Organising Policy-Relevant Knowledge for Climate Action: Integrated Assessment Modelling, the IPCC, and the Emergence of a Collective Expertise on Socioeconomic Emission Scenarios

Béatrice Cointe

IK Centre for Technology, Innovation and Culture, University of Oslo, Norway/beatrice.cointe@tik.uio.no

Christophe Cassen

Centre International de Recherche sur l'Environnement et le Développement (CIRED), CNRS, France

Alain Nadaï

Centre International de Recherche sur l'Environnement et le Développement (CIRED), CNRS, France

Abstract

Greenhouse gas emission scenarios are key to analyse of human interference with the climate system. They are mainly produced by one category of computer models: Integrated Assessment Models (IAMs). We analyse how IAM research organised into a community around the production of socio-economic scenarios during the preparation of the IPCC AR5 (2005-2014). We seek to describe the co-emergence of a research community, its instruments, and its domain of applicability. We highlight the role of the IPCC process in the making of the IAM community, showing how IAMs worked their way to an influent position. We then survey three elements of the repertoire that served to organise collective work on scenarios in interaction with the IPCC and the European Union, and which now frames the community and its epistemic practices. This repertoire needs to articulate epistemic practices with the pursuit of policy relevance, which shows how epistemic communities and patterns of co-production materialise in practical arrangements.

Keywords: climate change, models, scenarios, repertoires, epistemic community

Introduction

The apprehension of possible futures is a crucial part of how we understand and tackle climate change. Long-term quantitative scenarios are one of the main devices used for this apprehension. They are mobilised as descriptions of "plausible trajectories of different aspects of the future that are constructed to investigate the potential consequences of anthropogenic climate change" (IPCC, undated). Among such scenarios, greenhouse gas emission scenarios, usually associated with socioeconomic narratives,[1] play a pivotal role – here we refer to them as 'socioeconomic emission scenarios'. They map possible evolutions of the drivers of climate change, and are used as input for climate models and as a basis for assessing climate policy options. Successive sets of socioeconomic emission scenarios have informed IPCC Assessment Reports since 1990, serving as references across climate research communities (Moss et al., 2010; O'Neill and Nakicenovic, 2008). They provided the backbone of the assessment of mitigation in the IPCC Fifth Assessment Report (AR5) (IPCC, 2014a). But how are such scenarios made?

Socioeconomic emission scenarios are now almost exclusively produced using one type of models labelled 'Integrated Assessment Models' (IAMs), to the extent that it is difficult to consider the scenarios and the models independently. IAMs are large-scale, complex numerical models that represent interactions among environmental, technological and human systems in a single integrated framework. They are used to generate quantified scenarios about the long-term evolutions of these interactions, usually on a global scale. To do so, they integrate contributions from various disciplines, among which environmental sciences, economics and engineering, with the express intention to inform policy-making (Weyant et al., 1996). In the AR5, they are opposed to other approaches to scenario generation, such as qualitative scenarios or aggregated models for cost-benefit analysis (Clarke et al., 2014: 422).

Most IAMs emerged in the 1990s. They have developed and expanded over the past 15 years, and a dedicated research community has gradually formed around them. IAM research is now a rather prominent source of expertise on climate change policy, as suggested by its central position within the latest report of the IPCC Working Group III (WG III), dedicated to mitigation. In this paper, we analyse how IAM research has organised around the production of socioeconomic scenarios during the period leading up to the publication of the IPCC AR5, from 2005 to 2014. This episode was about the production of specific kind of knowledge on the future as much as about the definition of IAMs as a category of models and as a field of research. By retracing it, we seek to understand the establishment of IAMs as central devices in the production of climate projections, and, it follows, that of IAM research as legitimate expertise on climate action.

IAMs – and expertise on climate change mitigation more broadly – have received limited attention from STS scholars. So far, only a handful of STS publications have scrutinised them (Wynne, 1984; Shackley and Wynne, 1995b; Edwards, 1996; Lövbrand, 2011; Weszkalnys and Barry, 2013; Beck and Krueger, 2016). Yet, their central position within the IPCC, their intrinsic interdisciplinarity and their overt ambition for policy-relevance make them particularly intriguing objects from an STS standpoint.

As a first step into the exploration of this object, our objective is to characterise IAM research in terms of its social, material, theoretical and institutional organisation: what is it, and how did it take shape? How does its vocation for policy-relevance translate in this organisation, and in its relations with institutions such as the IPCC or the EU? Like Knorr-Cetina (1999) in her analysis of epistemic cultures, our focus is on the organisation of knowledge production rather than on the content and circulation of knowledge. Our paper is thus meant as a contribution to studies of the social as an instrument in the production of knowledge and to practice-oriented accounts of the constitution of scientific communities and fields. It investigates the emergence, stabilisation and dynamics of research communities as related to the applications of their research, especially when such applications have to do with policy. In that, it joins up with recent attempts to unpack the making of epistemic communities (Akrich, 2010; Lorenz-Meyer, 2010; Meyer and Molyneux-Hodgson, 2010; Demortain, 2017).

We rely on a qualitative study combining document analysis, interviews and ethnographic observation. We identified the research teams involved, retraced the chronology of the production of socioeconomic emission scenarios for the AR5, and collected materials related to the events and projects that contributed to it (reports, presentations, articles). One of us had first-hand knowledge of some of these projects as a member of CIRED's IAM team since 2008. We also participated in IAM-related conferences, and interviewed 15 modellers and experts from seven institutions to understand the individual and collective aspects of their work and get insights into the evolutions and challenges of IAM research.[2]

The first section clarifies our take on the IAM community and explains how we relate to work on epistemic communities, on the interface between climate science and policy, and on the collective dynamics of scientific research. We then retrace the history of the interactions between IAM research and the IPCC and relate how IAMs came to play a central role in the preparation of the latest IPCC report. Following this historical account, we look closer into the details of IAM research, first pointing out the heterogeneity across IAM models, and then analysing elements in the repertoire that enabled the constitution of a coherent community out of this heterogeneity.

Investigating the co-emergence of a policy-relevant science and of its applications

This paper is interested in how integrated assessment modelling holds together as a research community sharing a reliance on a type of large, complex numerical models labelled as IAMs and an ambition for climate policy-relevance. Our focus is on the collective organisation and establishment of an emerging research community as a policy-relevant field.

In studies of the science-policy interface, the concept of epistemic communities is prominent. The most influential definition of the term is that proposed by Peter Haas: epistemic communities as "network[s] of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue area" that share both a set of epistemic values and an orientation towards specific policy action (Haas, 1992: 9). While Haas's conceptualisation of epistemic communities explicitly draws on sociological approaches to the collective dimensions of scientific activities (such as Fleck's notion of 'thought collective' and Kuhn's paradigms), he used it primarily to introduce knowledge and expertise as relevant factors in the analysis of international politics, especially on environmental issues. His focus was on what epistemic communities do, rather than on how they are made. Since then, the notion has been taken up widely, with various reinterpretations (Lorenz-Meyer, 2010). In particular, it has been applied to the analysis of climate change as a global political issue largely framed by scientific expertise (Godard, 2001). Edwards (1996) argued that global comprehensive modelling (including both IAMs and Earth System Models) contributed to the emergence of an epistemic community by acting as a vehicle for shared knowledge, values, tools and data. Some studies of the IPCC have also relied on the epistemic community model to analyse the production of usable scientific knowledge on climate change and its institutionalization (Hughes and Paterson, 2017).[3]

IAM research is based upon trust in scientific knowledge and upon academic standards of validation; it has an ambition for policy-relevance; and it is a significant contributor to the IPCC reports, hence part of recognized expertise on climate issue. It can then be considered as part of a climate science epistemic community. It may even constitute an epistemic community in its own right, with distinct standards and norms of validation and, possibly, its own channels of policy influence, but so far, little is known of these standards, norms and validation. Our objective is to explore and understand the specificities of IAM research: what distinguishes it from other types of climate-related science? How is it organised? What does its authority within climate change expertise rely on? In other word, we seek to investigate how IAMs and socio-economic emission scenarios are made, which we consider a prerequisite to analysing how they are used and to inquire into the precise nature of their interactions with policy-making.

Our approach raises two questions related to different topics of research in STS. The first relates to diversity within climate science. While climate science has expanded dramatically over the past few decades, few studies have tried to unpack the plurality of scientific perspectives that make it up, and the relationships among them. Detailed analyses of the making of climate knowledge have tended to focus on the natural science side of climate research, and especially on Global Circulation Models (GCMs). Shackley and Wynne (1995a, 1995b), Shackley et al. (1999) and Demeritt (2001) have analysed how GCMs came to dominate climate science in a context of "mutual construction of climate science and policy" (Shackley and Wynne, 1995a) and of their expectations towards one another. However, when it comes to expertise on climate change adaptation and mitigation (that is, the domains of WG II and WG III of the IPCC), we know much less (Hulme and Mahony, 2010). Recent studies have mapped the research networks and disciplines involved in WG III of the IPCC (Corbera et al., 2015, Hughes and Paterson, 2017), but with a focus on personal trajectories and institutional affiliations, rather than on the scientific perspectives, instruments and practices used. Investigating IAM research as one of the scientific approaches represented within WG III – and a particularly influent one – is a step towards a more refined understanding of climate expertise.

Our practice-oriented approach relates to a second STS question, which has to do with the emergence of scientific communities and in particular epistemic communities. Early laboratory studies tended to shun approaches in terms of scientific community: instead of imposing abstract, predefined social units to the description of science, they argued, one should focus on empirical accounts of scientific practices and emphasise the multiple relationships in which such practices are entangled (Knorr-Cetina, 1982). Since then, STS have re-appropriated the notion of scientific community. While rejecting the characterisation of such communities as "focused largely on shared theories and constitutive of a discipline or field" (Leonelli and Ankeny, 2015: 702), they approach them from a practice-oriented perspective, providing material and situated accounts of the collective organisation of research (Molyneux-Hodgson and Meyer, 2009; Meyer and Molyneux Hodgson, 2010; Leonelli and Ankeny, 2015; Merz and Sormani, 2016). Similarly, STS have seized the notion of epistemic community with a view to enriching it. Meyer and Molyneux-Hodgson (2010), Akrich (2010) and Demortain (2017) have all pointed out a lack of research on how epistemic communities emerge and how they produce knowledge, share it, and make it relevant for policy: epistemic communities often appear as finished products, that is as homogeneous and readily available when policy problems emerge. This leaves behind the question of how policy-relevant research is produced and stabilised. Meyer and Molyneux-Hodgson (2010) suggest that we view epistemic communities as dynamic entities and call for studies on how they come into being, how they are made and materialised. This amounts to investigating how scientific knowledge is made so as to be policy-relevant and how scientists organise to act with knowledge. More broadly, this is an invitation to study the joint emergence and structuration of research and of its domains of applicability, especially when these domains of applicability have to do with policy-making.

IAM research appears particularly suited to take such analyses further: it predominantly takes place in academic settings, but its vocation for policy usefulness is explicit (Shackley and Wynne, 1995b: 122; Edwards, 1996; Weyant et al., 1996). It is also in large part organised in project-based collaborations of various types, such as large model intercomparison projects, EU-funded consortia, or contributions to the work of the IPCC. This entails specific conditions for knowledge production. For instance, in an analysis of the European Commission-funded project ADAM, Eva Lövbrand showed how integrated assessment modellers involved in the project aligned their scientific objectives with the European Commission's expectations, providing assessments that supported (rather than challenged) the EU's policy goals; but, in so doing, they opened new research questions and expanded their scientific horizons (Lövbrand, 2011: 232-233).

To account for the peculiar dynamics and organisation of IAM research, we borrow Leonelli and Ankeny's notion of 'repertoires' (Leonelli and Ankeny, 2015). Repertoires are shared sets of norms, infrastructures, procedures and resources that successfully adapt to the broader research and funding context, and that come to structure the development of communities committed to using them. Leonelli and Ankeny are interested in how some temporary projects perpetuate into lasting communities. For them, the notion of repertoire "captures what happens when specific projects become blueprints for the way in which whole communities should do science" (Leonelli and Ankeny, 2015: 705). By communities, they refer to "group[s] of individuals brought together by repeated interaction around one or more goals, which can range from the pursuit of a given interest to the production of a tool, the development of a procedure, or the use of a common space (whether physical or intellectual)" (Leonelli and Ankeny, 2015: 702). We use the term in a similar way when we refer to 'the IAM community'. Our objective is to map out how such a community emerged out of punctual projects, and what shared repertoire holds it together. However, contrary to the biological research communities that Leonelli and Ankeny study, IAM research is almost constantly concerned with its relevance and applicability: constructing policy-relevance is part of the work of establishing a repertoire.

The centrality of policy-relevance in the organisation of the IAM community shows in the type of projects in which the repertoire emerged. Indeed, these were largely driven by the agenda of the IPCC, especially in the preparation of the AR5, and, to a lesser extent, by requests from the European Commission to assess options for climate policy. The involvement of IAMs within the IPCC process thus appears as a key driver in the constitution of the repertoire of IAM research. The following section retraces the history of this involvement with a focus on how IAMs became central to the production of socioeconomic scenarios within the IPCC process.

The production of socioeconomic emissions scenarios for the AR5: a catalyst for structuring the IAM community

Socioeconomic emissions scenarios and IAMs in the IPCC AR5

IAMs have played a significant role in the AR5 (Edenhofer et al., 2014: 48), where they are described as "invaluable to help understand how possible actions or choices might lead to different future outcomes" (Edenhofer et al., 2014: 51), that is as guides for political decision. Two types of IAM-generated scenarios appear in the AR5. First, four 'Representative Concentration Pathways' (RCPs) representing contrasted possible emission trajectories to 2100 served as input for the elaboration of new climate change projections by climate models (IPCC, 2013: 164, 1060). They were produced by four IAMs. Second, IPCC WG III collected a database of 1184 peer-reviewed socioeconomic scenarios (IPCC, 2014b). Thirty models contributed to the scenario database, with eleven providing 966 out of 1184 scenarios (IPCC, 2014a: 1309-1310).

Box 1. Climate science acronyms

GCM: General Circulation Models are physics-based models of the atmosphere and ocean, used for weather forecasting, to study the climate, and to generate long-term projections of climate change.

ESM: Earth System Models are natural sciences-based models that represent biogeochemical cycles (especially the carbon cycle) in addition to the climate system.

IAM: Integrated Assessment Models draw on engineering, economics and natural sciences to represent interactions between human, technological and environmental systems. They are used to produce socioeconomic emission scenarios and to assess global climate policy options.

IAV: Impact, Adaptation and Vulnerability is a heterogeneous field that studies the vulnerability and adaption of socioeconomic and natural systems to the consequences of climate change, often at a regional rather than global scale.

IPCC: The International Panel on Climate Change, created in 1988, regularly produces overview of peer-reviewed climate science. It does not produce research and it claims to be policy-relevant, but not policy-prescriptive. It comprises three Working Groups: WG I on the physical basis of climate change; WGII on impacts, adaption and vulnerability; WG III on mitigation.

The use of IAMs to produce such scenarios specifically in view of IPCC assessment reports was not a novelty, though it gained importance in the AR5. The website of the Integrated Assessment Modeling Consortium (IAMC), a key forum for IAM research, mentions the involvement of IAMs as early as the First Assessment Report, and portrays the histories of IAMs and of the IPCC as intertwined:

> Development and analysis of global to regional and country scenarios have been at the heart of integrated assessment modelling from its earliest days: scenarios to underpin the 1st Assessment Report of the IPCC were elaborated with 1st generation IAMs. (IAMC Website, undated)

Looking back to the early days of the IPCC, this section shows how the production of socioeconomic emissions scenarios drove the development of IAMs and their involvement in the IPCC process. This intensified in the late 2000s, when the IPCC delegated the production of scenarios to the 'scientific community' (IPCC, 2006), and through the intermediary of a few IAM teams.

The historic role of IAMs in the production of IPCC socioeconomic emissions scenarios

In 1988, the IPCC received a mandate from the UN General Assembly to produce regular assessments of the physical impacts and climate policy aspects of climate change in order to inform policy-makers. Over its first four Assessment Reports, the IPCC has orchestrated the elaboration of three generations of socioeconomic emissions scenarios used as references for the evaluation of future climate change, its impacts, and its techno-economic implications.

The first two generations of IPCC socioeconomic emissions scenarios, the SA90 and IS92 (Leggett et al., 1992) were produced respectively in 1990 and 1995, as part of the IPCC's First and Second Assessment Reports. They were produced using the two main IAMs operational at the time: ASF, developed by the EPA in the US, and IMAGE, developed by the Dutch National Institute for Public Health and the Environment (RIVM).

In 2000-2001, the preparation of the Third Assessment Report (TAR) was a turning point regarding the substance of scenarios. Their construction was recognized as a means for organising and communicating the uncertainties associated with climate policy. Four storylines were developed using a forward-looking approach: first, describing socioeconomic driving forces, then modelling resulting emissions and atmospheric concentrations of greenhouse gas and aerosols. The reference scenarios were published in 2000 in the *Special Report on Emissions Scenarios* (SRES) (Nakicenovic et al., 2000).[4] They served as references in the Third and Fourth IPCC assessment reports (IPCC, 2001; 2007). In a sequential approach, the SRES scenarios provided emissions trajectories both for climate models (using them as input to project the magnitude and pattern of climate change) and for impact models (using them as input to evaluate climate change impacts).

The productions of SRES scenarios mobilised more modelling teams than the two previous generations of scenarios. Six IAMs were selected to develop reference scenarios: MESSAGE, IMAGE, MARIA, AIM, MiniCam, ASF. These models were developed in research institutes focusing on modelling environment and climate issues that were based in Europe (IIASA, RIVM), in Japan (RITE, NIES) and in the US (PNNL, EPA).

The SRES provided a first opportunity for IAM teams to work together. It also brought crucial upstream inputs for the two other IPCC Working Groups (Interview 6). The International Institute for Applied Systems Analysis (IIASA) played a central role. Founded during the Cold War to foster collaborations between scientists from the East and the West, IIASA builds upon a long tradition in the modelling of energy and environmental systems initiated in the 70s. Researchers in these fields have participated in IIASA's Energy Systems Program over the years. In the 90s, energy research and climate research began to merge and grew increasingly involved in the IPCC. Nebojsa Nakicenovic, head of the "Transitions to New Technologies Project", gradually emerged as a leading figure. Together with Bert de Vries (head of the IMAGE team at RIVM), he took on a major role in the coordination of the SRES as convening lead author.

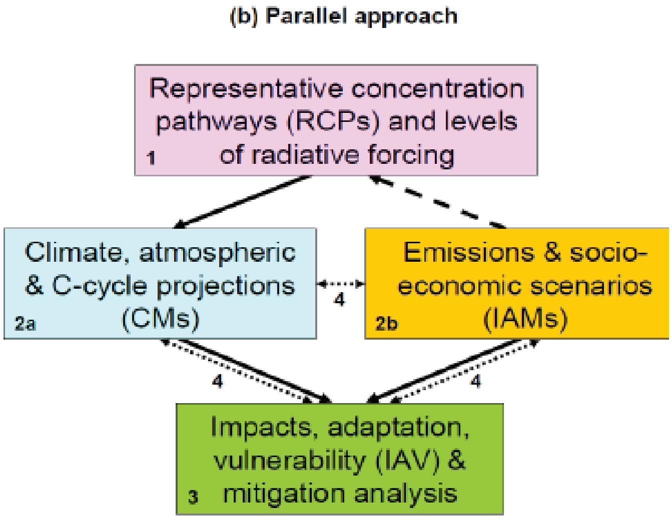

Figure 1. The AR5 new scenario approach (Source: IPCC, 2007)

Socioeconomic scenarios for the AR5: a new approach

The preparation for the Fifth Assessment Report (AR5) started in 2004, even ahead of the publication of the Fourth. The IPCC wanted to develop a new approach to socioeconomic emissions scenarios and, subsequently, to the interactions between IPCC and IAMs. Indeed, faced with criticism of the limitations of the SRES scenarios (Webster et al., 2003; van Vuuren and O'Neill, 2006), the IPCC acknowledged the need for new 'emissions scenarios' following the AR4. In 2005, it created a *Task Group on New Emission* Scenarios (TGNES) to study the matter. In 2006, the TGNES suggested a parallel approach to scenarios production associating the communities of climate modelling, Impact Adaptation and Vulnerability (IAV) and IAMs for the AR5 (Fig.1, Box 2). The IPCC endorsed this strategy at the Noordwijkerhout expert meeting in 2007 (Moss et al., 2008).

IAM teams, especially those that played a leading role in the SRES process, were significantly involved in both the TGNES (9 out of 31 members) and in the and in the preparation of the Noordwijkerhout meeting.

The delegation to IAMs: a catalyst for community-making

Alongside discussions about the production of new emissions scenarios, debates focused on the role of the IPCC in their development.[6] The IPCC had directly organised the development of the previous sets of socioeconomic scenarios. This time, the options favoured following the expert

Box 2. The "parallel approach" to scenarios

The parallel approach adopted for the AR5 process was intended to address the limitations of the SRES scenarios, especially the delay required to use the scenarios in studies of impacts, adaptation, and vulnerability (Parson et al., 2007; Moss et al., 2010) and the difficulty for models to completely reflect storylines decided separately from model construction. This new approach started with the selection of four RCPs, from available scenarios in the IAM literature. The RCPs were finalised after a huge work of harmonization with climate scientists. They were supposed to help develop new set of climate model simulations "at the same time that new work [was] carried out in the Integrated Assessment Model (IAM) and Impact, Adaptation and Vulnerability (IAV) communities" (van Vuuren et al., 2008). They served as references for the evaluation of socioeconomic implications and climate policy options by IAMs for the AR5 WG III[5]. IAM played a central role throughout this process, as they produced both RCPs (4 out of the 6 used in the SRES) and socioeconomic emissions scenarios for WG III.

meetings were for the IPCC to simply facilitate or coordinate the development of new socio-economic emission scenarios by independent researchers, rather than carry it out itself. This was seen as a way to avoid a technocratic process while guaranteeing the independence of the IPCC and the work across Working Groups.

At its 25th Session in 2006, the IPCC delegated the preparation of those scenarios to the 2research community" describing itself as a "catalyst" for scenario production (IPCC, 2006). Lobbying from the research community weighed in the decision. Our interviews suggest that IAM teams informally convinced the IPCC bureau, in particular the co-chair of the IPCC, Rajendra Pachauri, that they were able to convene the process. A group of modelling teams from IIASA and NIES, headed respectively by Nebojsa Nakicenovic and Mikiko Kainuma (who had both played a key role in the SRES), together with John Weyant (director of the Energy Modeling Forum, in Stanford), decided to establish a specific consortium to that end, the IAMC.

> So, we had convinced Pachauri and the bureau during the four workshops on scenarios during the AR4, this is in preparation for the next round essentially, we could do it. Toward the end of the period Pachauri told us: I know you guys want to do this, but you do not have any funding and support. He wanted to be sure we could make it. So, a few of us, N. Nakicenovic, M. Kainuma, got together overnight and said: we are starting a new institution, and we are going to have the Integrated Assessment Modelling teams and we are going to call it the Integrated Assessment Modeling Consortium with annual meetings, scientific assessment committee and so on. (Interview 11)

The IAMC was formally created in 2007 and a consortium agreement was elaborated with the IPCC. It is overseen by a "Scientific Steering Committee" comprising the three founding teams, PNNL, as well as several European (PBL/the Netherlands, PIK/Germany, FEEM/Italy) and Southern teams (IMA/India, ERI/China, UFRJ-COPPE/Brazil). The list of participants in the IAMC overlaps with that of lead authors in the contribution of WG III to the AR5, particularly those of chapter 6 on "transformation pathways", which was based on IAM outputs. So-called "transformation pathways" – IAM-generated scenarios – served as a red thread to ensure the overall coherence of the report, and researchers working with scenarios were spread out as authors across the chapters (Interview 3).

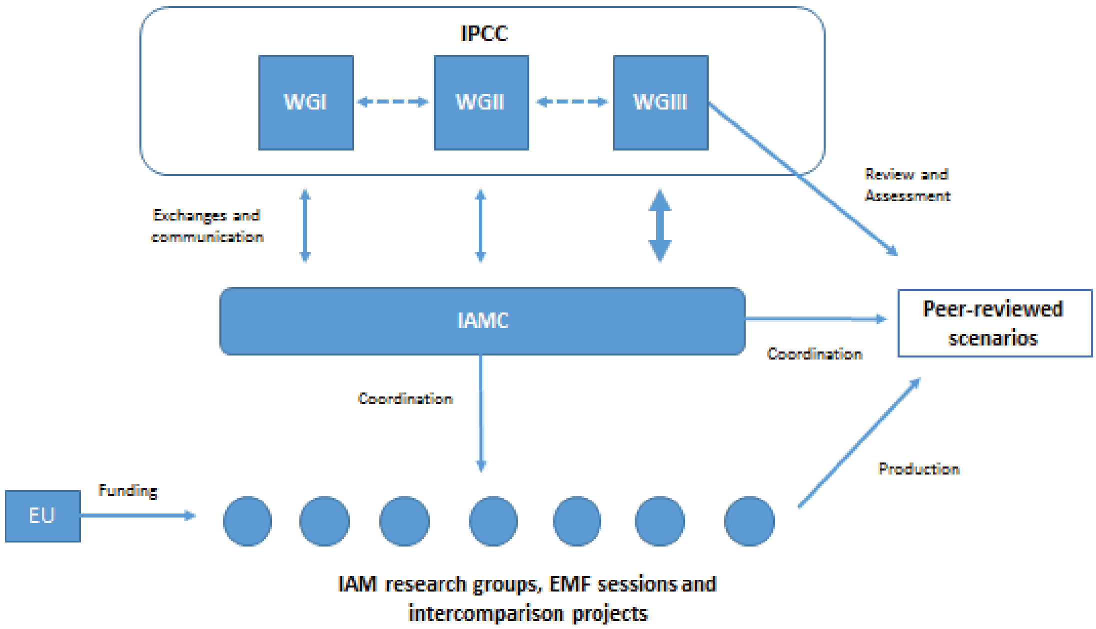

Figure2. Formal organisation of interactions between IAMC, IPCC and the IAM community during the AR5 process. Many people circulate across institutions and are involved in several of these groupings.

The main role of the IAMC is the coordination of research activities within the IAM community, initially focusing on the preparation of RCPs. The IAMC itself does not produce scenarios or conduct research. The scenarios referenced in the AR5 were produced either by individual teams (as in the case of RCPs) or in a series of Model intercomparison projects (MIPs). MIPs have been a regular feature of IAM research since the early 90s, in particular those organised by the Energy Modeling Forum (EMF). The EMF is a point of reference with an "enormous convening power on [the IAM] community" (Interview 4), and two sessions related to climate change took place within the AR5 timeframe (i.e. between 2004 and 2014). A new feature in this period was the increasing role of European projects funded by the Commission within the 7th research Framework Programme, which pushed for evaluation of the 2°C target as it was the backbone of EU climate policies (Lövbrand, 2011). EU-funded projects largely focused on estimating the possibility to comply with the 2°C objective and the related mitigation costs according to the ambition of countries' commitments or the availability of low carbon technologies among major emitters from North and South countries (Table 1). The outcomes of these projects were collected into dedicated databases, published in peer-reviewed publications, and assessed by the IPCC WG III (Fig. 2). These scenarios provided the backbone for the WG III report on mitigation (IPCC, 2014a; interview 5).

Since the early 90s, the production of socioeconomic emission scenarios has fostered collaborations among IAM teams. This was in large part a result of the demand from the IPCC for reference socioeconomic emission scenarios and, in the preparation of AR5, for a wide range of emission scenarios testing diverse options for climate policy. The preparation of the AR5 was a milestone in the structuration of the IAM community: it framed the production of a new generation of socioeconomic emission scenarios as a community-wide effort and gave more attention to IAMs than previous report. What are the specificities of this community, and what holds it together, aside from the participation in the production of emission scenarios?

Variety and convergence among IAMs

From the account of the interactions between the IPCC and the IAM community, IAM research can appear as a relatively small and close-knit field, comprising of about 30 teams that regularly collaborate in projects. However, taking a closer look, the IAMs referred to in the AR5 turn out to be quite diverse: they do not constitute a homogeneous category. In this section, we review the specif-

Table 1. Model Intercomparison Projects contributing to the AR5 database (adapted from IPCC, 2014a: 1311)

Modelling Intercomparison Projects	Date	Type	Leader	Teams	Models	Scenarios in the AR5 database
ADAM	2006-2009	EUFP6	Tyndall Center	7	5	15
EMF22	2008-2009	EMF session	Stanford University	23	17	70
AME	2009-2011	International	PNNL	17	27	83
POeM	2008-2011	EUFP7	Chalmers Univ of Technology	8	3	4
RECIPE	2008-2010	European	PIK	4	3	18
EMF27	2010-2013	EMF session	Stanford Univ	24	17	362
ROSE	2010-2012	Stiftung-Mercator funded	PIK	5	4	105
AMPERE	2011-2014	EUFP7	PIK	23	14	378
LIMITS	2011-2014	EUFP7	FEEM	13	7	84
GEA	2008-2012	IIASA	IIASA	2	2	1

icities of IAMs and outline what such specificities entail in terms of talking of an IAM community.

The heterogeneity of IAMs

IAMs share a few characteristics: their complexity, their global scale, the fact that they represent both physical and social phenomena, their vocation to "help understand how possible actions or choices might lead to different future outcomes" (Edenhofer et al., 2014: 51), and their use of economics as a basis for decision-making. Beyond these similarities, IAMs encompass a wide diversity of approaches to modelling, which is reflected across the thirty models referenced in the AR5 (Clarke et al., 2014: 422). Our point here is not to map this diversity or discuss classifications of IAMs – a task best undertaken by modellers themselves (Dowlatabadi, 1995; Weyant et al., 1996; Hourcade et al., 2006; Crassous, 2008; Clarke et al., 2014; Lefevre, 2016) – but to point to some manifestations of the disparate character of the IAM category besides the technical features of models.

First, integrated assessment modelling is interdisciplinary by definition. It shows in the backgrounds of modellers: among those we interviewed, aircraft engineering, physics, economics, applied mathematics, biology, operations research, environmental sciences, chemistry and government studies are represented (and sometimes combined). All IAM teams and models integrate elements from several disciplines, but they do so in different ways, and it tends to influence modelling choices and methods.

Second, whereas GCMs share a common physical basis, there is no single unifying theory of integrated assessment. Integrated assessment modelling borrows from various intellectual traditions, including energy systems modelling, macroeconomic forecasting and systems dynamics. Models vary in their architecture, in their philosophy and in the type of questions they are designed to address, with clear differences between natural science or engineering-based models and economics-oriented ones (Risbey et al., 1996: 372).

For instance, IMAGE is a geographically explicit simulation model that started from a systems dynamics approach. It has a distinctly environmental science orientation and a rather detailed energy system module:

> With IMAGE, our vision is to represent the world as much as possible in terms of the physical reality, so I prefer to describe the agricultural system in number of cows and the tons of cereals that are produced, and I'm not very interested in how many euros are produced, because the connections to the environmental change parameters are the cows in the area. (Interview 7)

By contrast, ReMIND, developed at PIK in Potsdam, started as an economic model to study endogenous technological innovation dynamics, and evolved to incorporate details on different energy technologies; it is now coupled to a land-use model developed in the same institute. In Italy, the FEEM's WITCH model is "a spin-off, essentially" in the tradition of Nordhaus' RICE model,[7] to which it added elements on technological progress as well as game-theoretical structure (Interview 12b).

Each IAM carves its own niche along the way. Common theoretical filiations, inclusions of modules from other models, shared assumptions, and other forms of kinships and coupling make the precise classification of IAMs a difficult business. IAMs tend to incorporate bits and pieces from different disciplines and intellectual traditions from which they build their own internal logic and relevance. These evolution patterns deserve further investigation, but IAMs appear to evolve through a complex interplay of available skills and interests, orientations given by funding, and research questions and insights that emerge along the way (Interview 10).

Differences across models affect the type of questions each model can address and the messages that can be derived from its outputs. Different IAMs have different strengths and limitations, and they are not all tailored to say the same things – though some limitations are shared by all, for instance the focus on technology change instead of lifestyle change or the reliance on economics as a basis for decision-making.

Increased cooperation across IAM teams

In such a disparate landscape, common ground cannot be taken for granted. The need for common standards and procedures, especially for model evaluation, was already pointed out in the beginnings of IAM research in the 1990s (Risbey et al., 1996). It remains a matter of reflection to this day (Schwanitz, 2013; Wilson et al., 2017).

At the same time, attempts at defining common standards indicate a will to orchestrate efforts so as to be able to speak as a community. From its early days, integrated assessment was conceived as a collective enterprise benefitting from a "healthy diversity of modelling approaches" that it was a good strategy to "maintain and extend" (Toth, 1995: 266). The challenge was – and still is – to articulate coherent messages out of this plurality, because the vocation of IAM research is to feed into the policy process (Weyant et al., 1996: 366). Though the IAM landscape has evolved, Risbey et al.'s diagnosis (1996) seems characteristic of the ambitions of IAMs:

> *As a community* we need to establish norms and procedures that distinguish good analyses from bad ones, to be more reflexive about our own analyses, and to make all efforts to guard against *our* analyses falling prey to political expediency. Otherwise, *we* run the risk of not being heard at all, or of speaking with the wrong voice in the political clamor over climate change (Risbey et al., 1996: 370, emphasis added)

In fact, the unifying principle behind IAM research does not lie in a core theoretical basis, but in the dual ambition to represent complex systems through a combination of disciplinary insights and to provide policy-relevant assessments – but its legitimacy to do so rests on epistemic grounds whose soundness needs to be collectively guaranteed. This distinctive feature of IAM research has largely shaped its collective organisation. It can account, at least partly, for the prominence of collective projects and institutional hubs in the IAM community. Institutions such as the EMF in Stanford, which has coordinated model intercomparisons since the 1970s, or IIASA, where many IAM researchers have spent time (Corbera et al., 2015), have served as nodes for sharing and comparing modelling perspectives and results. The IPCC seems to constitute a similar nodal point for IAM research. Corbera et al. (2015: 96) have analysed patterns of authorships in WG III, showing that a small number of researchers co-author regularly with each other; most have contributed to several IPCC reports, suggesting they may have organised their career around the IPCC process. Out of the top 20 authors in this group, we identified a dozen as directly involved in IAM research networks.[8]

Since the mid-2000s, contacts and common projects have multiplied, driven by the momentum provided by the preparation of the AR5 and by a series of EU-funded projects on climate mitigation options. Networks that used to be separate have merged (Interviews 4, 12a, 12b), and interactions across teams have intensified and stabilised. The following section analyses the repertoire that emerged and stabilised as IAMs were mobilised to produce scenarios in view of the AR5, and how it contributed to the organisation of the IAM community.

The IAM community's repertoire

Several large projects took place between 2005 and 2014 (Table 1), which was a period of intense collective activity for IAM researchers who worked on the RCPs and were expected to assess a range of mitigation scenarios. These projects were framed both by demands from the IPCC (a new generation of reference socioeconomic emission scenarios; an evaluation of the implications of a 2°C target), and by the EU's request for science-based support for its own climate policy objectives (Lövbrand, 2011). They stimulated cooperation, intensified interactions across IAM teams, and led to the setting up of devices and institutions to work with the heterogeneity of IAMs. These were not only crucial in the preparation of the AR5, they have remained in place to this day. They now shape the way IAM research is carried out, and delineate the IAM community: they constitute a 'repertoire' enabling the continuation of collective work, framing common goals and standards, and ensuring the transferability and legitimacy of IAM results (Leonelli and Ankeny, 2015). In this last part, we focus on the three main features of this repertoire: the IAMC, the organisation of work in Modelling Intercomparison Projects, and scenario databases. All address the same core challenge of IAM research: extracting a policy-relevant message out of diverse modelling approaches and philosophies.

The Integrated Assessment Modeling Consortium (IAMC)

The IAMC is a *sui generis* institution that has become a central node in the collective organisation of IAM research. It was created in 2007 to coordinate the production of RCPs for the IPCC but outlived this purpose to become a community organisation. As one of its founders summarised, "we are trying to do our own community, this is the role of IAMC now" (Interview 11).

From the start, the IAMC served as a forum to discuss the evaluation of modelling outputs in reaction to external requests and to organise relationships with end-users of scenarios, chiefly climate scientists. The coordination of the RCP process required the harmonisation of scenarios produced by different IAMs and their adaptation to the needs of the climate scientists who would use them. Once the RCPs were ready, the IAMC broadened its scope to become a proper discipline organisation. As one modeller recalls:

> All these people that were coming to the IAMC and were not part of the RCP development – I didn't know why they were coming, because on our annual meetings we were all the time discussing the RCPs. And so, a couple of years ago, we decided to completely reform the IAMC into a much more useful organisation, which is now this discipline organisation, similar to the AGU [American Geophysical Union] for geoscience. So, we want to become this discipline organisation which organises this annual conference to look into interesting topics and to share knowledge. Also at other moments of time, we have our working groups to help the community. (Interview 7)

The IAMC convenes annual meetings since 2008, and the number of attendees is slowly, but regularly, increasing. These meetings consist in an open conference, after which 'Scientific Working Groups' meet to discuss issues at the core of the practice of integrated assessment, such as data protocols, shared model documentations, or model evaluation and diagnostics. While actual work on these issues mostly takes place within specific projects (Interview 12a), the IAMC serves to bring it together in front of the whole community.[9]

The IAMC gradually established itself as a focal point for IAM research, "the central point where everything should go" and "the organisation that should coordinate activities" (Interview 12b). It provides an arena for negotiating and stabilising the epistemic culture of integrated assessment modelling as well as an institutional embodiment of the IAM community. All the same, it is a young organisation without permanent funding, which depends on the financial resources made available by member organisations. This limits its capacity to undertake much work beyond communication and meetings. The community remains largely dependent on government-funded projects for its activities. The IAMC also lives in the shade of better-known institutions such as the IPCC or IIASA: "it still needs to be credited" because "no one knows about it" (Interview 12b).

Model Intercomparison Projects (MIPs)

A significant part of IAM research occurs in MIPs. They aim to compare the outputs and behaviours of several models and to test how they react to specific sets of assumptions. Though inspired by climate science practices, this type of project is quite specific to the IAM community. The EMF has regularly organised such model intercomparisons since the 1990s, but the practice intensified and institutionalised during the preparation of the AR5. 95% of the scenarios considered in the report of WG III in the AR5 were generated in nine MIPs (Table 1). Each of these projects brought together more than a dozen of modelling teams from all over the world, strengthening interactions among them. Two were organised by the EMF, which coordinates but does not directly fund research; five were funded under the EU Framework Programmes. The EU-funded projects constituted a change in the scale and scope of MIPs, bringing European teams closer together and enabling their growth.

Participation in model intercomparisons, especially those convened by the EMF, is, as the leader of one team told us, "a matter of pedigree" (Interview 4): it is a sign that you belong to the community and that your model is recognised by this community. Besides, with the multiplication of EU-funded MIPs in the late 2000s, these projects have become one of the main sources of funding for IAM teams. They are also one of the main venues for collaboration across teams, influencing the organisation of IAM research. Because MIPs seek to pool together and make comparable scenarios produced by very different models, they entail both practical and theoretical reflections about the organisation and verification of modelling.

MIPs as they developed since the late 2000s tend to follow a similar pattern. Work is divided into several work packages, and it is shared between a project coordinator, leaders of work packages, and the rest of the participants. Starting from a central question, protocols are established to analyse sub-questions in separate work packages that define which types of scenarios need to be generated.

> [Protocols] change, of course, because they answer to different questions, but the structure is the same to isolate factors. Questions change but this is the same matrix with two axes: one axis with climate policy, typically 2°C, and on the other axis you have what you want to understand: technology, policy, structure, anticipation… and then you have scenarios – from 10 to 20 – in the matrix. The matrix has scenarios which are compulsory, optional. (Interview 12b)

The production of scenarios follows a standard protocol based on the comparison of policy scenarios against baselines without climate policies.

In a first step, a diagnostic describes how models differ in their response to climate policy, looking for instance at the rate of emission reductions for a given carbon price trajectory. Diagnostics aim at identifying patterns of model behaviour and contributing to their validation. This was inspired by the Coupled Model Intercomparison Project (CMIP) in climate science[10], as a consequence of the parallel process of scenarios production for the AR5 that encouraged exchanges across climate research communities. Scenarios assumptions are then implemented in a chosen set of models. This requires some harmonization across models in order to manage global uncertainty. Scenarios are generated by models and results analysed and compared in each work package, and each work package leader has scrutiny over the protocol and the processing of data.

MIPs entailed intense collaborations, fostering mutual learning about the specificities of each IAM. They drove improvements in model documentation and evaluation that helped to map and characterise differences between models. They contributed to the development of common modelling practices across teams and fostered innovation.

MIPs result in the production of sheer numbers of scenarios, and the need to manage them contributed to the development and stabilisation of another key element of the repertoire of the IAM Community: scenario database.

Scenario Databases

The first initiatives to constitute databases of socio-economic and emission scenarios date back to the 90s, but the practice gained prominence in the late 2000s. Here again, the development of standardised, publicly available scenario databases can be traced to the AR5 process. A first database was elaborated to gather the RCPs and make them available to their users. A second IPCC-related database followed, to collect scenarios as part of the preparation of the report of WG III, which planned to use them to map "the solution space" (Edenhofer, 2014).

In 2012, WG III issued an open call for scenarios: IAM teams were invited to submit socioeconomic emission scenarios for consideration by WG III. To be included in the database, scenarios had to meet a series of criteria: being peer reviewed, providing a minimum set of mandatory variables, scenario documentation, or coming from "formal energy-economic or integrated assessment models" with a large coverage of energy sectors (IAMC, 2012). The data template (an excel file) gathered general instructions, the description of the scenarios, a model classification and data breakdown by models/regions/variables every ten years until 2100.

These two databases are hosted on IIASA servers. IIASA has devoted human resources to the maintenance and operation of the databases in coordination with the IAMC (Interview 12a; Guivarch 2016, personal communication). A web-based infrastructure was built to enable modellers to upload their results and to allow outside users to access the data. It includes detailed information about the purpose of the database, the regions and sectors covered, the list of MIPs that contribute to the database, etc. (e.g. IPCC, 2014b)

With such infrastructure available, most MIPs now gather scenarios in similar databases. These are built according to similar templates and usually hosted on the same IIASA server, though not all of them are public. The evolution towards more standardised data management indicates an increasing professionalization of IAM-based scenario production, with a move from spreadsheets to big databases.

> While we previously, fifteen years ago, would run 3-4 scenarios and submit them via an Excel spreadsheet, and somebody would make – at hand – a PowerPoint presentation out of it, now we have these tools where we submit to a database, maybe 20 scenarios from each team, people have R scripts where they are able to pick up directly all kinds of analyses from these databases… So, we have become much more professional. (Interview 7)

Databases shape IAM research in several ways. First, they are tools for scientific research: they serve to organise collaboration, allow for rapid checking of errors in reported data, and have become "standards to read data" that modellers "use for themselves" as "a way to learn the model" (Interview 13). Second, they pool and order scenario data, making it available in usable forms. Some databases are public, and anyone can access the data and work with it: modellers consider they "make a huge service to other scientific communities" by creating and maintaining them (Interview 10). Third, the increased reliance on standardised database encourages a degree of convergence in modelling approaches.

Last, these databases pool together scenarios from a set of diverse models and organise them according to standardised templates, making them easily available. However, they do not stand alone: to work with them meaningfully, one must have a sense of how scenarios were produced, to answer which questions, and by which models. This is mostly transmitted informally, via discussions and mutual understanding fostered by regular interactions (Interview 5). The databases lose part of their meaning when separated from the collective that contributed to them, and in that respect subtly demarcate the IAM community. Integrated assessment modellers thus sometimes blame those who use the database without having access to this informal knowledge for treating these datasets "as numbers that are all the same", or as "statistical samples", whereas "to do justice to the database you would need to go through all the study protocols" (Fieldnotes, 2015b).

Effects of the repertoire: professionalization and convergence

The IAMC, MIPs and scenario database all emerged during the period of preparation of the IPCC AR5, largely as tools to organise the contribution of IAM research to it They have perpetuated and they play a crucial role in the current configuration of IAM research, shaping day-to-day work within research groups, collective organisation, and communication with external audiences. Modellers argue that the field has become "more professional" owing to the consolidation of this repertoire (Interview 7). Interactions among teams are more sustained and institutionalised, leading to better cross-knowledge of the strengths and weaknesses of models and to less heated debates about basic modelling approaches (Interviews 4, 7). The repertoire seems to allow for the articulation of common purposes. In particular, it has enabled a coordinated reflexion on model evaluation to eventually take place (Schwanitz, 2013; Wilson et al., 2017), mostly within MIPs but also via the IAMC and its scientific working groups. This comes with added visibility – and scrutiny – for IAMs and their results, especially since some scenario databases are publically available.

All the same, the consolidation of a repertoire for IAM research generates its own challenges and constraints. As Leonelli and Ankeny (2015: 706) noted:

> The adoption of a repertoire unavoidably creates strong commitments to particular techniques, assumptions, values, institutions, funding sources, and methods, which although initially productive, can sometimes act as constraints to future integration and innovation.

MIPs contributed to a proliferation of scenarios, to the extent that “[we might] reach a point where no two papers will use the same reference scenarios” (Fieldnotes 2015b). More crucially, the shared protocols of intercomparison and the standardisation required for inclusion in databases lead to a form of convergence and “group thinking” (Interview 7) that some critics consider as insularity (Fieldnotes 2015a; Interview 6). One widely acknowledged issue is that this organisation of research favours the investigation of common questions, the reproduction of scenarios, hence the development of similar features across models, to the expense of the improvement of models and the exploration of their core specificities (Interviews 5, 13). The convergence of research agendas is reinforced by the IAM community’s current dependence on EU funding, which directs research towards the assessment of specific climate policy objectives, such as the 2°C or 1.5°C targets (Interviews 12b, 13).

Conclusions

As part of an investigation of how the socioeconomic emission scenarios used to study human interference with the climate are produced, we have studied the research community that works on them. This community is unified not only by the scenarios that it produces, but also by the fact that it uses models labelled as IAMs to do so. Despite constituting a heterogeneous set of models, these IAMs are all interdisciplinary models with a vocation for policy-relevance.

We have shown how interactions within the IAM community have intensified and organised since 2005, spurred by the IPCC and the EU. The elaboration of the IPCC AR5 was instrumental in this process. When the IPCC delegated the preparation of new scenarios to the scientific community, IAM researchers were on the front line: RCPs used by climate models were generated by IAMs, and so were the socioeconomic emission scenarios assessed by WG III. As for the EU, it funded several large IAM projects to inform and support its climate policy and to feed into the IPCC process; these enabled IAM research groups to capitalise on existing collective arrangements like the EMF, and to develop new methods and tools for cooperation, thereby equipping the definition of IAMs as a category of models.

Last, we analysed three elements of the repertoire that emerged during this period of intense collaboration: the IAMC, Model Intercomparison Projects, and scenario databases. These are now central to the way integrated assessment modellers do research. They frame epistemic practices and demarcate the IAM community. This repertoire organises harmonisation and professionalization as well as increased interpersonal and informal exchanges. We showed how it seeks to articulate the technicity and diversity of IAMs, the ambition to combine the variety of perspectives they offer, and the need for transparency heightened by their ambition to inform policy. This repertoire was also shaped by an ambition for policy-relevance that is constitutive of IAM research and that translated in close ties to the IPCC agenda. Indeed, it was developed during projects that were largely driven and framed by the preparation of the IPCC AR5. As a result, on top of framing common epistemic practices, the repertoire ensures that IAM research works towards specific applications – namely, informing climate policy choices. We have thus analysed the emergence and organisation of one applied science. This leads us to a set of empirical observations that raise general issues about applied sciences and their relations to their expected users.

The applied character of IAM research and its ambition for policy-relevance materialise in its symbiotic relationship with the IPCC. The IPCC acts as a communication channel between climate negotiations and climate science, as well as among climate research communities; it has become a central feature in the organisation of climate change research itself. This is particularly striking in the case of IAM research, whose origins story ties the evolution of IAMs to that of IPCC reference scenarios. We showed how the IPCC plays in the orientation, rhythm and domain of applicability of IAM research, but also that IAM researchers were heavily involved in the IPCC process, thereby influencing it, particularly during the AR5 process. This interrogates the demarcation between research and assessment at the core of the IPCC, at least in the case of WG III. To an extent, the separation between the two activities seems artificial and mostly institutional, especially when many researchers are involved, and influential, in both.

All the same, and however difficult it is to maintain, the demarcation comes with constraints that partly shaped the repertoire of the IAM community. It led to the creation of an intermediary institution, the IAMC, to coordinate the preparation of RCPs. The peer-review criteria imposed a deadline for the publication of project results. Last, the choice by WG III to assess "the full breadth of baseline and mitigation scenarios in the literature" (Edenhofer et al., 2014: 51) spurred the creation of a scenario database, a practice which has now become a standard of multi-teams IAM projects.

The joint construction of the IAM community and of the applications for IAM research also appears through the influence of the EU. Since the mid-2000s, most of the funding for European IAM teams came from MIPs funded by the DG Research Framework Programmes (FP6 and FP7). These projects stimulated interactions among teams and heightened the need for common databases and protocols. The need for comparability and the expectations from the EU inevitably influenced IAM research priorities.

By describing this process, we have shown how the IAM community worked its way to its current position in the academic landscape and with respect to climate change discussions. This position, we suggest, rests upon the articulation of epistemic practices with the pursuit of policy relevance. Emphasising this articulation as constitutive of certain scientific communities can inform a dynamic conception of epistemic communities as scientific communities that manage the balance and tensions between epistemic practices and policy relevance.

In the case of IAMs, the vocation for policy-relevance does not necessarily curtail scientific dynamism. Lövbrand (2011) found that the ability of modellers to align to the European Commission's expectations actually opened new scientific perspectives. Similarly, the repertoire that was constituted to enable IAM research to meet demands from the IPCC and the EU seems to stimulate research and to give IAM teams "an innovation boost" (Interview 4). However, the positioning of IAM research as policy-relevant also generates constraints and tensions, especially since policy framing and priorities evolve. For the IAM community, maintaining and reinforcing its current position implies adjusting to the dynamics of assessment and policies, which could come at a cost for research in the long-run. For instance, since the 2015 Paris Agreement, international climate negotiations focus on bottom-up initiatives and national mitigation policies, rather than on global action. IAMs being less suited for studies at the national scale, the IAM community seeks to assert its relevance in the face of competing expertise. In the context of EU funding, it is also expected to assess increasingly stringent climate objectives, such as the 1.5°C, and *de facto* contributes to their institutionalisation even when models have to be pushed to their limits to achieve them (Beck and Mahony, 2017; Interview 13).

Our analysis of the emergence, workings and dynamics of 'epistemic communities' complement studies on the co-production of climate futures, because they account for the way patterns of co-production take shape and evolve. It provides a necessary basis to analyse the uptake of IAM results in the policy process and the implications of the IAM community's presumably dominant position within climate expertise.

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Notes

1 Emission scenarios project the evolution of greenhouse gases emissions and the resulting atmospheric concentrations on the basis of socioeconomic hypotheses. Socioeconomic narratives are coherent sets of assumptions about the evolution of key socioeconomic variables (such as world population or GDP). The distinction is not always clear-cut: for instance, the SRES scenarios perform both functions (Nakicenovic et al., 2000). As the emission scenarios we consider all rely on socioeconomic assumptions, we refer to them as "socioeconomic emission scenarios", while acknowledging that the status and origins of the socioeconomic assumptions underpinning them may vary.

2 We interviewed researchers from COPPE/UFRJ, NIES, PBL, PIK, EMF, FEEM, and the IPCC WG III Technical Support Unit between 2015 and 2017 (Appendix 2). Observation took place during the Conference "Our Common Future Under Climate Change", Paris, July 2015 and at the Eighth meeting of the IAMC, Potsdam, November 2015.

3 According to Hughes and Paterson (2017), analyses of the IPCC in terms of epistemic community tend to emphasise the need for a separation between scientific production and political action, whereas those viewing the IPCC as a boundary organisation stress the interrelations between science and politics.

4 Special reports provide assessments of a specific issue related to climate science or policy. They generally follow the same structure as a volume of an Assessment Report.

5 Further integration between RCPs, climate model results and IAMs failed, as the new socioeconomic narratives, the so-called Shared socio-economic pathways (SSPs), were not ready on time (Kriegler et al., 2012; Moss et al., 2010; van Vuuren et al., 2012).

6 New emissions scenarios for the IPCC process were discussed in workshops in Washington (January 2005), Laxenburg (July 2005) and Seville (March 2006).

7 RICE (Regionally Integrated Climate-Economics) is an economics-based model initially developed by Nordhaus in the 1990s.

8 As is the case for the IPCC more broadly, IAM research mostly takes place in developed countries. While there are IAM teams and WG III authors from developing countries, they usually have strong links with institutions based in developed countries (e.g. having spent time there or using models based on those of developed countries teams) (Corbera et al., 2015; Vardy et al., 2017)

9 However, those in charge of a specific Scientific Working Groups are often in charge of the same issue within projects. For instance, one of the co-chairs of the "data protocol and management working group" oversees the database infrastructure at IIASA; and two of the co-chairs of the "scenario working group" are representatives of the IAM Community in the "Scenario-MIP project".

10 https://cmip.llnl.gov/index.html [accessed 31/01/2018]; on collective practices in climate science, see Guillemot (2007), Sundberg (2010) and Edwards et al (2011).

Appendix 1 - Acronyms

AR: Assessment Report
AR4: Fourth Assessment Report
AR5: Fifth Assessment Report
EMF: Energy Modeling Forum
EPA: Environmental Protection Agency
FEEM: Fondazione Eni Enrico Mattei
GCM: General Circulation Models
IAM: Integrated Assessment Models
IAMC: Integrated Assessment Modeling Consortium
IIASA: International institute for Applied System Analysis
NIES: National Institute for Environmental Studies
PIK: Potsdam Institute for Climate
PNNL: Pacific Northwest National Laboratory
RCP: Representative Concentration Pathway
RITE: Research Institute of Innovative Technology of the Earth
RIVM: National Institute of Public Health and the Environment
SRES: Special Report on Emissions Scenarios
TAR: Third Assessment Report

Appendix 2 – List of interviews

1	IPCC author, background in engineering and economics
2	Modeller, IPCC author, member of IAMC Scientific Committee, background in applied mathematics and physics
3	Modeller (land-use), IPCC contributor, background in biology
4	Modeller, IPCC author, member of IAMC Scientific Steering Committee, background in physics
5	Former member of the IPCC Working Group III Technical Support Unit
6	Emeritus professor, former modeller, IPCC author, background in chemistry
7	Modeller, leader of an IAM team, background in chemistry and environmental science
8	Modeller (climate policy), background in economics and earth and life sciences
9	Junior modeller (climate and energy policies), background in climate studies
10	Modeller, background in economics
11	Coordinator of EMF, IPCC author, member of IAMC Scientific Steering Committee, background in engineering
12a	Modeller, IPCC author, background in environmental economics and operations research
12b	Modeller, IPCC author, member of IAMC Scientific Steering Committee, background in engineering and economics
13	Modeller, background in applied mathematics and economics
14	Modeller (economics), background in economics
15	Climate scientist