Dimensions of Geoengineering:

An Analysis of the Royal Society's 'Blob' Diagram

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Abstract

The Royal Society's 2009 report "Geoengineering the climate: Science, governance and uncertainty" is seen as a key reference on the subject of geoengineering and one of the diagrams which depicts a preliminary evaluation of the range of proposed techniques is one of the most remarked upon pieces of the report. For many, it presents a useful synthesis of the analysis that went into the report. For others, however, the diagram is problematic. This paper unpacks some of the diagram's limitations.

Its does so in the course of dissecting and analysing the major characteristics of this diagram. Namely:

- The four dimensions that are displayed – affordability, effectiveness, safety and timeliness
- The error bars
- The scale
- Reification
- What is excluded

It concludes by considering how the diagram can result in "picking winners", explores the implications of employing an alternative framing and concludes by considering whether in this case a picture really is worth a thousand words.

Introduction

The Royal Society's 2009 report "Geoengineering the climate: Science, governance and uncertainty" (Shepherd 2009) is one of the most well-cited and well-regarded studies of the subject. One diagram from that report (on page 49 of the printed version and page 63 of the pdf version) entitled "Figure 5.1. Preliminary overall evaluation of the geoengineering techniques considered in Chapters 2 and 3" provides a visual representation distilling the analysis of the report into a single image. This colourful and striking diagram (fig. 1), (known by many working in this field as "the Blob diagram"), was widely represented in the media and is the subject of this paper. It conveys information about four sets of characteristics of proposed geoengineering techniques in a two-dimensional image. It achieves this by using not only the x- and y-axes, but also the colour and size of the dot representing each technique to convey additional information.

The aim is laudable. To synthesize and convey the findings in a simple way aids in the dissemination of the report. The concerns raised here are that such simplification is dangerous – that in simplifying, the complexities are down-played. Also, that the choices made in the selection and prioritisation of what information is conveyed creates a framing that favours particular techniques.

Figure 5.1. Preliminary overall evaluation of the geoengineering techniques considered in Chapters 2 and 3.

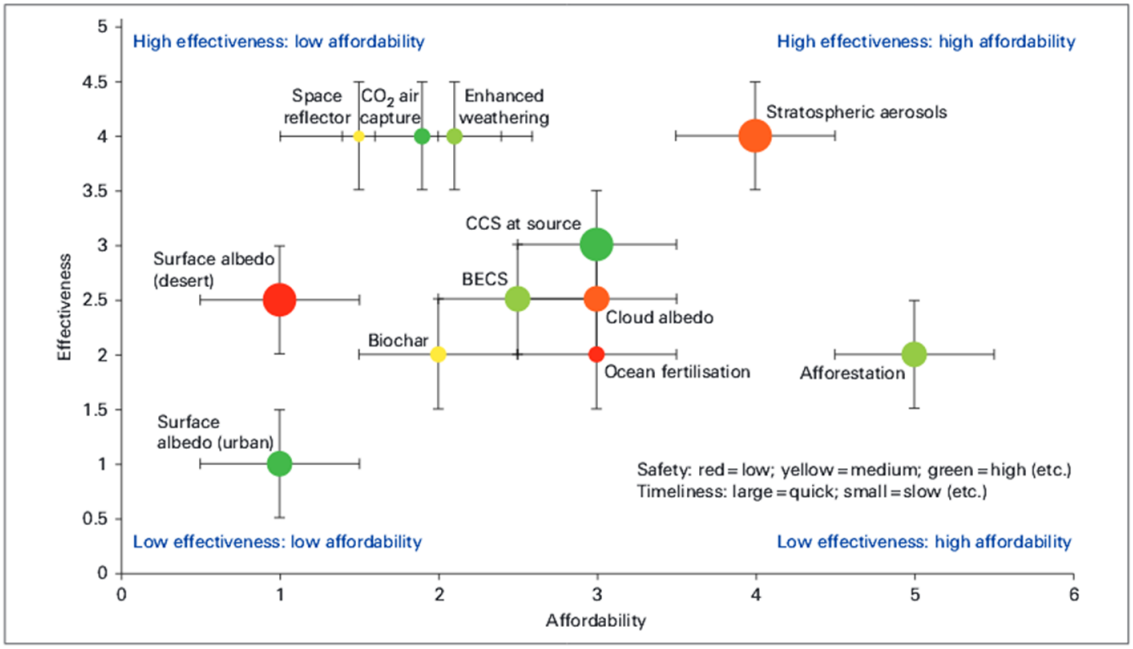

Fig. 1 The "Blob" diagram

This paper first considers the four dimensions displayed on the diagram – affordability, effectiveness, safety and timeliness – and then also considers other attributes of the diagram – the error bars and the scale. It then considers of the implications arising from the reifying effect that the diagram has and asks what is excluded from the diagram.

The paper then considers whether the findings portrayed are robust to a slight change in the framing. It considers the positioning of one of the points on the diagram using a different set of assessment bases and concludes by commenting on the merit of using such a diagram to convey information.

Dimensions

Four dimensions are portrayed in the diagram – affordability, effectiveness, safety and timeliness. This first section of the paper considers each in turn.

1. Affordability

   Firstly, the x-axis – affordability. This is arranged so that the cheaper, more favourable direction is to the right – the further to the right a particular dot is, the more affordable such a technique is. The first thing to note is that affordability is itself a compound function – it is a cost per something. What is it that this axis is displaying? In this case it is the cost per W/m2 – that is to say the amount of cooling that a particular technique can provide. This provides a tacit framing for what constitutes success – namely the control of temperature.

   Another thing to note is that the word affordable is a relative term – affordable compared to what? What is missing from this diagram is representation of mitigation measures that would prevent temperature increases. This then represents the proposed techniques which the diagram does show as a class of actions which could be used in the event of failure to mitigate.

   A key issue with affordability is the narrow framing of the "what is the 'cost' part of the cost per W/m2?" In the diagram, the cost is the implementation cost – the cost of designing, building and deploying the proposed technique – what is not included in these

costs are the associated costs. Scott Barrett (2008) writes of the incredible economics of geoengineering and he is right – the costs are incredible – that is to say they are not credible. Quite apart from non-monetizable social, political and ethical costs, there are monetizable, but not easily assessable, security costs (MacKerron, 2014) and there are the monetizable costs of safely exiting such a proposed deployment. This is especially the case with proposed Solar Radiation Management (SRM) techniques, where it is possible to suppress temperatures for the period during which they are deployed, but greenhouse gases must be removed back to a level compatible with a stable climate, before SRM could be safely switched off. Thus the full lifecycle cost of an SRM deployment would necessarily also include the costs of eventual removal of greenhouse gases from the atmosphere too.

2. Effectiveness

The y-axis is effectiveness. But effectiveness at what? The tacit assumption is temperature, but the question should be asked "why temperature?" and not precipitation, or human suffering, or food supply, or protection of biodiversity, or ocean acidification, or preserving an economic system that uses fossil fuels as the main source of energy, or a host of other potential metrics? An answer could be that limiting global mean temperatures rises below 2°C is a policy goal, but focusing on this metric alone will frame the discussion and the decisions in a way that is sub-optimal. If limiting human suffering were the goal instead, is limiting temperature rises an adequate proxy?

And effective over what time period? The longevity of different proposed techniques varies enormously and yet they are all displayed on the same diagram with a implicit pretence of comparability. Some biological process store carbon for less than a century or are not robust to changes in climate – afforestation may lock up carbon in organic matter for a few decades, before a forest fire precipitated by climate change results in all of the stored carbon being released back into the atmosphere. And since SRM techniques have a termination effect (the sudden increase in temperature that would result from an immediate cessation of deployment of such a

technique) – unless you believe that they can be maintained forever (and there are some people who do believe this) – then SRM is only effective as part of broader suite of actions.

And effective over what spatial scale? Any technique which has a material effect on the climate will affect precipitation patterns. While it may be that a particular technique has net beneficial effects if one considers impacts across the whole planet, there will inevitably be winners and losers at a regional or local level. Thus the metric of effectiveness is necessarily blurred. A rebuttal of this criticism is that it is not possible to convey this level of detail in a simple diagram – and the response to that rebuttal is that that is precisely what the problem with a simple diagram is – its blurred nature obscures the complexity that is integral to determining whether such approaches are societally acceptable.

3. Safety

The colour of the dots depicts the relative safety of the proposed techniques. Crucially this only reflects the physical aspects of proposed techniques and excludes (or ignores) the social aspects. The diagram would look very different if the social aspects were included. Many commentators would protest that it is impossible to quantify the social aspects – that the physical aspects are quantifiable and therefore displayable in a comparative fashion and that we can learn something useful by at least comparing those things that we can compare. This is to make an error that is both elementary and fundamental, as it wilfully excludes from analysis those aspects that are difficult to quantify and effectively underweights 'difficult to analyse' data. Such partial analysis is as likely to mislead as to inform – and worse, provides a false sense of certainty in the analysis. An analogy might be undertaking polling of voting intention in say, India, by means of an internet survey – the analysis will inevitably be skewed by the demographic of internet users, which is likely to be very different from the voting population as a whole. A prediction based on the responses can be made, but whether the prediction is meaningful is another matter.

The governance and governability of SRM over an extended time period (several centuries has been suggested by some of those proposing such techniques) is hugely problematical. There is a very

real potential for the deployment of SRM to be a *casus belli*. That is not to say that an ungeoengineered world affected by climate change is preferable to a geoengineered one – climate change itself could result in increased global tensions. What is clear, however, is that assessment of the safety of proposed techniques needs to consider far more than the physical aspects alone.

The safety of a proposed technique needs to be considered over its entire lifetime. If you are considering using a drug to treat a disease you need to understand not only the side-effects associated with its use, but also the withdrawal effects when it is stopped. Given the termination effect that is associated with SRM techniques, it is essential to consider what is the exit strategy from an SRM deployment. A drug with few side-effects could not be described as safe if the withdrawal affects from ceasing to use the drug were catastrophic.

And the physical aspect of safety ignores some other very real hazards. Those techniques that propose removing carbon dioxide from the atmosphere though terrestrial photosynthetic means (afforestation, BECCS and biochar) would put severe strains on land usage for biodiversity and food production, if they were to be applied at a scale that would make a material difference to the climate. Can a process be described as safe if it leads to a significant decrease in biodiversity or a severe restriction of global food production?

4. Timeliness

The size of each point on the diagram reflects the timeliness of the proposed technique – the larger the point the faster such a technique can be deployed. This provides a tacit emergency framing – the response time of proposed techniques is valuable in those circumstances. By including timeliness as one of the four dimensions portrayed in the diagram (rather than depicting other potential dimensions), priority is given to speed. But again, as with safety, the focus is on technical implementation. If the timeliness also reflected the necessary social licence to operate, then time to implementation would be considerably extended, especially for those techniques that are more contentious.

The selection of the Affordability and Effectiveness as the x- and y-axes respectively, privileges these two dimensions in the diagram. If one takes the four dimensions as described above, then there are six possible permutations for the two axes – as illustrated in Bellamy,2013 (fig. 2) (See also: Bellamy 2015, and Bellamy et al. 2012, 2013 and 2014). These six permutations convey very different messages. In the configuration in the Royal Society report stratospheric aerosols resides in the top right corner of the diagram – with any other choice of axes it does not occupy as privileged a position.

Error bars

The diagram portrays error bars around each of the proposed techniques. These error bars are shown in the diagram to be all of the same length, which would seem to indicate that the uncertainty around the proposed techniques are the same for each proposed technique. Given the paucity of information currently available, a truer representation of the error bars around the points would show them stretching across the whole extent of the diagram for most of the points depicted. This would make the diagram much more difficult to read, but interestingly this difficulty in reading the diagram would convey a better representation of the state of knowledge than what is currently depicted.

Scale

The scales of the axes range from 0-6 on affordability, 0-5 on effectiveness, a 5-point scale for safety and a 3-point scale for timeliness. What is not clear is whether what is shown on the diagram is the full extent of the scale. Are we perhaps only viewing a corner of a 100-point scale of affordability and effectiveness closest to the origin? And is the scale scalar or logarithmic in character? If the scale is scalar then it would suggest that the effectiveness of afforestation plus ocean fertilisation would together be equivalent to the effectiveness of stratospheric aerosols (which is not the case). It would also suggest that air capture is only twice the cost of stratospheric aerosols (which seems unlikely). On the other hand if each point on the scale indicates an order of magnitude, then the summation of all the proposed techniques which are not scored 4 on effectiveness are not as effective as any one of those techniques. This

is because if the scale is by orders of magnitude – i.e. a 4 is ten times more than a 3 then five processes that score three are together only half as effective as one process that is scored 4

One of the authors of the diagram has described the scale to me in conversation as "logarithmic-ish", but an explanation of the scale is not provided in the text accompanying the diagram.

Reification

Reification is the fallacy of treating an abstraction as if it were a real thing. In this case, the placing of the dots on the diagram presents to readers a determination of the comparative worth of the range of proposed techniques, which is unsupported by the evidence base that is available. By the very action of placing the dots on the diagram, a degree of confidence is imbued in the analysis that is unwarranted. Despite accompanying text describing the diagram as "tentative", "approximate", "preliminary" and "somewhat illustrative" (see quote below), most people presented with the diagram will not be made aware of these caveats and of those who are, few will internalise them. To use a phrase employed by Daniel Kahnemann – "What you see is all there is"(Kahneman et al., 2011)

This is a prime example of Whitehead's fallacy of misplaced concreteness (Whitehead, 1925). By depicting what scant data there is in a diagram, it is lent far more credibility than is justified. The desire to represent what knowledge that does exist obscures the fact that such knowledge is overwhelmed by a far greater degree of ignorance.

As previously explained, a true representation of the error bars would yield a diagram that is essentially unreadable. For the sake of communication, the diagram is simplified to make it readable, but in the process of simplification the depiction of the degree of ignorance and uncertainty is severely downplayed.

This is a far from trivial point. Policymakers will often rely on preliminary analysis to determine where resources should be employed. This can create a path dependency at a very early stage and result in a narrow range of proposed techniques being explored. Within a short space of time vested interests around particular proposed techniques can develop and influence be brought to bear which places alternative, competing

techniques beyond the regulatory Pale, effectively marginalising them as serious contenders.

Such a focusing of resources on potential "winners" is not inappropriate, *once there is an adequate assessment base on which to make such judgements*, but that is far from the case at present. It should also be noted that while, in the future, it may be possible to arrive at such judgements as to winners and losers, those judgements will be subjective in nature as they will necessarily require assessment of the relative worth of various factors that are traded off against each other.

What is excluded

Consideration needs to be given to what was not in the diagram – what is significant by its absence, to paraphrase a quote from Arthur Conan Doyle's "Silver Blaze", "the dog that didn't bark"?[1]

The diagram displays four dimensions – but which other dimensions could have been displayed? Some others that might have been considered include:

- social acceptability
- legality
- commercial potential
- disruption to existing energy systems
- potential disruption to international relations or international security (Nightingale & Cairns, 2015)

Why were the dimensions that were chosen, chosen? The physical nature of most of the dimensions chosen is reflective of the predominant engineering framing of geoengineering. Even the safety dimension is framed as safety with respect to physical impacts.

Determining the deployability of proposed techniques would require an understanding of not only the physical efficacy of proposed techniques, but also whether such proposed techniques have a social licence to operate. Ultimately, decisions on the deployment of such techniques will be taken by policymakers, who, though they may call on scientists and engineers for advice, will also bring to bear the views of many other

[1] Conan Doyle, Arthur. "Silver blaze." London: Strand Magazine (1892).

parties, who doubtless will hold an array of opinions. The analysis depicted in the diagram is reflective of the way that those who created the analysis view the world, and by its nature privileges that perspective.

Also by excluding certain techniques the diagram tacitly makes a hasty judgment on those techniques that are excluded – perhaps because they were not considered serious 'contenders' by those undertaking the assessment or perhaps because information was not in the public domain at the time of the diagram being created. So removal of greenhouse gases other than carbon dioxide is omitted (indeed the category Carbon Dioxide Removal by its very naming omits consideration of other greenhouse gases), land-use modification is not considered (in which different grazing patterns are used to increase soil carbon) and cirrus cloud thinning is not included (though to be fair most of the work on that proposed technique post-dates the report).

Picking winners

It is worth quoting en extensive part of the text from the Royal Society report to illustrate the next point. The key words are italicised (my italics) for emphasis:

"This diagram is *tentative* and *approximate* and should be treated as no more than a *preliminary* and *somewhat illustrative* attempt at visualising the results of the sort of multi-criterion evaluation that is needed. It may serve as a prototype for future analyses when more and better information becomes available. *However*, even this preliminary visual presentation may already be useful, simply because an ideal method would appear as a large green symbol in the top right-hand quadrant of the figure, and no such symbol exists. *The nearest approximation is for stratospheric aerosols*, which is coloured amber, because of uncertainties over its side-effects…"[2]

Despite the fact that there are so many qualifiers, the report still feels comfortable to 'pick a winner'. Indeed it only qualifies it with 'uncertainties over its side-effects', which dramatically underplays the issues that might restrict its deployability.

[2] Section 5.3, page 49 of the printed version, page 63 of the pdf version.

An alternative framing

Having criticised the methodology of presenting this information in this diagrammatic way, I will however examine what would happen to the shape, colour and location of one particular dot if the social issues associated with deployment were factored in. Consider the dot for stratospheric aerosols – in the original diagram it is a large orange dot in the top right corner of the plot.

- Affordability. If the costs of removing greenhouse gases from the atmosphere is factored into the cost of stratospheric aerosols (not doing so would make it dangerous to exit, and not having a safe exit strategy would militate against deployment in the first place), then the affordability moves from 4 to 1.
- Effectiveness. Provided the definition of effectiveness is retained as that of reducing global mean temperature, then the location on the vertical axis of the diagram is correct.
- Safety. Factoring in the social, political, ethical and security issues rather than just focusing on the technical issues would suggest that the dot's colour should be red rather than orange.
- Timeliness. While the technical timeliness may indeed be short, the overall timeliness, once social licence to operate and creation of governance structures stable enough to endure for a centuries-long deployment, is likely to be extremely long. In that respect, some biological techniques such as afforestation and biochar are implementable immediately, even if they are not implementable on a scale that could have a material impact on climate change.

So the big orange dot in the top right corner would become a small red dot on the upper left corner. (Fig. 3)

Figure 5.1. Preliminary overall evaluation of the geoengineering techniques considered in Chapters 2 and 3.

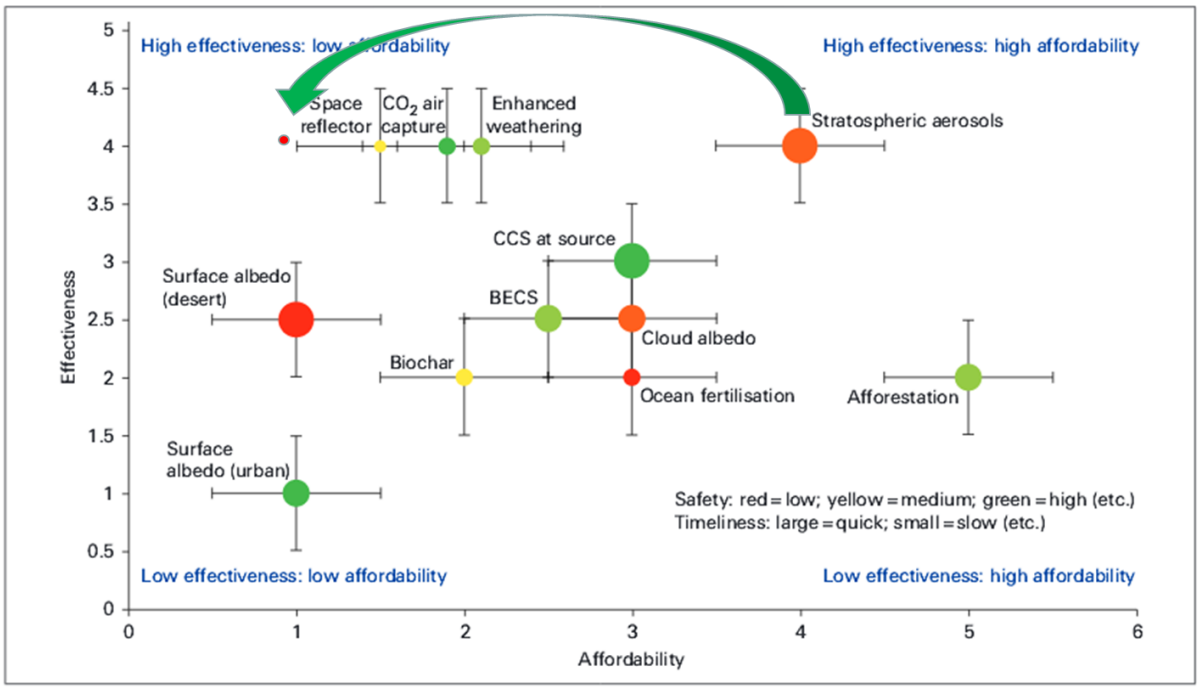

Fig. 3 The effects of an alternative framing on the position of the Stratospheric Aerosol dot, assuming effectiveness is defined as reducing global mean temperature

And if the criteria for effectiveness were to be to counter ocean acidification, then it would become a small red dot in the bottom left corner. Indeed SRM techniques could actually accentuate ocean acidification (cooler sea surface temperatures at a given concentration of carbon dioxide leads to more carbon dioxide being drawn into the ocean). If that were the case then the placement of the small, red dot would be below the horizontal axis. (Fig. 4)

Figure 5.1. Preliminary overall evaluation of the geoengineering techniques considered in Chapters 2 and 3.

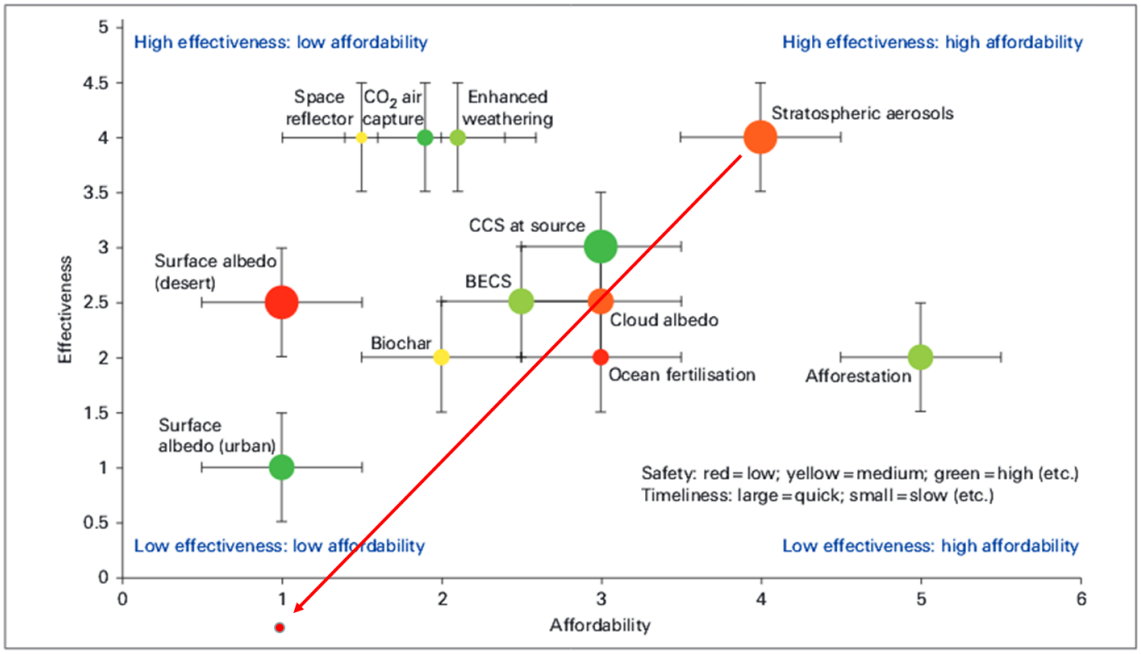

Fig. 4 The effects of an alternative framing on the position of the Stratospheric Aerosol dot, assuming effectiveness is defined as counteracting ocean acidification

Conclusion

There is a saying that a picture is worth a thousand words. In this case the picture requires well over a thousand words to explain the limitations of the information that it attempts to portray. All three of the social scientists on the Royal Society working group that wrote the report have subsequently expressed reservations about the inclusion of the diagram in the report. As a colourful visual diagram it certainly helped with awareness of the report, but this benefit is outweighed by the potential for the information conveyed to mislead.

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