Bounding Boundaries:

The Construction of Geoengineering on Wikipedia

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Climate Geoengineering Governance (http://geoengineeringgovernanceresearch.org) is a research project which aims to provide a timely basis for the governance of geoengineering through robust research on the ethical, legal, social and political implications of a range of geoengineering approaches. It is funded by the Economic and Social Research Council (ESRC) and the Arts and Humanities Research Council (AHRC) - grant ES/J007730/1

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Abstract

Definitions and classifications of geoengineering are fluid and contested. Wikipedia offers an opportunity to study how people negotiate and construct these definitions. Geoengineering related Wikipedia articles were identified in an overall dataset of climate change related articles, with data on both article inter-linkage and the commenting activity of article editors. This enabled analysis of how geoengineering is constructed on Wikipedia, in itself and in relation to wider climate change discourse.

The main finding is that a distinction is made on Wikipedia between two groups of geoengineering methods. On the one hand, there is a group of land-based sequestration technologies, strongly related to adaptation and mitigation discourse, and on the other hand a set of geoengineering technologies, including solar radiation management, ocean iron fertilisation, weather modification and planetary engineering, that is relatively separate from the overall climate change discourse on Wikipedia.

1. Introduction

As attempts at agreeing global policy in response to global warming forecasts are struggling to deliver on expectations, increasing attention has been given to geoengineering technology. Geoengineering is typically defined as "*deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change*" (Royal Society 2009). It would predominantly involve the removal of greenhouse gases from the atmosphere, or attempts at reflecting more energy away from the planet to counter warming. Geoengineering is often presented as a complement, and sometimes alternative, to climate mitigation and adaptation.

The imagined potential of geoengineering technology is manifested in a growing number of academic publications, policy reports and discourse in wider media. To date, the investment in research has been limited, and what is at stake is, among other things, the need for funding of this kind of research.

We can trace the origins of geoengineering back to diverse activities including weather modification practices (Fleming 2006), the use of emergency arguments in climate policy discourse (Hulme 2008) and scientific attempts at exploring the Earth system (NOVIM 2009). At the same time, its emergence may be marking a new phase in our attempts to make sense of the relationships between the climate, science & technology (S&T) and society (Crutzen and Stoermer 2000).

Geoengineering is also a controversial topic, characterised by heated argument as well as cold-shouldering and strategic silences. Explicit challenges come from environmental NGOs, notably the ETC group (2010), and there are also many outspoken critics and ambivalent researchers in academia (e.g. Robock 2008). The concerns are numerous, including potentially disastrous side-effects on Earth systems associated with some of the proposed technologies and the difficulties of finding out about effects and impacts before large-scale deployment.

The ways in which geoengineering is defined and presented are diverse and dynamic (Scholte et al. 2013). The shape of the geoengineering imaginary appears malleable and its fate wide open. Indeed, the very definition of geoengineering is part of what is contested. For example, several technologies that would fall in the definition given above, like afforestation or biomass carbon dioxide capture and storage (BECCS), have also been labelled mitigation technologies. The proponents of such technologies may not want to be considered geoengineers. For others, the geoengineering label may open up new sources of funding and support.

This paper contributes to the analysis of how the boundaries of the geoengineering concept have been constructed by participants in public discourse on geoengineering. In particular, we ask how geoengineering is constructed on Wikipedia. Wikipedia consists of a networked structure of delimited but inter-related topics, which offers an appealing opportunity for studying how the boundaries of geoengineering are negotiated when a group of people seek to express what they know and think. With this in mind, we ask the following questions:

1) How is geoengineering constructed on Wikipedia?
2) How does this relate to what is said on Wikipedia about climate change, i.e. how is geoengineering constructed in relation to the discourse on climate change?
3) How does this definition-by-doing differ from common explicit definitions and from other definitions-by-doing?

2. Pinning down geoengineering

What do we mean by one (1) technology anyway?

This can seem like a trivial question, but ask any patent bureau official and you'll find that the task of classifying technology is far from simple. One difficulty is intimately related to what we mean by technology.

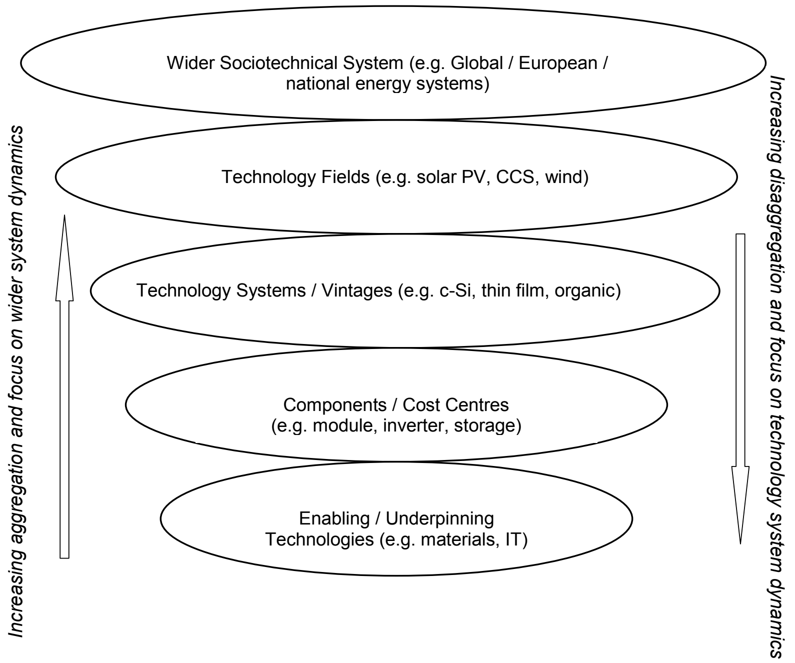
We may be tempted to see technologies as *pieces of kit*, i.e. as bounded material artefacts. Although clearly a technology like iron ocean fertilisation, or indeed a mundane technology like the agricultural cultivation of a field, is a much more open system than that.

It may be tempting to see *function* as the defining property of a technology seen as a technical system. But this quickly opens up a new question of how to define systems. Figure 1 shows an attempt to create a framework for comparing low-carbon energy technologies, and reconciling the multitude of system levels perceived by practitioners from different technical communities. What counts a relevant system level to assess may be very different for a solar PV[1] and a CCS[2] practitioner (and indeed what counts as functioning). Also, any technology could serve more than

[1] Photovoltaics
[2] Carbon dioxide capture and storage

one function. E.g. biochar could be seen as part of an energy system or an agricultural system (and no doubt other systems).

Figure 1 System levels for comparison of low carbon energy technologies



Source: Winskel et al. (2013)

We may want to define technologies by the distinct *knowledge base* they embody, in the sense that the knowledge of the possibility of the wheel enabled the development of early modes of transportation. But clearly this knowledge base underlies both bicycles and cars and many other technologies, and equally clearly, these technologies are dependent on other bodies of knowledge too.

A further complication lies in the recursive nature of technology. What is technology made of? A plausible answer is technology. The development of new technologies (like the car example above) is to a high degree a process of reuse and recombination of old things. Any 'new' technology contains considerable amounts of old technology: old artefacts, old knowledges, old practices, etc. An implication of this is that any distinction between what counts as a novel technology and its predecessor(s) may not be so clear cut.

At the very least, this discussion shows that what should count as one technology is not obvious and trivial. Technology is a heterogeneous, multi-dimensional phenomenon, and there is choice as to which dimension(s) to use for classification, and where to draw the lines. Classification choices depend on their purpose, are rarely if ever water-tight, and any choice made is always in principle contestable.

The contested heterogeneity of geoengineering

Geoengineering is a promising case for the study of how boundaries around a technology are drawn. Geoengineering presents the challenge of how to assemble knowledge from Earth science, pieces of kit and other elements into a functioning whole. As can be expected, there are multiple definitions, and contested choices. Geoengineering[3] is most often seen as a third type of response to climate change, alongside mitigation and adaptation (e.g. Royal Society 2009). But, there are also those who suggest we abandon the term, arguing that it is misleading, given the large technical and political diversity of different geoengineering approaches (Heyward 2013). So, how is geoengineering being defined and bounded?

As a starting point, it is useful to observe that there are at least three levels of conceptual aggregation in use, with geoengineering being the most generic, and a range of more specific technologies, including biochar, sulphate aerosol injection and ocean iron fertilisation, being the most detailed. In between, there are middle-level concepts like unencapsulated geoengineering (Royal Society 2009) and 'Arctic geoengineering' (AMEG 2012).

However, geoengineering is a more troublesome category than that. The middle-level distinction between carbon dioxide removal (CDR) and solar radiation management (SRM) is in wide use (Royal Society 2009, POST 2009, Heyward 2013), and the exhaustiveness of this subdivision is rarely questioned. However, proposals like the spraying ice sheets with freshwater to modify surface salinity in order to reduce the slowdown of termohaline circulation in the North Atlantic fit the Royal Society definition, but are neither SRM nor CDR, illustrating the eternal difficulties of designing water-tight classificatory systems (de Lurio 2009).

[3] Common synonyms include 'climate engineering' and 'climate geoengineering'. Moreover, geoengineering should not be confused with 'geotechnical engineering', a branch of civil engineering concerned with the behaviour and use of earth materials.

Moreover, geoengineering can be seen as part of wider technical categories. Fleming (2006) talks of geoengineering as a kind of macro-engineering, alongside things like changing the direction of Siberian rivers, and also compares it with the terraforming of planets other than Earth. At the other end of the conceptual hierarchy, it is clearly possible to distinguish between different versions of the individual technologies. For example, ocean iron fertilisation could be designed in many different ways. We could reasonably denote each of those as individual technologies.

It is clear that the geoengineering as a linguistic object is heterogeneous. Apart from the conceptualisation challenges involved in demarcating different levels of aggregation and the scope for making different internal distinctions, the boundary between geoengineering and non-geoengineering, i.e. between geoengineering and its context, is also blurred and contested.

Moreover, how technologies are defined and classified is not an innocent question. The stakes can be very high. Again, the patent officer would have a lot to tell us. For the purpose of understanding geoengineering, the financial implications might be relatively distant in time, but they could be enormous. And certainly, there are careers at stake in research.

There are other reasons for why the relationship between geoengineering and mitigation (and adaptation) is hotly contested. Should geoengineering be included as one option (set of options) in our attempt at designing adequate policy responses to climate change, or is it too dangerous? Is even the mere mention of it a way of undermining the support for mitigation, or can we not afford to explore this option? Are afforestation and reforestation really geoengineering technologies, when they have hitherto been seen as an important parts of mitigation strategies?

There are strategic moves being made with regard to how geoengineering is defined. Unsurprisingly, this is easiest to discern when oppositional voices articulate alternatives to the dominating framings. The ETC (2010) go so far as to question if geoengineering is primarily a technology or a political move, and both they and Fleming (2006) suggest that weather modification should be seen as part of geoengineering.

3. Methodology

So, there is choice regarding how to define and classify geoengineering, such choices are being made, and at least some of those are distinctly political. Explicit geoengineering definitions and classifications are fluid and contested. This makes the question of what people de facto refer to when they invoke the term interesting, i.e. how geoengineering is defined and bounded in practice.

Wikipedia offers a promising place to look for an answer to this question. The topology of Wikipedia means that there we find a set of topics with clear labelling that are inter-linked to each other. Within that structure, there is a lot of flexibility for the contributors to delimit, merge and split topics, as well as to indicate their complex relationships through directional links, and so the genre offers a structured space for exploring and negotiating boundaries between issues. Wikipedia also includes documentation of discussions among the contributors offering further scope for analysing definitions and classifications as social actions.

The dataset

The starting point for this analysis is a dataset from the Electronic Maps to Assist Public Science (EMAPS) project[4]. The dataset contains data about 998 Wikipedia articles with content specifically relating to climate change that were identified and downloaded in May 2012. The articles were selected through a combination of using the category structure of Wikipedia, articles with lists of related topics and expert knowledge (EMAPS 2012).

Specifically, the dataset includes data in two forms: comments on editing and links. Wikipedia captures information about editing of the articles, and provides so-called talk pages where editors discuss article content and edits. The data set includes data on comments made for each Wikipedia article. Talk pages accumulate comments over time, and the data collected reflect the entirety of the discussion over time up until the point of data collection.

To measure the controversiality of each Wikipedia article, we considered the thread structure of the discussions on the associated talk page. According to Laniado et al. (2011), a discussion can be represented as a tree where each comment is a node, having for parent node the comment to which it replies (or the root, in case of comments initiating a thread)

[4] FP7 project: www.emapsproject.com.

thus forming a thread of related comments. Using the information extracted from Wikipedia on the thread structure, we developed a measure of controversiality that mirrors the famous h-index used in bibliometrics to assess the impact of a scientist (Hirsch, 2005): a scientist has an h-index of N, if N of his or her papers receive N citations or more. In our case, the controversiality h-index takes into account both the width and the depth – as it were – of a discussion. For example, an article with an h-index of 10 has a discussion with at least 10 threads that each encompasses at least 10 comments.

The overall level of controversiality/liveliness in the3 data set varies from an h-index of 0 (e.g. 'carbon lock-in' and 'solar cities in Australia') to 17/18 (e.g. 'global warming' and the 'climatic research unit email controversy'). Generally, the Wikipedia debate on climate change is dominated by issues surrounding the attribution and existence of global warming.

The second type of data is the hyperlinks between the articles in the dataset. This allows the analysis of how article authors see the relationships between article topics. The dataset contains several metrics describing the structure of article inter-linkage.

The data can be visualised, and rendered suitable for visual analysis, using software. See Figure A1. The GEPHI[5] network visualisation software (Bastian et al. 2009) has been used for this purpose. Among other things, the software has been used to spatialize the network (by drawing closer the nodes representing articles that link to each other) and to colour its nodes in order to visually represent the different subjects of the debate. In particular, all the most controversial articles of the dataset have been manually attributed to three main meta-controversies: Existence/attribution, Mitigation and Adaptation/consequences, (a final category of nodes indicate articles that concern two or three of these controversies, and are here labelled General). See Figure A1 and a stylised representation in Figure A2.

The spatialisation of the graph is obtained through a so-called force-vector algorithm. Unlike scatter-plots or geographical representation such techniques does not rely on a pre-existing space. The nodes are not positioned according to pre-defined coordinates, or to a category to which they are deemed to belong. Rather, the algorithm simulates a system of physical forces: nodes are charged with a repulsive force driving them

[5] https://gephi.org/

apart, while edges introduce an attractive force bounding nodes together. Once the algorithm is launched nodes are displaced until the opposing forces reach a stable equilibrium. At the state of balance, therefore, the distance among the nodes is significant: the system of forces draws closer the nodes that are more directly connected and draws apart the nodes that are disconnected or more indirectly connected. The geometric distance between nodes, in other word, becomes an indicator of their mutual connectivity. Likewise, the different density in the node distribution is also significant: denser clusters represent groups of nodes more frequently inter-related than related to the rest of the network.[6] In particular, we used the algorithm ForceAtlas 2, checking the option of LinLogMode option and setting gravity to gravity zero.[7]

As we said above, the colour of the nodes is instead decided by means of a manual classification of the articles in the three meta-controversies. The fact that nodes of the same colour end up being close in the visualisation, therefore, is evidence of the fact that the classification that we propose is consistent with the hyperlink structure of Wikipedia. Articles within one category tend to be more often inter-related than related to articles in another category.

The dataset contains data on climate geoengineering related topics. This suggests that the dataset can say something about the relationship between geoengineering specific discourse and the overall climate change discourse. By the same token, the dataset should also be able to provide evidence about the coherence of the 'geoengineering' construct and the boundary between it and other climate change related topics.

4. Results

The position of geoengineering in the dataset

[6] In this paper, the word 'cluster' is used to refer to dense areas in spatialised networks, whereas 'groups' are identified through manual classification. Clusters and groups may of course coincide, as discussed in the next section.

[7] ForceAtlas 2 is a force-directed network layout algorithm that has been developed with a view to combine usability for network analysts with rigorous grounding in network theory. The LinLog mode uses a particular formula to calculate the attracting and repulsing forces between nodes. To know more about this algorithm and its settings, see Jacomy et al. (2012).

Most articles related to geoengineering are located in a small and clearly defined cluster in the bottom of the image; see Figures A1 and A3. This suggests that geoengineering is constructed by the editors of Wikipedia as a cohesive and distinct thematic entity. Starting from this visual observation of a geoengineering related cluster in the visualisation of the overall dataset, we have manually selected all articles that are specific to geoengineering, broadly defined to include all CDRs, SRMs and weather modification. Based on visual analysis, supported by metrics in the dataset (page rank and degree of in/out linking), we divided this set into two groups – depicting a relatively separate cluster of geoengineering articles, and a group of articles that is intertwined with mitigation topics. The resulting 43 articles (33+10) are listed in Tables 1 and 2.

Two groups of geoengineering articles were thus visually identified. The first one includes the topic of 'geoengineering' itself, as well as more specific technology categories like solar radiation management (SRM) and space shades. The second one includes technologies like bioenergy with carbon dioxide capture and storage (BECCS) and biochar. This group is less separate/distinct and instead intertwined with CCS and other mitigation topics. The first group is positioned at equal distance from the adaptation and mitigation clusters respectively.

The second group is not distributed randomly across the overall network, but neatly lined up along the boundary of the first group. This suggests that, whilst this group may be strongly linked in with other climate change topics, notably adaptation and mitigation, it is not independent of the first group.

The database provides quantitative metrics on inter-linkage that can be used to complement the visual analysis. The widely used page rank metric shows that the articles in the first of the two groups typically have a low degree of visibility within the global set of Wikipedia articles, and the articles in the second one generally a higher degree of visibility. (Note that this does not mean that all the constitutive articles in the first group are separated off from the overall network. The individual 'Geoengineering' and 'SRM' articles score rather highly on the relevant metrics.) This confirms the visual result.

Table 1 Nodes in 'core' group

Title	h-index	page rank [*10^{-4}]
Arctic_geoengineering	5	2.97
Geoengineering	5	58.34
Iron_fertilization	4	11.95
Nathan_Myhrvold	3	2.88
Planetary_engineering	3	1.60
Space_sunshade	3	6.60
Stratospheric_sulfate_aerosols_(geoengineering)	3	5.07
Stratospheric_sulfur_aerosols	3	4.37
Stratospheric_sulfur_aerosols_(geoengineering)	3	1.56
Weather_modification	3	3.25
David_Keith_(scientist)	2	2.08
ETC_Group	2	3.39
Intellectual_Ventures	2	2.78
Ken_Caldeira	2	4.04
Ocean_nourishment	2	3.73
Solar_radiation_management	2	25.98
Solar_shade	2	1.56
Stephen_Salter	2	3.56
Asilomar_International_Conference_on_ Climate_Intervention_Technologies	0	2.81
Bio-geoengineering	0	2.76
Christopher_McKay_(planetary_scientist)	0	1.67
Cloud_reflectivity_enhancement	0	1.56
Cloud_reflectivity_modification	0	7.69
Five_Ways_to_Save_the_World	0	2.92
Great_Green_Wall	0	1.56
Hydrological_geoengineering	0	1.56
List_of_geoengineering_topics	0	2.85
Lowell_Wood	0	4.16
Outline_of_geoengineering	0	4.07
Paul_J._Crutzen	0	33.79
Photophoresis	0	2.60
Solar_Radiation_Management	0	1.60
Stratospheric_Particle_Injection_for_Climate_ Engineering	0	2.64

Table 2 Nodes in the 'boundary' group

Title	h-index	page rank [*10^-4]
Biochar	3	100.23
Bio-energy_with_carbon_capture_and_storage	2	47.36
CarbFix	2	47.72
Carbon_dioxide_removal	2	71.55
Reforestation	2	15.26
Cool_roof	2	1.56
Biorecro	0	140.45
Enhanced_weathering	0	66.90
Greenhouse_gas_remediation	0	37.78
Klaus_Lackner	0	68.17
Negative_carbon_dioxide_emission	0	11.03

The distinction between the two groups can also be supported with reference to the controversiality h-index. The first group has a maximum h-index of 5, whereas the second group only has a maximum h-index of only 3. (To contextualise, the maximum h-index of non-GE nodes near the GE cluster is 7, and the overall maximum in the database is 18.[8])

It is therefore reasonable to conclude that there are two groups of geoengineering articles. The first group forms a topologically separate cluster whereas the second is intermingled with mitigation. The first group contains the geoengineering article itself, and will therefore here be called the 'core' group. The second group of technology topics closely interlinked with CCS, carbon sequestration, carbon sink and biosequestration. Notably, 'CDR' is included in this group. We will call this the 'land-based sequestration boundary' group, or 'boundary' group for short.

What is in the two groups?

Firstly, we can observe that there are mainly 'fields of science and technology' in the groups. And it should be noted that both groups contain science and technology categories at several levels of aggregation from the broadest category of 'geoengineering', to intermediate level

[8] This might also, in part, reflect the age of the articles, with GE probably being younger than the average in the dataset, and so having accumulated fewer comments.

categories like ‘arctic geoengineering’ and SRM, to relatively specific technology labels like OIF. In addition to fields of science and technology, there are Wikipedia articles on scientists and engineers working on geoengineering like Ken Caldeira, David Keith, Stephen Salter and Nathan Myhrvold. The two groups also include a few organisations and companies, e.g. the environmental organisation ETC and the company Biorecro. In addition, the groups contains one event and one film.

The two geoengineering groups identified relate to different specific geoengineering technologies. The core group includes SRM, space mirrors, ocean iron fertilisation, weather modification and others. See Table 1. There are several articles relating to SRM. The boundary group contains mainly land-based sequestration technologies, like BECCS, Biochar and reforestation. Air capture has no Wikipedia article as such, but Klaus Lackner is represented in the boundary group. An exception to this rule is that the topic of the ‘Great green wall’, which is about using forestry to handle land degradation and desertification in the Sahel and the Sahara, and is in the core group rather than the boundary group.

It is also somewhat surprising that enhanced weathering is here not seen to be part of the core geoengineering group. A look at the editing history of the enhanced weathering article reveals that it started off being about land-based weathering, and that its focus has shifted towards marine approaches over time.

Clearly there can be no ultimate, perfectly comprehensive list of specific geoengineering technology proposals, but compared to prominent reports like the Royal Society report, it is worth noting that a few technologies are ‘missing’ in the dataset. There is only one article with land-based albedo methods: ‘cool roofs’. Ocean upwelling and downwelling are not represented. This is mainly an effect of how the dataset was created, with its primary purpose to map climate change discourse, rather than geoengineering discourse. For example, upwelling has a Wikipedia article, but it is not included in this dataset. (Table 4 below, gives a similar result, when comparing to the list compiled in the meta-analysis by Bellamy et al. 2012). Overall, geoengineering technologies are rather well represented in the dataset covering climate change related topics, as compared to those listed in prominent reports including the Royal Society report.

How do the two groups relate to wider climate change discourses?

The boundary group is intermingled with mitigation topics and technologies like CCS, as discussed above. Prominent neighbouring topics here are CCS, carbon sinks, carbon sequestration and bio-sequestration (with h-indexes ranging from 3-4, so moderately lively). The exception to this rule is the 'cool roofs' article, an outlier that is instead intertwined with adaptation and existence/attribution topics.

There are also – much less blurred – boundaries with other topics in the dataset. Table 3 displays a set of prominent (high h-index) nodes close to the core group. These topics predominantly belong to the (overlapping) existence/attribution and the adaptation categories; cf. Figure .2.

Looking in more detail at the most prominent topics in this vicinity, several themes emerge that link geoengineering to these wider discourses. Firstly, there are links to topics providing underpinning knowledge for geoengineering: Earth's atmosphere, albedo and global warming potential. Secondly, there are links that highlight connections between geoengineering and other global environmental problems: ozone depletion and ozone acidification. In one case, the link is political – the support of James Lovelock, the originator of the Gaia hypothesis.

The final theme revolves around emergency and the urgent threats from strong, short term GHGs (methane, nitrous oxide). There are several related themes nearby as well, including runaway climate change and tipping points. This result corresponds well with previous studies that indicate that the emergency frame is prevalent in geoengineering literature (Scholte et al. 2013; Nerlich and Jaspal 2012). Climate emergency is in the database mainly related to articles about the existence of global warming and articles about adaptation, rather than articles on mitigation.

In the context of climate change related articles on Wikipedia, GE is constructed in relation to knowledge about the atmosphere, climate change generally and specific mechanisms involved in climate change. There are also relations constructed to other global environmental problems like ozone depletion, and ocean acidification. Finally, there are links to issues surrounding the storyline of potential 'climate emergency' – an argument often used in support of GE.

Table 3 Prominent neighbours

	h-index	Category	Comment
Albedo	5	Existence	SRM techniques intended to work by modifying the planet's albedo
Gaia_hypothesis	6	None	James Lovelock has come out in support of geoengineering, after earlier opposition.
Earth's_atmosphere	5	Existence	General underpinning knowledge
Ozone_depletion	7	Adaptation	Sulphate aerosols may exacerbate this.
Ocean_acidification	7	Adaptation	SRM does not solve this, which is frequently mentioned as a flaw
Methane	5	Existence	Short term GHG that is potentially released from melting permafrost and marine clathrates
Nitrous_oxide	4	None	Strong, short-term GHG that is potentially released from melting permafrost
Global_warming_ potential	4	Mitigation	Relation between gas concentrations and radiation balance is key knowledge for design of CDR interventions

Note: in order of sequence as they appear along the boundary in Figure A.3.

Comparing the apparent definition on Wikipedia with other definitions

The core group identified here matches quite well what Bellamy et al. (2012) found are the technologies most often included in technology appraisals, cf. Table 4. But, in contrast with the ranking continuum presented by Bellamy et al. (2012), our results point towards a discontinuity between the core and land-based sequestration groups.

It is interesting to note that the study does not conform to the ubiquitous and indeed dominating CDR-SRM distinction. Ocean iron fertilisation is a CDR technology, but is here clearly associated with the core geoengineering group. This lends some credibility to the notion of 'unencapsulated' geoengineering technology, referring to technologies that depend on the release of material into open Earth systems (Royal Society 2009). Although by that definition space shades should not be in the core group.

Table 4 Frequency of inclusion in geoengineering appraisals

Technology	# appraisals	Core	Boundary
Stratospheric aerosols	22	x	
Space reflectors	17	x	
Air capture and storage	16		x
Iron fertilisation	16	x	
Mechanical cloud albedo	15	x	
Afforestation	13		x
Urban albedo	10		x
Bio-char production	9		x
Cropland albedo	7		
Bio-energy with carbon sequestration	6		x
Carbonate addition	6		x
Desert albedo	6		
Phosphorous addition	6	x	
Grassland albedo	5		
Settlement albedo	5		
Enhance downwelling	4		
Enhance upwelling	4		
Nitrogen fertilisation	4	x	
Biological cloud albedo	3	x	
Terrestrial enhanced weathering	3		x
Ocean enhanced weathering	2		x
Other	16		

The inclusion of weather modification among the core geoengineering group is at odds with attempts at drawing a line between this practice and its history and geoengineering (Fleming 2006, ETC 2010). Furthermore, this challenges the construction of geoengineering as something novel and unprecedented. However, this result may be dependent on the overall frame of reference in this study being climate change. Weather modification has little relevance for climate change other than through the debate around geoengineering, and a different result might emerge with a different overall frame.

5. Conclusions

Based on this study, we find that on Wikipedia, geoengineering is constructed to include the notion of SRM itself and most SRM technologies, as well as ocean iron fertilisation and weather modification. The distinct division between core geoengineering methods and the boundary group of land-based sequestration methods is a new finding. The analysis suggests that the land-based sequestration technologies are typically seen as conventional mitigation or adaptation technologies, rather than geoengineering ones.

A possible explanation for this is that the technologies in the land-based sequestration group have already been relatively well established as climate mitigation and adaptation technologies, whereas the core group represents technologies with a less secure role in policy and with less well developed support bases and funding streams. Furthermore, it is possible that the inclusion of both kinds of technology in more formal discourse like appraisals, and their inclusion by definitional fiat in explicit definitions, has served to legitimise core technologies by the more well-established technologies of the land-based sequestration boundary. These hypotheses deserve exploration in further research.

Further work is planned to improve this analysis, along several lines:

1) Further empirical exploration will (a) look into the history of these Wikipedia articles, and (b) explore how geoengineering Wikipedia articles relate to topics on Wikipedia other than climate change, through the creation of a new dataset, which takes geoengineering related Wikipedia articles as its starting point and does not pre-suppose that climate change is the only context of geoengineering.

3) A strengthened justification and social scientific reflection on the overall methodology as a way of studying the public discourse around controversial techno-scientific objects like geoengineering will be developed.

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Appendix

Figure A.1 The dataset with the location of the geoengineering nodes [with geoengineering core circled in]

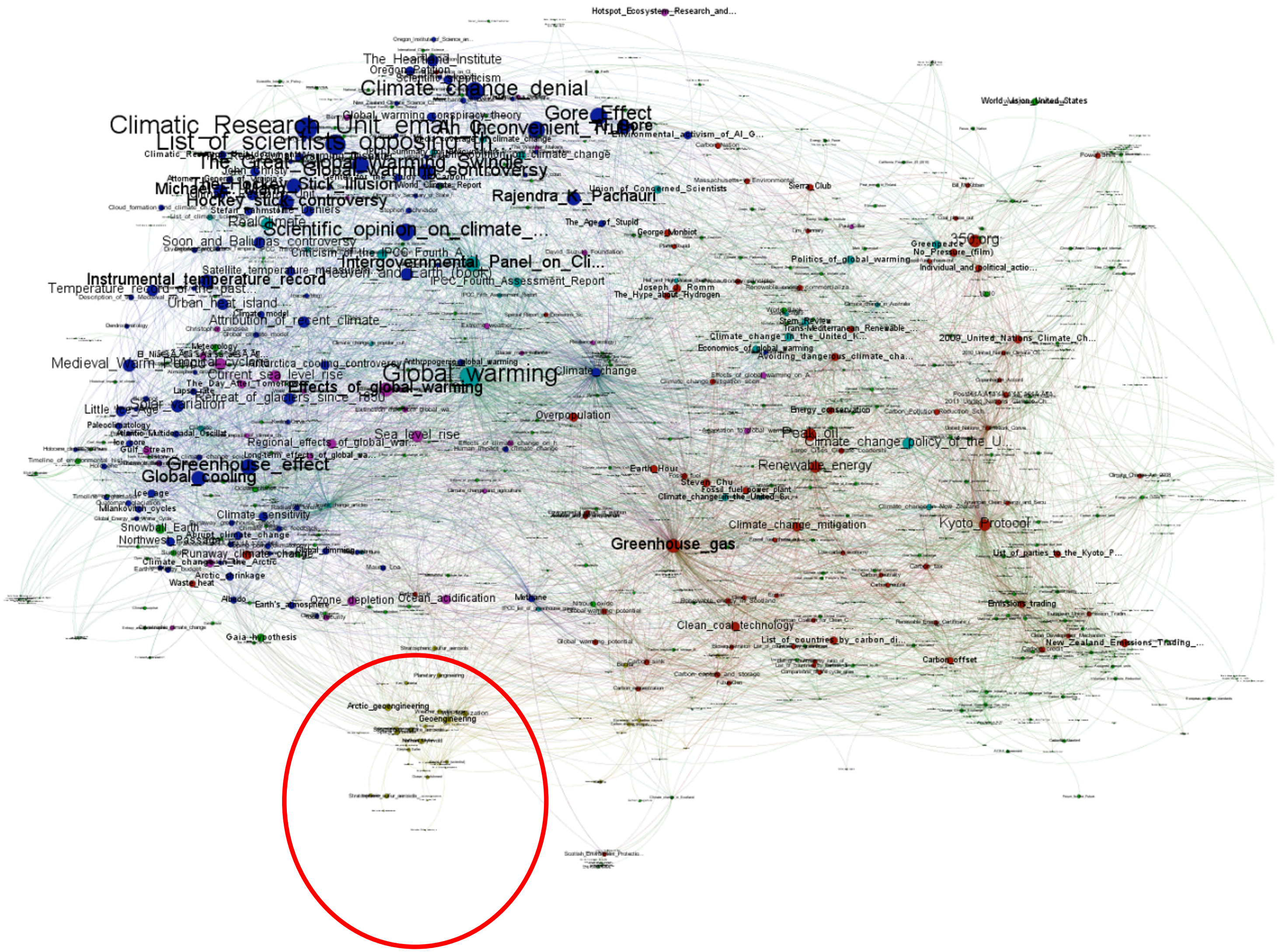

Figure A.2 Stylised representation of meta-categories

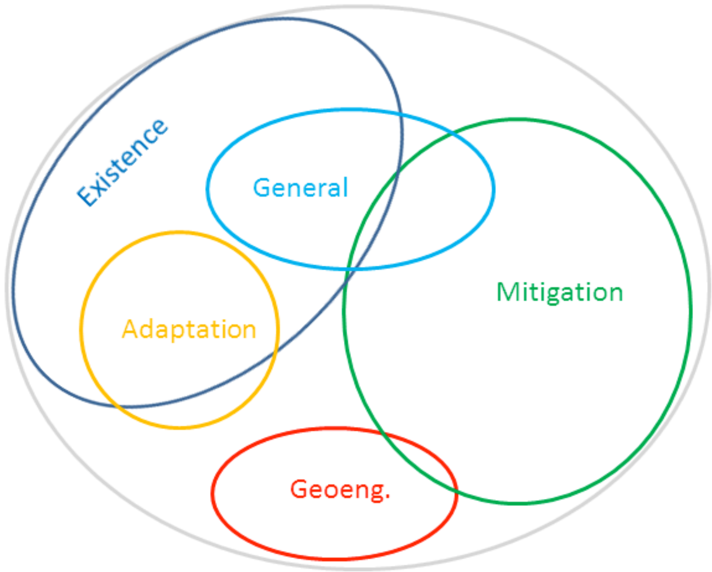

Figure A.3 Zooming in on geoengineering [with geoengineering nodes (and their out-links) coloured red]