

APMT Capability Demonstration Problems: *Environmental Impacts*

Presented to: TRB AEDT/APMT Workshop #4

By: Professor Ian A. Waitz

Date: December 6-8, 2006



Federal Aviation
Administration



Results presented

- To illustrate our results, we will focus on the environmental impacts of the baseline versus 15% and 100% fuel price increases
- We will show **balance sheets** for a **wide range of environmental impacts with multiple metrics** that provide decision-makers with different perspectives on the policy



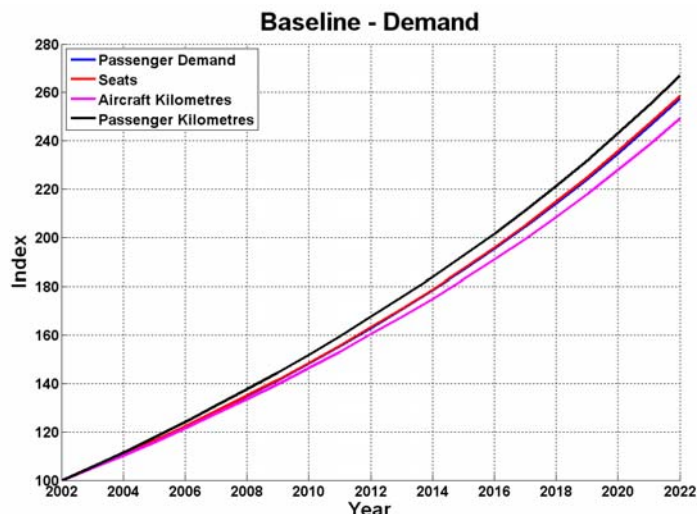
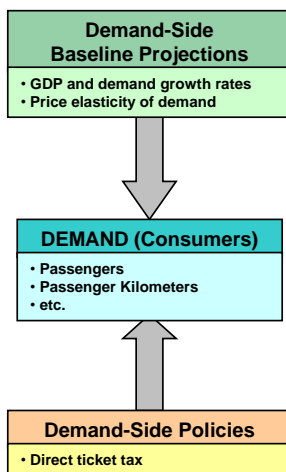
Results presented

- Noise
 - Noise contours, people impacted **US and global**
 - Valuation of noise impact at **93 US airports**
 - Overall noise impact for **93 US airports**
- Local Air Quality
 - Local Emissions (below 3000') **US and global**
 - Health impact of ozone due to NO_x, **Continental US only**
 - PM mortality and morbidity, **Continental US only**
- Climate
 - Baseline temperature change, damage, and NPV, **global**
 - Change in temperature, damage, and NPV due to policy, **global**
- Interdependencies
 - Relative changes in noise, LAQ, and climate impacts due to policy



Balance Sheet: Demand Side

	Passenger Demand	Seats	Aircraft Kilometres	Passenger Kilometres
100% Fuel Tax	-8.9%	-8.9%	-8.9%	-9.4%
15% Fuel Tax	-1.5%	-1.5%	-1.5%	-1.6%

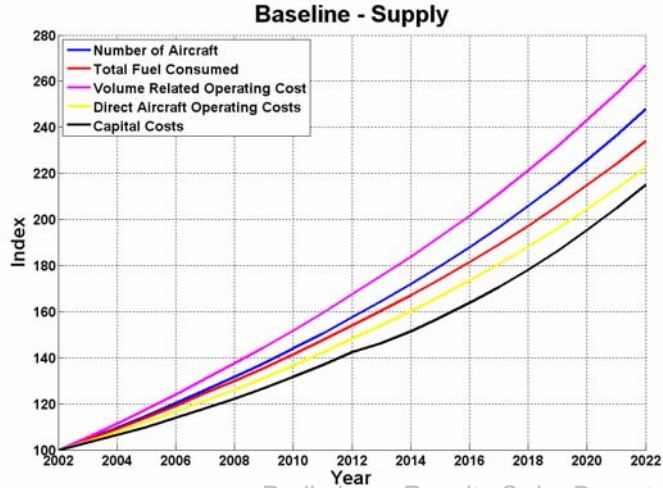
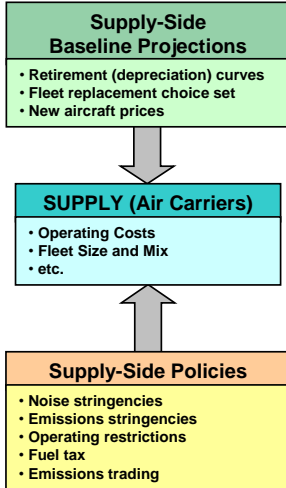


Preliminary Results Only--Do not cite



Balance Sheet: Supply Side

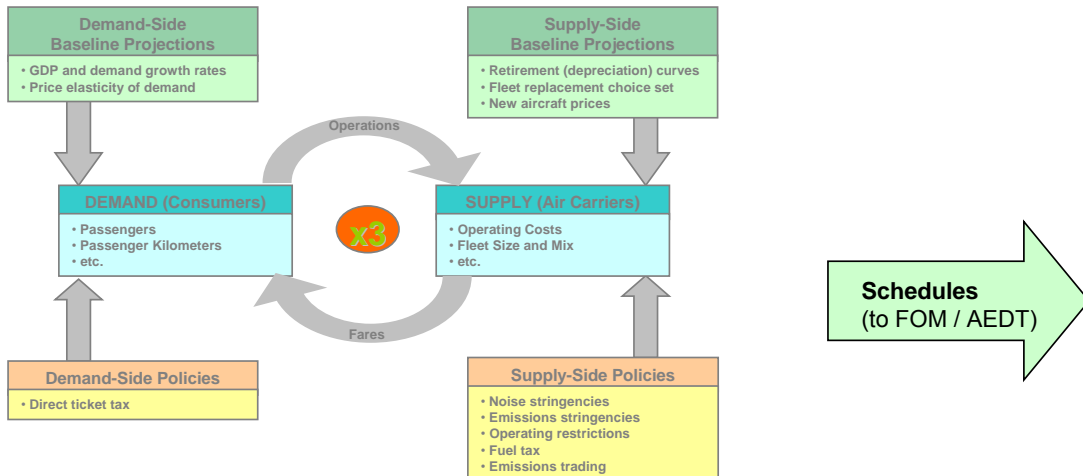
	Number of aircraft (2022)	Number of new aircraft purchased	Fuel Consumed	Direct aircraft operating costs	Capital costs
100% Fuel Tax	-12.3%	-8.8%	-8.8%	13.2%	-11.3%
15% Fuel Tax	-2.9%	-1.5%	-1.5%	2.1%	-1.9%



Preliminary Results Only--Do not cite

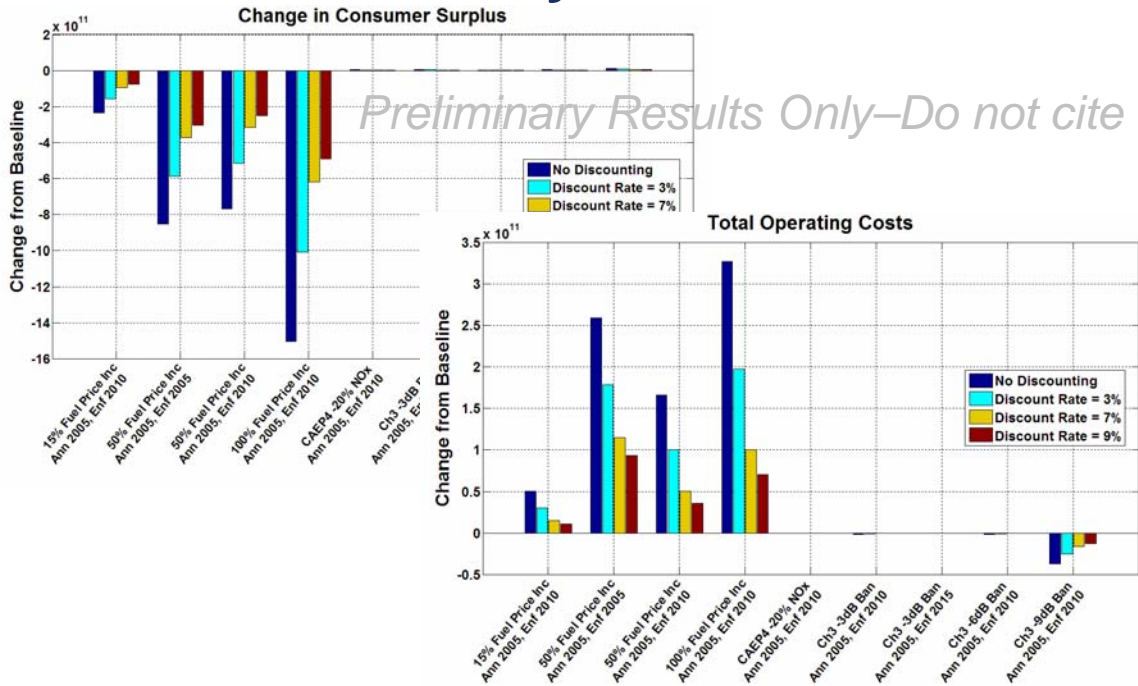
Balance Sheet: Cost Summary

[US\$B2005]	Costs to Airlines-- Δ Total Operating Costs		Costs to Aviation Consumers-- Δ Consumer surplus	
Fuel Tax (15%, 100%)	\$B30.3	\$B197.1	\$B158	\$B1010



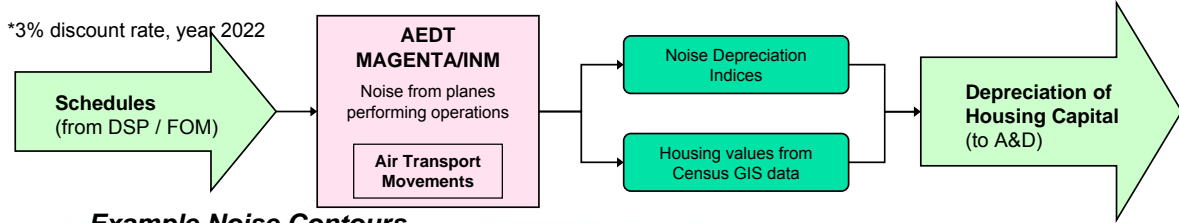
Preliminary Results Only--Do not cite

Summary of Costs

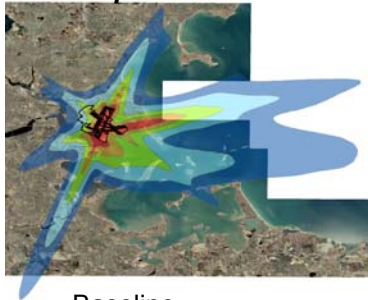


The Balance Sheet: Noise Impacts*

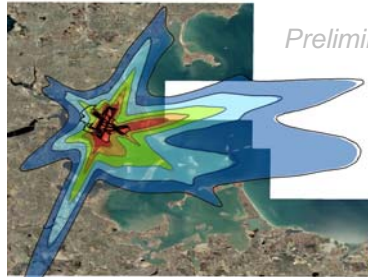
Policy-baseline		Δ Number of people in 60 dB DNL, 2022 (in thousands)		Δ NPV Housing Capital Depreciation 2002-2022 [US\$M2005]	
Fuel Tax 15%	Fuel Tax 100%	-138	-880	-\$95M	-\$480M



Example Noise Contours



Baseline



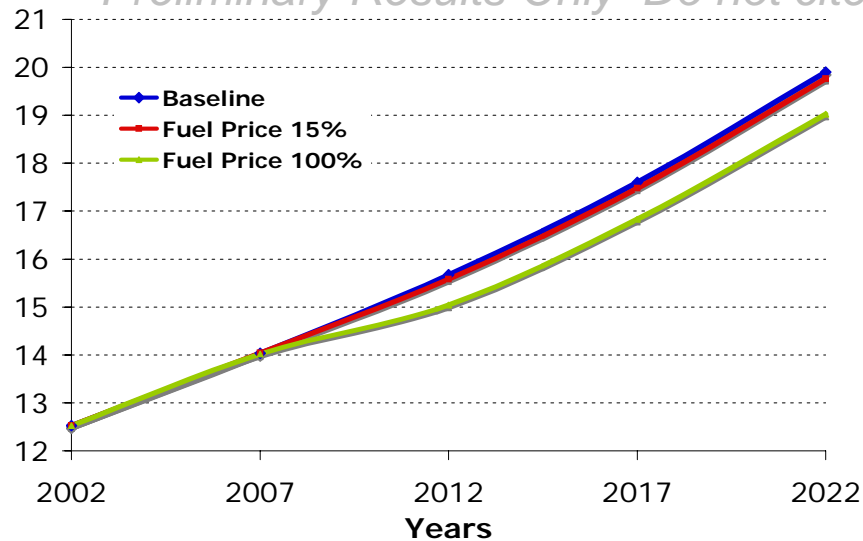
100% Fuel Price Increase

Preliminary Results Only--Do not cite

Impact of 100% Fuel Price Increase on Population affected by noise

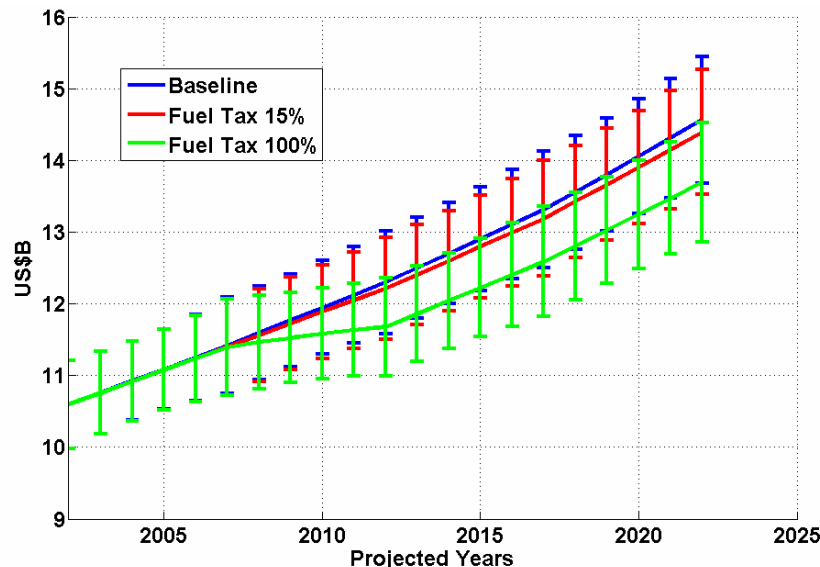
Number of people in the 60dB contours worldwide

Preliminary Results Only—Do not cite



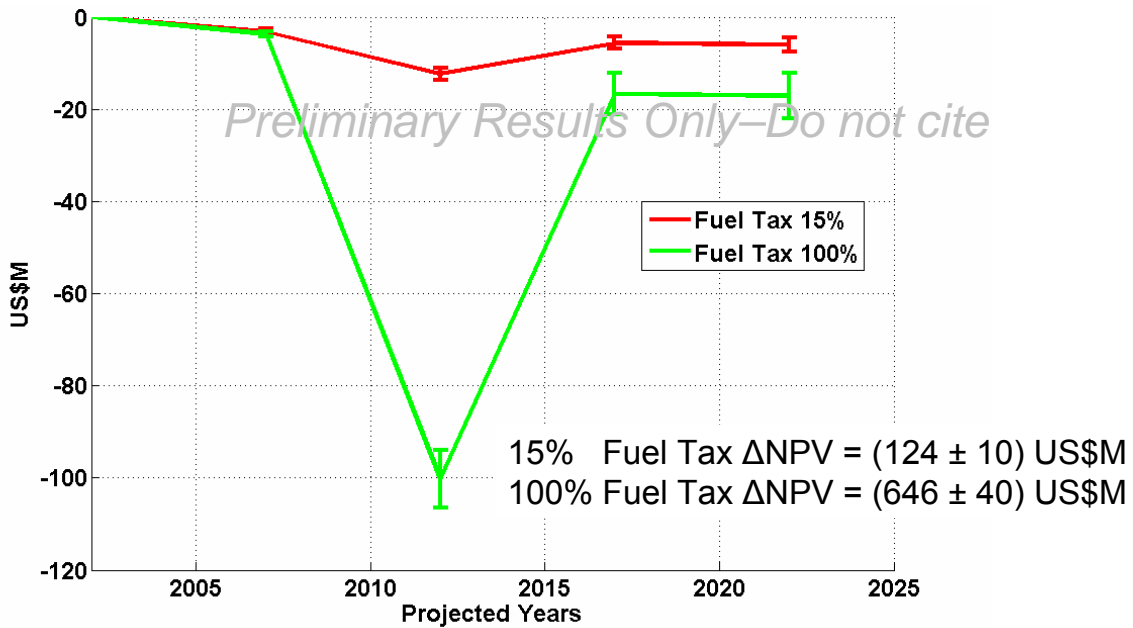
Noise impact over time

- Housing capital depreciation (within 94 US airports) in each scenario



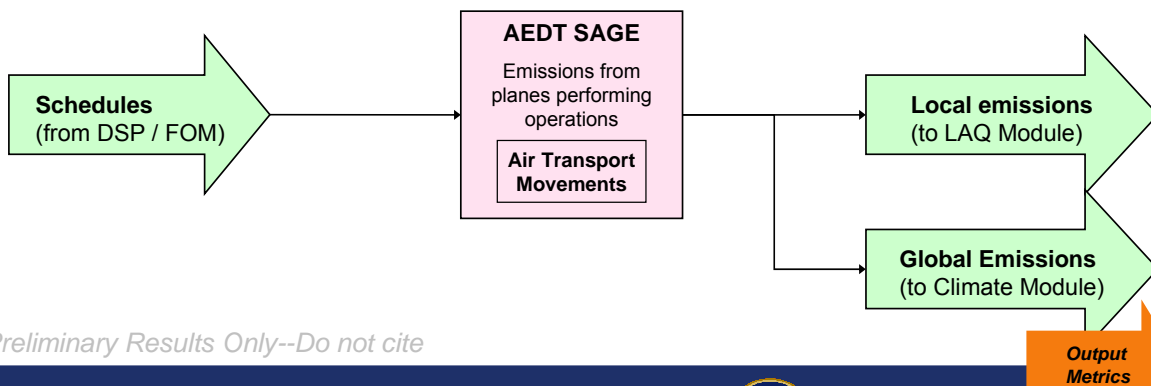
Noise impact over time

- Policy effect on housing capital (Discount Rate 3%)



Balance Sheet: Emissions

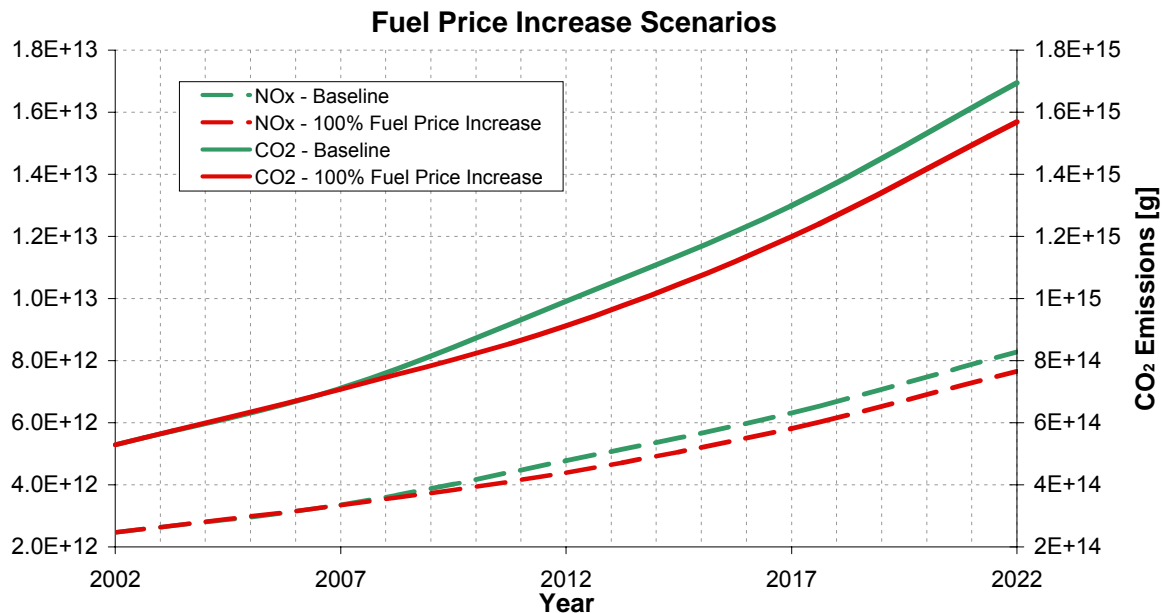
<ul style="list-style-type: none"> • By airport • By aircraft type • By altitude-band • Regional emissions • Global emissions • User-specified aggregation 	CO ₂ [g]	Fuel [kg]	NO _x [g]	SO _x [g]	PM [g]
Baseline	5.225 e15	1.656 e12	2.52 e13	1.325 e12	1.569 e11
15% Fuel Tax Change	-1.0%	-1.0%	-1.0%	-0.7%	-0.8%
100% Fuel Tax Change	-5.9%	-5.9%	-6.1%	-5.9%	-5.1%



Preliminary Results Only--Do not cite



Emissions vs Time

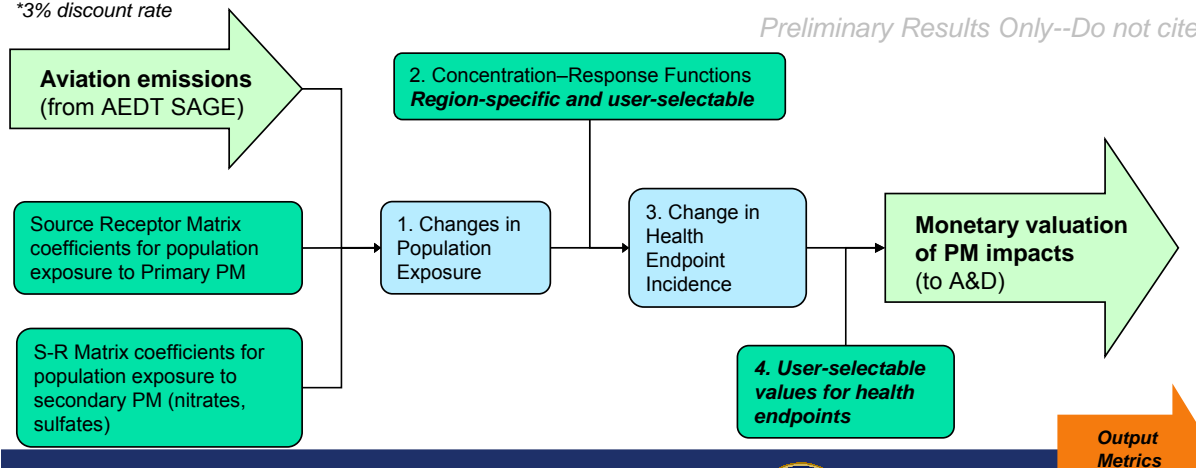


The Balance Sheet: LAQ - PM*

	NO _x	Mortality & morbidity (NO _x)		Mortality & morbidity valuation (NO _x)		Total LAQ Benefits [US\$B]	
	SO _x	Mortality & morbidity (SO _x)		Mortality & morbidity valuation (SO _x)			
	PM	Mortality & morbidity (PM)		Mortality & morbidity valuation (PM)			
Fuel Tax (15%, 100%)	NO _x	255 deaths	238 deaths	1.6 USB\$	1.5 USB\$	0.3 USB\$	1.54 USB\$
	SO _x	86 deaths	80 deaths	0.54 USB\$	0.50 USB\$		
	PM	61 deaths	57 deaths	0.38 USB\$	0.36 USB\$		

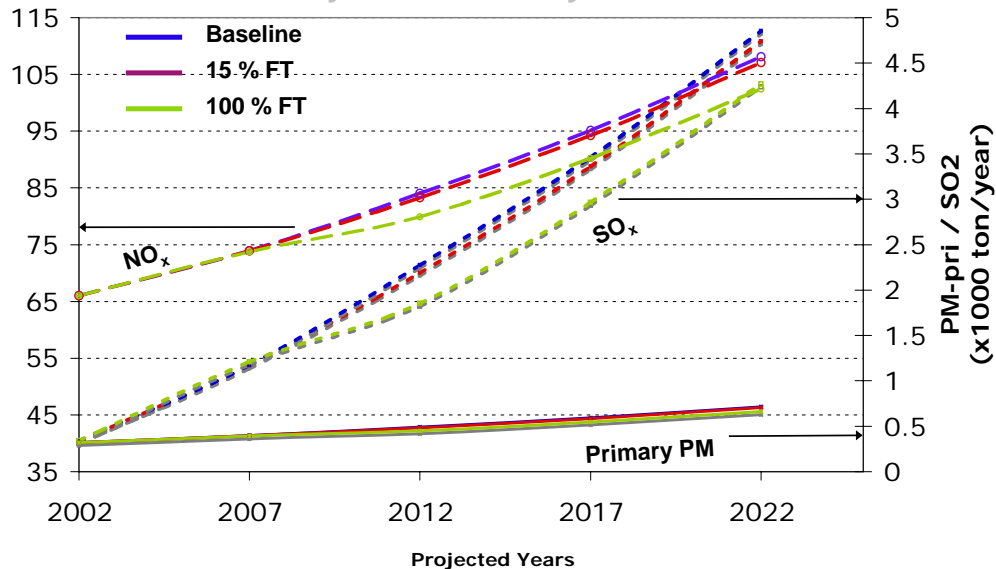
*3% discount rate

Preliminary Results Only--Do not cite



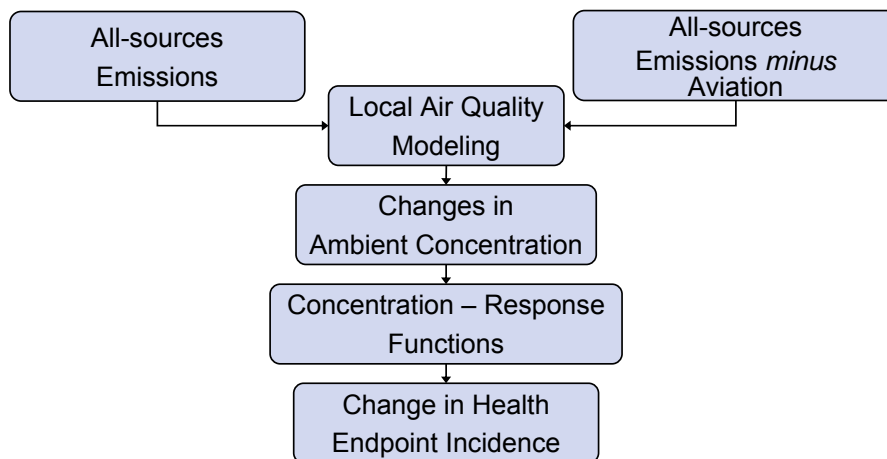
Changes in emissions below 3000' (U.S. only)

Preliminary Results Only—Do not cite



Health impacts assessment

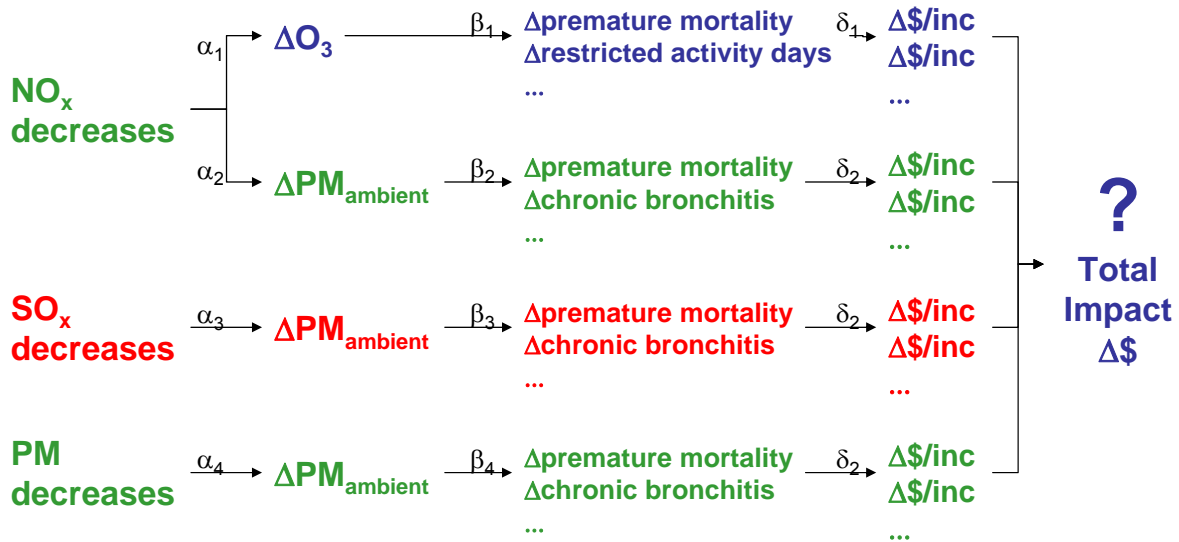
- Consistent with EPA and EU practice, only considering effects of ozone and PM



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



Impact pathway

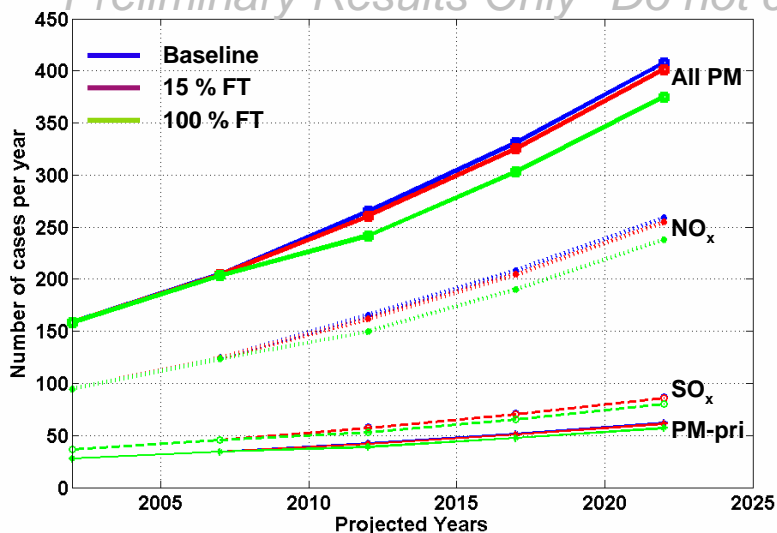


Local air quality and climate response cannot be determined simply from observing changes in inventories

PM health impacts

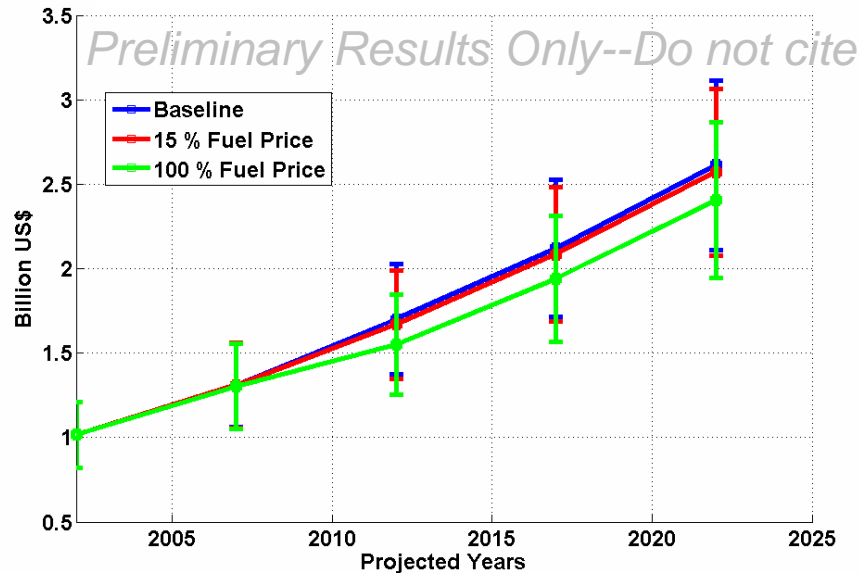
Premature mortality from exposure to aviation-emitted primary and secondary PM_{2.5}

Preliminary Results Only--Do not cite



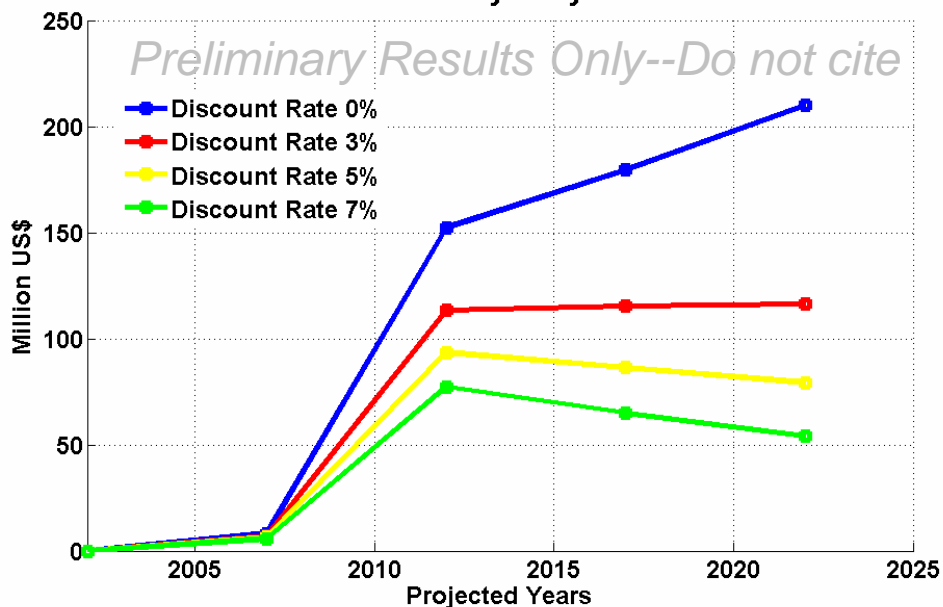
PM health impact valuation

Aggregated monetary metric: total yearly economic value of PM-related health impact

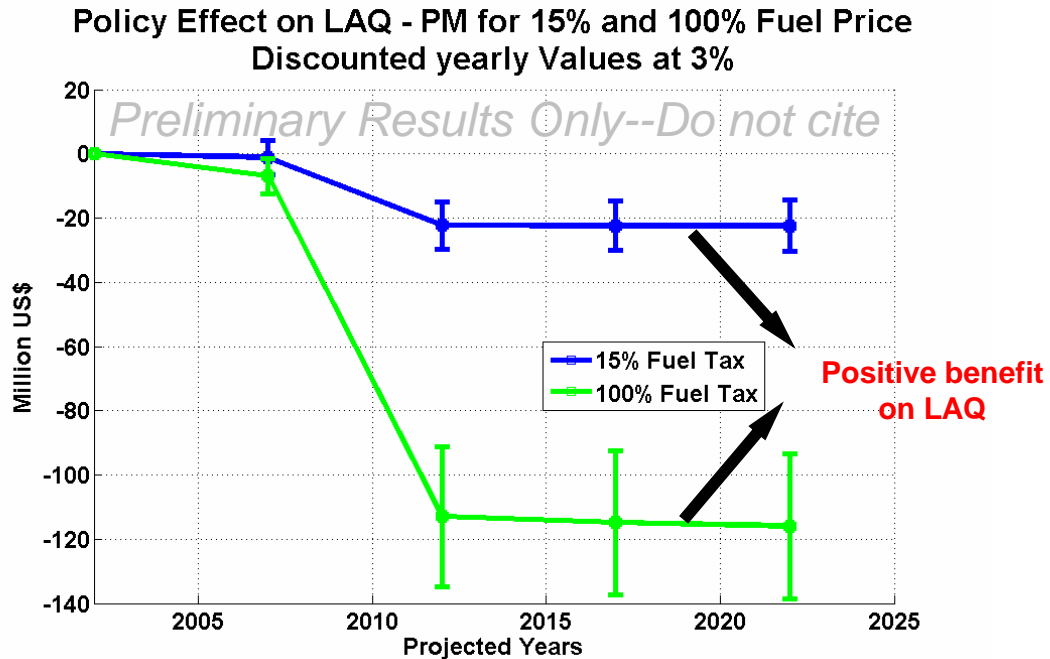


Discount rate impact on policy effect

100% Fuel Tax Policy effect on LAQ - PM
Discounted yearly values



Comparison of policies



Net present value of PM health impacts changes

- Final assessment of the policy effect through Net Present Value (NPV)
- Discounted to first year of the analysis (2002)

Preliminary Results Only--Do not cite

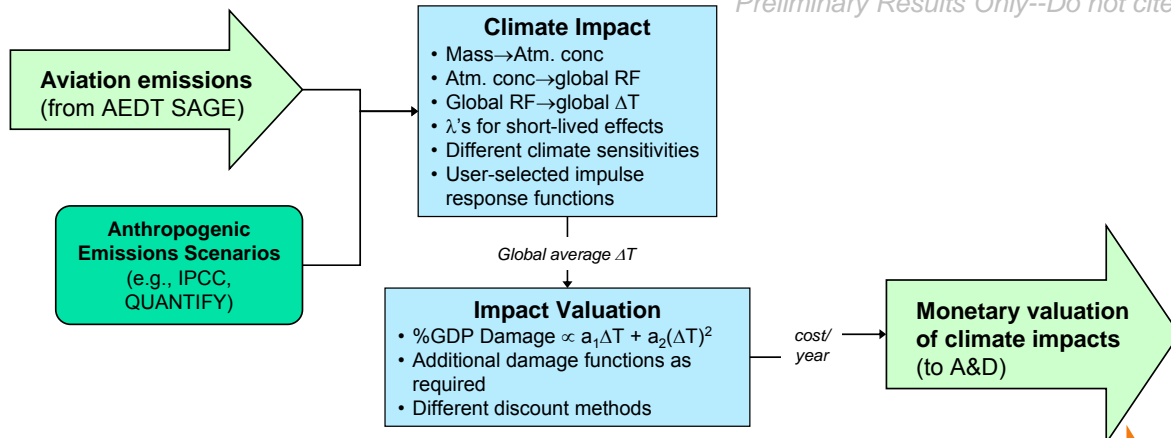
Discount Rate	0%	3%	5%	7%
NPV of 15% Fuel Tax Policy effect on PM-related health impact in US\$B (Standard deviation)	0.45 (±0.18)	0.30 (±0.12)	0.23 (±0.10)	0.18 (±0.08)
NPV of 100% Fuel Tax Policy effect on PM-related health impact in US\$B (Standard deviation)	2.32 (±0.46)	1.54 (±0.31)	1.19 (±0.24)	0.92 (±0.19)



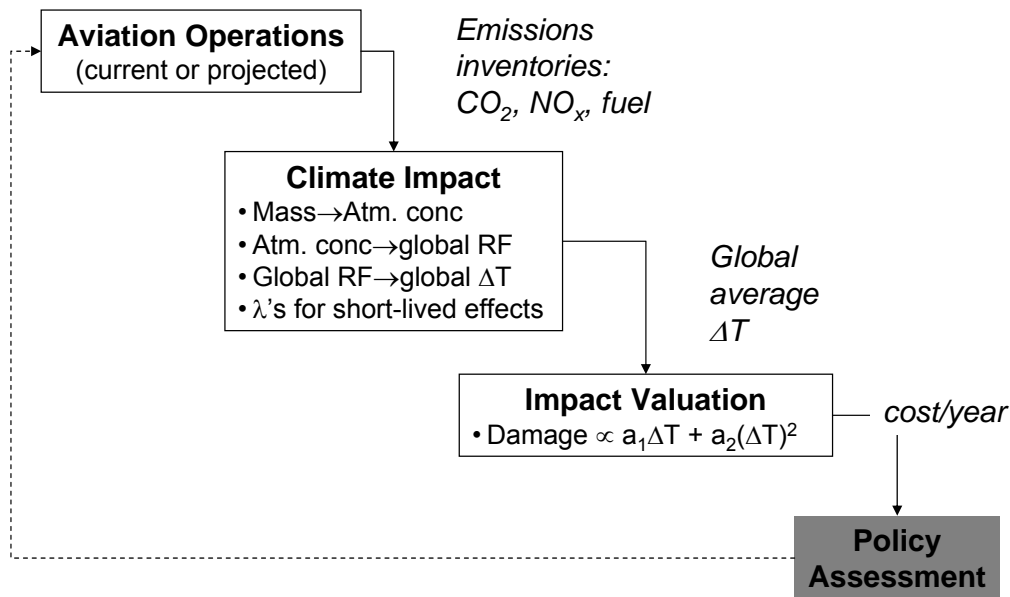
The Balance Sheet: *Climate Impact*

3% discount rate $\lambda = 2.5K$	ΔT_{CO_2} -year		%GDP _{CO2} -year		NPV _{CO2} -year		NPV of Climate Impacts [US\$B]	
	$\Delta T_{short-lived-i}$ -year [K]		%GDP _{short-lived-i} -year		NPV _{short-lived-i} -year [US\$B]			
	ΔT_{total} -year		%GDP _{total} -year		NPV _{total} -year			
Fuel Tax (15%, 100%)	-0.027	-0.156	-0.12%	-0.73%	-13.23	-77.27	-21.39	-125.06
	-0.016	-0.094	-0.02%	-0.13%	-8.29	-48.50		
	-0.043	-0.250	-0.15%	-0.86%	-21.39	-125.06		

Preliminary Results Only--Do not cite



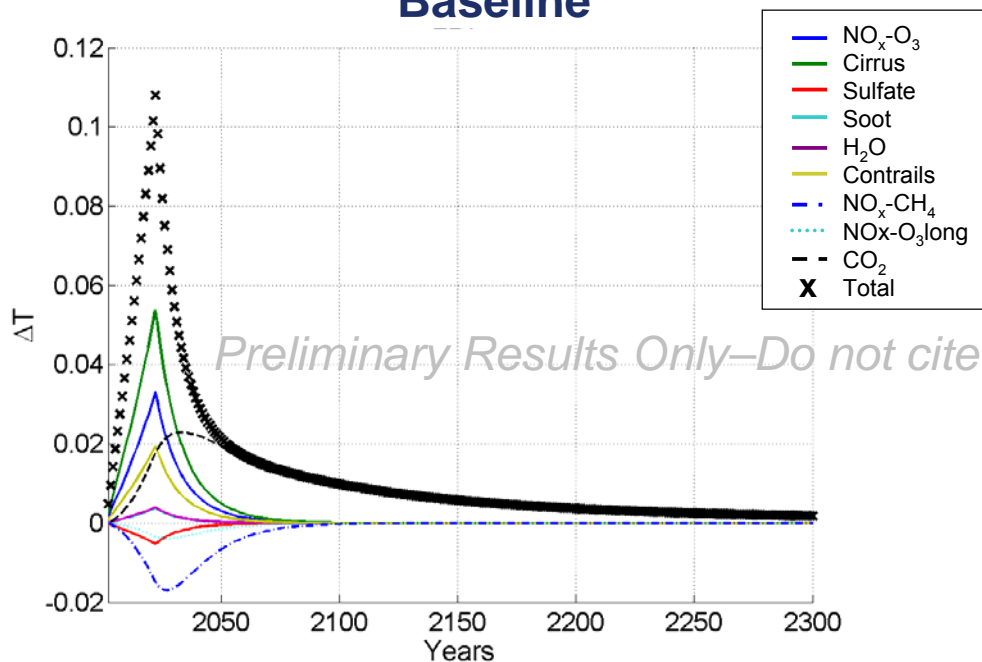
Simplified methods for valuing the impact of aviation on climate



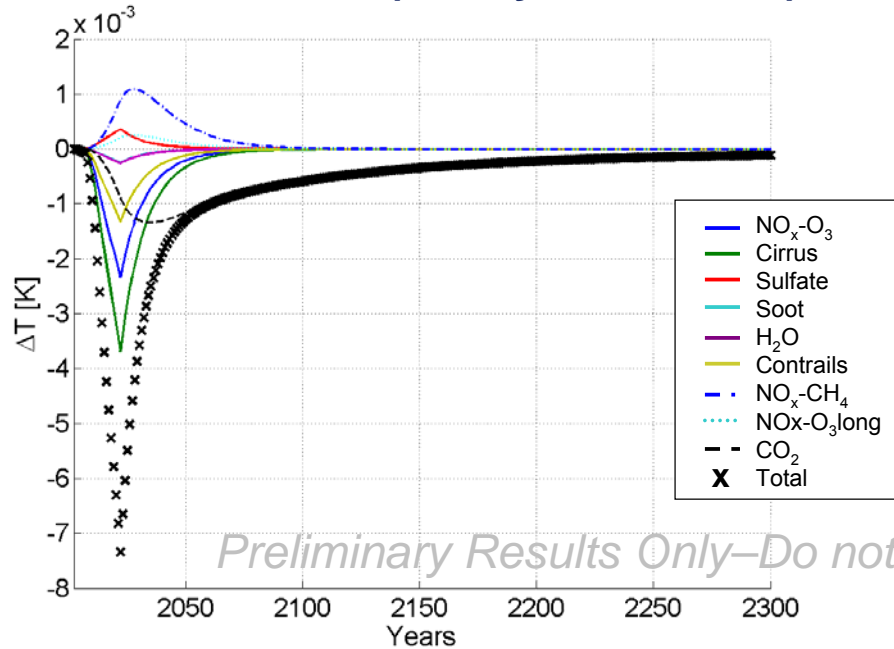
Treatment of uncertainty

- Sensitivity, Monte Carlo, and Vary-all-but-one analyses
- Some uncertain parameters specified with uniform or triangular distributions
 - Emissions inventories (fixed here)
 - RF's for short-lived effects (Sausen, et al., 2005)
 - Climate sensitivities (Hansen, et al., 2005)
- Other uncertainties addressed with scenarios/choices/cases
 - IS92 background scenarios
 - FESG aviation scenarios
 - CO₂ response function choice
 - Temperature response function choice
 - Damage function choice
 - Discount rate choice
 - Distribution shape for uncertain parameters
 - Double uncertainty for all uncertain parameters

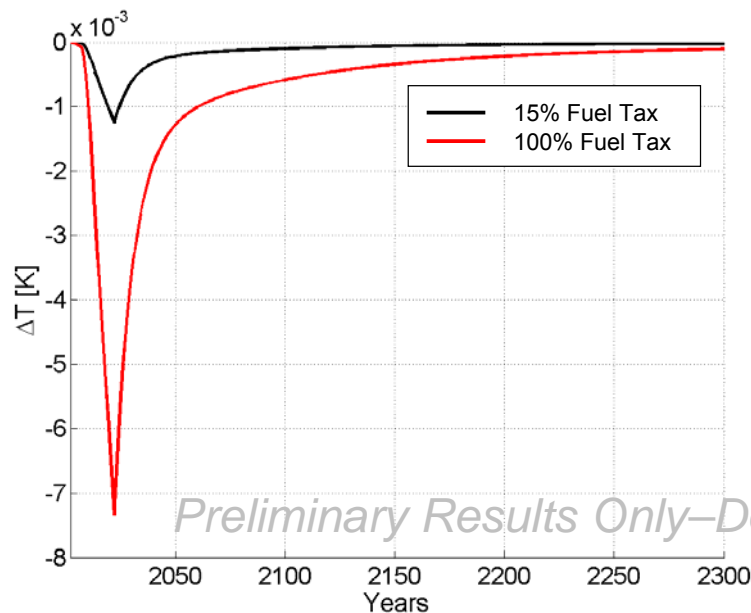
ΔT [K]: Baseline



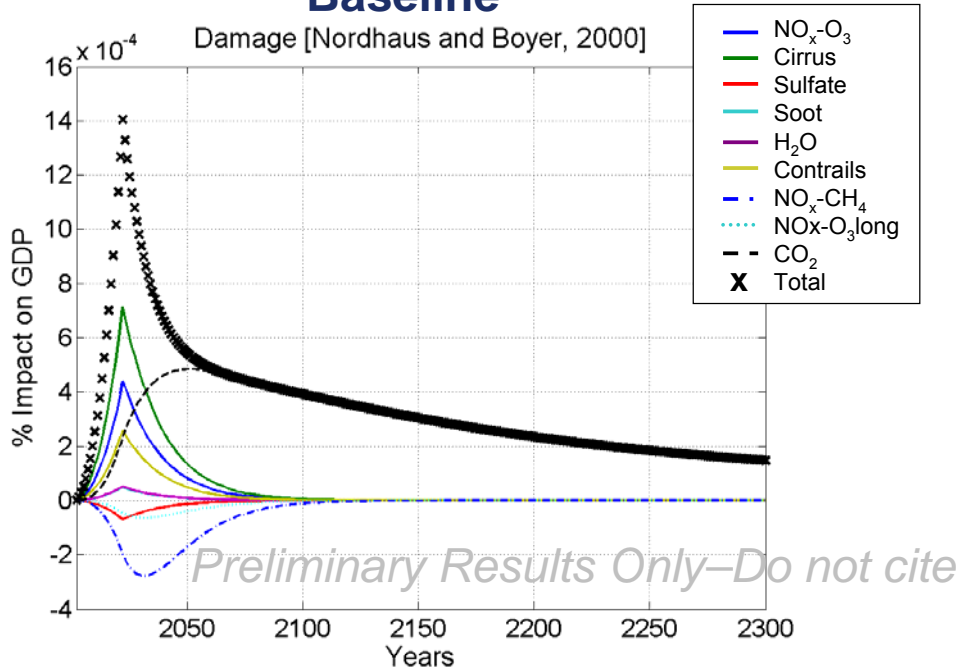
Change in ΔT [K]: 100% Fuel Tax (Policy – Baseline)



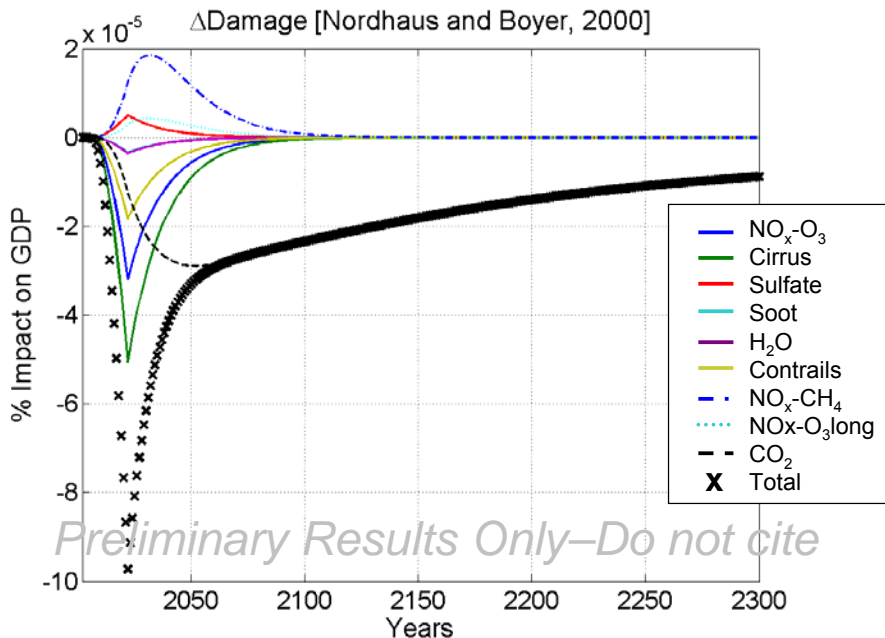
Change in ΔT [K]: Policy Comparison (Policy – Baseline)



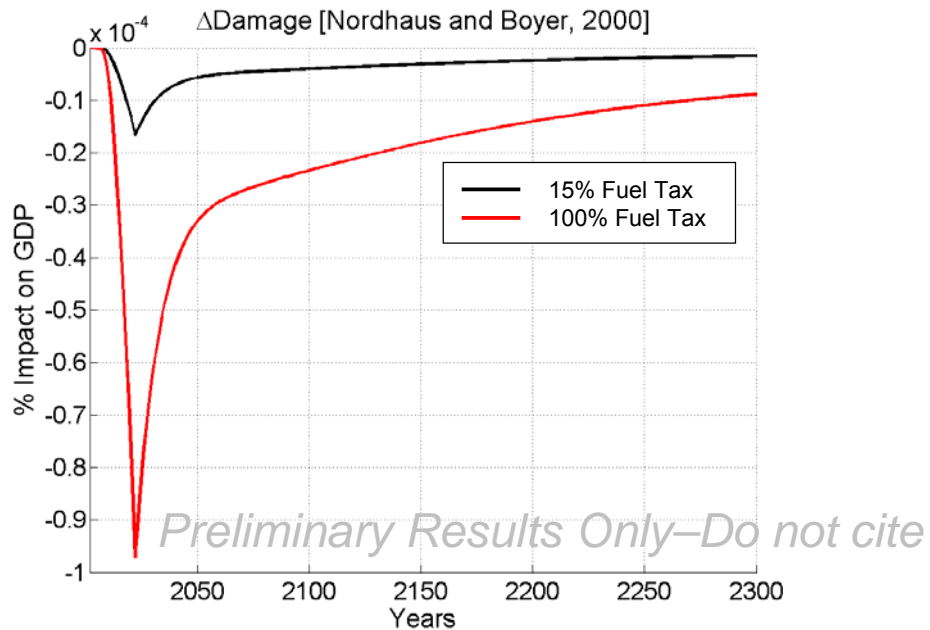
Damage [% GDP]: Baseline



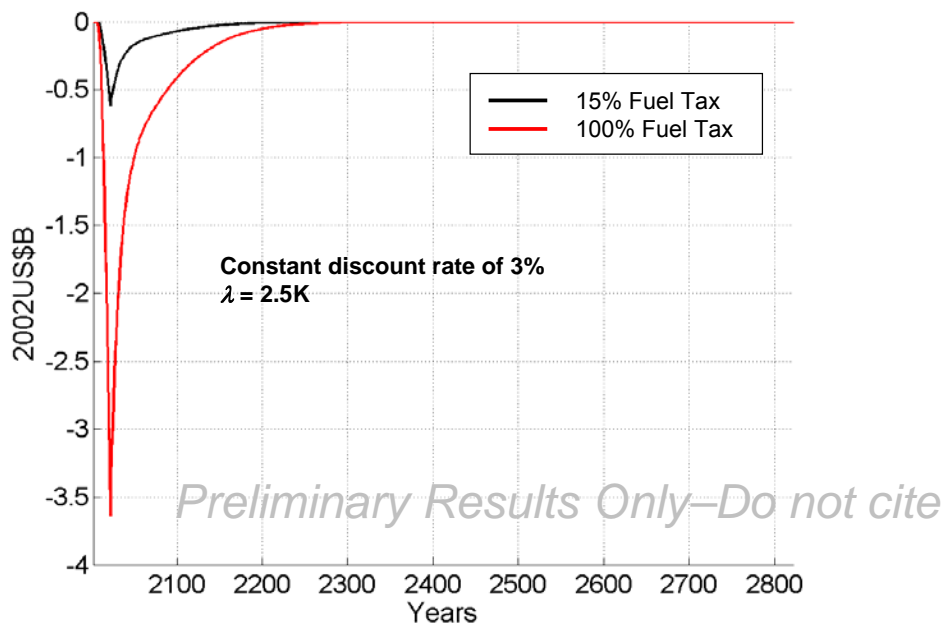
Change in Damage [% GDP]: 100% Fuel Tax (Policy – Baseline)



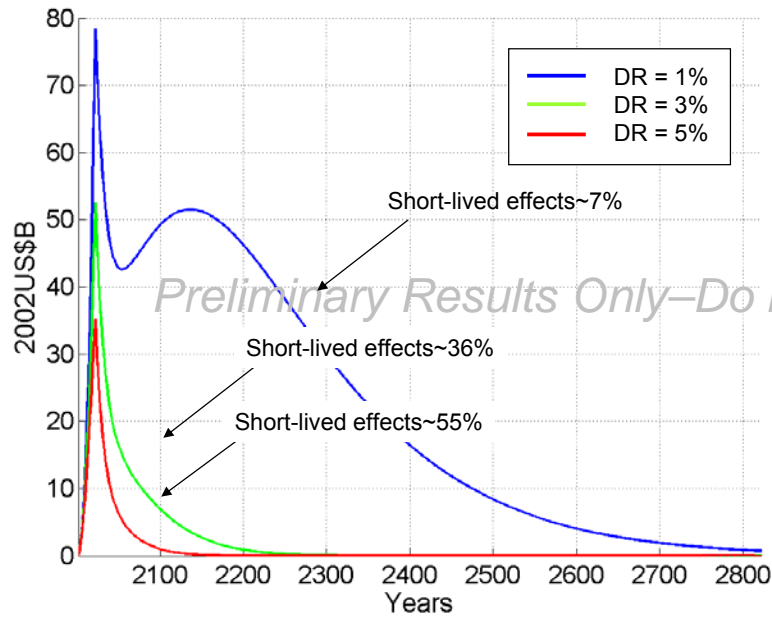
Change in Damage [% GDP]: Policy Comparison (Policy – Baseline)



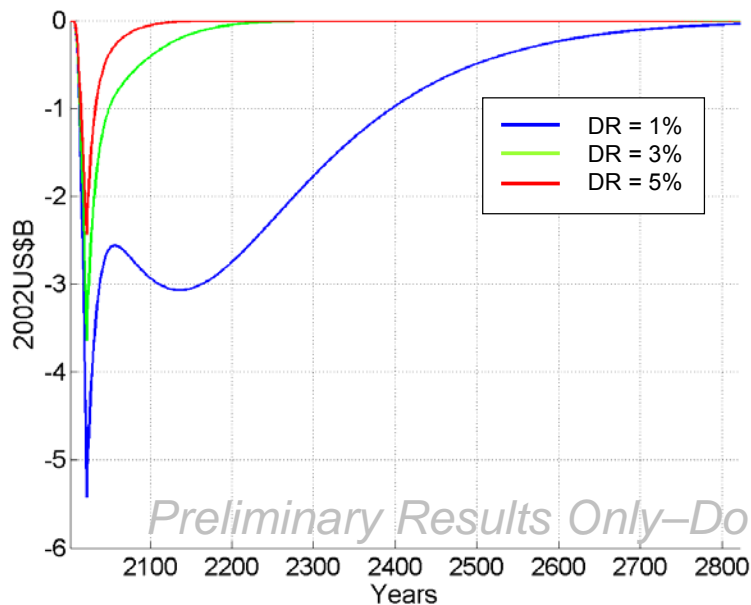
Change in NPV: Policy Comparison (Policy – Baseline)



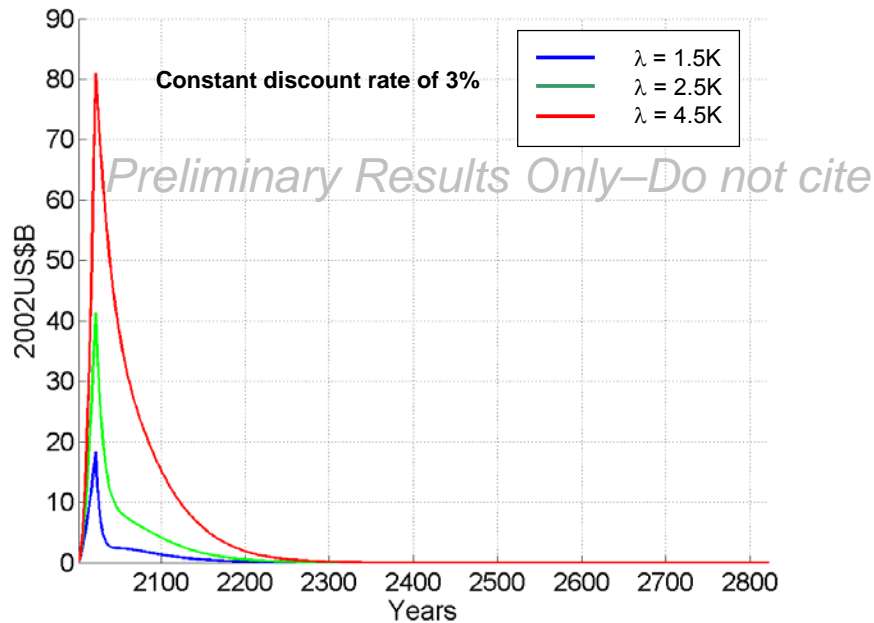
Impact of Discount Rate on Present Value: Baseline



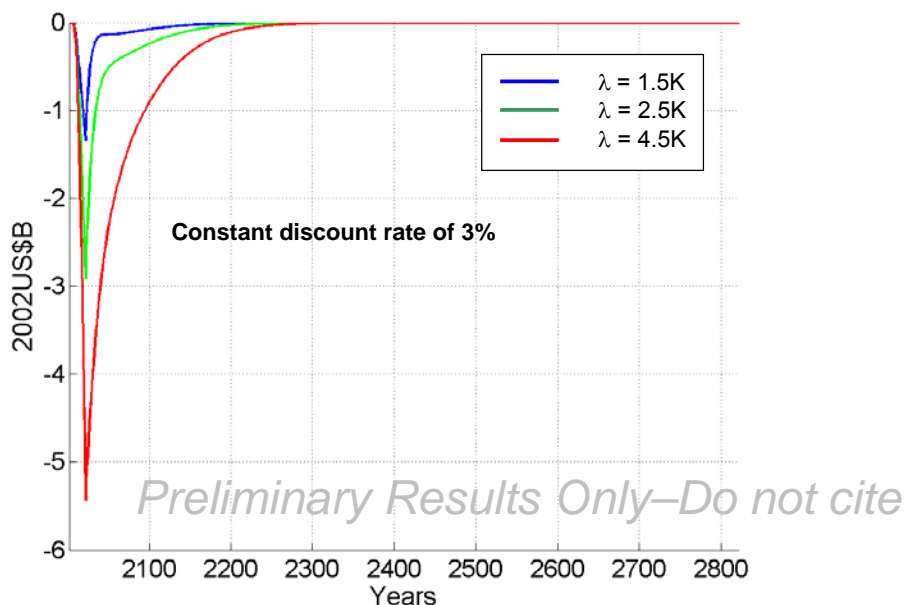
Impact of Discount Rate on Present Value: 100% Fuel Tax (Policy – Baseline)



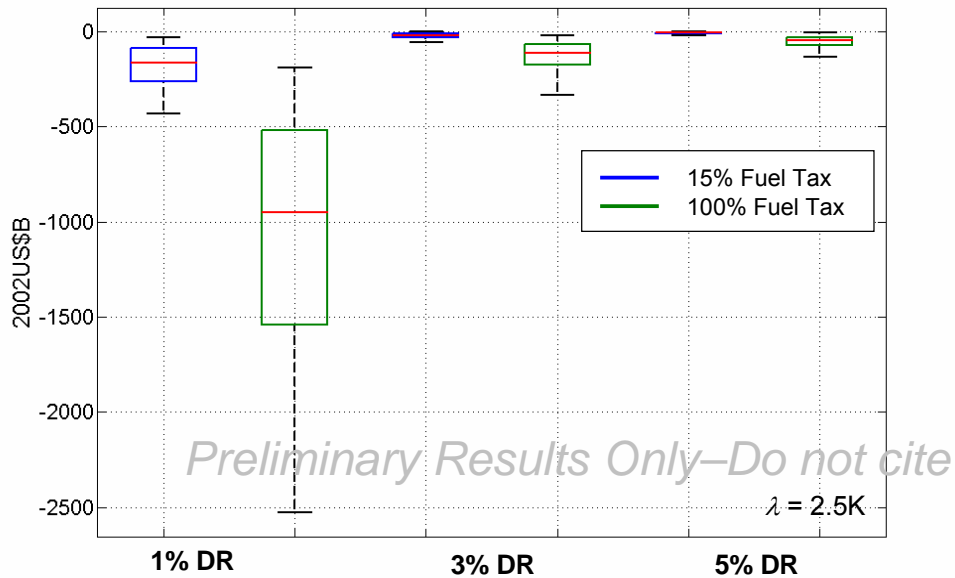
Impact of Climate Sensitivity on Present Value: Baseline



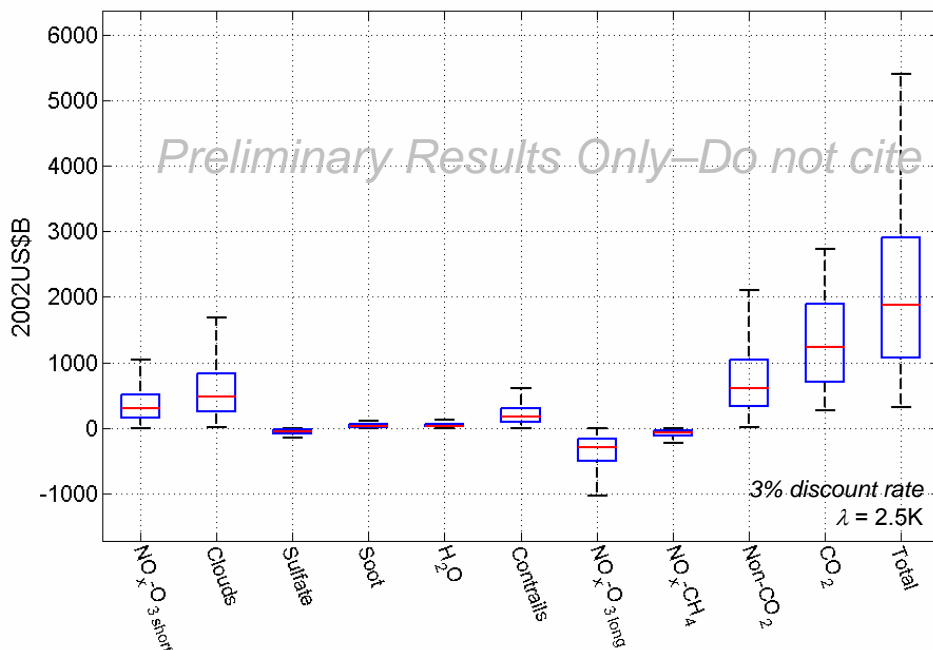
Impact of Climate Sensitivity on Present Value: 100% Fuel Tax (Policy – Baseline)



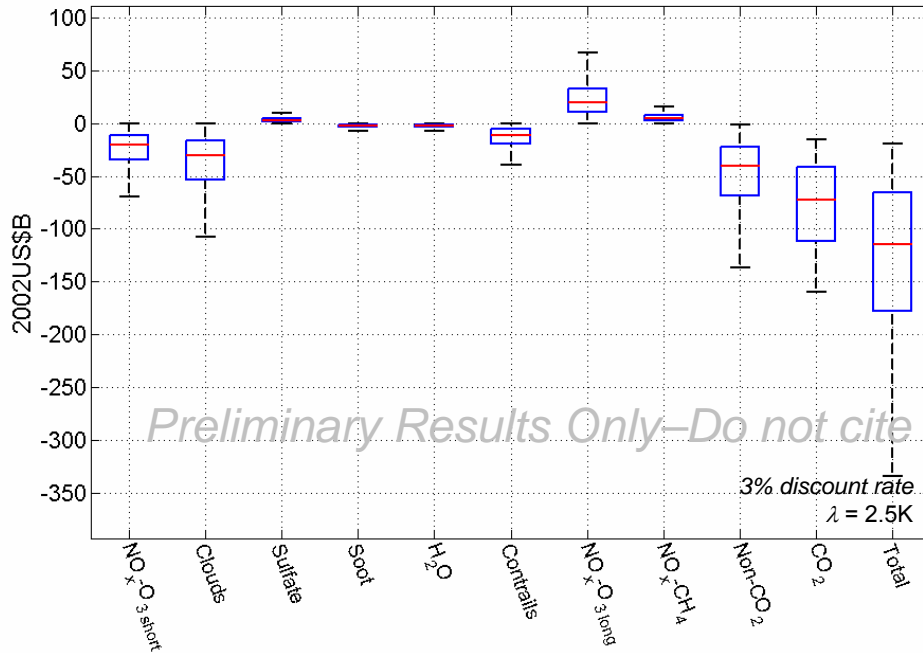
Impact of Discount Rate on NPV Change: Policy Comparison (Policy – Baseline)



NPV of Climate Impacts: Baseline



NPV of Climate Impacts: 100% Fuel Tax (Policy – Baseline)*



*Difference between policy and baseline values.

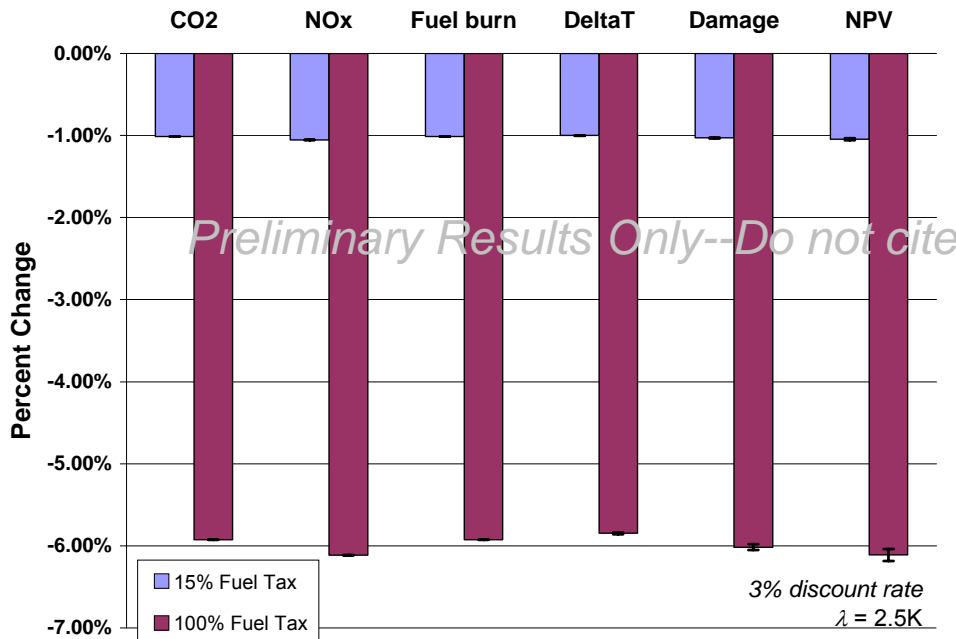
APMT Capability Demonstration Problems: Environmental Impacts
December 6-8, 2006



Federal Aviation
Administration

39

Summary of Impact of Fuel Price Increase



APMT Capability Demonstration Problems: Environmental Impacts
December 6-8, 2006

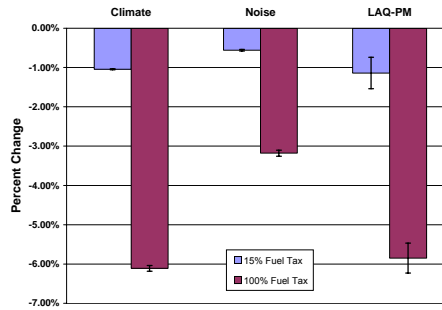
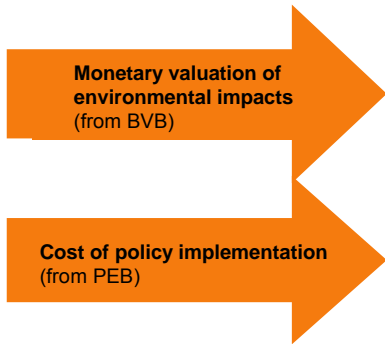


Federal Aviation
Administration

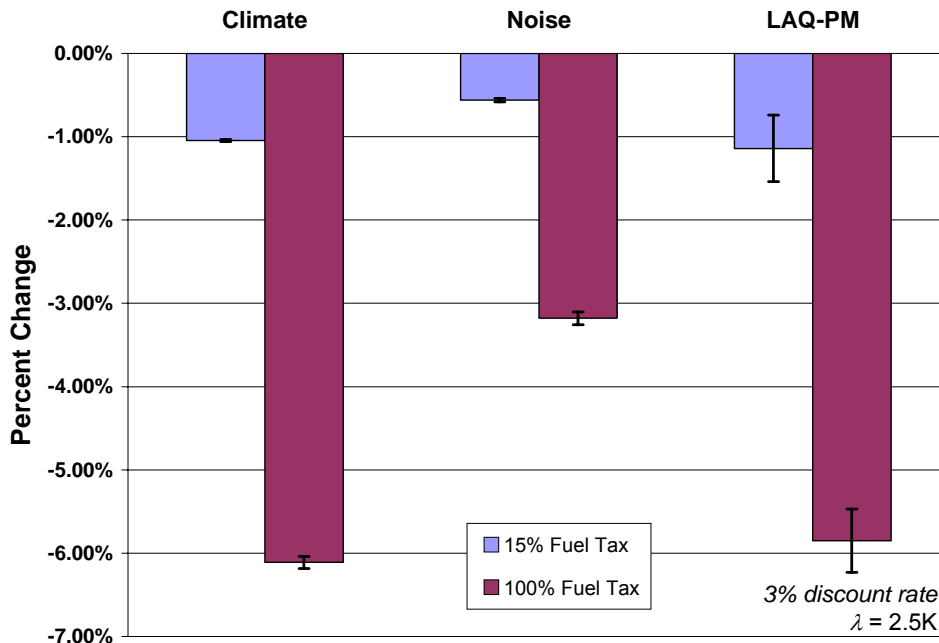
40

The Balance Sheet: Summary

US\$B, 3% discount rate		Results for different assumptions, scenarios, user-selected preferences.										
<ul style="list-style-type: none"> •By airport •By aircraft type •By altitude-band •Regional emissions •Global emissions •User-specified aggregation 	Consumer surplus (global)		Airline operating cost (global)		Noise Benefits (89 airports)		Local Air Quality Benefits (U.S.)		Climate Benefits (global)		Total Benefits - Costs NOTIONAL ONLY!!	
	Fuel Tax (15%, 100%)	-158	-1010	30.3	197.1	-0.124	-0.646	0.30	1.54	-21.39	-125.06	-149



Summary of Policy Impact



A word of caution

- **These are NOT the “answers”**
 - Apples-to-oranges comparisons
 - For a notional policy case
 - The numbers reflect a particular set of assumptions and scenarios
 - There may be errors
- **These are examples of work in progress**
 - Much work remains to assess and improve
 - And to better understand how to communicate and use such results



Summary of status

- **Complete problems:**
 - Reduced thrust
 - Fuel price increase
- **Other problems are well under way**
 - NOx reduction
 - Noise phase-out
- **We are producing results for all these problems; and**
 - Analyzing their implications for policy-making
 - Comparing and assessing different policies
- **Much additional evaluation and documentation required**



Next steps

- **Key areas for development include**
 - Expanding data sources world-wide (census data, local air quality, etc.)
 - Global air quality modeling
 - Improved response surfaces for ozone and PM
 - Calibration and assessment of the PEB
 - Linkage between fleet selection in PEB and EDS
 - Addressing areas of uncertainty identified in assessment activities



Summary

- **Capability demonstrator problems specified in July**
- **CD's have been valuable in identifying errors and gaps in our methods -- this was the primary purpose**
 - PEB
 - NOx-ozone relationship
 - MAGENTA interface
 - Many others...
- **CD's also provide a glimpse of what the future will hold for APMT**
 - **Comprehensive policy guidance** with multiple metrics for multiple market segments, regions and effects
 - **Rigorous, with explicit representation of uncertainty**
 - **A true capability for assessing interdependences**



??? Questions ???

FAA Environmental Tools web site:

http://www.faa.gov/about/office_org/headquarters_offices/aep/models/

