Integrated Assessment Models in the Policy Process

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Outline

- What is an "Integrated Assessment Model"?
- Their Role in the Policy Process
  - What are some applications/contributions to date?
  - Where could they be increasingly useful going forward?
    - Examples in Federal regulatory analysis
- Detailed Example: Development and Use of USG SC-GHG Estimates

What is an "Integrated Assessment Model"?

- In the broadest sense:
  - "*approaches that integrate knowledge from two or more domains into a single framework*" (Nordhaus 2013)
- Literature on "IAMs" is vast and spread across many disciplines
  - e.g., earth sciences, biological sciences, environmental engineering, economics, sociology, technological change, etc.
- In environmental economics, we are concerned with IAMs that combine natural processes and economic systems in a single modeling framework
  - E.g., models that "*connect economic activity with environmental consequences, and ultimately, with valuation*" (Keiser and Muller 2018)
  - "*a computer representation of the economics, physics, and other aspects of the problems that are deemed important to formulating policy*" (Kolstad 1999)

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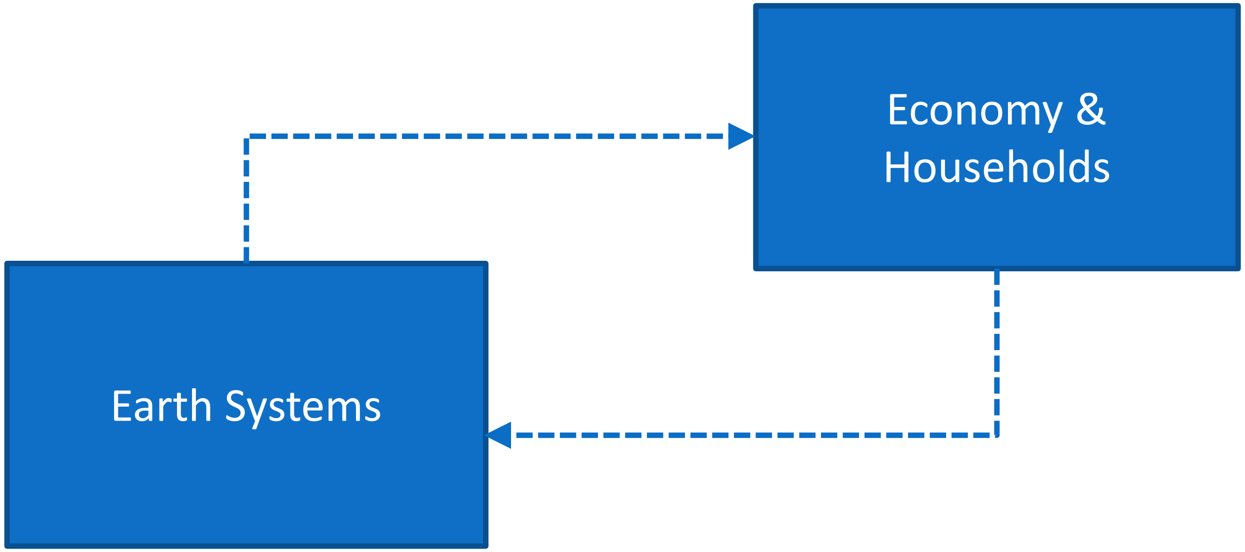
What is an "Integrated Assessment Model"?



- IAMs vary <u>significantly</u> in structure, geographic resolution, the degree to which they capture feedbacks within and between natural and economic systems and include valuation, and application.

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Why use IAMs?

- Provide a formal, transparent, reproducible way to model the consequences of problems that are complex, operate at different levels in time and space, are immersed in uncertainty.
- Bring discipline to how we chart the links within and between economic and natural systems
- Inform which feedbacks and interactions are worth worrying about
  - E.g., help identify unintended consequences of a single policy, spillovers across policies, tradeoffs or complementarities
  - Sort out priority areas for policy and additional research
  - When does the research have sufficient information at the system level to be able to recommend a policy outcome?
- “It’s not giving you precise answers…[but] it’s good guidance for policy” - Dr. Bert Metz

What have IAMs been used to study?

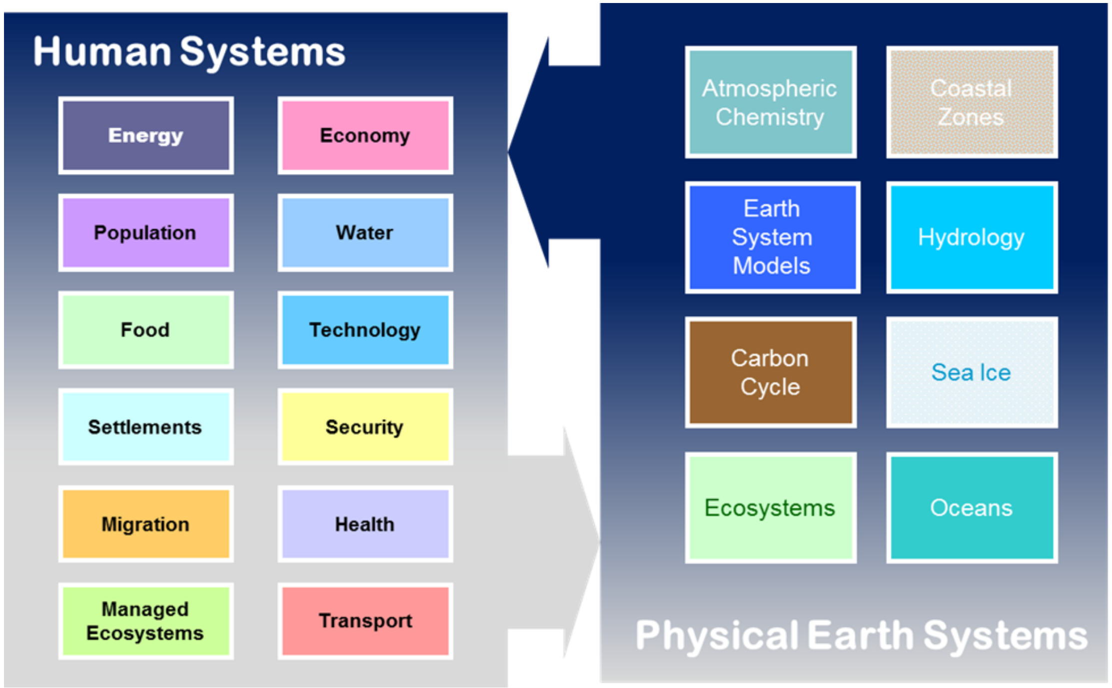
- IAMs have been used in the empirical environmental economic literature for nearly 40 years to study, e.g.,
  - Stock pollutants, primarily GHGs (e.g., Nordhaus 1993)
  - Flow pollutants, such as air pollution (e.g., Mendelsohn 1980) and water pollution (e.g., conceptual work by Freeman 1979, 1982)
- Over time, research in some areas is increasingly focused on improving representation of interactions and feedback loops
  - e.g., interaction between GHG mitigation and urban and regional air pollution policies (e.g., Reilly et al. 2007), linking dynamic economic and ecosystem GE models to study fisheries management (e.g., Finnoff and Tschirhart 2008), developing complete IAM of food-water-energy nexus (Kling et al. 2017), etc.
- While in other areas current efforts are still trying to develop IAMs to trace changes in pollutant loadings through to physical and human impacts, and on to valuation
  - e.g., to estimate benefits of surface water quality policies

IAMs of Global Climate Change

"..computational models of global climate change that include representation of the global economy and greenhouse gas emissions, the response of the climate system to human intervention, and impacts of climate change on the human system" - National Academies of Sciences, Engineering, and Medicine (2017)

Types of Climate IAMs

- ***Detailed-structure***– used for describing the detailed interactions of human and physical Earth systems, mostly in physical units.
- ***Reduced-form***– the primary models used in developing the social cost of carbon.



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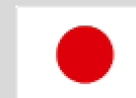
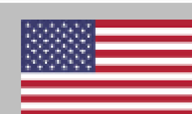
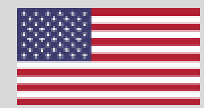
Detailed-structure climate IAMs
(or "Detailed Process", "complex", "highly resolved")

- More disaggregated, physical system representations are spatially and structurally explicit, interactions between impact areas the socioeconomic system can be tracked at various geographical scales
  - Originally developed to study the effects of technology and policy on GHG emissions (e.g., Edmonds and Reilly, 1983)
  - Increasingly include elements of impacts and adaptation (e.g., Reilly et al. 2012a; Calvin et al. 2013)
- Generally do not measure economic damages and reduced growth due to climate change
- Often used in scenario development, cost-effectiveness analysis, to study climate impacts by sector and region, to answer "What if..", "How can we get to.." questions

Detailed-structure IAMs are developed by interdisciplinary teams

Model	Home Institution (Staff)	
*AIM** Asia Integrated Model	National Institutes for Environmental Studies, Tsukuba Japan (50 IAM / 50 Climate)	
*GCAM** Global Change Assessment Model	Joint Global Change Research Institute, PNNL, College Park, MD (30 IAM)	
IGSM Integrated Global System Model	Joint Program, MIT, Cambridge, MA (25 IAM / 25 Climate)	
*IMAGE** The Integrated Model to Assess the Global Environment	PBL Netherlands Environmental Assessment Agency, Bildhoven, The Netherlands (40 IAM)	
*MESSAGE** Model for Energy Supply Strategy Alternatives and their General Environmental Impact	International Institute for Applied Systems Analysis; Laxenburg, Austria (50 IAM)	
REMIND Regionalized Model of Investments and Technological Development	Potsdam Institute for Climate Impacts Research; Potsdam, Germany (65 IAM / 50 Climate)	

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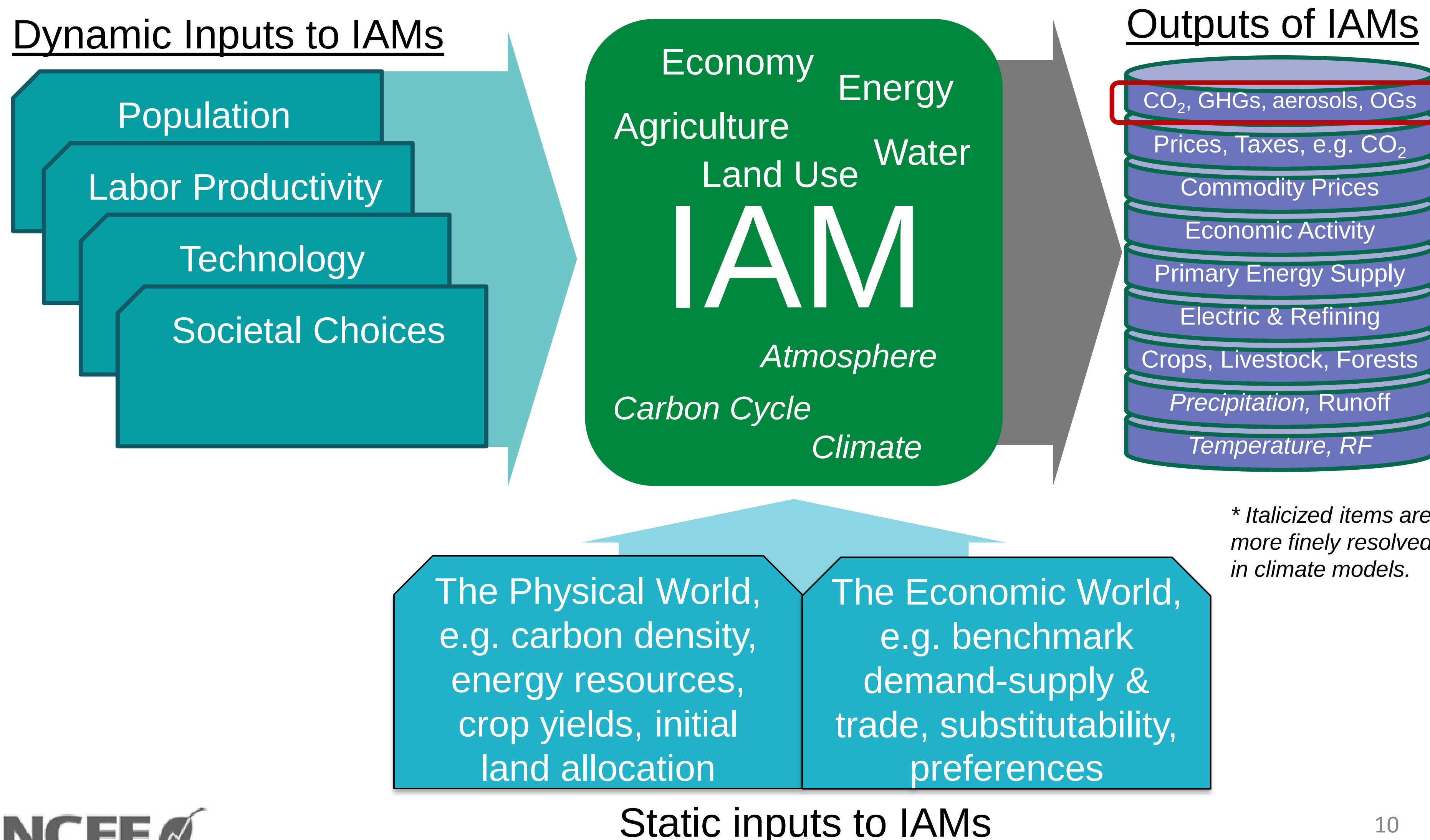
** Produced one of the four RCP's*

Detailed-structure IAMs: Inputs and outputs



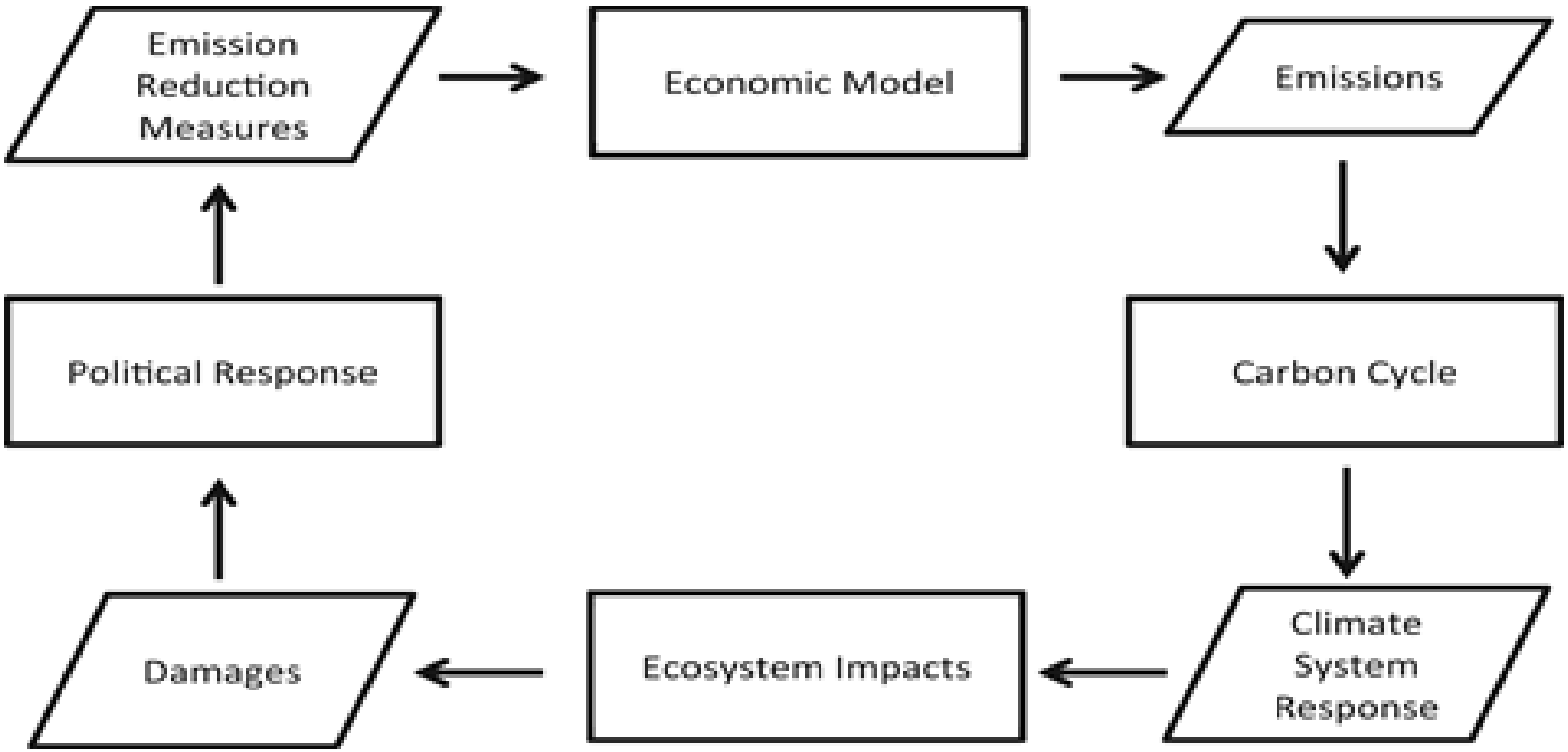
Applications of Detailed-structure IAMs

- Mitigation analysis
  - Study energy-economy impacts of climate change mitigation policies, including inter-model comparison studies (EMF, etc.)
  - Input to IPCC scenario development (SRES, RCPs, AR4, AR5, 1.5^0 report, SSP)
    - E.g., 31 IAMs contributed pathways to the IPCC's most recent fifth assessment report, which drew from a database of 1,184 distinct scenarios.
  - International negotiations: IAMs are relevant to political processes, even if IAM results have less relevance for detailed negotiations over legal text.
- Climate impact analysis
  - Serve as input to National Climate Assessment
- Integrated mitigation and impacts analysis
  - Consider physical and economic interactions between impact sectors and feedbacks to climate
    - E.g., competition between for water between agriculture and power plant cooling needs in a hotter, drier climate, etc.

Reduced-form climate IAMs
(or "Benefit-Cost", "simple", "highly aggregated")

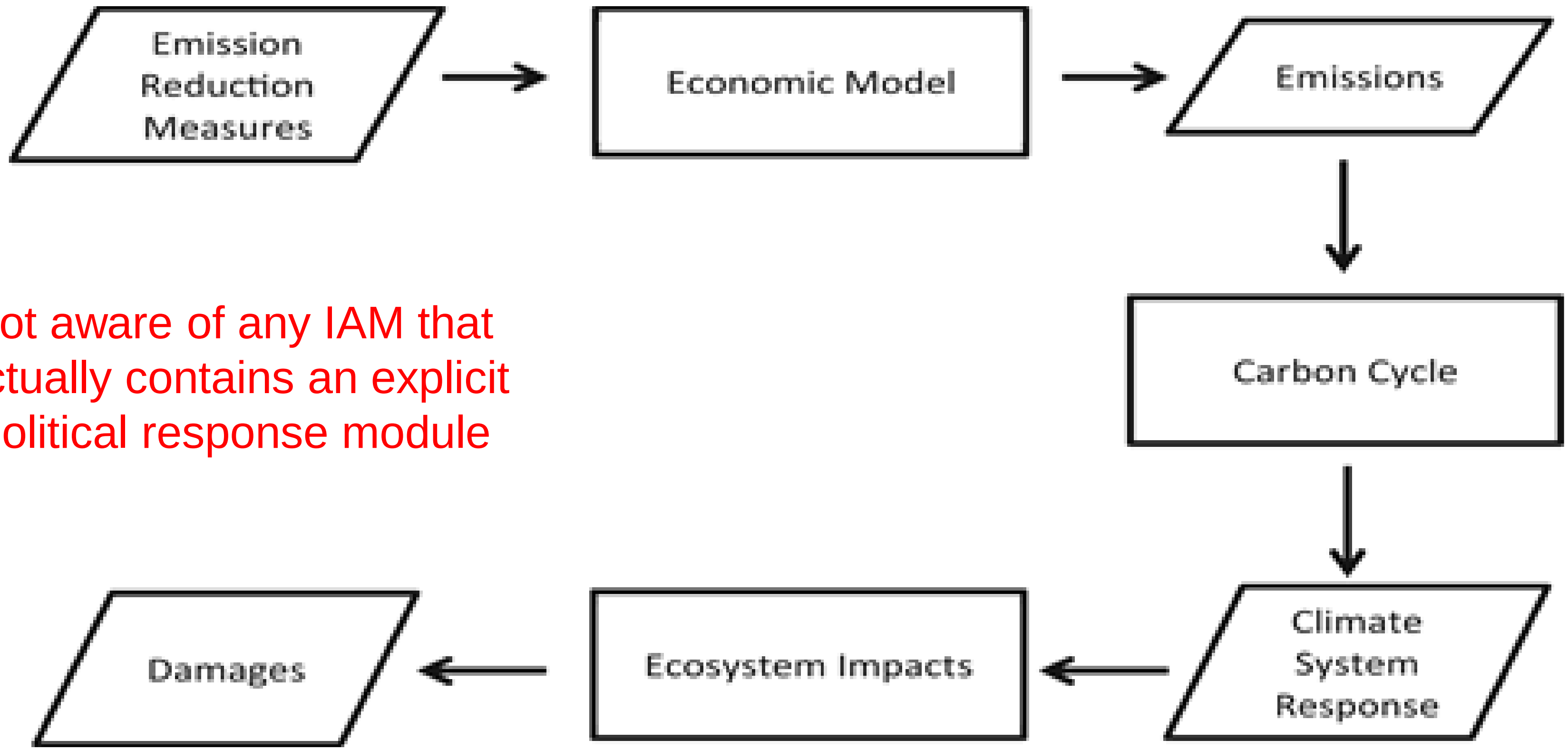
- More aggregated representation of climate mitigation costs and impacts by sector and region into single economic metric
  - Originally developed (e.g., Nordhaus, 1994) to study optimal global CO_2 emissions trajectories and carbon prices that maximize global welfare.
- Include rough valuation of climate damages
- Geared towards use in BCA – to identify optimal climate policies, monetize costs or benefits of non-optimal policies, calculate social cost of carbon and other GHGs
- Generally developed by small teams (mostly economists), e.g.:
  - DICE/RICE (Nordhaus, 2014), PAGE (Hope, 2013), FUND (Anthoff and Tol, 2013), WITCH (Bosetti et al., 2007), ENVISAGE (Roson and Van der Mensbrugghe, 2012), VOICE (Newbold and Marten, 2014), CRED (Ackerman et al., 2013), AD-RICE (de Bruin et al., 2009), and other derivatives and unnamed single application models

Reduced-form climate IAMs



Source: Metcalf and Stock 2017; adapted from Nordhaus 2013

Reduced-form climate IAMs



not aware of any IAM that actually contains an explicit political response module

Source: Metcalf and Stock 2017; adapted from Nordhaus 2013

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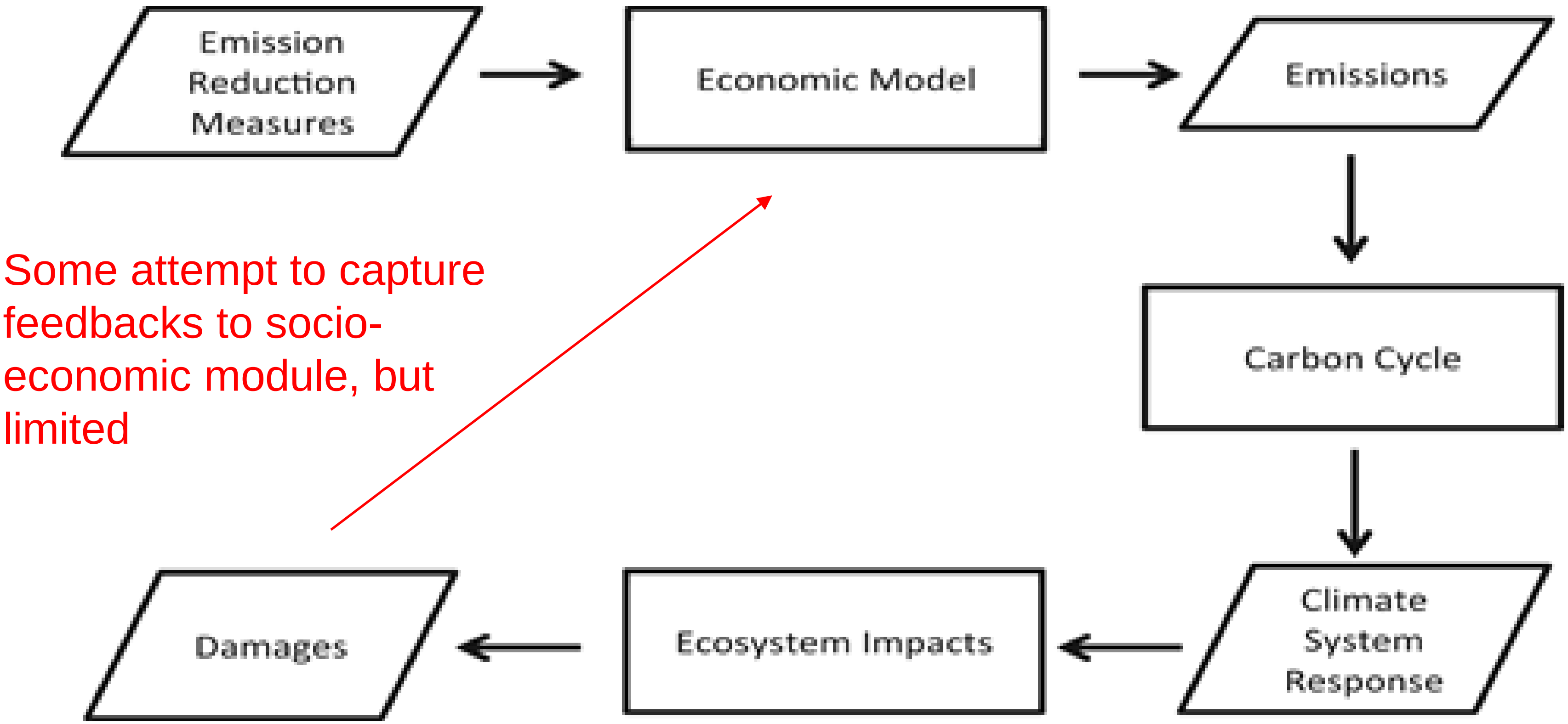
Reduced-form climate IAMs



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Applications of Reduced-form climate IAMs

- Determine “optimal” climate policies
  - Optimal policy is set where marginal abatement cost = marginal benefit of emission reduction
  - Although range of optimal carbon tax estimates is large, the IAMs have helped to highlight the important drivers of projected costs and benefits – e.g., discounting, damage functions

- Evaluate costs and benefits non-optimal climate policies
  - Shed light on relative cost and benefits of non-optimal (e.g. max temperature increase of 2^0 C) vs. optimal policy

- Estimate the social cost of carbon and other GHGs (SC-GHG)
  - Used to value GHG emissions changes in regulatory BCA, and some non-regulatory contexts

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Basic IAM for water or air pollution

- Full IAMs combine four components—emissions, pollution transport, environmental and human outcomes, and valuation
- Each component could have a stand-alone model, and some IAMs merely consist of links among four existing stand-alone models.
- Existing IAMs in this contexts generally do not yet capture feedbacks across components to close the loop

Emissions
specific water or air pollutants from point and nonpoint sources

↓

Dispersion/concentrations
fate and flow of pollutants using hydrologic or atmospheric models

↓

Exposure
to natural systems and humans

↓

Physical effect
of exposure on natural systems and humans

↓

Valuation
values of use at different levels of quality/pollution

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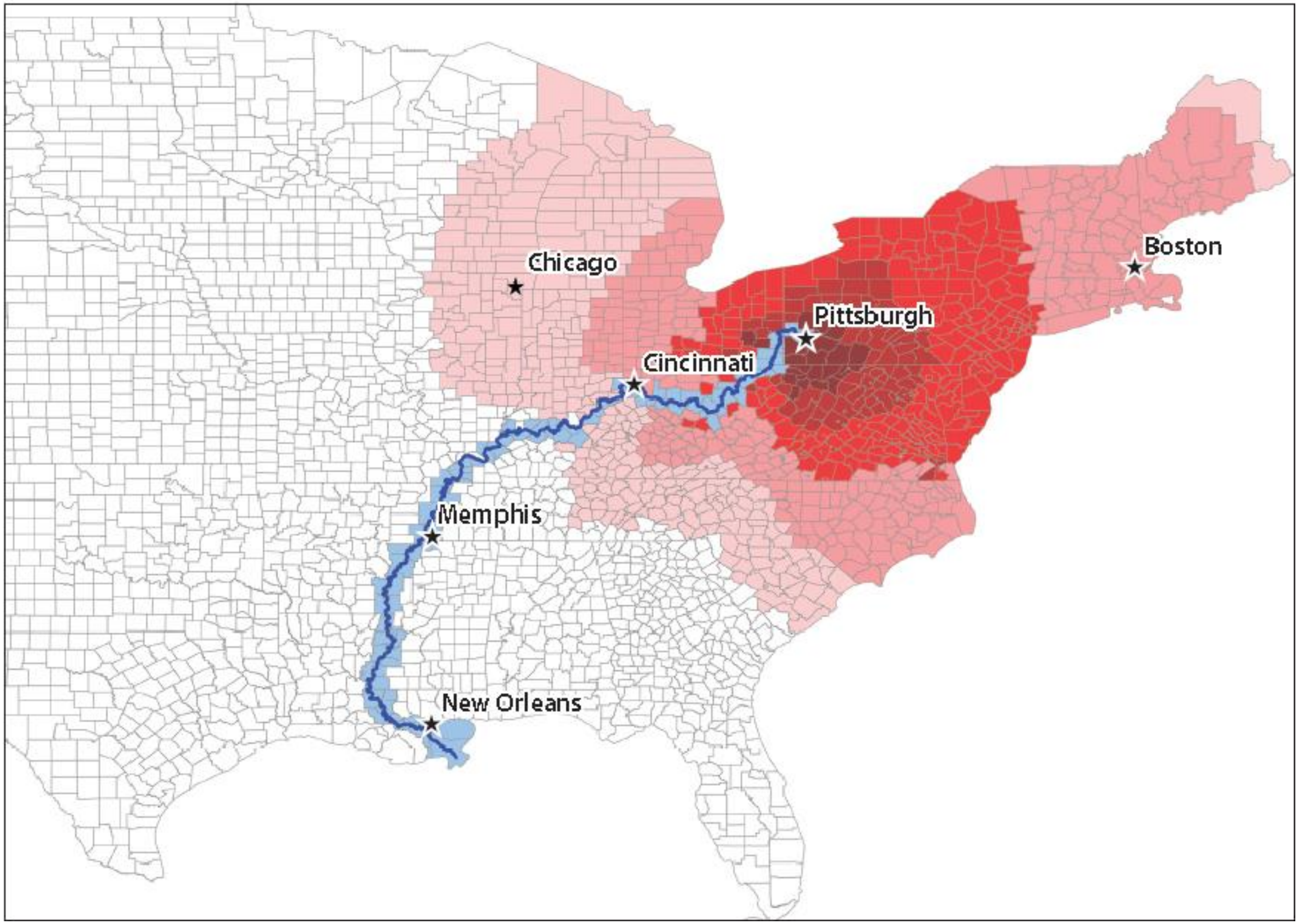
Source: Keiser and Muller (2017)

Potential differences in transport of air and water pollution



Downwind and downstream counties from Pittsburgh, PA

Source: Keiser and Muller (2017)

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IAMs for air pollution

- Tracking and Analysis Framework (TAF)
  - Early example of IAM for air pollution
  - Developed within National Acid Precipitation Assessment Program (NAPAP), funded by U.S. DOE, to study EPA's Acid Rain program
  - Used to advise several states and EPA and basis of several articles (e.g., Burtraw et al. 1998), and motivated follow on work

- Current air IAMs in the literature include APEEP/AP3 (more on this from Nick!) and others (EASIUR, InMAP?)

- Some EPA analyses are also in effect IAMs
  - E.g., periodic reviews mandated by Congress -- 812 Reports (1 retrospective and 2 prospective BCA of CAA and CAAA)
  - EPA's current approach for some ex ante regulatory analyses may also be considered to be IAM

Tracking Analysis Framework (TAF)

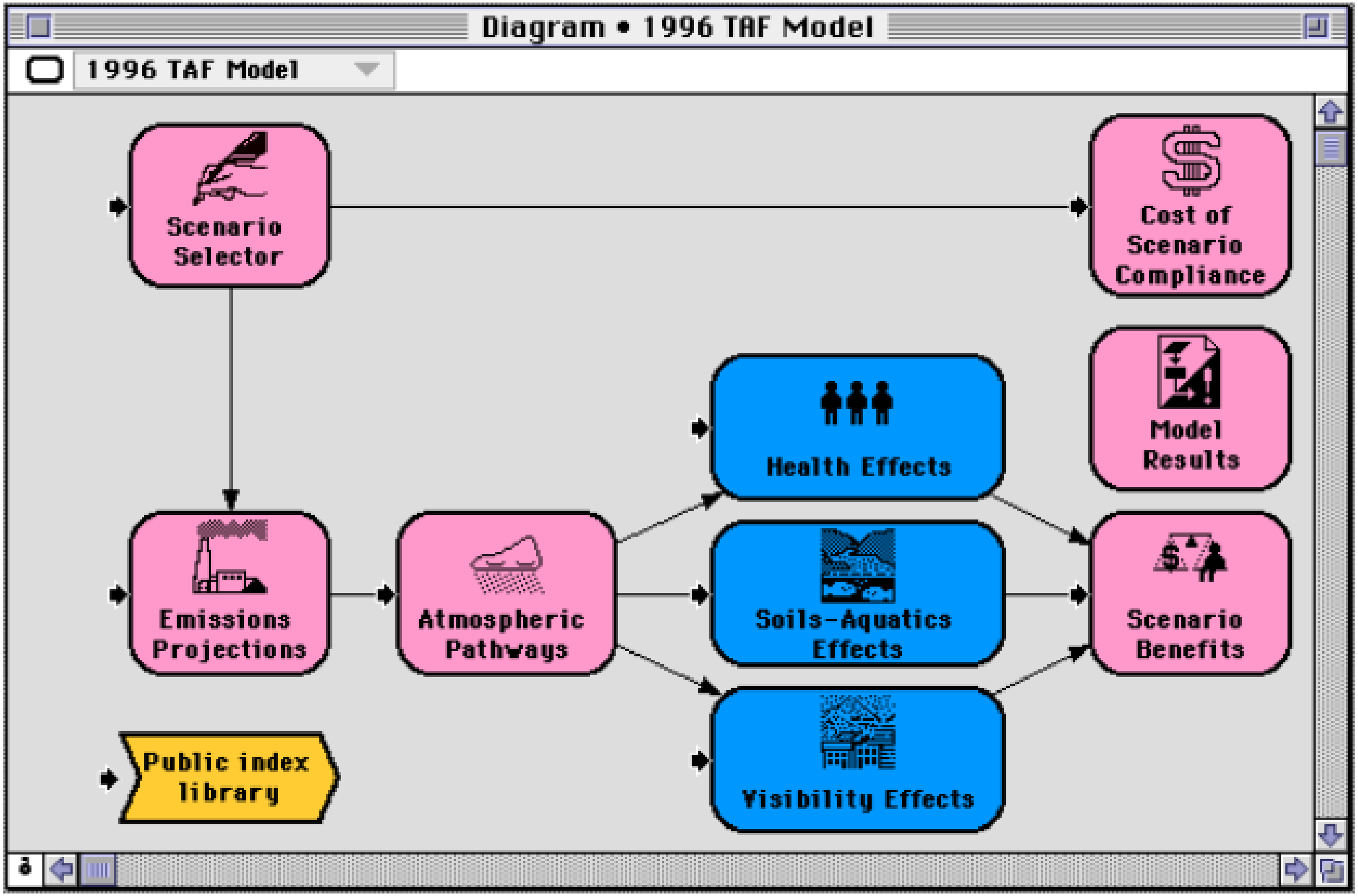


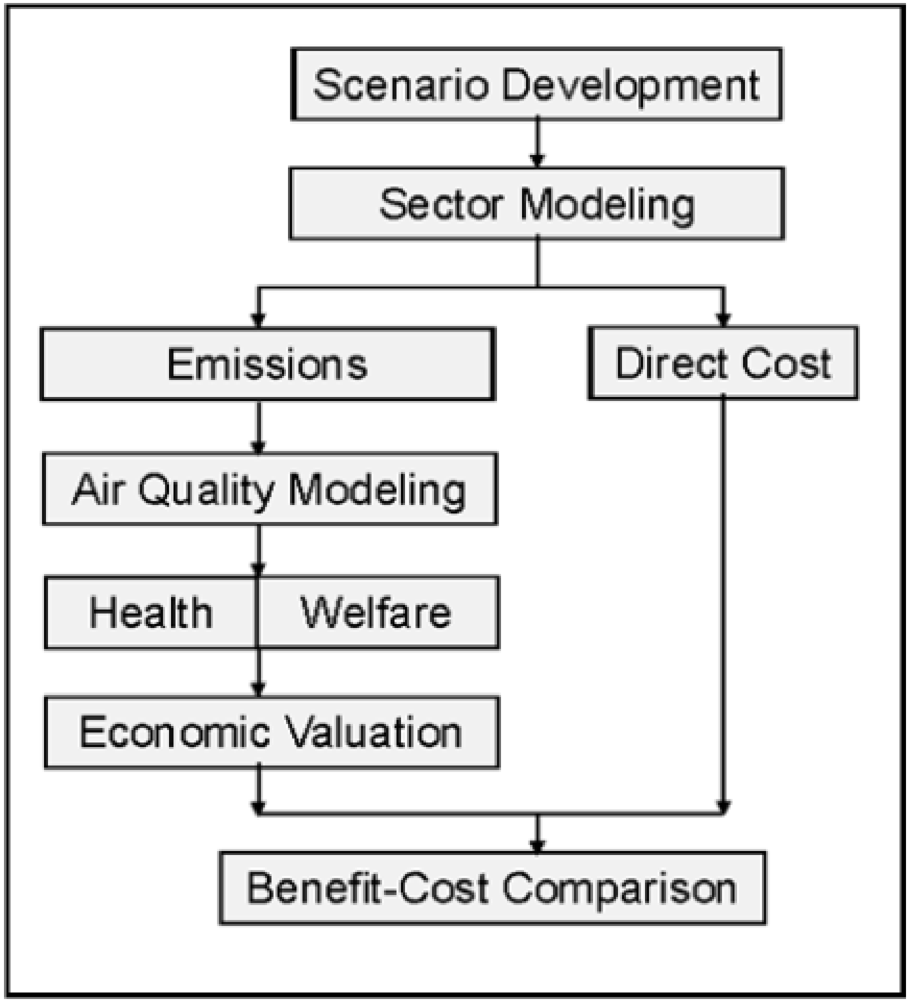
FIGURE 2-3 Top-Level TAF Model Diagram V

Source: Argonne National Lab (1996)

EPA's 2nd prospective 812 Study: Benefits and Costs of the Clean Air Act, 1990 to 2020

- Benefits: Greater reliance on nationwide air quality models for each criteria pollutant, rather than aggregating the results of multiple models. Added speed and simplicity to the overall analytic process, and facilitated disaggregation of benefits.

- Costs: Supplementary analysis included estimation of GE impacts of control costs, and some feedbacks from benefits side (i.e., improvements in labor force participation and productivity, and savings on costs of treating air pollution-related illnesses).



Analytical sequence of 2nd prospective study (EPA 2011)

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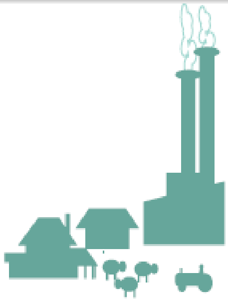
Current EPA modeling framework for analysis of electricity/mobile rules

IPM for EGUs;

MOVES for mobile

CAMx/CMAQ for photochemical modeling

BenMAP for exposure, dose-response, health endpoints, valuation



Emissions
specific water or air pollutants
from point and nonpoint sources

↓

Dispersion/concentrations
fate and flow of pollutants using hydrologic
or atmospheric models

↓

Exposure
to natural systems
and humans

↓

Physical effect
of exposure on natural systems
and humans

↓

Valuation
values of use at different levels
of quality/pollution

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In what areas could IAMs be increasingly useful in the policy process?

- Well, countless..
- …but let's focus on regulatory benefit-cost analysis.
  - Potential "generic" advantages of using IAMs vs. starting from scratch for each analysis
  - Best practices for reducing misuse and increasing *acceptance* in the policy process
  - 3 examples in EPA regulatory BCA

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Potential advantages of IAMs in regulatory BCA

- More cost-effective than starting from scratch each time you face a challenge to quantify the benefits (or costs) of a policy change.

- Decision makers (and the public) invest in understanding the output and reporting of results.

- Increases consistency across analyses

- Allows a more complete exploration of co-benefits and co-costs, and better ways to capture feedbacks

- Fosters research and competition. As EPA uses IAMs, research community responds with better models. Easier to focus scarce resources on model improvements.

Best practices for IAMs in regulatory BCA

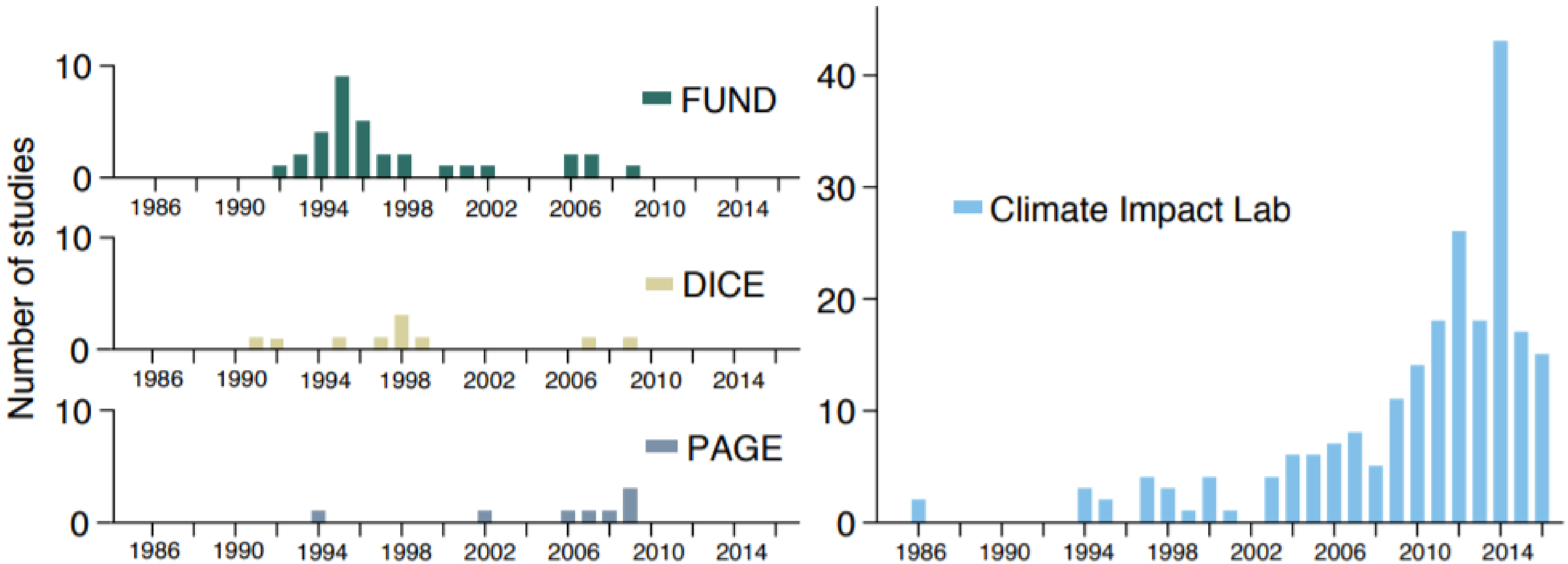
- Developed with interdisciplinary input
  - Even most reduced form IAM could benefit from more cross-disciplinary discussion (e.g., representation of "catastrophic" climate impacts (Kopits et al. 2013))
- Understandable and transparent
  - Documentation!
  - Ideally, the model can be in the public domain so others can replicate results
- Careful communication of model purpose, results, and esp. treatment of uncertainty
- Regular updating process and peer review!
  - Peer review is critical to establishing broad, durable support
  - Regularized updating balances benefit of responding to evolving research with the need for a thorough and predictable process, including proper review of changes
- Flexible and fast enough to use *for the policy process it intends to inform*

3 Examples in EPA regulatory analysis

- Continued updating of SC-GHG estimates, including "domestic" SC-GHG
- Help in benefits evaluation of air rules?
- Water quality benefits valuation

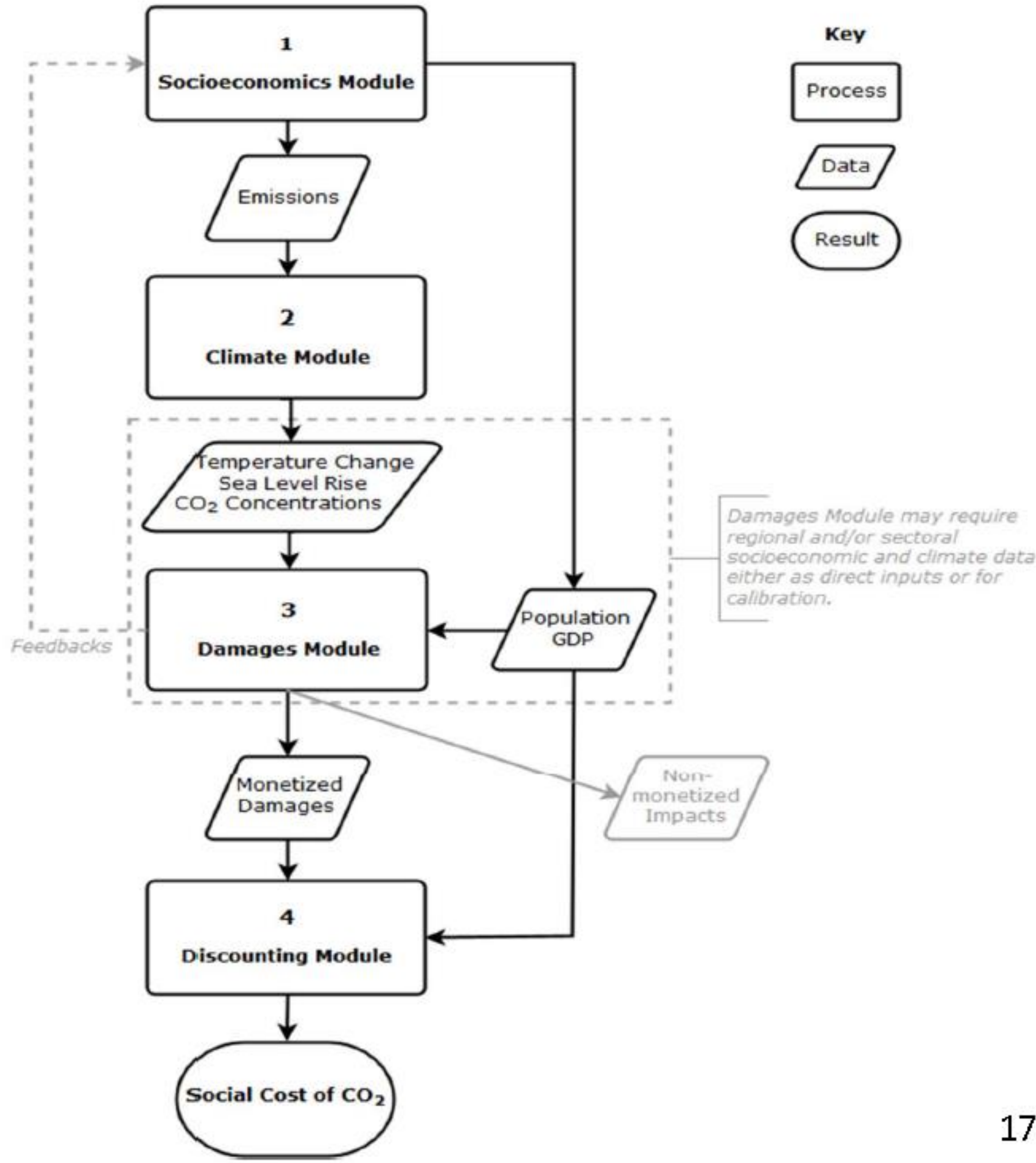
Example 1: SC-GHG

- SC-GHG estimates are needed for BCA of federal regulations, and are potentially useful for non-regulatory policy analysis as well.
- Strengths and limitations of USG estimates that are currently used have been thoroughly discussed.
- At a minimum, everyone can agree they do not reflect the best available science and economics.



Example 1: SC-GHG

- In 2015, USG asked National Academies for advice on how to proceed
- 2017 National Academies report
  - Proposed an integrated, modular framework for estimation
  - Specific recommendations for each of the 4 key modeling steps in the near term (2-3 years) and the longer term
  - Directions for future research
- Research community has started large scale efforts in response to these recommendations:
  - Resources for the Future
  - Climate Impact Lab



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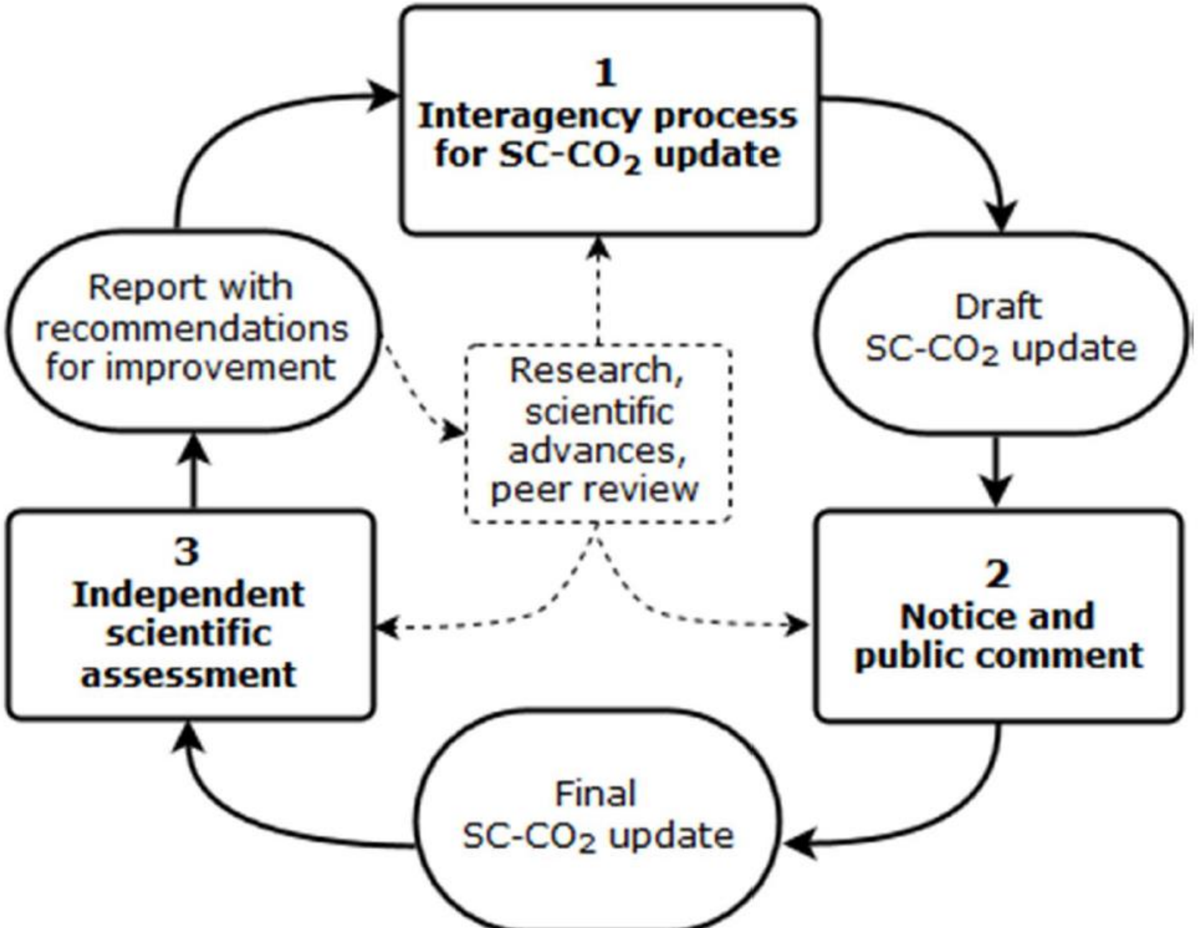
Example 1: SC-GHG

- National Academies report also offered a very useful roadmap for a regularized updating process going forward.



Example 1: SC-GHG

- There will also continue to be a need for improved characterization of “domestic” damages
  - OMB Circular A-4 guidance for regulatory analysis:

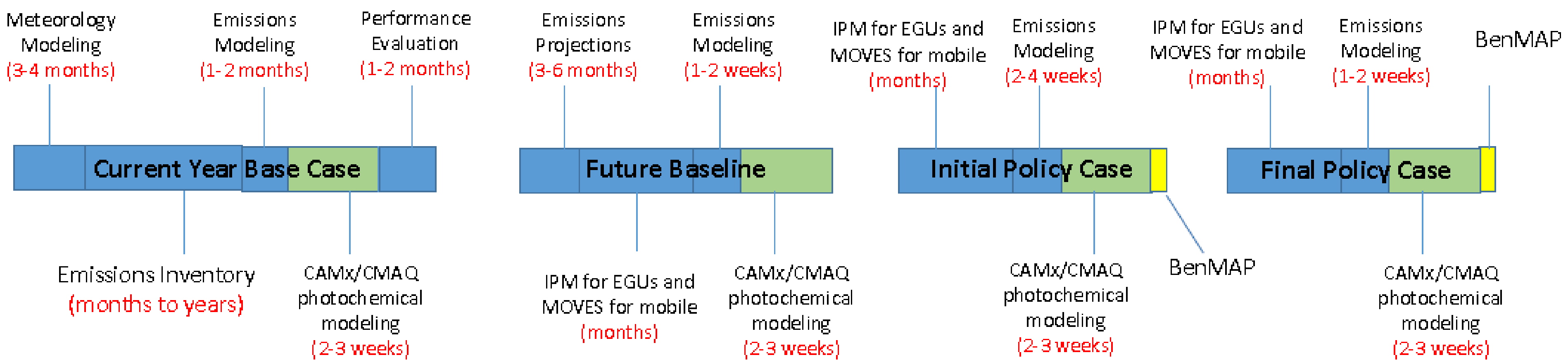
    “Analysis should focus on benefits and costs that accrue to citizens and residents of the United States….[when evaluating] a regulation that is likely to have effects beyond the borders…, these effects should be reported separately.”
  - Current “interim domestic” estimates provide crude measure of damages resulting from physical climate impacts occurring within using borders

- As discussed in the National Academies report,
  - Important to consider what constitutes domestic impact in the context of a global pollutant that has international implications that affect the US.
  - Existing IAMs do not model all relevant interactions among regions.
  - In estimating domestic SC-GHGs need to consider potential implications of climate impacts on other countries and actions by other countries.

Example 2: Help in evaluating air rules?

EPA's current process for evaluating air pollution rules:

- Full-Scale Air Quality Modeling Process (illustrative schematic)



- When there is not enough time or resources to do this, the agency often relies on benefit-per-ton (BPT) estimates or other approximation approaches to shorten parts of this process
- EPA has project underway to evaluate the degree of consistency between RF approaches such as BPT and full-scale AQM

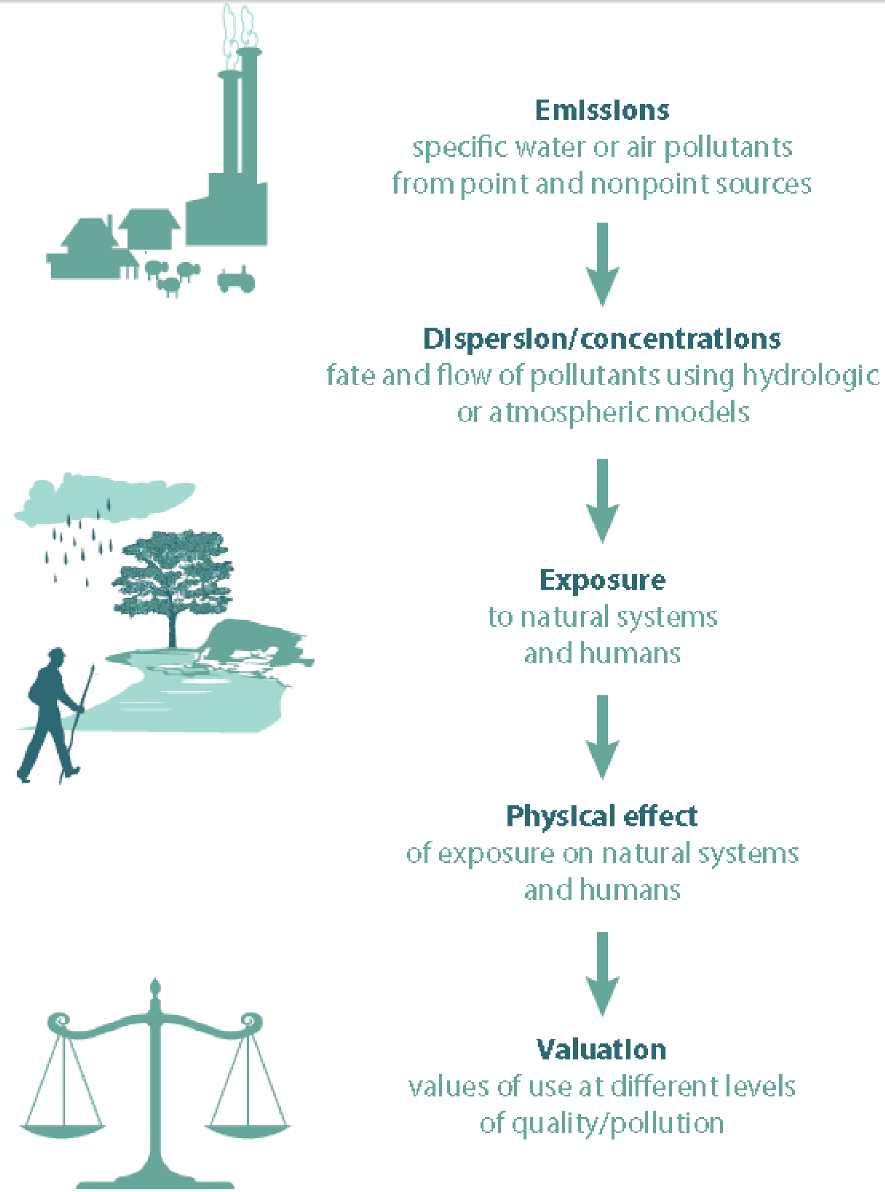
Example 2: Help in evaluating air rules?

IPM for EGUs;

MOVES for mobile

CAMx/CMAQ for photochemical modeling

BenMAP for exposure, dose-response, health endpoints, valuation



Example 2: Help in evaluating air rules?

IPM for EGUs;

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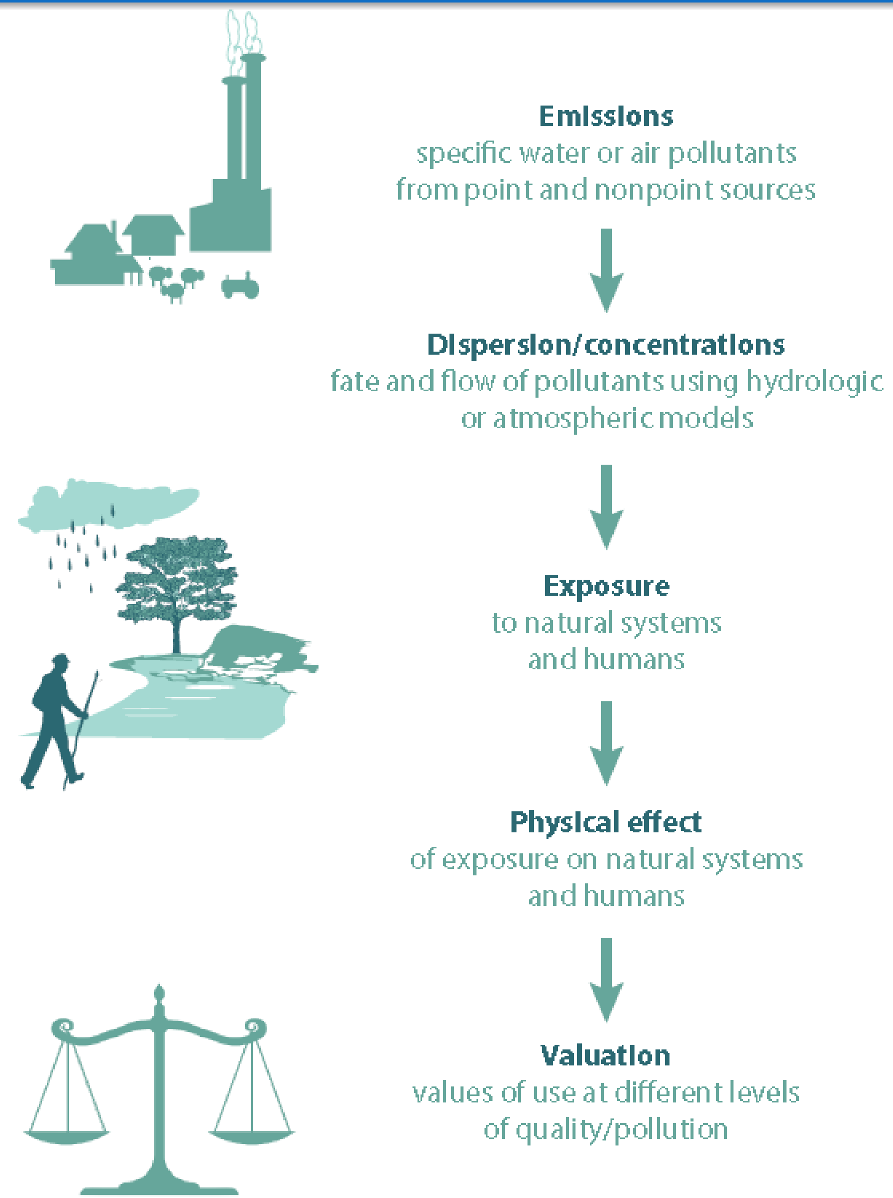
Current

“Benefit-per-ton”

or other approx method



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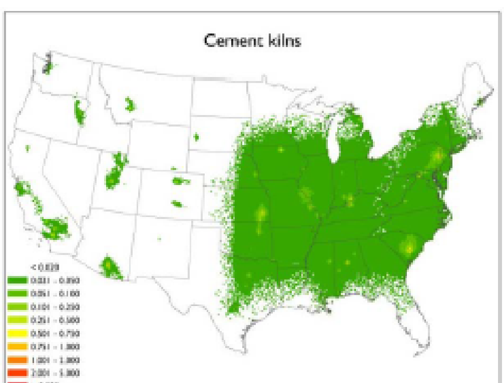
Example 2: Help in evaluating air rules?

EPA's "Benefit-per-ton" approach:

- Air quality modeling, either via a single scenario or via source apportionment, can estimate the response of a particular pollutant (e.g., annual average PM2.5) to the emissions from a selected scenario or sector at the grid cell level
- BenMAP estimates the health impacts and economic value associated with these model-estimated pollutant responses at the county-level (baseline incidence)
- Benefit-per-ton values are then calculated by dividing the nationally-aggregated BenMAP estimated benefits by the scenario/sector emissions for a single national-scale aggregated metric



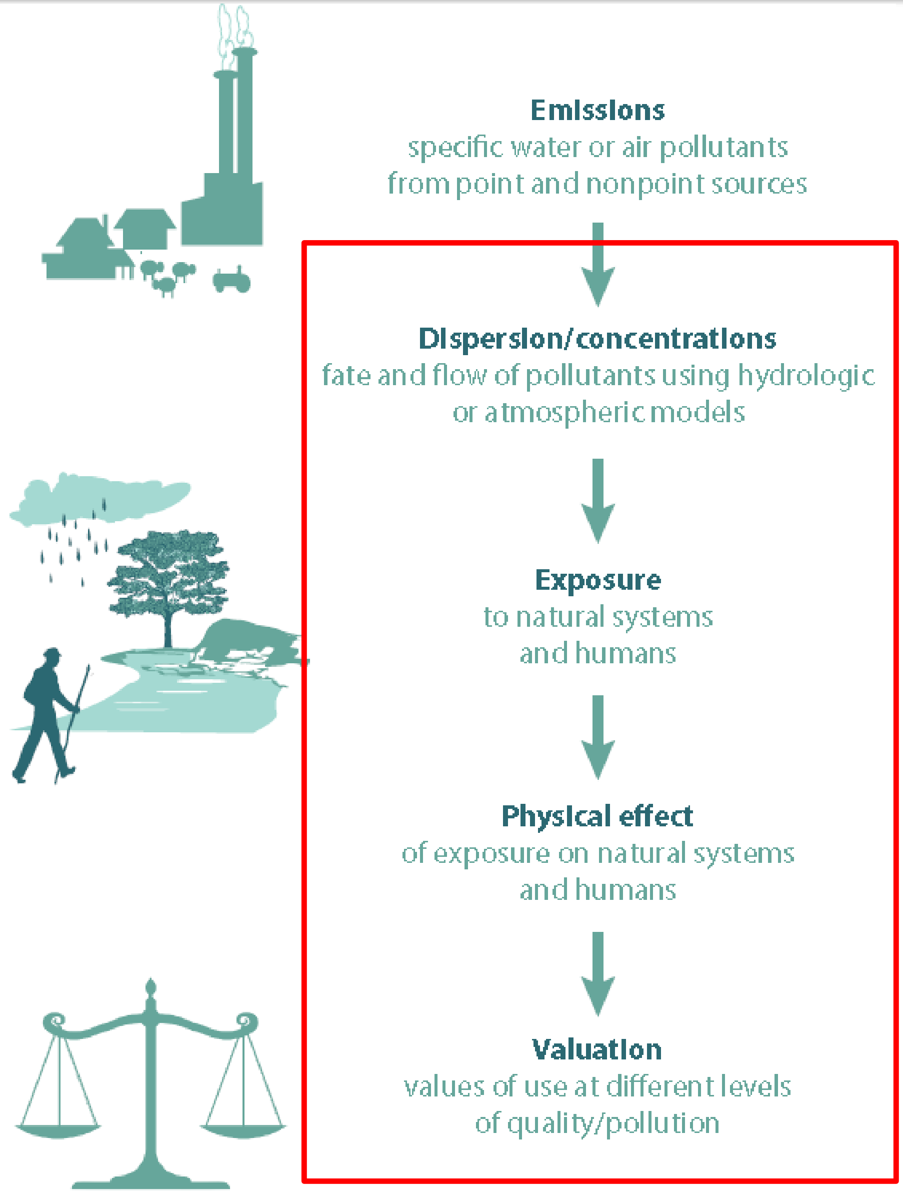
BenMAP COMMUNITY EDITION

$$Health\ Benefits \div Emissions = Benefit\ per\ ton\ (\$/ton)$$

Example 2: Help in evaluating air rules?

Questions for consideration:

- In what cases are relationships in the chain from emissions to valuation reasonably locally linear within the neighborhood of the regulatory action under consideration?
- If there are considerable non-linearities, can reduced-form IAMs improve on BPT approaches, when timely full-scale air quality modeling is not possible?



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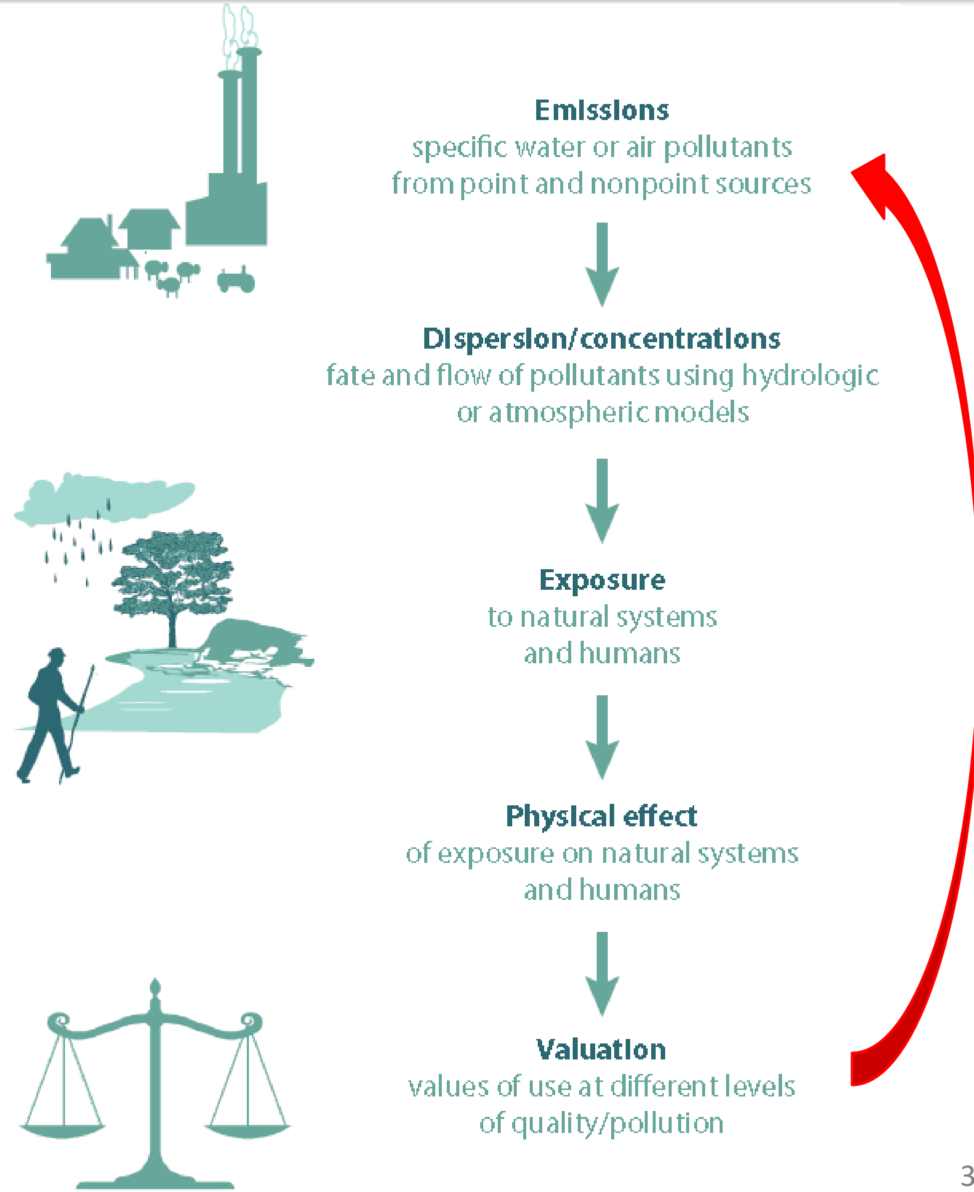
Example 2: Help in evaluating air rules?

Questions for consideration:

- Can IAMs help inform when feedbacks to close the loop are important to capture in non-climate applications?
- Marten and Newbold (2017) have done some initial work in this area looking at GE feedbacks from reductions in mortality risk



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Example 3: Water quality valuation

- Trends in regulatory analysis of water quality improvements:
  - less reliance on case studies to estimate benefits, and
  - greater reliance on large-scale water quality models (e.g., NWPCAM, SPARROW).
  - progress has been much slower with valuation measures. Challenges have included: (a) the standardization of measures of water quality improvement, (b) the measurement of benefits arising from ecological protection and restoration, and (c) the measurement of nonuse benefits.

- Efforts underway in academia and government to make progress on the valuation component in a way that can be integrated with the output of water quality fate and transport models for broad-scale water quality benefits analysis
  - April 2019 Cornell workshop organized by David Keiser, Cathy Kling, and Dan Phaneuf to coordinate and encourage research and discussion of IAMs of social cost of water pollution
  - EPA is developing an IAM that combines a newer, faster water quality model (HAWQS) with a new benefits module (BenSPLASH)

Example 3: Water quality valuation

Current EPA Effort:

- Objective: Develop a modeling framework to quantify the economic benefits of aquatic environmental changes nationwide
  - Open source
  - National, spatial
  - Freshwater rivers/streams, lakes, (coasts, wetlands)
- Advantages of the two models
  - HAWQS – faster, more efficient, less costly modeling (e.g., reduces repeat studies), open-source architecture to promote transparency
  - BenSPLASH – replaces ad hoc benefits approaches and expands benefits coverage to national scale; based on established data sets (NLCD, Census, NHDv2) and widely-used tools (Water Quality Index, Meta regression).
  - Together, integrated use of HAWQS+BenSPLASH can support benefits assessment at national, regional, state, and local scales

Example 3: Water quality valuation

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- Objective: Develop a modeling framework to quantify the economic benefits of aquatic environmental changes nationwide
  - Open source
  - National, spatial
  - Freshwater rivers/streams, lakes, (coasts, wetlands)
- Two models
  - HAWQS – Water Quality Model
  - BenSPLASH – Benefits Model
- Case study using HAWQS 1.0 and BenSPLASH prototype now available! (Corona et al. 2019)

Source: Corona, Doley, Griffiths, Massey, Moore, Muela, Rashleigh, Wheeler, Whitlock, and Hewitt (2019)

Example 3: Water quality valuation

- **Hydrologic and Water Quality System (HAWQS)**
- **A national watershed and water quality assessment system**
  - Web-based user interface
  - National data layers
  - SWAT as core engine
- Cooperative project of the:
  - USEPA
  - USDA-ARS Grassland Soil and Water Research Lab
  - AgriLIFE Research, Texas A&M University
- HAWQS 1.0 released September 2017, currently developing 2.0

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Example 3: Water quality valuation

HAWQS

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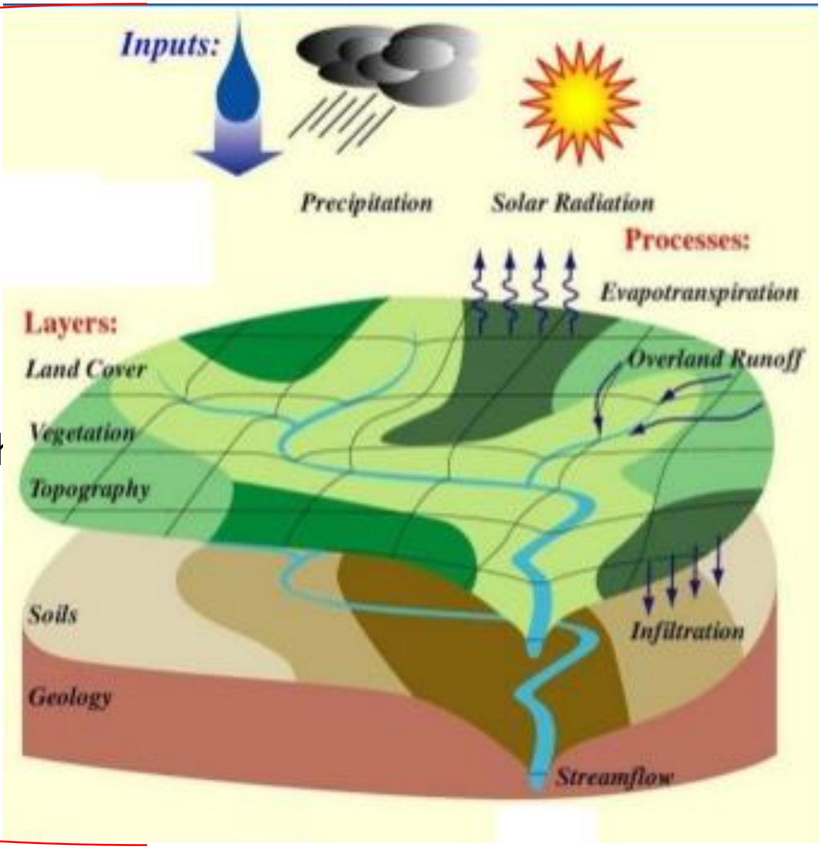

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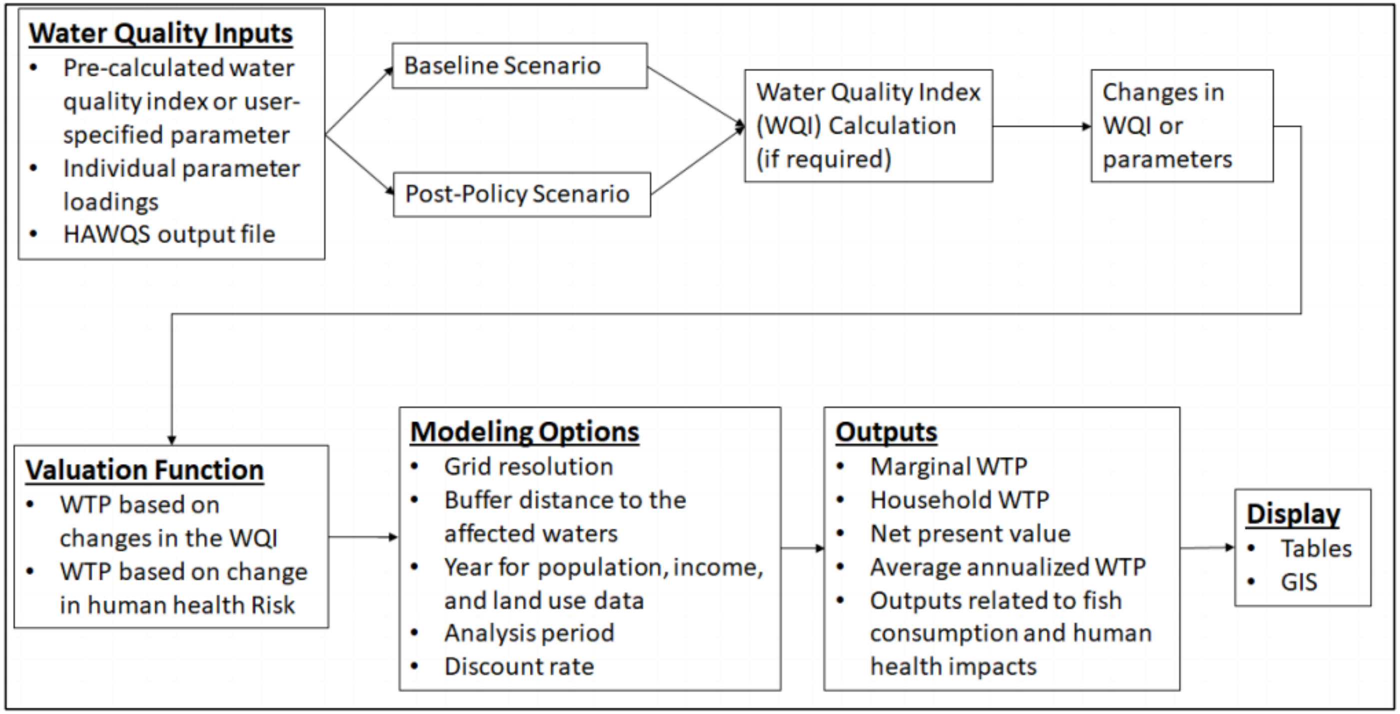
Source: Corona, Doley, Griffiths, Massey, Moore, Muela, Rashleigh, Wheeler, Whitlock, and Hewitt (2019)

Example 3: Water quality valuation

- **Benefits Spatial Platform for Aggregating Socioeconomics and H²O Quality (BenSPLASH)**
- Prototype developed as proof of concept for EPA leadership in 2016
  - Focused on valuation practices commonly used to support EPA regulations
  - Borrowed heavily from existing models/data, some proprietary

BenSPLASH today

- Currently under development
- Open source
- Default valuation approaches + R window for user-defined applications



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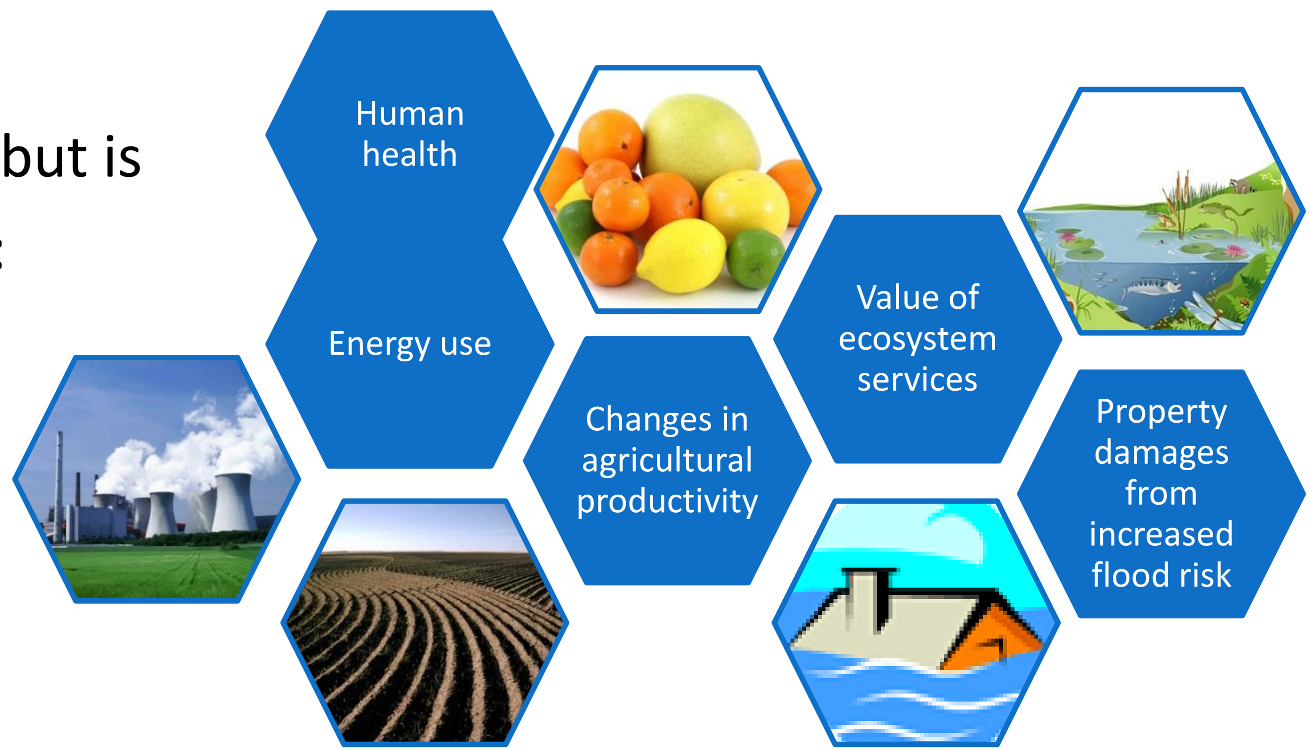
Source: Corona et al. (2019)

Example: Development and use of USG SC-GHG Estimates

What is the Social Cost of Carbon?

- The SC-CO_2 is the cost to society of adding 1-metric ton of CO_2 to the atmosphere in a particular year (in US dollars)
- It is intended to be a comprehensive measure of the monetized value of the additional CO_2 (including both negative and positive impacts).

This includes, but is not limited to:



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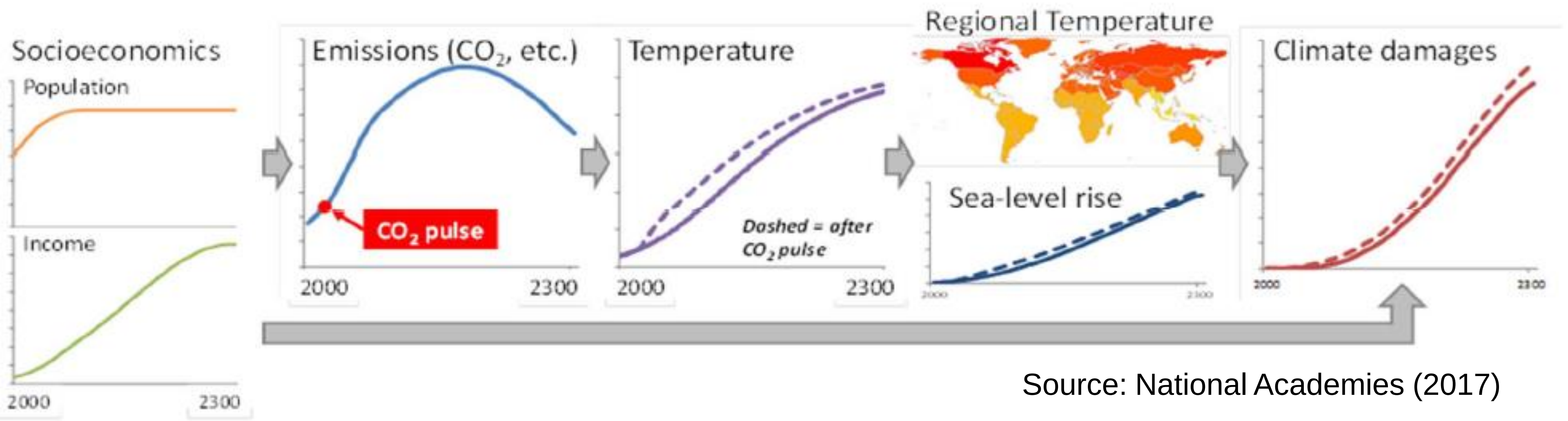
Basic process for estimating SC-CO_2



Source: National Academies (2017)

1. Translating GDP, population into CO_2 emissions
2. Translating CO_2 emissions into changes in mean global temperature
3. Estimating the impact of temperature on the physical & economic environment
4. Discounting climate damages, expressed as a percent of GDP

This 4-step procedure is done with both baseline emissions and with a small additional amount (a pulse) of CO_2 emissions in a particular year.

SC-CO_2 is the per-ton difference in present value of damages due to the pulse.

Why do we need an estimate of $SC\text{-}CO_2$?

- Rigorous benefit cost analysis (BCA) is a core tenant of the U.S. federal rulemaking process
  - It provides a consistent framework for comparing regulatory designs that have different costs and emission reductions for multiple pollutants
- Since 1981, BCA is required for all significant U.S. Federal regulations (E.O. 12866)
- The $SC\text{-}CO_2$ is an estimate of the benefits of reducing emissions of CO_2, which allows those benefits to be considered in BCA

In 2008, the U.S. Ninth Circuit Court of Appeals remanded a fuel economy rule to DOT for failing to monetize CO_2 emissions. The court stated, "*[w]hile the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero.*"

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Development of $SC\text{-}CO_2$ Estimates for Federal Regulatory Analysis

- $SC\text{-}CO_2$ estimates have been published in the academic literature for many years.
  - Meta-reviews of estimates as early as 2002 (Clarkson and Deyes 2002)
- In 2008, different agencies began using different estimates of the $SC\text{-}CO_2$ to monetize carbon reduction benefits in rulemakings.
- In 2009, the Obama Administration launched an interagency process to promote consistency in the $SC\text{-}CO_2$ values used by agencies.
  - In 2009 "interim" USG $SC\text{-}CO_2$ estimates issued based on literature review
  - Final USG $SC\text{-}CO_2$ estimates were issued in 2010 and updated in 2013
  - Estimates of the social cost of methane ($SC\text{-}CH_4$) and nitrous oxide ($SC\text{-}N_2O$), consistent with the $SC\text{-}CO_2$ methodology, were issued in August 2016
  - In January 2017, National Academy of Sciences issued recommendations for updating and research to ensure that estimates continue to reflect the best available science
- In March 2017, the Trump Administration issued E.O. 13783
  - disbanded the interagency process and withdrew the SC-GHG estimates used to date
  - instructed agencies to look to OMB Circular A-4 to develop new estimates, especially with respect to accounting for domestic vs. international impacts and discount rates.

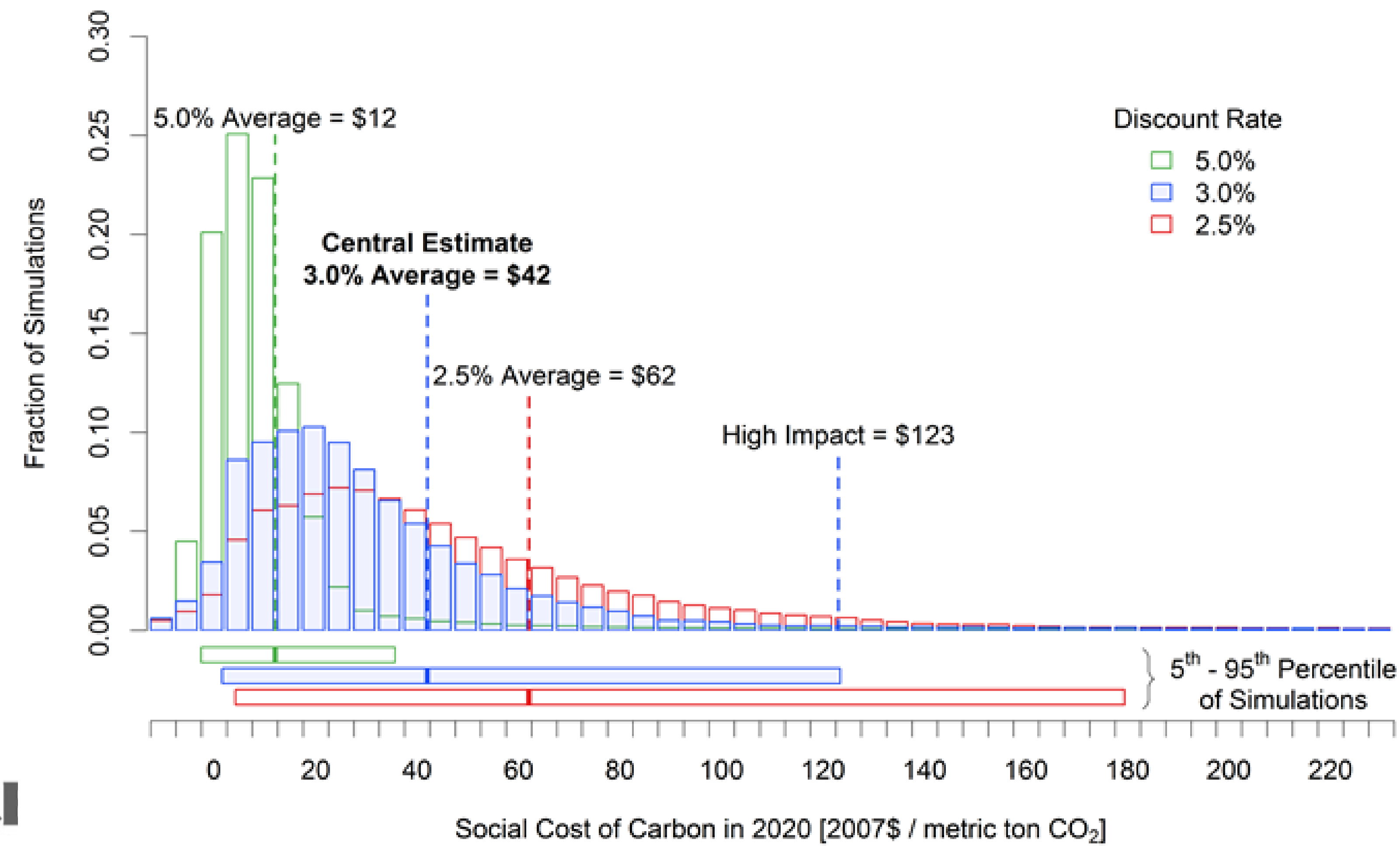
Key Modeling Decisions

- USG SC-GHG estimates used over 2010-2016:
  - Used 3 IAMs - DICE, PAGE, and FUND – equally weighted
  - Applied a common set of assumptions in each model for:
    - Trajectories of future population, economic growth, and GHG emissions
    - Equilibrium climate sensitivity (ECS) – a measure of the climate system's response to increased concentrations of GHGs in the atmosphere
    - Discount rates (2.5%, 3%, and 5%)
  - Maintained default assumptions for all other features of the IAMs
  - Consider global damages from incremental GHG emissions

- "Interim" SC-GHG estimates under E.O. 13783:
  - Maintain same models and input assumptions as above except:
    - Consider only damages resulting from climate impacts occuring within U.S. borders
    - Apply discount rates of 3% and 7%
  - EPA RIAs also include sensitivity analysis using global estimates and 2.5% d.r.

Frequency Distribution of USG SC-CO_2 Estimates in 2020 (used in 2013-2016 regulatory analyses)

- The distributions from each model and scenario are equally weighted and combined to produce separate frequency distributions for SC-CO_2 in a given emissions year, one for each discount rates



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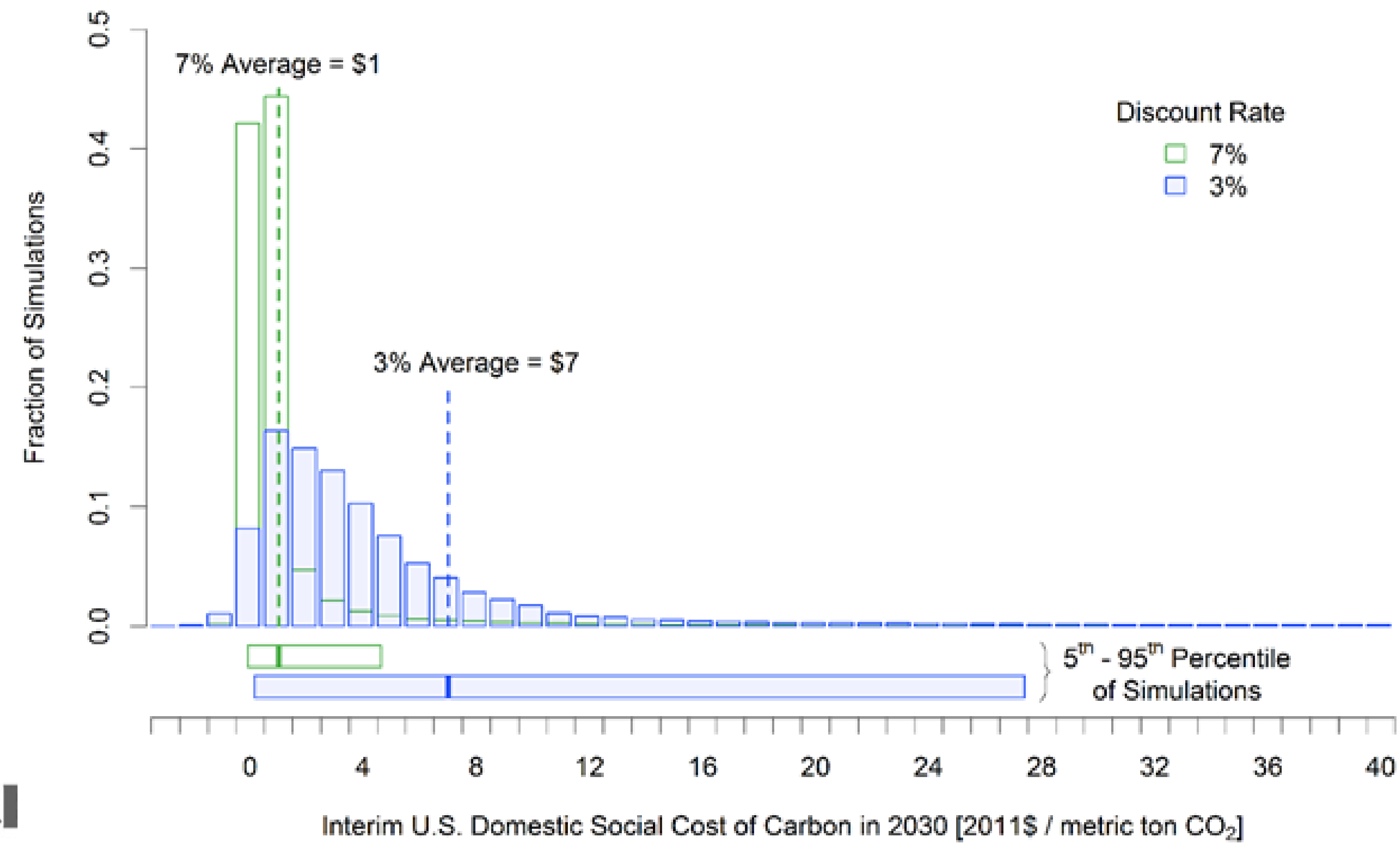
Frequency Distribution of Interim Domestic SC-CO_2 Estimates in 2030 (used in regulatory analyses since 2017)

"Domestic" estimates are based on location of physical impact and not ultimate location of welfare loss in a globalized economy



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Social Cost of Non-CO_2 GHGs

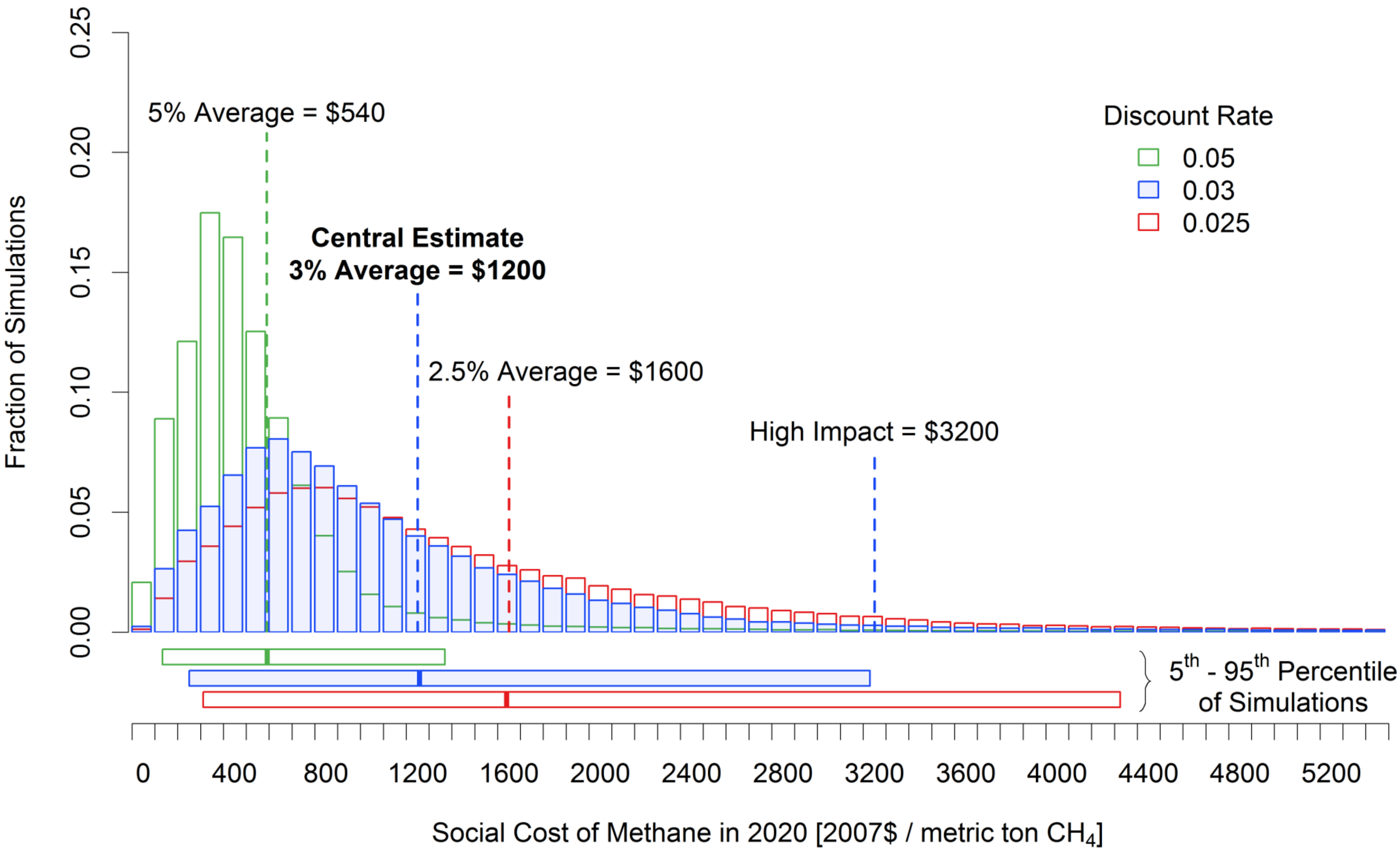
- Similar to the SC-CO_2, the SC-CH_4 and SC-N_2O are metrics that estimate the monetary value of impacts associated with marginal changes in CH_4 and N_2O emissions, respectively, in a given year.
  - Approximating non-CO_2 GHG damages via emissions conversion to CO2eq and applying SC-CO_2 can produce large errors

- Marten et al. (2015) provided the first published estimates of the SC-CH_4 and SC-N_2O that were consistent with the USG SC-CO_2 modeling assumptions.

- Methodology and estimates went through multiple stages of peer review and their use in regulatory analysis was subject to public comment (e.g., in rules by EPA, DOT, DOI).

- The SC-CH_4 and SC-N_2O estimates were folded into the USG SC-GHG guidance in August 2016.

Frequency Distribution of USG SC-CH_4 Estimates in 2020 (used in 2016 regulatory analyses)



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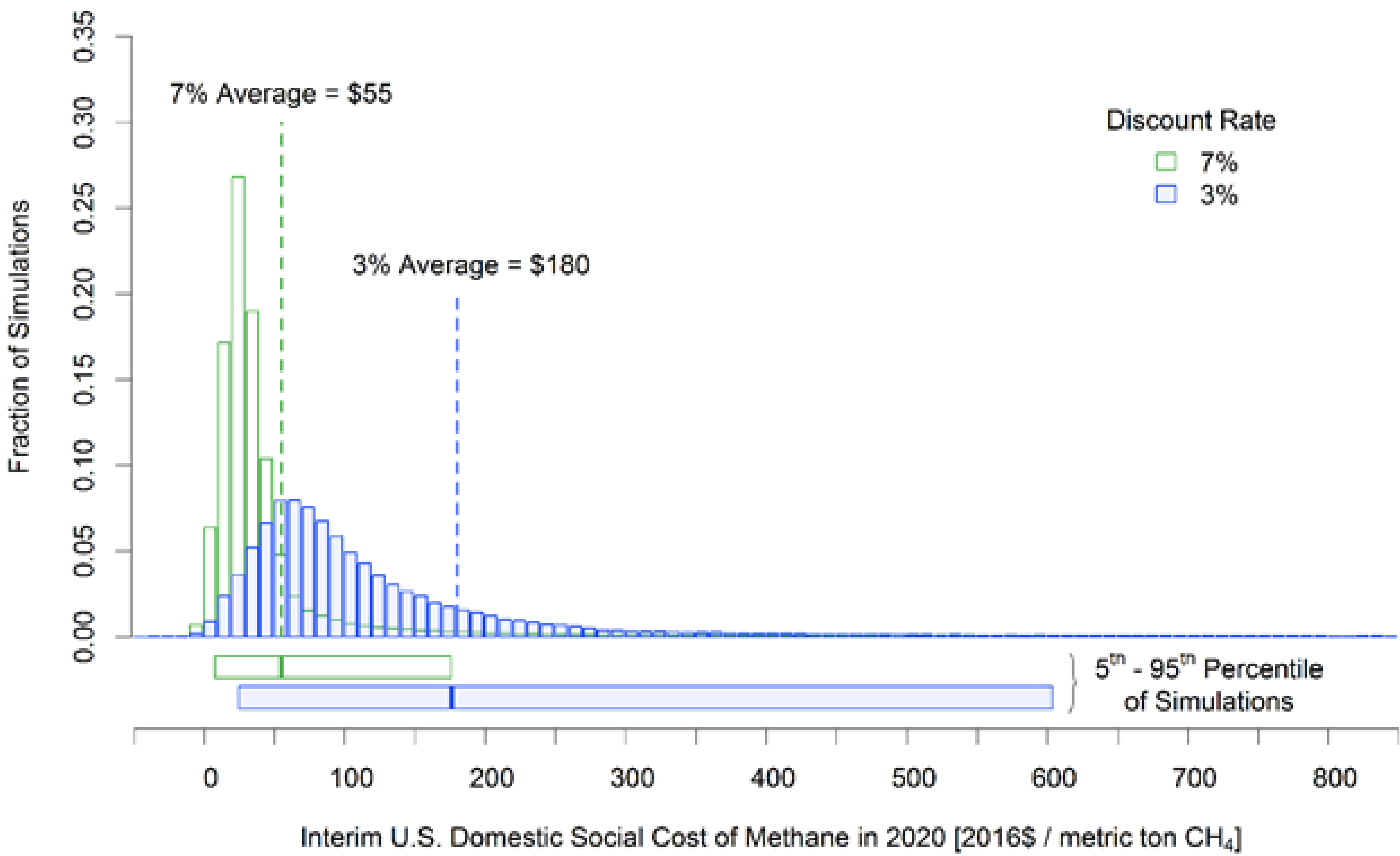
Frequency Distribution of Interim Domestic SC-CH_4 Estimates in 2020



Use of USG SC-GHG Estimates to Date

- U.S. federal government
  - Regulatory analyses (primarily DOE, EPA, and DOT)
    - USG SC-GHG global estimates used in 75+ RIAs over 2009-2016
    - Interim domestic SC-GHGs have been used in a handful of RIAs since 2017
  - NEPA analyses, and some other project level BCAs
  - Legislative proposals - American Opportunity Carbon Fee Act (introduced in 2014, updated in February 2018)
- Increasing use in analyses/discussions by non-Federal entities
  - e.g. states (NY, IL, CO, MN, WA, CA), regional organizations, other nations (Canada), international organizations, NGOs, researchers
- Legal Challenges – esp. related to NEPA
  - where an agency touts the economic benefits of fossil fuel extraction, it opens the door to assessment of economic costs of climate change (*e.g., High Country v Forest Service* and *W. Org. of Res. Councils v BLM*), though courts appear more willing to defer to agencies' judgments not to monetize damages in other circumstances

Limitations and Challenges

- Ensuring that damage functions continue to reflect the most recent primary impacts literature
- Addressing incomplete or omitted damage categories (e.g., ocean acidication)
- Interactions between damage categories (e.g., land-water-energy nexus)
- Long-term discounting under uncertainty (e.g., declining discount rates)
- Formal incorporation of socioeconomic and emissions uncertainty over long time horizons
- Improving incorporation of relative prices changes over time as a result of climate change impacts
- Improving characterization of endogenous adaptation
- Incorporating water into economy-wide economic models
- Not an exhaustive list…

Public input, review, updating to date

- Extensive opportunities for public input on SC-GHGs:
  - Public comment process in rulemakings using SC-GHGs since 2007.
  - OMB initiated separate comment process on SC-CO2 TSD in 2013/4.
- But reviews and updates have been sporadic and limited in scope
  - In 2013, the damage functions were updated to reflect newer published versions of FUND, DICE, and PAGE
  - 2014 GAO review of the interagency working group processes and methods
  - 2015-2017 National Academies study on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies
  - In 2016, improved presentation of uncertainty, in response to National Academies' Interim recommendations, but no change in numbers
  - In 2017, agencies changed discount rates and focused on "domestic" damages in response to an Executive Order
- There has been no comprehensive update of the USG SC-GHGs methodology since 2010.

Areas of Debate

- Criticisms of IAMs often focus on uncertainties in key model components that drive the results (e.g., Pindyck 2013)
  - Climate sensitivity, damage functions, "catastrophic" impacts, discount rates
- Do the uncertainties and sensitivities of IAMs "*make them close to useless as tools for policy analysis*"?
  - Metcalf and Stock (2017) - it is hard to imagine a successful process for estimating SC-GHGs that doesn't use IAMs, but need stable updating process with regular oversight by the National Academies
  - Pindyck (2016, 2017a, 2017b) – advocates for increased use of expert elicitation for developing SC-GHGs
- Approaches for setting a carbon tax?
  - Pindyck (2017b) - USG SC-GHG reasonable rough and politically acceptable starting point; update as we learn more
  - Kotlikoff (2019) – considers approaching problem with OLG model instead of social planner welfare maximization

Recommended Reading

- Griffiths, C., H. Klemick, M. Massey, C. Moore, S. Newbold, D. Simpson, P. Walsh, and W. Wheeler. 2012. U.S. Environmental Protection Agency Valuation of Surface Water Quality Improvements. Review of Environmental Economics and Policy 6(1): 130–146.
- Keiser, D., C. Kling, and J. Shapiro. 2018. The low but uncertain measured benefits of US water quality policy. PNAS 116(12): 5262–5269.
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- Kling, C., R. Arritt, G. Calhoun, and D. Keiser. 2017. Integrated Assessment Models of the Food, Energy, and Water Nexus: A Review and an Outline of Research Needs. Annu. Rev. Resour. Econ. 9:143–63.
- Metcalf, G., and J. Stock. 2017. Integrated Assessment Models and the Social Cost of Carbon: A Review and Assessment of U.S. Experience. Review of Environmental Economics and Policy 11(1): 80-99.
- National Academies of Sciences, Engineering, and Medicine. 2017. Valuing Climate Changes: Updating Estimation of the Social Cost of Carbon Dioxide. National Academies Press.
- Pindyck, R. 2017. The Use and Misuse of Models for Climate Policy Review of Environmental Economics and Policy 11(1): 100-114.
- Weyant, J. 2017. Some Contributions of Integrated Assessment Models of Global Climate Change. Review of Environmental Economics and Policy 11(1): 115–137.

Parting Thought

“‘Integrated Assessment’ is a state of mind.”

- Dallas Burtraw (May 23, 2019)