Integrated Assessment Models for Climate Change FREE

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Summary

To guide climate change policymaking, we need to understand how technologies and behaviors should be transformed to avoid dangerous levels of global warming and what the implications of failing to bring forward such transformation might be. Integrated assessment models (IAMs) are computational tools developed by engineers, earth and natural scientists, and economists to provide projections of interconnected human and natural systems under various conditions.

These models help researchers to understand possible implications of climate inaction. They evaluate the effects of national and international policies on global emissions and devise optimal emissions trajectories in line with long-term temperature targets and their implications for infrastructure, investment, and behavior. This research highlights the deep interconnection between climate policies and other sustainable development objectives.

Evolving and focusing on one or more of these key policy questions, the large family of IAMs includes a wide array of tools that incorporate multiple dimensions and advances from a range of scientific fields.

Keywords: integrated assessment models, benefit-cost analysis, cost-effectiveness analysis, climate mitigation targets, climate policy tools, climate change damages

Definition of Integrated Assessment Models

Integrated assessment models (IAMs) are simplified mathematical descriptions of reality that integrate knowledge from two or more disciplinary domains (e.g., climate sciences and economics) into a single framework. Components of these models are traditionally studied and developed independently within physical, biological, earth, economic, and social sciences. The necessity of studying interdisciplinary interactions between these components, as for example in the case of climate change, has led to the creation of unifying and consistent frameworks that involve multiple components to more effectively evaluate the status and the consequences of environmental change and policy responses to it.

IAMs are used to study a wide variety of environmental problems (e.g., acid rain, biodiversity loss). This article focuses on IAMs developed to analyze climate change, which are the most numerous and most widely used models for scientific research and policy support. It is important to distinguish IAMs from climate models. The former explicitly include humans and their activities whereas the latter take into account emissions scenarios generated by IAMs and model the physical and chemical responses of the climate system using a system of differential equations.

History of IAMs

The first major project in integrated assessment of an environmental issue was the Climatic Impact Assessment Program, which investigated effects of disturbance to the upper atmosphere caused by the propulsion effluents of a projected world high-altitude fleet (supersonic transport aircraft) on people, plants, and animals. This research was done in the early 1970s and entailed projections up to 1990. Although climate change was part of this program's mandate, most of the work focused on the potential of supersonic transport to deplete the stratospheric ozone layer and the increases in ground-level ultraviolet radiation and damages to humans and ecosystems that would result (Parson & Fisher-Vanden, 1995).

During the second half of the 1970s, although consensus on the anthropogenic influence on the increase of carbon dioxide concentrations in the atmosphere and the resulting implications for average global temperatures had already coalesced, the socioeconomic implications of this phenomenon were still poorly understood. Jule Charney et al. (1979) report on carbon dioxide and the climate stated that: "It appears that the warming will eventually occur, and the associated regional climatic changes so important to the assessment of socioeconomic consequences may well be significant, but unfortunately the latter cannot yet be adequately projected" (Charney et al., 1979).

In 1980, a letter to the U.S. National Academy of Sciences Climate Research Board by a group of scientists led by Thomas Schelling concluded that too little was known about the socioeconomic implications of climate change and that the timing of the problem has to be understood better (Schelling et al., 1980). One of the emerging concepts from this period was that of adaptation to climate change and its role in defining optimal policies: humans had experienced changes in the climate before and had proven their ability to adjust to these changes either by adapting their way of life or by migrating.

In 1983, the U.S. Congress commissioned a report by the Carbon Dioxide Assessment Committee of the National Academy of Sciences (National Research Council. 1983). The report was divided into two parts, the first authored by physical scientists and the second by economists (including William Nordhaus, who went on to win the Nobel prize for economics for his work with IAMs). A disciplinary division emerged in the main recommendations of the report. Climate scientists, recognizing the responsibility of humans in the modification of the climate, argued for immediate policy action. The economists, although acknowledging the increase in carbon dioxide concentrations in the atmosphere, the role of fossil fuel burning as its main cause, and the implications on global temperatures as its main effect, also emphasized the uncertainties surrounding the socioeconomic impact of alternative future carbon dioxide trajectories and associated changes in climate. A simplified version of an IAM was developed for this report to project future anthropogenic emissions (rather than simply extrapolating forward past emission growth rates). Another novel idea was the argument in favor of pricing carbon: If carbon emissions produce negative effects on society that are not accounted for in economic and industrial planning, then associating a monetary value to such social costs allows internalization of this externality and ensures that excessive carbon emissions are not spewed in the atmosphere. The report argued that the uncertainty surrounding the socioeconomic implications of increased temperatures did not address the question of whether it would make more economic sense to enact a stringent carbon dioxide mitigation policy (i.e., imposing a high price on carbon) or to adapt to a warmer climate while enacting a milder carbon dioxide mitigation policy (i.e., imposing a modest price on carbon emissions).

The 1985 report introduced one of the main streams of research performed with IAMs: comparing benefits of avoided climate impacts and costs of decarbonization efforts in climate change mitigation. In particular, this type of research generated the family of so-called benefit-cost IAMs, which include DICE - Dynamic Integrated Climate-Economy - (Nordhaus, 1977), FUND - Climate Framework for Uncertainty, Negotiation and Distribution- (Waldhoff et al., 2014), and PAGE- Policy Analysis of the Greenhouse Effect- (Dietz, Hope, & Ranger, 2014). These IAMs have been used in contexts ranging from the Stern Review (Stern, N. H., & Great Britain, 2007) to the U.S. interagency working group on the social cost of greenhouse gases (Pizer et al., 2014).

Driven by the Intergovernmental Panel on Climate Change (IPCC), the United Nations body established in 1988, and by other efforts such as Stanford University’s Energy Modeling Forum, a parallel process emerged and nourished a second family of IAMs. These “detailed process” IAMs are significantly more complex and bring together standalone modules for land use and the climate system. Although it would be a misleading oversimplification to identify detailed process IAMs with earth sciences or engineering and benefit-cost IAMs with economics, it is worth noting that many detailed process models stem from earth, natural, or physical sciences whereas prominent examples of benefit-cost IAMs, such as DICE and FUND, stem from the economic discipline.

The IPCC has the mandate of producing comprehensive periodic assessment reports about the state of scientific, technical, and socioeconomic knowledge on climate change (IPCC—Intergovernmental Panel on Climate Change). In 1995 the IPCC’s second assessment report introduced a specific working group to study the economic and social dimensions of climate change. The third assessment report (2001) explicitly focused on climate change mitigation. The research assessed by this IPCC working group triggered the demand for knowledge on mitigation strategies and emission scenarios, which in turn required further development of detailed process IAMs.

During the 1990s, detailed process models were mostly tasked with the production of carbon dioxide emission trajectories consistent with plausible future demographic, economic, and technological trends and policies. When scenarios do not account for any mitigation policy they are referred to as “baseline” or “business as usual” emission scenarios and represent a key input to the assessment of the climatic response of the earth system performed by climate scientists using global circulation models.

The earliest detailed process IAMs included the Integrated Model for the Assessment of the Greenhouse Effect (IMAGE) and the Atmospheric Stabilization Framework (ASF) model. The IMAGE model was developed by the Dutch National Institute for Public Health and the Environment in 1990 (Rotmans, De Boois, & Swart, 1990) and was the main simulation model used to generate emission projections for climatologists in the first and second IPCC reports (IPCC, 1992, 1995). The ASF model was developed and maintained by the U.S. Environmental Protection Agency (Lashof & Tirpak, 1989).

In 2000, the publication of the IPCC's Special Report on Emission Scenarios (Nakićenović, 2000) represented a turning point, as four storylines were developed to describe narratives of the future, and multiple teams worked on the quantification of such scenarios through a collection of IAMs. In addition to the IMAGE and ASF models, the report also featured results from MESSAGE, developed in Austria (Strubegger, Totschnig, & Zhu, 2004); MARIA (Mori & Takahashi, 1998) and AIM (Matsuoka, Morita, & Kainuma, 2001), developed in Japan; and MiniCam, developed in the United States (Brenkert, Smith, Kim, & Pitcher, 2003).

As noted in (Cointe, Cassen, & Nadaï, A., 2019), this was the first opportunity for several detailed process IAM teams to work together, sharing simulation protocols and boundary conditions and following in the steps of climate scientists who had already embraced this community research approach. The International Institute for Applied System Analysis and the Energy Modeling Forum played a central role in this process, with research hubs built on a long tradition in modeling energy and environmental systems that dated back to the 1970s. By 2010, in preparation for the IPCC's fifth assessment report and a new generation of emission scenarios, various IAM groups, including many newcomers and representing more than 20 countries, established the IAM Consortium. The consortium has the explicit objective of convening the process of scenario generation. The consortium webpage provides information on the Scientific Steering Committee, the founder teams, and the models belonging to the consortium (IAMC—Integrated Assessment Modeling Consortium).

Taxonomy

In the context of climate change, IAMs have been developed to answer one or more of the following fundamental questions:

(1) What are the climate implications of a "baseline" or "business as usual" trajectory; that is, a scenario characterized by no meaningful action to reduce anthropogenic greenhouse gas emissions? Models are used to quantify the greenhouse gas emissions associated with the scenario, as well as the resulting alteration of the global temperature. Although implications for the climate system are traditionally the focus of climate science research, IAMs can produce coarse but accurate projections of temperature change with the aid of emulators of complex global circulation models. The latest effort in baseline scenarios is represented by so-called shared socioeconomic pathways, which represent five storylines about the future that span possible evolutions of economic and demographic growth as well as convergence across and within countries (Riahi et al., 2017).

(2) What are the implications for global greenhouse gas emissions of a scenario that combines all national policies that countries have pledged to undertake? A prominent example would be the study of global emissions resulting from the implementation of the Nationally Determined Contributions; that is, reductions in greenhouse gas emissions that countries have pledged under the United Nations Framework

Convention on Climate Change _<https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs>_. An example of this type of analysis would be Aldy et al. (2016).

(3) What techno-economic investments and strategies would achieve a given climate target at minimum cost? A prominent example would be the analysis of the technologies and strategies required to reach a global emissions scenario compatible with a 2°C target by the end of the 21st century, as analyzed in Clarke et al. (2014) and IPCC (2018).

(4) What is the "optimal" increase in temperature? "Optimal" is defined as the level of temperature increase that balances the cost of mitigating emissions with the benefit of the avoided climate damage. To perform such a calculation, the model must include estimates of the macroeconomic impact of an increase in global temperature. This benefit-cost analysis allows assessment of the social cost of carbon emissions. Prominent examples of this type of analysis are those undertaken by the U.S. Environmental Protection Agency, which have resulted in a widely accepted definition of the social cost of carbon (Greenstone, Kopits, & Wolverton, 2013).

(5) What are the multiple physical impacts associated with climate change? Are there feedbacks, links, and potential risks due to nonlinear processes within the earth's system? Moving beyond the stylized benefit-cost IAMs and their overly simplified interpretation of climate damage, the latest efforts undertaken by detailed process IAMs attempt to take a holistic and truly integrated approach that includes climate change impacts on the natural and human systems.

Because these policy questions differ in their nature and are best investigated through various computational tools, and given that researchers located in different nations or coming from different disciplinary fields have attempted to address them, IAMs vary immensely. These diverse computational tools have been referred to generally as IAMs, an ambiguity in language that has frequently generated confusion among scholars and users of these models (Evans & Hausfather, 2018).

Notwithstanding this diversity, a core set of ingredients is common to all IAMs: They all include some way of mimicking economic activities and the greenhouse gas (GHG) emissions these activities generate, and they all include the translation of emissions into atmospheric concentration and the resulting temperature change or some other indicator of the earth system response. Apart from this set of core characteristics, the universe of IAMs is populated by models that differ in their level of complexity, basic philosophy, way of finding a solution, and so on. The following are examples of the dimensions over which these models can differ.

First, some models account for climate change damage feedback; that is, they translate the change in climatic conditions into the various impacts on natural ecosystems or into their socioeconomic implications. In particular, if damages are translated into economic impacts, then models can be used to perform a benefit-cost analysis of climate; that is, they can be used to balance the costs and benefits of climate change mitigation using the same monetary metric.

Second, models may vary in the level of detail with which they portray a specific domain. For example, some models only represent the whole global economy as a single sector and the production of a single final good, the numeraire; and others account for multiple technologies for each of the many portrayed economic sectors in each of the world's countries.

Third, some models only use temperature as a proxy for climate change, while others account for changes in precipitation, sea level rise, change in snow and ice cover, and so on.

A final important dimension over which these models may differ is the representation of agents. In some cases, a single representative agent (the benevolent planner) is considered. As climate change is a global problem, it may be an acceptable simplification to consider humanity as a single entity, as when exploring key uncertainties driving long-term emissions projection (Gillingham et al., 2018). In other contexts, it becomes critical to be able to represent at least one agent for each macro-region of the planet, for example when studying international climate agreements (Nordhaus & Yang, 1996). Other applications may require representing multiple agents and their interactions, such as when modeling the adoption and penetration of a new technology (McCollum et al., 2017).

Given the richness and diversity of these tools, it is useful to find ways of clustering IAMs. Historically, they have been categorized based on which of the integrated components was better developed or more prominent (e.g., the macro-economy, the land-use sector, the energy sector). A traditional distinction was made between top-down (focus on the macro economy) and bottom-up (focus on technological detail of the energy sector) models (Edenhofer, Lessman, Kemfert, Grubb, & Kohler, 2006). This distinction blurred over time, as each type of model developed to include more features of the other type, thereby creating a new class of hybrid models (Hourcade, Jaccard, Bataille, & Ghersi, 2006). Other classifications have built on other key distinctions, such as type of solution (simulation vs. optimization) or sectoral coverage (partial vs. general equilibrium).

A useful categorization of IAMs, which might be more relevant for some of the most recent debates, can be found in Pezzey (2019) and Weyant (2017). This classification is based on the vocation of models to either address questions 1–3 and 5 or question 4 (2017) states:

> there are two basic types: detailed process (DP) IAMs and benefit–cost (BC) IAMs. Both types of IAMs have been applied to climate change mitigation policy questions for several decades. Although both types of IAMs include projections of GHG emissions and the costs of various approaches to mitigate them (e.g., energy conservation, changes in production processes, fuel switching), they handle climate change impacts differently. DP IAMs are more disaggregated and seek to provide projections of climate change impacts at detailed regional and sectoral levels, with some using economic valuation and others using projections of physical impacts such as reductions in crop growth, land inundated by sea level rise, and additional deaths from heat stress. In contrast, BC IAMs provide a more aggregated representation of climate change mitigation costs and aggregate impacts by sector and region into a single economic metric. The main motivation for developing BC IAMs has been to use them to implement benefit cost analysis to identify “optimal” climate policies, but they have also been used to calculate the costs and benefits associated with polices for which marginal costs and marginal benefits are not equal. (p. 117)

It is important to note that since the very beginning, these two families of IAMs have coexisted and influenced each other. Indeed, the two types of models are complementary in many ways and should be used in tandem. However, as often happens in this period of highly specialized science, the two disciplines have been growing apart. As a result, the gap between scholars contributing to the two categories of models has grown and the potential for cross-fertilization and complementary work has decreased.

Key Scientific Contributions

IAMs have contributed in many ways to the process of designing science-based strategies and policy responses to climate change. This overview of their main contributions is articulated along the five key questions noted in the previous section.

Question 1: Business-as-Usual Emissions and Resulting Global Mean Temperature

One of the key achievements of IAMs is their analysis of how humans contribute to GHG emissions. Climate scientists need information about plausible GHG emission trajectories for the full century (or the coming centuries, depending on the scenario) as an input to their global circulation models. These projections include emissions of all GHGs from all sectors (e.g., the energy sector, agriculture, heavy industries). There are two main IAM research streams that produce forward projections: representative concentration pathways (RCPs) and shared socioeconomic pathways.

RCP scenarios include time series of emissions and concentrations of the full suite of GHGs and aerosols, as well as land use and land cover (Lamarque et al., 2011; Moss et al., 2010; van Vuuren et al., 2011). Each pathway represents one of the many possible scenarios that lead to specific radiative-forcing characteristics (the change in the net radiative flux at the top of the atmosphere). IAMs have produced RCPs that serve as key inputs for the climate science community. Shared socioeconomic pathways (Moss et al., 2010; O'Neill et al., 2014) describe alternative futures of socioeconomic development in the absence of climate policy intervention ("baselines"). This stream of research has shown that current levels of emissions and business-as-usual scenarios could lead to an increase in global mean temperature as high as +4°C by 2100. In addition, they improve understanding of the impacts of various socioeconomic drivers, such as population, GDP growth, and technological change (Riahi et al., 2017).

Question 2: Emissions Gap and the Implications of Nationally Determined Contributions

IAMs also contribute to the understanding of the implications of policies identified within the United Nations Framework Convention on Climate Change, including the Nationally Determined Contributions, and how far these short-term policies go in terms of reducing emissions to meet long-term goals.

Studies such as those by Aldy et al. (2016) and Harmsen et al. (2019) analyze the implications of national policies on global emissions. Their findings show how far countries are from the efforts required to meet global temperature targets (e.g., the 2°C maximum increase in average temperature by the end of the 21st century described in the Paris Agreement). The difference between short-term efforts and long-terms targets is referred to as the “Emissions Gap” (UNEP, 2019) and has been well reported thanks to research performed using IAMs. Understanding the size of the gap helps countries to assess their efforts, and associated data are a key input to international climate negotiations.

Question 3: Long-Term Decarbonization Pathways

The investigation of least-cost investments, innovation, and technological strategies to meet long-term temperature targets have been an essential component of the research performed with IAMs.

This strand of research focuses mostly on the characteristics of low-carbon and carbon-free technologies, as well as how to deal with policy questions arising from efforts to decarbonize the economy (i.e., decarbonization transition). For example, numerous important energy transition questions have been addressed with IAMs, such as the economic implications of intermittent energy technologies, the role of nuclear power, the importance of decarbonizing the transport sector, and the role of negative emissions.

IAMs used to perform these analyses have been developed with a very detailed definition of the energy sector and, increasingly, a detailed definition of land use and related emissions. An exogenously defined constraint (that is, a constraint on cumulative emissions, GHGs atmospheric concentrations, radiative forcing, or global average temperature) is imposed as a boundary condition on the model and the implications for the various sectors are studied. A comprehensive review of this literature can be found in the IPCC’s Fifth Assessment Report (Clarke et al., 2014) and Special Report on Global Warming (Rogelj et al., 2018). The forthcoming Sixth Assessment Report will extend this review to include the latest literature and touch on issues such as as geoengineering and the role of human behaviors.

A recent research trend has been to model and account for societal goals other than climate change (e.g., Sustainable Development Goals) in order to understand the implications of deep decarbonization on these other important objectives. For example, studies have been done on the implications of deep decarbonization on deforestation and land use (Thomson et al., 2010), water usage (Hejazi et al., 2015), and food security (Fujimori et al., 2019).

Question 4: Optimal Climate Policies and the Social Cost of Carbon

Climate change implies a set of impacts, some of which are gradual and some of which are nonlinear in nature. These impacts are typically quantified by their physical effects (e.g., speed of the melting of ice sheets, change in agricultural yields, increase in occurrence of wildfires). Most of this research was covered in the IPCC’s 2014 assessment reports (e.g., IPCC,2014). Economic implications of a subset of these impacts can also be assessed (e.g., the economic implications of reduced agricultural yields, the capital costs due to increased flooding) and aggregated in a reduced form equation referred to as “damage function,” which allows a comparison of various monetary implications of mitigation activities.

A comprehensive review of the empirical work assessing these impacts can be found in Dell, Jones, and Olken (2014) and Carleton and Hsiang (2016), which investigate the relationship between climatic variables and a very broad set of economic activities. Dell et al. (2014) emphasize that “this literature has important implications for the ‘damage function’ in climate change models, which consider how future changes in climate—i.e., future changes in the stochastic distribution of weather—will affect economic activity” (p. 741).[1]

Indeed, a set of key ingredients is crucial to performing a full-fledged benefit-cost analysis. IAMs used for this purpose need to be able to deal with a long-term temporal horizon, as climate-related damages occur far into the future. They must cover the full global economy, either including interacting macro-regions or assuming a global planner. They must include a simplified climate module able to calculate the temperature derived from cumulated emissions for each period. Above all, they have to contain a channel of feedback on economic activities–induced damages on the economy, which is done by climate damage functions building on the empirical work just described. As noted in the section “Limitations and Critiques,” quantifying the full economic losses associated with climate damages is challenging. For this reason, the use of benefit-cost IAMs to assess the optimal climate policy (e.g., the optimal increase in temperature with respect to preindustrial level) may be misleading and has been extensively criticized (Pezzey, 2019). However, these models still have the crucial role in the policy discussion of setting the social cost of carbon (i.e., the monetized damages associated with an incremental increase in carbon emissions). As noted in Greenstone et al. (2013): “Monetized estimates of the economic damages associated with carbon dioxide emissions make it possible for benefit–cost analyses to incorporate the social benefits of regulatory actions that are expected to reduce these emissions.”

Rather than defining the optimal policy, the social cost of carbon can be used to perform benefit-cost analysis of policies or investments accounting for the economic values of reducing emissions. A key example of this is discussed in (Interagency Working Group on Social Cost of Carbon, 2010).

Question 5: Holistic Approach to Climate Change Impacts

State-of-the-art detailed process IAMs provide important information on the multiple impacts of climate change and their interactions. Understanding the connections and interactions among energy, water, and land systems is crucial to achieving a comprehensive view not only of the implications of temperature changes but also of changes in sea levels, storm surges, snow and ice cover, and precipitation. This recent research stream illuminates our understanding of the full extent of climate change (see Calvin, Wise, Kyle, Patel, Clarke, & Edmonds, 2014; Herrero et al., 2013; Mosnier et al., 2014; van Ruijven, De Cian, & Sue Wing, 2019).

Limitations and Critiques

Both benefit-cost and detailed process IAMs have been extensively criticized (Ackerman, Decanio, Howarth, & Sheeran, 2009; Anderson & Peters, 2016; Pezzey, 2019; Pindyck, 2017; Stern, 2013). However, not all critics are aware of the distinctions described in this article and some have erroneously addressed their critiques to the full family of IAMs.

The most frequent critique relates to the difficulty of fully representing climate change impacts in monetary units, given the complexities and the uncertainties associated with the assessment process. This limitation is often addressed to all IAMs, while it obviously makes sense solely when referring to benefit-cost IAMs. Detailed process IAMs rarely include climate change economic effects on the macro economy. To address this critique, a number of efforts have been made within the benefit-cost IAMs community to include improved estimates of climate damages that also take uncertainty into account (Carleton & Hsiang, 2016). In addition, efforts have been made to better gauge the implications of these uncertainties in the models themselves (Lemoine & Traeger, 2014; Lontzek, Cai, Judd, & Lenton, 2015). Leaving aside this major challenge, other limitations include the following.

First, most IAMs are not able to mimic extreme and discontinuous outcomes (Weyant, 2017). This can lead to inaccuracies in the results, considering that both climate change and climate change mitigation (e.g., innovation in new technologies) could trigger disruptive and nonlinear changes in both the economic and the natural systems.

Second, although efforts are under way to better represent agents' heterogeneity, most IAMs are still very simple in this respect (Rao, van Ruijven, Riahi, & Bosetti, 2017). Progress in this direction is crucial for representing distributional impacts associated with climate change or mitigation policies, mimicking the uptake and diffusion of mitigation technologies, and representing the heterogeneity of behaviors.

Recent efforts in agent-based modeling offer promising solutions to both problems, allowing for a richer representation of agents and their interactions and the emergence of nonlinear processes (see (Castro et al., 2020) for a review of agent-based modeling of climate-energy policy).

Third, when projecting over a century, uncertainties are large and cannot be ignored. Huge efforts have been undertaken (Gillingham et al., 2018; Marangoni et al., 2017) to better gauge which findings are robust across models and how much they depend on key assumptions (e.g., long-term growth of the economy, monetary implications of climate damages, diffusion and cost of key mitigation technologies). But more work is needed to quantify these uncertainties. In principle, every time a projection is made, the full exploration of uncertainties should be undertaken. In addition, research should highlight best practices for presenting these uncertainties.

Fourth, the real-world feasibility of some of the decarbonization strategies emerging from IAM studies is questionable. Some of these technological and economic transformations may be technically feasible but may not be realistic when political economy, international politics, human behaviors, and cultural factors are taken into consideration. Although the notion of "feasibility" itself is debatable (Majone, 1975), outcomes of IAMs have been often defined as unfeasible. To cite just a few examples, the practicality of the pace of short-term decarbonization implicit in some of these models' results has been challenged (Loftus, Cohen, Long, & Jenkins, 2015). Similarly, the massive employment of negative emission technologies (Anderson & Peters, 2016; Gambhir et al., 2017) that characterizes some IAM results has been questioned. Huge efforts are now underway within the IAM community, in collaboration with several other disciplines, to better characterize feasibility along dimensions that are external to the models.

One last important critique is that IAMs are "black boxes," the functioning of which cannot be fully understood. This undermines the trust policymakers and users might have in their results.

To mitigate such criticism, the code and extensive model documentation are now available online for several of these models (IAMC wiki—IAMC-Documentation; FUND Model; DICE/RICE models—William Nordhaus | Yale Economics). In addition, a growing number of IAMs report key features online, and similar documentation accompanies IPCC reports (e.g., IAMC wiki—IAMC-Documentation <https://www.iamcdocumentation.eu/index.php/IAMC_wiki>). Although this represents a useful start, with the exception of few simplified tools (e.g., DICE), code availability does not enable full understanding because models are extremely complex.

A more fruitful approach lies in another effort toward transparency: IAMs are now saving most of the scenarios' output and associated input information in open source data sets (e.g., Huppmann et al., 2019). This has the objective of allowing users to download, explore, and study produced data that can be questioned, scrutinized, and analyzed at will. This practice has also triggered a process of vetting and cross-validation within the modeling community itself.

Conclusions

IAMs are an essential tool in the climate policymakers' toolkit. As the topic of science-based target slowly becomes central to the political, financial and macroeconomic scene, these tools will provide a common platform where to experiment and explore future decarbonization scenario.

Links to Digital Materials

The website of the Integrated Assessment Models Consortium <https://www.iamconsortium.org/> provides information about the history of the community and projects the community is involved in.

This brief informative article explains IAMs in simple terms.: "How Integrated Assessment Models are Used to Study Climate Change <https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change>."

Climate Analytics provides a primer on integrated assessment models <https://climateanalytics.org/publications/2018/integrated-assessment-models-what-are-they-and-how-do-they-arrive-at-their-conclusions/> and their results.

The IAM Consortium <https://www.iamcdocumentation.eu/index.php/IAMC_wiki> provides information on individual models.

Further Reading

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Notes

1. Note that what the authors refer to as climate models should instead be called IAMs.

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