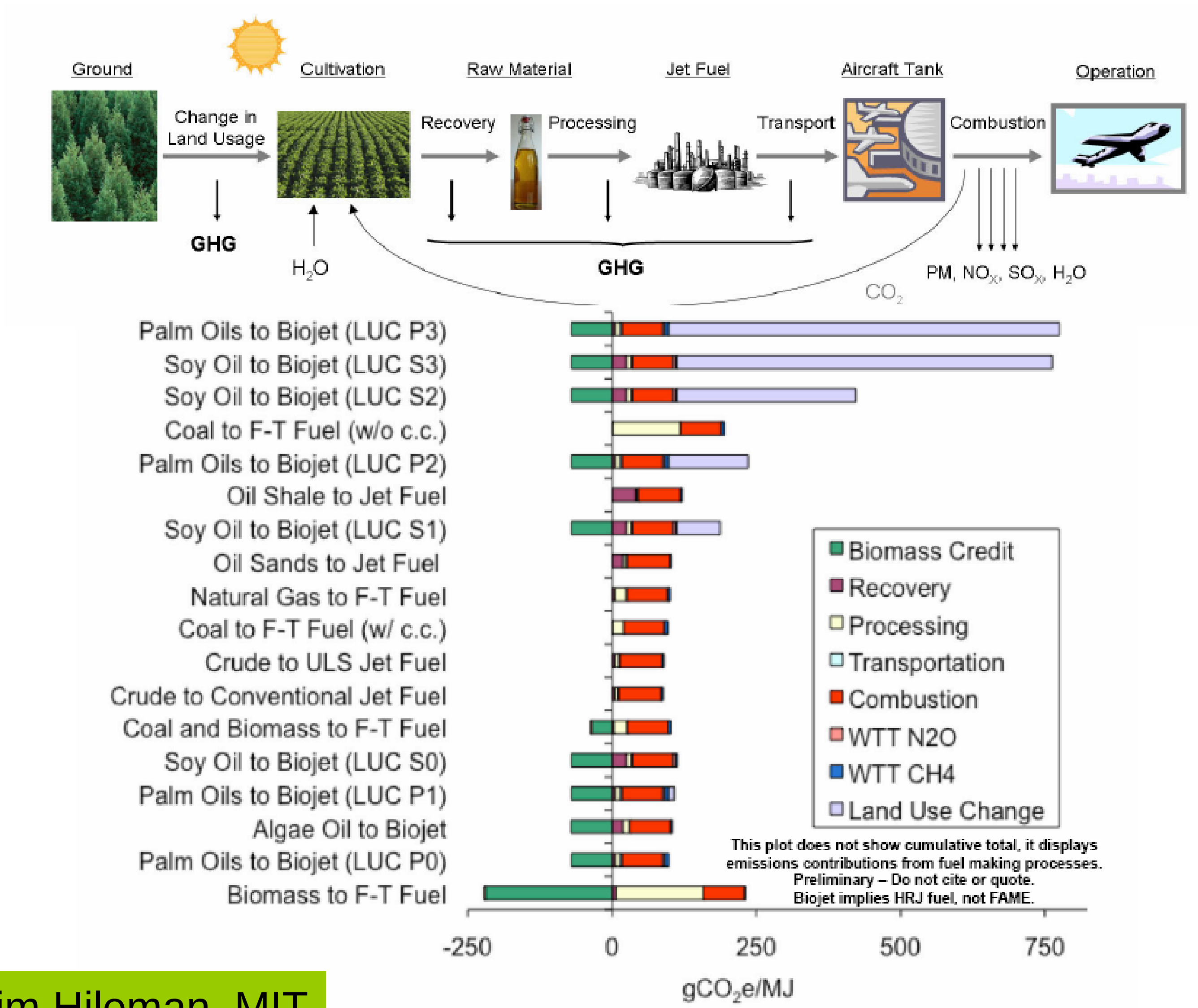
As expected lower PM emissions with synthetic fuel due to its chemical composition (higher H/C ratio and no aromatics/Sulfur)

ASTM Fuel Qualification Process: Refinement needed to speed up the process



Combination of Referee Rig Tests and Modeling tools can be an effective alternative to component/engine testing

Lifecycle GHG analysis for Alternative Fuels Critical in understanding benefits of AF fuels



Courtesy Jim Hileman, MIT

Fuel composition of alternative fuels can impact fuel delivery system

Impact of Alternative fuels on Aircraft fuel delivery system and combustion needs to be characterized

NASA sponsored AAFEX Test, 2009

Take Aways

- Several environmental challenges require advancement on multiple fronts
- PM emissions from aviation are small but can potentially have a significant impact on LAQ and GC
- Alternative Fuels offer several benefits on emissions front by reducing GHG and PM emissions
- Impact of Alternative Fuels on engine and aircraft operation needs to be further evaluated
- Global collaborations essential for success

Thank you