PARTNER

Partnership for AiR Transportation Noise and Emission Reduction

An FAA/NASA/TC-sponsored Center of Excellence

Aviation Mobility, Economy and Environment

Evaluating Choices and Options

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Massachusetts Institute of Technology

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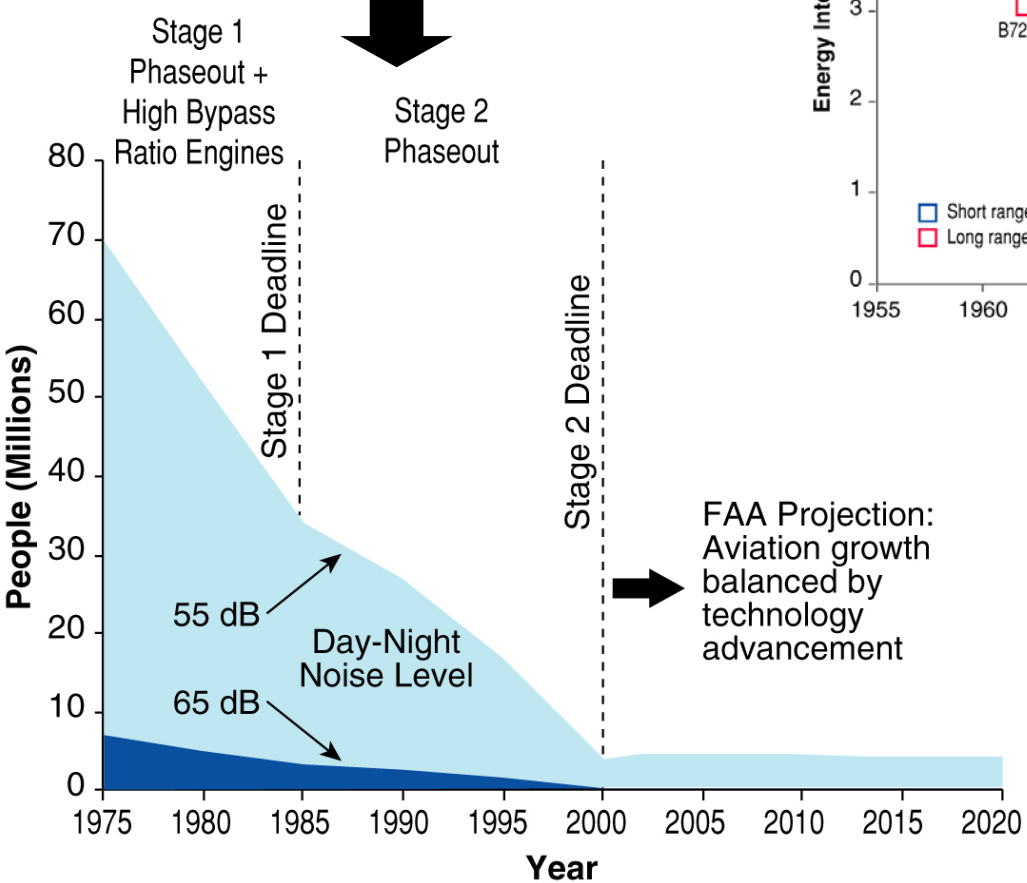
Mobility, economy, environment

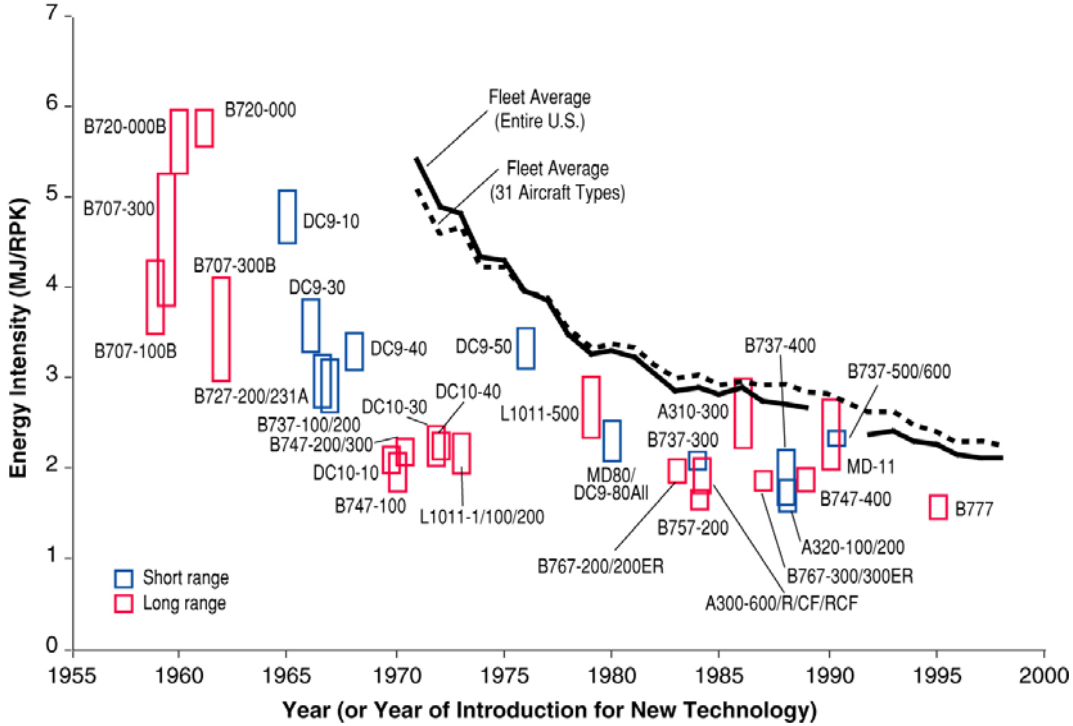
- Aviation is a unique service, an integral part of the economy
  - 740 million enplanements in 2005 in the US (ATA, 2006)
  - 28 billion revenue ton miles of freight in 2005 (ATA, 2006)
  - 9 million people employed, $640 billion to economy (Blakey, 2007)
- Environmental impacts are small, but not insignificant
  - Climate: perhaps 2% to 4% of the contribution to climate change
  - Local air quality: perhaps 200 premature deaths/yr in the U.S.
  - Noise: perhaps 5 million people annoyed in US (> 55dB DNL)
- **Environment may be the dominant constraint on growth of the US air transportation system**
- **Twin negatives:**
  - **Environmental impacts on people and ecosystems**
  - **Economic impacts on people through constraining mobility and increasing costs**

Gains from technology and operations

95% reduction in people impacted by noise



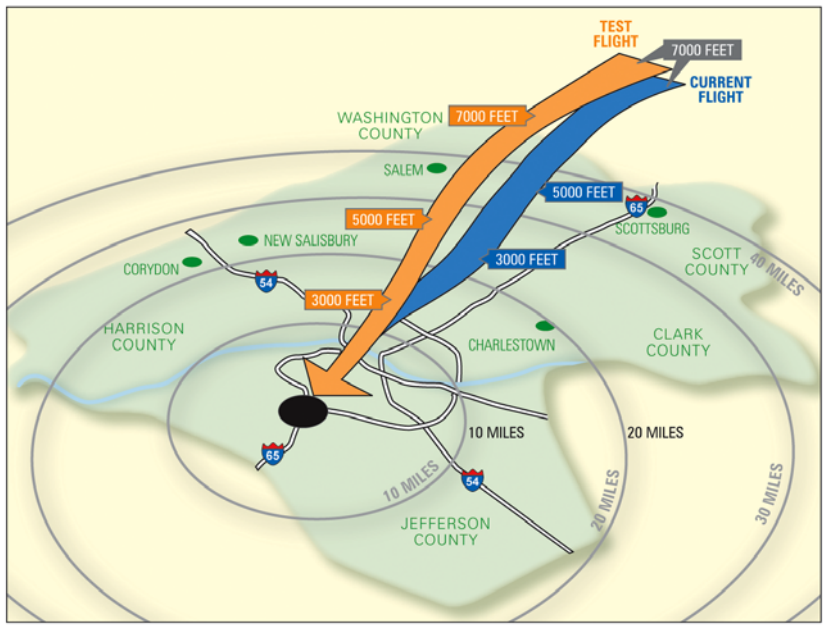
FAA Projection: Aviation growth balanced by technology advancement

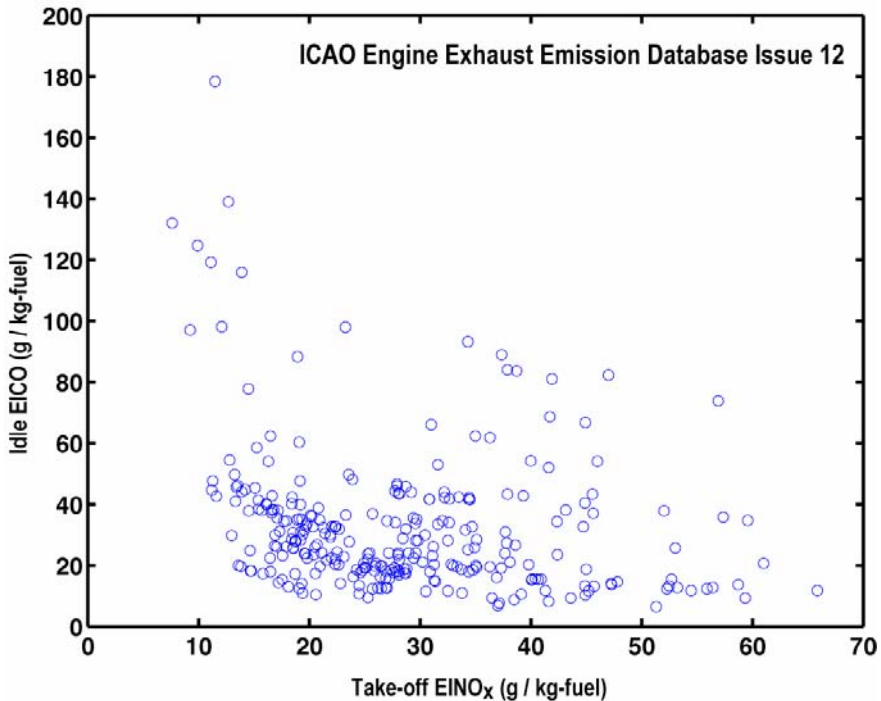


60% improvement in efficiency

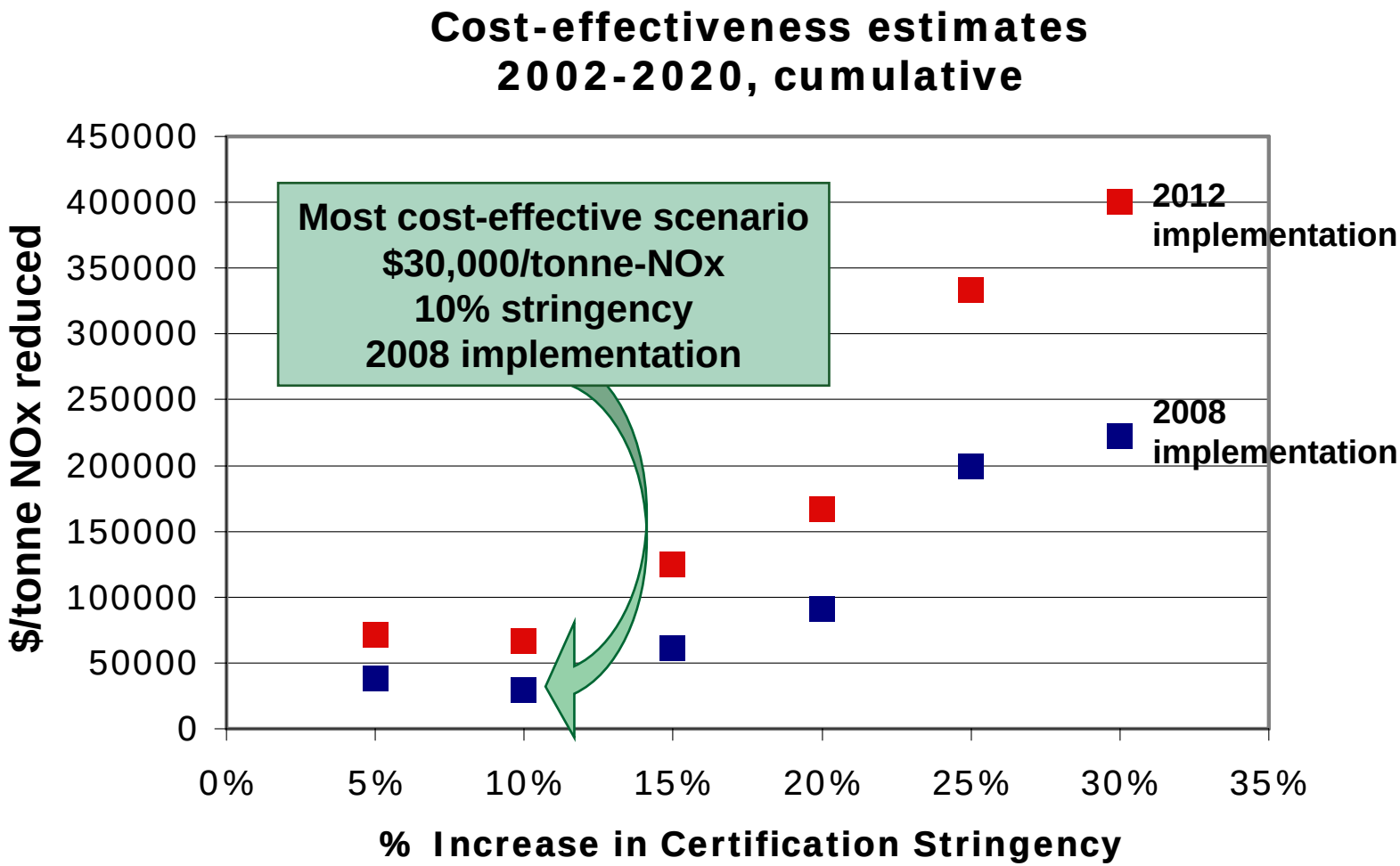
Choices exist

- **Every airplane design represents a different balance of noise, performance, emissions**
- **Every operational procedure represents a different balance of noise, performance, emissions**
- The capital costs are high (e.g. $10B for a new airplane program)
- The time-scales are long (20-30 years)





How do we make choices today?
ICAO CAEP/6 NOx stringency



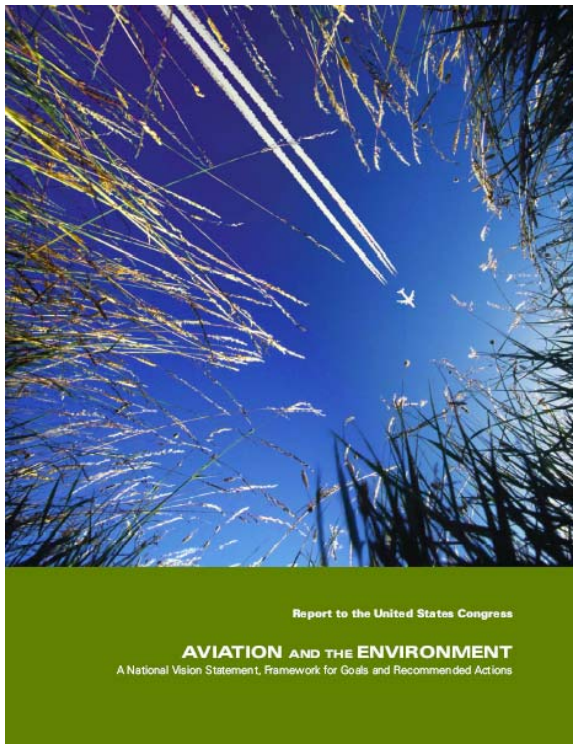
Source: FESG CAEP/6-IP/13, estimates shown assume high estimate of manufacturers' NRC and lost fleet value, discount rate 3%

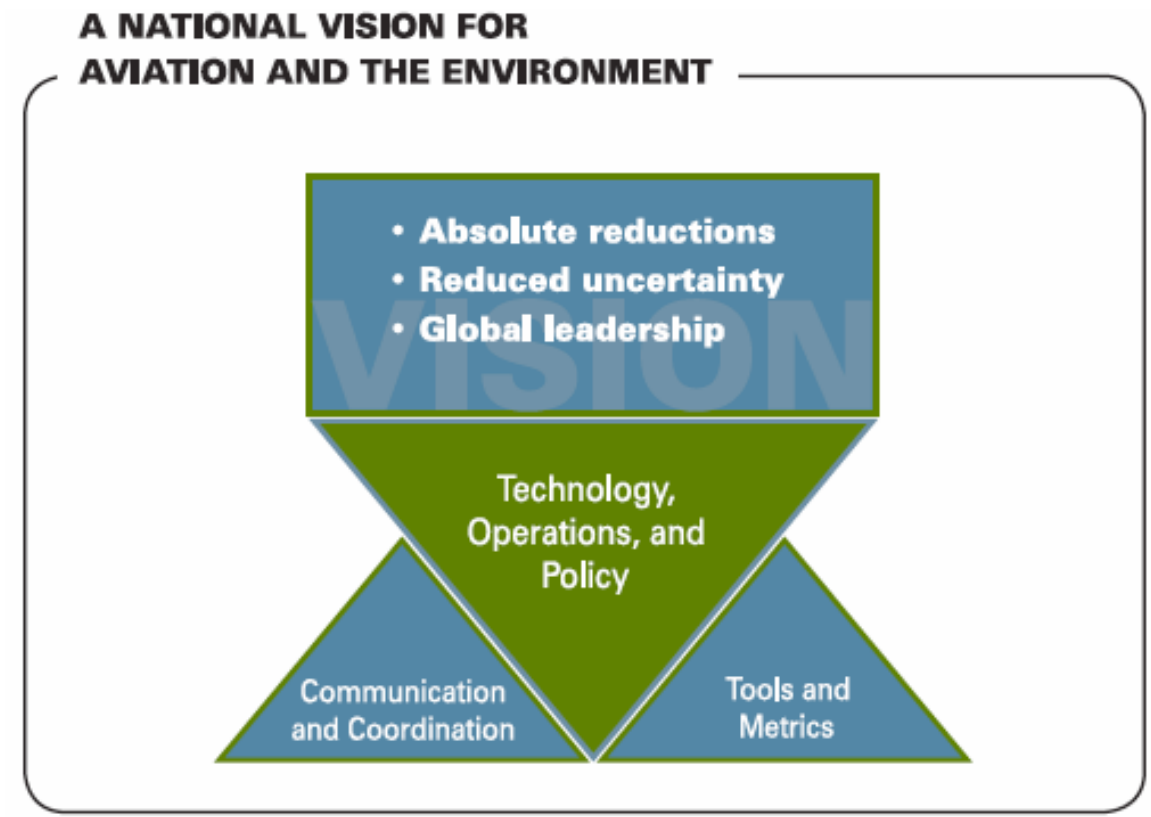
An incomplete balance sheet

- CAEP/6 NOx stringency example
  - Of several options for NOx reduction, the least expensive is $30,000/tonne-NOx; does this produce a net benefit to society?
  - **What is the impact of the additional fuel burn and noise** estimated to be associated with the NOx reduction?
- Must fill in the balance sheet to assess trade-offs
  - Local air quality, noise, climate change, consumer and industry costs
- **The stakes are high (serious impacts, billions of $)**
  - **We, as a community, need to improve our methods and tools and do this better than we do it today**

How should we make choices?

- Aviation benefits and environmental effects result from a complex system of interdependent technologies, operations, policies and market conditions





Report to the U.S. Congress, 2006, available at www.partner.aero

FAA is building the tools to help make better-informed choices

- **FAA Environmental Design Space (EDS)**
  - Aircraft level technology trade-offs
- **FAA Aviation Environmental Design Tool (AEDT)**
  - Translating aircraft and operations into emissions inventories and noise footprints
- **FAA Aviation Environmental Portfolio Management Tool (APMT)**
  - Evaluating economic and health and welfare impacts of technology, operations, market, environmental and policy scenarios

APMT functionality

(reports available at www.partner.aero)

inputs

Policy scenarios
- Certification stringency
- Market-based measures
- Land-use controls
- Sound insulation

Market scenarios
- Demand
- Fuel prices
- Fleet

Environmental scenarios
- CO_2 growth

Technology and operational advances
- CNS/ATM, NGATS
- Long term technology forecasts

APMT

Cost-effectiveness
- $/kg NOx reduced
- $/# people removed from 65dB DNL
- $/kg PM reduced
- $/kg CO_2 reduced

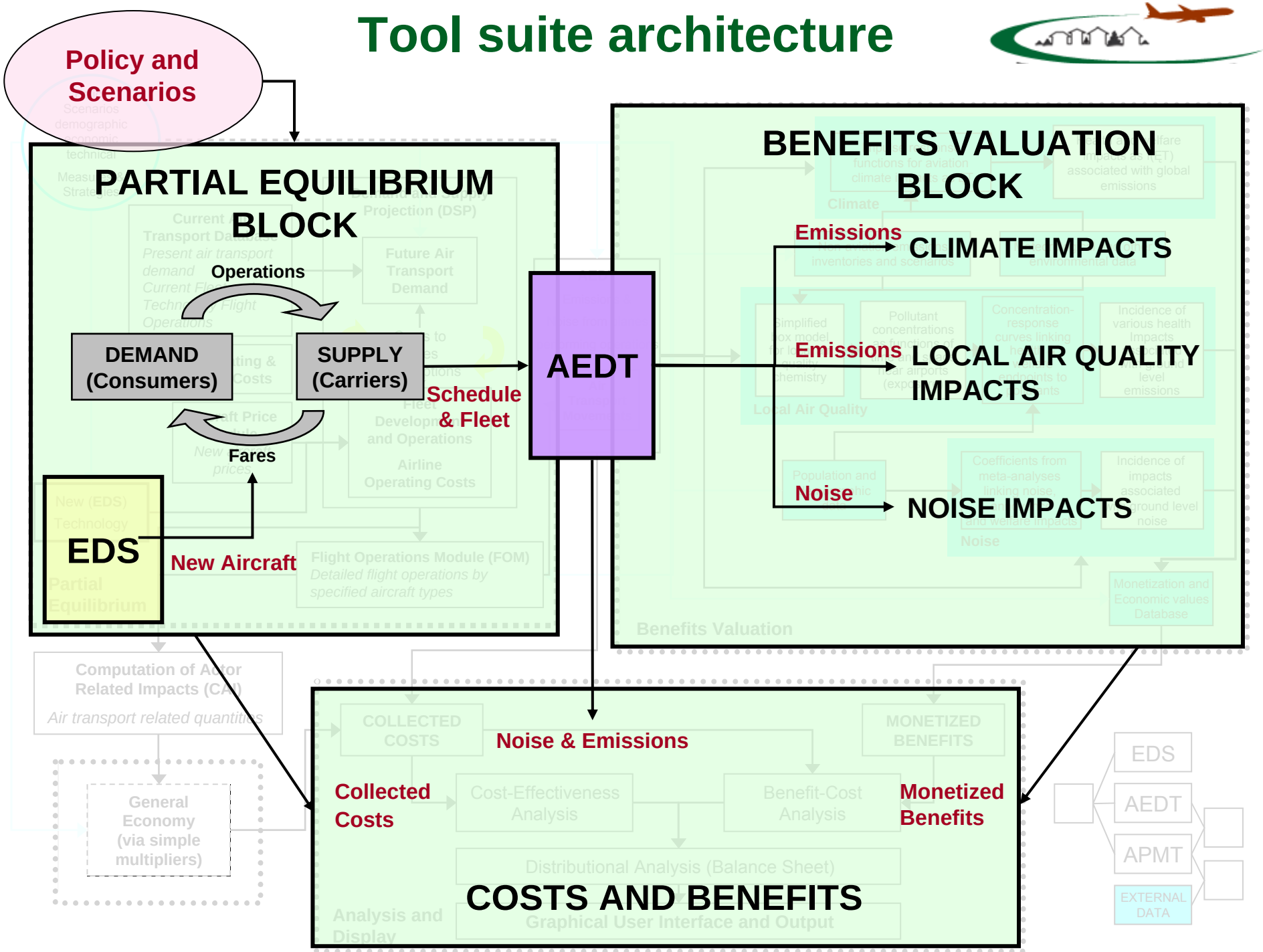
Benefit-cost
- Health and welfare impacts
- Change in societal welfare ($)

Distributional analyses
- Who benefits, who pays
- Consumers
- Airports
- Airlines
- Manufacturers
- People impacted by noise and pollution
- Special groups
- Geographical regions

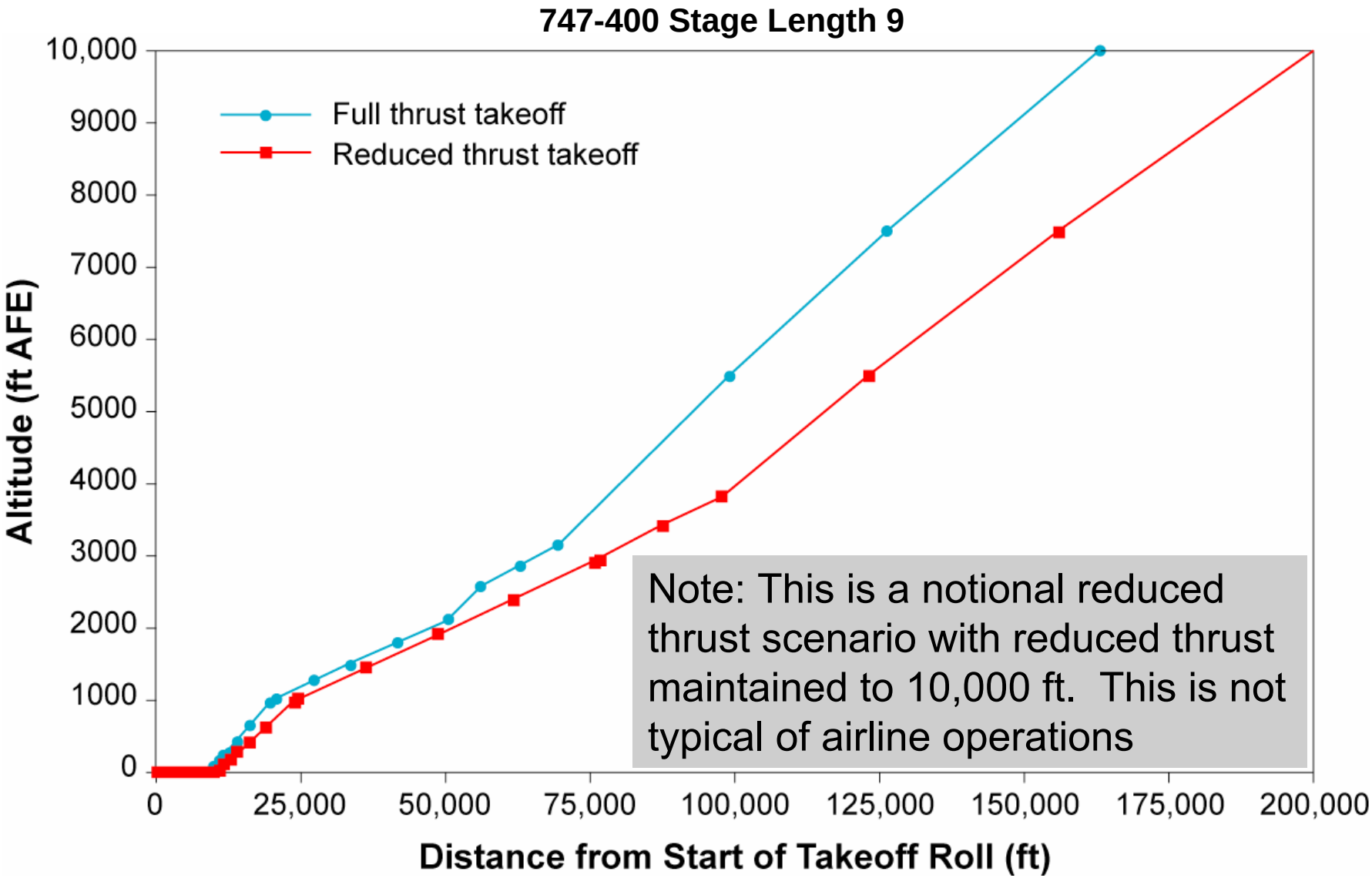
outputs

Global, Regional, Airport-local

Tool suite architecture



Notional example application



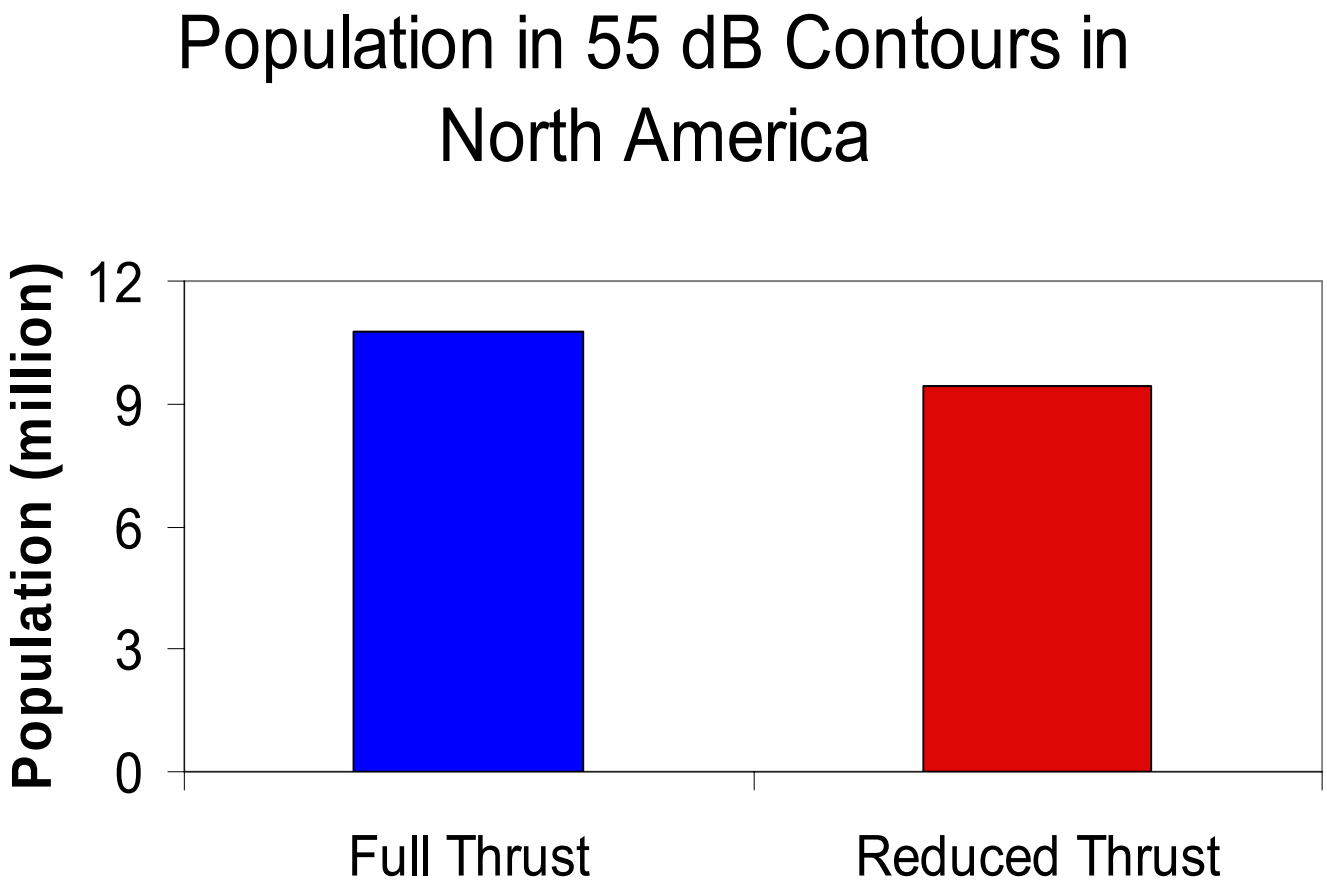
Note: This is a notional reduced thrust scenario with reduced thrust maintained to 10,000 ft. This is not typical of airline operations

Notional example application

Even simple changes may lead to complex trade-offs, for example…

- One aspect of airplane operations changed
  - Throttle setting reduced during take-off
- Emissions and noise change
  - **CO_2 increases**
  - **NO_x decreases**
  - **SO_x increases**
  - **PM decreases**
  - **Noise decreases**
- Affects aviation economics

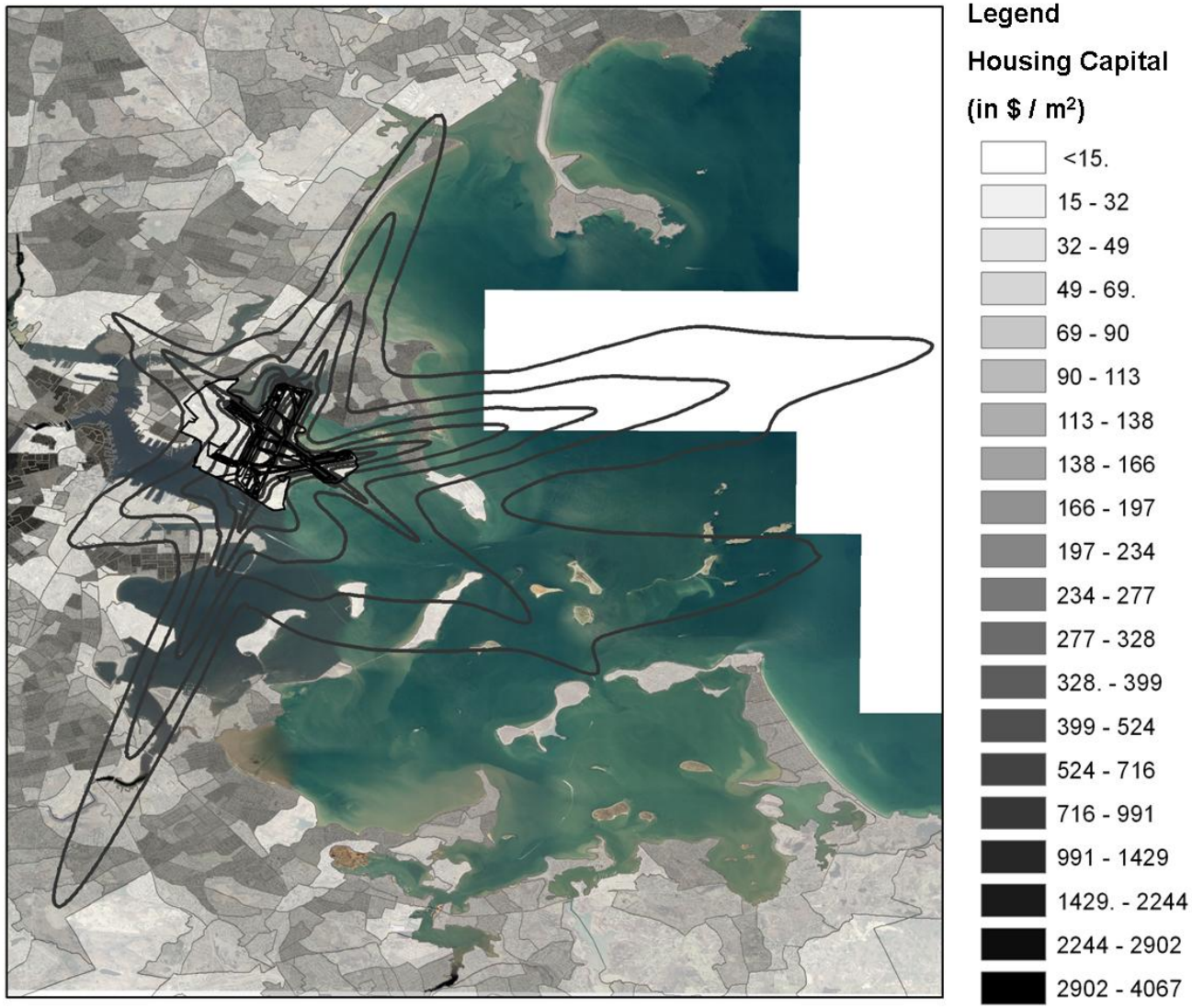
Noise impact
(number of people impacted)



Noise impact

Noise Depreciation Index (NDI) used to correlate noise levels with housing capital depreciation

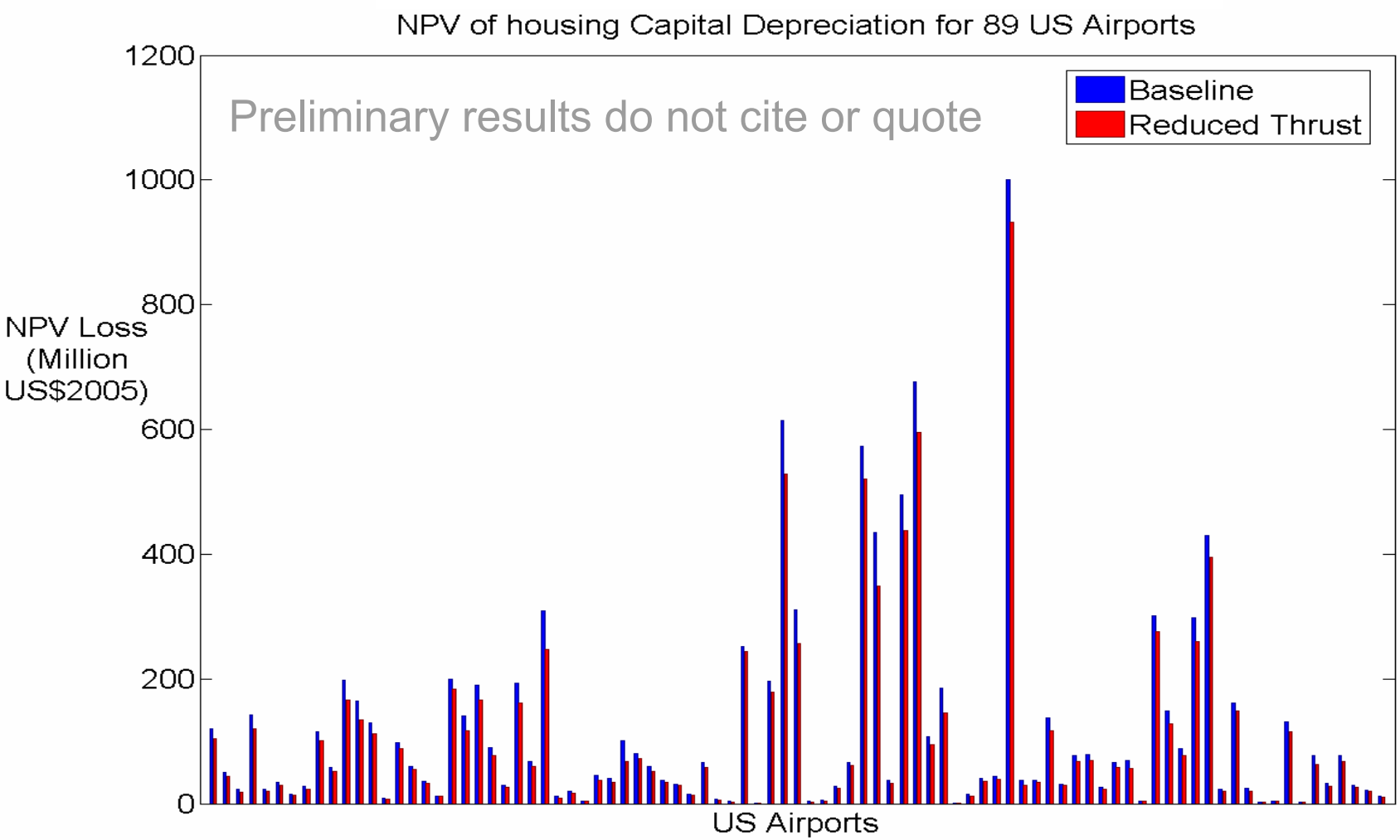
Adding additional noise metrics in the near future



Noise impact

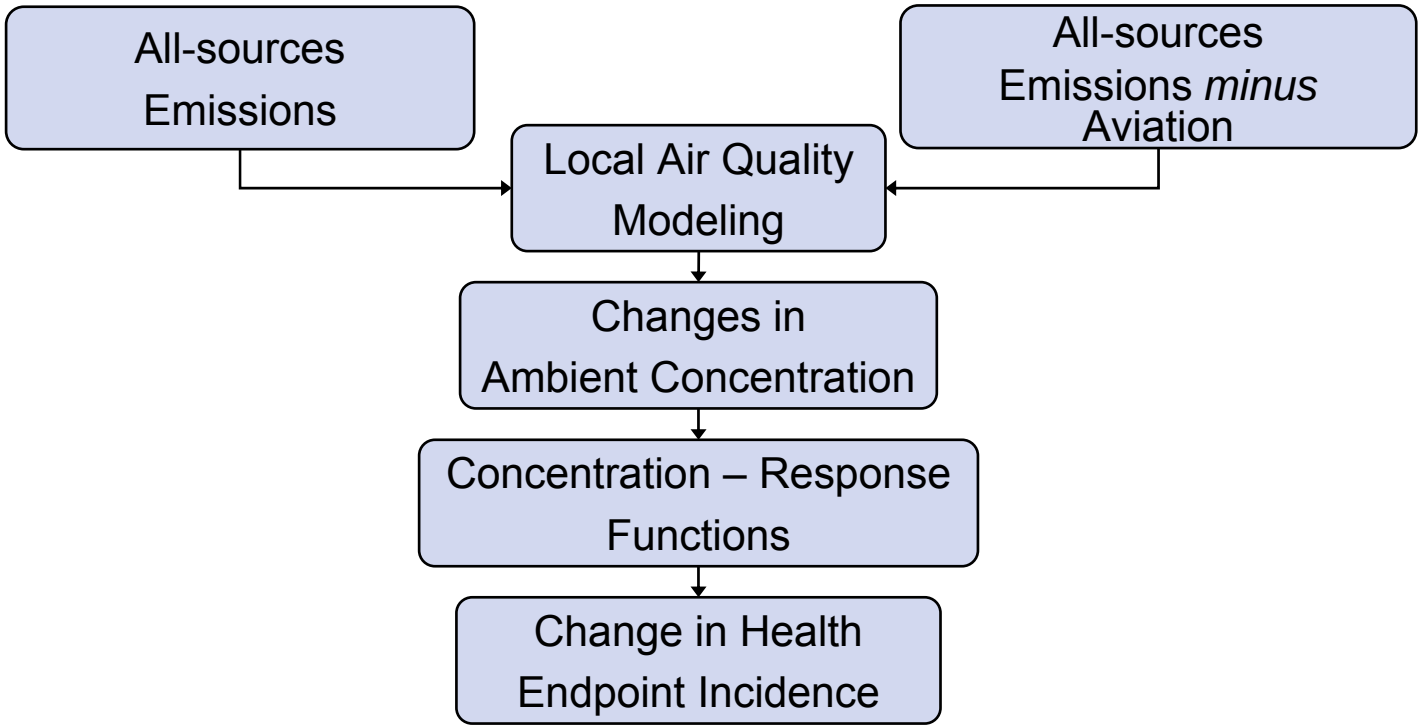
Net present value of depreciation of housing capital

(*MAGENTA Shell 1 U.S. airports only*)



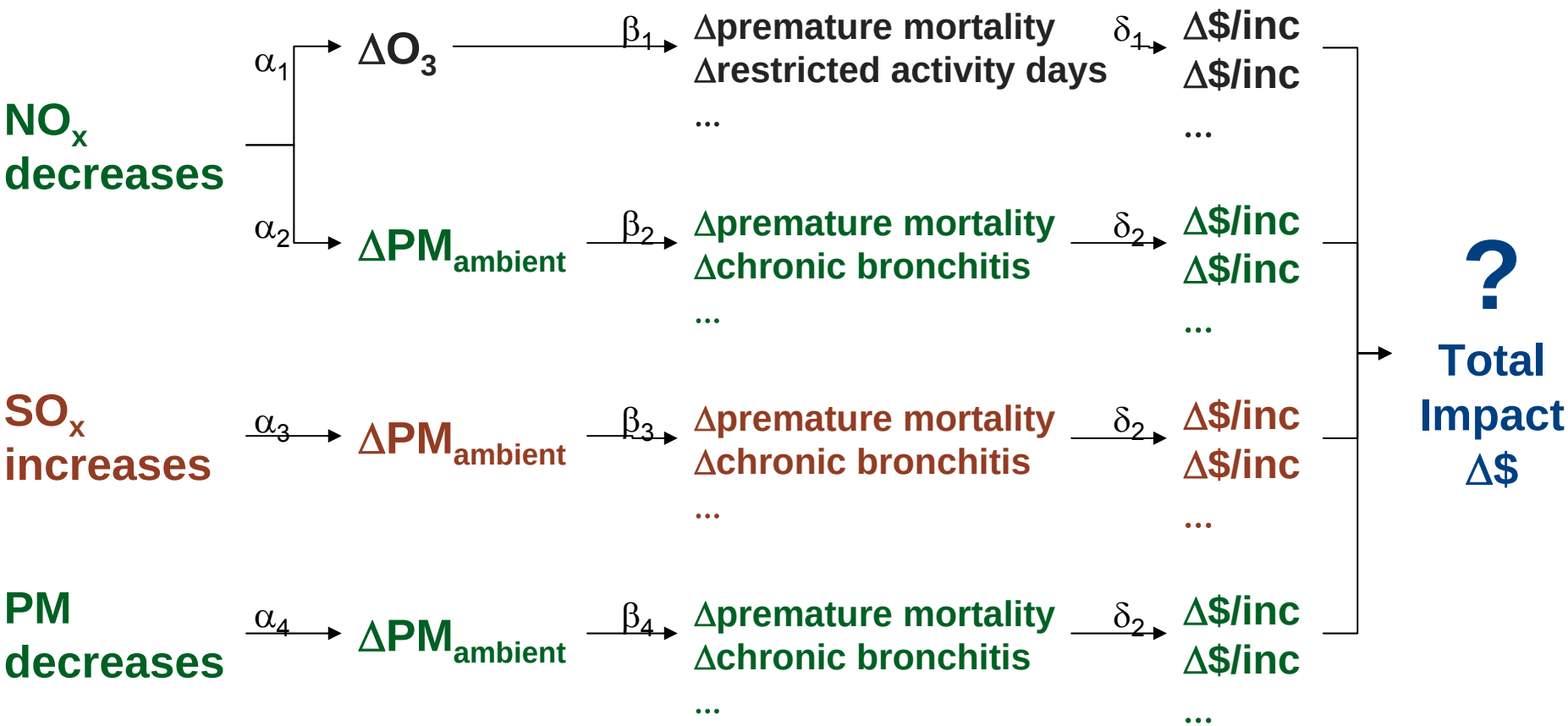
Health impacts assessment

Consistent with EPA and EU practice, only considering effects of ozone and PM



$$\Delta\ \textbf{health costs} = \Delta\ \textbf{emissions} \times \frac{\Delta\textbf{ambient concentration}}{\Delta\textbf{emission}} \times \frac{\textbf{health incidence}}{\Delta\textbf{ambient concentration}} \times \frac{\textbf{cost}}{\textbf{health incidence}}$$

Impact pathway



Local air quality and climate response cannot be determined simply from observing changes in inventories

Contribution of aviation to emissions inventory (U.S. only)

Preliminary results do not cite or quote

	Total Anthropogenic [million tons]*	Total Aviation Baseline [million tons]**
Primary $PM_{2.5}$	**6.6**	**0.00025 (0.004%)**
NO_x	**22**	**0.04 (0.2%)**
SO_x	**16**	**0.0015 (0.01%)**

*EPA 2001, latest available data
**Total aviation emissions below mixing height

Reduced thrust emissions impact

For 266 major airports within continental US, emissions below 3000 ft

Preliminary results do not cite or quote

Emissions below mixing height (in 10^3ton/year)	Nitrogen Oxides (NO_x)	Sulfur Dioxide (SO_2)	Primary Particulate Matter
Baseline Full thrust	39.7	1.46	0.25
Policy Reduced thrust	39.6	1.51	0.23

Local air quality impact of aviation PM
(*cases per year, U.S.*)

Preliminary results do not cite or quote

PM-related Endpoints (mean estimates shown, 95% confidence intervals typically ± 50% of mean)	Baseline: Full Thrust	Policy: Reduced Thrust	Compare: Highway Vehicles
Premature mortality:			
Long-term exposure (adults age 30+)	198	195	26500
Long-term exposure (infants age <1 yr)	1.31	1.29	172
Chronic bronchitis	79.5	78.7	10590
Hospital admissions-respiratory	26.3	26.1	7700
Hospital admission-cardiovascular	57.8	57.3	7660
Emergency room visits for asthma	113	112	15140
Minor restricted activity days	77,171	76,437	10,270,000

Local air quality impact

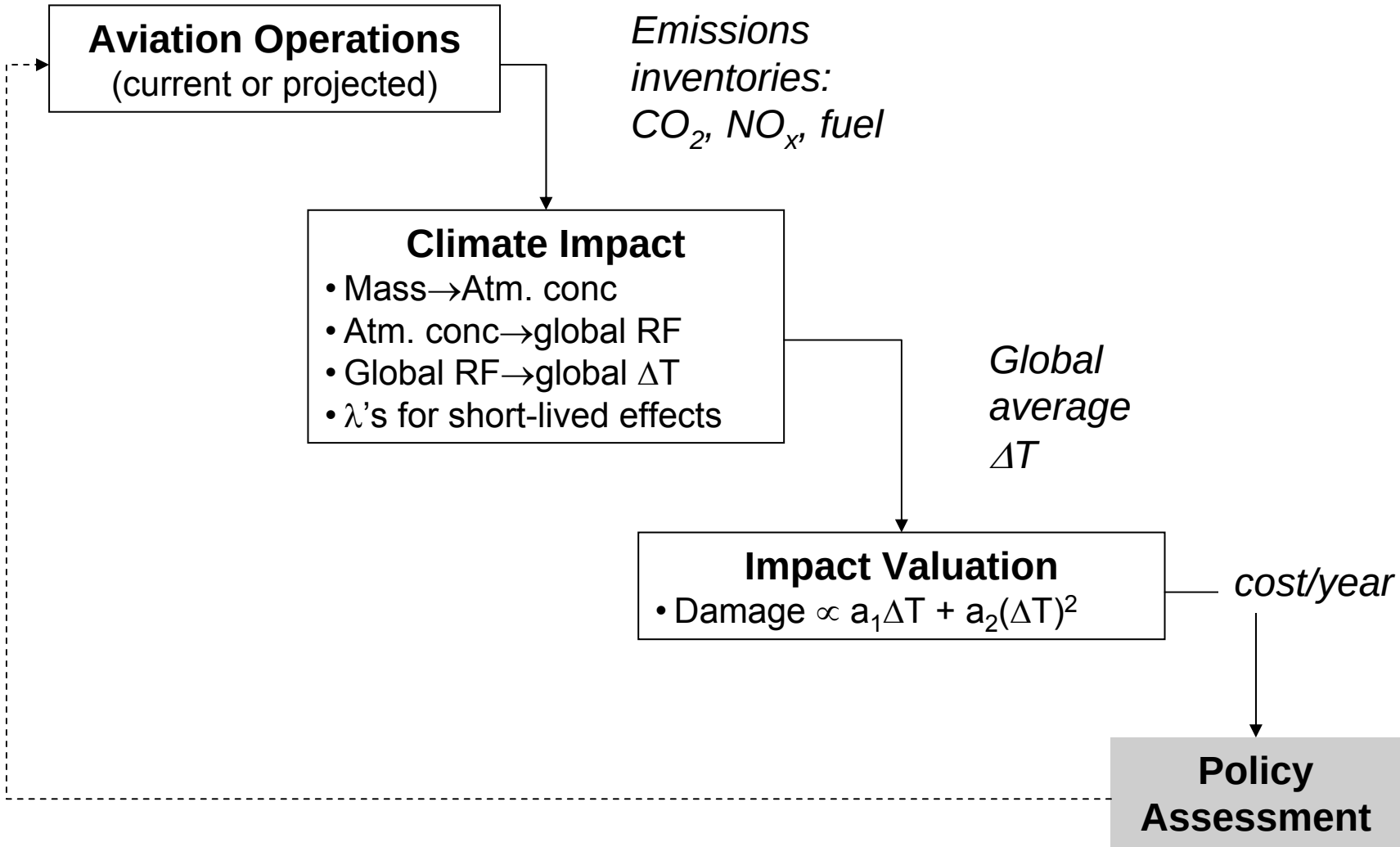
Aggregate metrics derived from estimates of aviation pollution effects

Preliminary results do not cite or quote

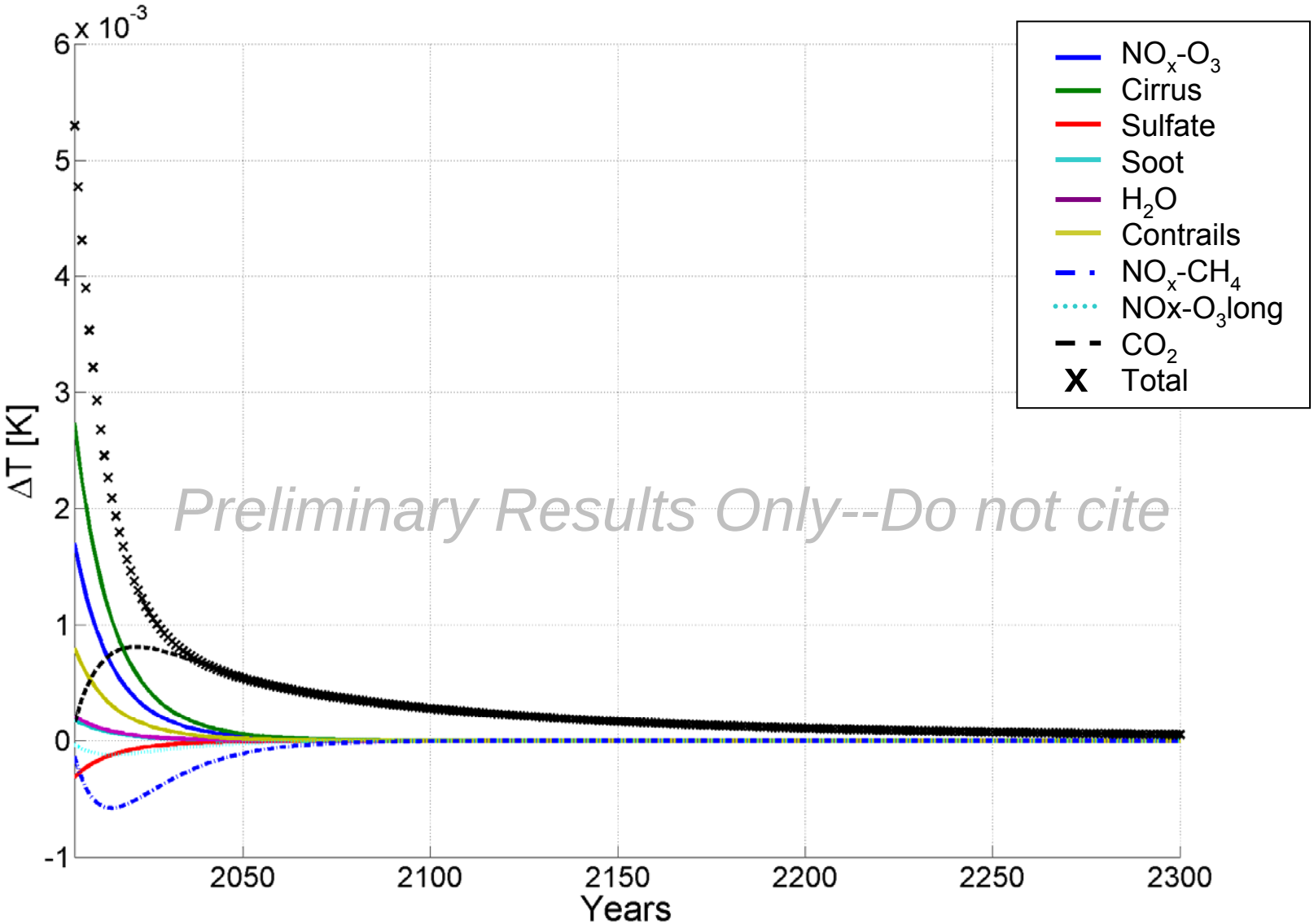
	Primary PM	SO_x via PM	NO_x via PM	NO_x via Ozone*
Total health impact of pollutant ($ per kg emitted)	**591**	**127**	**22.9**	**2.0**
Amount emitted (10^6 kg per year)	**0.25**	**1.45**	**39.7**	**43.3**
Cost ($M per year)	**150**	**185**	**907**	**46**

*Total ozone health impact divided by total NO_x emissions

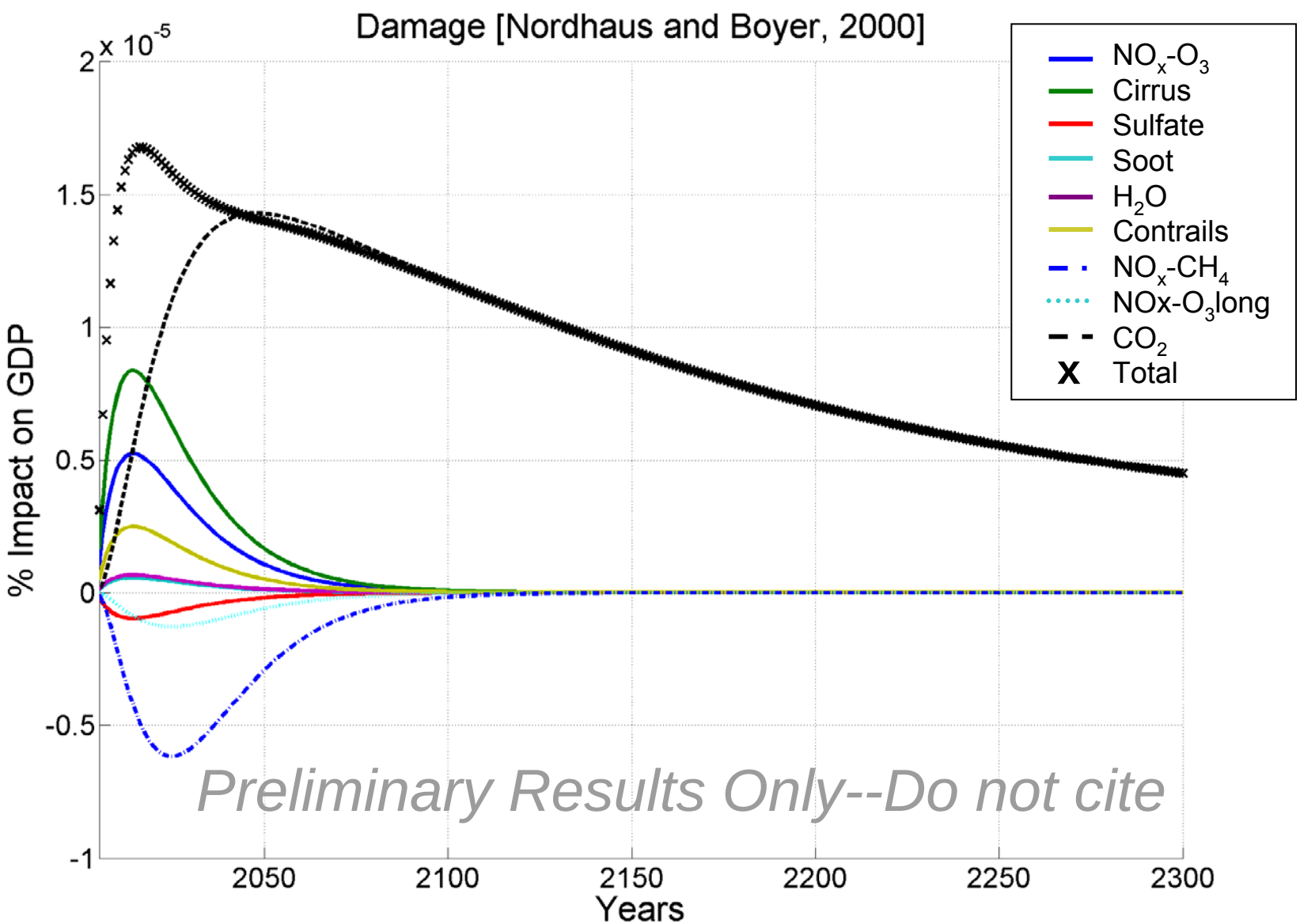
Simplified methods for valuing the impact of aviation on climate



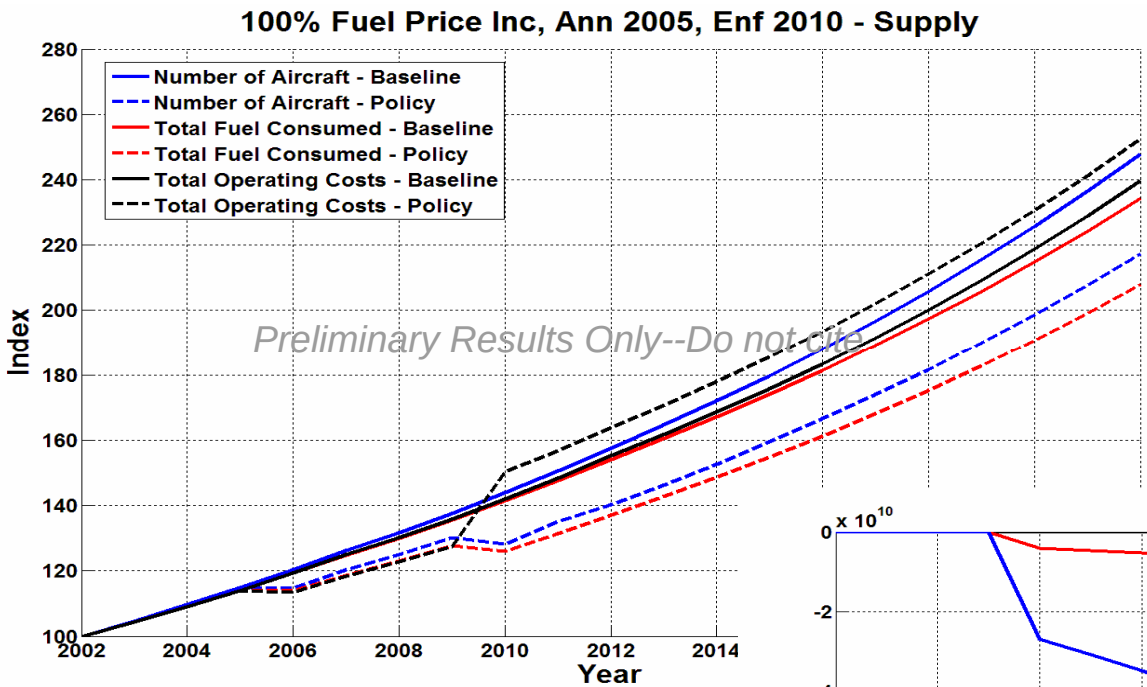
Average global surface ΔT:
Full power



Damage [% GDP]:
Full power



There are significant economic interdependencies too



operating costs

⇩

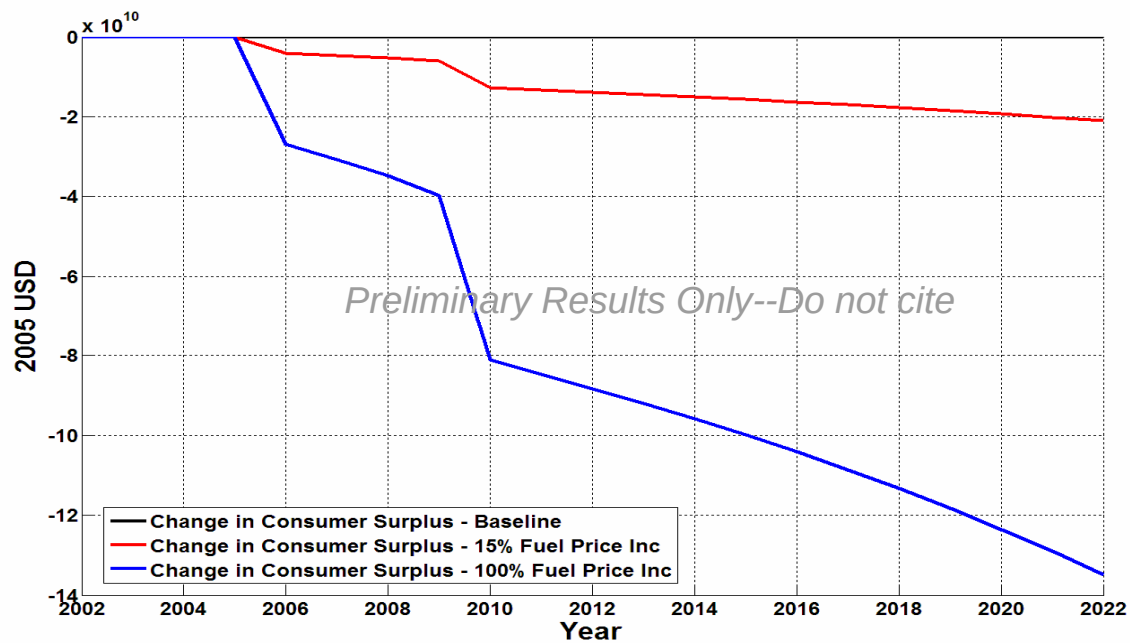
ticket prices

⇩

demand

⇩

change in consumer surplus



Summary

- **FAA has made a commitment to use APMT/AEDT/EDS**
  - to inform decision-making for the ICAO/CAEP meeting in 2010
  - to help establish trades among noise, local air quality and climate impacts in order to better quantify and manage the impacts associated with NextGen operations
- We have many challenges ahead of us
- **Our purpose**
  - is not to provide “one answer” or a single “best estimate”
  - but to provide **a framework that may be used to communicate potential outcomes using a variety of metrics, under a variety of assumptions and scenarios**

Final words

- These tools will not make decision-making easier (they may well make it harder)

- However, **our goal is to make decision-making better informed (not to make it easier)**