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Review

Climate and environmental science denial: A review of the scientific literature published in 1990–2015

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ABSTRACT

Denial of scientific findings is neither a new nor an unexplored phenomenon. In the area of environmental science and policy though, the research on denial has not been systematically summarized and analyzed. This article reviews 161 scientific articles on environmental and climate science denial published in peer reviewed international journals in the last 25 years and aims to both identify research gaps and enable learning on the phenomenon. Such knowledge is needed for the increasingly important task to provide effective response to science denial, in order to put an end to its influence on environmental policy making. The review, which is based on articles found in the databases *Web of Science*, *Scopus* and *Philosopher's Index*, shows that denial by far is most studied in relation to climate change, with a focus on Anglo-American countries, where this form of denial is most common. Other environmental issues and other geographical areas have received much less scientific attention. While the actors behind climate science denial, their various motives and the characteristics of their operations have been thoroughly described, more comparative research between issues and countries is needed in order to draw reliable conclusions about the factors explaining the peculiarities of denial. This may in turn lay the ground for developing and actually testing the effectiveness and efficiency of strategies to counter environmental science denial. Irrespective of the ambitions of environmental goals, science-based policies are always preferable. The scientific community therefore needs to increase its efforts to dismantle false claims and to disclose the schemes of denialists.

Contents

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1. Introduction

The initial decisions of the Donald J. Trump administration in the United States raise considerable concern over future US environmental and climate science and policy. With several ministers, as well as the President himself, expressing doubt about the central tenets of climate science, there is an obvious risk that environmental policy will be less science-based in the years to come. In particular, there is a fear that organized efforts to spread doubt about the reliability of scientific data will be spurred and significantly delay environmental policy processes. This fear is not unfounded. Empirical studies from other policy fields confirm that organized science denial perpetrated by actors with considerable political or economic capital can affect how society responds to serious threats or problems. In South Africa, for instance, governmental AIDS denialism has resulted in hundreds of thousands of premature deaths (Nattrass, 2007; see also Specter, 2009 on vaccination). The tobacco industry's denial of tobacco-induced diseases has had equally serious consequences (Oreskes and Conway, 2010; Proctor, 2012).

Climate science denial is not a new, or academically unexplored, phenomenon. A substantial body of scientific literature exists, in particular regarding the situation in the United States (Dunlap et al., 2016). However, while covering numerous aspects and spanning a wide area of disciplines, this research has not yet been systematically analyzed. Similarly, it remains to be investigated to what extent the findings of this literature can be extended to non-Anglo-American countries and to other environmental policy fields, such as chemicals regulation. In this article, we review the scientific literature on environmental science denial published in the last 25 years with the aim to facilitate such analyses. By identifying the main issues and trends observed in the scientific literature, and by describing the characteristics of denial and strategies to counter it, we aim to search for research gaps and enable learning about the science denial phenomenon. Such knowledge is needed for the increasingly important task to provide response to science denial, and put an end to its influence on environmental policy making.

In this article, we present a systematic review of the scientific literature on environmental science denial published in the last 25 years. The review is based on 161 peer-reviewed academic articles published in English between 1990 and 2015 and located through an extensive search in three databases: *Web of Science*, *Scopus*, and *Philosopher's Index*. The review is organized around five research questions:

- What is being denied?
- Who denies?
- How is science denial defined, and what are the strategies of science denial?
- How is science denial explained?
- What strategies can be used to counter science denial?

The findings of the review are reported on in sections 4–8. Section 2 describes the methods used in the review, including selection of databases, choice of search terms, and method of analysis. Section 3 reports on the bibliographic results obtained, including publication venues and geographic perspectives. In section 9, the findings are analyzed and research gaps are identified.

2. Methods

The literature review was structured and performed using Denyer and Tranfield, 2009 five steps of a systematic review process: (1) question formulation, (2) locating studies, (3) study selection and evaluation, (4) analysis and synthesis, and (5) reporting and using the results. Steps (1) and (4)–(5) are reported on in sections 1 and 4–9 respectively. Steps (2) and (3) are described in this section.

2.1. Selection of databases and bibliographic limitations

Three bibliographic databases were selected for the review: *Web of Science* (all databases), *Scopus*, and *Philosopher's Index*. Web of Science and Scopus were chosen because they were judged to index a large majority of the articles published on science denial.[1] *Philosopher's Index* was added in order to make sure articles addressing science denial from a philosophy of science perspective were captured, if published in highly specialized philosophical journals not indexed in *Web of Science* or *Scopus*. *PubMed* is another database of conceivable relevance; however, a preliminary scanning indicated a comparatively small number of references of potential interest and the database was therefore not selected for the review.

In order to obtain a manageable number of sources, a decision was made to focus on peer-reviewed scientific articles published in English between the years 1990-2015.[2] There is an additional significant body of literature, consisting of mainly books and some grey literature, addressing environmental and in particular climate science denial (e.g. Anshelm and Hultman, 2015; Cook and Lewandowsky, 2011; EEA, 2001, 2013; Hoggan and Littlemore, 2009; Mann, 2012; Nuccitelli, 2015; Pooley, 2010; Washington and Cook, 2011). However, since grey literature in general is not peer reviewed and the inclusion of peer reviewed books would reduce the clarity of what has been published scientifically, a decision was made not to include them in the review.

2.2. Choice of search terms

First, a general search was made using the search string [denialism OR (denial AND (scien* OR evidence)) OR (scien* AND skepticism) OR anti-science] (Search #1). This search generated

[1] Web of Science covers over 12,000 journals from science and arts and humanities (Thomson Reuters, 2013). Scopus covers over 21,500 journals from social sciences, life sciences, health sciences and physical sciences (Elsevier, 2016)

[2] One of the reviewed articles (Austgulen and Stø, 2013) had an English abstract but was written in Norwegian. Since the article was identified in our selection and since Norwegian is a language that the authors of the present article can read, the article was included in the review. A handful of editorials on science denial published in peer-reviewed academic journals were included in the review.

approximately 5000 hits (duplicates included), see Table 1.

Second, two field-specific searches were made using the following search strings (Search #2 and #3):

(environment* AND skepticism) OR anti-environment*
(denial* OR skeptic*) AND (scien* OR evidence) AND (environment* OR climat*)

These searches generated approximately 2000 hits (duplicates included), see Table 1.

When surveying the abstracts of the relevant articles obtained through the abovementioned searches, it became obvious that a majority dealt with climate change. To make sure that no important articles in other environmental areas had been missed, additional field specific searches were made using the search string [(denial* OR skeptic*) AND (scien* OR evidence)] in combination with a number of search words targeting various other environmental policy areas (Search #4):

ozone
((air OR water) AND pollut*)
((nature AND conservation) OR ((endangered OR threatened) AND (species OR genetic)) OR (invasive AND species))
(wildlife OR wolf OR (overhunting OR overfishing))
(((endocrine OR hormone) AND disrupt*) OR (cocktail AND effects) OR ((emerging AND (contamin* OR pollut*))))

Taken together these searches added approximately 100 hits (duplicates included), see Table 1.

The abovementioned searches were carried out in spring 2015 (see Table 1 for dates) and covered literature published between January 1990 and March 2015. Another four searches, using the same search strings and selection criteria as previously used but covering only the literature published in 2015, were completed in October 2016 (Search #5–8). These searches generated approximately 700 hits (duplicates included).

2.3. Selection of articles

All hits obtained through the literature search were scanned by one of the authors based on title and abstract. Relevant articles were saved and imported to the EndNoteWeb© reference management system. The imported articles were then sorted into four subject matter categories and all duplicates were removed:

A. Environment (including climate change and energy),
B. Health (including vaccination, AIDS/HIV, tobacco),
C. Evolution
D. Other issues and/or general discussion

Based on the aim and focus of the literature review a decision was made to only include the category A and D articles (around 200 articles). The articles were distributed among three of the authors and read thoroughly. A number of articles were again excluded because they did not fulfil the selection criteria (e.g. they were book reviews, not written in English or not published in a peer reviewed journal) or were deemed to be irrelevant or of only slight relevance to the review. In most cases, the decision to exclude an article was made after consultation with one or two of the other authors. After this reading 161 articles remained.

2.4. Method of analysis

Bibliometric information about author, year of publication, title, journal, and first author affiliation was inserted into a word file together with brief notes about the five research questions outlined above (What is being denied?, Who denies?, How is science denial defined, and what are the strategies of science denial?, How is science denial explained?, What strategies can be used to counter science denial?). The word file is accessible as a supplementary file on the journal website. The summarizing notes were then analyzed, question for question, in order to find specific themes, patterns, and where possible, typologies in the material, as reported below in the results section. Although the 161 articles were initially divided between the three authors responsible for reading and analyzing the articles, in many cases one and the same article was read by more than one person. The findings were presented and discussed at recurrent project meetings involving all four authors.

2.5. Limitations of the research

As indicated above a number of choices were made when conducting the review. First, with a few exceptions only peer reviewed articles in English were selected in order to obtain scientifically credible and a manageable number of sources. Books, reports, and other grey literature were thus not included in the review. It is possible that some phenomena related to environmental science denial would have been easier to capture if, for example, some books had been included. Second, the choice of search terms, although identified after careful deliberation, may have affected the outcome of the review. For example, using a search string such as "misrepresentation AND evidence" might have added further articles to the review. Third, there is always a possibility that articles, or parts of articles, can be misinterpreted. When multiple authors are involved in reading and interpreting articles, there is in addition the risk that different authors may interpret the articles differently. In order to prevent that problem, the articles were continuously discussed at project meetings and in many cases co-read by two or three of the authors, see above.

3. Bibliographic results

The literature search described above involved scanning the titles and abstracts of over 5000 articles, of which a total of 161 articles were selected for the present review. The bibliographic results presented below relate to these 161 articles.

3.1. In which journals are the articles published?

The articles are published in a range of different journals covering both the natural and social sciences and the humanities, see Table 2. The five most frequent scientific journals for the reviewed articles were:

Global Environmental Change (15 papers, 9.3%),
American Behavioral Scientist (7 papers, 4.3%),
Climatic Change (6 papers, 3.7%),
Environmental Research Letters (6 papers, 3.7%),
Global Environmental Politics (6 papers, 3.7%),

3.2. Who writes about environmental science denial?

Most of the articles were written by academics, predominantly in English-speaking countries. A few of the authors were either unaffiliated or employed by non-academic organizations, including British Nuclear Fuels, Environmental Law Foundation, Hoover Institution, and OxyGeneva. The five most common country affiliations among the first authors (including unaffiliated authors and authors employed by non-academic organizations) were:

Table 1
Number of hits for each search string and database.

	Date	Search engine	Hits
Search #1	**Search string:** denialism OR (denial AND (scien* OR evidence)) OR (scien* AND skepticism) OR anti-science		
	17/02/2015	Web of Science (TOPIC)	2589
	17/02/2015	Philosopher's Index (BASIC SEARCH)	285
	03/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	2137
Search #2	**Search string:** (environment* AND skepticism) OR anti-environment*		
	17/02/2015	Web of Science (TOPIC)	310
	18/02/2015	Philosopher's Index (BASIC SEARCH)	27
	02/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	292
Search #3	**Search string:** (denial* OR skeptic*) AND (scien* OR evidence) AND (environment* OR climat*)		
	02/03/2015	Web of Science (TOPIC)	579
	02/03/2015	Philosopher's Index (BASIC SEARCH)	32
	02/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	861
Search #4	**Search string:** ((denial* OR skeptic*) AND (scien* OR evidence)) AND ozone		
	26/03/2015	Web of Science (TOPIC)	6
	26/03/2015	Philosopher's Index (BASIC SEARCH)	0
	26/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	5
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND ((air OR water) AND pollut*)		
	26/03/2015	Web of Science (TOPIC)	14
	26/03/2015	Philosopher's Index (BASIC SEARCH)	0
	26/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	11
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND ((nature AND conservation) OR ((endangered OR threatened) AND (species OR genetic)) OR (invasive AND species))		
	26/03/2015	Web of Science (TOPIC)	14
	26/03/2015	Philosopher's Index (BASIC SEARCH)	1
	26/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	13
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND (wildlife OR wolf OR (overhunting OR overfishing))		
	26/03/2015	Web of Science (TOPIC)	13
	26/03/2015	Philosopher's Index (BASIC SEARCH)	1
	26/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	8
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND (((endocrine OR hormone) AND disrupt*) OR (cocktail AND effects) OR ((emerging AND (contamin* OR pollut*))))		
	26/03/2015	Web of Science (TOPIC)	8
	26/03/2015	Philosopher's Index (BASIC SEARCH)	0
	26/03/2015	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press")	5
Search #5	**Search string:** denialism OR (denial AND (scien* OR evidence)) OR (scien* AND skepticism) OR anti-science		
	07/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	181
	07/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	28
	19/10/2016	Scopus (TITLE-ABS-KEY) (Limit to Year 2015) (Limit to "Article" or "Article in Press")	235
Search #6	**Search string:** (environment* AND skepticism) OR anti-environment*		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	52
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	2
	19/10/2016	Scopus (TITLE-ABS-KEY) (Limit to Year 2015) (Limit to "Article" or "Article in Press")	43
Search #7	**Search string:** (denial* OR skeptic*) AND (scien* OR evidence) AND (environment* OR climat*)		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	73
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	10
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	75
Search #8	**Search string:** ((denial* OR skeptic*) AND (scien* OR evidence)) AND ozone		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	1
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	1
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	2
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND ((air OR water) AND pollut*)		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	1
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	1
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	1
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND ((nature AND conservation) OR ((endangered OR threatened) AND (species OR genetic)) OR (invasive AND species))		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	1
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	1
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	0
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND (wildlife OR wolf OR (overhunting OR overfishing))		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	1
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	1
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	1
	Search string: ((denial* OR skeptic*) AND (scien* OR evidence)) AND (((endocrine OR hormone) AND disrupt*) OR (cocktail AND effects) OR ((emerging AND (contamin* OR pollut*))))		
	24/10/2016	Web of Science (TOPIC) (Limit to Year 2015)	0
	24/10/2016	Philosopher's Index (BASIC SEARCH) (Limit to Year 2015)	0
	24/10/2016	Scopus (TITLE-ABS-KEY) (Limit to "Article" or "Article in Press") (Limit to Year 2015)	0

Table 2
Publication venues and number of articles.

Journal	Number of articles
Advances in Sustainability and Environmental Justice	1
Ambio	1
American Behavioral Scientist	7
American Journal of Medicine	2
Analyses of Social Issues and Public Policy	1
Annals of the American Academy of Political and Social Science	1
Bioethics	1
Bulletin of the American Meteorological Society	1
Capitalism, Nature, Socialism	2
CBE – Life Sciences Education	1
Chemical Engineering Research and Design	1
Climatic Change	6
Conservation Biology	1
Critical Criminology	1
Critical Policy Studies	1
Current Biology	1
Development and Change	1
Economy and Society	1
Ecopsychology	1
Ecosystem Services	1
Energy and Environment	1
Energy Policy	1
Energy Research and Social Science	1
Environment: Science and Policy for Sustainable Development	1
Environmental Communication	4
Environmental Health Perspectives	2
Environmental Law and Management	2
Environmental Philosophy	1
Environmental Politics	4
Environmental Research Letters	6
Environmental Science and Policy	3
Environmental Values	3
European Journal of Philosophy of Science	1
European Journal of Physics	1
European Journal of Public Health	1
Frontiers in Psychology	1
Futures	2
Geoforum	3
Global Environmental Change	15
Global Environmental Politics	6
Globalizations	1
Human and Experimental Toxicology	1
Human Dimensions of Wildlife	1
International Journal of Press/Politics	1
International Sociology	1
Journal of Environmental Studies	1
Journal of Business Ethics	1
Journal of Education Policy	1
Journal of Environmental Economics and Management	1
Journal of Homeland Security and Emergency Management	1
Journal of Sustainable Tourism	1
Journal of the Royal Society of New Zealand	1
Journal of Toxicology and Environmental Health-Part A	1
Journal of Youth Studies	1
Journal of Zoo and Wildlife Medicine	1
Journalism Studies	1
Nature Climate Change	1
Nature Immunology	1
New Zealand Journal of Psychology	1
Organization and Environment	2
Organization	1
Personality and Individual Differences	1
Philosophical Transactions of the Royal Society A	2
Policy Review	1
Political Power and Social Theory	1
Proceedings of the National Academy of Sciences of the United States of America (PNAS)	2
Psychological Science	1
Public Relations Review	1
Public Understanding of Science	5
Risk Analysis	2
SAGE Open	1
Science and Engineering Ethics	1
Science Communication	3

(*continued on next page*)

Table 2 (*continued*)

Journal	Number of articles
Science	1
Social Forces	1
Social Problems	1
Society and Natural Resources	1
Sociological Quarterly	1
Survival: Global Politics and Strategy	1
Sustainability	1
Synthesis Philosophica	1
The American Biology Teacher	1
The Geographical Journal	1
The Journal of Environmental Education	1
The New Zealand Medical Journal	1
The Sociological Quarterly	1
Theory, Culture and Society	1
Tidsskrift for Samfunnsforskning	1
Tourism Management	3
Trends in Biotechnology	1
Trends in Ecology and Evolution	1
Trends in Microbiology	1
Urban Forestry and Urban Greening	1
Whether, Climate and Society	1
Wiley Interdisciplinary Reviews – Climate Change	3

United States (67 affiliations, 42%),
United Kingdom (32, 20%),
Australia (13, 8%)
New Zealand (9, 5.6%)
Canada (6, 3.7%)

3.3. When (between 1990 and 2015) are the articles published?

Fig. 1 shows the number of reviewed publications per year between 1990 and 2015. The data shows that there has been a steady increase in publications since 2010. In a study on the links between conservative think tanks and climate change books published between 1980 and 2010, Dunlap and Jacques (2013) note a corresponding increase in published climate change denial books beginning a few years earlier, in 2007.

3.4. Geographic perspective

Although a large percentage of the articles have a cross-national perspective or discuss environmental science denial on a general level (around 40% of the articles in the review), a majority of the articles have an Anglo-American perspective and focus on environmental and climate science denial in the US, UK, or Australia (around 48%). Other represented countries include Japan (Asayama and Ishii, 2014), Norway (Austgulen and Stø, 2013; Norgaard, 2006), Germany (Engels et al., 2013), Hong Kong/China (Lo, 2015; Lo and Jim, 2015), Sweden (Ojala, 2015), Switzerland (Shi et al., 2015; Stoll-Kleemann et al., 2001), Serbia (Zivojinovic and Wolfslehner, 2015), Finland (Sarkki and Karjalainen, 2015), and Russia

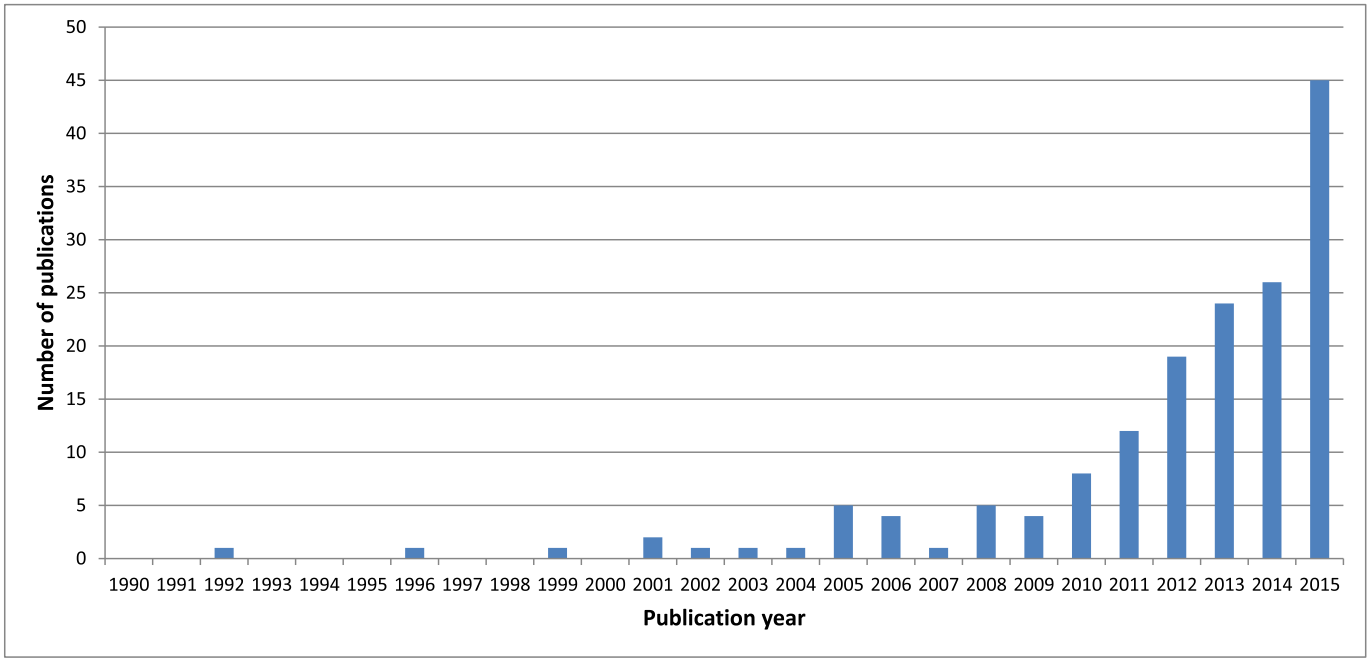

Fig. 1. The number of publications found in the literature review on science denial and their publication year (1990–2015).

(Poberezhskaya, 2015). Only a few articles include developing countries in their analyses (Brüggemann and Engesser, 2014; Capstick et al., 2015; Painter and Ashe, 2012).

3.5. Distribution of articles among the five research questions

What is being denied? With only one or two exceptions the articles in the review focus on environmental and/or climate science denial, or focus on science denial in general but mention environmental or climate science denial as one example, see section 4 for further analysis.

Who denies? A majority of the articles in the review (around 90%) identify one or several environmental or climate science deniers. Only around 10% of the articles do not give a clear answer to the question of who denies, see section 5 for further analysis.

How is science denial defined, and what are the strategies of science denial? Around 30% of the articles in the review provide a definition of science denial (or skepticism) or discuss the meaning of science denial/skepticism and similar concepts ("contrarianism", "dismissal", etc.). Around 40% of the articles mention one or several strategies used in science denial, see section 6 for further analysis.

How is science denial explained? Around 60% of the articles in the review attempt to explain the occurrence of science denial or discuss one or several drivers behind science denial, see section 7 for further analysis.

What strategies can be used to counter science denial? Around 40% of the articles in the review give one or several suggestions regarding how to counter science denial, or discuss various countermeasures on a more general level, see section 8 for further analysis.

4. What is being denied?

About four fifths of the articles are climate-related. The others discuss science denial in other environmental issues or on a more general level (e.g. Diethelm and McKee, 2009; Ehrlich, 1996; Holtcamp, 2012; Jacques, 2006, 2008; Kraft et al., 2015; Zhou, 2015). Climate science denial is by far the most coordinated and well-moneyed form of science denial, constituting the backbone of the opposition to environmentalism and environmental science in general, particularly in the United States but also to some extent in the UK and Australia (Dunlap and McCright, 2011).

Several of the surveyed articles distinguish between three variants of climate science denial that are attributed to Rahmstorf (2004) (cf. Matthews, 2015; Poortinga et al., 2011). *Trend* denialists contest that any significant warming takes place. *Attribution* denialists instead question its anthropogenic nature, often attributing it to solar activity. *Impact* skeptics accept anthropogenic climate change, but deny that it will have significant (negative) impacts on humans or the environment. Engels et al. (2013) added a fourth variant, *consensus* denial, which concerns questioning the existing consensus among climate scientists about anthropogenic climate change (cf. also Cohen's (2001) tripartite conception of denial, outlined below).

McCright (2016) summarized previous studies on the prevalence of trend, attribution, impact, and consensus denialism in four countries: Germany (Engels et al., 2013), Australia (Leviston and Walker, 2012), Britain (Poortinga et al., 2011), and the United States (McCright and Dunlap, 2011a). He concluded that, with the exception of Germany, where all forms of climate science denial are uncommon, attribution, impact, and consensus denial are all more common than trend denial in these countries. Still, a large share of the American population does not belief in global warming (McCright and Dunlap, 2011a).

Although climate change denial constitutes the core of the organized opposition to environmental science and regulation today, the strategies employed by those who actively deny climate science are also employed in other environmental policy fields. These attempts are documented, for example, by Oreskes and Conway (2010), who lay bare the denialist tactics used by actors opposing regulation of sulfur and nitrogen emissions (which cause acidification) and emissions of chlorofluorocarbons (which harm the ozone layer). Although denial of the science related to stratospheric ozone depletion is mentioned in a few of the reviewed articles (e.g. Jacques, 2006; Jacques et al., 2008), only one article takes the case of ozone depletion as departure point for the analysis. Andersen (2015) identifies the success factors behind the Montreal Protocol on ozone depletion, and makes comparisons with climate change. In contrast to climate change denialists, opponents of ozone science "never had much of a following and certainly never attracted much financial support" (2015:149). Bell et al. (2014), on the other hand, argue that the scientists themselves were too late in recognizing the role of eutrophication in the damage of coral reefs. This contributed to ineffective monitoring, evaluation, and remediation of damaged areas.

Conversely to denial of science pointing out environmental problems, a few articles criticize what the authors consider to be denial of e.g. various claimed problem solutions. Rutberg (2013) discusses the concept of "socially constructed ignorance" in the field of wildlife management. He argues that resistance to scientific results on wildlife management through contraception has delayed progress in this area. The resistance has taken many forms, including "denial of research permits, omission from research reports and management documents, and repetition of misleading or false information in public forums and the media" (p. 38). Miller et al. (2008) maintain that what they consider to be unscientific articles on genetic modification have sometimes been published even in prestigious scientific journals. Wilkinson (2006) argues that the risks of nuclear power have been exaggerated, due in part to ignorance or deliberate misrepresentation of the underlying science. Ropeik (2015) relates recent findings in the decision-theoretical, neurological, and psychological sciences to the differences in risk perception concerning chemicals.

5. Who denies?

The articles in our review identify six categories of actors and organizations that deny environmental science in general and climate science in particular. The categories are not mutually exclusive but used here as a means of structuring the discussion.

1. Denying scientists. A small minority of scientists actively deny the evidence of environmental problems such as acid rain, ozone depletion, and climate change (cf. Anderegg et al., 2010; Oreskes and Conway, 2010). They are typically not part of the established community of researchers working in the field in question. In particular, many of the very few academic climate science denialists in the United States have been physicists, rather than climate scientists as outlined by Lahsen (2008). Some denialists can also be found among older members of two communities of atmospheric scientists, namely theoretical and empirical meteorologists (Lahsen, 2013). Lahsen (2008, 2013) explains their stance with political and socio-cultural factors, such as their professional socialization, their hostility against the increasing allocation of government funding to applied (impact) research rather than to basic science, and their waning role as science-policy advisors. Many of the denialists are not affiliated with any academic institution but are working for a think tank, such as the Heartland Institute or the Marshall Institute in the United States, or The Institute of Public Affairs (IPA) in Australia (as described by McKewon, 2012; Oreskes and Conway, 2010; Plehwe, 2014).

In an experimental study, Aklin and Urpelainen (2014) showed that when respondents were told that there was some, albeit insignificant, disagreement among scientists on an environmental problem, their level of belief in the environmental problem and their support of its regulation decreased, compared to when respondents did not receive any information about disagreement. This indicates that support among the general public for science-based environmental policies can be reduced by the publication of an alleged scientific controversy.

2. Governments. Young and Coutinho (2013) show how ignorance-building strategies were used by former Australian (Howard) and Canadian (Harper) administrations to decrease public commitment to climate mitigation. This included the efficient use of an acceptance-rejection approach, that is, these governments did not deny the reality of anthropogenic climate change but questioned the need to act decisively against it. Several articles identify the former George W Bush administration as a significant actor in "the war on science", including climate science (Editorial, 2008; cf. McCright and Dunlap, 2003, 2010). According to Dunlap and McCright (2011:154), this presidency "institutionalized climate science denial throughout the most powerful branch of the US government, allowing representatives of the fossil fuels industry and conservative think tanks CTTs [conservative think tanks] to undermine climate science and policy from within the administration". The new Trump administration seems possibly second to none in this context – outside the time frame for our review, a search on Google Scholar at the time of writing (April 2017), using the search string ((science AND denial) AND Trump), gave about 3,050 hits, when the search was limited to the years 2016–2017.

3. Political and religious organizations. A large part of the articles address science denial that is coordinated by political or religious organizations, including think tanks, foundations, and institutes. However, a large majority of the reviewed articles focus on the American conservative establishment: CTTs such as the Heritage Foundation, the Cato Institute, and the Heartland Institute, neoliberal and neoconservative groups, the Republican party, the Tea Party movement, and the Christian right (Antonio and Brulle, 2011; Armitage, 2005; Dunlap, 2014; Dunlap and Jacques, 2013; Hamilton and Saito, 2015; Jacques, 2006, 2008; 2012; Jacques et al., 2008; McCright and Dunlap, 2003, 2010; McKewon, 2012; Wright and Mann, 2013). A polarization is noted in literature outside the review between mainstream Protestant churches that often support global climate action and those Protestant churches that deny the need of doing so (Daley Zaleha and Szasz, 2015; see also Copeland Nagle, 2008; Danielsen, 2013; Smith and Leiserowitz, 2013).

Only few authors discuss science denial in political or religious organizations outside the US. McKewon (2012) analyzes the strategies of the think tank Institute of Public Affairs (Australia), and Plehwe (2014) those of the "Stockholm network" that has members in several European countries. Dunlap and Jacques (2013) show how American think tanks disseminate climate science denial to other countries, including the United Kingdom, Canada, and Australia. Plehwe (2014) shows how the Committee for a Constructive Tomorrow (CFACT) contributes to the close links that exist between European, American, and Australian think tanks.

4. Industry. In many of the articles, private companies, industry associations, business groups and coalitions (e.g. International Climate Science Coalition, Australian Climate Science Coalition) are identified as important funders of activities inimical to environmental science (Freudenburg and Muselli, 2013; Salinger, 2010; Talbot and Boiral, 2015; Wright and Mann, 2013). Many of the companies claimed to promote climate science denial are involved in oil or coal extraction (Exxon Mobil, Peabody Coal). Steel, mining, and car industries are also important contributors. Some corporations in these sectors channel their denialist activities through seemingly independent organizations such as the Global Climate Coalition (GCC) and the Information Council on the Environment (ICE) (Dunlap and McCright, 2011).

Several of the reviewed articles draw parallels to the science denial espoused by the tobacco industry (McKie and Galloway, 2007; Salinger, 2010; see also Oreskes and Conway, 2010). The strategies developed by the tobacco industry are currently reused by climate science denialists. However, Salinger (2010) points out that climate science denialists have added a number of potent strategies of their own, most notably that of falsely accusing climate scientists of conspiracy and scientific misconduct (see section 6).

5. Media. Several articles address science denial in media outlets (Brüggemann and Engesser, 2014; Elsasser and Dunlap, 2013; Feldman et al., 2012) and their links with other denialist activities (Freudenburg and Muselli, 2013; Hoffman, 2011). Painter and Ashe (2012) study of newspapers in the US, Brazil, China, France, India and the UK shows a strong correlation between right-wing affiliation and the publication of denialist articles. This was confirmed by Dunlap and McCright (2011). Feldman et al. (2012) showed that the conservative Fox News was more likely than MSNBC and CNN to present claims contradicting the scientific consensus on climate change and to feature climate science denialists.

Several articles discuss denialism in social media such as blogs (Elgesem et al., 2015; Lewandowsky et al., 2013; Lewandowsky, 2014; Matthews, 2015; Nerlich, 2010; Sharman, 2014; see also Jacques and Connolly Knox, 2016). Such social media are an influential part of what Elsasser and Dunlap (2013) call the "echo chamber" of climate science denial.

6. The public. In a series of articles based on data obtained from the annual Gallup polls, McCright and Dunlap (2011a; 2011b; McCright et al., 2014) investigate the American public's views on global warming. Data from these polls show that Americans identifying themselves as liberals or democrats are more likely to believe in global warming than those who hold conservative or republican views. (See also the section on "political and religious organizations" above.) This polarization has deepened in the twenty-first century. Denialist views are most common among conservative white males (McCright and Dunlap, 2011a, 2011b; McCright et al., 2014), even though Gauchat (2015) shows several additional parameters to be relevant.

Outright rejection of climate science is uncommon among the British public, but not impact denialism (Poortinga et al., 2011; Ratter et al., 2012; Scruggs and Benegal, 2012; Whitmarsh, 2011). In Britain, climate science denialism is over-represented among elderly people from poor socioeconomic backgrounds, people with conservative views, men, and car owners. As many as two fifths of the respondents in a UK population survey erroneously believed that the scientific community is divided over the reality of anthropogenic climate change (Whitmarsh, 2011). Climate science denialists are in a minority in Germany as well. In contrast to findings in the US and UK, there is no strong correlation with socio-economic variables, but denialism is over-represented among men and people living in eastern Germany (Engels et al., 2013). In a survey of the New Zealand public, 7% adhered to trend denialism and 10% to attribution denialism. Trend denialism was more strongly associated than attribution denialism with lacking support for emissions reductions and lack of self-reported pro-environmental behavior (Sibley and Kurz, 2013). For additional information, see Lo and Jim (2015, Hong Kong), Shi et al. (2015, Switzerland), Ojala (2015, Sweden), Milfont et al. (2015, New Zealand), and Tranter and Booth (2015, fourteen industrialized nations).

Some studies specifically investigate science denial at the local level. Norgaard (2006) found that the lack of climate activities in a Western Norway rural community did not depend on disbelief in anthropogenic climate change but on unwillingness to transform

this knowledge into social action. Jepson et al. (2012) interviewed inhabitants in Nolan County, Texas, a site of considerable wind energy development. The interviewees supported wind energy development due to its benefits on the local economy, but did not endorse the underlying climate policy goals.

6. Defining and characterizing science denial

Many alternative words are used about environmental and climate science denial: denial(ism), skepticism, contrarianism, anti-science, doubt, dismissal (see also Jacques, 2012; Janko et al., 2014; Howarth and Sharman, 2015). The interpretations of some of these terms vary (O'Neill and Boykoff, 2010). As noted by several authors, "skepticism" is an obvious misnomer and should not be used about science denial (Jacques, 2006, 2012; Lewandowsky et al., 2013; Liu, 2012; Monbiot, 2005; O'Neill and Boykoff, 2010; Whitmarsh, 2011).

Science denial is commonly defined as unwillingness to believe in the existing scientific evidence (Austgulen and Stø, 2013; Dunlap, 2013; Goldsby and Koolage, 2015; Howarth and Sharman, 2015; Liu, 2012). Disseminating doubt about valid scientific data and results is at the very heart of science denial (Dunlap and Jacques, 2013; Oreskes and Conway, 2010; cf. Specter, 2009). This strategy has been applied not only to environmental science but also, for example, to tobacco epidemiology (Carter and Chapman, 2003; Oreskes and Conway, 2010), evolution (Pigliucci, 2005) and HIV/AIDS (Nattrass, 2007, 2012). Several authors emphasize that denialism misrepresents the workings of science (e.g. Rosenau, 2012) and dismisses the scientific consensus (Diethelm and McKee, 2009; Ferkany, 2015).

Reference is often made to Diethelm and McKee (2009) five characteristics of science denialism: conspiracy theories, reliance on fake experts, selectivity in picking papers that in isolation seem to support their claims, impossible expectations of what research can deliver, and misrepresentation and outright logical fallacies (Cook, 2010; Liu, 2012). Holtcamp (2012) refers to a partly overlapping list that has been presented by Sean Carroll in a keynote talk 2012. It includes additional items such as questioning the personal motives and integrity of scientists, framing issues as threats to personal freedom, and representing mainstream science as based on some particular philosophical or religious belief.

Some additional distinctions are made in the reviewed articles. Ferkany (2015:710) distinguishes between laypersons' "naïve" denial caused by ignorance of the facts, and "motivated" denial among those who have access to adequate information. Several articles make use of Cohen, 2001 distinction between literal denial that rejects the facts, interpretive denial that accepts them but makes a different interpretation, and implicatory denial that opposes the psychological, political or moral implications that conventionally follow from them (Austgulen and Stø, 2013; Hobson and Niemeyer, 2013; Leviston and Walker, 2012; Norgaard, 2006).

The reviewed articles make no reference to the much older and more developed literature on the characteristics of pseudoscience. A sizable number of lists of such characteristics are available; for overviews, see Hansson (2008) and Mahner (2007). The overlap between the lists of characteristics of science denial and the corresponding lists for pseudoscience is small, with the exception of selectivity (cherry-picking) that is mentioned on both types of lists. Possibly, this may be due to differences in the perspectives of study rather than in the nature of the deviations from legitimate science that are usually called science denial respectively pseudoscience (Hansson, 2017; Nuccitelli, 2015).

7. How is science denial explained?

The explanation of science denial will have to consider the context and who is the denier. Ferkany (2015) above-mentioned distinction between naïve and motivated denial is useful here. Several of the reviewed studies emphasize that many interplaying factors may contribute. Diethelm and McKee (2009) emphasize motivations such as greed, ideology, faith, and eccentricity. Gauchat (2015) discusses how scientific illiteracy, rightwing ideology, religion, and conservative collective identity interact in a US setting.

Psychological factors. Several articles explain science denial as a psychological defense, often in response to what is perceived as an unsolvable problem. Friedrichs (2011) sees it as a self-deceptive reaction to an existential and intractable predicament. In contrast, Grusovnik (2012) explains science denial as caused by cognitive dissonance (Festinger, 1957). Stoll-Kleemann et al. (2001) and Austgulen and Stø (2013) report empirical evidence that cognitive dissonance contributes to science denial (cf. Holtcamp, 2012; Kraft et al., 2015; Stoknes, 2014).

Sociological factors. Rayner (2012) refers to denied scientific knowledge as "uncomfortable". McCright and Dunlap (2011b:161) invoke the elite cues hypothesis, according to which "people often rely selectively on information from partisan leaders whom they trust". The costs of not agreeing with the dominant views in one's social or political group can be high (O'Sullivan and Emmelhainz, 2014; Parkes, 2013; Rosenau, 2012). Lacking scientific literacy may also have a role (Zhou, 2015).

Values and worldviews. Climate science denial appears to be correlated with individualistic world views (Austgulen and Stø, 2013), anthropocentrism (Jacques, 2006, 2008), support of private property rights (Lo, 2014), belief in capitalism (McCright and Dunlap, 2011a; or free market neoliberalism, see Bohr, 2016), conservative core values (Jacques, 2006, 2008; McCright and Dunlap, 2010, 2011a; 2011b), and religious evangelism (Jacques, 2006; cf. Evans and Feng, 2013). A combination of several such ideological and value-related factors has the best explanatory power (Gauchat, 2015; see also McCright et al., 2016).

Organized denial. Numerous studies have investigated in depth how the "denial machine" (Dunlap, 2013) has generated science denial among laymen and politicians. Lobbying and propaganda with this purpose are performed by political, industrial and religious organizations and think-tanks in particular in North America (Freudenburg and Muselli, 2013; Talbot and Boiral, 2015). The rationale for driving this grand denial project has been attributed to conservative ideology, vested interest in fossil fuels or a combination of these (Armitage, 2005; Elsasser and Dunlap, 2013; Freudenburg and Muselli, 2013; Hess, 2014; McKewon, 2012; Talbot and Boiral, 2015). Due to a misconceived application of the balancing principle in the media, denialist disinformation has been treated on par with scientific information (Boykoff, 2013; Brüggemann and Engesser, 2014; Freudenburg and Muselli, 2013; Parkes, 2013). Howlett (2014) points out that risk aversive policy-makers commonly seek "blame avoidance", which may result in problem denial.

8. What strategies can be used to counter science denial?

About half of the reviewed articles argue for various strategies against denialism. These proposed strategies differ markedly in their emphasis.

The need for change. Most articles promote only incremental changes of current approaches. Those proposing radical change commonly assert that the normal academic response does not work since it presupposes that both parties follow basic rules of rational argumentation such as looking at the evidence as a whole (Aklin and Urpelainen, 2014; Dryzek and Lo, 2015). The difficulties in communicating uncertainty cause considerable problems (Corner et al., 2012; Hedley et al., 2008), and it is argued that denialism

cannot be defeated by just providing more information (McCright and Dunlap, 2011b; Sterman, 2011). According to Diethelm and McKee (2009:4) "it is necessary to shift the debate from the subject under consideration, instead exposing to public scrutiny the tactics they employ and identifying them publicly for what they are". Others have emphasized the need to build "green" identities and lifestyles in the long run (Aklin and Urpelainen, 2014; Dryzek and Lo, 2015; Grusovnik, 2012).

The need for context-dependent strategies. Leviston and Walker (2012) assert that different types of denial require different responses. Capstick and Pidgeon (2014), propose that whereas scientific consensus should be emphasized in responses to denial of the knowledge base, denial of the need for action should be countered with messages on common efforts, citizenship and participation.

Various *communication strategies* are proposed in about a seventh of the reviewed articles. This includes focusing on the reality of climate change rather than its anthropogenic causes (Sibley and Kurz, 2013), visualizing the consequences of inaction (Stoll-Kleemann et al., 2001), highlighting benefits of low-carbon lifestyles and pro-environmental behavior (van Prooijen and Sparks, 2014; Whitmarsh, 2011), focusing on what we can do right rather than what we have done wrong (Holtcamp, 2012; Stoknes, 2014), and replacing top-down communication processes by interactive learning (Sterman, 2011; see also Bliuc et al., 2015; Leombruni, 2015; Poortinga et al., 2011). Several articles argue for a more fundamental 'integrative shift' in climate discussions, usually involving a refocusing from the knowledge base to underlying interests and values (Hoffman, 2011; Holtcamp, 2012; Lo, 2014; O'Sullivan and Emmelhainz, 2014; Stoknes, 2014; Whitmarsh, 2011). This could lead to discussions on national security, human rights, religious stewardship, technology, and health (Hoffman, 2011; Lo, 2014; O'Sullivan and Emmelhainz, 2014; Stevenson et al., 2014; Valles, 2015).

The need for *education* is emphasized in several of the articles (Ehrlich, 1996; Ferkany, 2015; McGowan, 2011). Many authors emphasize that education should clarify the high level of consensus on anthropogenic climate change (e.g. Lewandowsky et al., 2013; McCright et al., 2014). However, Colston and Vadjunec (2015) report that teaching climate change as a controversy can be a useful strategy. Several authors emphasize the teaching of epistemology, scientific practice, and critical thinking (Ferkany, 2015; Kudrna et al., 2015; Ojala, 2015). Herrick (2004) and Nerlich (2010) emphasize the importance of clarifying that science is inherently uncertain and that policy may have to be based on incomplete information. Based on empirical studies of middle-school students, Stevenson et al. (2014) argue that worldviews rather than lack of factual knowledge induce science denial. They argue that since adolescents have not yet formed entrenched worldview they are more receptive than adults to scientific information about climate change. Antilla (2005) proposes education targeted at journalists. Feldman et al. (2012) and Evans and Feng (2013) argue that education should target groups with a high prevalence of denial such as political conservatives, rather than the public at large.

Changing the focus of scientists. In some of the articles, scientists are exhorted to participate in the debate (Ropeik, 2015), address the social drivers of science denial (Rosenau, 2012), enter the political arena (Editorial, 2008), and be more self-reflective on norms (Brysse et al., 2013). A 2008 *Nature Immunology* editorial proposes a re-building of scientific institutions and infrastructure, including the appointment of heads of science agencies, making sure that government advisory panels are not "[s]tacked with scientists with ties to industry or with strong religious views" (Editorial, 2008:217). Others have proposed the use of systematic reviews to disclose selective citation (Diethelm and McKee, 2009) and co-operation with pro-environmental corporate actors (Wright and Mann, 2013). Based on experiences from the preparation of the Montreal Protocol for ozone layer protection, Andersen (2015) proposes collaboration with stakeholders, including industry, and the avoidance of political review in science panels such as the IPCC.

9. Discussion

The aim of this review was to give a state-of-art account of the environmental science denial research field in order to shed light on how decision makers and others working in the fields of environmental and climate policy can respond to the denial phenomenon. A second aim was to identify research themes and questions that are in need of further scholarly attention. Based on the reviewed literature we draw the following conclusions.

First, although there is a substantial body of literature discussing the phenomenon of climate science denial – in terms of what is being denied (e.g. "trend", "attribution", "impact" denial), who denies, characteristics of science denial, possible explanations, and counter-strategies – there is a noticeable lack of studies addressing other environmental issues. Only around one fifth of the articles deal with non-climate change related issues, alternatively discuss science denial on a more general level. Although individual exceptions exist there is no integrated body of literature, at least not in the last 25 years, addressing science denial in, for example, land, water or biodiversity management, chemicals policy, or air or water pollution management—policy areas that are also to a significant extent affected by strong economic interests and could therefore be expected to be vulnerable to the organized denial activities manifested in climate policy.

There could be several explanations for the observed shortage of literature. The shortage in our material of studies addressing denial of non-climate environmental science can in part depend on our choice of search terms, for instance such literature does not always use the term "denial" (cf. Rudén and Hansson, 2008).[3] If the search had been broadened (to include e.g. "anti-regulation"), a greater number of studies would likely have been captured, related to, for example, contentions on chemical risks, a contested area (Karlsson, 2005). Analyzing such a potential flora of studies would indeed be important. Second, it is possible that non-climate related environmental science denial is primarily discussed in publication venues not covered in this review (e.g. books). For example, Oreskes and Conway (2010) devote a chapter each to acid rain and ozone depletion. Similarly, the European Environment Agency has published two books (EEA, 2001; 2013) where researchers, and some regulators, present several case studies where environmental denial has played a central role over time, for example regarding fisheries and the control of pesticides and PCBs. It would be valuable if more of these findings could be published in peer-reviewed journals. Another possible explanation is that science denial is simply not as common in environmental policy fields, at least not during the period studied here. However, the acid rain and ozone depletion examples discussed by Oreskes and Conway, as well as the EEA case studies, show that science denial does indeed exist in other environmental policy fields, although it is perhaps not as prevalent at present (see e.g. Thelander and Lundgren, 1989; for previous periods). From this we draw the conclusion that environmental science denial is a research area that is in need of further investigation. Insights from the climate science denial literature

[3] Chapron (2014) is one example of an article discussing misuse of scientific evidence that was not captured through our search. The article deals with the misuse of wolf research by Swedish politicians.

should be useful in this line of inquiry.

Second, the articles in this study show that environmental science denial is produced and perpetuated by a number of societal actors. The articles we have reviewed can roughly be divided into those that address organized denial, financed and perpetrated by actors being active against environmental and climate science, and those that focus on lay skepticism, that is, "spontaneous" denial and skepticism of certain individuals in society. Both types of studies provide insights into the general phenomenon of science denial. A relatively small number of articles address organized denial initiated and perpetuated by governments, including heads of state and government ministers. We expect a rise in the number of such studies in the coming years, specifically analyzing the US Trump administration, considering the large number of recent publications we found on Google Scholar. Academics, in particular political scientists, ought to follow this issue closely in the future, and we hope that the state-of-science review presented here will form a basis for future analyses and discussions.

Third, although some links between the beliefs and actions of the identified actors are discussed in the literature, there is room for further such investigations. This holds in particular for the relationship between the beliefs and arguments of denying scientists, how those beliefs and arguments are represented in the media (both in social media, blogs etc., and conventional media channels), and how they are taken up by the public. Although the links between think tanks, industry, and government representatives have been fairly well exposed, particularly in the United States, there is still room for similar investigations in other countries. Valuable insights could be gained from cross-national comparisons of the public's support of (or lack of support of), environmental and climate science, exposing further the links that exist between how organized science denial affects individual citizens and, by extension, the environmental policies that are adopted and pursued at national and local levels.

Fourth, the review shows that different words are used in the literature to describe the phenomenon of science denial, and that there is an ongoing discussion about which term(s) are most appropriate to use in the debate. Further analyses of the terms used and how they relate to each other could make a valuable contribution to the research field. This holds true in particular of the terms "science denial" and "skepticism". Because skepticism in the sense of being willing to question scientific evidence is an innate part of the scientific enterprise, the difference between a reasonable skeptic position and outright denial must be clearly delineated, and we consider "denial" to be the term most appropriate to build on and develop onwards. Any definition will have to be grounded in normatively justified arguments about how individual and collective belief systems ought to be adjusted to new information or evidence. In addition, the relationship between science denial and other types of pseudoscience is another interesting topic for further investigations.

Fifth, the review illustrates how complex and diverse the reasons behind science denial are. Personal psychological mechanisms on the one hand and organized lobbying efforts on the other are interlinked into a circle that might be vicious. As Dunlap et al. (2016) recently pointed out this has been the likely case in the US during the last decade concerning climate change denial. It is moreover interesting to see that denial can be strong also in a country such as Norway, which is basing much wealth on oil resources but is also known to commonly take a pro-environment position, for example, in international negotiations. Departing from the fact that the number of countries where climate change denial is strong is still limited to a handful, it would be interesting to study how various forms of science denial play out elsewhere, for instance why the impact of denialism is limited in many EU countries, whether these are environmental forerunners or not, and how denial in other countries has developed over time. Denial of chemical risks appears to be an interesting area for such studies.

Finally, the reviewed literature clearly shows that the question of how to address science denial has attracted substantial interest in the academic community. However, although various strategies for improved communication, framing, etc., are argued for, the number of studies developing – and actually testing – the effectiveness and efficiency of these strategies in a focused way is still rather limited (however, see Cook (2010) and references therein). This is particularly the case for other environmental issues than climate change. Consequently, to close this identified research gap, more research is needed that focuses on assessing, developing and comparing specific strategies to counter science denial, including action research. Ideas on more radical and fundamental strategy change are in need of more thorough analysis, as are proposals to refine scientific structures and processes. Such research might gain from considering a wider analytical approach than what was apparent in many of the analyzed articles. For example, references to articles on transformations of human and natural systems, environmental and risk governance, philosophy of science, and science and technology studies were quite few in the reviewed material.

In conclusion, the research conducted on environmental science denial in the last 25 years shows that denial indeed has a significant negative impact on societal debates and decision-making. Despite huge advances in environmental sciences over this time period, denial prevails in some cases, and is even on the rise in the current US administration. This is indeed unfortunate, from multiple perspectives. Irrespective of the ambitions of environmental goals, science-based policies are always preferable. It is therefore as urgent as ever that the scientific community increases its efforts in dismantling false claims, disclosing the schemes of denialists, and developing effective and efficient strategies to counter science denial.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2017.08.066.

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