Assessing company climate policy risk – a scientific foundation for companies, investors, and others

And perspectives on the social cost of carbon

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Today – stakeholder requests a part of the company landscape

TCFD TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

Ceres
Sustainability is the bottom line.

UNEP FINANCE INITIATIVE
CHANGING FINANCE, FINANCING CHANGE

…and more

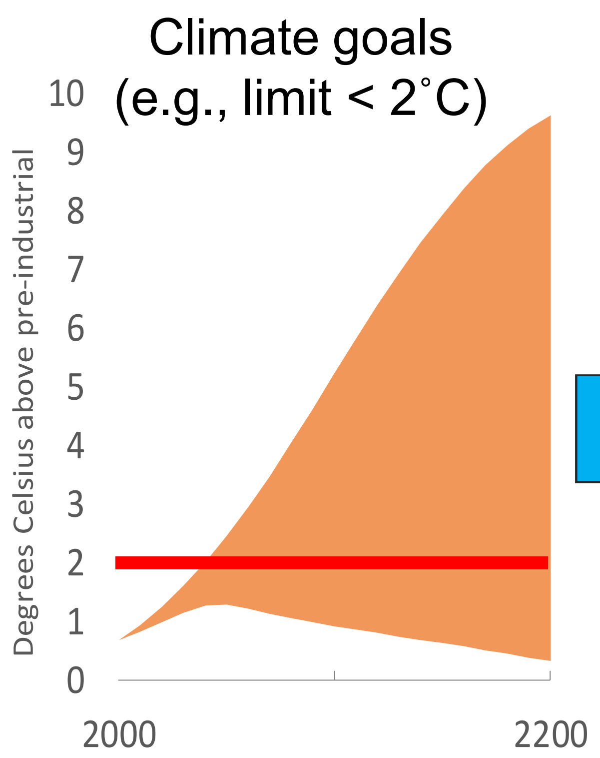
- Stakeholders increasingly requesting that companies analyze the policy cost risk of managing climate change
  - In particular, limiting global warming to 2˚C
- Similarly, companies receiving requests to set GHG emissions reductions targets
- And, organizations creating recommendations, methodologies, and tools they would like companies to apply (e.g., TCFD, Science Based Targets, Ceres, UNEP FI)

Today – stakeholder requests a part of the company landscape

…and more

1. **Dialogue lacking a scientific foundation**
   - Analyses are technically challenging for companies to undertake and for stakeholders and the public to evaluate
   - Most not knowing what they are asking for
   - Limited consideration of scientific knowledge
2. **Sound scientific understanding is a requisite first step for companies, methodologies, and dialogue**
3. **Need to slow down and characterize and use current scientific knowledge for grounded dialogue and decisions**

Global climate goals and the relationship to companies?

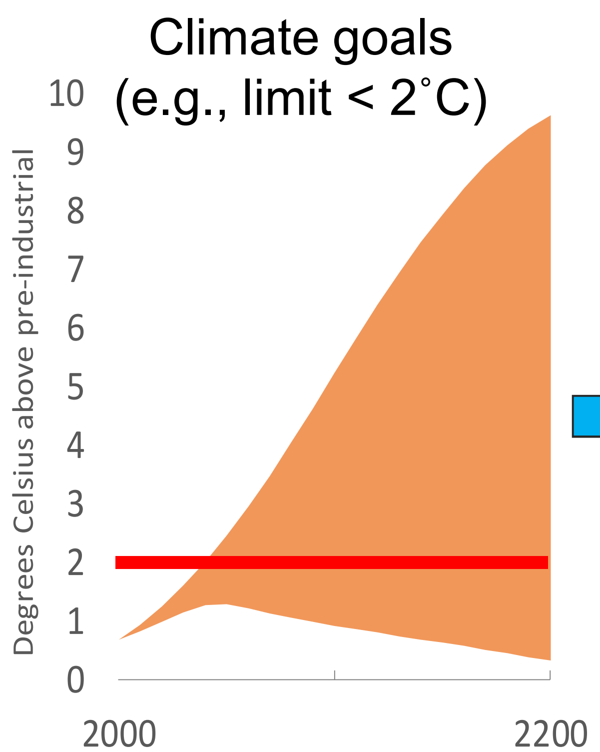


?

Company

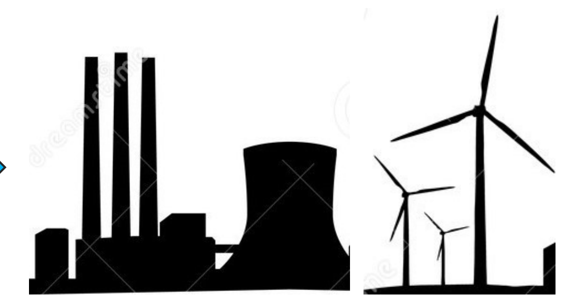
Global climate goals and the relationship to companies?

We evaluate scientific understanding of the relationship between a company and a global average temperature goal



Global GHGs? → National GHGs? → Subnational GHGs? →

Company

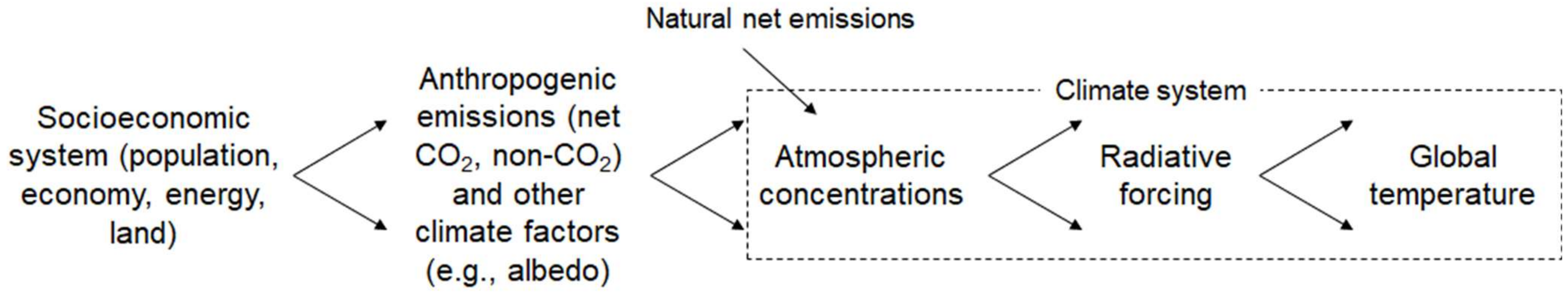


Potential energy systems, economic activity, and policy?

Significant global emissions scenario resources available, but appropriate interpretation critical

- **Large relevant global emissions scenarios peer literature** (>1000 scenarios & 30 models)
- **A single scenario misleading** – not a prediction or prescription, a projection contingent on the model & assumptions
- **Sets of scenarios appropriate and useful** – reflect uncertainty, help identify robust insights
  - Sets provide ranges, but not distributions or statistics (medians, percentiles) and only partial uncertainty
- **And, results represent aggregate sectors and markets**, not individual companies or that all companies should behave the same

Global emissions scenario modeling



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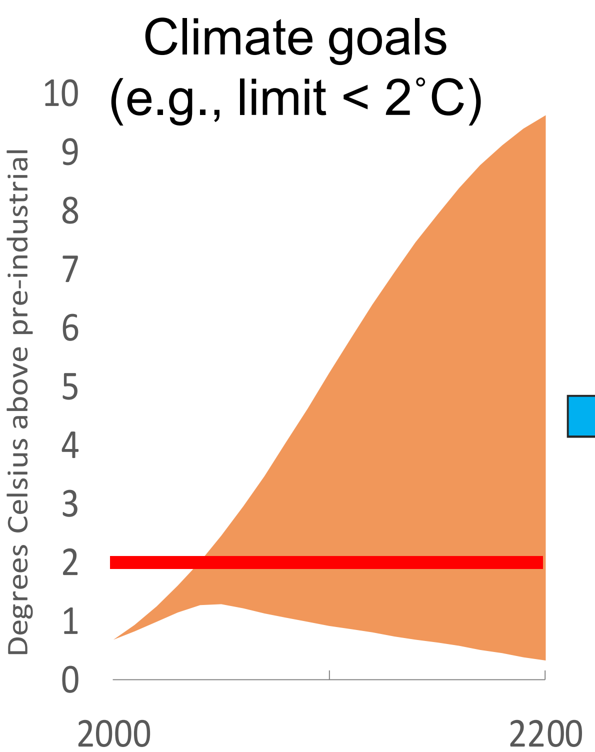


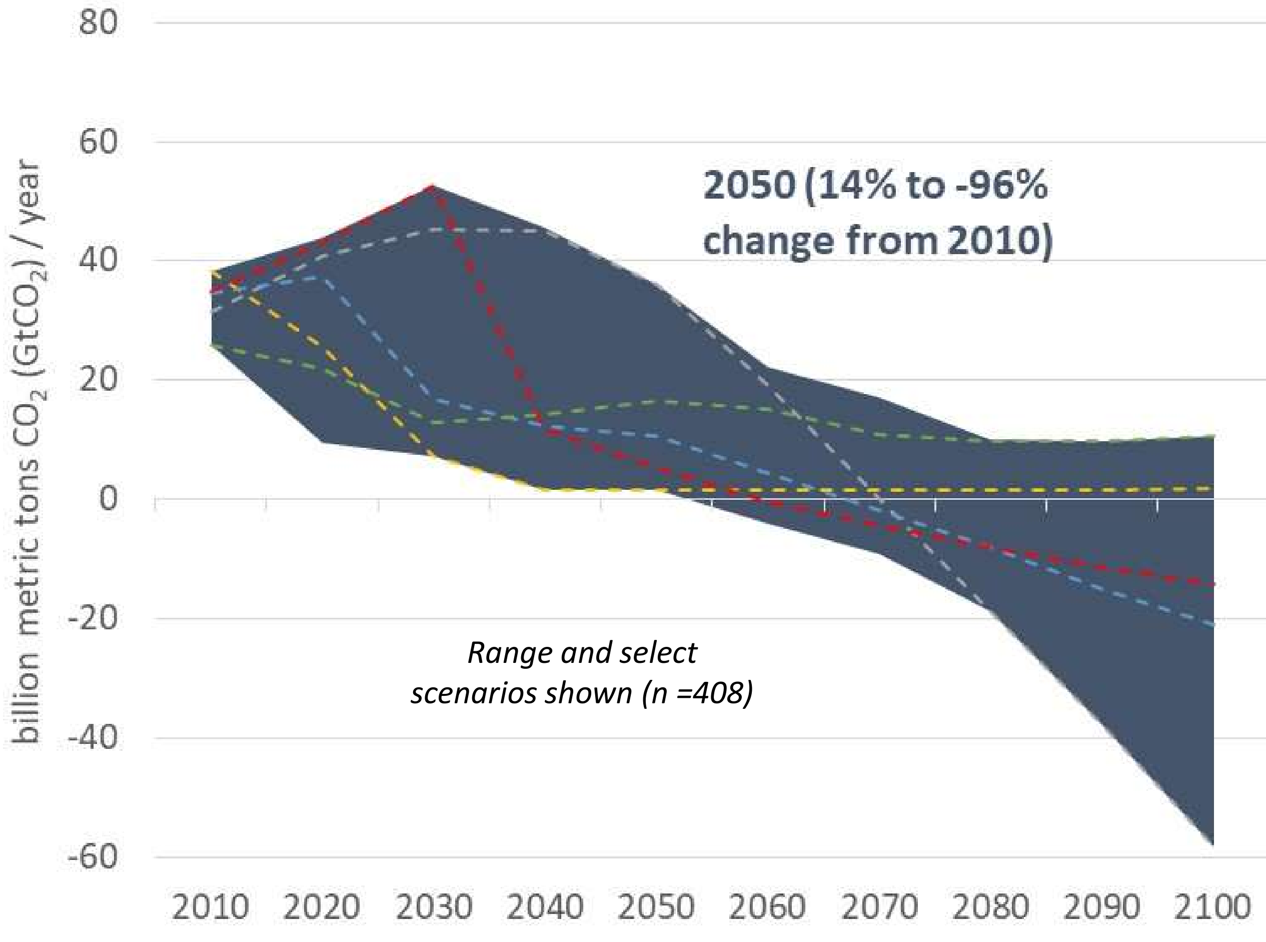
Global GHGs? → National GHGs? → Subnational GHGs? →

Company

Potential energy systems, economic activity, and policy?

A broad range of global CO_2 pathways consistent with 2˚C

Global CO_2 Pathways Consistent with 2˚C



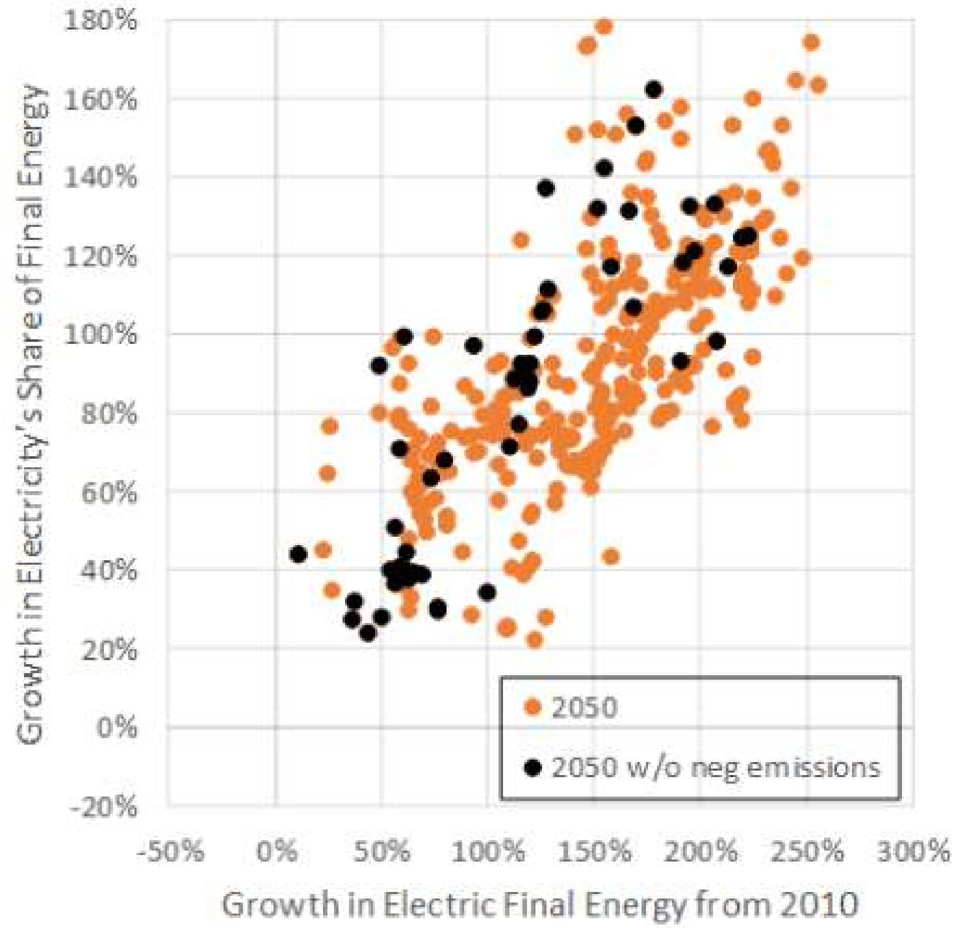
Developed from IAMC (2014) data

- Broad range of global CO_2 pathways, budgets, and 2030 & 2050 reductions consistent with 2˚C
- Broad ranges for regions & sectors too
- Ranges reflect uncertainties – climate system, economic, energy use, technology, policy timing, as well as differences in models (e.g., structure, history, time horizon, solution)

Assumptions matter for properly using results – technology & policy design important for countries, sectors, and companies

- Is increasing electrification (above baseline) consistent with the 2˚C goal?
- Should the electric sector reduce emissions by a larger fraction than the overall economy and other sectors?
- **Not necessarily!**
  – Current scenarios misleading with assumptions facilitating decarbonization with electricity:
    1. Idealized global economy-wide policy and coordination
    2. Availability of cost-effective low-carbon generation technologies
  – Policy design & technology are uncertainties to evaluate, matter to cost-effective reductions, electrification, and the attainability of 2˚C pathways
- **Subglobal results dependent upon global assumptions**

Global 2050 electrification from current 2˚C scenarios



Developed from IAMC (2014) data

Policy design a key absent uncertainty for companies

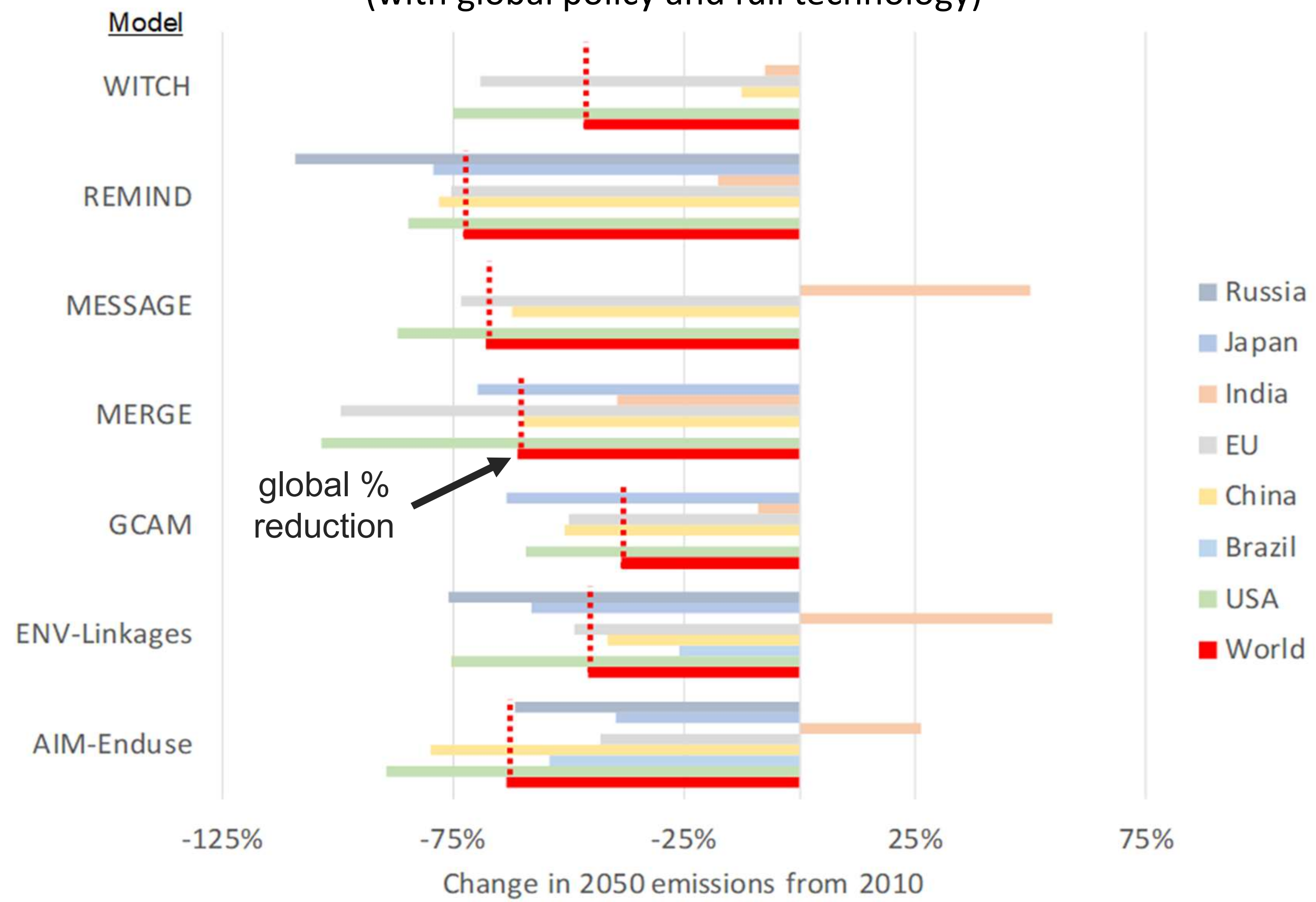
- **Policy design uncertainty absent from existing scenarios**
  - Most assume global economy-wide action and coordination. Unlikely.
- **Uncertain policy design features…**
  - Sector/emissions coverage
  - Sector/emissions coordination
  - Eligible technologies
  - Policy instrument type
  - Offsets (uncovered emissions)
  - International partnerships
- **Policy design features affect cost, environmental effectiveness, and cost-effective role of sectors and companies**

Applying uniform GHG targets (e.g., 80% in 2050) across companies is unlikely to be cost-effective for society

Scenarios find cost-effective country % reductions differ from global % reductions

(also true for sectors and GHG intensities)

2050 energy CO_2 changes from 2010 for 450 ppm CO_2eq scenarios (with global policy and full technology)



Developed from EMF-27 study data (Weyant and Kriegler, 2014). Sample of results shown. Some models did not report results for each country.

Global emissions pathway attainability another uncertainty for companies

- **Companies don't know whether the world can achieve the global pathways suggested**
  - 2˚C (and below) pathways found to be extremely challenging – geophysically, technologically, economically, and politically
  - And realization of near-term country pledges (NDCs) uncertain
- **As a result, other global pathways are plausible**
  - e.g., when global emissions might peak is an uncertainty for companies (e.g., 2020, 2030, 2040, 2050)

Rising emissions abatement costs one indication of the challenge

Regional GHG emissions reduction costs and maximum global temperature
with increasing levels of regional emissions constraints

			Regional cost (% reductions in discounted regional per capita aggregate consumption)					
Scenario	**Max °C**		**U.S.**	**EU**	**Other G20**	**China**	**India**	**Other Countries**
Baseline	6.9 (3.8-9.6)		None					
NDC only | Base	6.0 (3.4-8.3)		0.2%	0.3%	0.3%	1.4%	0.1%	-0.2%
NDC+ | Base	5.4 (3.0-7.4)		0.3%	0.4%	0.6%	2.3%	0.0%	-0.5%
NDC++ | Base	5.0 (2.8-7.0)		0.5%	0.7%	1.1%	4.8%	-0.1%	-0.7%
NDC++ | Level 1	3.8 (2.2-5.3)		0.5%	0.7%	1.0%	4.8%	0.8%	-0.6%
NDC++ | Level 2	2.7 (1.6-3.8)		0.5%	0.7%	1.0%	4.9%	2.0%	0.2%
NDC++ | Level 3	2.3 (1.4-3.1)		0.5%	0.8%	1.0%	5.1%	4.3%	2.1%
2°C post-2030	2.0 (1.3-2.6)		2.1%	2.2%	5.2%	12.3%	14.1%	6.5%

Source: Rose et al. (2017)

Model infeasibilities another indication of the challenge

models producing scenario / # models that tried

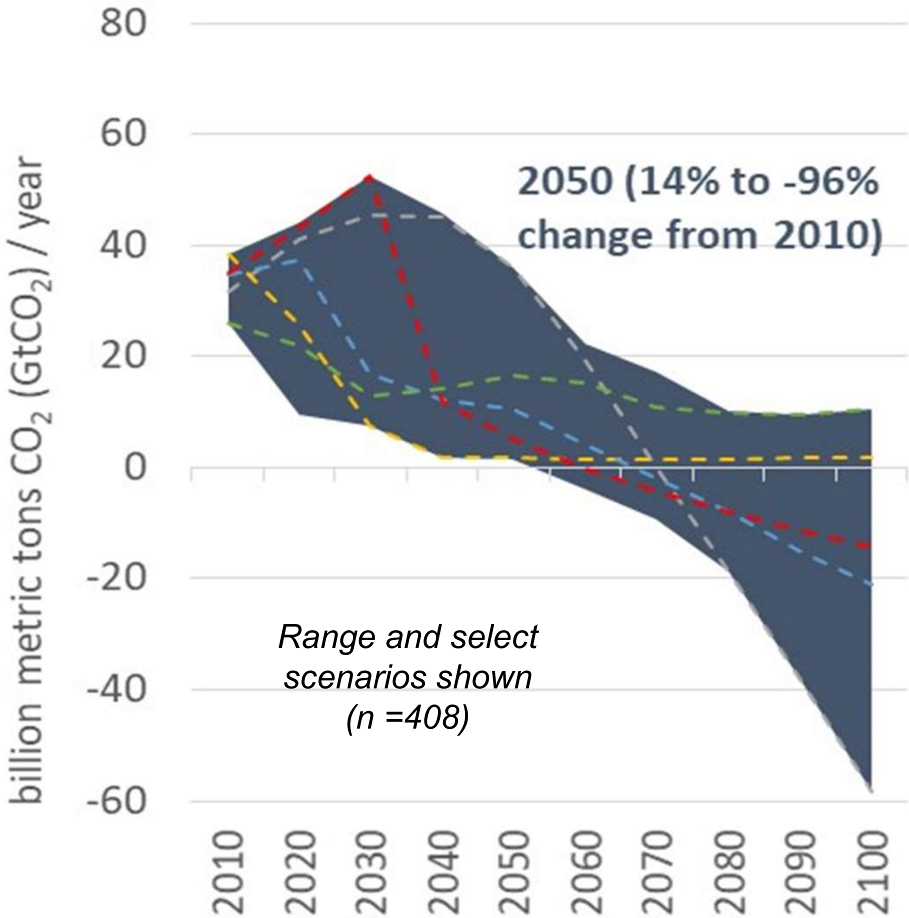
	Full default technology	CCS unavailable (fossil and bioenergy)	New nuclear unavailable and phase out of existing	Solar and wind electricity share constrained	Biomass supply constrained	CCS and new nuclear unavailable*	CCS and new nuclear unavailable, and solar, wind, and biomass constrained
Higher atmospheric concentration target (550 ppm CO_2eq)	13/13	12/12	11/11	11/11	13/13	12/12	6/9
Lower atmospheric concentration target (450 ppm CO_2eq)	10/11	4/11	9/10	9/10	9/11	6/11	0/10

Source: Krey et al. (2014)

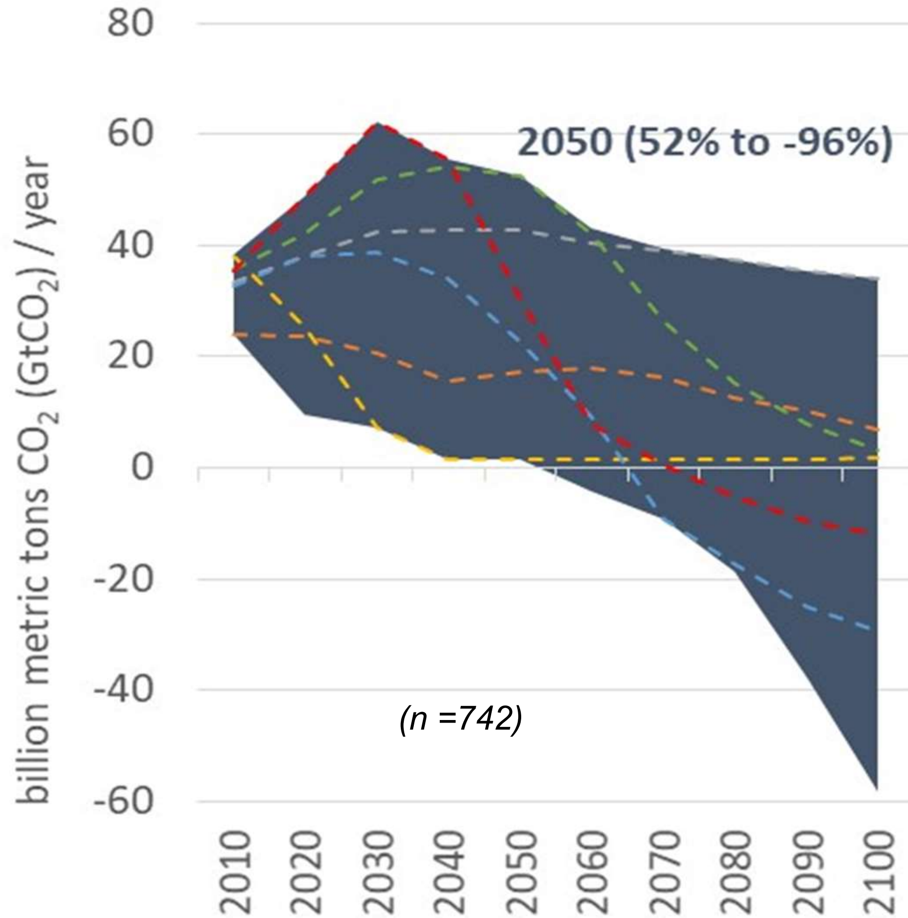
Some cannot solve and absent from database. 10-100% absent when technology constrained.

Uncertainty about pathway attainability implies even larger range of global emissions pathways relevant to companies

Global net CO_2 pathways consistent with 2˚C



Global net CO_2 pathways peaking before mid-century



For companies, range expands due to pathway attainability uncertainty. Probabilities could also be considered.

Developed from IAMC (2014)

Other risks (non-climate-policy) & company strategy also matter

- Climate policy risk for companies needs to be put in context with respect to other risks to operations and investments
- Risk assessments also need to consider current company climate-related policy planning
- GHG emissions represent only one part of an asset's or portfolio's value to society

Ranges of 2050 changes in baseline levels relative to 2020 for a subset of economic and technological projections

	US		World	
	min	max	min	max
GDP	42%	95%	106%	152%
Energy Consumption	-10%	26%	41%	72%
Electricity Consumption	9%	58%	39%	117%
Transportation Electricity Consumption	-7%	3327%	6%	4018%
Natural Gas Price	-20%	183%	-22%	129%
Capital Cost NGCC	-24%	1%	-24%	3%
Capital Cost Nuclear	-13%	34%	-3%	50%
Capital Cost Solar CSP	-26%	-3%	-26%	-3%
Capital Cost Solar PV	-65%	-10%	-65%	-10%
Capital Cost Wind Onshore	-56%	-6%	-26%	-6%

Developed from EMF-27 study data (Weyant and Kriegler, 2014)

Despite broad ranges, there are robust insights

Insights found consistently across models and assumptions that provide a solid decision-making foundation for companies and others

For instance

- An emissions pathway cost-effective for a given set of assumptions will not be cost-effective for every plausible future
- The cost-effective emissions reduction role of an economic sector is highly uncertain
- The more ambitious the climate objective, and the more constrained the set of emissions mitigation options, the higher the emissions reduction costs and the rate of scenario infeasibilities
- The emissions relationship with global temperature becomes increasingly uncertain the finer the resolution of the emissions source

Key insights for companies, investors, and others

- **Individual company perspective:** Essential for defining relevant uncertainties and company-specific context
- **Scientific basis:** Approaches and strategies should be based on scientific understanding to characterize uncertainties and identify robust insights
- **Cost-effective societal role of a company:**
  - A company's role in reducing GHG emissions at the lowest cost to customers and society is highly uncertain
  - It will be difficult to identify a unique company-level pathway or target that is cost-effective in all plausible futures (if choosing one, uncertainties important to communicate)
  - The cost-effective pathway or target for a company will likely differ from what is cost-effective at the global, country, and sector level, as well as at other companies
- **Uncertainty, flexibility, and robust strategies:**
  - Characterizing and incorporating the numerous uncertainties relevant to companies will be important (GHG policy one of many)
  - Having flexibility in emissions reduction levels and how they are met will be important for containing societal costs
  - Identifying a robust strategy that makes sense in different future contexts will be important
    - More than a target or pathway – an approach that recognizes uncertainty, provides flexibility, and can respond appropriately

Key insights represent principles for evaluating & developing methodologies

A checklist for methodologies

Company analysis issues for methodologies

- Emissions scenarios used?
- Uncertainties considered and how?
  - Temperature-emissions
  - Global pathway attainability
  - Policy design
  - Non-climate-related
- Consideration of company-specific context?
- Uniform vs. varied GHG targets across companies?
- Consideration of flexibility options?
- Quantitative comparison of alternatives?
- Evaluation of strategy robustness?

Table ES-3
How different approaches address company analysis issues identified by this study

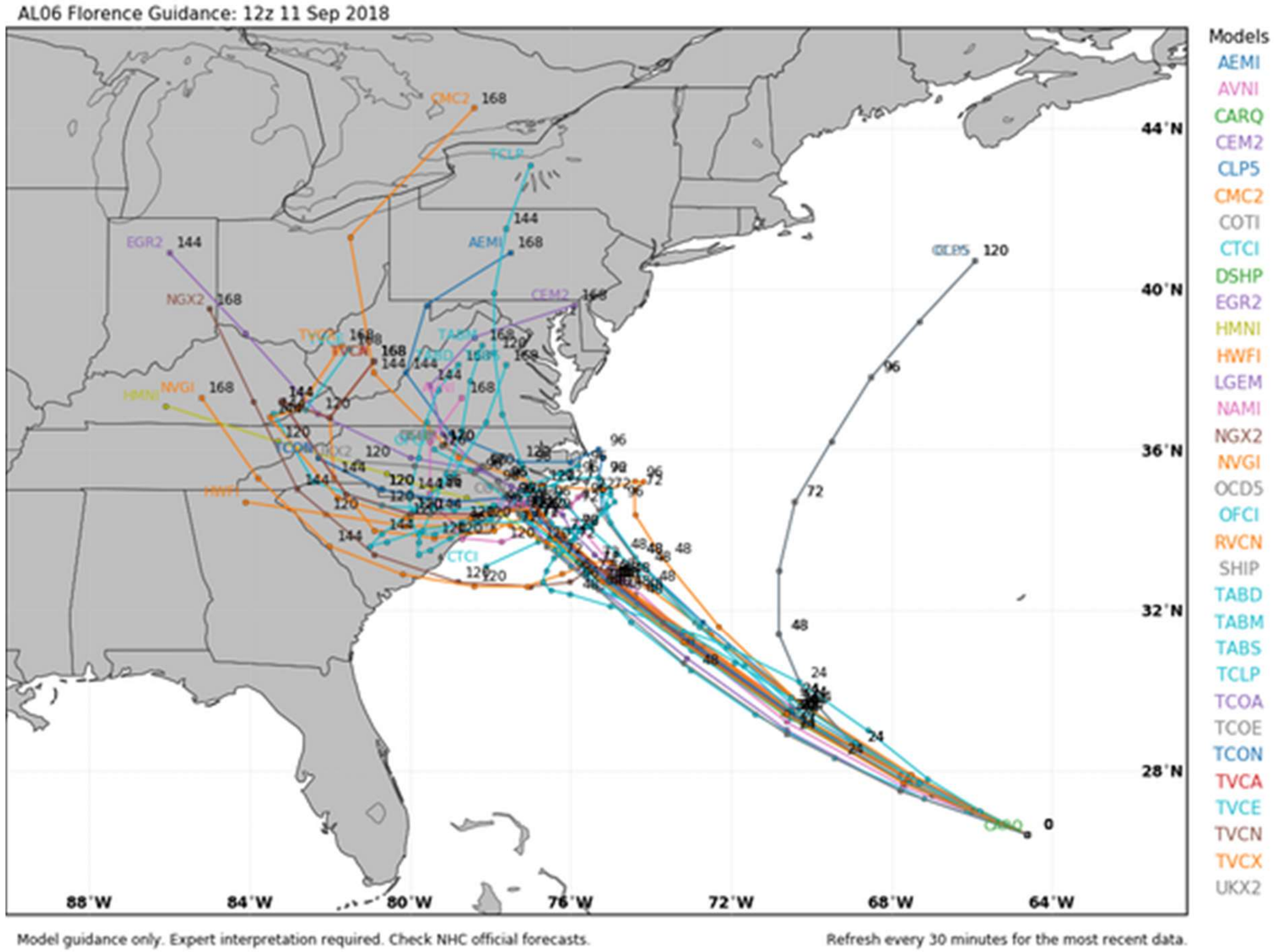
Sources: Developed from this study, SBTi (2015, 2017), IEA (2016), Ceres (2018), and UNEP FI (2018)

Issue to consider	This study		SBTi	Ceres	UNEP FI pilot
Scenarios used	1000+ (a)		1 (b)	See note (c)	See note (d)
Uncertainties					
Global temperature-CO_2 relationship for 2°C (cumulative 2011-2050 $GtCO_2$)	Global net	465 to 1692	--	--	1139
	Global energy	324 to 1636	1085	--	1022
	Global electric	94 to 642	335	--	261
Global temperature-CO_2 relationship for 2°C (annual changes in 2050 relative to 2010)	Global net	14% to -96%	--	--	-72%
	Global energy	9% to -99%	-52%	--	-58%
	Global electric	-2% to -163%	-89%	--	-94%
	U.S. net CO_2eq	-58% to -110%	--	-81% (80% relative [illegible]	[illegible]
	U.S. electric	-44% to -170%	[illegible]	[illegible]	[illegible]
[illegible]	(1) Consider uncertainty about att[illegible] (2) Potentially assign [illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible] reflected in global		Not considered	Not considered	Not considered
[illegible]	Consider (e.g., service demand, fuel markets, technology costs)		Not considered	Some discussion	Some discussion
Company-specific context	Important, varies from company-to-company (e.g., current assets, markets, systems, and policy & strategy)		Limited consideration (base year activity and emissions, target year activity)	Some discussion	Some discussion
Uniform vs. varied GHG targets across companies	Uniform targets found unlikely to be cost-effective		Proposes globally uniform sectoral targets	Proposes uniform target for all utilities	Implies uniform targets within sector segments
Company flexibility	Consider flexibility in GHG reduction levels and how achieved		Constrained to single GHG target without coordination	Constrained to single GHG target (coordination not considered)	Not considered
Quantitative comparison of company alternatives	Compare cost, environmental effectiveness, cost risk, and sensitivity of results		No method	Various potential comparisons noted (e.g., technology, cost)	Not discussed
Company strategy robustness	Evaluate by considering uncertainties and risk management		Not considered	Not considered	Not considered

- Recent methodologies do not represent uncertainty evident in the literature related to 2˚C.
- They also propose applying uniform targets across companies

Scenario ranges are valuable information: lessons from Florence

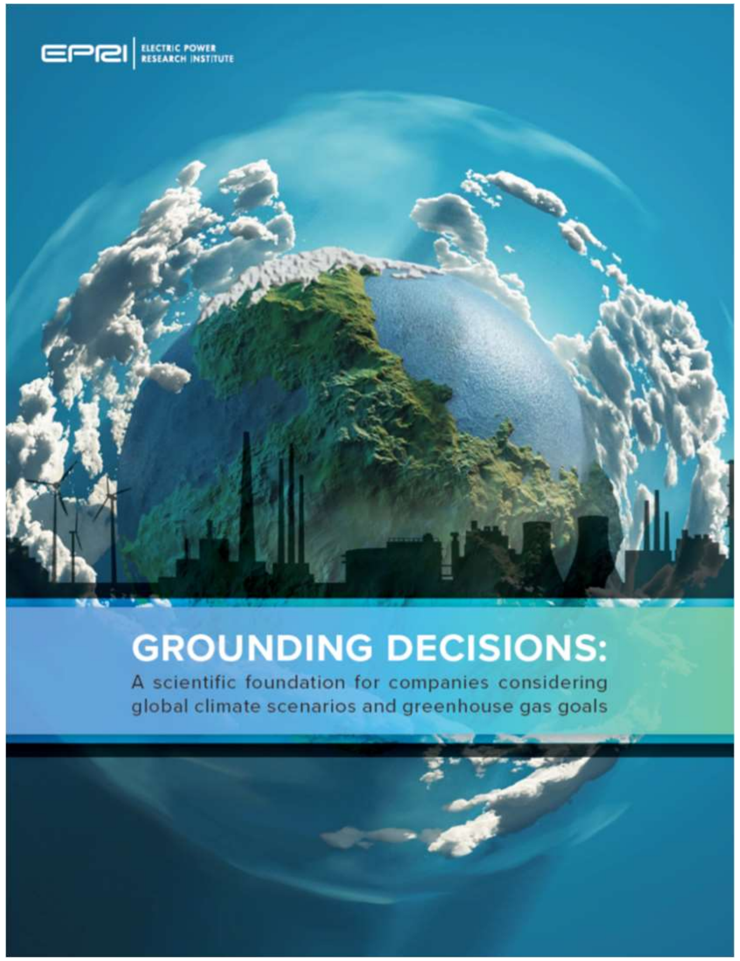
- **The set of results informs planning by identifying possibilities**
- All decision-relevant information. Anything less can mislead.
- Note: key difference from global emissions projections – hurricane paths are forecasts (vs. projections)



Summary remarks on company climate risk assessment

- **Growing enthusiasm for climate risk assessment and goals, but lacking a scientific basis**
- **Need to slow down, get grounded, and educate (companies AND stakeholders)**
  - Significant knowledge available
  - Understanding and proper use essential
  - Embrace uncertainty, want flexibility, and develop strategies robust to alternative futures
- **New EPRI study is an initial step in informing analyses, discussions, decisions**
- **Finding the same or stronger insights for 1.5˚C scenarios**

Grounding Decisions: A Scientific Foundation for Companies Considering Global Climate Scenarios and Greenhouse Gas Goals (#3002014510, www.epri.com)



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Perspectives on the social cost of carbon

The social cost of carbon (SCC) or other greenhouse gases

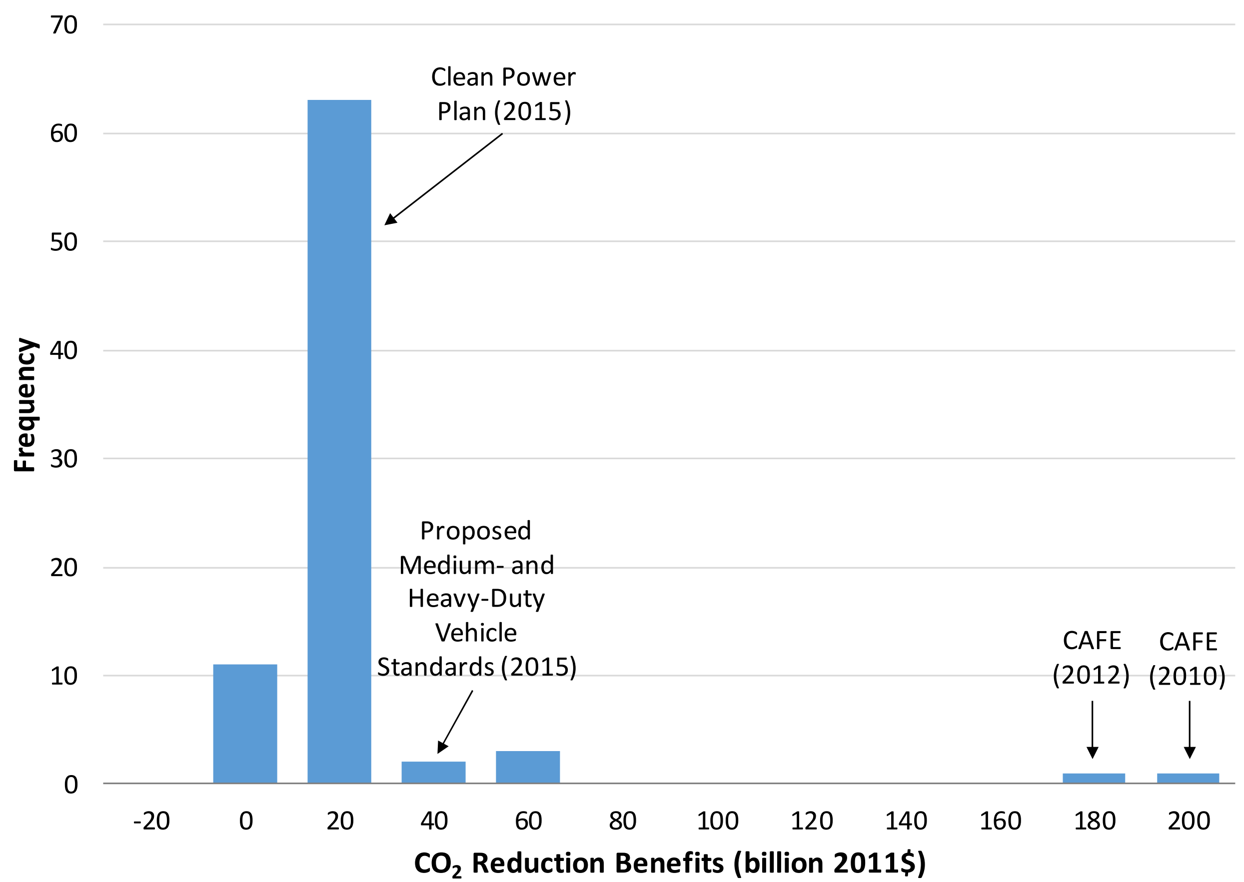
US Government global SCC estimate

$42 of damages to the world from a tonne of CO_2

But, what does $42 mean?

Little known about underlying modeling or implied societal risks, or SCC use

US Government SCC rulemaking use

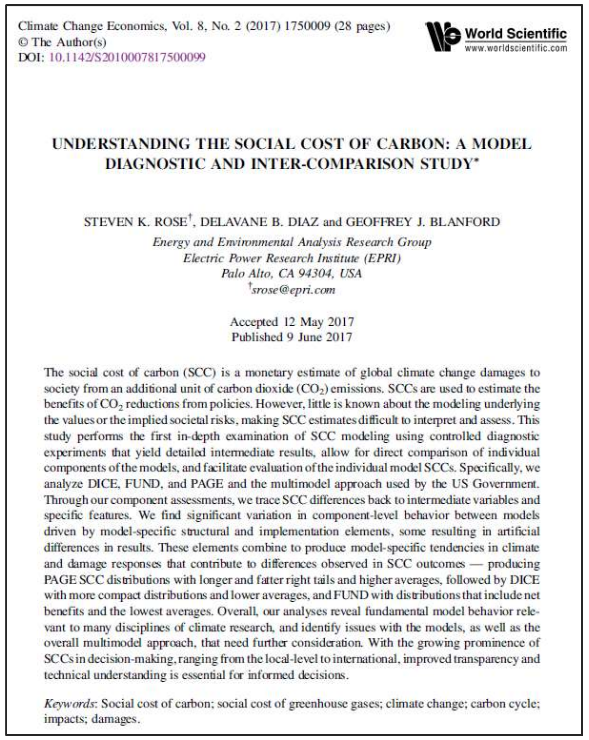


EPRI SCC estimation and use studies

EPRI study assessing SCC modeling

Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study

(*Climate Change Economics* Vol. 8, No. 2, 2017)


Climate Change Economics, Vol. 8, No. 2 (2017) 1750009 (28 pages)

DOI: 10.1142/S2010007817500099

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UNDERSTANDING THE SOCIAL COST OF CARBON: A MODEL DIAGNOSTIC AND INTER-COMPARISON STUDY*

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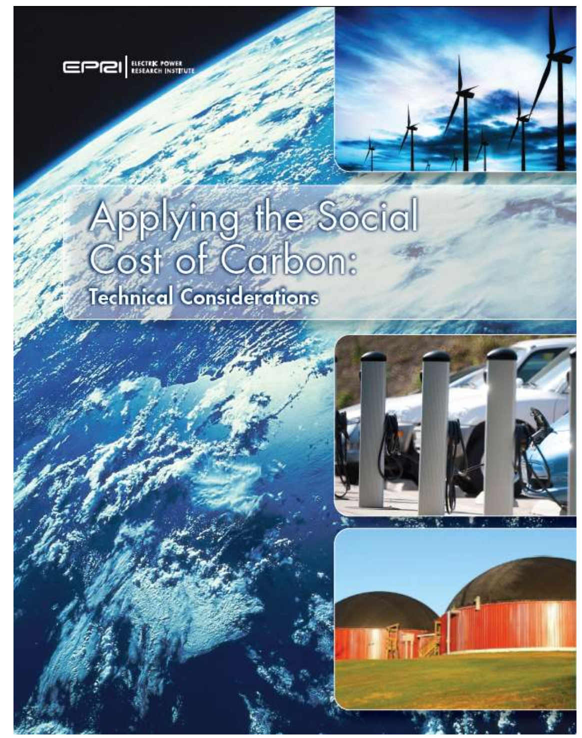
The social cost of carbon (SCC) is a monetary estimate of global climate change damages to society from an additional unit of carbon dioxide (CO_2) emissions. SCCs are used to estimate the benefits of CO_2 reductions from policies. However, little is known about the modeling underlying the values or the implied societal risks, making SCC estimates difficult to interpret and assess. This study performs the first in-depth examination of SCC modeling using controlled diagnostic experiments that yield detailed intermediate results, allow for direct comparison of individual components of the models, and facilitate evaluation of the individual model SCCs. Specifically, we analyze DICE, FUND, and PAGE and the multimodel approach used by the US Government. Through our component assessments, we trace SCC differences back to intermediate variables and specific features. We find significant variation in component-level behavior between models driven by model-specific structural and implementation elements, some resulting in artificial differences in results. These elements combine to produce model-specific tendencies in climate and damage responses that contribute to differences observed in SCC outcomes — producing PAGE SCC distributions with longer and fatter right tails and higher averages, followed by DICE with more compact distributions and lower averages, and FUND with distributions that include net benefits and the lowest averages. Overall, our analyses reveal fundamental model behavior relevant to many disciplines of climate research, and identify issues with the models, as well as the overall multimodel approach, that need further consideration. With the growing prominence of SCCs in decision-making, ranging from the local-level to international, improved transparency and technical understanding is essential for informed decisions.

Keywords: Social cost of carbon; social cost of greenhouse gases; climate change; carbon cycle; impacts; damages.

Available OPEN ACCESS

EPRI study assessing SCC use

Applying the Social Cost of Carbon: Technical Considerations," (www.epri.com, #3002004659)



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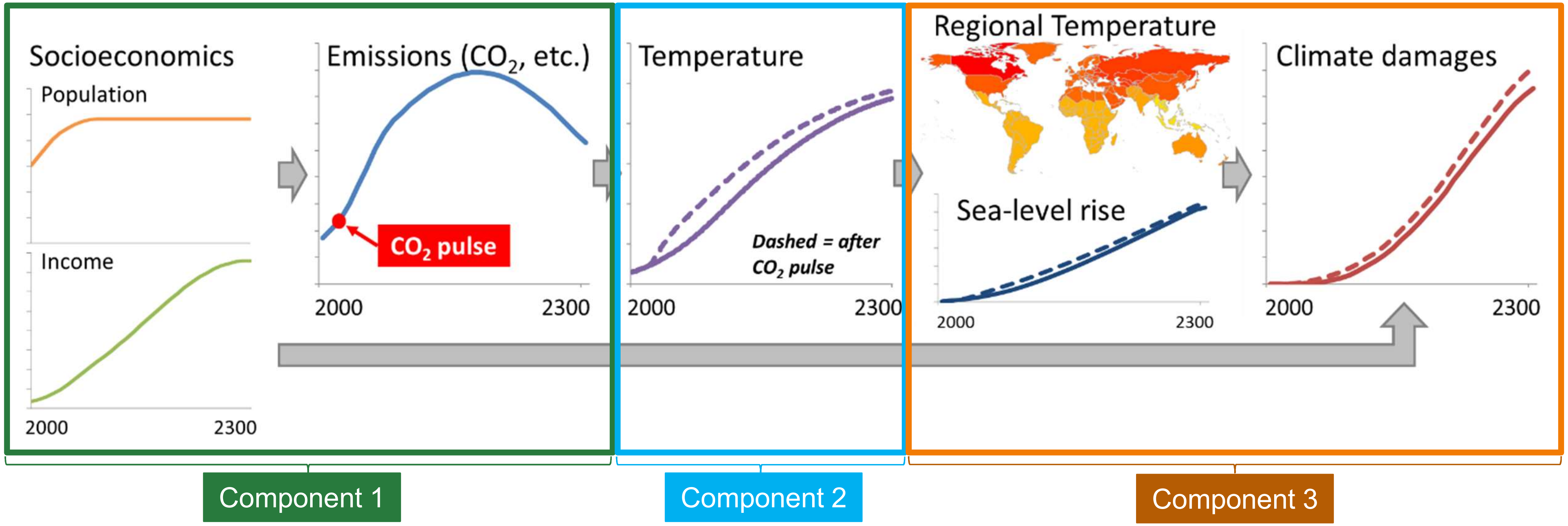
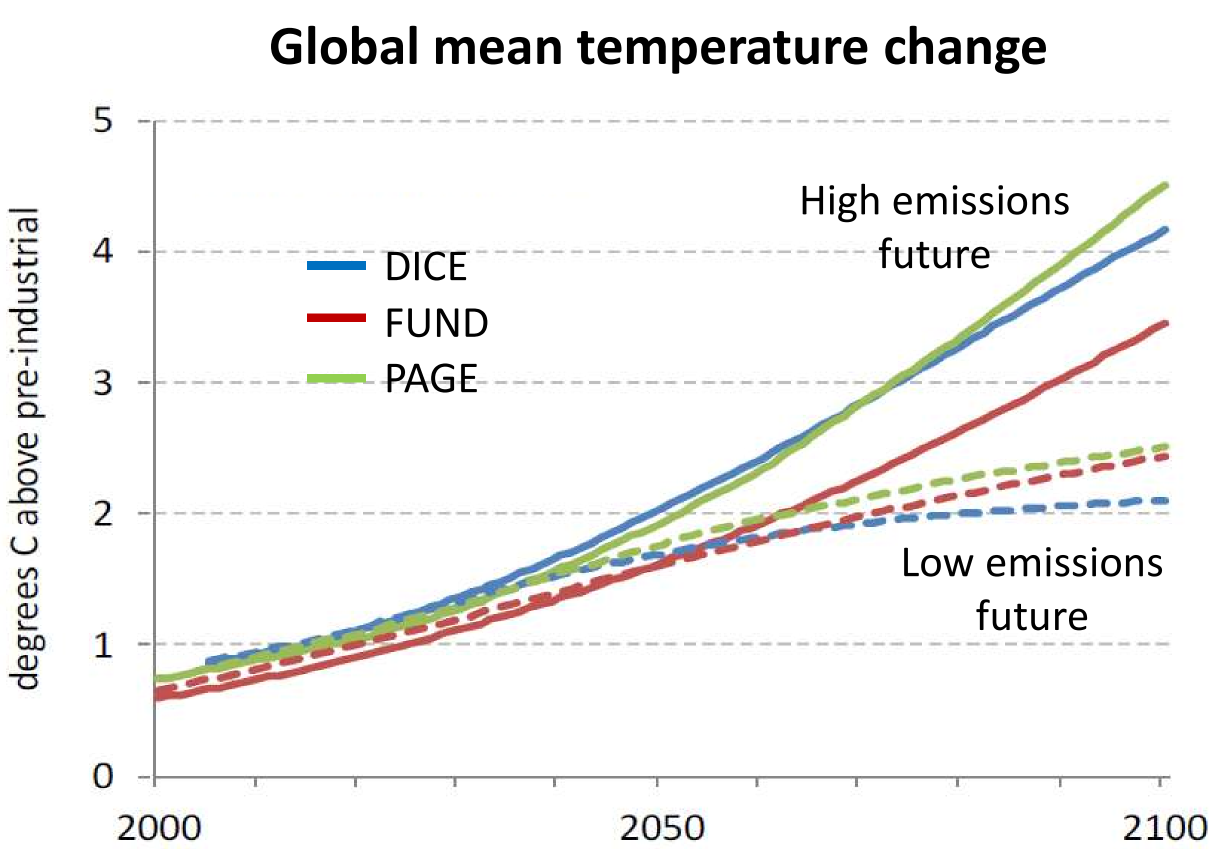
Assessing SCC modeling component-by-component & overall

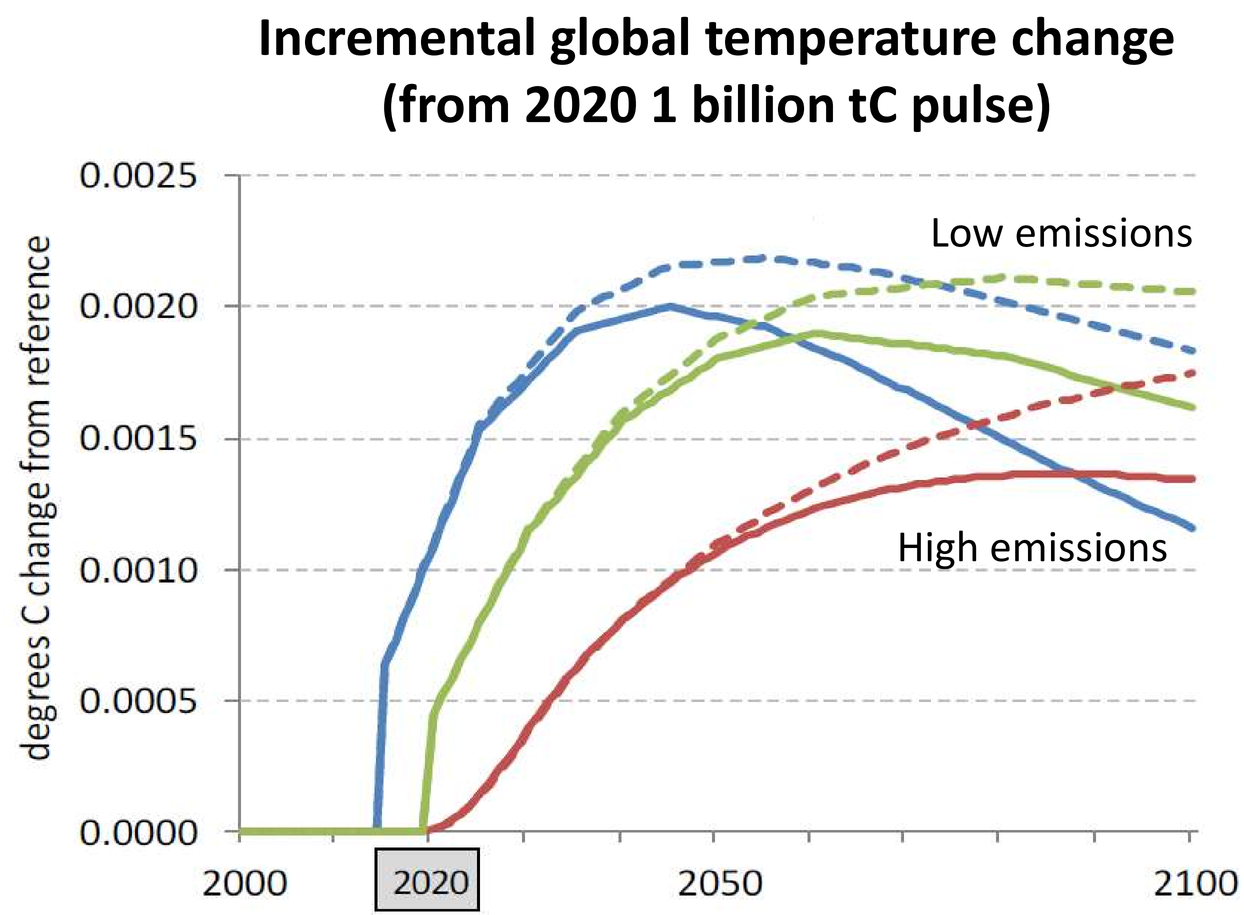


Reviewing modeling & code, programming components, running diagnostic scenarios, comparing, exploring multiple perspectives

- Examining the **inner workings** of the modeling
- **4 separate technical assessments** – elucidating & assessing individual modeling components & overall USG experimental design
- Learning about **the raw intermediate modeling and behavior** – undiscounted & disaggregated

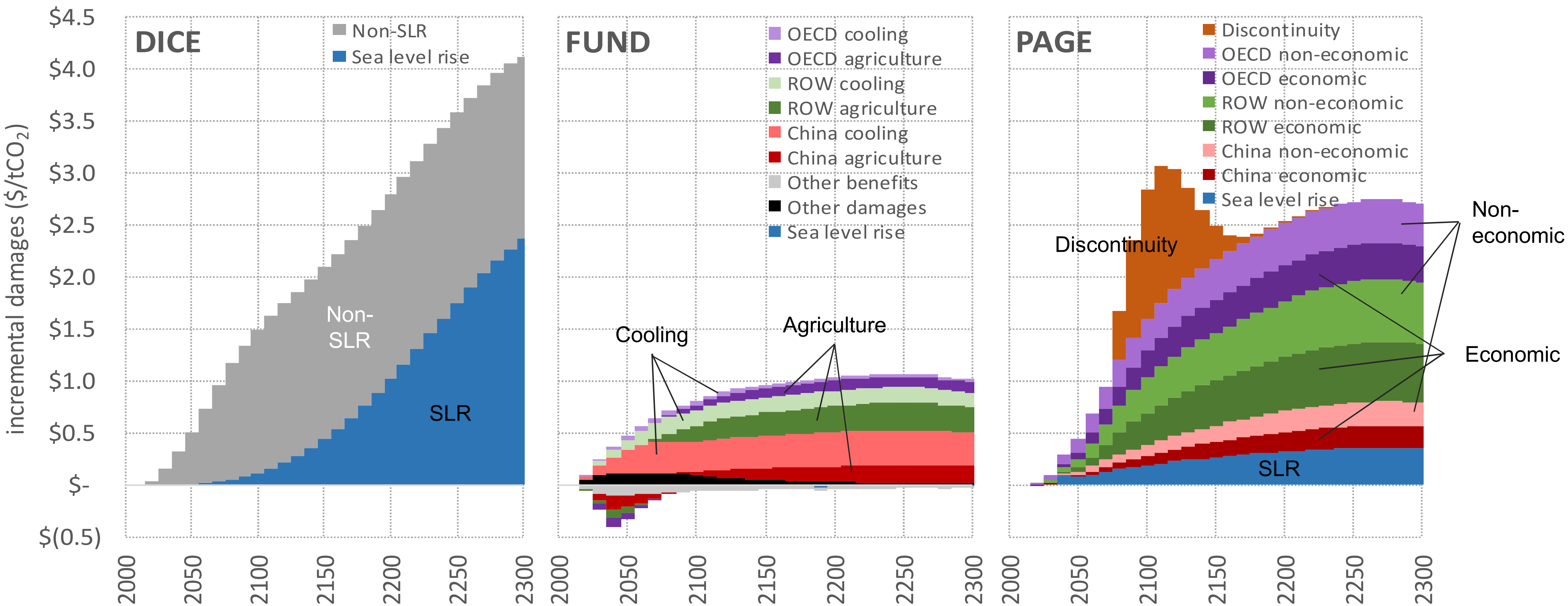
Climate component assessment – global temperature responses to 2100





Meaningful differences in outcomes and sensitivity for the same inputs. Trace to modeling & implementation features (e.g., carbon cycle, non-CO_2, forcing translation, pulse implementation).

Damage component assessment – annual incremental damages to 2300



Model specific features dominate incremental damages

Found fundamental SCC estimation & use issues that need to be addressed

Issues that impact the scientific reliability of SCC estimates, CO_2 reduction benefit and net benefit calculations, and insights and conclusions

SCC estimation issues

- Individual model issues
  - Model-specific issues
  - Transparency and justification
  - Damage representations dated & dependent
- Multi-model framework issues
  - Transparency and justification
  - Structural uncertainty representation
  - Input and parametric uncertainty representation
  - Comparability and independence of results
  - Robustness of results unlikely
  - Multi-model approach – reconsider.

Source: "Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study," *Climate Change Economics,* Vol. 8, No. 2, 2017.

SCC use issues

- Conceptual and methodological issues
- Different types of SCC estimates
- How to use multiple SCC values
- Consistency between benefit & cost calculations
- Accounting for net global CO_2 changes (leakage = lower CO_2 benefits)
- Valuing/pricing CO_2 more than once
- Valuing non-CO_2 GHGs

Source: *"Applying the Social Cost of Carbon: Technical Considerations,"* http://eea.epri.com (under "Research," "Integrated Assessment").

Summary remarks on SCC (SC-GHG) estimation and use

- For the first time we understand the inner workings of the SCC (and SC-GHG) modeling used by both the Trump & Obama Administrations
- We find fundamental issues with the modeling and use
- Issues that undermine confidence in current results and insights
- We need to pursue immediate improvements given the need for estimates today
  - Note: difficult to assess bias in current estimates given the issues and biases in both directions
- There are opportunities for immediate improvement
- Longer term improvement is also important, however, there are significant challenges to overcome

Concluding comments

- For company climate policy risk assessment and GHG goal setting, companies, stakeholders, and methodologies need to slow down and get grounded in science

- For the social cost of carbon, current model and use has fundamental technical issues, but there are immediate opportunities for improvement

Thank you!

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Resources

- Bistline, J and SK Rose, 2018. Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies, *Environmental Research Letters* 13 014027.
- Rose SK and J Bistline, 2016. *Applying the Social Cost of Carbon: Technical Considerations*. EPRI Report #3002004659 (Palo Alto, CA), http://epri.co/3002004659.
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- Rose, SK, M Scott, 2018. *Grounding Decisions: A Scientific Foundation for Companies Considering Global Climate Scenarios and Greenhouse Gas Goals*. EPRI, Palo Alto, CA. #3002014510.
- USG Interagency Working Group on Social Cost of Carbon, 2015. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, July.
- USG Interagency Working Group on Social Cost of Carbon, 2016. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, August.

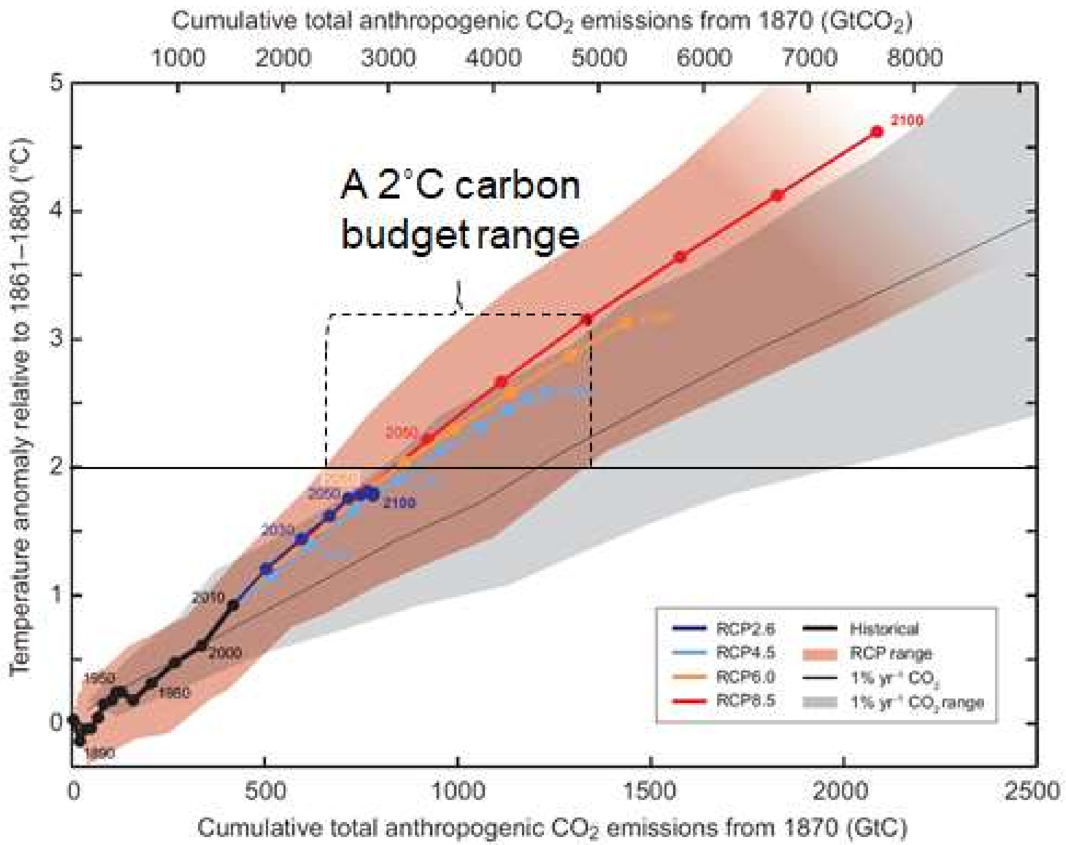
Appendix

Technical issues for companies & others to consider

1. What is the relationship between a company and a climate goal?
2. What does the 2˚C goal represent?
3. How do potential alternative company strategies compare?
4. How might non-climate-policy related risks and current strategy be considered?
5. Given uncertainties, what is a robust strategy?

A broad range of global CO_2 budgets consistent with 2˚C

- **Wide range of cumulative emissions (carbon budgets) consistent with a temperature**



IPCC WGI (2013)

IPCC scenarios category (CO_2eq concentration in 2100, ppm)		2011-2050 CO_2 budgets in scenarios ($GtCO_2$)	Probability of staying below 2˚C	Probability of staying below 3˚C
1	430-480	504-1423	63-88%	97-99%
2	480-530	465-1692	39-68%	90-97%
3	530-580	809-1999	16-46%	81-92%
4	580-650	1037-1925	7-26%	65-86%
5	650-720	1245-1767	5-12%	57-74%
6	720-1000	1424-2026	0-3%	17-45%
7	> 1000	1524-2694	0%	2-8%

Developed from IPCC WGIII (2014) and IAMC (2014)

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, Rose, Fujimori et al. (2018)

Despite broad ranges, there are robust insights

Insights found consistently across models and assumptions that provide a solid decision-making foundation for companies and others

- Global emissions must peak and decline for goals equal to or more ambitious than a 50% chance of limiting global warming to 3˚C
- A range of emissions pathways is consistent with a particular temperature because of uncertainty about the future
- An emissions pathway cost-effective for a given set of assumptions will not be cost-effective for every plausible future
- The cost-effective emissions reduction role of an economic sector is highly uncertain
- The cost-effective annual GHG reduction level (%) for a country/sector will not equal the cost-effective global level (%)
  - Assigning a global or other aggregate goal across countries and/or sectors will not be cost-effective
- The more ambitious the climate objective, and the more constrained the set of emissions mitigation options, the higher the emissions reduction costs and the rate of scenario infeasibilities
- For the most ambitious temperature targets (2˚C and lower), the largest rate of scenario infeasibilities occurs when negative emissions technologies (e.g., bioenergy with CCS, afforestation) are unavailable or constrained
- The emissions relationship with global temperature becomes increasingly uncertain the finer the resolution of the emissions source as more factors and interactions separate the source from global average temperature

Operationalizing the insights

The insights represent principles for evaluating methodologies, developing analyses, setting expectations

Company analysis issues for methodologies

- Emissions scenarios used?
- Uncertainties considered and how?
  - Temperature-emissions
  - Global pathway attainability
  - Policy design
  - Non-climate-related
- Consideration of company-specific context?
- Uniform vs. varied GHG targets across companies?
- Consideration of flexibility options?
- Quantitative comparison of alternatives?
- Evaluation of strategy robustness?

General steps for operationalizing insights

1. Utilize existing science
2. Develop emissions ranges
   - Uncertainties in the literature support emissions futures that exhibit slower growth, no growth, and declining, low, zero, and negative emissions
3. Specify alternative policy designs
4. Overlay company-specific context
5. Run preliminary analysis
6. Implement a scenario design
7. Identify risk management alternatives
8. Develop a robust strategy

Evaluating methodologies – sample

Attainability uncertainty widens ranges even further

Issue to consider	This study		SBTi	Ceres	UNEP FI pilot
	Emissions	Consistent with 2˚C			
Uncertainty in global temperature-CO_2 relationship for 2˚C (cumulative 2011-2050 $GtCO_2$)	Global net	465 to 1692	–	–	1139
	Global energy	324 to 1636	1085	–	1022
	Global electric	94 to 642	335	–	261
Uncertainty in global temperature-CO_2 relationship for 2˚C (annual changes in 2050 relative to 2010)	Global net	14% to -96%	–	–	-72%
	Global energy	9% to -99%	-52%	–	-58%
	Global electric	-2% to -163%	-89%		-94%
	U.S. net CO_2eq	-58% to -110%	–	-81% (80% relative to 1990)	–
	U.S. electric	-44% to -170%	–	-92% (90% relative to 1990)	–
Uniform vs. varied GHG targets across companies	Uniform targets found unlikely to be cost-effective		Proposes globally uniform sectoral targets	Proposes uniform target for all utilities	Implies uniform targets within sector segments

- Recent methodologies do not represent the uncertainty evident in the literature regarding emissions pathways consistent with limiting warming to 2˚C.
- They also propose applying uniform targets across companies

Fundamental issues with SCC models and USG framework

The study offers perspectives on models & differences not previously available

We observe fundamental scientific issues, and improvement opportunities for greater confidence in results

Fundamental Individual Model Issues

- **Model-specific issues**
  - **DICE** – no climate feedback, CO_2 pulse, quadratic damages, implied adaptation, limited parametric uncertainty, damages dependent on other models
  - **FUND** – partial radiative forcing, long temperature lag, potential for climate benefits and adaptation
  - **PAGE** – non-CO_2 forcing, ECS implementation, slow carbon cycle, CO_2 pulse, regional damage scaling, undefined damages, fixed adaptation, damages dependent on other models
- **Transparency and justification** for individual model structure and behavior
- **Damage representations** dated and dependent

Fundamental Multi-Model Framework Issues

- **Transparency and justification**
- **Structural uncertainty** representation
- **Input and parametric uncertainty** representation
- **Comparability and independence** of results
- **Robustness** of results unlikely
- **Multi-model approach** – reconsider.
  - Challenges (transparency, justification, comparability, and independence)
  - Consider developing a model component-by-component

NAS SCC Committee agreed that a new approach and model components were needed (NAS, 2017)

Rose et al (2017)