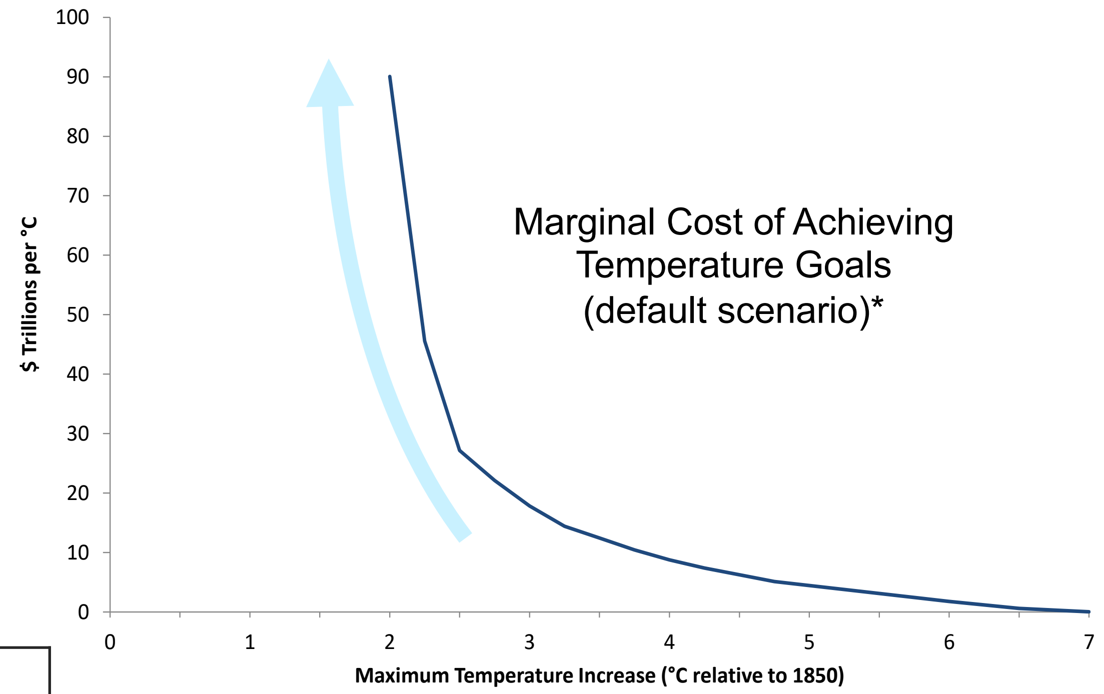
Trade-Offs in Managing Global Climate Damages

Steven Rose
Energy and Environmental Analysis Research Group

Rapid System Transitions Towards Low GHG Futures Workshop, Snowmass, CO
July 23, 2019

Given What We Know about the Cost of Containing Temperature...

- The cost of containing temperature rises rapidly with greater ambition
- Pragmatic to consider the value and trade-offs (and inform beyond extreme costs, implied infinite benefits, and model infeasibilities)
- While uncertainties make this a difficult question to resolve, it is a question society cannot ignore



Source: Blanford et al. (2014)

Regional Costs for Increasingly Ambitious Emissions Reduction Goals
(Reductions in Discounted Average Per Capita Consumption through 2100)

	US	EU	Other G20	China	India	Other Countries	Max ˚C
S1							6.9 (3.8-9.6)
S2	0.2%	0.3%	0.3%	1.4%	0.1%	-0.2%	6.0 (3.4-8.3)
S3	0.3%	0.4%	0.6%	2.3%	0.0%	-0.5%	5.4 (3.0-7.4)
S4	0.5%	0.7%	1.1%	4.8%	-0.1%	-0.7%	5.0 (2.8-7.0)
S5	0.5%	0.7%	1.0%	4.8%	0.8%	-0.6%	3.8 (2.2-5.3)
S6	0.5%	0.7%	1.0%	4.9%	2.0%	0.2%	2.7 (1.6-3.8)
S7	0.5%	0.8%	1.0%	5.1%	4.3%	2.1%	2.3 (1.4-3.1)
S8	2.1%	2.2%	5.2%	12.3%	14.1%	6.5%	2.0 (1.3-2.6)

Regional costs increase at an increasing rate

Source: Rose et al (2017b)

Modeling Approach

- **Application of EPRI's MERGE model**
  - Global intertemporally optimizing coupled energy-economic and climate model with detailed energy technologies
  - Extended to consider characterizations of potential global climate damages and a range of uncertainties as alternative sets of assumptions
- **Consider sets of assumptions for fundamental uncertainties** across the causal chain from projected socioeconomics to climate to damages
- **Compute an "optimal" emissions path for each assumption set**
  - In each case, endogenously balance marginal mitigation costs and avoided climate damages, producing an "economically optimal" or "economically efficient" emissions path for each set of assumptions
- **Intentionally not probabilistic**
  - Because of the many uncertainties, difficulties with identifying probability distributions, uncertainty about the resolution of uncertainty, and optimization computational challenges
  - Instead, characterizing the trade-off decision space, the role of uncertainties (and combinations), and raising questions about the state-of-knowledge and probabilities

Evaluating Uncertainties

Example of a set of assumptions

Socioeconomic future	Mitigation technologies available	Climate system dynamics	Global climate damages*
Model default	All default options	Equilibrium Climate Sensitivity (ECS) = 3.0˚C	USG-DICE central perspective
Pessimistic economic growth	CCS unavailable (fossil & biomass energy)	ECS = 1.5˚C	USG-FUND central perspective
Low energy intensity of economic growth	Pessimistic (CCS & new nuclear unavailable, renewables slower cost improvements)	ECS = 4.5˚C	USG-PAGE central perspective
		ECS = 6.0˚C	USG-FUND extreme risk

Evaluating every combination of assumptions.

Types of uncertainties and specifications based on the scientific literature

** Based on damage component assessment results from Rose et al (2017) of the US Government versions of DICE, FUND, and PAGE*

Evaluating Uncertainties

Another set of assumptions

Socioeconomic future	Mitigation technologies available	Climate system dynamics	Global climate damages*
Model default	All default options	Equilibrium Climate Sensitivity (ECS) = 3.0˚C	USG-DICE central perspective
Pessimistic economic growth	CCS unavailable (fossil & biomass energy)	ECS = 1.5˚C	USG-FUND central perspective
Low energy intensity of economic growth	Pessimistic (CCS & new nuclear unavailable, renewables slower cost improvements)	ECS = 4.5˚C	USG-PAGE central perspective
		ECS = 6.0˚C	USG-FUND extreme risk

Evaluating every combination of assumptions.

Types of uncertainties and specifications based on the scientific literature

** Based on damage component assessment results from Rose et al (2017) of the US Government versions of DICE, FUND, and PAGE*

Evaluating Uncertainties

Another set of assumptions

Socioeconomic future	Mitigation technologies available	Climate system dynamics	Global climate damages*
Model default	All default options	Equilibrium Climate Sensitivity (ECS) = 3.0˚C	USG-DICE central perspective
Pessimistic economic growth	CCS unavailable (fossil & biomass energy)	ECS = 1.5˚C	USG-FUND central perspective
Low energy intensity of economic growth	Pessimistic (CCS & new nuclear unavailable, renewables slower cost improvements)	ECS = 4.5˚C	USG-PAGE central perspective
		ECS = 6.0˚C	USG-FUND extreme risk

Evaluating every combination of assumptions.

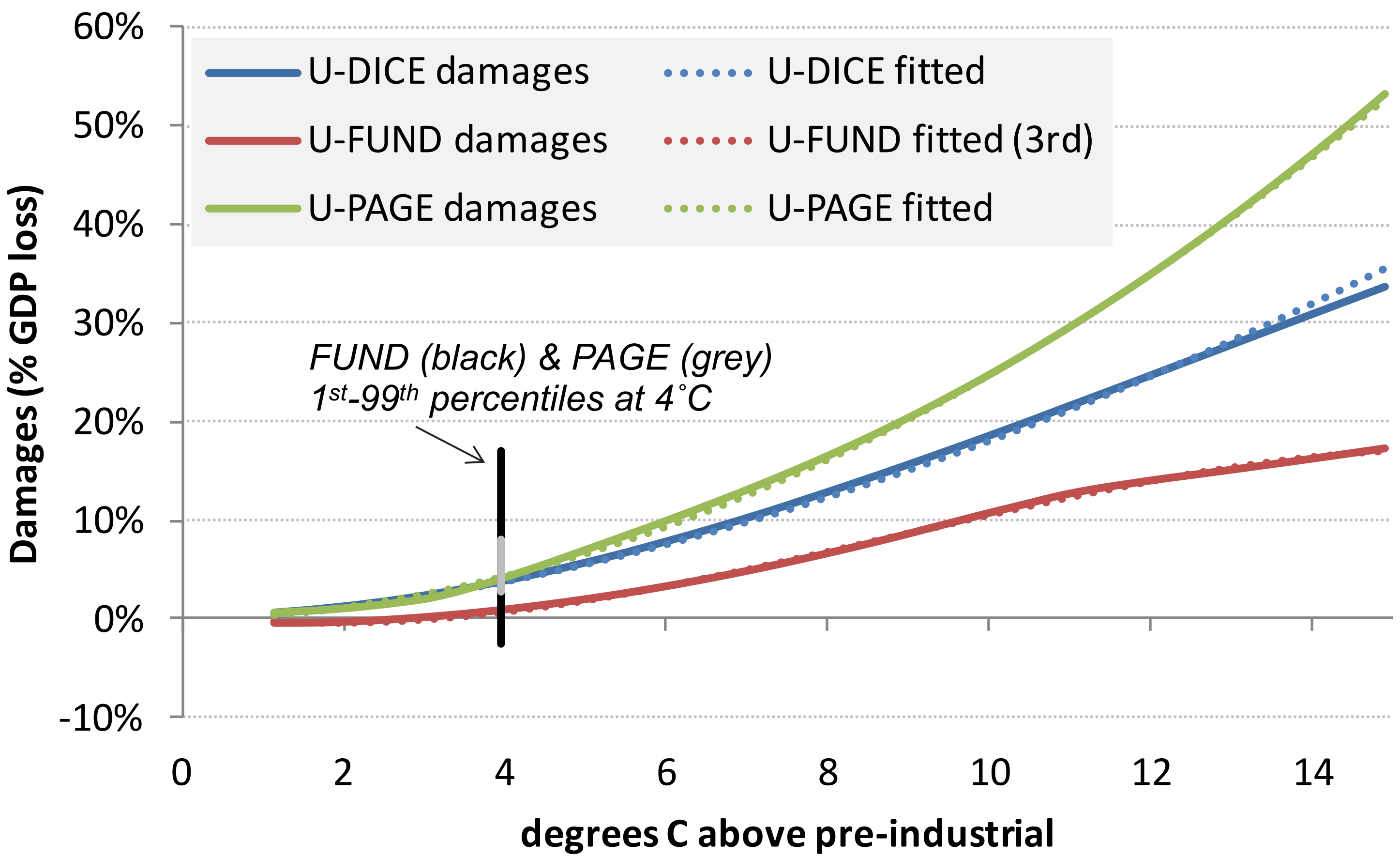
Types of uncertainties and specifications based on the scientific literature

** Based on damage component assessment results from Rose et al (2017) of the US Government versions of DICE, FUND, and PAGE*

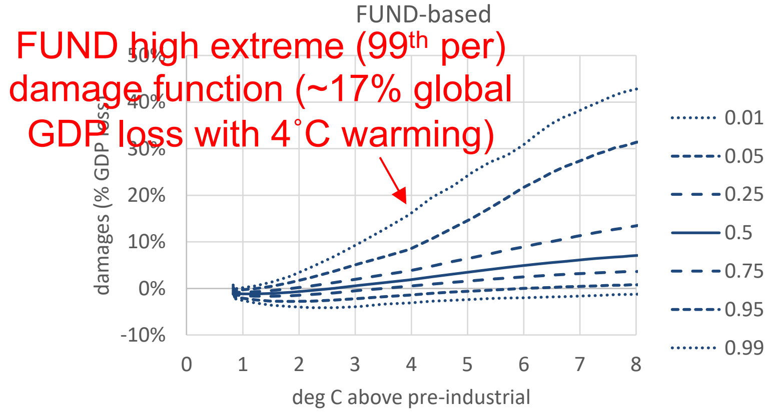
Alternative Perspectives on Potential Climate Damages

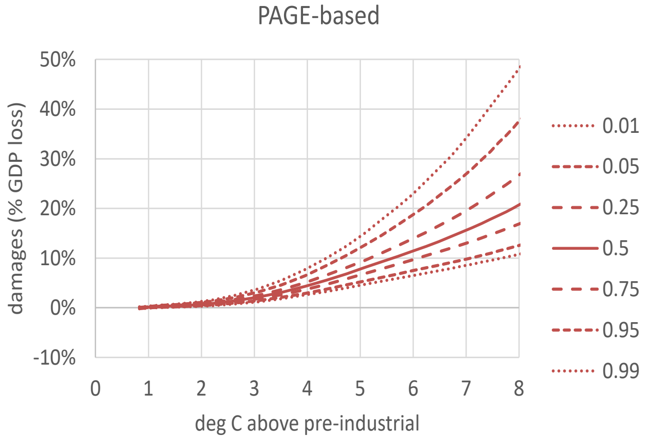
Estimated Climate Damage Functions (developed from Rose et al (2017) social cost of carbon modeling assessment)

Fitted global damage functions



Distributions of implied damage functions



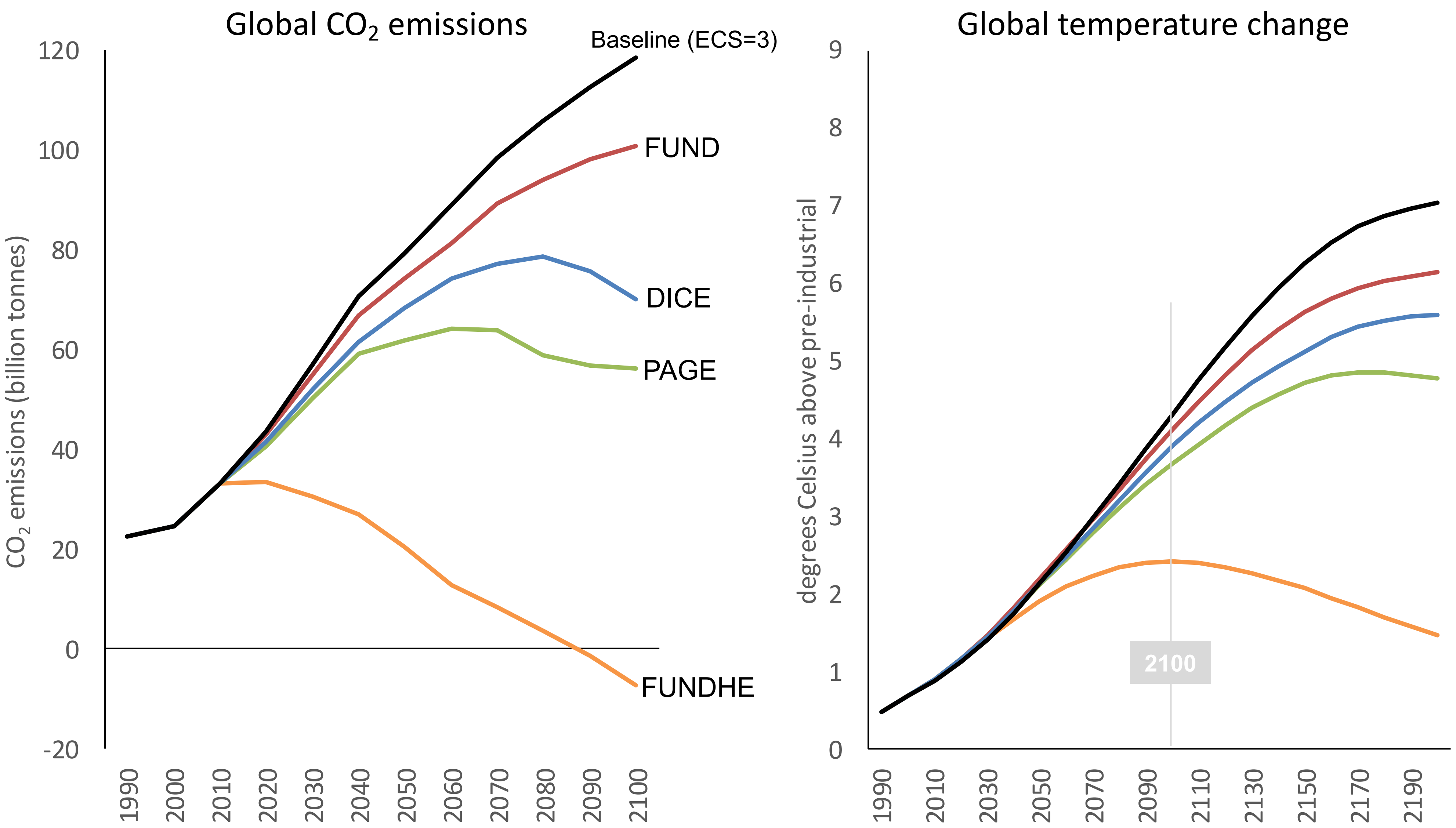


Developed using Rose et al. (2017a) technical assessment of damage components in social cost of carbon modeling

“Optimal” Global CO_2 Emissions & Temperature Pathways Varying Only Damages

If expect PAGE-like damages, significantly more mitigation effort “optimal,” but only modest difference in temperature to 2100.

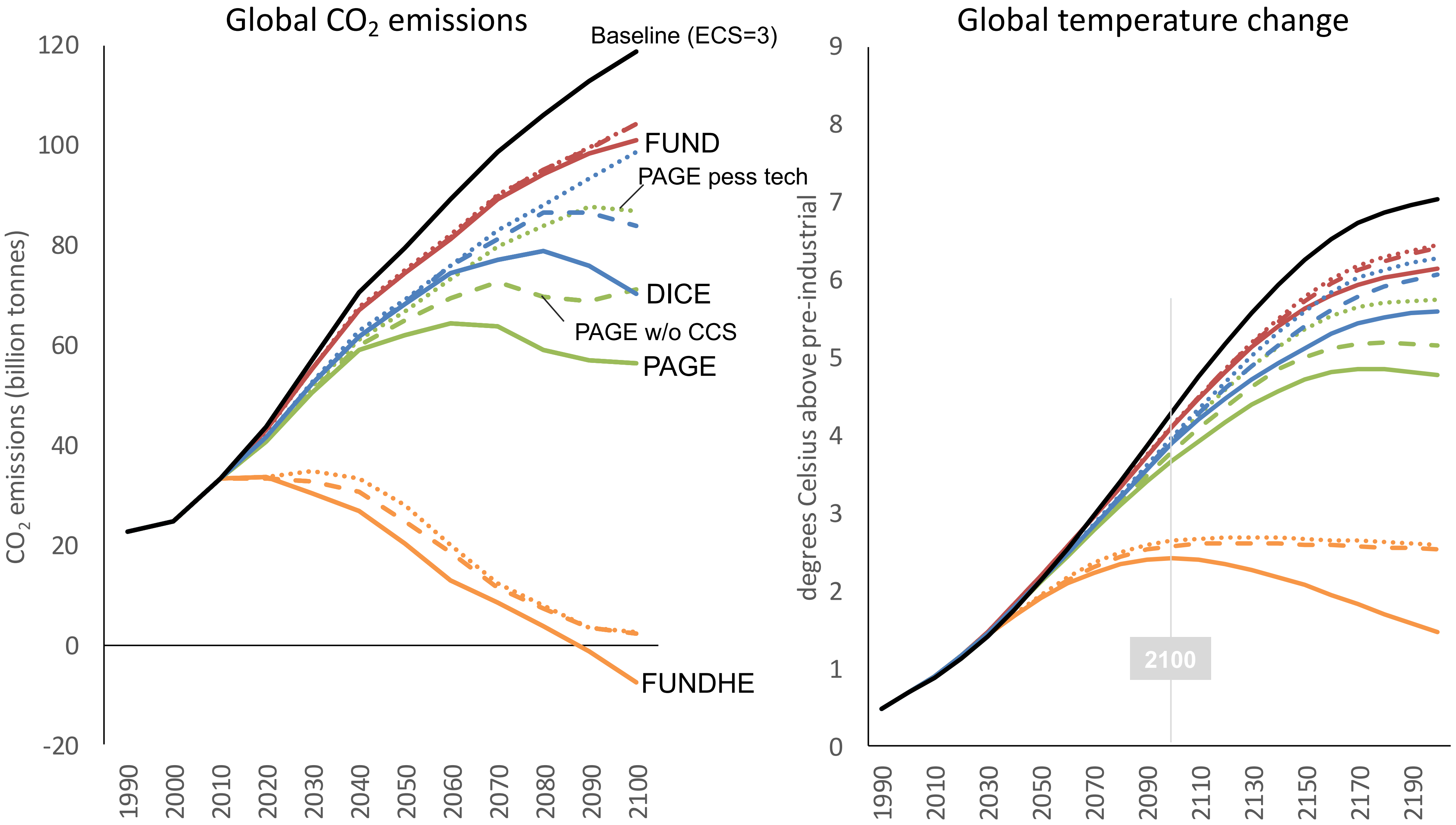
Immediate peak in emissions only if expect extreme damages.



"Optimal" Global CO_2 Emissions & Temperature Pathways Varying Damages and Technology

Fewer technology options imply higher marginal mitigation costs and higher optimal pathways.

Emissions pathway implications more muted with **both low and extreme expected damages**.

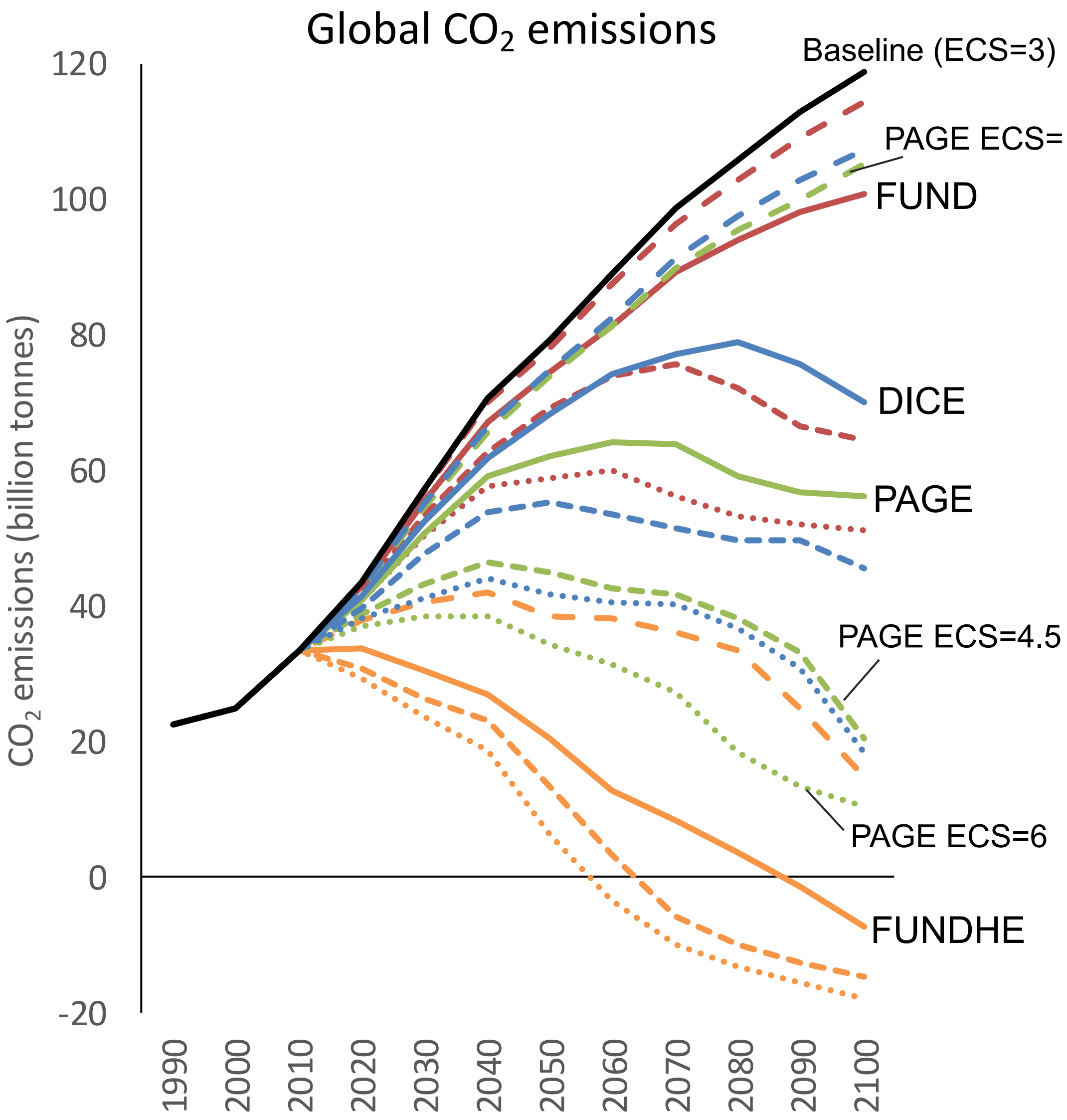


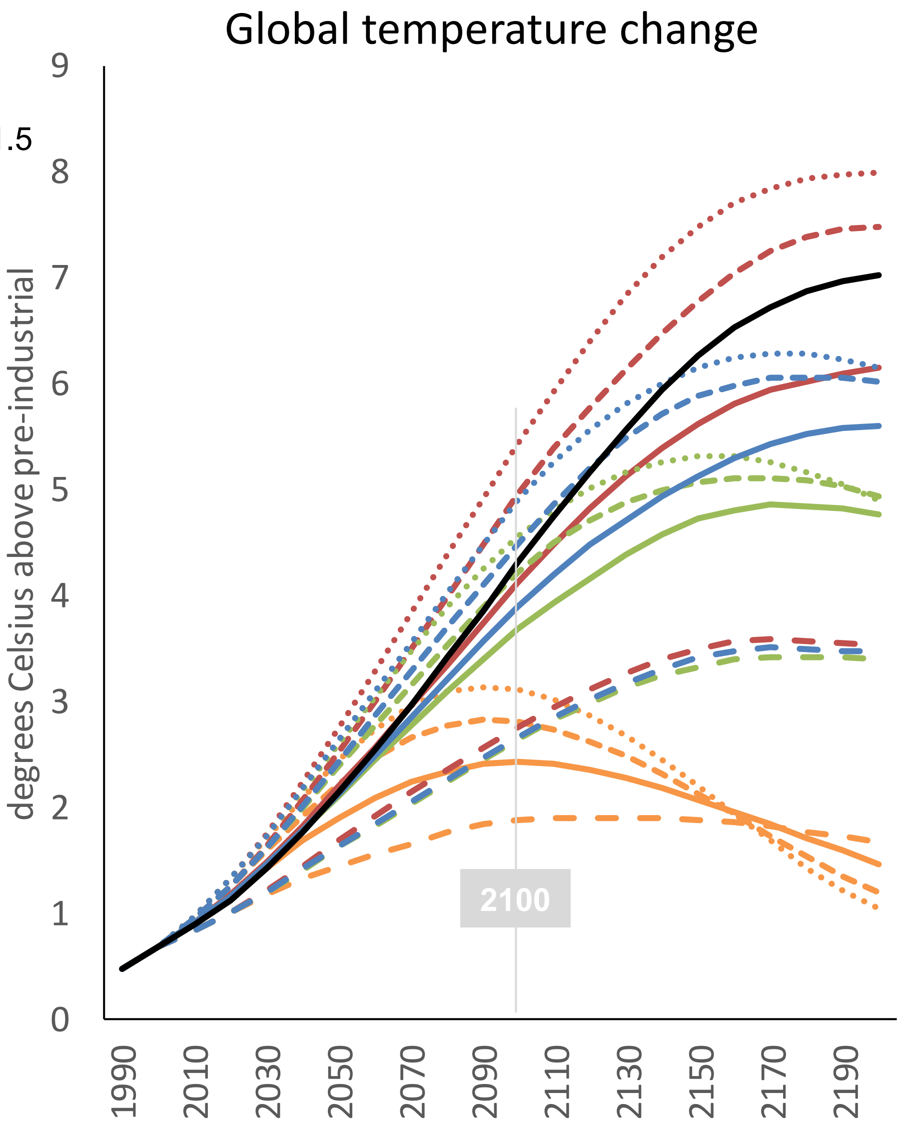
"Optimal" Global CO_2 Emissions & Temperature Pathways Varying Damages and Climate Sensitivity

Higher climate sensitivity implies higher damage risk and greater mitigation effort...

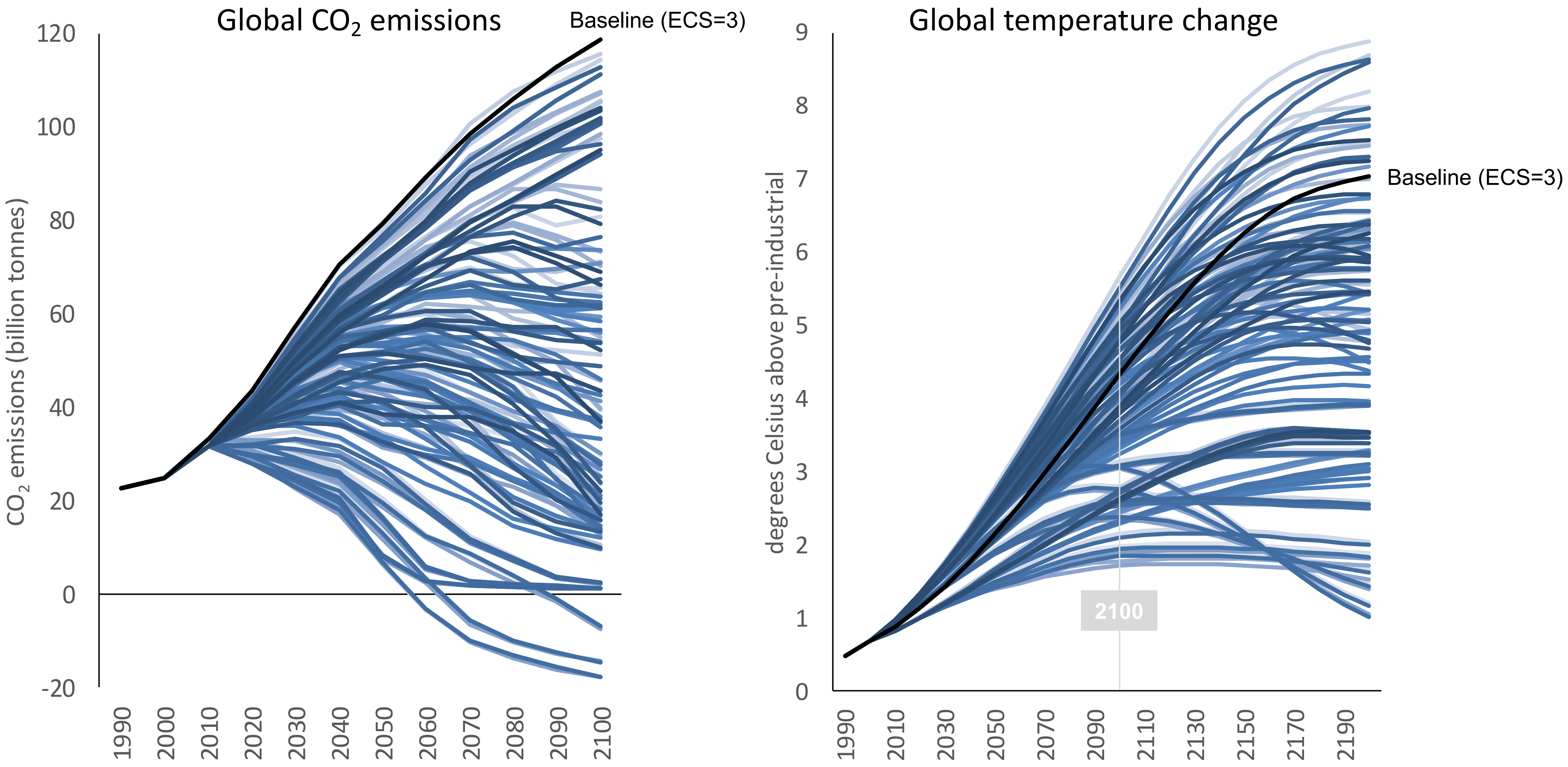
But, also higher optimal temperatures because the climate system is harder to manage.

Low climate sensitivity implies lower optimal temperatures and less effort.





The Full Set of "Optimal" Global Emissions and Temperature Pathways (n=144)

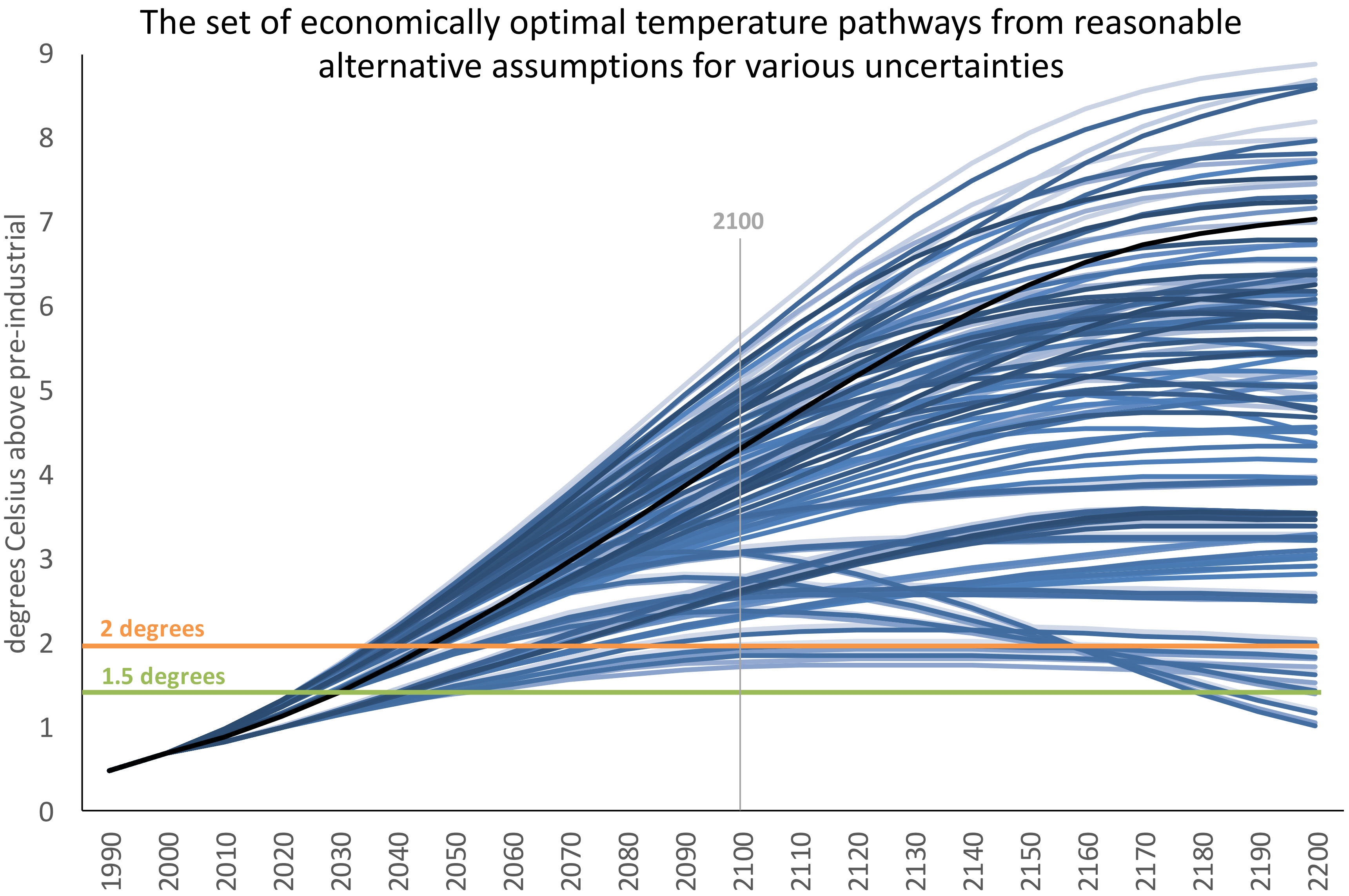


The Full Set of "Optimal" Global Temperature Pathways

Only a few optimal pathways below 2˚C (6 of 144).

None below 1.5˚C.

What are the characteristics of 2˚C pathways?



Assumptions Consistent with Temperature Outcomes

Global average temperature max	# scenarios (out of 144)	Consistent set of assumptions
< 1.5˚C	0	None
1.5 – 2.0˚C	6	• Extreme damage risk, with • Low climate sensitivity, with • Full tech available and/or lower baseline emissions growth
2.0 – 2.5˚C	12	• Extreme damage risk, with • ECS=3 if full technology, or • Limited tech if low climate sensitivity
2.5 – 3˚C	24	• ECS=3 and limited tech if extreme damage risk • ECS=4.5 if full technology and extreme damage risk • PAGE-like damages without CCS if low climate sensitivity • DICE-like damages if full tech and low climate sensitivity

Concluding Preliminary Remarks and Insights

Primary learnings…

- Broad range of decision-relevant emissions and temperature pathways
- There are trade-offs – should we pursue a goal regardless of the costs?
- Uncertainties are not equal in their implications for trade-offs
- Only 6 combinations of assumptions (of 144) suggest a pathway < 2˚C, and none < 1.5˚C
  - Only with extreme damage risk AND favorable climate dynamics AND fuller mitigation options or lower baseline emissions (AND immediate global action and cooperation)
- Even pathways limiting warming to 2.5˚C and 3˚C require the “right” set of circumstances
- Higher climate sensitivity implies lower optimal emissions, but temperature may be impossible to contain to low levels
- Low-carbon R&D valuable but primary value may be managing post-2100 climate

Additional learnings…

- <u>Global action</u>: when delay global action to 2030, higher temperature pathways optimal
- <u>Mitigation options</u>: additional negative emissions options (even if inexpensive), result in more mitigation but optimal max temp above 2˚C this century, but lower post-2100 temperatures (extreme risk, ECS=3)
- <u>Damage likelihood</u>: extreme risk damages being modeled with certainty – probability < 1 implies higher “optimal” pathways than shown

Concluding Preliminary Remarks and Insights (Cont.)

Additional considerations not modeled (but informed by results thus far)…

- Affecting mitigation costs – low carbon R&D, missing costs, policy details and coordination
- Affecting mitigation benefits – adaptation policy, co-benefits, externalities of large deployments, damage feedbacks

From this exercise, we are able to…

- Define the global decision space and its characteristics
- Evaluate trade-offs and the role of different drivers and uncertainties
- Characterize assumptions consistent with outcomes
- Inform feasibility discussion – only plausible futures possible (for a given set of assumptions)
- Inform evaluating what we know and don't and what it might mean if we knew more

Overall, this analysis raises questions about…

- What we know, likelihoods, expectations about the future and system dynamics
- R&D and research opportunities
- What is consistent with pursuing climate objectives

A community study replicating this work might be worthwhile

Thank you!

Steven Rose, Senior Research Economist

Energy & Environmental Analysis Research Group

srose@epri.com, (202) 257-7053

Resources

- Blanford, G, R Mendelsohn, S Rose, R Richels, 2014. *The Price of a Degree: Marginal Mitigation Costs of Achieving Long-Term Temperature Targets*. EPRI, Palo Alto, CA. 3002003937, http://epri.co/3002003937.
- Rose, SK, 2017. *Managing Climate Damages: Exploring Trade-offs*. Discussion Paper. EPRI, Palo Alto, CA. 3002009659.
- Rose, SK, DB Diaz, GJ Blanford, 2017a. Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study, *Climate Change Economics* 8 (2).
- Rose, SK, R Richels, G Blanford, T Rutherford, 2017b. The Paris Agreement and Next Steps in Limiting Global Warming. *Climatic Change* 142(1), 255-270.

Model infeasibilities another indication of the challenge

e.g., Energy Modeling Forum 33rd Study on Feasibility of Large-Scale Global Bioenergy

models producing scenario / # models that tried

		Full default technology	100% higher advanced bioenergy tech	Advanced bioenergy technology not available until 2050	No biofuel from lingo-cellulosic biomass	Bioenergy w/ CCS technologies not available	No advanced bioenergy technologies	Modern biomass supply max. 100 EJ/yr
	High energy CO_2 budget (1600 $GtCO_2$)	11/11	10/10	10/10	11/11	10/11	10/11	9/9
< 2˚C	Low energy CO_2 budget (1000 $GtCO_2$)	11/11	8/10	7/9	10/11	6/11	5/11	8/9
< 1.5˚C	Very low energy CO_2 budget (400 $GtCO_2$)	6/10	6/10	5/10	5/10	0/10	0/10	2/10*

40% can't solve and absent from database. 50-100% when technology constrained.

* The two feasible scenarios had extremely high CO2 prices

Developed from Bauer et al. (2018)