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From Integrated to Integrative: Delivering on the Paris Agreement

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Received: 11 May 2018; Accepted: 28 June 2018; Published: 3 July 2018

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Abstract: In pursuit of the drastic transformations necessary for effectively responding to climate change, the Paris Agreement stresses the need to design and implement sustainable, robust, and socially acceptable policy pathways in a globally coordinated and cooperative manner. For decades, the scientific community has been carrying out quantitative modelling exercises in support of climate policy design, primarily by means of energy systems and integrated assessment modelling frameworks. Here, we describe in detail the context of a hitherto ineffective scientific contribution to policymaking, highlight the available means to formulate a new paradigm that overcomes existing and emerging challenges, and ultimately call for change. In particular, we argue that individual modelling exercises alone widen the gap between formal representation and real-life context in which decisions are taken, and investigate major criticisms to which formalised modelling frameworks are subject. We essentially highlight the importance of employing diverse modelling ensembles, placing the human factor at the core of all modelling processes, and enhancing the robustness of model-driven policy prescriptions through decision support systems. These altogether compose a truly integrative approach to supporting the design of effective climate policy and sustainable transitions and, therefore, strengthen the modelling–policymaking interface.

Keywords: climate policy; integrated assessment models; Paris Agreement; decision support; uncertainty; stakeholders; sustainable transitions; governance

1. Introduction

Responding to climate change requires transdisciplinary processes of putting together a jigsaw of initiatives that altogether constitute effective, socially acceptable, and robust domestic climate policies in a globally coordinated and cooperative manner. Recent developments like the Paris Agreement, based on which parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to periodically submit their Nationally Determined Contributions (NDCs) to the global climate action, indicate that serious steps are being taken in this direction. NDC submissions from 2025 onwards are expected to consider the results of a newly introduced mechanism, which still needs to be further specified and established, the global stocktake. The purposes of this mechanism will be to review global cumulative efforts of tackling climate change and calculate their impacts on temperature rise, on a five-yearly basis. Additionally, it will ensure that these efforts are in line with the equity-related values [1] of the Agreement.

Aside from concerns over the effectiveness of the embedded ratcheting mechanism and associated investment signals [2], the Paris Agreement features significant challenges. Although intended as a dynamic system revolving around the notion of progression, which is loosely defined in Article 4.3, this periodic pledging mechanism may prove inadequate in terms of on-time mitigation and inconsistent in terms of equity across all participating members [3]. In particular, there emerges a wide gap between the overall objectives of the Agreement and the temperature trajectories we are tracking towards as a result of currently submitted NDCs. On the one hand, the objectives are summarised in the need to limit global average temperature rise to well below 2 °C above pre-industrial levels while pursuing to further constrain this increase to 1.5 °C. On the other hand, the currently foreseen emission reduction trajectories are only expected to likely limit warming below 3.5 °C [4]. This divergence may even be considered optimistic, since these estimates do not include some climatic feedbacks that can significantly deteriorate climate change and jeopardise its control, such as permafrost thawing (e.g., [5,6]). In addition, the extent to which NDCs are adequate on a national scale greatly varies among the different submissions, with only a few NDCs appearing to be compatible with the Paris Agreement temperature rise objectives. Other instances feature challenges of monitoring nature; for example, the submission of a collective NDC from the European Union requires that Member States deliver on their national commitments and the Community successfully monitor progress made at both scales. At the same time, the global stocktake is expected to establish a cooperative basis for assessing progress and informing national pledge requirements across all dimensions of climate policy. It is also expected to foster international cooperation and encourage knowledge, technology, policy, and financial transfer. This requirement, in turn, further formalises climate action at all scales in the globally cooperative yet highly complex and abstruse global stocktaking mechanism.

In this ever-challenging context, the scientific community must provide the necessary tools for credibly and efficiently underpinning policymaking processes. So far, scientists have offered the invaluable yet daunting integrated assessment models (IAMs). Despite their undoubted contribution to the domain of climatic change, the extent to which IAMs can effectively help policymakers and support effective governance of climate policy has been challenged for decades (e.g., [7]). Among the key major criticisms of IAMs, we firstly focus on the ineffective—if any—inclusion of policymakers and other stakeholder groups in the heart of modelling activities [8]; and the inflexibility to model the multiplicity of policy instruments in the formalised modelling frameworks [9]. Furthermore, we highlight the limited capacity to assess different types of uncertainty that are inherent in climate change or associated with mitigation and adaptation policy strategies [10]; and the nature and number of assumptions [11], which are often formed outside stakeholder consultation and neglected when presenting assumption-driven modelling results to policymakers.

These criticisms compose the puzzle that the scientific community must solve in order to effectively contribute to the climate action talks and inform policymaking processes, on realistic grounds and in response to actual policy needs. They also constitute the background of our research question: how can scientific processes inform policy processes, while promoting transparency, inclusion, legitimacy, and robustness of the modelling tools and results?

In this positioning paper, we argue that scientific activities in support of climate policy design, in light of the Paris Agreement and the emerging challenges, must satisfy three essential conditions. First, they must build on ensembles of different and complementary—in terms of geographic and sectoral coverage and detail, theoretical underpinnings and mathematical structure—IAMs and other modelling tools with the capacity to extend the analysis beyond the usual research questions. The integration of different modelling approaches allows carrying out true multi- and inter-disciplinary assessments. Secondly, they must place all relevant actors at the core of modelling activities, from the formulation of policy questions and the definition of modelling assumptions in a demand-driven approach, to the mobilisation of their knowledge in bridging knowledge gaps. Thirdly, they must include well-established methodologies that, when meaningfully soft- or hard-linked with IAMs, can effectively address the aforementioned challenges and result in robust and reliable policy prescriptions.

2. The Power of Many

There is a multitude of models used for the purposes of underpinning climate and energy policies [12]. This is also evident in the number of literature reviews on modelling frameworks as well as the different scope and focus of each of these reviews. There is a reason for this diversity, which is embedded in the range of scientific disciplines and methodologies involved in their development, the variety of the underlying assumptions and their mathematical structures, and most importantly the array of research and policy questions they have been designed to address. It also reflects the fact that no single model can cover the full spectrum of issues relevant to policymaking in such a diverse and complex domain. Especially following the Paris Agreement, these issues must not be limited to traditional research questions but refer to the more ambitious goals, the newly introduced mechanisms, and the highlighted values of the Agreement. Therefore, analyses must be extended to include:

- the assessment of the role of different implementation and international coordination regimes, such as different settings of emission trading systems and a variety of financing mechanisms;
- the quantification of the costs associated with realistically covering the gaps between cumulative NDC contributions and the 1.5 °C and 2.0 °C trajectories;
- the correlation, complementarity, and trade-offs between NDCs and the Sustainable Development Goals of the 2030 Agenda for Sustainable Development;
- the consideration of emission sinks through land use and land use change and the respective environmental implications;
- the quantification of ancillary benefits and the evaluation of gains from more stringent climate control;
- the identification of distributional (e.g., on jobs and livelihoods) and inequality (e.g., gender and income) implications of climate change and policy, across different geographic scales; and
- the consideration of synergistic effects resulting from policies outside the energy and climate framework (e.g., adaptation and mitigation policies), which can have synergies or conflicts with low-carbon transitions.

In addition to the focus areas and topics that modelling activities must delve into, there is also the point of equity highlighted in the description of the global stocktake: policy efforts must safeguard just allocation of efforts and secure technology transfers and financial flows that can promote a global pathway to decarbonised and climate-resilient development. This requirement adds to the already existing reasons (spill-over effects, international policy instruments such as emission trading systems, etc.) for assessing national climate policy across different geographic scales. Also, in respect to equity, effective climate policy in this globally coordinated context must, at the very least, consider assessments of national pledges of both major and minor emitting countries, since the former are looking primarily at mitigation action and the latter are in pursuit of technological and financial aid, as well as global-level analyses. But, despite the large variety of climate-economy models, no single model can offer universal coverage with the all-possible levels of granularity and geographical disaggregation.

Finally, different types of modelling structure offer different types of insights; in fact, two exercises based on different model structures may result in significantly different or even conflicting policy prescriptions. Establishing connections between models that deploy different methodologies is a complex and understudied yet critical aspect in this domain, given that certain models focus on specific sectors or aspects while often ignoring changes taking place in other sectors or impacts on other aspects. This is why combining different modelling structures can produce better, more robust and reliable results leading to credible policy prescriptions, by overcoming the weaknesses inherent in each modelling structure [13] that no individual model can escape; and highlight uncertainties related to the model choice. Besides, it is by default that IAMs must cover in detail the interactions between energy, economy, climate, and it is these models that are often criticised for either not having the necessary level of model granularity or being too complex to manage or understand. As Reference [14] notes, the strengths and weaknesses of each modelling framework ensure that combinations of such frameworks provide valuable policy insights, in contrast to individual models. For example, general equilibrium models seek solutions in market demand–supply equilibrium across all sectors of the economy, which are analysed in high resolution and assumed completely intertwined; while macroeconometric models, inter alia [15], can complement general equilibrium-model oriented exercises by more accurately representing real-world dynamics in the short term. Complementing these with energy system models can help to examine in detail the potential of existing and emerging technologies and offer a discussion on negative emissions, which is central to realising long-term decarbonisation visions.

All of the points raised above advocate that climate-economy modelling activities in meaningful support of policy making must be built on groups of IAMs and other modelling frameworks that altogether can cover a multiplicity of geographic scales, economic sectors, topics of interest, and greenhouse gases, as well as draw from different economic and mathematical modelling structures and methodologies [16]. By employing ensembles of varying models, instead of representing only part of the climate-society system, more aspects of the climate processes can be captured [17].

An equally critical reason for using all-covering combinations of multiple models lies in the prospect of meaningful model inter-comparisons. Over the last decade, a series of numerous research and innovation efforts have been awarded to a core group of modelling consortia, driving in essence the production of hundreds of academic publications and scenarios, forming the bedrock of low-carbon pathways analyses in large scientific assessment reports, including the Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC). These efforts largely focus on model inter-comparisons between a series of IAMs, drawing from their different attributes, such as the degree of representation of technologies (particularly at the generally poorly-specified end-use side) or the regional and sectoral coverage. These differences have been highlighted as an advantage, and indeed the editors of high impact journals evidently favour model inter-comparisons (e.g., [18]), as these are more robust than single-model studies. However, there has really been no systematic comparison of models and their differences. Wherever this has happened [19], the models in comparison have been treated as having attributes, almost akin to "personalities", which are separate from the assumptions on structure and inputs that have actually been put into them. Even so, such efforts tend to successfully contribute to the study of climate change and the support of respective policies, for example, in better understanding uncertainties [20]. This raises another point: aside from underpinning policy with ensembles of IAMs, modelling activities should orient on transparent, fully-harmonised input scenarios and datasets, leading to more meaningful inter-comparisons that clearly explain differences in the modelling outputs. This, in turn, will have clear, positive implications for both policymaking and advances in climate-economy modelling.

3. Opening the 'Black Box'

In their bid to support the infamous (see Reference [21]) science–policy interface, Turnheim et al. recently referred to and argued in detail for the importance of initiative-based learning: realising the desired transitions can be achieved if all relevant actors are involved in defining, legitimising, and deploying new technologies, initiatives, and practices [22]. Mapping and comprehending the motives, concerns, strategies, and expertise of actors on the ground is of vital importance to policymakers, if their purpose is to design policies that are able to promote socially acceptable, robust, and sustainable transitions. This inclusiveness is in line with the Talanoa facilitative dialogue that Conferences of the Parties (COPs) 21–23 gradually established, towards giving voice in the climate conversations to everyone, expert or otherwise. This, in essence, stresses the need for both harmonising policy with market-driven actions and considering the socioeconomic, technological, and regulatory transitions required for effective climate action. These transitions are represented by numerous stakeholder groups, which (apart from policymakers) include the private industry, national governments, the research community, non-governmental organisations (NGOs), labour and trade unions and associations, representatives from other relevant institutions, and the civil society. Being the driving forces of these transitions required towards transforming our societies and economies, each and every one of these stakeholder groups should lie at the heart of policy support—including modelling—processes, especially in the context of an ongoing and systematic review and reshaping of climate action. Besides, recent pieces of literature suggest that gathering information, input, and preferences from a wide range of experts and including them in modelling activities significantly contributes to both transparency and robustness [23].

So far, common practice with model-based research in support of climate and energy policy indicates that stakeholders are either completely excluded from modelling activities, or to a limited extent invited in engagement processes, somewhere along a project, that are at best soft-linked with actual modelling assumptions and scenario formulation. Consequently, there emerges a wide gap between the formal representation, including the model and the processing procedures applied to or intertwined with it, and the real-life context in which decisions are made, executed, and judged. Modelling must be demand-driven and the modelling community evidently acknowledges this. Yet there is little evidence that combinations of scenarios, such as the shared socioeconomic pathways and representative concentration pathways [24,25], and high-level messages will eventually be useful to authorities involved in NDC design, submission, and implementation.

Perhaps even more importantly, for a non-involved modeller, it is practically impossible to see inside the 'black box' of these models; this clearly limits the credibility of the modelling results and the associated policy recommendations. Policymakers are, therefore, skeptical of modelling outcomes, for the underlying assumptions and robustness of which there is little information [26]. This is not just about developing open source modelling frameworks and allowing code to be made publically available or at least accessible to policymakers; besides, the latter are hardly ever interested in walls of code scripts or raw formulae. It is really about clear and simple explanations and carrying out systematic comparisons of modelling attributes and, in the case of modelling ensembles, putting efforts towards complete harmonisation of all input parameters across models, with the aim of improving the transparency of modelling processes. And, although there have been transparency-oriented initiatives from the IAM community's side (e.g., [27]), these have not been successful, at least to the point of satisfying policymakers and other relevant stakeholder groups; drastically promoting ownership of scientific outcomes; and thus transforming policy recommendations into actual policy. The failure of these efforts to sufficiently provide information on how linkages and principles are integrated in IAMs is discussed in more detail in Reference [28].

Admittedly, there have been modelling advances from a technical perspective, such as more detailed representation of new technologies or trending focus on mitigation scenarios that do not solely rely on a core subset of carbon dioxide removal technologies [29]. But to what extent do these efforts secure that policymakers feel comfortable with the results to the point of actually making large investments in particular strategies, purely on the basis of these results? If, for example, the robustness of mitigation pathways relying on bioenergy with carbon capture and storage or on direct air capture is as good as the underlying assumptions on extraction and capital costs of bioenergy plants or as the acknowledgement of no actual hitherto implementation respectively, is this clearly conveyed to policymakers? And, if so, do they still feel comfortable with these pathways or do they favour carrying out more research on the realistic capacity to diffuse and take advantage of negative emission technologies?

Any modelling activity that stands a chance of defeating this incumbency must therefore begin with an in-depth survey to systematically understand what policymakers need from the models and what part of that they have not been getting, including expectations from and understanding of the modelling tools. This can be implemented by (a) identifying what the key stakeholders are for each specific topic; (b) effectively informing them on what scientific tools, including IAMs and other modelling frameworks, can do and what policymakers should expect from them as well as how to best use their results; and (c) actually including all stakeholder groups across all stages of the modelling exercises. This new paradigm of placing the human factor at the core of modelling processes, oriented on co-design and co-production of knowledge, will ensure that modelling activities are both realistic and demand-driven, and that their results will in fact be used to effectively inform climate policymaking.

4. Removing Noise

The most one can expect from any model is a useful approximation to reality [30]. Foundations behind IAM damage functions aside, respective analyses suggest a level of knowledge and precision that does not exist [31]. Even if stakeholders and actual policy needs drive modelling processes and provide a more or less discursive basis for bridging knowledge gaps, there are two key issues of emerging concern.

The first concern regards the ways in which stakeholders' input can be elicited and transformed into a useful format in a structured and facilitative manner. And yet, there exist methodologies outside the IAM spectrum that enable the identification and assessment of aspects that are otherwise excluded from modelling activities, including barriers and risks, policy instruments, and key uncertainties [32]. And, although examples of coupling these with modelling frameworks exist, this is not a common practice among the scientific community. For example, multiple-criteria decision making has been successfully used in this domain [33] and in various settings coupled with climate-economy and energy system models before, like WITCH and TIAM [34], AIM and TIMES [35], and a MARKAL model [36]. System mapping is another expertise-driven methodology that was recently framed in this domain [37], aimed at barrier identification and analysis and heavily based on systems of innovation tools, which too have recently been used to inform climate policy studies (e.g., [38,39]). Fuzzy cognitive maps have also been used to bring stakeholders closer to modellers and translate their inputs into quantitative systems analyses (e.g., [40]).

The second issue concerns the robustification of modelling results by understanding, assessing, and reducing uncertainties and the associated noise of socioeconomic and concentration trajectories (e.g., [41]), which is key to energy and climate policy [42]. In this respect, portfolio theory and regret analysis approaches, integrated with stochastic uncertainty treatment components, already hold a fine record of integration with IAMs. Indicatively, Pugh et al. [43] used advanced technological scenarios implemented in the GCAM model and then applied expert judgment to assess the likelihood of achieving the respective R&D commercialisation goals, which they then used to build optimal technological investment portfolios. Similarly, the authors of [44] also used outputs from the DICE2007 and MiniCAM (former version of the GCAM) models, and combined economics and decision analysis to implement probabilistic data on energy R&D policy, in response to global climate change and associated risks. Acknowledging the difficulties in estimating the variance and correlations of uncertain parameters used in IAM simulations, Hu et al. [45] employed a multivariate normal distribution-based stochastic optimisation model to produce robust policy strategies with the DICE model. Outside the limited scope of deterministic frameworks and scenarios, such methods can, when coupled with modelling activities, provide information about the degree of certainty for selecting specific courses of climate action and eventually reinforce the robustness of policy prescriptions. Other bottom-up tools have also been used to provide knowledge in aspects, which are commonly under-represented in integrated assessment models and thus contribute to uncertainty, such as life cycle impacts of technologies [46,47].

All of the points raised above constitute to the development of an integrative policy support framework that promotes transparency, legitimacy, and governance, and are summarised in Figure 1.

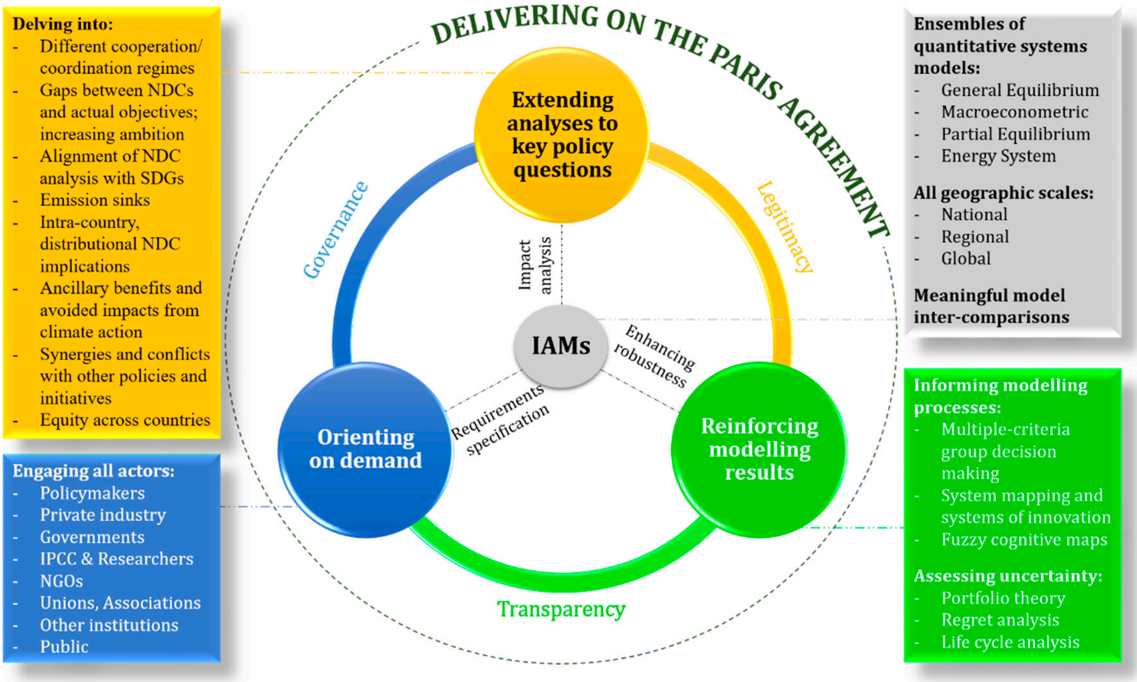

Figure 1. An integrative climate policy support framework for delivering on the Paris Agreement. (IAMs = Integrated Assessment Models; NDCs = Nationally Determined Contributions; SDGs = Sustainable Development Goals; IPCC = Intergovernmental Panel on Climate Change; NGOs = non-governmental organisations.)

An example of implementing the proposed integrative framework, comprising components based on recent advances in the literature, includes (i) the use of integrated assessment modelling results on the effectiveness of policy instruments promoting specific energy technologies (in terms of costs, greenhouse gas emissions reductions, other socio-economic co-impacts like health and employment, etc.); (ii) the identification and evaluation of risks hindering the implementation of these policies and the associated technological diffusion, from the stakeholders' perspective and by means of an appropriate multiple-criteria group decision making approach (see Reference [33]); (iii) the formulation and portfolio analysis of a multi-objective problem, in which both the modelling results and the overall policy portfolio risk are considered as different evaluation objectives; and (iv) the robustness analysis of the resulting near-optimal solutions by means of stochastic uncertainty treatment approaches, such as the Monte Carlo method. Such a framework further legitimises the scientific processes in support of policymaking and highlights the effectiveness and sustainability of the resulting policy recommendations by integrating a multitude of authoritative methodologies from different disciplines; ensures the transparency of these processes via the inclusion and active participation of stakeholders; and enhances the robustness of the modelling results by looking into and providing policymakers with information regarding both the recommended strategies and the level of uncertainty associated with them. In a different example of an integrative approach, a fuzzy cognitive mapping exercise can be used to bring stakeholders closer to the IAM processes (as suggested in Reference [8]) and mobilise their knowledge to develop real-world socio-economic and technological modelling scenarios; and, following the IAM analysis, a regret analysis can be used to inform policymakers with the most robust decarbonisation strategies that perform well independently of which plausible future eventually occurs.

5. Concluding Remarks

The Paris Agreement highlights existing and brings about new challenges, overcoming which will require from the scientific community great collaboration among research groups and integration of multiple sciences, instead of technical analyses that encourage fixations on unachievable transition pathways [48]. These challenges and requirements highlight the relevance of this study to global climate policymaking: the proposed paradigm essentially calls for a shift from the stand-alone use of integrated assessment modelling frameworks to truly integrative processes, in which multiple actors and methods complement each other. Broken down into three main pillars (use of all-covering modelling ensembles, systematic stakeholder inclusion, and transdisciplinary decision support methodologies), it is argued that this paradigm must constitute the basis of effective scientific support that is robust, legitimate, transparent, and sustainable.

Mach and Field [49] recently argued that responding to climate challenges presents opportunities for synergies; instead, it may be that synergies between different scientific groups are a prerequisite to effectively responding to climatic change. What is more, strengthening the ties between the research community and all relevant stakeholder groups, including but not limited to policymakers, will not only root policy advice in practice and foster governance of climate policy [50]; it may actually result in more effective and robust model-driven policy prescriptions in the first place.

With the Talanoa facilitative dialogue as the initial global stocktaking exercise taking place in 2018, climate action is officially entering a locked-in, strictly formalised phase. Considering the new challenges that the Paris Agreement brings about, it is fair to say that successfully reshaping our world in sustainable, socially robust pathways dictates that scientific support to climate policymaking be revolutionised as well. A diversity of IAMs and other modelling tools aside, both stakeholders and a multiplicity of necessary methodologies are out there and, opportunity or necessity, truly integrative policy support is just around the corner. It is up to the modelling community, decision theory researchers, and all relevant actors to work together.

Author Contributions: Conceptualization, H.D., A.N., M.G.-E. and I.A.; Methodology, H.D. and A.N.; Writing—Original Draft Preparation, H.D. and A.N.; Writing—Review & Editing, H.D., I.A. and A.A.-K.; Visualization, A.N.; Supervision, H.D. and M.G.-E.

Funding: This research received no external funding.

Acknowledgments: No other parties are to be acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

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