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Fabian Krause

U.S. Emissions Trading and what it can teach us for a Post-Kyoto World

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Table of abbreviations

AAU	Assigned Amount Unit
AB 32	California Assembly Bill 32
ACES	American Clean Energy and Security Act
ACMA	Alternative Compliance Market
APA	American Power Act
ARP	Acid Rain Program
ATU	Allotment Trading Unit
BAU	Business as Usual
C&C	Command and control
CAA	Clean Air Act
CAAPP	Clean Air Act Permit Program
CARB	California Air Resources Board
CBA	Cost Benefit Analysis
CCR	Cost Containment Reserve
CDM	Clean Development Mechanism
CDM EB	Clean Development Mechanism Executive Board
CER	Certified Emissions Reductions
CO_2	Carbon dioxide
CO_2e	Carbon Dioxide equivalents
COATS	RGGI CO_2 Allowance Tracking System
CoP	Conference of the Parties
EPA	Environmental Protection Agency
ERC	Emission Reduction Credits
ERG	Emission Reduction Generator
ERMS	Emissions Reduction Market System
EUR	Euro
EUTS	European Union Emissions Trading System
FESOP	Federally Enforceable State Operating Permit
GDP	gross domestic product
GGRF	California's Greenhouse Gas Reduction Fund
GHG	Greenhouse Gases

ICJ	International Court of Justice
ICJ	International Court of Justice
IEPA	Illinois Environmental Protection Agency
iNDC	Intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change
ITMO	Internationally transferred mitigation outcomes
MGGRA	Midwest Greenhouse Gas Reduction Accord
MOU	Memorandum of understanding
MRR	Mandatory Reporting Requirements
MWe	Megawatt electrical
MWh	Megawatts per hour
NDC	Nationally determined contribution
NO_X	Nitrogen Oxide
OECD	Organisation for Economic Co-operation and Development
OSHA	U.S. Occupational Safety and Health Administration
PDD	Project Design Document
R&D	Research and development
RGGI	Regional Greenhouse Gas Initiative
RGGI MR	Regional Greenhouse Gas Initiative Model Rules
SO_2	Sulphur Dioxide
Source	Emissions source as covered by a program
U.S.	United States
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
USD	United States Dollar
VOM	Volatile Organic Material
WCI	Western Climate Initiative

A. Introduction

I. Introduction to the topic

1. The topic

The topic of this thesis is environmental regulation relating to climate change. While environmental law is an established and highly dynamic field with an increasing importance, some topics remain subject to ongoing, often controversial debate. The relationship between the increasing threat of climate change and economic concerns is at the center of this. As our knowledge of climate change continues to grow, we have identified economically sensitive sectors, such as the energy and transportation industry, as its main cause. As it became clear that the emission reductions required to at least halt climate change would only be possible at considerable economic costs, politicians and regulators have put a focus on using so-called "economic instruments," such as emissions trading.

At the same time, policymakers have tried to answer the global nature of climate change and global pollution's character as a "tragedy of the commons,"[1] with international treaties like the Kyoto Protocol or the Paris Agreement. This brings two aspects of environmental regulation into focus: the current status and future of emissions trading as the "economic instrument" used in many countries nowadays, and the methods of international cooperation regarding environmental pollution, especially regarding climate change. This thesis examines both topics and their relationship with each other.

This thesis also contains an analysis of the major emissions trading systems in the United States of America and thus concerns itself with emissions trading as a regulative compliance tool used to achieve emissions reductions. Apart from providing data-based case studies on the status and performance of such emissions trading systems, this thesis aims to review the lessons we can learn from such systems, both relating to the idea of emissions trading as environmental regulation as well as, more generally, environmental regulation on a national or international level. To that end, this thesis reviews emissions trading systems from two perspectives: as a

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1 *Cf.* page 101 for definition and discussion of this term.

regulative compliance tool and as a sample concept for the development of environmental regulation as a whole, regardless of its specific regulative type.

In connection with that, this thesis reviews the state and the methods of international cooperation against climate change. In view of the shift in policy between the Kyoto Protocol and the Paris Agreement, which can be understood as *caesura* in the international cooperation regarding climate change, this thesis aims to study lessons from the reviewed United States emissions trading systems relating to this policy shift from a "top-down" to a "bottom-up" approach. This is appropriate as while the Member States of the European Union have chosen to ratify the Kyoto Protocol and subsequently created an international "top-down" regulative approach to environmental regulation, the United States has chosen to go a different route. Instead of following most of the international community in its "top-down" approach to pollution utilized in the Kyoto Protocol, some North American federal states developed grassroots "bottom-up" environmental regulation in lieu of, or to supplement, federal policy.

This thesis aims to analyze this step in the broader context of a general policy shift away from multinational agreements with "top-down" regulation to a "bottom-up" approach, focusing on whether bottom-up regulation based on emissions trading is indeed an alternative to international regulation and whether such a system is likely to emerge on the global stage within the extremely short timeframe required to attack pollution and climate change.

2. Research context

This topic was chosen for multiple reasons.

For one, much has been written on the performance of the European Trading System. Comprehensive and independent, data-driven, legal case studies on the much smaller trading systems in the United States are less common, especially from a European perspective. More importantly, the few case studies available limit themselves to the analysis of an individual system and do not analyze the potential interaction between systems and their respective linking dynamic, which given the shift away from international binding approaches (such as the Kyoto Protocol) towards national approaches (as displayed in the Paris Agreement) is particularly interesting to analyze.

The topic was chosen because of the possibility of comparing and making cross-references between the systems. Such cross-references are valuable for multiple reasons, but two stand out in particular: Cross-references can suggest whether issues with individual trading systems are specific to that individual trading system, or whether such issues are systematic to emissions trading as a whole. It can also address whether the possible linkage between systems and regulative regimes has the potential to form a drastic counterapproach to the (arguably) failed approach taken in the Kyoto Protocol, thus allowing us to academically test the theory of a replacement of international level regulations by local regulations—an approach taken by the Paris Agreement—which as a method, marks a *caesura* in international cooperation.

3. Research objectives and questions

This thesis aims to contribute to the understanding of environmental regulation, specifically of emissions trading systems. Despite the failure of most emissions trading systems—empirically proven by the data reviewed in the course of this thesis—and the subsequent academic discussion in opposition of emissions trading, further research and discussion of emissions trading as the "economic instrument" of choice in many countries is still relevant, especially relating to the root causes for the failure of emissions trading. In the United States, recent polls still show large public support for emissions trading.[2] The European Union, which considers itself a world leader in fighting climate change,[3] still relies heavily on emissions trading as a compliance instrument in order to achieve designated emissions reductions and continues to discuss emissions trading as a main component of its legal climate change approach. This is exemplified by the fact that despite the shortcomings of the European Emissions Trading System discussed later in this thesis, which are mirrored by the systematic issues of the emissions trading systems implemented in the United States, the European Union has chosen to enter a fourth trading period until

2 *Americans Support Strong Climate, Energy Policies* Yale Climate & Energy Institute (Sept. 9, 2019), https://www.climatechangecommunication.org/wp-content/uploads/2019/09/American-Voters-Support-Climate-Action.pdf.

3 Cornelia Klugman, *The EU, A World Leader in Fighting Climate Change*, European Parliament (May 2018), http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/621818/EPRS_BRI(2018)621818_EN.pdf.

2030[4] and even discusses expanding the scope of the European Union Emissions Trading System (EUTS). Other major emitters have shown a tendency towards emissions trading systems as well, leading with China or Mexico, both of which in 2017 chose to adopt its own emissions trading system. Other Latin American states, such as Brazil, are discussing implementation of emissions trading systems.[5]

This tendency of state actors to observe other emissions trading systems leads to the second research question discussed in this thesis: In addition to an analysis of emissions trading systems in the United States, this thesis looks at the possibility of using emissions trading as growing "bottom-up" regulation as an alternative to the international "top-down" approach. This is a relevant research question, as the "top-down" approach that was previously chosen by international actors in the Kyoto Protocol has been replaced by a "bottom-up" approach in the Paris Agreement. Given these two interacting factors, legal science must address the question of whether the combination of emissions trading and a "bottom-up" approach can replace an international "top-down" system.

a. Analysis of emissions trading in the United States

Once a highly innovative concept resulting from ideas from some of the world's leading scholars, emissions trading systems are now amongst the most disputed types of environmental regulation, with opinions ranging from treating emissions trading as a "silver bullet" for reducing carbon pollution to viewing cap-and-trade systems as a "carbon carousel" mostly catering to industry interests.[6] In legal and environmental scholarship, emissions trading is highly disputed as well. Many scholars believe it to be ineffective at its main objective: reducing emissions. Despite that, it continues to play an essential role in international environmental policy and remains at the core of most nation states environmental regulation. In

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4 EU Directive 2018/410 of the European Parliament and of the Council of March 14, 2018 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814.

5 For a comprehensive list of enacted and discussed systems *see Emissions Trading Worldwide: Status Report 2019* International Carbon Action Partnership, https://icapcarbonaction.com/en/icap-status-report-2019 (last visited March 18, 2020).

6 For an introduction, *see* Joseph Goffman, *Title IV of the Clean Air Act: Lessons for Success of the Acid Rain Emission Trading Program*, 14 Penn St. Envtl. L. Rev. 177 (2005-2006).

view of this debate, this thesis chooses to analyze enacted emissions trading systems, with the aim of answering the following questions:

(i) Is this criticism warranted relating to systems in the United States, i.e., how did enacted systems perform environmentally and economically?
(ii) If emissions trading is indeed found to be ineffective, what are the lessons that can be learned from this going forward?

The review is first and foremost a legal review. However, additional insight is gained by using a quantitative review approach rooted in an economic analysis of the law. The value of this reveals itself in the following pages. For example, legal scholarship has often been content with stating that a given emissions trading system is overallocated and thus environmentally inefficient, i.e., it misses its main legal objective. While this is sufficient from a legal perspective, the root causes for the overallocation remain obscure, which hinders scholars from gaining a complete understanding of the regulative structure. A further quantitative review can be of value to supplement legal conclusions.

Pollution, especially pollution causing climate change, is a problem of international scale. Hence, this thesis seeks to explore how local carbon markets relate to a global environmental regulation regime, especially against the backdrop of the shift away from the "top-down" approach taken in the Kyoto Protocol towards the "bottom-up" approach of the Paris Agreement.

The United States was chosen as the main reviewed jurisdiction for multiple reasons. For one, they are one of the major contributors to global pollution and environmental damage around the world. But they also have more individual trading systems on a state level designed to address this problem than any other country and were amongst the first countries worldwide to address environmental pollution with legal regulation. In this way, they share a unique characteristic with some Canadian and Mexican states: climate regulation on a state level rather than on a federal or even international level. In addition to this, the United States has the longest experience with emissions trading, with the first emissions trading system having been enacted in the 1970s.

b. Grassroots environmental regulation as a potential solution to the Kyoto shortcomings: Policy shift from Kyoto to Paris

Based on the above, a further focus of this thesis is the development of "bottom-up" markets in the United States. This is an interesting develop-

ment, especially as some of these systems have established links with other systems or have otherwise grown their jurisdiction. This thesis looks at this "bottom-up" movement and analyzes its lessons for a world after the Kyoto Protocol regarding the possibility of a shift from the current international "top-down" approach to a grass-roots regulative regime and whether such a policy could be efficient if based on emissions trading as compliance tool.

Such a shift could be important for many reasons. For example, results of the Kyoto Protocol were disappointing. One may argue that this follows directly from the regulative tool of choice used by some states, i.e., emissions trading. However, this thesis argues that at least some of the reasons lie in the nature of international agreements. Consequently, it is interesting to examine if local grassroots environmental regulation can solve the international problem that is pollution.

This question remains relevant given that states and some scholars seem to favor such a "bottom-up" approach going forward, for reasons later discussed herein.

II. Methods

This thesis uses both a qualitative and quantitative research approach to answer the research objectives detailed above. Qualitatively, much of the research is done as doctrinal research, i.e., "research which asks what the law is,"[7] or as defined by Hutchinson, "Research which provides a systematic exposition of the rules governing a particular legal category, analyzes the relationship between rules, explains areas of difficulty and, perhaps, predicts future development."[8]

Of course, it is doubtful whether doctrinal research can be understood as qualitative research, at least when seen from a western standpoint[9] as this would imply that "the law" is found and not reasoned. Consequently, the doctrinal research employed here is modeled after the rigorous research template designed by Fink[10] and adopted for legal research by

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7 Research Methods for Law 17 (Mike McConvill & Wing Hong Chui, eds., 2017).

8 Terry Hutchinson, Researching and Writing in Law 7 (2nd ed. 2006).

9 *Cf.* Legal Hermeneutics: History, Theory, and Practice (Gregory Leyh ed., 1992); also the 52 Duq. L. Rev. (Winter 2014).

10 Arlene Fink, Conducting Research Literature Reviews: From the Internet to Paper 3 (2nd ed. 2005).

Ian Dobinson and Francis Johns,[11] which emphasizes selection of, *inter alia*, research questions, search questions, and review. For this purpose, the review is primarily focused on the body of law providing rules on the subject (referred to as primary sources) such as the legislation and any case law on the subject—for example, state and federal legislature on a given emissions trading system as well as case law concerning its application. In addition to analyzing primary sources, this thesis uses a library-based review of secondary literature, such as legal dictionaries, textbooks, journal articles, case digests, and legal encyclopedias.[12] Both German and English secondary literature is consulted. Due to the connection to public policy, this thesis also heavily relies on material released by government authorities or governing bodies, such as opinions, statements and press releases, that are often available online only. Such material is identified correspondingly in the references.[13]

The regulatory framework of a given emissions trading system is summarized and its application to a set of real-world facts are synthesized. This doctrinal research is supplemented with non-doctrinal research, often referred to as "law reform" research, aimed at identifying issues and proposing changes to the law.

In an effort to identify issues susceptible to "law reform" research, this thesis heavily relies on quantitative research. "The term 'quantitative method' refers in large part to the adoption of the natural science experiment as the model of scientific research, its key features being quantitative measurement of the phenomena studied and systematic control of the theoretical variables influencing those phenomena."[14] The topic discussed in this thesis is very conducive to this research method as the success of emissions trading systems can, according to their objective, be measured in emissions reductions, which makes it necessary to analyze emission reduction data. In addition to that, other implications of a legal rule found after the doctrinal research discussed above can be measured in data as well. This will be detailed later in this thesis and concerns data relating to, for example, market volume or market revenue, which according to economic theory allows inferences to certain results caused by a given legal rule. Especially when reviewing market failures, this economical approach

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11 Research Methods for Law, *supra*, at 23.

12 Hutchinson, *supra*, at 7.

13 *Cf. infra* at 7, 8 regarding the implicit possibility of biased opinion in such material.

14 Martyn Hammersley, What is Social Research? 39 (1993).

can add valuable information to a qualitative analysis. For example, when analyzing the root causes of an overallocation of allowances in a given market scheme, one must look at the quantitative market data to gain a full understanding of the causes of overallocation.

In the context of an "economic analysis of the law," this approach can be understood as a *descriptive* economic analysis of the law—i.e., an analysis concerning the effects of a legal rule. A *normative* economic analysis of the law, i.e., an analysis pertaining to the social desirability of the legal rule,[15] seems less significant in the environmental context as any reduction in pollution is desirable by itself. The analysis in this thesis therefore uses a descriptive economic analysis of the law especially pertaining to the cost-efficiency of such reductions. Of course, the reliance on provided data produces a problem inherent to most quantitative research: the collection and selection of data will inadvertently influence the results of the qualitative analysis. To avoid any possible data bias, this thesis follows the research rules suggested by King and Epstein that

> *(i) identify the population of interest; (ii) collect as much data as is feasible; (iii) record the process by which data come to be observed; and (iv) collect data in a manner that avoids selection bias.* [16]

To that end, all publicly available data for the years leading up to the year 2015 are used, with the respective data provider and any possible bias resulting from their role being duly noted and taken into account.

However, in many data reviews conducted in this thesis, usage of biased data is inevitable, as available data are often limited to what is provided by interested parties, such as a state's environmental protection agencies. In addition to that, in some cases specific data was not obtainable, which inherently reduces the value of a comparison between systems. This thesis accounts for that in its quantitative analysis.

Another challenge arose due to the transition of administrations on January 20, 2017. Before this date, both the federal as well as the state Environmental Protection Agencies published extensive data on their respective websites, thus allowing in-depth review. After the transition, most of this data was no longer publicly accessible. However, most of the data review in this work was finished prior to that. The respective data being affected by this are marked in this thesis.

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15 Steven Shavell, Foundations of Economic Analysis of Law 1 (2004).

16 Lee Epstein & Gary King, *Empirical Research and the Goals of Legal Scholarship: The Rules of Inference* 69 U. Chi. L. Rev. 99 (2002).

III. Structure and contents

This thesis is divided into multiple chapters.

Chapter B briefly introduces pollution and its consequences for the environment. It discusses root causes and some environmental effects of pollution, with an emphasis on global climate change as a result of the introduction of pollutants, such as "greenhouse gases," into earth's atmosphere and the corresponding need for legal regulation as an answer to the issue of climate change.

Chapter C provides an in-depth discussion of the international response to climate change. The nature of global pollution causing climate change as (in economic terms) a "free rider" problem is presented and the resulting implications for a concerted international response are discussed. Consequently, Chapter C describes history and the current status of international treaties regarding climate change, from the United Nations Framework on Climate Change to the Paris Agreement. It also analyzes the codified and noncodified legal principles in international law as they relate to climate change with the intent of demonstrating the existence of a binding legal framework that obliges national actors in their approach to climate change.

Chapter D presents and analyzes the debate on the usage of legal regulation. Following from the topic of this thesis, this chapter focuses on the usage of economic instruments as regulative tools to reduce pollution. In analyzing economic instruments, this thesis focuses on two proposed economic instruments: Pigouvian taxes and emissions trading. Key regulative features of emissions trading systems are reviewed in detail, and the chapter ends with an analysis of design features theoretically necessary for an effective emissions trading system. Bottom-up trading and top-down regulation are introduced as opposing concepts and as the subject of this thesis.

Chapter E analyzes past and current emissions trading systems in the U.S. After a discussion of present U.S. regulation governing climate change, individual emissions trading systems are analyzed. Following the discussions in the previous chapters, the analysis has several focal points: Are there examples for effective emissions trading systems? Can U.S. experiences with emissions trading help us gain a better understanding of the development of bottom-up regulation? How have they affected other trading schemes? What can we learn going forward? Subsequently, chapter E contains detailed quantitative and qualitative research on the Acid Rain Program, the Illinois Emissions Reduction Market System, the Regional

Greenhouse Gas Initiative, and the California Global Warming Solutions Act of 2006. The review is divided into multiple research questions and points. Each system is approached with the same research questions to ensure comparability: First, a brief history of each program is provided. This is followed by a detailed description of the relevant regulation. Then a detailed environmental and economic analysis is provided for each system. Relating to the theories discussed in Chapter D, this is followed by a subsequent review pertaining to whether and to what extent the respective system can be used as an example for bottom-up regulation and how results and experiences with the system relate to a post-Kyoto regulative system.

Based on the reasons discussed for the Kyoto Protocol's failure in Chapter C, Chapter F provides a conclusion of the lessons learned from U.S. experiences with emissions trading and considers alternative policy approaches with a focus on the development of bottom-up regulation as an alternative to top-down approaches like the Kyoto Protocol. Scholarship on the requirements of effective regulative policy and on coalition forming is presented and reviewed. This chapter asks: In theory, could the development of an international policy on pollution happen "from the ground up", i.e., by the development and linking of local regulation?

The last Chapter G serves as a final synthesis of findings and conclusions drawn in the previous chapters, especially Chapter E.

IV. Terms

In theory, two types of emissions trading programs exist: cap-and-trade programs and credit trading programs. "Emissions cap-and-allowance trading programs impose a strict regulatory standard that reduces pollution—a permanent cap on the amount of allowable emissions—as well as an allowance trading program, whereas 'emissions credit trading programs are grafted onto existing regulatory programs, and allow sources that emit below their baseline levels to trade the resulting credits once they receive regulatory approval.'"[17]

In this thesis, the terms emissions trading and cap-and-trade are used synonymously, acknowledging that the concept of trading pollution rights does not necessarily require a cap on emissions.

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17 Byron Swift, U.S. *Emissions Trading: Myths, Realities and Opportunities*, 20 Nat. Res. & Envt. 3, 4 (2005).

In reviewing emissions trading, the term "property rights" is used to describe, *inter alia*, emissions credits. The term is used to stay consistent with the traditional usage of terms and does not suggest that there is a "right to pollute."[18]

18 *See* Kirk W. Junker, *Ethical Emissions Trading and the Law*, 13 U. Balt. J. Envtl. L. 149 (2005-2006).

B. Climate change and the necessity of regulation

Climate change has been called the defining environmental issue of the twenty-first century.[1] This is drastic but not surprising given its nature as a worldwide environmental problem that endangers not only humankind and its natural resources, but the earth itself and all species on it. Climate change can be defined as the process of "change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."[2] The main cause of climate change is pollution. Pollution is generally defined as the introduction of contaminants into the natural environment that causes adverse change.[3] This sounds rather unassuming upon first sight, and indeed, the introduction of such contaminants is a cultural phenomenon that has accompanied human development from the beginning. Every life form on this planet is dependent on using its environment in some way or another. For humans, the usage of the environment was not only *condition sine qua non* for their existence, but also for their cultural advancement, which started as early as 5,000 years BCE with the first dammed rivers and irrigation systems in Mesopotamia, i.e., the start of human manipulation of the environment. Consequently, the idea of humankind "co-existing" with nature is a rather novel concept in human history. For example, in 1678 citizens of the alpine community of Fiesch in Switzerland applied to Pope Innozenz XI for permission to

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1 David Hunter, James Salzman & Durwood Zaelke, International Environmental Law and Policy 607 (4th ed. 2011).

2 Definition used by the International Panel on Climate Change (IPCC) *cf.* International Panel on Climate Change (IPCC), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Annex III: Glossary (T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley, eds., 2013). The UNFCCC defines climate change as "a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods," *cf*. Article 1 para. 2 of the Convention.

3 Marquita K. Hill, Understanding Environmental Pollution 8 (3rd ed. 2010).

conduct a prayer procession for the retreat of the nearby Aletsch glacier, which was threatening the village. In 2010, 332 years later, the community reversed course and received the Pope's verdict allowing them to change their prayer as the glacier has almost fully melted,[4] much like many other glaciers in the European Alps.[5]

Science has shown that humans are using more of the earth's resources than the earth can endure.[6] A 1997 article found that among other impacts, humans have transformed up to 50 percent of the earth's land surface. Over 20 percent of the concentration of atmospheric greenhouse gases resulted from human action. Humans also put almost 60 percent of the world's accessible fresh water to use.[7] Since then, human influence has increased even more. Nowadays, there is a clear consensus in the scientific community that human influence in the form of environmental pollution is not only affecting biodiversity and the health of eco-systems, but it is also changing the global climate. For example, "[t]he Intergovernmental Panel on Climate Change (IPCC) is now 95 percent certain that humans are the main cause of current global warming. In addition, the SYR [Synthesis Report] finds that the more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long-lasting changes in all components of the climate system."[8] In 2005, the Millennium Ecosystem Assessment, a first of its kind four-year study carried out by 1,400 scientists with a $20 million USD budget found that at least 60 percent of services supporting life on earth[9]

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4 *Cf.* Tagesanzeiger, Walliser beten für den Gletscher, 27.07.2012, available online at http://www.tagesanzeiger.ch/panorama/vermischtes/Walliser-beten-fuer-den-Gletscher/story/31501391 (last checked January 11, 2020).

5 *Cf.* Deutscher Alpenverein, Gletscherrückgang und tauender Permafrost, available online at https://www.alpenverein.de/natur/klimaschutz/ausstellung-klimawandel-klimaschutz/gletscherrueckgang-und-tauender-permafrost_aid_28388.html (last accessed January 11, 2020).

6 Of course, this thesis is not a work in natural science, and a law thesis is hardly the right place to discuss current scientific debates. The author is aware of the very controversial discussion relating to scientific findings regarding climate change.

7 Sandra L. Postel, Gretchen C. Daily & Paul R. Ehrlich, *Human Appropriation of Renewable Fresh Water*, 271 Science 785 (1996).

8 International Panel on Climate Change (IPCC), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* 5 (R.K. Pachauri & L.A. Meyer eds., 2014).

9 This includes fresh water, fisheries, forests and vital species.

are being used in an unsustainable fashion.[10] This includes consumption of resources as well as the introduction of pollutants.

Almost any chemical or material from human (and natural) sources can be a pollutant. Scientists class pollutants into organic chemicals, inorganic chemicals, organometallic chemicals, acids, physical, radiological, and biological pollutants.[11] The results of pollution sometimes are blatantly obvious. For example, Ohio's Cuyahoga River had such a high amount of oil on its surface in 1959, that it caught fire and burned for eight days straight. At least thirteen such fires are recorded.[12] However, they are sometimes invisible and less obvious, such as the increasing concentration of pollutants in the earth's atmosphere, which leads to the topic of climate change.

Climate change is usually defined as a change in weather patterns. One of these changes is the warming of the earth's atmosphere, often referred to as "global warming." Responsible for this warming process is the so-called greenhouse effect: Solar radiation passes through Earth's atmosphere and heats its surface. Non-absorbed heat energy is reflected upon the earth's surface and emitted back to space. However, scientific research suggests that pollution has altered the atmospheric composition, which has caused its capacity to absorb heat energy to increase. As a consequence, the atmosphere's capacity to emit heat energy not absorbed by the earth's surface is lowered; non-absorbed energy cannot be emitted back into space, but is instead trapped under the atmosphere similar to heat being trapped under a greenhouse roof, hence the term greenhouse effect.[13] As a consequence, the earth's surface is warming.

There are a multitude of pollutants responsible for this effect. These gases are classified as "greenhouse gases." Considered to be responsible for atmospheric changes are carbon dioxide (CO^2), methane (CH^4), nitrous oxide (N^2O), tropospheric ozone (O^3), and CFC-11. Most of these gases are emitted in connection with industrial activity. For example, the concentration of CO_2 in the northern hemisphere has increased by 109 parts per million compared to pre-industrial revolution levels; the CH4 levels increased

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10 Millennium Ecosystem Assessment Board, *Living Well Beyond Our Means: Natural Assets and Human Well-being Statement of the MA Board*, (March 2005), http://www.millenniumassessment.org/documents/document.429.aspx.pdf.

11 Hill, *supra* note 3, at 11.

12 Jonathan H. Adler, *Fables of the Cuyahoga: Reconstructing a History of Environmental Protection*, 14 Fordham Envtl L. rev. 103–104 (2002).

13 Kirstin Dow & Thomas E. Downing, *The Greenhouse Effect* in Atlas of Climate Change (2011).