Geoengineering, Scientific Community, and Policymakers: A New Proposal for the Categorization of Responses to Anthropogenic Climate Change

Joana Castro Pereira

Abstract
Besides mitigation and adaptation, geoengineering has been emerging as a new approach to deal with the challenges posed by anthropogenic climate change. However, the various definitions and designations for the concept and its clusters, as well as their unclear boundaries with the concepts of mitigation and adaptation, distort and invalidate the existence of a valuable debate in both academic and public contexts. Identifying the current overlaps, and making a comparative analysis with two previous proposals for the categorization of responses to anthropogenic climate change, this article presents a new categorization proposal directed to promote the essential rapprochement between the scientific community and policymakers. This proposal removes the term geoengineering, pointing out the advantages of a debate specifically oriented toward each method in particular. It is also explained how each category should be envisaged, rethinking the importance of international cooperation and stressing the decisive impact that public awareness could play in dealing with this challenge.

Keywords
climate change, geoengineering, interventional mitigation, radiation management, international cooperation

Introduction
In the face of one of the greatest challenges of the 21st century—climate change—geoengineering has been attracting increased international attention as it is seen as a potential complementary strategy to traditional responses given by mitigation and adaptation (Forum for Climate Engineering Assessment, 2015; Stilgoe, 2015; Rickels et al., 2011). Several reports have been published on the potential use of geoengineering methods, such as the one from The Royal Society (2009), titled Geoengineering the Climate, and the two recent reports titled Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration (National Research Council, 2015a) and Climate Intervention: Reflecting Sunlight to Cool Earth (National Research Council, 2015b) by the U.S. National Research Council in February 2015. Besides, the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC; 2014c), released in 2014, has been the most extensive of all IPCC reports on the assessment of geoengineering options (Peterson, 2014). However, the overlap of the concepts of mitigation, adaptation, and geoengineering, as well as the different definitions of geoengineering (Bellamy, Chilvers, Vaughan, & Lenton, 2012), hinder and distort the debate on this issue (IPCC, 2012). This is particularly problematic given that climate change is a “wicked problem” (Prins et al., 2010), which demands a profound understanding of its multidimensionality and complexity, that is, a holistic approach able to link human society with its biological basis. This means that science and politics must join synergies to better understand the problem and find truly effective responses. The difficulties surrounding the debate on geoengineering hamper this path of cooperation between the scientific world and the political world, and consequently climate governance.

Thus, analyzing the current ambiguity among the various concepts and two alternative categorization proposals previously published by Heyward (2013) and Boucher et al. (2014),1 this article presents a new proposal for the categorization of responses to anthropogenic climate change. It aims to simplify and clarify the debate to make science more understandable to politics. This is not, nor could it be, a closed proposal, but another contribution to further discussion on the resolution of the problem. It should be noted that

1Lusíada University, Porto, Portugal

Corresponding Author:
Joana Castro Pereira, Rua Dr. Lopo de Carvalho, 4369-006 Porto, Portugal.
Email: mail@joanacastropereira.com
the presentation of each geoengineering method, as well as the risks and opportunities associated with them, is beyond the scope of this article. Also, this article does not take a position for or against geoengineering, considering that the debate should shift to a new one, specifically oriented to each geoengineering method in particular.

The Importance of a Science-Policy Debate

The challenges associated to climate change may be shaping and might shape the world and social interactions on a global scale. Anthropogenic climate change is perhaps the largest global challenge (both in its essence and scale of action) humanity is facing, threatening to enhance the onset of tension and conflict, and therefore calling for unprecedented cooperation. In addition, it is a multidimensional issue, which cuts across a wide range of topics, such as economics, security, energy, culture, human rights, among many others, demanding an interdisciplinary approach. It seems fair to say that the future largely depends on the international community’s ability to understand the entire problem’s dimensions, as well as possible solutions, and create an effective web of multilateral governance (Pereira, 2015). However, the international community is failing on finding joint and effective solutions for the climate change problem, which leads us to the emergence and increased relevance of new strategies capable of assisting in tackling the issue. Geoengineering is one of these approaches.

As Sustainable Development Goals replace Millennium Development Goals in the post 2015 development agenda, climate change will become increasingly important for stakeholders, governments, and funders. In this context, geoengineering might be truly taken into account as a tool to fight anthropogenic climate change and help achieve Sustainable Development Goals (Sharma, 2015). Nevertheless, as we shall see later in this article, this is a controversial field, which is not yet very well understood and demands close collaboration between scientists and policymakers. It is fundamental that scientists and science organizations, non-governmental organizations, and government bodies . . . [apply] their capacities to begin imagining what geoengineering might be like, planning what research might be necessary to achieve (or avoid) imagined futures, and what institutional designs and guidelines might be necessary to govern research and possible deployment (Foley, Guston, & Sarewitz, 2015, p. 5).

For this to be achieved, a key point lies in a better understanding of science by policymakers. This implies the simplification and clarification of some scientific concepts and ideas, for them to be more easily understood and assimilated by the political field. A better understanding of science might help to create an institution that has the global political legitimacy to make decisions about an issue such as geoengineering (Morrow, Kopp, & Oppenheimer, 2013).

What Is Geoengineering?

Geoengineering, climate engineering, and climate intervention (among others) are interchangeable expressions used when one refers to purposeful interventions in the climate system to counteract anthropogenic climate change (National Research Council, 2015c). Besides, there are several definitions for geoengineering (Bellamy et al., 2012) and the concept has evolved over time. Before the modern view of the term, addressed to the climate change issue, one can say that geoengineering has been recognized as a possibility since the 1830s studies on weather modification (The Royal Society, 2009). Geoengineering proposals specifically designed to counteract the greenhouse effect are known at least since 1965, when a report of the U.S. President’s Science Advisory Committee was issued (The White House, 1965). However, the term geoengineering itself would only be coined for the first time in the 1970s by Italian physicist Cesare Marchetti who proposed that carbon dioxide (CO₂) from combustion could be injected into the ocean to reduce the atmospheric burden of this greenhouse gas (GHG; IPCC, 2012). At the end of the century, in an article titled “Geoengineering the Climate: History and Prospect,” Keith (2000) discussed in detail the history and etymology of geoengineering, arguing that large scale, deliberated intent and the degree of impact play central roles in defining what actions could fit in the concept. Still, “there is no definition of ‘geoengineering’ or ‘climate engineering’ which is agreed on by the research, policy and civil society communities at large” (Boucher et al., 2014, p. 25).

The specialized literature commonly divides geoengineering into two categories: CO₂ removal (CDR) and solar radiation management (SRM; The Royal Society, 2009). In a nutshell, CDR technologies are designed to remove CO₂ from the atmosphere and SRM technologies for reducing sunlight absorbed by the earth to cool the planet’s surface. CDR is also referred to as negative emissions technologies (NETs), a subset of GHG removal (GGR; Caldecott, Lomax, & Workman, 2015), or as remediation technologies (Asilomar Scientific Organizing Committee, 2010); and SRM is also referred to as solar geoengineering (Keith & MacMartin, 2015), albedo modification (National Research Council, 2015b), a subset of radiation management (RM; Rickels et al., 2011), or as intervention technologies (Asilomar Scientific Organizing Committee, 2010). Concerning the overlap of concepts, the analysis made in this article assumes the most common division of the concept of geoengineering (CDR and SRM).

Mitigation, Adaptation, and Geoengineering: Identifying Gray Areas

The proliferation of various alternative expressions for the concept of geoengineering and its categories, the many existing definitions, and the fact that geoengineering is often regarded as a “third kind of response to climate change,
besides mitigation and adaptation” (IPCC, 2014b, p. 219) with very unclear boundaries among these concepts (Heyward, 2013), are obstacles to the promotion of a clear and productive debate on the issue. As a result, there are confusing discussions about geoengineering in both academic and public contexts, as outlined in the IPCC Expert Meeting on Geoengineering held in 2011 in Lima, Peru (IPCC, 2012). This is a clear barrier to the conduction of a fruitful debate on how to deal with the anthropogenic climate change problem. It undermines a holistic approach that brings the scientific community and policymakers together, as set out in the first part of this article.

The overlapping among the concepts of mitigation, adaptation, and geoengineering is addressed here through the identification and description of five “gray areas” (Figure 1), analyzing the definitions adopted at the IPCC AR5 and the United Nations Framework Convention on Climate Change (UNFCCC).

**Gray Areas A and C**

In the IPCC AR5 glossary (2014a), mitigation is defined as “a human intervention to reduce the sources or enhance the sinks of greenhouse gases” (p. 125; the UNFCCC uses the same type of definition). According to Boucher et al. (2014), the inclusion of the enhancement of GHG sinks within the mitigation concept was originally “designed to include sustainable forms of agriculture and forest management, reforestation and afforestation within the scope of the UNFCCC and the Kyoto Protocol” (p. 25). So, the classic definition of mitigation was unlikely to be designed for the inclusion of the full spectrum of CDR methods that have now been proposed. It is also important to note that, during the IPCC Expert Meeting on Geoengineering (IPCC, 2012), the discussion on CDR revolved around the following question: “Which CDR methods can and should be generally considered as geoengineering?” The answer was that, depending on the scale and impact, any CDR method can be considered as geoengineering or not, although “no conclusions were reached on the exact location of the boundary” (IPCC, 2012, p. 6). The definition of geoengineering at the IPCC AR5 glossary (2014a) adds that two key characteristics of geoengineering methods are the fact that they “use or affect the climate system (e.g., atmosphere, land or ocean) globally or regionally and/or could have substantive unintended effects that cross national boundaries” (p. 123).

Therefore, on one hand, (a) if the deployment of a specific CDR method, apart from its intent, does not have enough scale and impact to be envisaged as geoengineering; and (b) if it does not, at the same time, fit in the classic definition of mitigation given by the IPCC and the UNFCCC, one can assume that it falls into the gray area C (Figure 1). On the other hand, if a CDR method is framed within the classic mitigation definition given by the IPCC and the UNFCCC (regardless of whether or not it is possible to assess if it should be or not be classified as geoengineering), one can assume that it falls into the gray area A (Figure 1). The existence of the gray area A is clearly assumed in the CDR definition at the IPCC AR5 glossary (IPCC, 2014a): “the boundary between CDR and mitigation is not clear and there could be some overlap between the two given current definitions” (p. 119).

**Gray Areas B and D**

In the IPCC AR5 glossary (2014a), the definition of SRM indicates that “SRM techniques do not fall within the usual definitions of mitigation and adaptation” (p. 127). This can lead us to consider that if the deployment of a specific SRM technique, apart from its intent, does not have the supposed large scale, as well as a sufficient degree of impact to be classified as geoengineering, it will fall into the gray area D (Figure 1). Here, it is also relevant to introduce the definition of adaptation. Adaptation is defined as “the process of adjustment actual or expected climate and its effects” (IPCC, 2014a, p. 118). Similarly, the UNFCCC defines it as the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (UNFCCC, n.d.). Based on these definitions, and even if the concept of SRM presented by the IPCC discards their inclusion in the usual adaptation definitions, it is not hard to imagine that SRM techniques applied to the mitigation of the urban heat island effect (such as whitening roofs and increasing reflectivity of other surfaces) can easily be seen as a form of adaptation (The City of London, 2010). Thus, it seems fair to admit the existence of a gray area B (Figure 1).

**Gray Area E**

The CDR and SRM categories do not cover all the geoengineering methods proposed. The proposal to “deplete the high and cold cirrus clouds to enable more thermal radiation to escape the Earth’s atmosphere” (Muri, Kristjánsson, Storelvmo, & Pfeffer, 2014, p. 1) is one of them. In the definition of SRM.
at the IPCC AR5 glossary (2014a) one can read, “methods to modify some fast-responding elements of the long wave radiative budget (such as cirrus clouds’), although not strictly speaking SRM, can be related to SRM” (p. 127). This creates unnecessary ambiguity. Furthermore, the expression albedo modification is sometimes adopted in place of SRM (National Research Council, 2015b), making it more evident that the proposal on the cirrus clouds manipulation should be included in another category. As stated by Muri et al. (2014), this method, which modifies longwave radiation, can be categorized as a form of thermal radiation management (TRM). In this case TRM and SRM categories could be seen as subsets of a main category called RM (Rickels et al., 2011). Therefore, the gray area E relates to geoengineering methods that are beyond CDR and SRM techniques.

**Banishing the Gray Areas**

A substantial number of these concept overlaps are overcome if one removes them from the geoengineering hat. This is what Heyward (2013) did in her alternative categorization proposal, where the term geoengineering was eliminated. Beyond that, there are a number of other reasons that justify and reinforce the importance of getting away from the term geoengineering.

First of all, the geoengineering label carries a negative connotation that can influence unfounded opinions and inhibit the debate on specific methods, especially in the political sphere, simply because they are connoted with the concept of geoengineering. In fact, this term was always used in a derogatory manner by conservationists (Frost & Sullivan, 2010). For instance, in the 90s, new technologies for CO₂ sequestration were labeled as geoengineering by the opponents to those technologies, while the advocates did not label them as geoengineering (Keith, 1998). According to Peterson (2014), this stigma lives on. In his opinion, the authors of the IPCC AR5 *Work Group III Summary for Policymakers* did not use the term geoengineering because they were afraid that geoengineering might carry a negative association. Second, talking about the pros and cons of geoengineering does not make much sense. The debate on the various geoengineering proposals should be directed to each method in particular because each one has its specific potential, very different risks, and opportunities even within CDR and SRM clusters (National Research Council, 2015a, 2015b; The Royal Society, 2009). One debates on the pros and cons of nuclear energy, the strengths and weaknesses of the various forms of renewable energy, the different ways to increase energy efficiency, among many others, and it is not conceivable to discuss all this under the same label (for instance, “the pros and cons of mitigation”). The same should be done with the geoengineering methods. However, it is likely that a debate directed to the specific features of each proposed method could naturally occur as each method becomes more scientifically realistic for implementation and more primary literature is published.

In addition, it should also be noted that the debate on the pros and cons of geoengineering has often confused and mixed with the pros and cons of a particular SRM method called stratospheric aerosol injection (SAI). SAI aims to “deliberately alter radiative-forcing at sufficient scale to measurably alter the global climate” (Keith & MacMartin, 2015, p. 1) and “offset some of the consequences of global warming within years . . . at a relatively low direct cost” (National Research Council, 2015c), decreasing the planet’s temperature by, in some way, mimicking volcanic eruptions. Besides sharing with other SRM techniques the failure to intervene directly in solving the problem of high concentrations of GHG in the atmosphere and, therefore, possibly creating inertia in implementing the essential measures for cutting emissions, this technique is associated with a serious concern pointed out by some authors: SAI could be “unilaterally undertaken by a nation or smaller entity” (National Research Council, 2015b), with unpredictable global consequences (Gardiner, 2013; Hulme, 2014; Reynolds, 2015). Also, there is a lack of legal regulation addressed to SRM research, beyond those that apply to scientific research (National Research Council, 2015c). Thus, the mixture of the high potential effectiveness and high affordability of the SAI technique (The Royal Society, 2009) with the new challenges that it introduces on political, social, legal, ethical, and security levels made it stand out at the geoengineering debate arena. Furthermore, it is also important to underline that despite CDR methods being normally associated with the introduction of new lower overall risks comparing with SRM methods, there are CDR methods, such as ocean fertilization, which also entail risk of great transnational magnitude (Strong, Chisholm, Miller, & Cullen, 2009). Therefore, it is prudent to avoid generalizations. This also emphasizes the need to specifically discuss each technique by its own.

Another key element for the elimination of overlaps among the concepts is dependent on the natural proximity between the concept of mitigation and CDR methods. Heyward (2013) discussed this issue and concluded that CDR is a subset of mitigation, but she also argued that, in this stage, its isolation in a separated category has advantages. The first one lies on the fact that this makes CDR methods more prominent. The second one has to do with the fact that it may be important to distinguish between two separate stages of mitigation “in the process of avoiding dangerous anthropogenic interference” (Heyward, 2013, p. 25). This brings to mind the phrase “a novel form of mitigation” attributed in the 90s to the idea of “zero emissions” fossil fuel power plants equipped with carbon capture and storage (CCS) technologies (Keith, 1998). Later, CCS directly at power plants would be fully integrated as a mitigation option (IPCC, 2005).

So, it seems to make sense envisaging mitigation by two prisms. On one hand, the conventional mitigation in which
the aim is the reduction of new GHG inputs into the atmosphere; on the other hand, a way to mitigate that one could dare to call interventional mitigation, because there is an interaction with the atmosphere and with past GHG emissions to reduce the concentration of these gases in the atmosphere by removal techniques (this concept would include not only all CDR methods but also technologies for removal of other GHG besides CO₂). Excluded from the concept of interventional mitigation would be situations where despite there being an interaction with the atmosphere and with past GHG emissions, they do not have the purpose of removing CO₂ but to reduce emissions that would otherwise be generated in the absence of better land management approaches (such as reducing emissions from deforestation and forest degradation). The same exclusion applies to bioenergy and biofuels where there is not, in the sum of bioenergy and biofuel production cycles and utilization, a negative CO₂ emission (the balance between the captured CO₂ and the released CO₂ is more or less balanced according to the choice of crop and management practices but never negative; Adler, Del Grosso, & Parton, 2007).

Categorizing Responses to Anthropogenic Climate Change: A Proposal

The alternative proposal presented by Heyward (2013) focused on the abandonment of the term geoengineering and the considering of a new category called “rectification,” which encloses the principles of compensation and reparation, needed for dealing with historical global harms. Thus, the proposal included five response categories: mitigation, CDR, SRM, adaptation, and rectification (Heyward, 2013). As mentioned above, although the author had concluded that CDR is a mitigation subset (because she considers that “mitigation refers to activities that either reduce the flows of CO₂ and other GHGs into the atmosphere or increase sinks [and] CDR refers to activities which increase sinks” (Heyward, 2013, p. 25), she chose to keep the CDR methods in a separate category, but at the same level of mitigation. This can continue to create some confusion. It is also unclear in which category future technologies for removal of other GHG besides CO₂ would fit. One final aspect to point to Heyward’s proposal (2013) concerns the gray area E addressed in this article in the sense that a division between CDR and SRM does not cover all proposed geoengineering methods.

A more “climate-science-based” proposal was presented by Boucher et al. (2014), which includes an interesting and useful link between the categories proposed and the “spatial and temporal scales and Earth systems processes impacted” (p. 24; dimensions that are closely linked with those that commonly must be evaluated to consider a particular method as geoengineering or not). The proposal includes five response categories: anthropogenic emission reductions (AERs), territorial or domestic removal of atmospheric CO₂ and other GHGs (D-GGR), trans-territorial removal of atmospheric CO₂ and other GHGs (T-GGR), regional to planetary targeted climate modification (TCM), and climate change adaptation measures (CCAMs). It is a categorization that eliminates a number of ambiguities in relation to existing terminology and establishes a link between the different categories and the hypothetical trans-boundary or transnational side effects that result from the application of each measure. Noteworthy is the fact that the first category (AER) refers to most forms of mitigation excluding the human-induced CO₂ sink enhancement. It is therefore equivalent to the idea of conventional mitigation admitted earlier in this article. Another detail relates to the fact that this proposal clearly aims at integrating the assumption of small-scale SRM techniques in the CCAM category (essentially constituted by what is commonly defined as adaptation). This reveals the link indicated above between SRM and adaptation (when analyzing the gray area B). However, and although even sober definitions may have underlying social implications, being a “climate-science-based” approach proposal, it does not aim to create a label capable of transposing the scientific frontier and getting into other fields of debate, such as the political and civil ones.

It is important to figure out a way through which the main categories can (a) be simple for a cross understanding by all actors involved in the discussion of anthropogenic climate change issue and (b) eliminate (or at least minimize) the gray areas described in this article.

So, for the main categories, we propose the approach presented on Figure 2. They are associated with five easily memorizable and viewable goals: fewer inputs (into the atmosphere), more outputs (from the atmosphere), cooling the earth, avoiding, and compensating (a few examples are added for an easier understanding).

The broad spectrum categories intend to minimize the number of categories needed for covering the whole diversity of responses provided to meet the challenge of anthropogenic climate change. Nevertheless, for a better understanding, the Interventional Mitigation category should be viewed as being composed by the subsets of CDR and other GHG removal. Also, the RM category should be now be considered to be composed by the subsets of TRM and SRM (Muri et al., 2014; Rickels et al., 2011). As explained by Marcia McNutt (2015) about the elaboration of the National Research Council reports (2015a, 2015b), the authors have opted to use the expression “albedo modification” and not SRM, because they consider it to be a more honest expression because the current state of the art on these technologies does not allow enough control for the desired results to be achieved. So, in their opinion, it can be excessive to use the word “management.” This idea was not followed in this categorization proposal because it is not considered a critical point and it is hoped to preserve, as far as possible, the most widespread nomenclatures.
Figure 3 summarizes the comparison among the present proposal and the ones made by Heyward (2013) and Boucher et al. (2014), an attempt at demonstrating the scope of this new categorization.

As stated earlier, the areas not addressed by Heyward (2013) under the Interventional Mitigation and Radiation Management categories relate, respectively, to the removal of other GHG from the atmosphere (besides CO₂) and to TRM methods.

On the proposal of Boucher et al. (2014), and although the authors do not refer to it in their categorization table, they indicate throughout the article the possibility of considering an additional category of rectification (in the same way as described by Heyward (2013). It is also important to note that the displacement between the RM boundary and the CCAM category has to do with the aforementioned fact that Boucher et al. (2014) include small-scale SRM methods in this category. Although these methods can be considered as adaptation under certain circumstances, in this proposal they can be ranked cumulatively because they will not cease to be RM methods (it is not considered to be a relevant overlap).

**Understanding the Categorization Proposal and the Importance of Cooperation**

“Borrowing,” and recovering the analogy used by Heyward (2013), an attempt will be made to explain the proposed categorization (going a little further) to bridge the gap on the importance of international cooperation to deal with the problem of anthropogenic climate change.

Imagine a man who eats too much, especially high-fat fast food for a longtime, having excessive weight and high blood pressure problems, as well as the respective increased risk of having a stroke. To address this problem, he can first change his eating habits to eat fewer fats (conventional mitigation—fewer inputs). In addition, he can exercise to eliminate the accumulated fat and reduce his weight (interventional mitigation—more outputs). He can also take medication for lowering his blood pressure (RM) even if he is not trying to modify his eating habits, that is, even if he is not trying to eliminate the source of the problem. If this is the case, and for some reason he has to stop taking the medication, he will suddenly be in a much worse state than the one he was initially (this is one of the concerns associated to the hypothetical future deployment of RM methods, specifically the SAI technique; Burns, 2013; Davies, 2013; Hamilton, 2013; Hulme, 2014). In addition to these measures, this man can move to the countryside to avoid stressful situations and live in a healthier way even having the symptoms related to his health problem (adaptation). Large multinational fast-food companies that have developed and obtained large profits at the expense of aggressive campaigns to promote their food may take reparation actions toward consumers (rectification).
Let us now focus on the fastest and cheapest SRM technique (SAI), which, as explained above, has assumed a prominent role in the debate on geoengineering. It should be noted that, in this analogy, the decision of whether or not to take the medication would be the responsibility of the doctor who accompanied the patient. At an early stage, the doctor could propose a change in the patient’s eating habits, avoiding stressful situations and eventually some physical exercise (conventional mitigation, adaptation, and interventional mitigation). Later, however, if this advice was not producing the desired effects, it is very likely that the doctor would not think twice to prescribe medication (RM—SAI technique). Even if the patient does not modify his eating habits, his life expectancy is limited and the important thing would be to keep the man alive, increasing his life expectancy to match the average as closely as possible. The problem is that when we transpose this story to the reality of climate change, humanity does not have a life expectancy of a few more decades, so the decision becomes much more complex, especially because taking any “medication” will have to be a temporary measure.

As in the case of a more serious disease, where we want to get advice from more than one doctor, the complexity of the anthropogenic climate change problem brings us to the increasing need for effective international cooperation to resolve the climate issue and to minimize the already inevitable consequences. With an “immortal patient,” this “medical team” will move the problem to future “medical teams,” and the options that are now taken will influence and limit options for them; future “medical teams” will also judge what was previously done (these aspects reflect the so-called intergenerational issue; Burns, 2013; Gardiner, 2013). Thus, important questions have arisen. Should we or should we not invest in the creation of “medication” (investment on RM methods research, especially on the SAI technique)? Does not having “medication” make its use much more likely? At what point is it reasonable to take it? (Doughty, 2015; Gardiner, 2013; Hamilton, 2013; Hulme, 2014; Lane, 2013; Morrow et al., 2013). These questions do not have a direct answer and no isolated actor can address them at this time. It is necessary that the responses, as well as the mix of measures to be taken, are as inserted in the sphere of international cooperation as possible, with an attitude of cooperative “treatment,” which involves all stakeholders and takes into account the multidisciplinarity of the problem. However, it is important to underline that even Gardiner (2013) and Keith (2013), who have different opinions on the deployment of the SAI technique, agree that its usage “would not be ethical in the absence of a simultaneous reduction in CO₂ emissions” (Wanucha, 2013). This means that taking any “medication” (RM—SAI technique) will only be fair after making a visible change in “eating habits” (conventional mitigation). This is a great difference and a major challenge in relation to our overweight man where the medical decision to prescribe medication for high blood pressure is easily done.

It is true that humanity may be heading for a situation where the problem will no longer be solvable with the change of “eating habits” and the avoidance of “stressful situations.” It is very likely that we will have to, in a coordinated way and at the same time, “change our diet,” “exercise more intensely,” “take some medication,” and “avoid situations of greater stress.” The exact mix of these responses will be much better defined, the broader and more holistic the “team” deciding it is. This scenario is pointed out by David W. Keith and Daniel Shrag (Wanucha, 2013): “even in the most optimistic of scenarios, we may not be able to solve the climate change problem acting on the GHG emissions alone.” Furthermore, in the IPCC AR5 (2014c), it is possible to note that two CDR methods have now been included in a large number of mitigation scenarios, namely, large-scale afforestation and, perhaps in some unexpected way, the CDR method known as BECCS (bioenergy production with CO₂ capture and storage).

**What We Can Control and What We Cannot**

Finally, despite the complexity of everything in which we can intervene, the climate will also continue to depend on external non-human-induced climate forcings such as volcanic eruptions and changes in solar radiation reaching the earth (Keith, 2013). Even from a human-induced perspective, wild cards, especially in the energy sector, and the evolution of some identified disruptive techs, such as large-scale electric energy storage (Manyika et al., 2013) can, at any moment, modify the mix of the idealized responses to counter anthropogenic climate change. Many of these great impact innovations are in some way not controlled by human desires, as stated by Taleb (2007) in his emblematic work *The Black Swan. The Impact of the Highly Improbable*: “almost no discovery, no technologies of note, came from design and planning—they were just Black Swans”⁹ (p. xxi). Nevertheless, if on one hand some unexpected findings could hypothetically become beneficial for solving the climate change problem, then on the other hand, the work of Taleb leads us to a less optimistic reflection on the political *modus operandi*. The truth is that political recognition comes mainly from immediate effects associated to a short-term view. In the example (purposely exaggerated) given by Taleb, if a visionary policymaker had directed colossal financial resources to improve air safety and prevent the 9/11 (for instance, continuous airspace patrolling by military aircrafts, the imposition of expensive security measure implementation by airline companies, among others), no statue would be erected in his name; he would never be recognized as the man who helped avoid the 9/11 attack. On the contrary, the resources spent (apparently unwarranted) on something for which there was no public awareness of real danger would get him booted out of the office. Similarly, if there is no real public awareness of the extent of the climate change...
problem, this will contribute to the inertia of policymakers regarding decision making and the allocation of resources to solve the issue. No politician will be remembered for having avoided what for many people has never been in question, was never an issue, would never happen. This issue was recently addressed by Barack Obama in an online Q&A session in which, when asked about how to deal with climate change deniers in the U.S. Congress, the president answered, “The science is overwhelming but what will move Congress will be public opinion. Your voices will make them open to facts” (Phillips, 2015). Therefore, efforts must be made to demonstrate the ramifications of the climate change problem and to underline that other problems that are taken as a priority can be tackled at the same time, with a holistic view, one which mobilizes synergies among responses and sustainable development (addressed by the IPCC in the AR5, 2014c). Hopefully for humankind, this can be done not only after major catastrophes take place.

Conclusion

As we have seen throughout this article, the concept of geoengineering and its clusters have very unclear boundaries when compared with the traditional concepts of mitigation and adaptation. This ambiguity, plus the negative connotation that the concept of geoengineering carries, makes the debate on the responses to be taken to address the problem of the anthropogenic climate change neither clear nor fruitful at the academic, public, and political levels. For the debate to be more valuable and effective, it was argued that it should be increasingly oriented to each method in particular instead of being under a “reducer hat” of a yes or a no to geoengineering, because this concept encompasses a huge list of options with very distinct features, challenges, and risks.

So, this article presented a new proposal for the categorization of responses to anthropogenic climate change with an easy understanding and visualization terminology: conventional mitigation (fewer inputs into the atmosphere), interventional mitigation (more outputs from the atmosphere), RM (cooling the earth), adaptation (avoiding), and rectification (compensating). This proposal was compared with two prior proposals presented by Heyward (2013) and Boucher et al. (2014), trying, on one hand, to meet some of its possible gaps and, on the other hand, integrating the strongest points of each of them. Clearly, in a purely scientific view on the proposal made by Boucher et al., it has great value, but the terminology used lacks the simplicity needed for it to be widely used in the public and political spheres (and this was not the aim of the authors either). Thus, the proposal presented in this article aimed to eliminate as much as possible the gaps and overlaps existing among the various concepts and at the same time provide a simple naming and quick understanding, which can be used by the various actors involved, not despising the necessary scientific rigor. So, this is an attempt to help building bridges between science and politics which, as stated before, will be crucial for defining the most advantageous measures to be taken regarding the issue of anthropogenic climate change. The new proposal is another contribution to the prosecution of the debate on this matter, believing that a comprehensive approach to this, for instance in a future IPCC special report on geoengineering, would be extremely useful.

As in the analyzed proposals (Boucher et al., 2014; Heyward, 2013), this one also eliminates the concept of geoengineering, which may represent a failure on the opinion of the defenders of the purest forms of mitigation as the ones and only ways to resolve the problem of anthropogenic climate change (essentially based on the adoption of renewable energies). Given the weight and negative connotation the term geoengineering has among the public, this can function as an additional barrier to the adoption of the methods commonly considered to be within this concept. Similarly, the proposal to consider CDR methods as a subset of a category that includes the term mitigation (interventional mitigation) can face identical resistance. However, it is worth remembering that the current concept of mitigation already integrates measures that are also widely criticized. Such measures include, for instance, CCS directly at fossil fuel power plants (CCS is criticized because of the potential risks of future leakages and for the possibility of its usage by fossil energy companies with the aim of maximizing the extraction of fossil fuels from the underground, coupling CCS and enhanced oil recovery [EOR] techniques; Fuhr & Hällström, 2014). It should be noted, one more time, that the scope of this article was not to analyze the different geoengineering methods or to take a position as to its implementation, but to pass the message that this decision should be debated as widely as possible, including the number of actors as possible, bringing the scientific community closer to the political sphere. Thus, the belief is that, regardless of the terminology used, the less ambiguous the debate is, the better humanity will be served regardless of the measures that may be adopted.

The position and fears of those who argue that we should act only to “reduce emissions fast, while developing alternative energy sources that allow us to leave fossil fuels in the ground” (Fuhr & Hällström, 2014) are understandable. Obviously, other alternatives can create a general inertia in the pursuit of measures to tackle the root causes of the problem, but it is important to remember that this inertia has always existed, even when measures classified as geoengineering were not on the table. Therefore, one must not take refuge in this idealistic position and ignore what reality is revealing: A scenario where traditional answers are not sufficient is not at all liable to be overlooked. This is considered a pretty likely scenario by many scientists and was clearly assumed in the last IPCC Assessment Report (2014c) with the integration of CDR methods in various mitigation scenarios. In this sense, it is believed that clear and holistic reflections, analyzing as many scenarios as possible, will
always bring more advantages than disadvantages for the future of humanity. The social and political implications of the non-existence of a debate on each method in particular will be worse than the possible consequences carried by new terminologies. Finally, and as it was discussed in the last part of the article, redoubled efforts must be made in increasing public awareness of the anthropogenic climate change issue and its ramifications, especially for those who still defend and believe in a solution exclusively based on the purest mitigation options, taking into account the impact that this increased awareness about the problem might have among policymakers.

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**Notes**

1. It was made an analysis and a comparison with these two proposals because they are recent and embrace the entire spectrum of categories of responses to anthropogenic climate change. Moreover, they share the same concerns regarding the need to reform these categories. They are also open proposals that enable future contributions.

2. Deliberate intent implies that the goal of the action is the intervention in the climate system, and this intervention is not the result of a side effect of the action.

3. Despite being a useful division, it does not cover all geoengineering methods, as we shall see later in this article.

4. Albedo is “the technical term for the proportion of sunlight that Earth’s surface and atmosphere reflect back to space” (National Research Council, 2015c).

5. The type of impact and the time scale under consideration were also mentioned as factors that should be taken into account.

6. Tendency of an urban area to be hotter than its surroundings due to human disturbance (European Economic and Social Committee [EESC], 2011).

7. “Cirrus clouds reflect some incoming solar radiation, but this albedo cooling is smaller than the cirrus’ greenhouse effect” (Muri, Kristjansson, Storelvmo, & Pfeffer, 2014, p. 1).

8. In a web search query made on Google Search Engine on May 25, 2015, the number of results found for the term solar radiation management was about 10 times higher than the results for the term albedo modification.

9. Term popularized by Nassim Taleb. Black Swans are unexpected and extremely difficult/impossible to predict events with major impact. Black Swan events tend to be rationalized when retrospectively analyzed, making us believe it would not be so difficult to predict them.

10. It is worth noting that, to increase this public awareness of the importance of the problem, new elements are emerging. For instance, in the religious field, Pope Francis wrote the historical Encyclical *Laudato Si’* (made public in June 2015) entirely dedicated to the environment, and specifically to climate change. In this letter, Pope Francis passes a message to the international community and calls for action by political leaders, in an attempt to influence the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

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**Author Biography**

**Joana Castro Pereira** is Assistant Professor of International Relations at Lusíada University (Porto) and Associate Researcher at IPRI (Portuguese Institute of International Relations, New University of Lisbon). In 2014, at the age of 25, she received the PhD Degree in International Relations — Globalization and Environment, from the New University of Lisbon. Her research interests include the international system in the Anthropocene, international political economy of climate change, and globalization and governance.