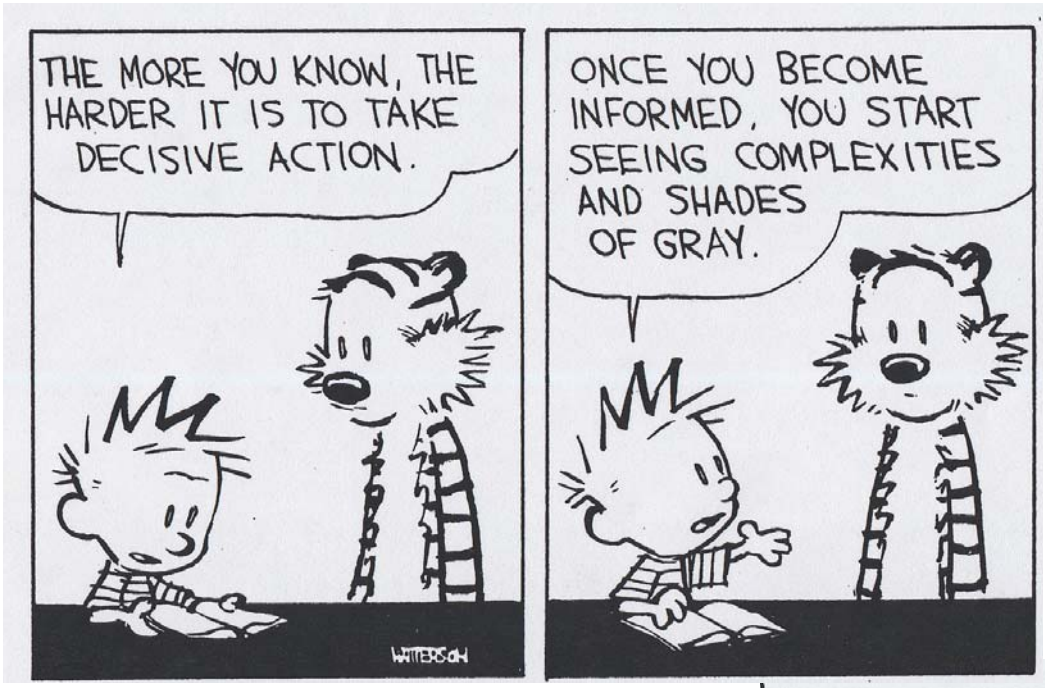
Considering Risk in Developing a Regulatory Response to Climate Change

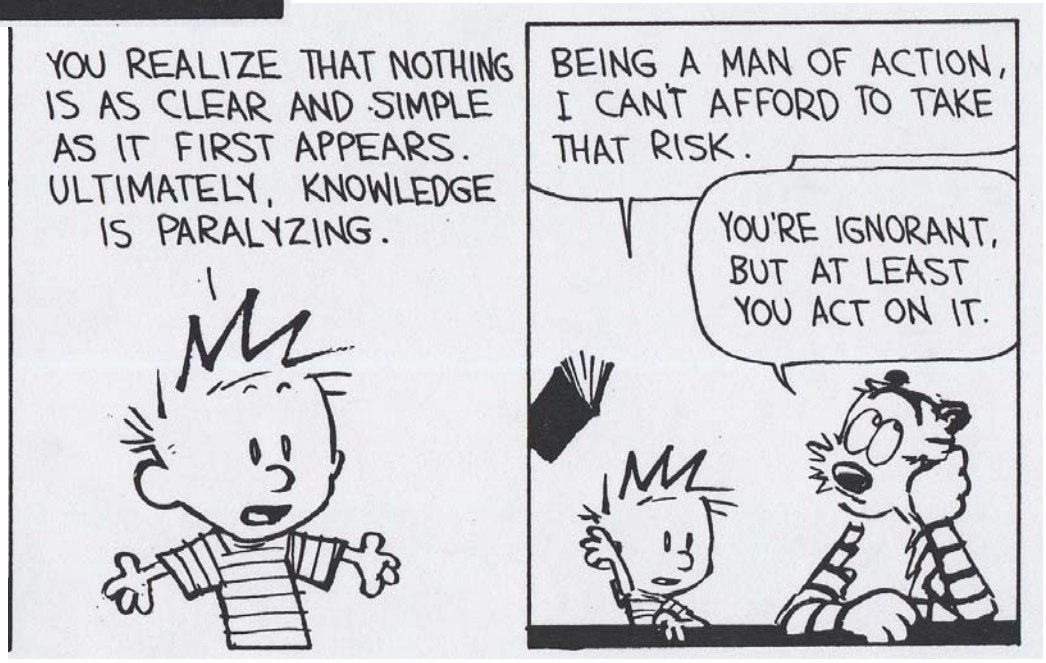
Mort Webster

Engineering Systems Division
MIT Joint Program on the Science and Policy of Global Change
Massachusetts Institute of Technology

New Ideas for Risk Regulation
Society for Risk Analysis / Resources for the Future
June 22, 2009

Calvin's View on Risky Decisions





Outline

- Motivation:
  - Regulatory decisions about climate change
- Risk-Based Information about Climate Change
- Encouraging Signs
- How WE (scientific community) could do better

Climate Change: Highly Uncertain and Potentially Catastrophic Risks

- Why Worry about Global Climate Change?
- Mean Projection:
  - 2 to 4 degrees warming over this century?
- No!!!
  - Possibility of > 8 degrees warming
  - Possibility of sea level rise > 1 meter
  - Possibility of changes in climate variability and weather extremes
  - Possibility of catastrophic impacts on natural and human systems from climate shifts

Climate Change Policy: Choosing a Long-Term Target

- UN Framework Convention on Climate Change

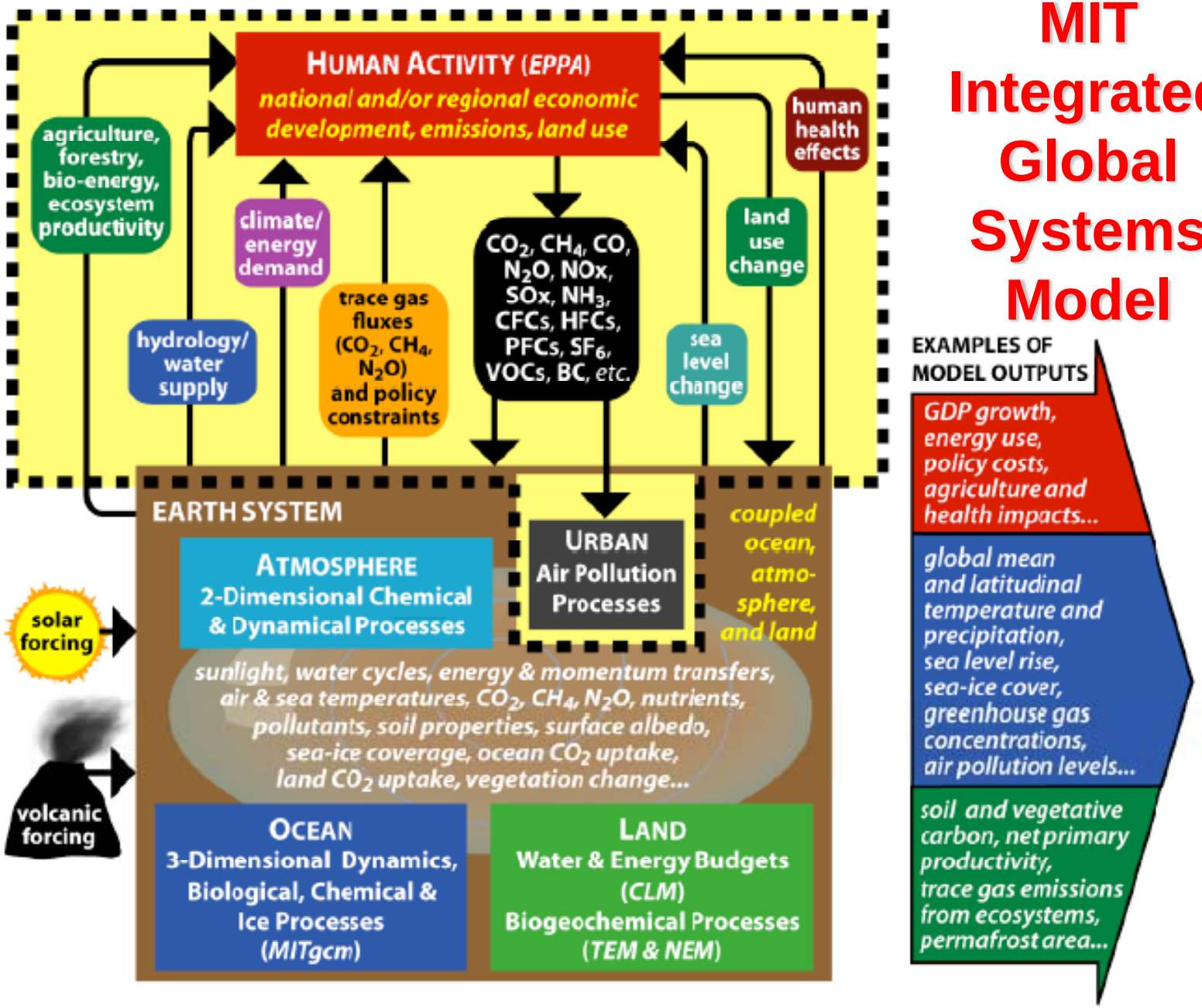
  "…*stabilization* of greenhouse gas concentrations in the atmosphere *at a level* that would prevent *dangerous* anthropogenic interference with the climate system."

  [emphasis added]

Regulatory Decisions for Climate Change

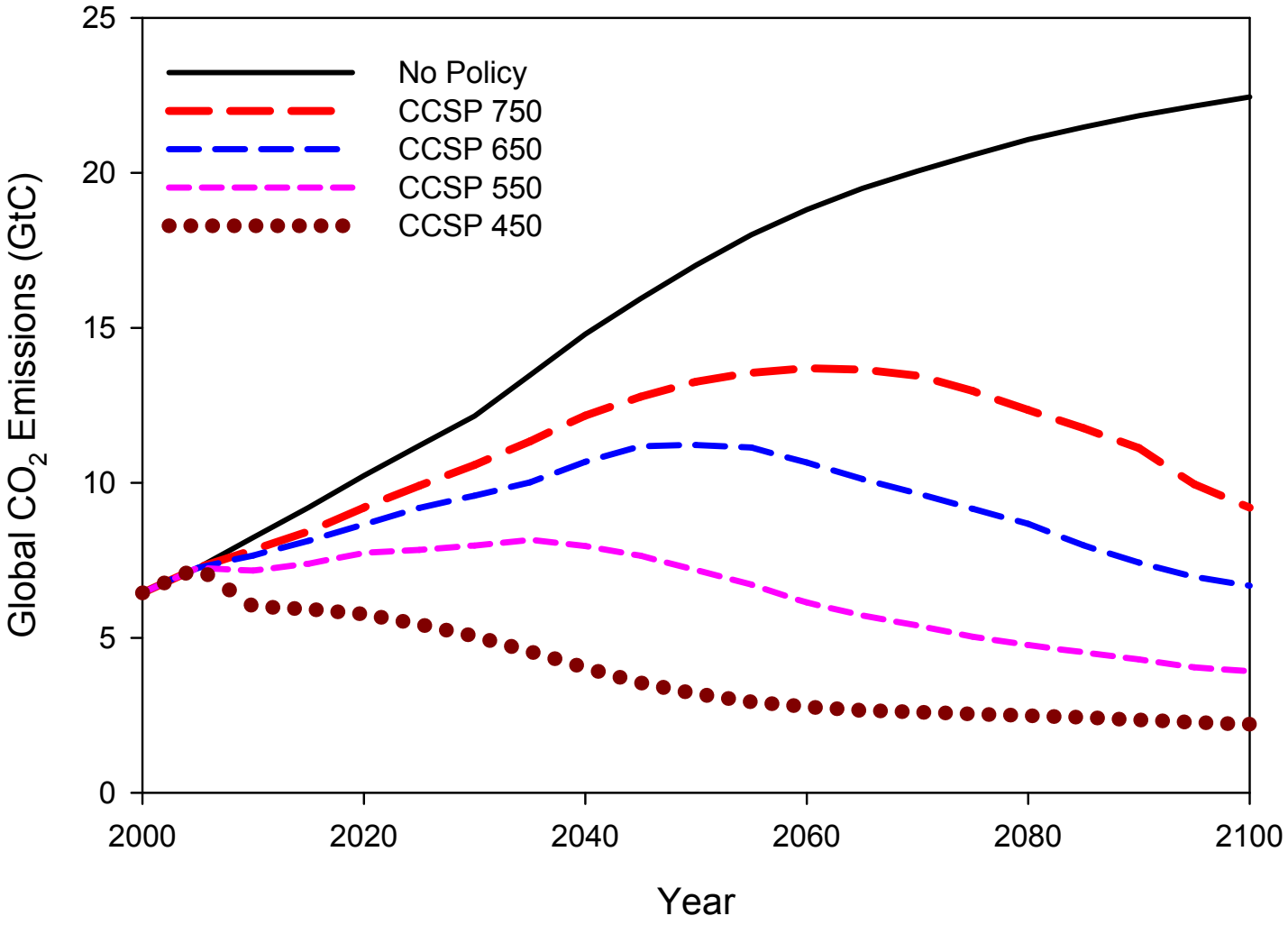
- International Negotiations
  - Long-term target
  - Near-term action
  - Burden-sharing
- Domestic Regulation
  - U.S. position on a long-term target
  - Greenhouse gas legislation
    e.g., Waxman-Markey
  - E.P.A. regulation of GHG emissions
  - E.P.A. implementation of GHG legislation

MIT Integrated Global Systems Model

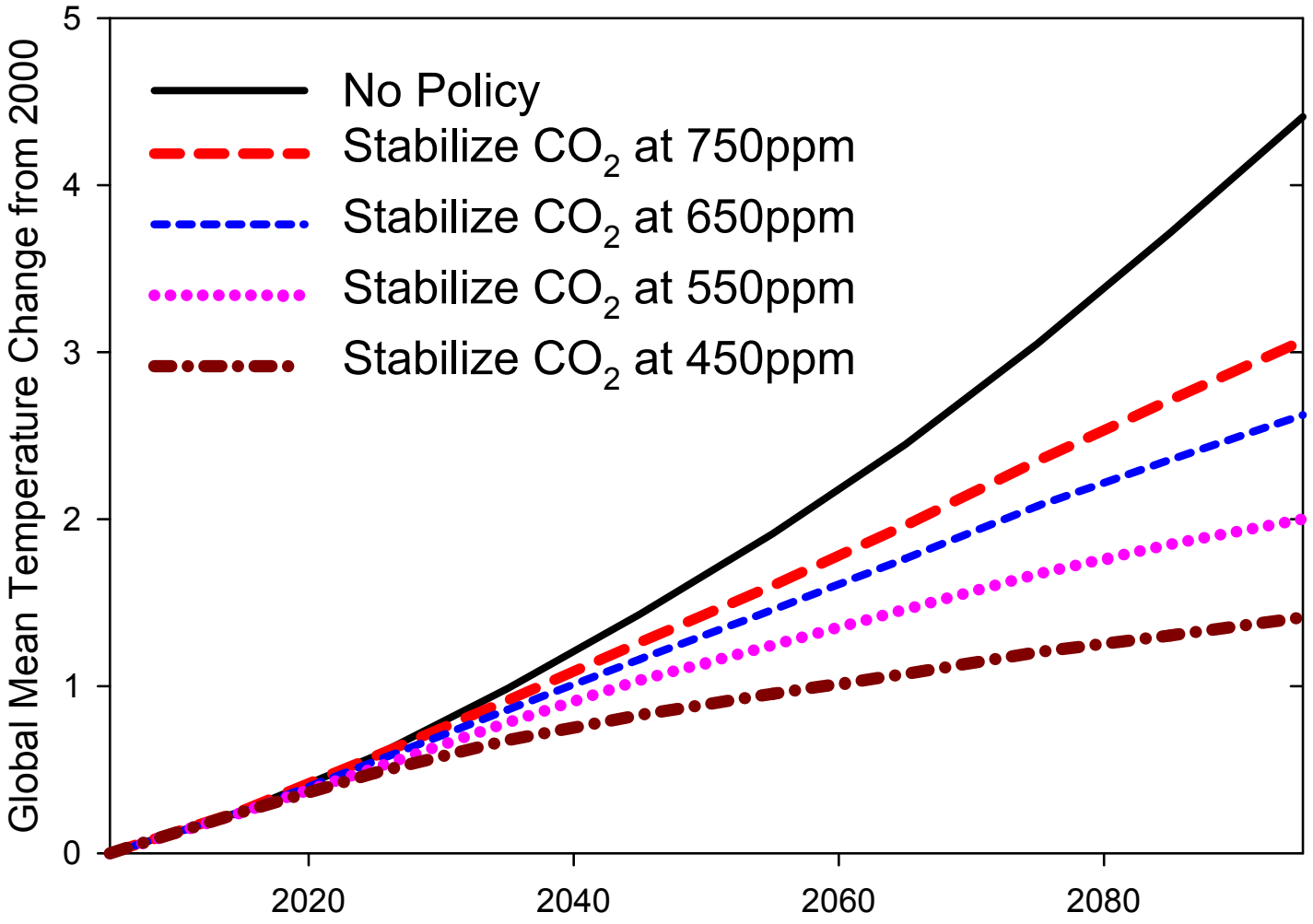


Stabilization Scenarios

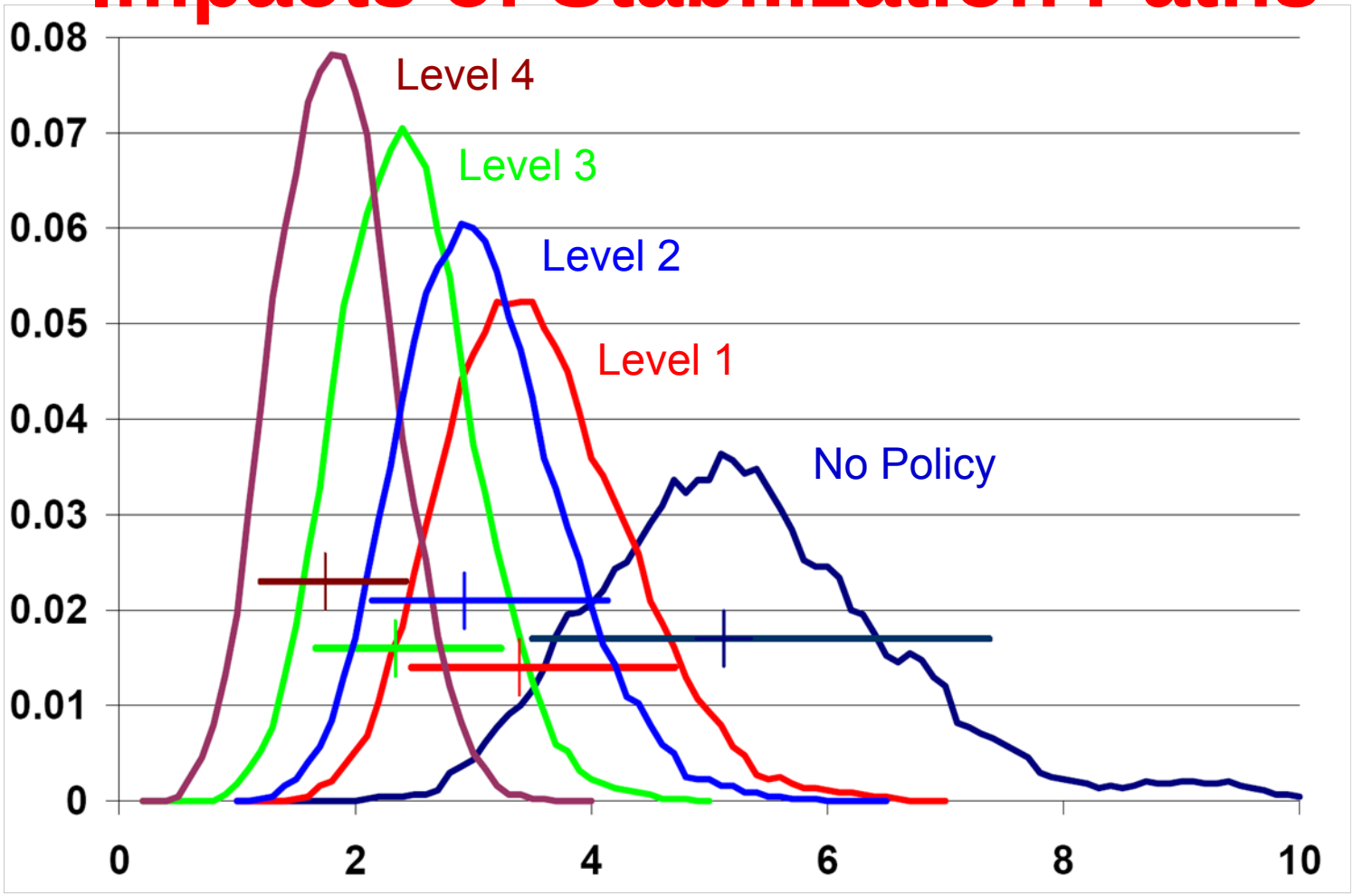
(Source: U.S. CCSP Product 2.1a)



Global Mean Temperature Change (Deterministic)

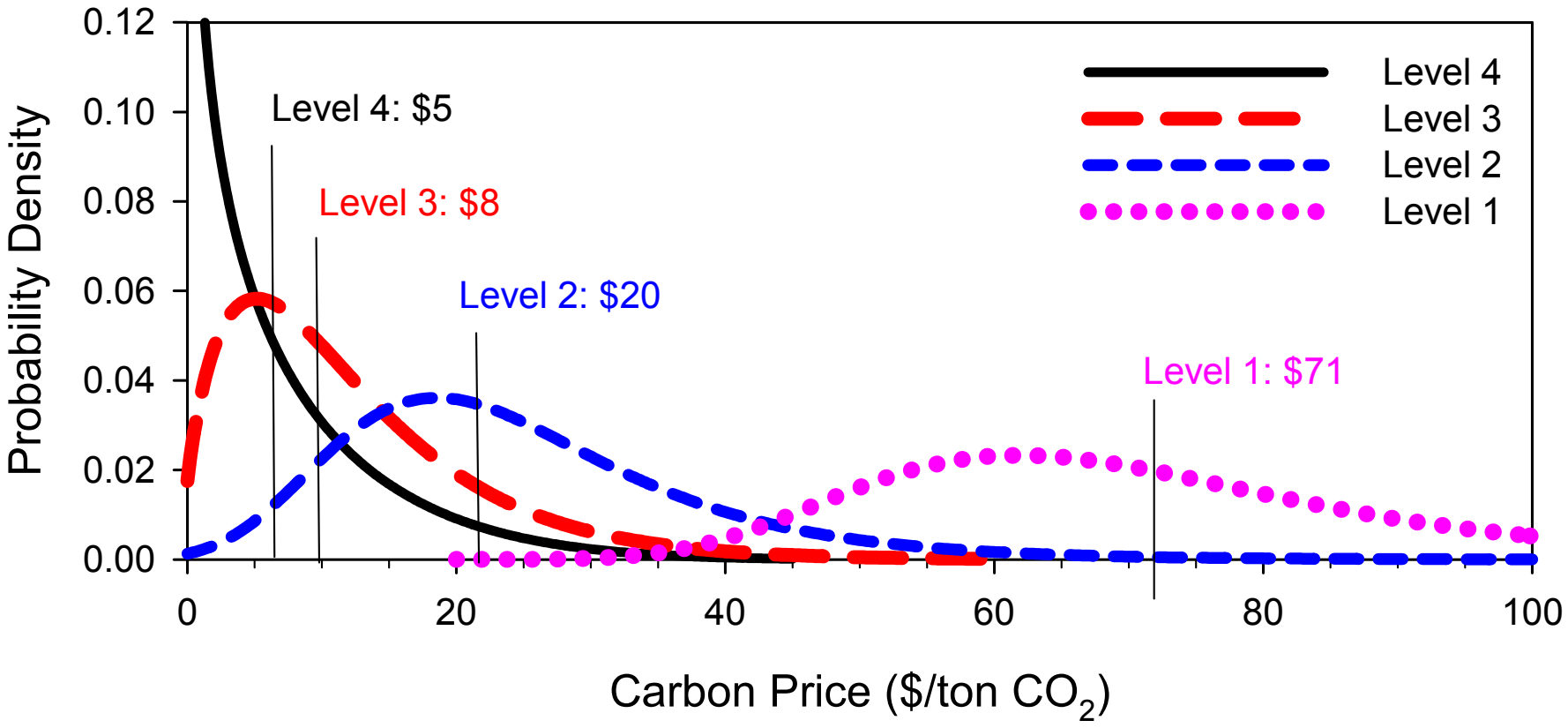


Results: Temperature Change
Impacts of Stabilization Paths

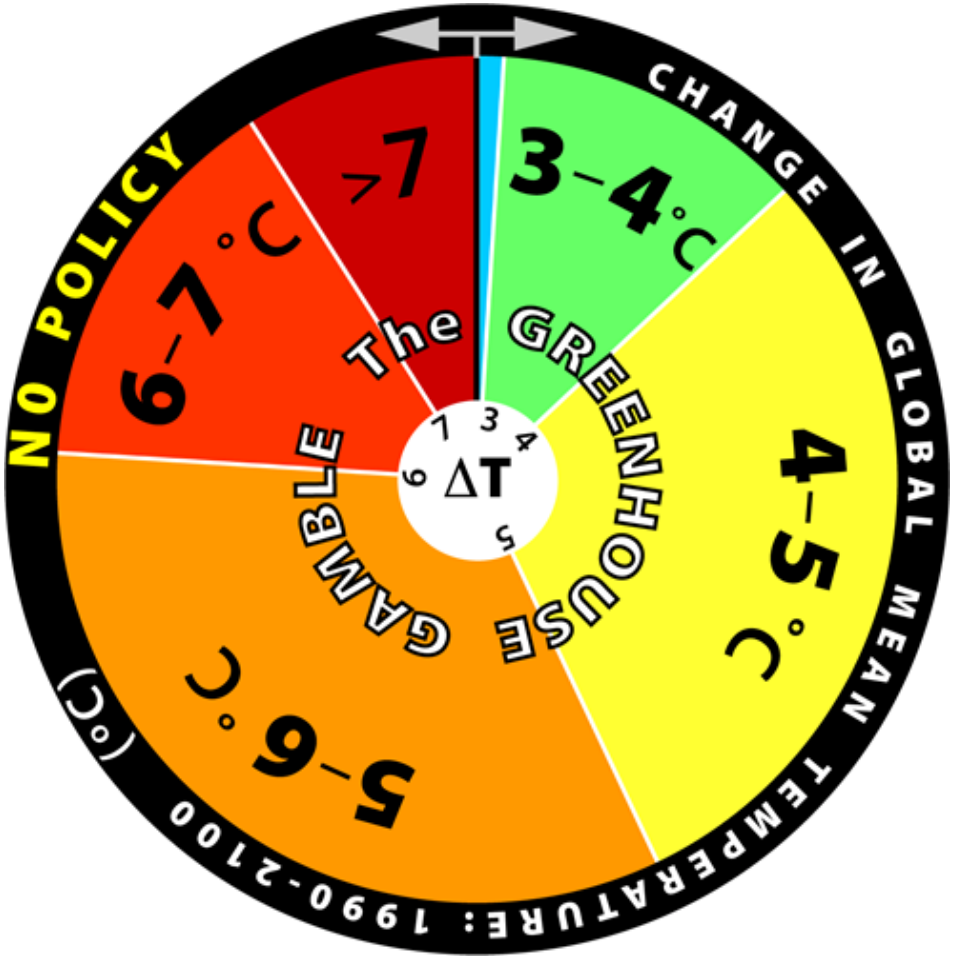


Global Mean Surface Temperature Increase (°C)
(1981-2000) to (2091-2100)

Carbon Prices in 2020

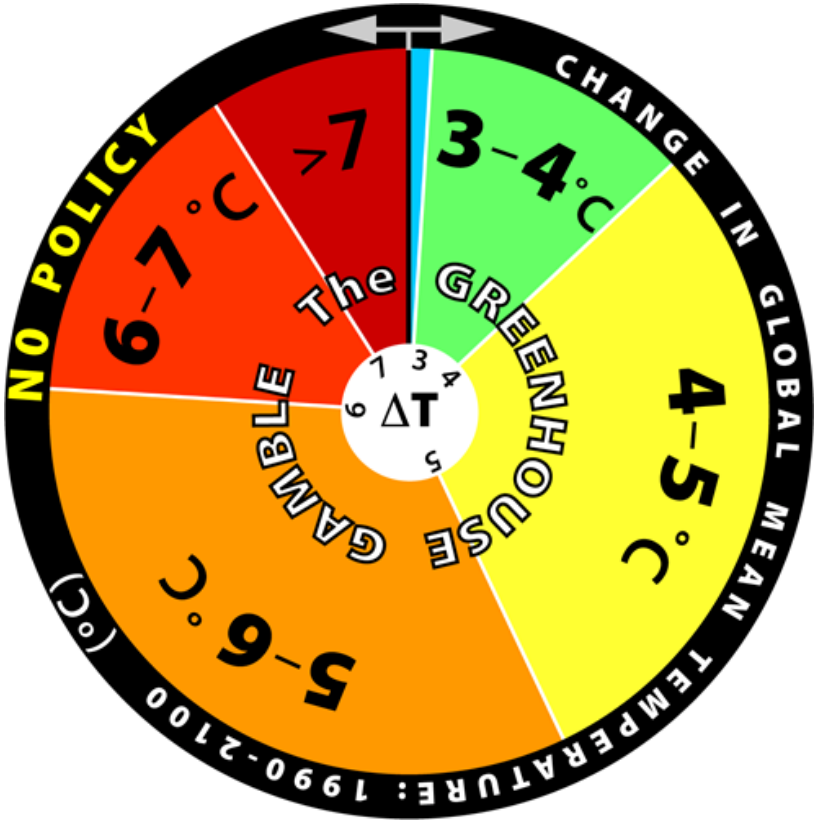


Communicating the Odds of Temperature Change

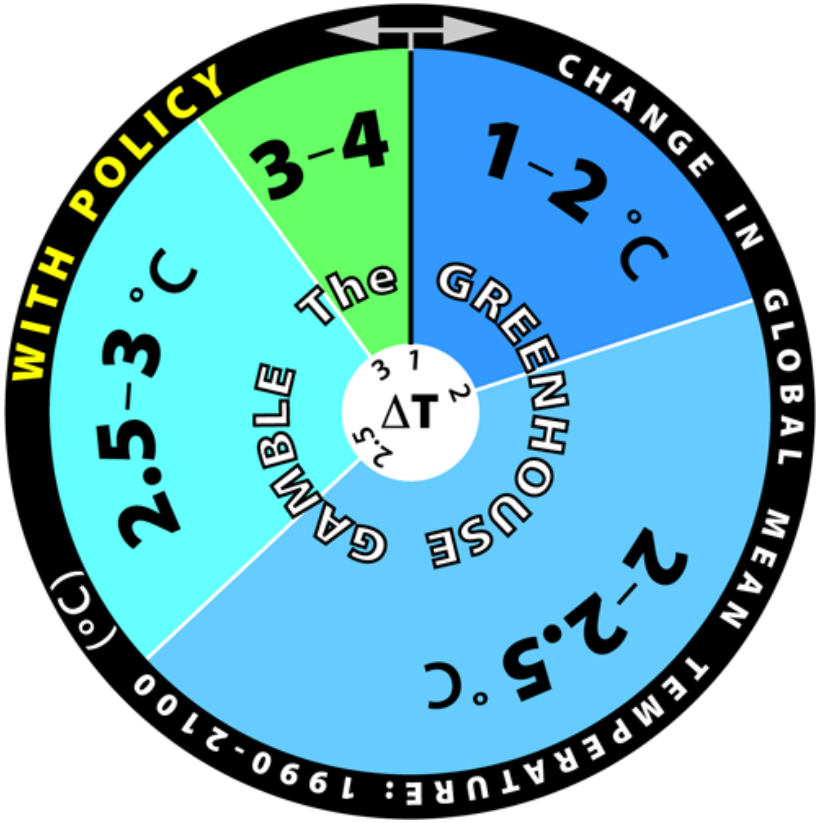


Communicating the Impact of Policy

No Policy



Stringent Policy
(~550 ppm)



USING THE IGSM, WHAT IS THE PROBABILITY OF GLOBAL WARMING for 1980-2100, WITHOUT & WITH A 450, 550, 650 or 750 ppm CO_2-equivalent STABILIZATION POLICY?

(400 random samples for economics & climate assumptions)

	ΔT > 2°C	ΔT > 4°C	ΔT > 6°C
No Policy	**400 in 400**	**17 in 20**	**1 in 4**
Stabilize at 750	**400 in 400**	**1 in 4**	**1 in 400**
Stabilize at 650	**97 in 100**	**7 in 100**	**<1 in 400**
Stabilize at 550	**8 in 10**	**1 in 400**	**<1 in 400**
Stabilize at 450	**1 in 4**	**<1 in 400**	**<1 in 400**

USING THE EPPA, WHAT IS THE PROBABILITY FOR WELFARE LOSS (% change in 2020), WITHOUT & WITH A 450, 550, 650 or 750 ppm CO_2-equivalent STABILIZATION POLICY?

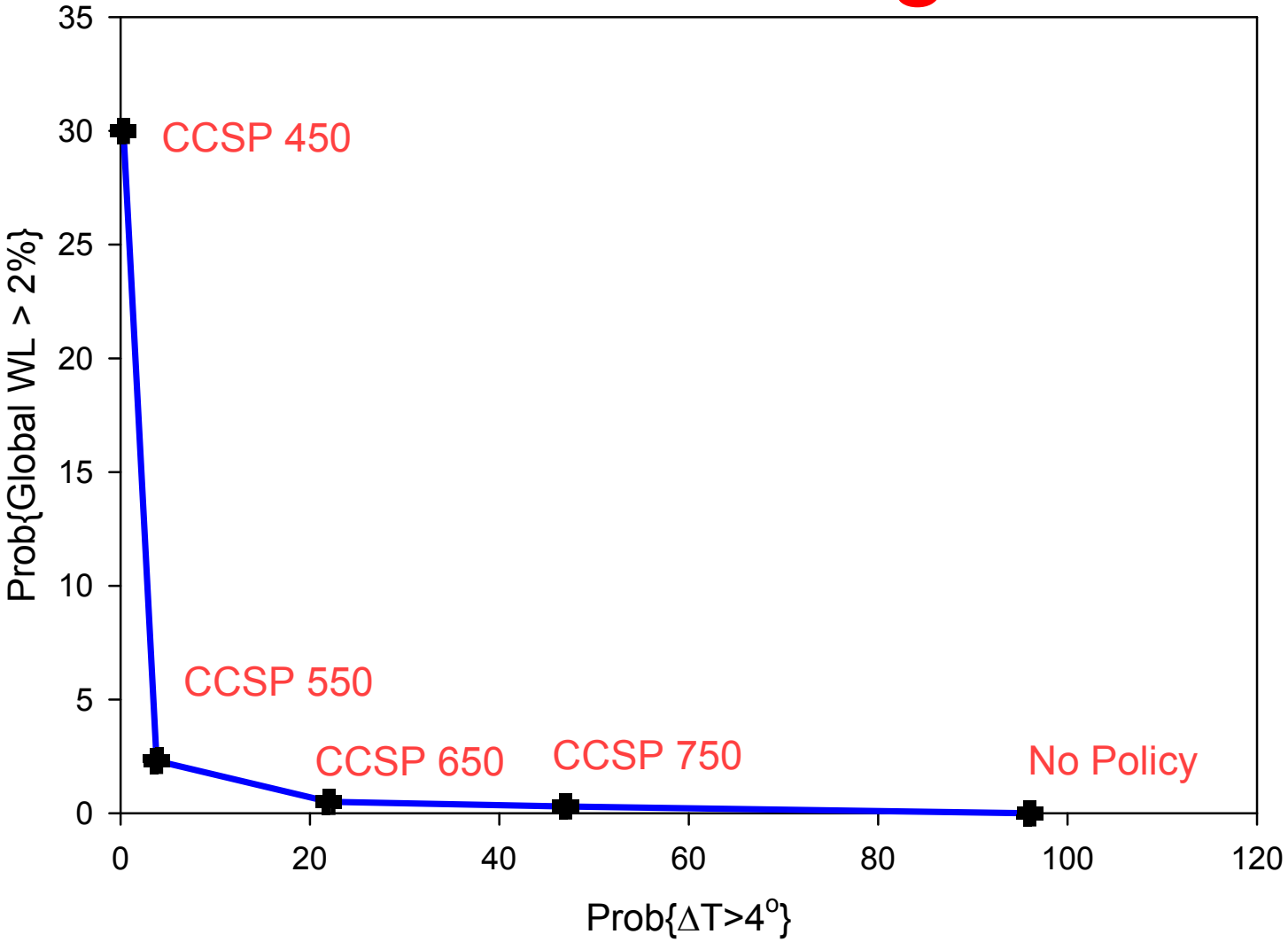
(400 random samples for economics assumptions)

	ΔWL>1%	ΔWL>2%	ΔWL>3%
No Policy	-	-	-
Stabilize at 750	1 in 100	1 in 400	<1 in 400
Stabilize at 650	3 in 100	1 in 200	<1 in 400
Stabilize at 550	1 in 4	1 in 50	1 in 200
Stabilize at 450	7 in 10	3 in 10	1 in 10

Marginal Reduction in Probability of Exceeding 5°C Global Temperature Change

	Probability of exceeding target	Reduction in Probability (percentage points)	Cum. CO_2 Emissions 2000-2100 (GtC)	Reduction in Cumulative CO_2	δProb/δCum
No Policy	54.0%		1605.0	-	-
Stabilize at 750	2.5%	51.5%	1123.1	481.9	**0.107%**
Stabilize at 650	0.3%	2.3%	910.9	212.2	**0.011%**
Stabilize at 550	0.0%	0.3%	634.7	276.2	**0.001%**
Stabilize at 450	0.0%	0.0%	381.1	253.6	**0.000%**

Risk-Risk Tradeoffs in Choosing Stabilization Targets

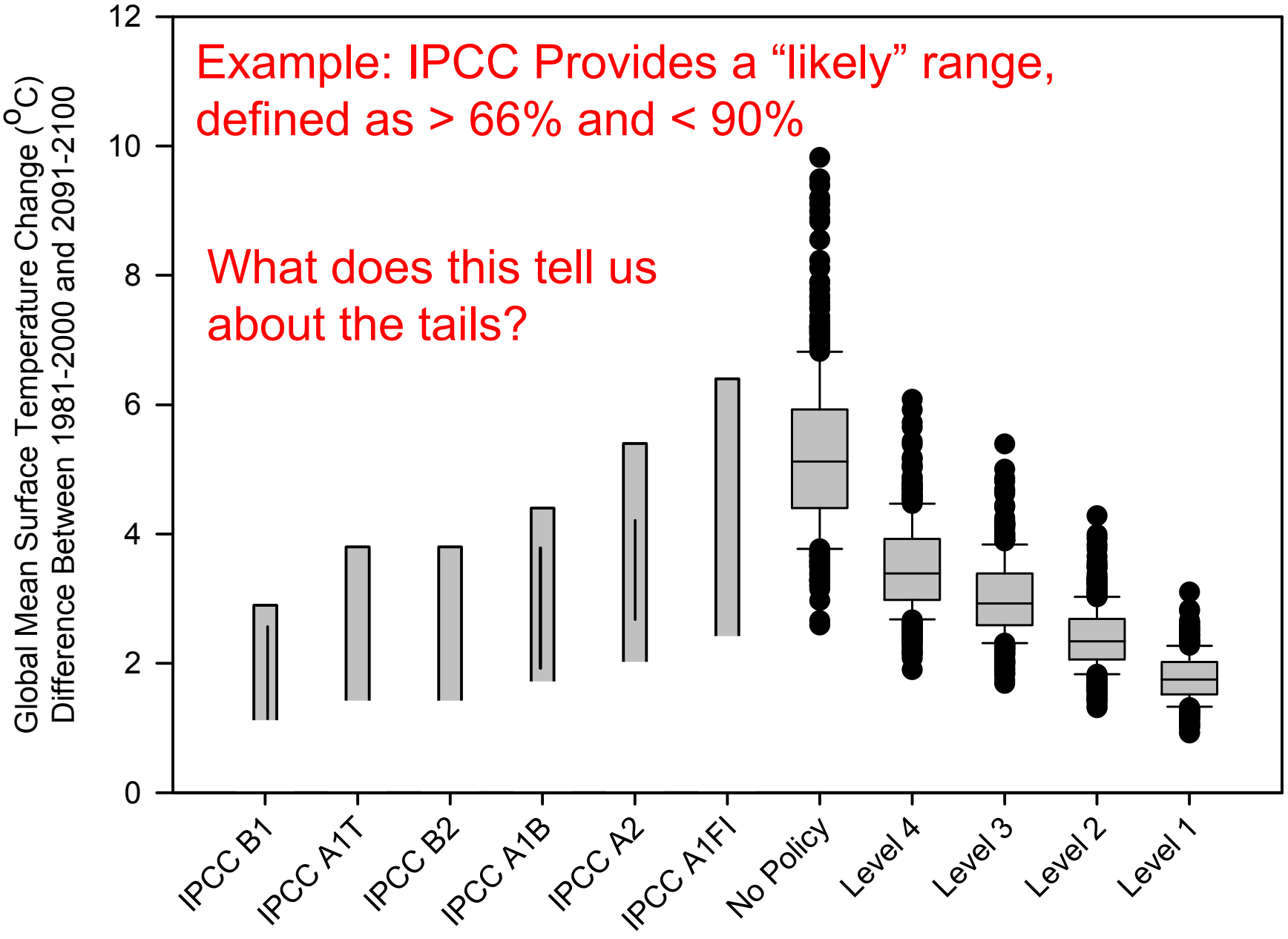


Promising Signs?

- Environmental Protection Agency
- Interested in Marginal Reductions in Risk from Increasing Levels of GHG Emissions Abatement

How Can the Scientific Community Help?

1. Provide More Probabilistic Risk-Based Results
2. Provide Information about Impacts that Matter to the Public and Regulators
   - Local/regional impacts
   - Costs
3. Provide Probabilistic Information in a Useful Form


Example: IPCC Provides a "likely" range, defined as > 66% and < 90%
What does this tell us about the tails?
Global Mean Surface Temperature Change (°C)
Difference Between 1981-2000 and 2091-2100
0
2
4
6
8
10
12
IPCC B1
IPCC A1T
IPCC B2
IPCC A1B
IPCC A2
IPCC A1FI
No Policy
Level 4
Level 3
Level 2
Level 1

Thank You!!!

USING THE IGSM, WHAT IS THE PROBABILITY OF GLOBAL SEA LEVEL RISE for 2000-2100, WITHOUT & WITH A 450, 550, 650 or 750 ppm CO_2-equivalent STABILIZATION POLICY?

(400 random samples for economics & climate assumptions)

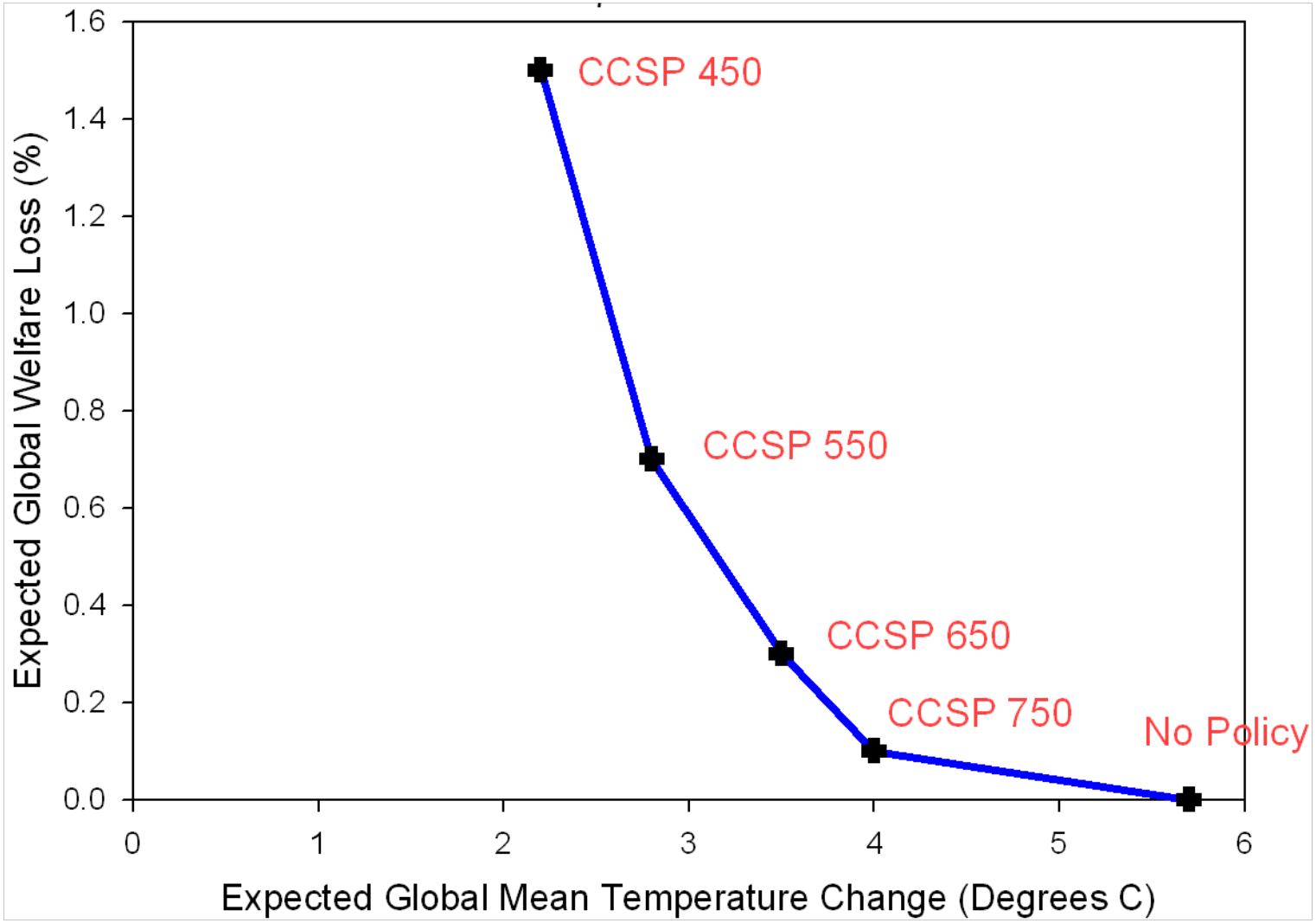
	Sea Level Rise > 0.2m	Sea Level Rise > 0.4m	Sea Level Rise > 0.6m
No Policy	**400 in 400**	**13 in 20**	**9 in 100**
Stabilize at 750	**396 in 400**	**1 in 5**	**< 1 in 400**
Stabilize at 650	**97 in 100**	**1 in 10**	**< 1 in 400**
Stabilize at 550	**9 in 10**	**1 in 50**	**< 1 in 400**
Stabilize at 450	**7 in 10**	**<1 in 400**	**< 1 in 400**

USING THE EPPA, WHAT IS THE PROBABILITY FOR WELFARE LOSS (% change in 2050), WITHOUT & WITH A 450, 550, 650 or 750 ppm CO_2-equivalent STABILIZATION POLICY?

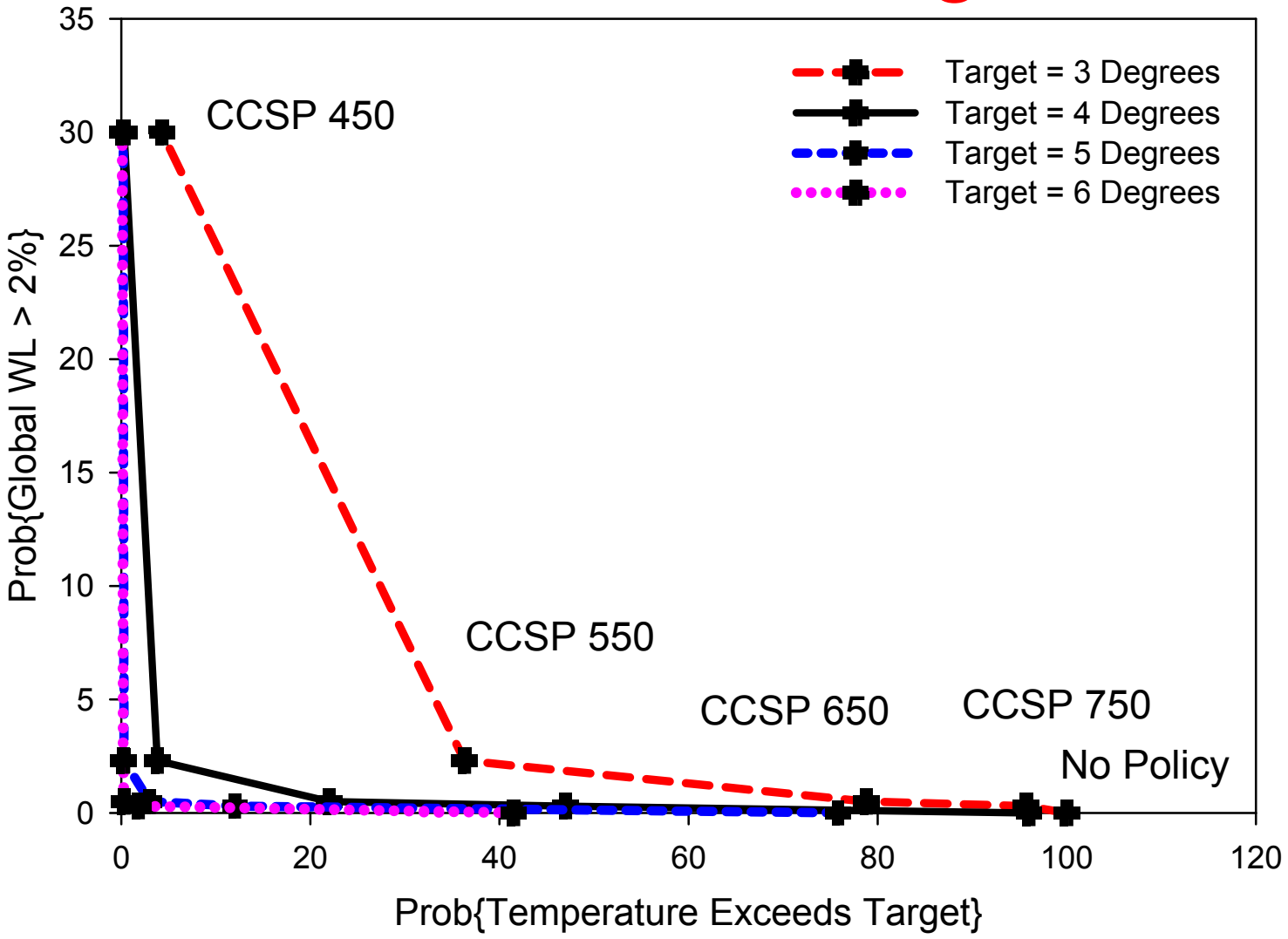
(400 forecasts with equally probable economics assumptions)

	ΔWL>1%	ΔWL>2%	ΔWL>3%
No Policy	-	-	-
Stabilize at 750	1 in 12	3 in 200	3 in 400
Stabilize at 650	1 in 3	1 in 20	3 in 400
Stabilize at 550	9 in 10	3 in 5	1 in 4
Stabilize at 450	98 in 100	96 in 100	85 in 100

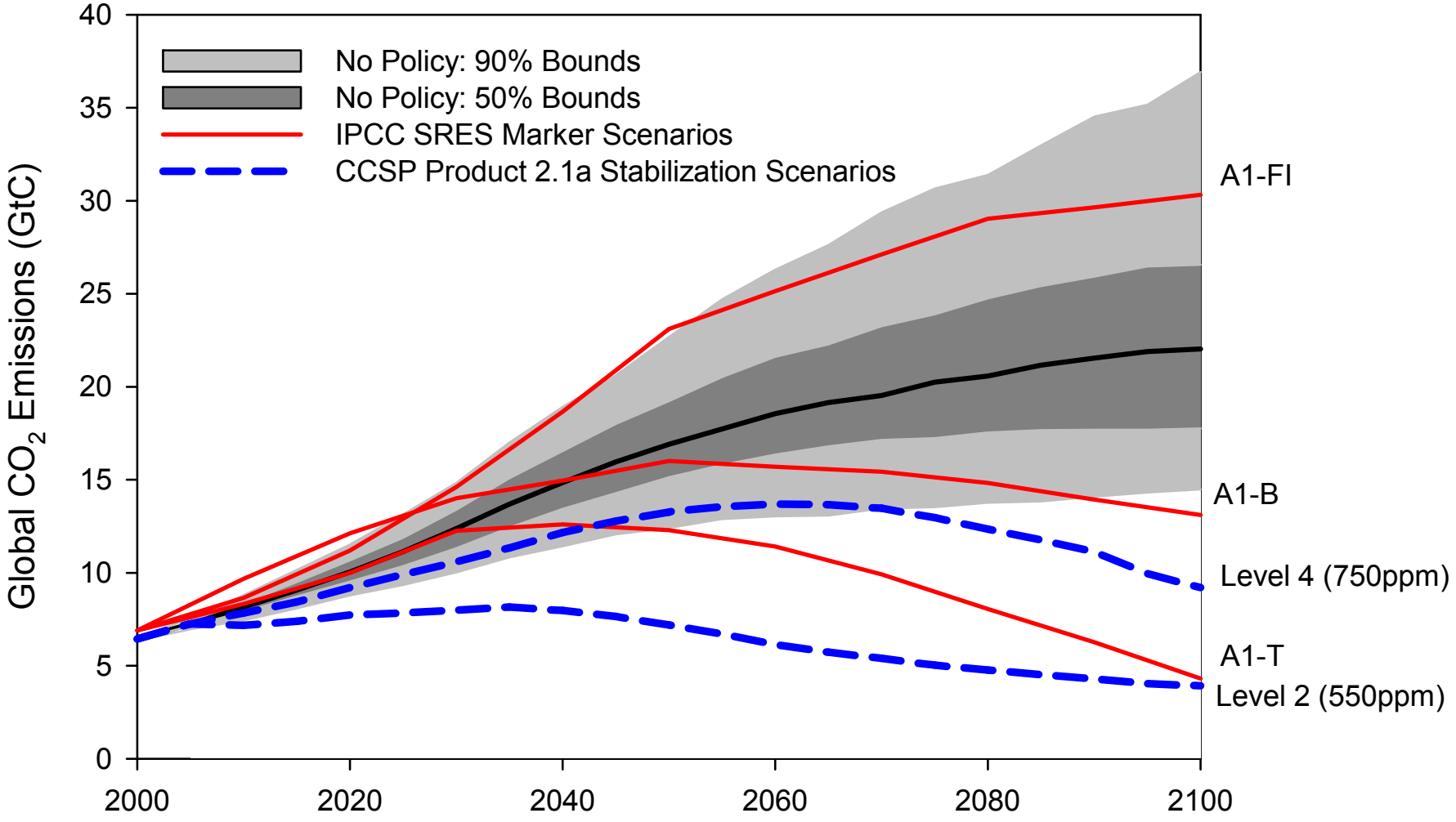
Tradeoffs in Choosing Stabilization Targets: Expected Values



Risk-Risk Tradeoffs in Choosing Stabilization Targets



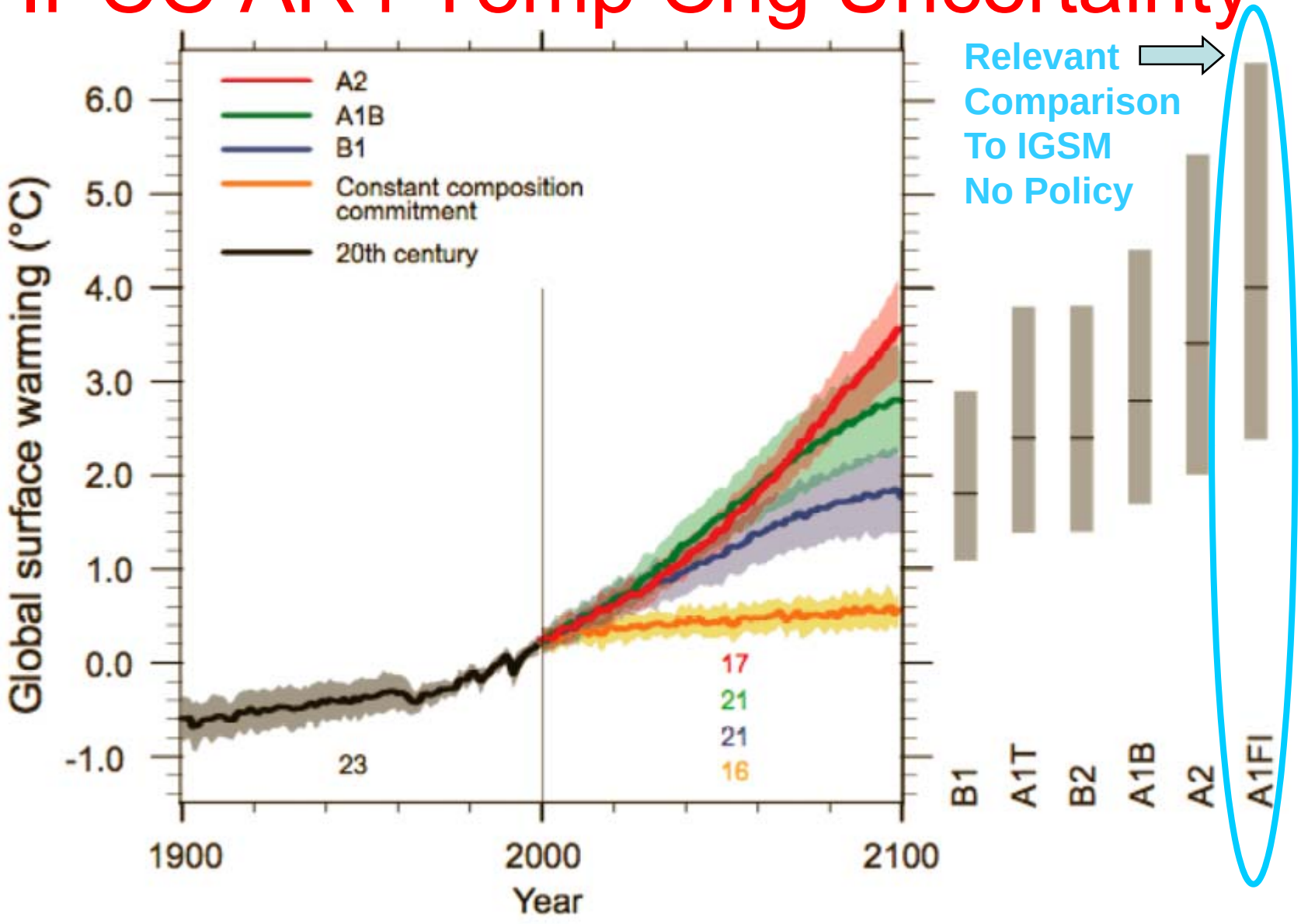
Uncertainty in CO_2 Emissions
(No Policy)



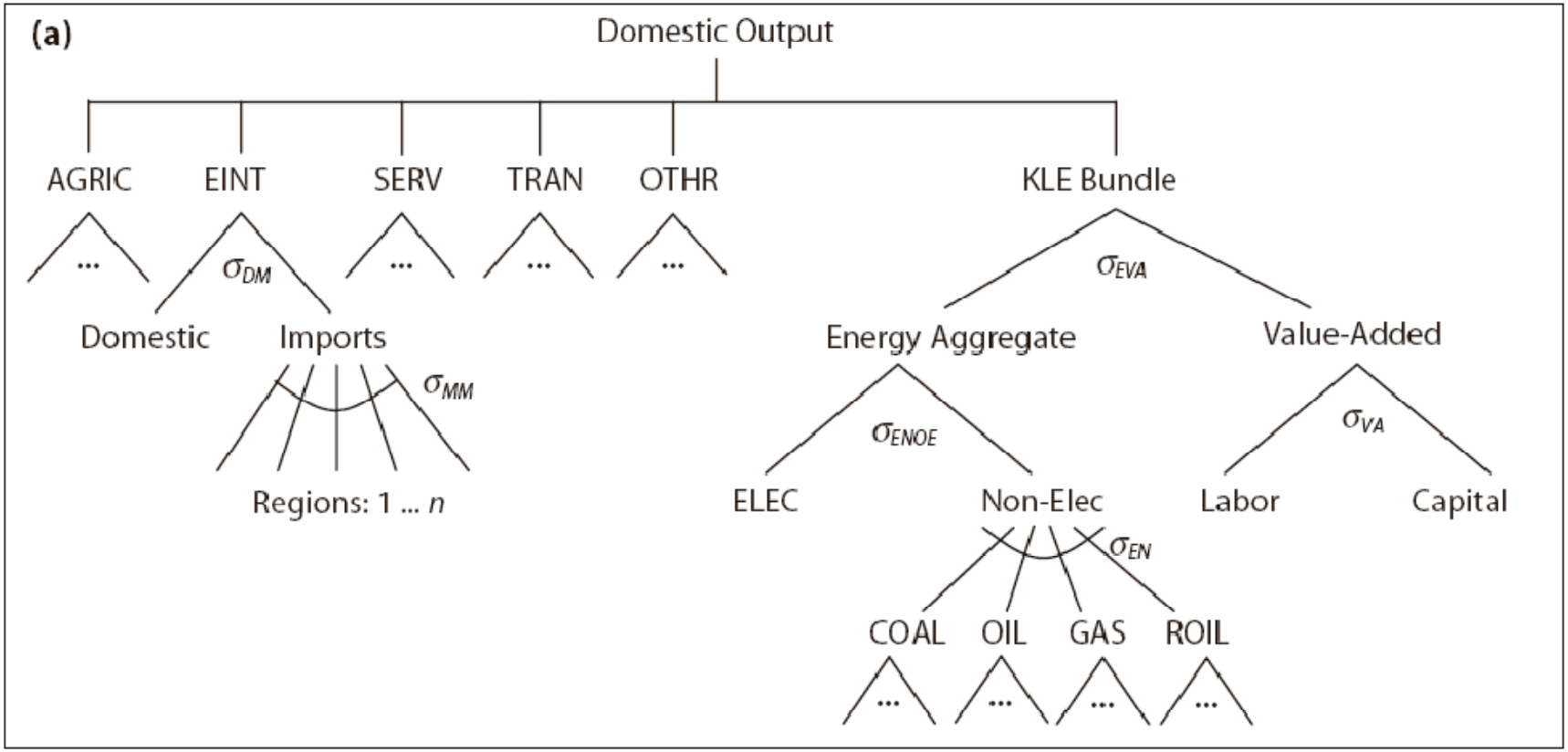
Why are the probabilities shifted to higher temperatures than in our previous calculations (Webster et al, 2003)?

- Radiative Forcing Increases?
  - Emissions (higher lower bound)
  - Reduced Ocean Carbon Uptake
  - Additional forcing such as Black Carbon & Tropospheric Ozone (additional forcing included but still calibrated by net aerosols in 1990s)
- Climate Model Response?
  - Climate Model Parameters show higher response
- Learning?
  - Distributions better defined
  - Distributions shifted higher

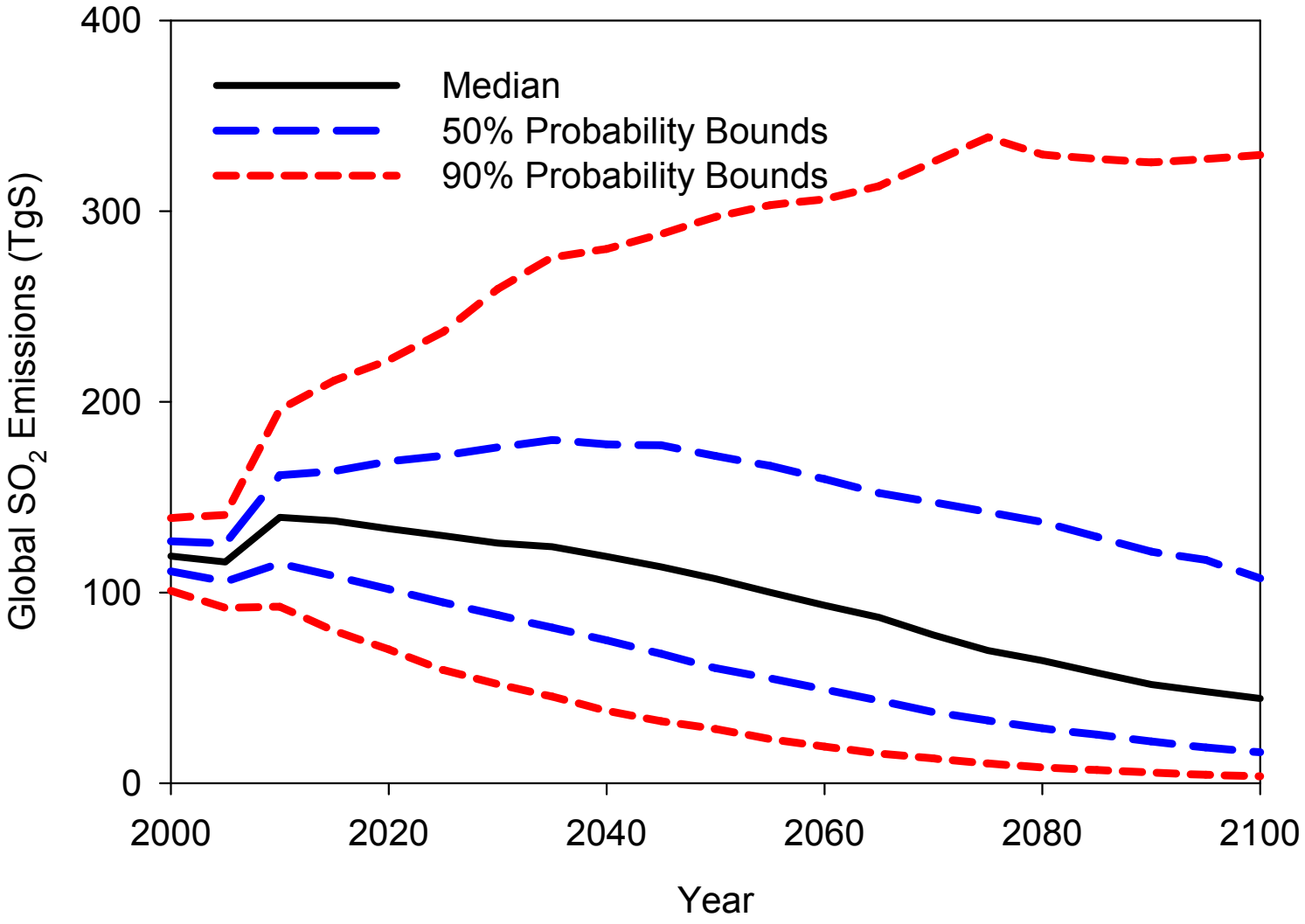
IPCC AR4 Temp Chg Uncertainty



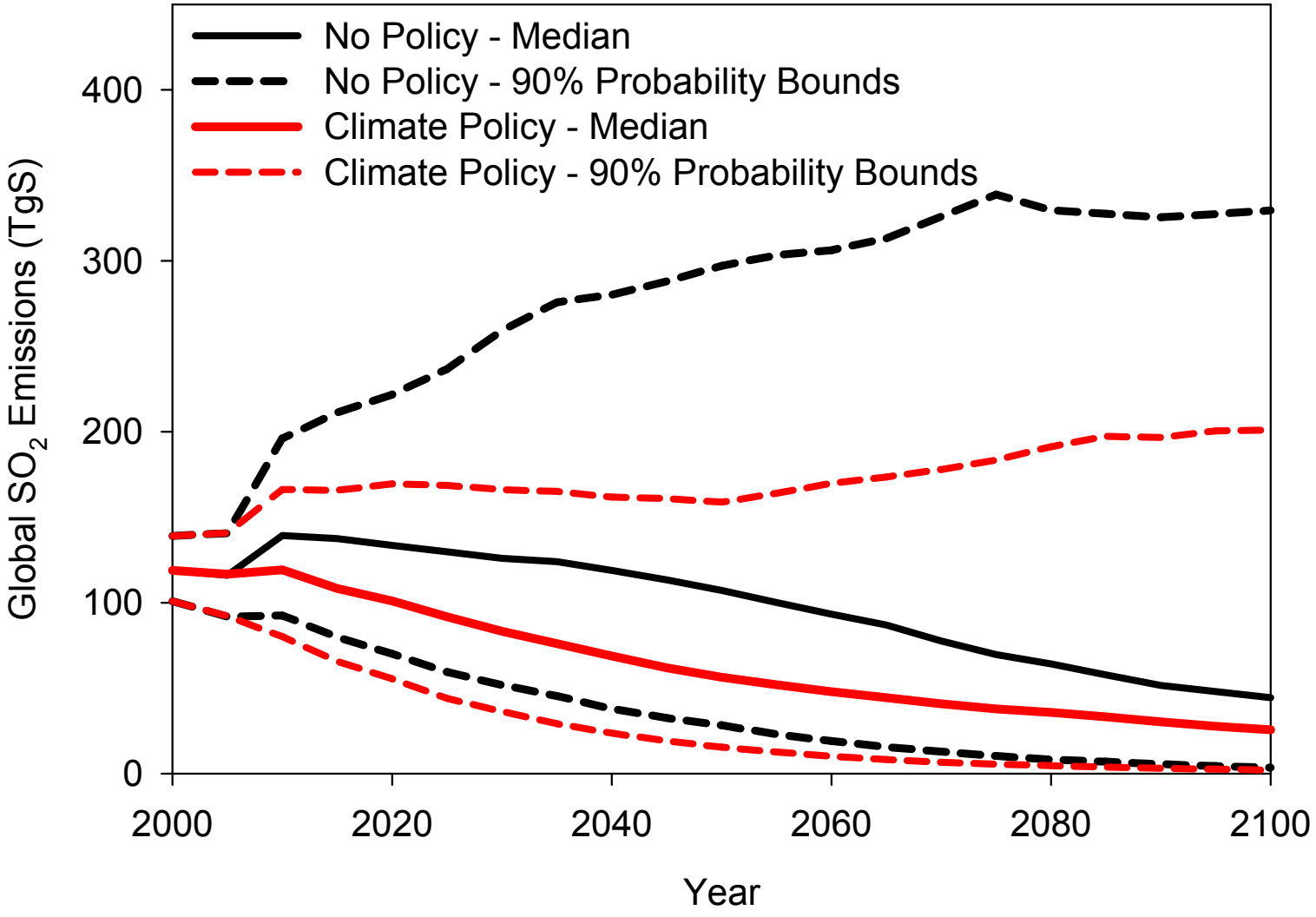
Typical Production Function in EPPA



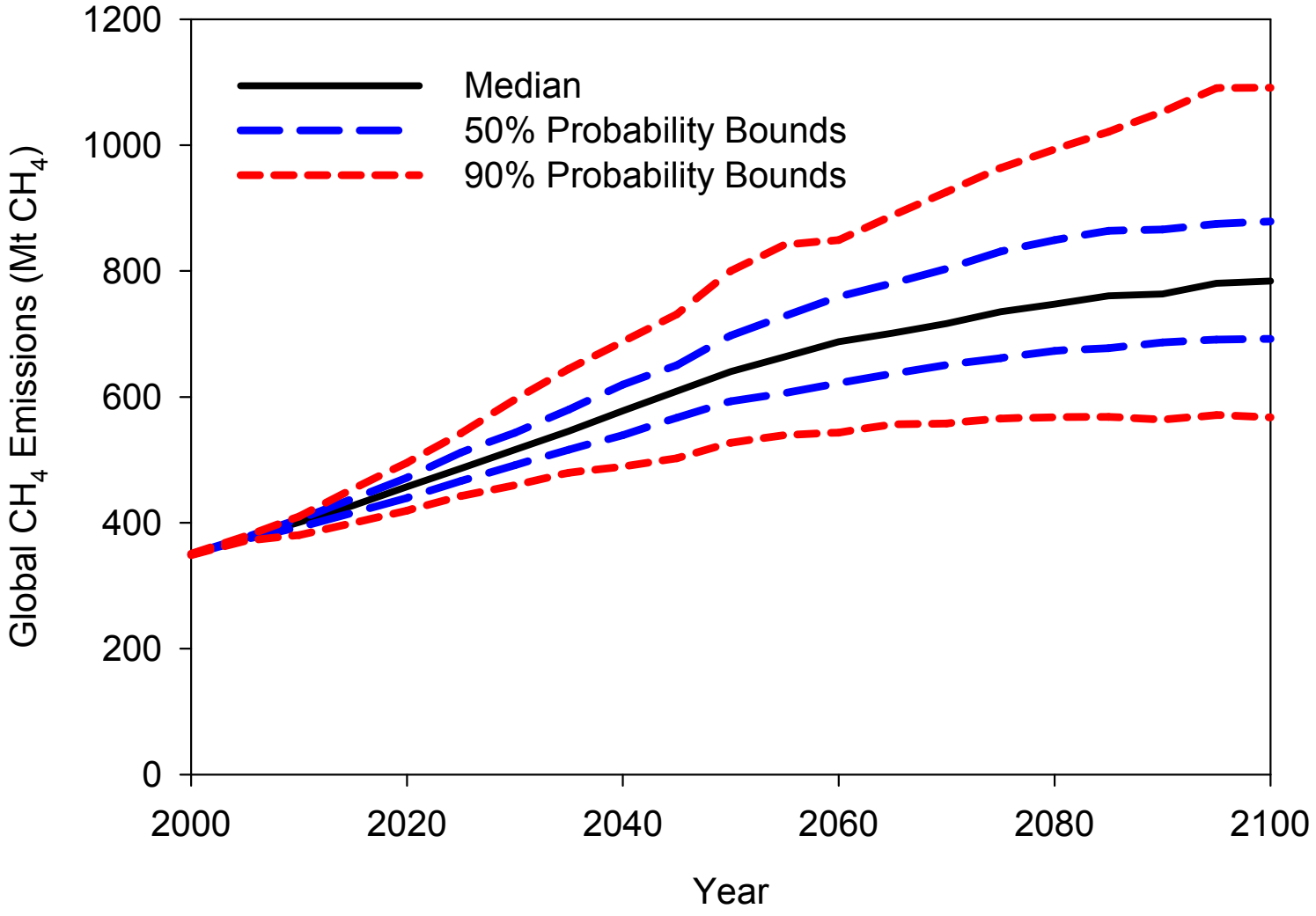
Uncertainty in SO_2 Emissions (No Policy)



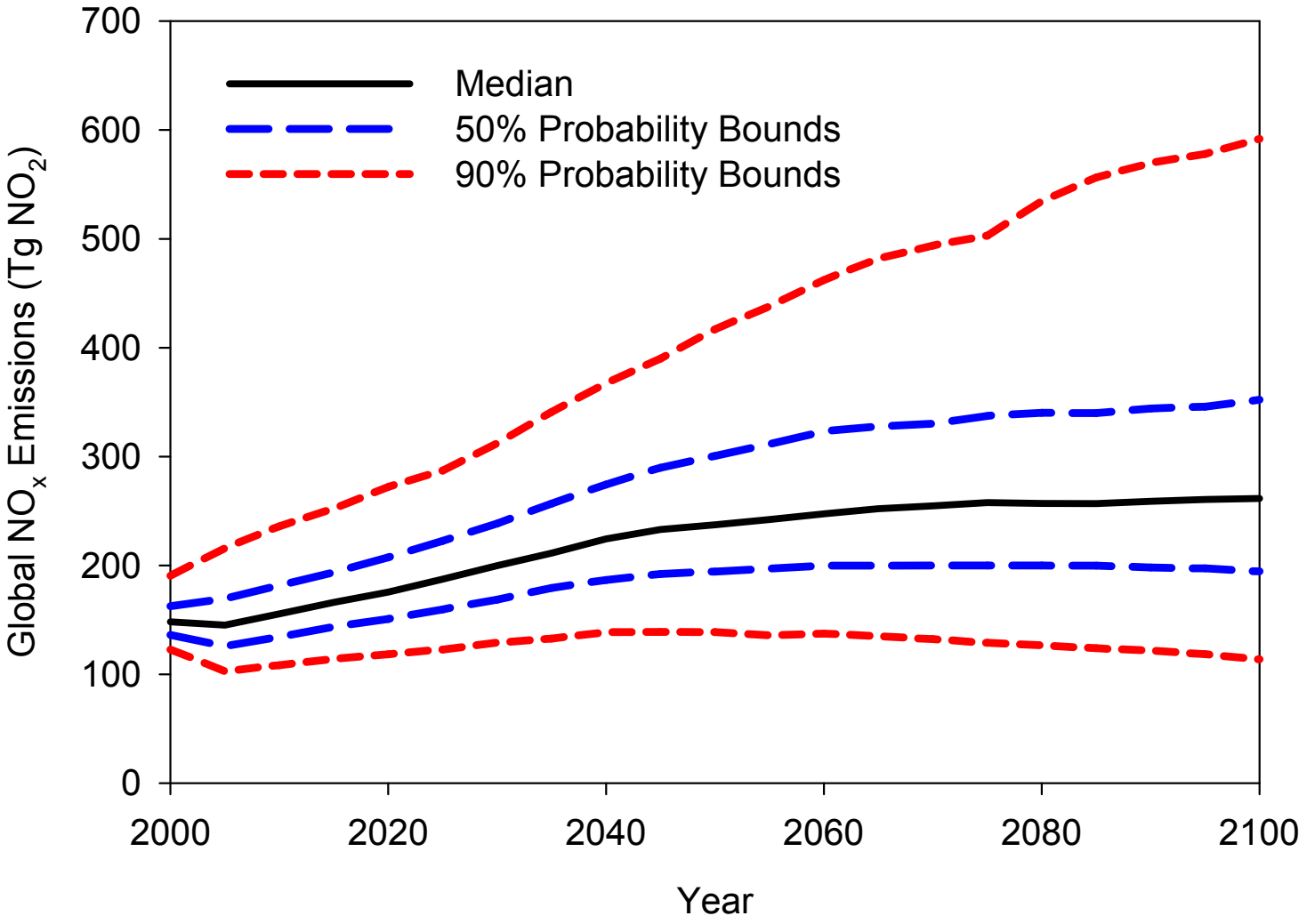
Uncertainty in SO_2 Emissions (No Policy vs. CCSP-550)



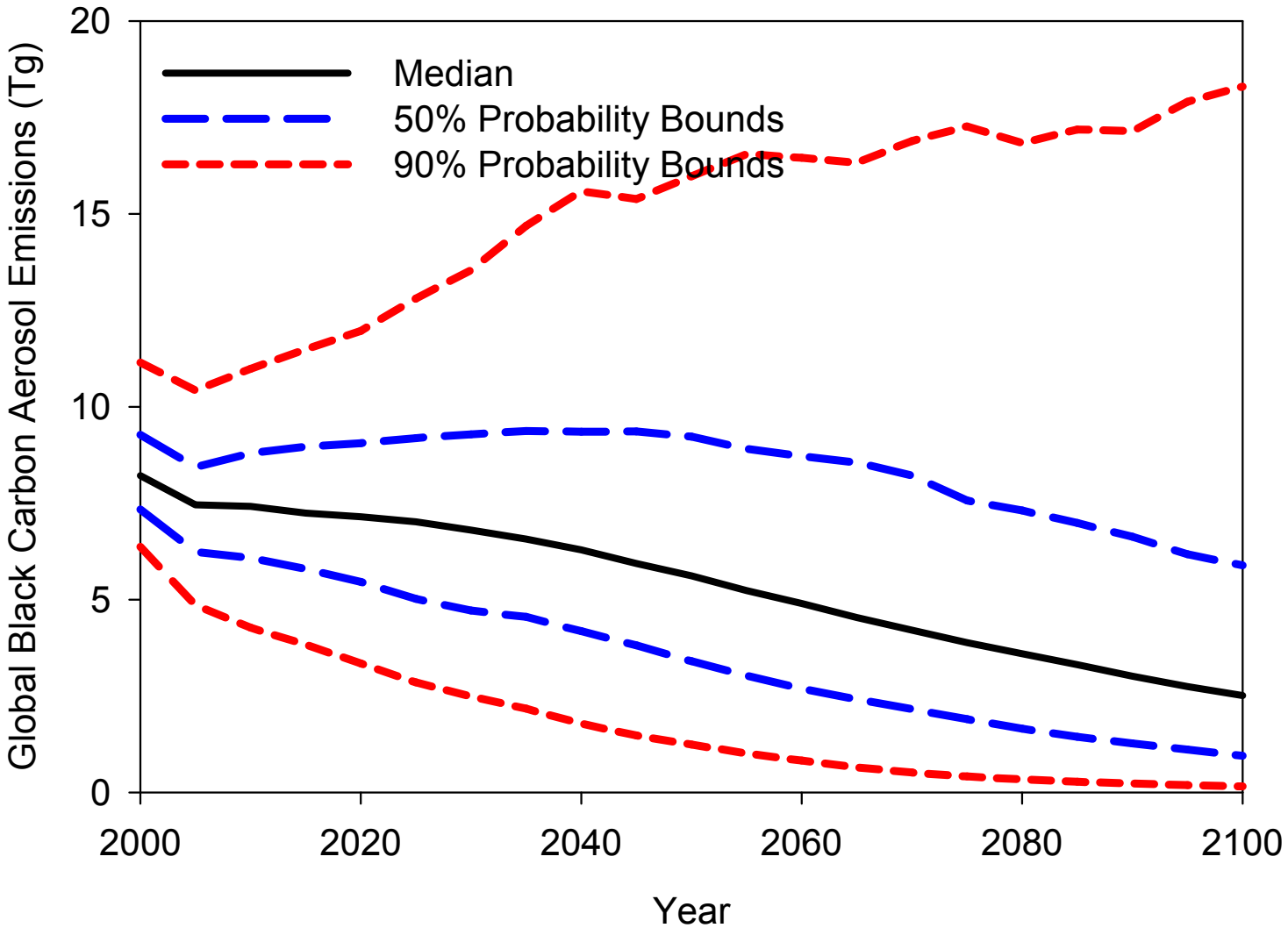
Uncertainty in Methane Emissions



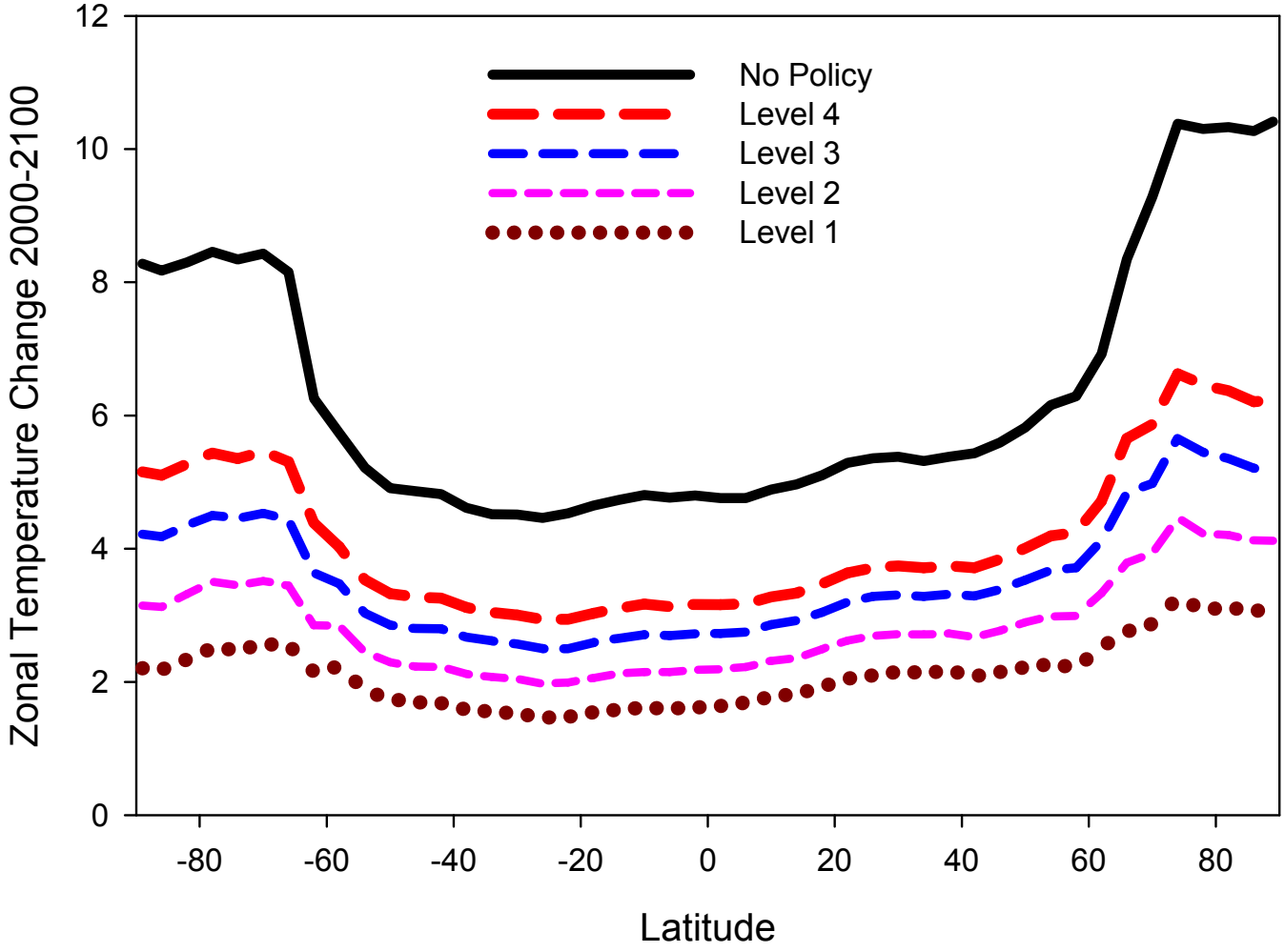
Uncertainty in NO_x Emissions



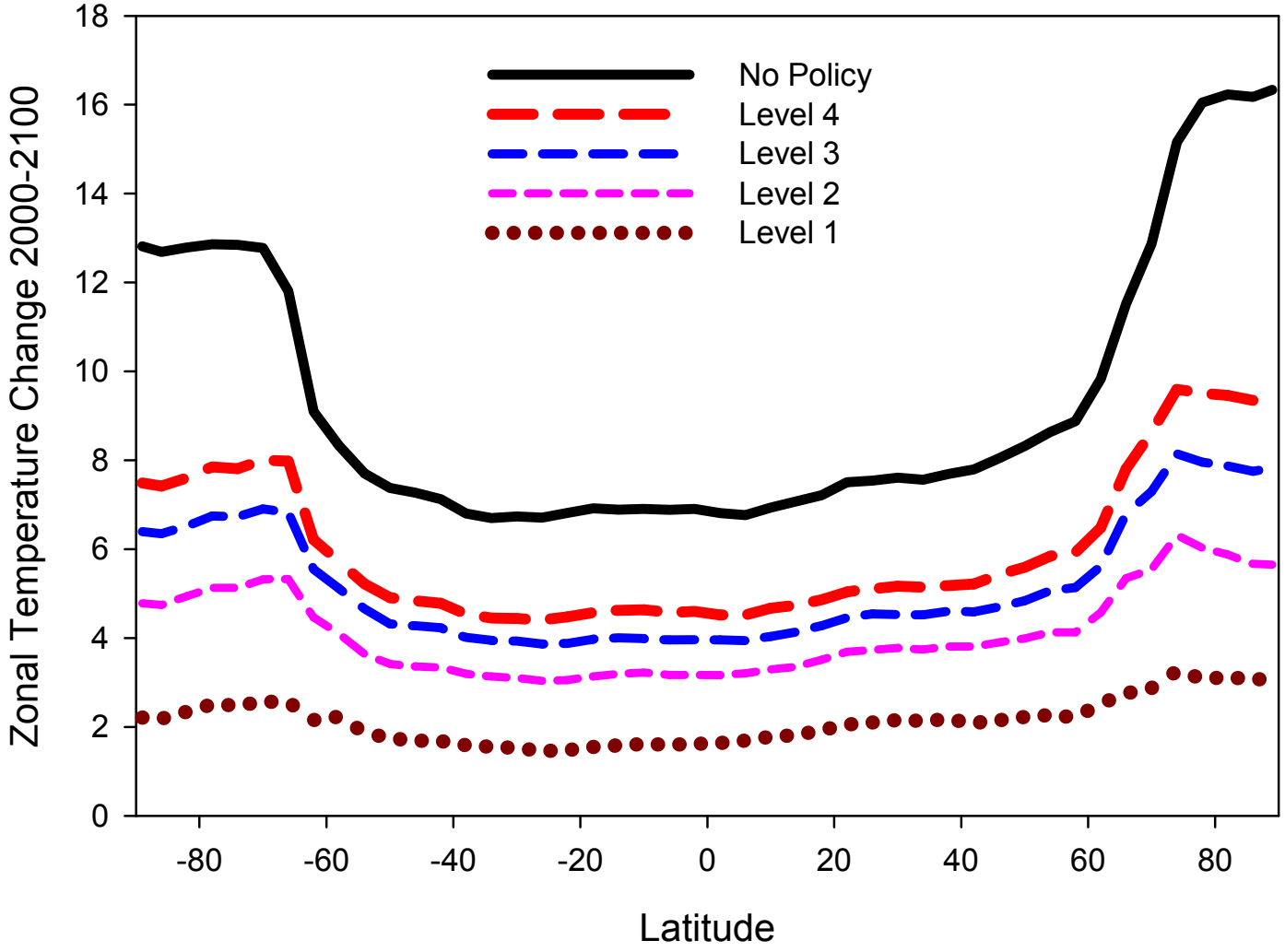
Uncertainty in BC Emissions



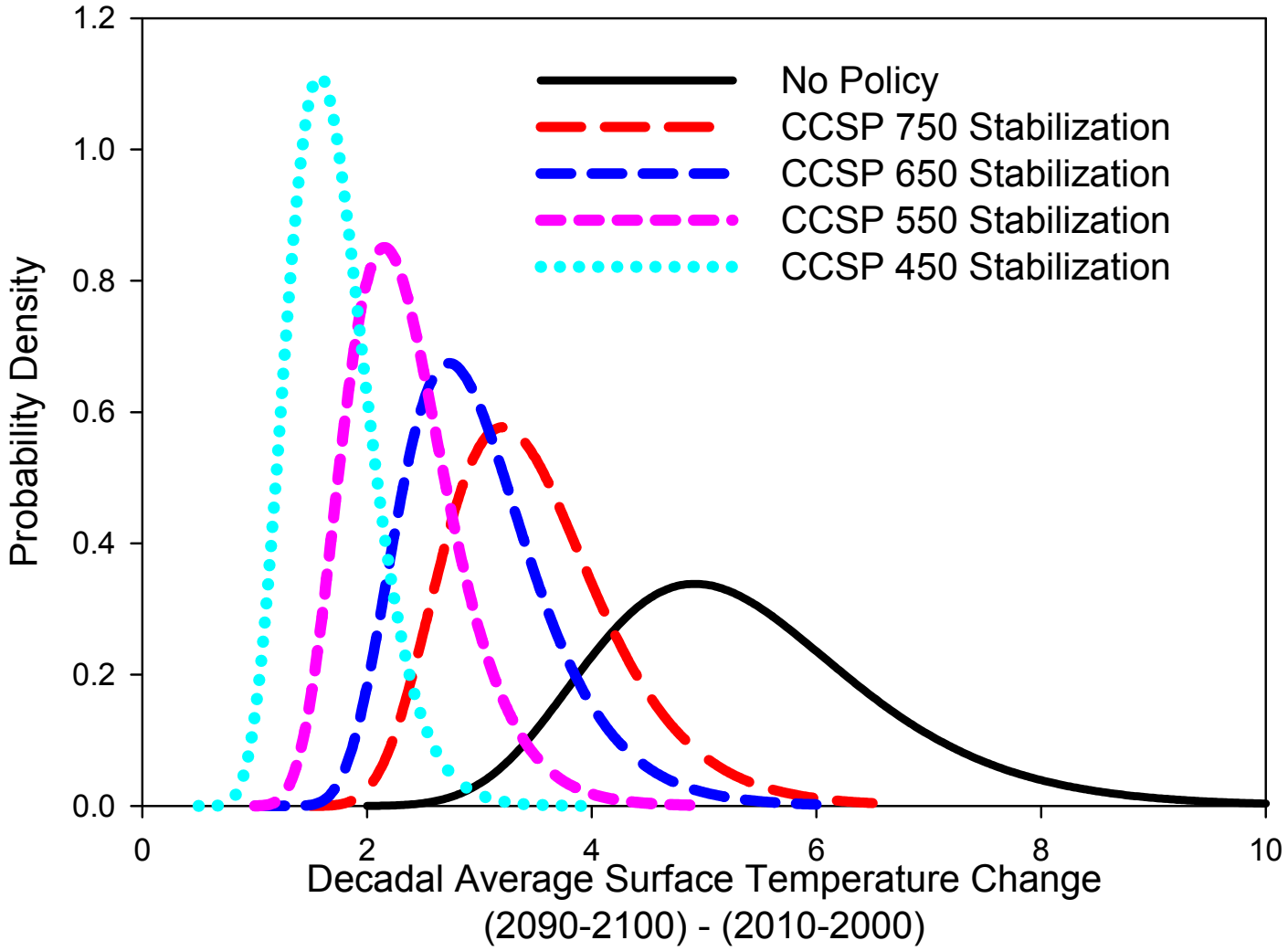
Zonal Temperature Change 2000-2100 (Median)



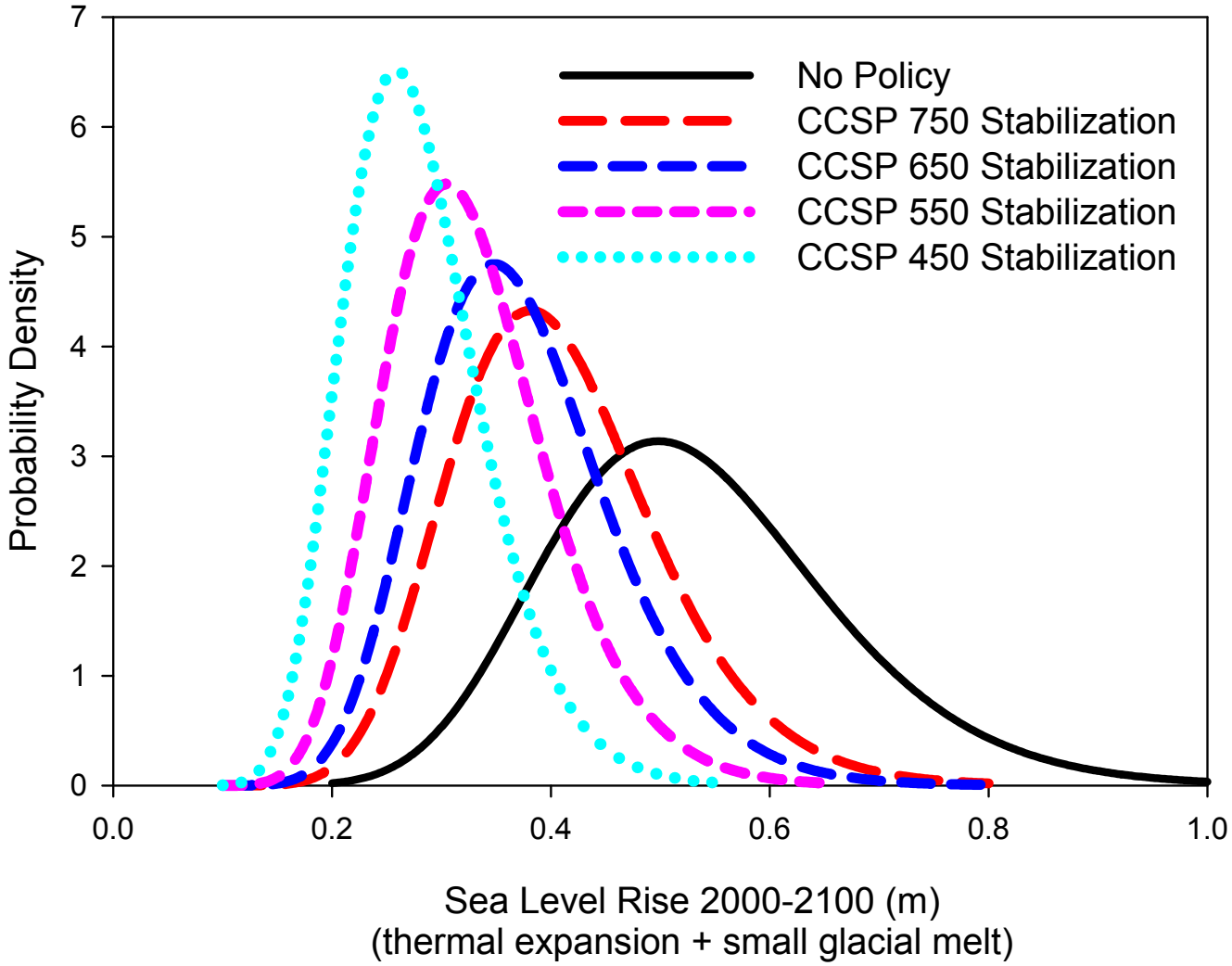
Zonal Temperature Change 2000-2100 (95th Percentile)



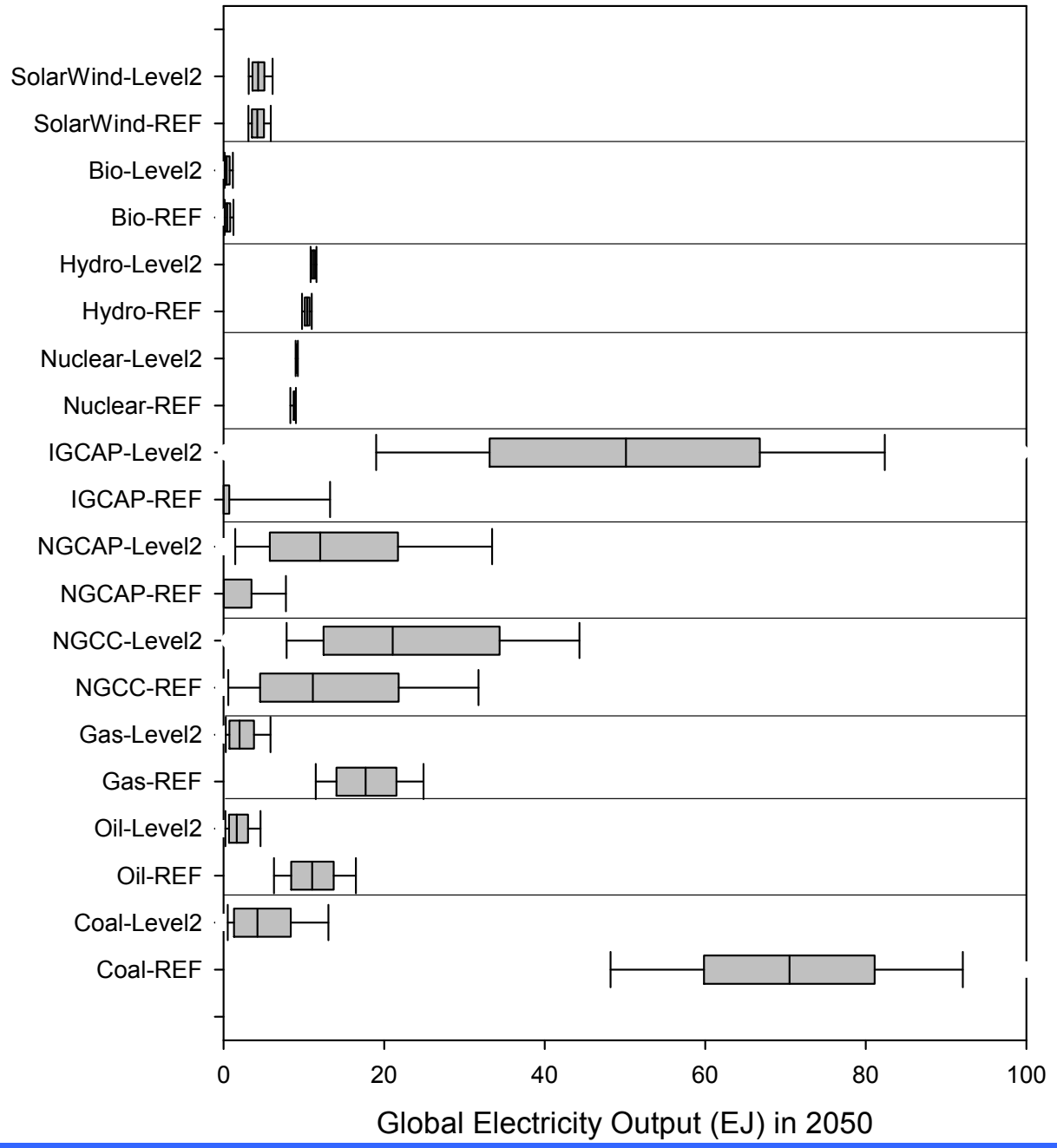
PDFs of Global Mean Temp. Chg.

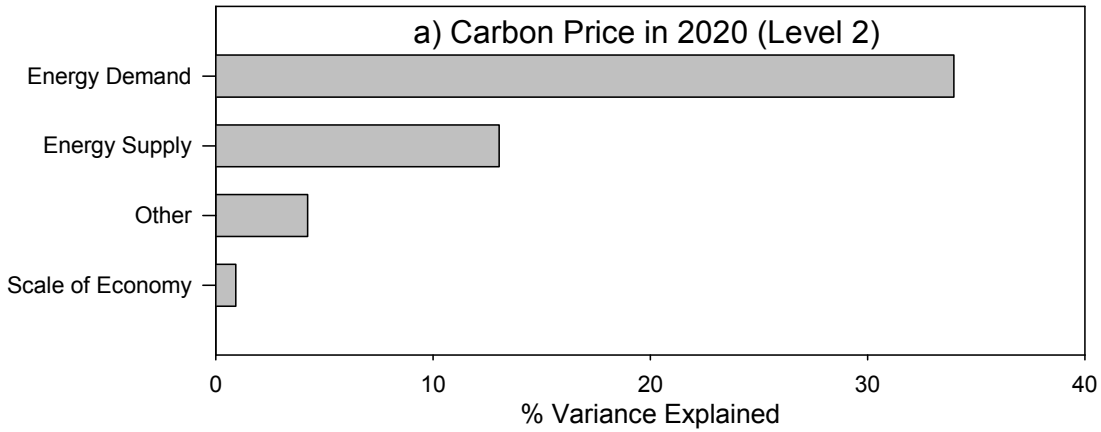


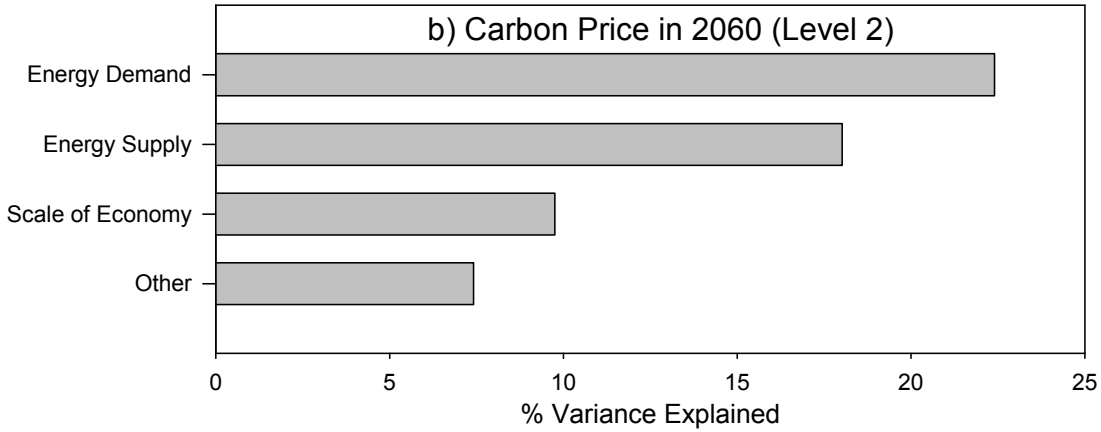
PDFs of Sea Level Rise
(Excluding Greenland and WAIS)

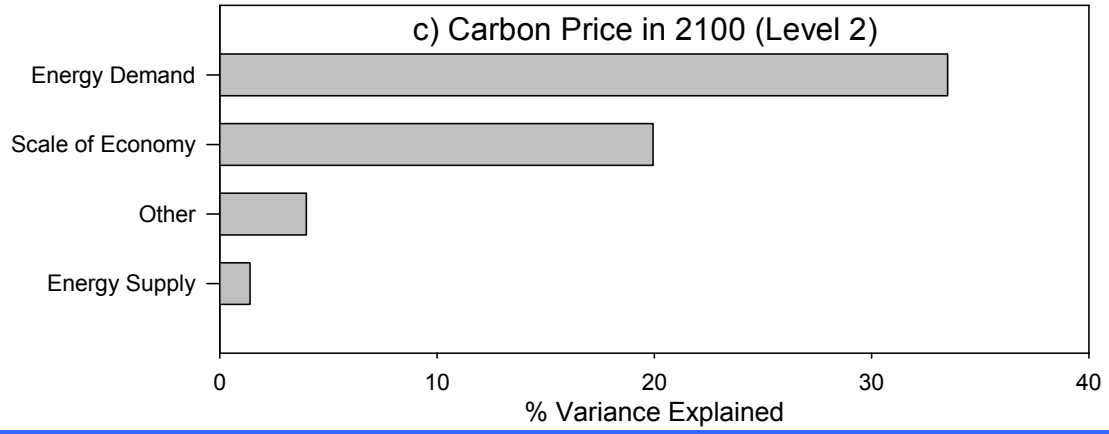


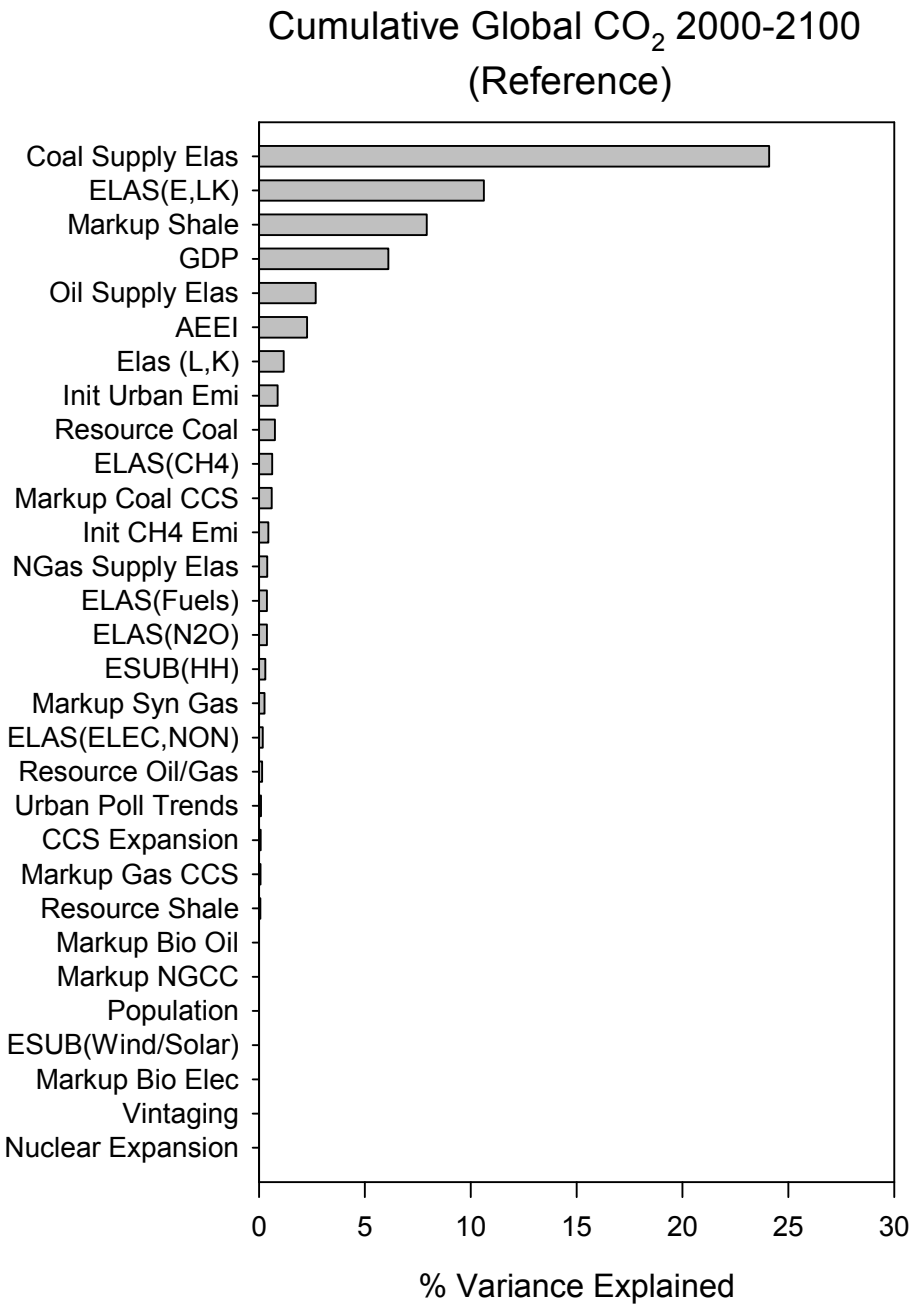
Global Electricity Consumption by Technology and Fuel

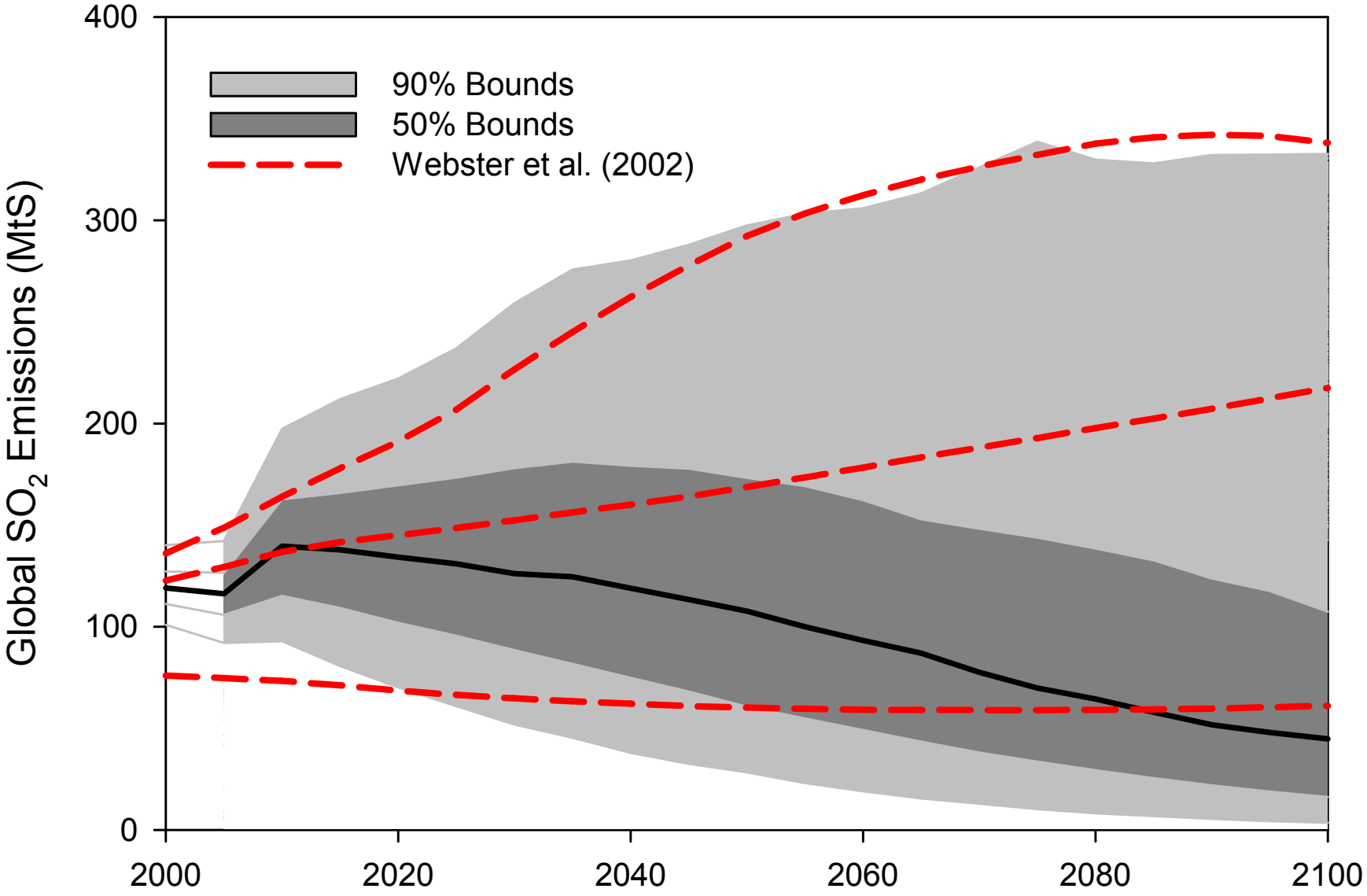



a) Carbon Price in 2020 (Level 2)
Energy Demand
Energy Supply
Other
Scale of Economy
0
10
20
30
40
% Variance Explained

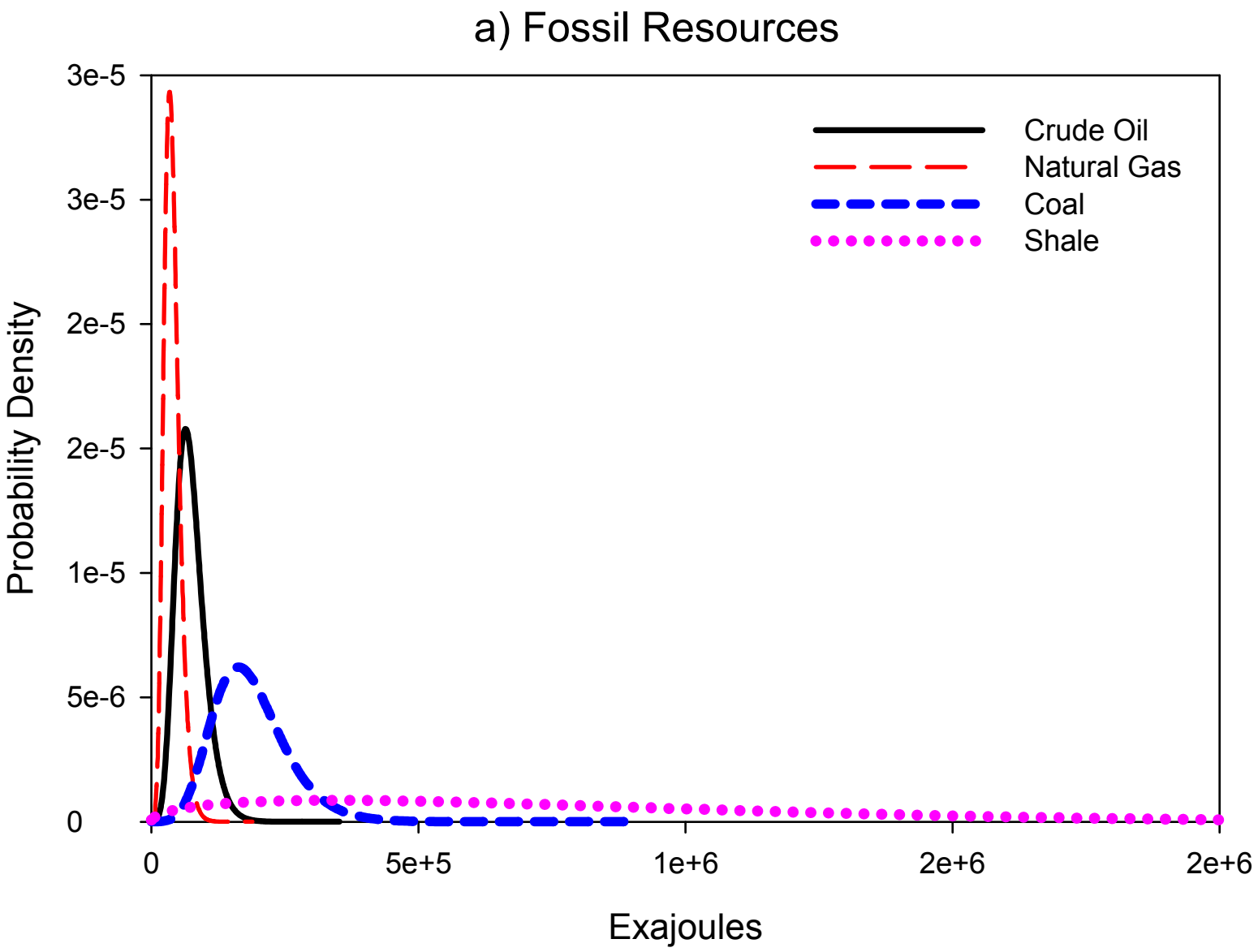

b) Carbon Price in 2060 (Level 2)
Energy Demand
Energy Supply
Scale of Economy
Other
0
5
10
15
20
25
% Variance Explained

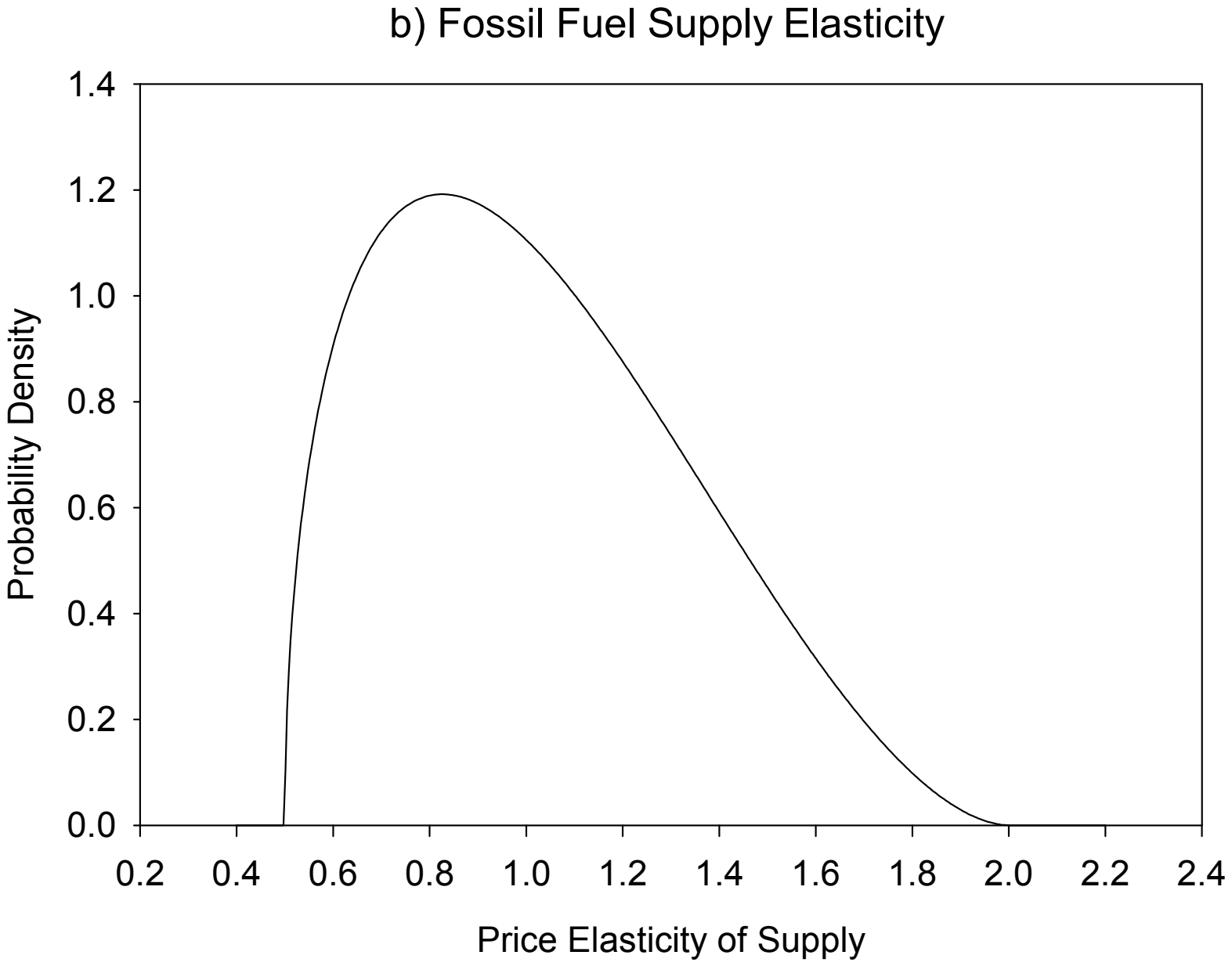

c) Carbon Price in 2100 (Level 2)
Energy Demand
Scale of Economy
Other
Energy Supply
0
10
20
30
40
% Variance Explained

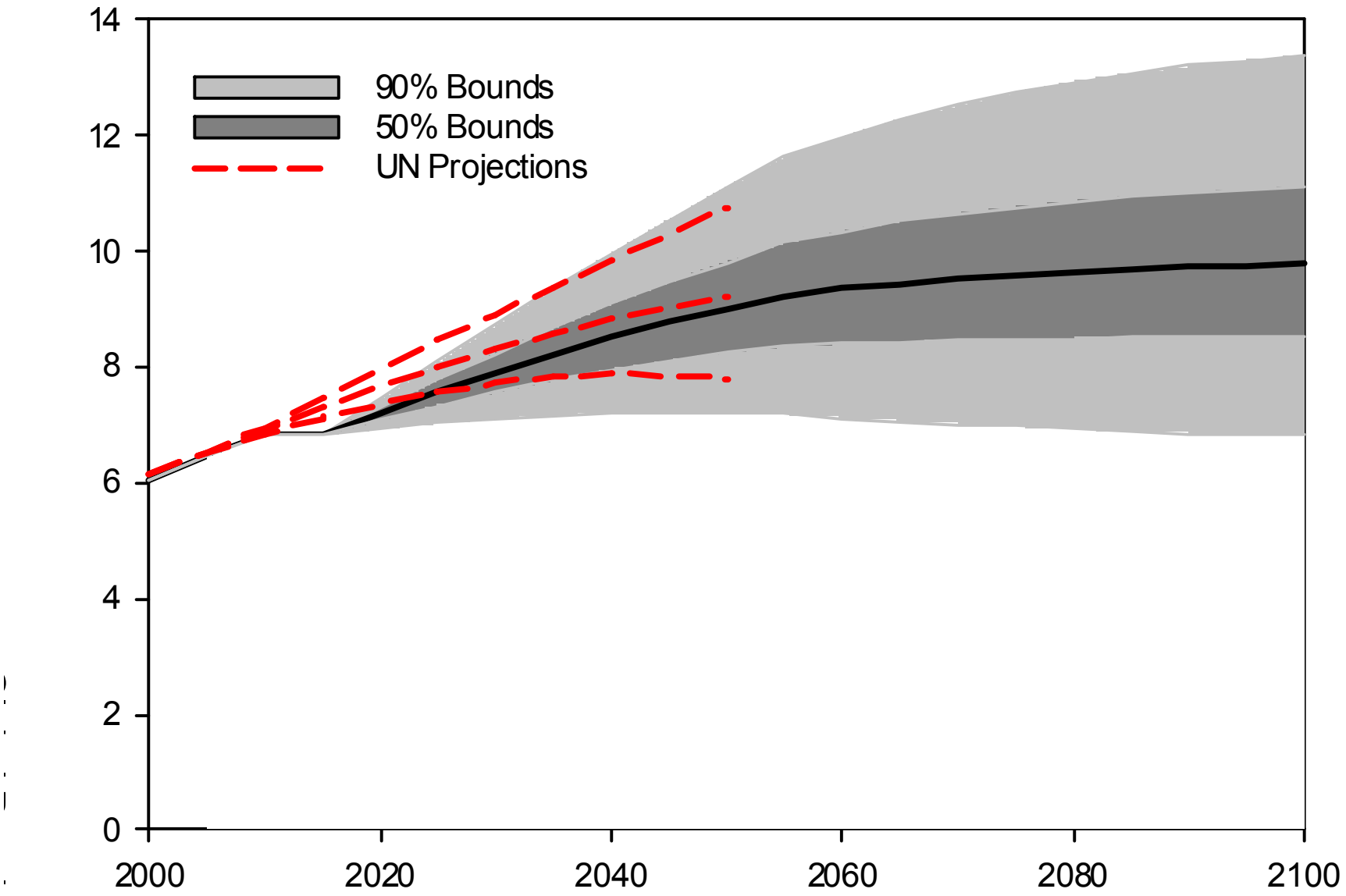

Cumulative Global CO_2 2000-2100
(Reference)
Coal Supply Elas
ELAS(E,LK)
Markup Shale
GDP
Oil Supply Elas
AEEI
Elas (L,K)
Init Urban Emi
Resource Coal
ELAS(CH4)
Markup Coal CCS
Init CH4 Emi
NGas Supply Elas
ELAS(Fuels)
ELAS(N2O)
ESUB(HH)
Markup Syn Gas
ELAS(ELEC,NON)
Resource Oil/Gas
Urban Poll Trends
CCS Expansion
Markup Gas CCS
Resource Shale
Markup Bio Oil
Markup NGCC
Population
ESUB(Wind/Solar)
Markup Bio Elec
Vintaging
Nuclear Expansion
0
5
10
15
20
25
30
% Variance Explained

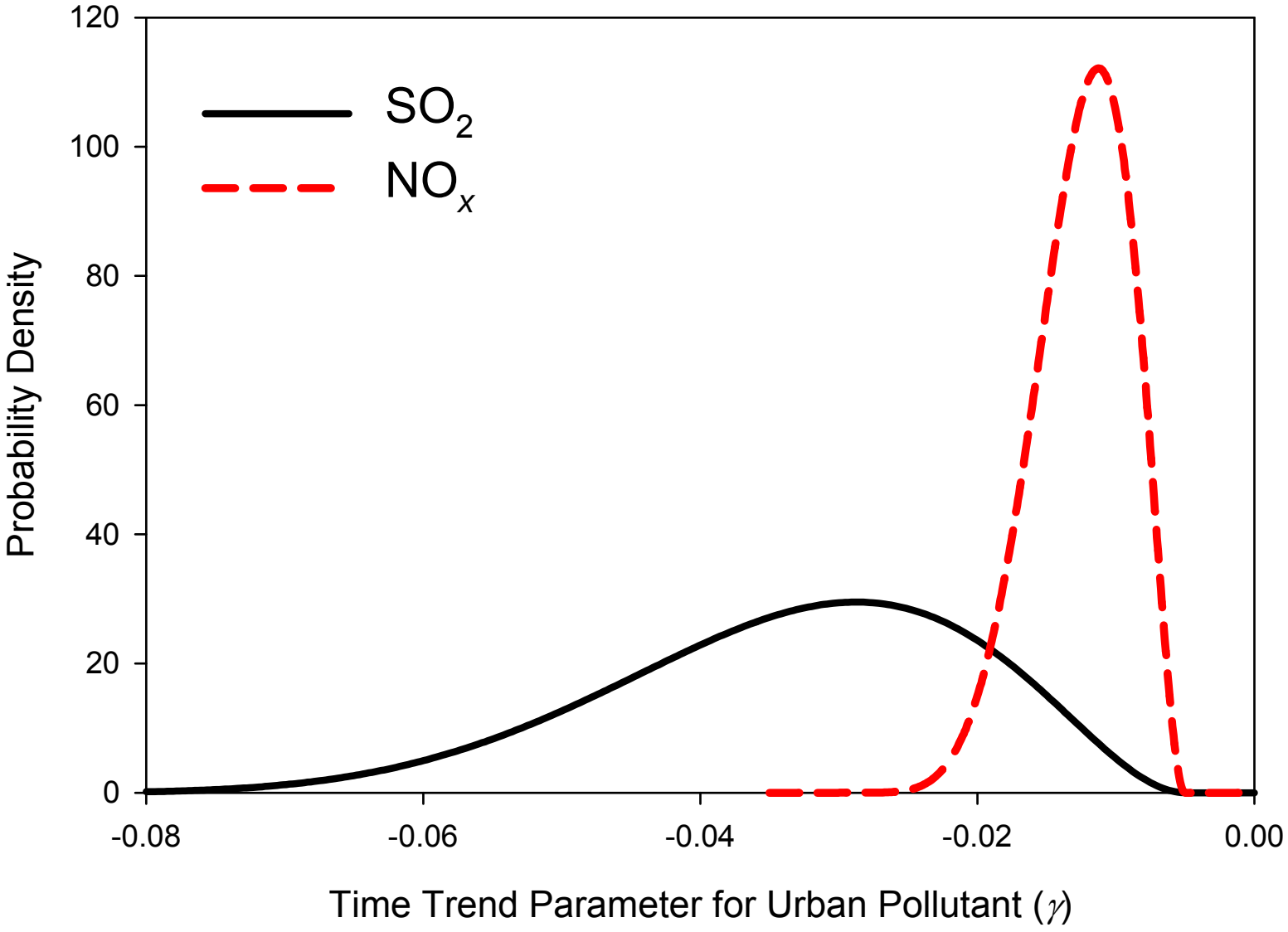

90% Bounds
50% Bounds
Webster et al. (2002)
Global SO_2 Emissions (MtS)
400
300
200
100
0
2000
2020
2040
2060
2080
2100

Region	Historical 1950-2000 (%)		Projected Annual Average Growth Rate (%) 2000-2100		
	Mean	*Std Dev*	*0.05*	*0.5*	*0.95*
USA	2.2	2.3%	1.7	2.1	2.5
CAN	2.3	2.3%	1.7	2.1	2.5
MEX	2.2	5.2%	1.2	2.1	2.9
JPN	4.9	3.5%	1.7	2.2	2.7
ANZ	2.0	1.8%	2.0	2.3	2.6
EUR	2.8	1.6%	1.9	2.1	2.4
EET	1.1	3.9%	2.1	2.8	3.3
FSU	1.1	5.3%	2.0	2.8	3.7
ASI	4.3	4.7%	1.8	2.6	3.3
CHN	4.3	3.7%	2.5	3.1	3.7
IND	2.3	2.7%	2.3	2.7	3.1
IDZ	2.7	5.0%	1.1	2.6	3.9
AFR	1.0	1.8%	2.0	2.3	2.6
MES	2.3	3.3%	1.5	2.1	2.6
LAM	1.7	2.0%	1.7	2.1	2.5
ROW	2.2	3.5%	1.7	2.3	2.8
GLOBAL			2.2	2.4	2.6


a) Fossil Resources
Probability Density
3e-5
3e-5
2e-5
2e-5
1e-5
5e-6
0
0
5e+5
1e+6
2e+6
2e+6
Exajoules
Crude Oil
Natural Gas
Coal
Shale


b) Fossil Fuel Supply Elasticity
Probability Density
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Price Elasticity of Supply

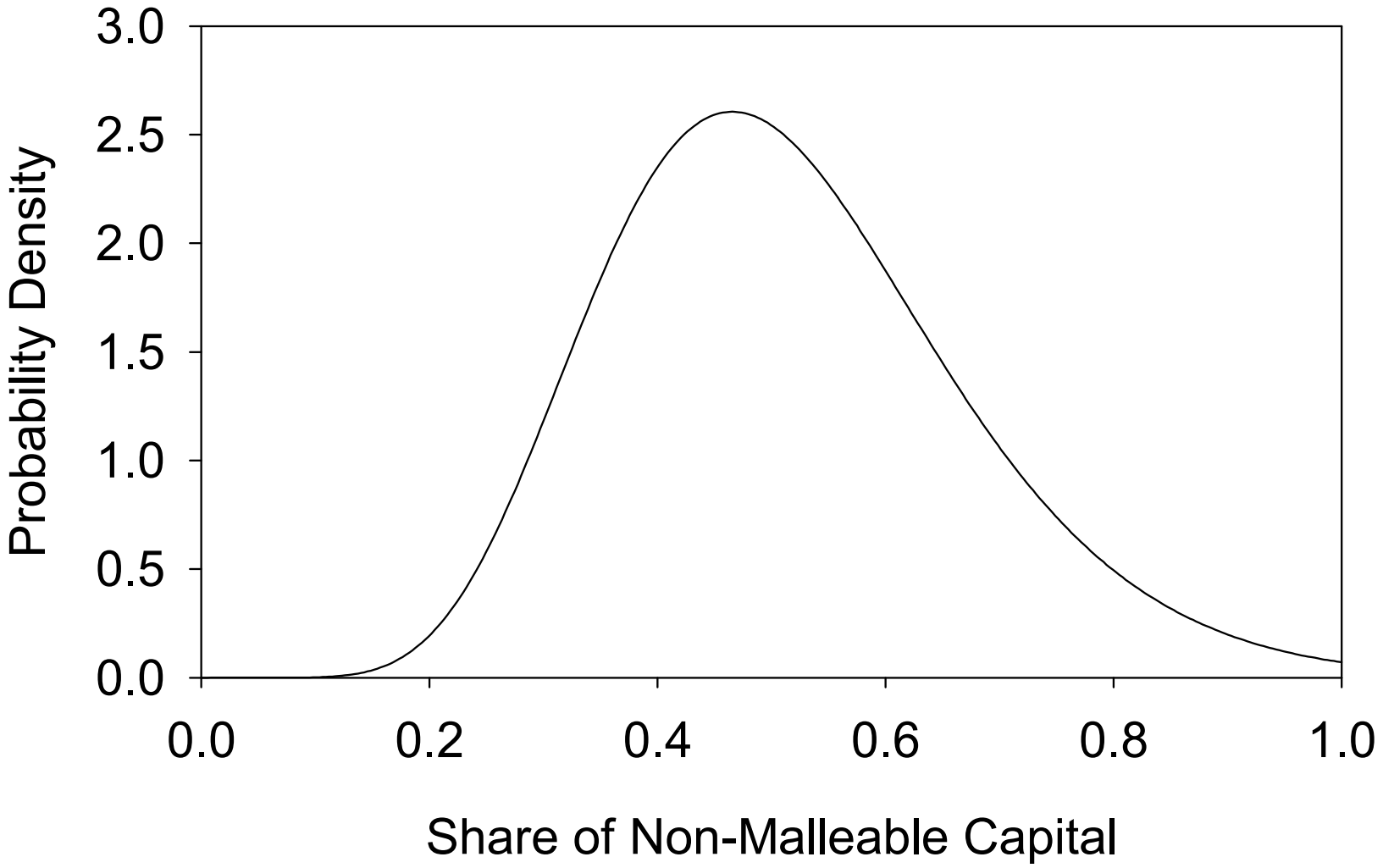

14
12
10
8
6
4
2
0
2000
2020
2040
2060
2080
2100
90% Bounds
50% Bounds
UN Projections


120
100
80
60
40
20
0
Probability Density
SO2
NOx
-0.08
-0.06
-0.04
-0.02
0.00
Time Trend Parameter for Urban Pollutant (γ)

	Fractile	Expert 1	Expert 2	Expert 3
Synthetic Oil Markup	***5%***	2.0	2.1	2.5
	50%	3.5	4.3	4.3
	95%	5.0	5.8	6.0
Coal Gasification Markup	***5%***	3.4	1.9	3.9
	50%	4.3	3.0	5.2
	95%	6.5	6.5	6.9

		Expert 4	Expert 5
Advanced Coal with Carbon Capture	***5%***	1.1	1.1
	50%	1.1	1.2
	95%	1.4	1.3
Natural Gas with Carbon Capture	***5%***	1.1	1.1
	50%	1.2	1.2
	95%	1.3	1.2
Natural Gas Combined Cycle	***5%***	0.8	0.9
	50%	0.9	0.9
	95%	1.0	1.0

Input Factor Markups	**Mean**	**Std. Dev.**
Shale Oil	3.20	0.77
Coal Gas	3.94	0.82
Advanced Coal with CCS	1.18	0.10
Advanced Gas with CCS	1.15	0.05
Advanced Gas without CCS	0.90	0.04
Bio-Oil	3.94	0.82
Bio-Electric	3.94	0.82
Elasticity of Substitution		
Wind and solar	0.25	0.20
Penetration Rates		
New Tech Penetration Rate	2.25	1.13


3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability Density
0.0
0.2
0.4
0.6
0.8
1.0
Share of Non-Malleable Capital

Parameter	Correlated Across (dimensions of matrix)	Correlation Coefficient
AEEI	Regions (16x16)	0.9
Elasticity of Substitution (L,K)	Sectors (8x8)	0.8
Methane Elasticities (cost)	Regions (16x16)	0.8
N_2O Elasticities (cost)	OECD, LCD, FSU, EET (4x4)	0.8
Fossil Resources	Oil, Natural Gas (2x2)	0.9
Urban Pollutant time Trends	Urban Pollutants (7x7)	0.9

Carbon Price Under Level 1 (450ppm)