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MINE - Mapping the Interplay between Nature and Economy. A digital gateway to the foundations of Ecological Economics

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Abstract

MINE – Mapping the Interplay between Nature and Economy is a digital archive and visual map showing the intersection between nature and economy. By focusing on the interconnections between fundamental concepts e.g. of time, thermodynamics, evolution, responsibility and justice, a new concept of economic activity emerges *within* nature. This leads to new interpretations of current ecological, social and economic problems and, in addition, to an in-depth understanding of the modes of thought and policy needed to find sustainable solutions.

On the most fundamental level, the dominant view of Mainstream Economics, which considers nature as part of the economy, Ecological Economics amends this view by the perspective that the economy in its physical side is seen as part of nature. Thus, Ecological Economics complements the strengths of Mainstream Economics on a practical level by interdisciplinary research highlighting, spots which do not receive the attention, by Mainstream Economics, they deserve.

The research project that ultimately launched MINE began in the 1970s at the University of Heidelberg, conducted by an interdisciplinary group of scientists around Malte Faber, mainly economists, mathematicians, philosophers and physicists. It has contributed and can be broadly linked to the field of Ecological Economics.

MINE digitally summarizes the experiences of this research and the accompanying policy-advising in Germany, the European Union, the US and China. It gives a web-based access to its publications and shapes new networks for scientists, students and practitioners.

Following the Introduction (Section 1), this paper explains the MINE project (Section 2) and introduces our methodology (Section 3). In Section 4, we outline 15 concepts and heuristics for tackling the environmental problem. Finally, we provide an outlook for further work (Section 5).

JEL Classification B0, B4, B52, D72, H8, Q53, Q57

Keywords: Environmental Economics, Ecological Economics, History of Economic Thought, Homo Oeconomicus, Homo Politicus, Thermodynamics, Joint Production, Time, Irreversibility, Evolution, Ethics, Sustainability, Responsibility, Ignorance, Absolute and Relative Scarcity, Methodology, Interdisciplinarity.

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1. Introduction

Safeguarding the natural basis of life is currently a central task for securing prosperity in developed countries and achieving prosperity in developing countries, and ultimately for securing life on earth (Becker et al. 2015).

The complexity of this task is challenging in two ways. Insofar science is involved into finding the solution of environmental problems (which is a practical one), several very different disciplines must work together closely. Coping with the different methodologies and concepts is just as demanding as the different terminologies that prevail in the respective sciences (Faber, Proops 1985). In addition to the interdisciplinary cooperation, another difficulty arises: Gaining scientific knowledge alone is not sufficient to solve the problem, for the findings must be communicated in such a way that policy, jurisprudence, administration and civil society are able to derive and implement effective measures from it. Further, the long-term time scale complicates the task as it requires to take novelty into account which, in turn, often implies irreducible ignorance (Faber, Manstetten, Proops 1992). Altogether, these challenges make a masterplan "carved in stone" impossible.

Hence, we face the environmental problem not only with a lack of knowledge, but also with a lack of strategy and communication skills, both between the sciences as well as between science and the public, for the systematic analysis presented by scientists is often difficult for non-scientists to understand. Thus, politicians and administrators are confronted with a taxingly complex situation. How can we take on this task? We believe our research at the Heidelberg University and our decades of experience advising governmental bodies on environmental policy, from also at the Helmholtz Center for Environmental Research in Leipzig, can contribute to this arduous endeavor.

All our scientific research and policy advising experience has been published in journals and books by publishers from different disciplines, e.g. in economics, ecological economics, political science, philosophy, literature, ecology, physics, and chemistry. The breadth of the organs of publication spread over four decades not only makes access to them difficult, but furthermore, in the digital age, practically leads to the disappearance of these findings in public since they mainly were published in print. Today, however, digital availability is of necessity. In order to do justice to this development and to help overcome the communication gap outlined above, we initiated the project "MINE – Mapping the Interplay between Nature and Economy" in 2015. The central question of the project was, how can the complexity of environmental policy be reduced? From our experience in research, teaching and advising governments, we learned that we need only relatively few and encompassing concepts to recognize, analyse and maybe even solve problems.

This paper begins by tracing the development of the MINE project (Section 2) and then explains the methodology we employed to cope with the complexity of the problem (Section 3). We then propose a set of 15 concepts and heuristics for tackling the environmental problem. An abstract of each of the concepts and heuristics is given to inform the reader about the content of MINE (Section 4). In conclusion, we outline future work for the next steps of the project (Section 5).

2. Developing the MINE Project

During the 1970s, researchers at the Heidelberg University began to work on long-term economic issues. The MINE project – Mapping the Interplay between Nature and Economy began by identifying key tools and methods to study the complex and, in particular, long-term environmental and economic interactions.

In the natural sciences, we first dealt with thermodynamics, the doctrine of energy and entropy (see Section 4.1) as every change in nature and economy requires energy. This enabled us to develop a toolkit to simultaneously study processes in both the ecosystem and the economy[1]. At the same time, from the 1980s onward, we began to advise the governments of the Federal Republic of Germany and the United States on water and the state of Baden-Württemberg on waste. To that end, we used capital-theoretical methods based on activity analysis[2], input-output analysis[3] and calculable equilibrium models.[4] Over the course of our advising work, we learned how necessary political and philosophical understanding is for effective policy advice. Our consulting practice showed us where there were deficits in science and how they could be diminished or even remedied. Therefore, our work process was one of learning by doing. This approach has since been consolidated in further consultancy activities (e.g. for China since 2007). In particular, we have incorporated questions on the concept of humankind, by expanding the Homo Oeconomicus through the Homo Politicus[5] due to the importance of responsibility[6] and power of judgment[7] which emerges during political action. We realised that the concepts of sustainability and justice needed a philosophical foundation.[8] An understanding of thermodynamics[9] also aided our investigation of the climate problem[10] and our research into the chemical industry during the 1990s [11]since the concept of joint production can be deduced from the first two laws of thermodynamics (Baumgärtner et al. 2006). The concept of joint production is particularly suitable to explain the ubiquitous generation of pollutants (Section 4.1). Central to the development of our research was the practical implementation of our tools and methods, which in turn enabled us to improve them.

Over the course of our investigations, the importance of concepts of time became increasingly evident for our research and consulting. As a result, we developed a stocks framework for

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[1] Baumgärtner et. al. 2006; Faber, Niemes and Stephan, 1983/1995.
[2] Faber 1978; Niemes 1982; Stephan 1983; Maier 1984; Wodopia 1986; Michaelis 1991; Faber et al. 1999.
[3] Faber et al. 1983; Proops et al. 1993; Jöst 1994; Faber et al. 1999.
[4] Faber et al. 1989; Stephan 1989.
[5] Faber et al. 1997, Manstetten 1999, Faber et al. 2002.
[6] (Jonas 1979, Baumgärtner et al. 2006.
[7] Klauer et al. 2017 and Section 4.3 below.
[8] Becker 2012; Becker et al. 2015; Klauer et al. 2017.
[9] Faber et al. 1983/1995, Proops 1985, 1987; Ruth 1993.
[10] Faber, Proops and Wagenhals 1993.
[11] Müller-Fürstenberger 1995.

long-term thinking on environmental policy (Section 4.2).[12] In the course of our work, we also developed an interdisciplinary concept of evolution.[13]

Over the years, more and more interdependencies between the different disciplines and fields emerged. During our analysis of these interdependencies, we identified three broad areas and 15 fundamental concepts and heuristics within those fields[14]:

- Environment,
- Time,
- Humanity,

each containing five concepts and heuristics (see Section 4).

Each of the concepts and heuristics is presented as an element of MINE and structured in the following way:

Abstract

1. History
2. Concept
3. Practice
4. Literature.

Each of them is between 20 and 30 pages in length.

In addition to the 15 concepts and heuristics, MINE provides answers to Frequently Asked Questions (FAQs). The website also includes an index of about 400 terms and a second index of about 60 people whose ideas figure prominently in MINE. There is also an index of about 50 researchers from different disciplines who have contributed to the underlying research; some of whom belonged to this project for several years, others even for several decades. For the last four years, a group of six individuals, scientists as well as experts in design, communication and editing[15] have been working together to develop an up-to-date digital platform presenting the results of this scientific endeavour.
We now turn to the methodological framework to explain how the concepts and heuristics enable us to cope with economic-environmental interactions.

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[12] Faber et al. 2005; Klauer et al. 2017.
[13] Faber and Proops 1998; Section 4.2.
[14] Faber 2008.
[15] In addition to Malte Faber, Marc Frick and Dominik Zahrnt (authors of this paper), the collaborators include Suzanne von Engelhardt, Caspar Kolster and Johannes Tolk (see acknowledgement).

3. Methodological Foundations

In the following, we reflect on our approach in terms of scientific theory.[16]

The primary focus of our research project in creating the MINE website is to explore humankind's relationship to its environment. It has become clear that an adequate evaluation of that relationship demands knowledge from multiple fields: society, economy, politics and law. In modern times, the sciences give us access to all of these fields. No single individual can master all of those sciences at once. Even if there were such a universal genius with outstanding expertise in economics, law, the social sciences and the natural sciences, especially physics, biology and chemistry, that individual still would not possess the skills to bring all of that knowledge together into a comprehensive understanding or help achieve such a comprehensive understanding and its network of concepts.

This means in practical terms (practical in the sense of practical philosophy which concerns itself with human action) that these fields can only be understood through science which is accessed through simpler overarching concepts. These concepts do not form a hierarchically structured system within MINE. Instead they are conceived as a network of interdependent concepts that reference each other but also remain categorically distinct from one another.

Hence, we have general concepts fundamental to understanding the world, such as *time*, *irreversibility* (Section 4.2) and *causality* [Falkenburg (2012) highlights the fact that the two terms *irreversibility* and (deterministic) *causality* stand in opposition to one another][17]. Furthermore there are constitutive concepts of nature in the natural sciences, such as *thermodynamics*, and concepts in the social sciences like that of *Homo Oeconomicus* and *Homo Politicus* (Section 4.3). The latter is not simply a counterpart to Homo Oeconomicus, but has its roots in practical, normative metaphysics, as developed for instance by Immanuel Kant (*Metaphysics of Morals*, 1979/2009).

In addition there are concepts like *joint production* (Section 4.1) on the one hand and *responsibility* (Section 4.3) on the other which attempt to capture the physical side of economic production. Both terms exhibit a structural relatedness, which is why they are especially well suited to more precisely define the requirements of practical politics in their relationship to the environment.[18]

Finding such concepts or principles is always a matter of judgement[19] because these concepts cannot be deduced from a series of potentially different types of observations. The power of judgement (Section 4.3) has the ability to reflect on such possible principles that may allow us

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[16] E.g. Faber et al 2002: chapters 9 to 12; Faber and Manstetten 2010: Chapters 4 to 8; Klauer et al. 2017: Chapter 7; Section 8.2; Manstetten 2018: 18-22.
[17] "The causal processes in physics are *either* deterministic, reversible and symmetrical in time (mechanics, electrodynamics, signal propagation after Einstein), *or* they are asymmetrical in time, irreversible and indeterministic (thermodynamics, quantum mechanical measurement process)" (Falkenburg 2012: 399, emphasis from the original; our translation).
[18] Baumgärtner et al. 2006, Part III: Ethics, pp. 223-267.
[19] Section 4.3, Klauer et al. 2017: Chapter 7; Faber and Manstetten 2010: 64-67.

to understand differing fields and how they are interrelated. On the one hand there are principles that remain within the realm of judgement, as it were, because they are only principles of reflection. Principles of refection are principles which guide reflection and scientific research yet cannot become scientific propositions or laws themselves. They therefore are principles upon which we only reflect. An example of such a principle of reflection is the sentence *Natura non facit saltus* (Nature does not make jumps) or, as Kant showed (1790/2001), the teleology in observing nature (Section 4.3).

Teleology (Section 4.1), the study of purposes[20], understands objects as purposeful creatures, striving for self-preservation, growth and reproduction. This is how it understands natural organisms, and this is often essential in guiding scientific research which intends to explore the functions peculiar to each organism. For instance, we can only adequately grasp the function of the eye if we regard the eye as an organ for seeing. That means we understand the eye as an organ whose purpose is for seeing. And yet, even though the teleological approach is an important prerequisite for research, teleology itself can never become a constituent concept of science. Laws discovered by science expressly may not contain any teleological elements.[21]

We can say that teleology is a perspective which the power of judgement lends to science. If judgement is able to develop perspectives like teleology, then it is also able to find constitutive principles of nature from which phenomena can be deductively explained, as for instance thermodynamics and Newton's law of universal gravitation. Once judgement has found such constituent principles, they become part of science, and judgement has made itself superfluous to a small extent, because explaining phenomena through these principles now only requires reason (see Wieland 2001: 173-175).

Having presented the scientific theory behind our method, we now turn to the content of MINE and its online platform.

4. Introduction to the Concepts and Heuristics

We have developed 15 concepts or heuristics which we have organised, as mentioned above, into three areas: *Environment* (Section 4.1), *Time* (Section 4.2) and *Humanity* (Section 4.3). Each of these elements consists of an abstract, history, theory, practice and literature, and is roughly twenty to thirty pages in length. To give the reader a taste of what MINE has to offer and an idea of its content, the following gives the abstract of the 15 elements. We begin with the elements within the scope of the *Environment* and continue with *Time* and *Humanity*.

[20] Kant (1787/1929); Spaemann and Loew 1985; Faber, Manstetten, Proops 1995; Wieland 2001; Faber et al. 2002: Chapter 9; Faber and Manstetten 2010: 85-89.
[21] The biologist J. B. S. Haldane remarked in the 1930s, "Teleology is like a mistress to a biologist. He cannot live without her but he is unwilling to be seen with her in public."

4.1 Environment

The area *Environment* builds on the foundation of life in ecosystems and economic activity, in particular energy. The use of energy in production implies that more than the good itself is produced, meaning there is always joint production. Further, we deal with the concept of scarcity, which is the reason that living beings have to be concerned with their own subsistence. Finally, we have to ask what nature is and what the foundations of the basics of life are.

1. Thermodynamics

During the 19th century, physics underwent a revolution. Sadi Carnot, Lord Kelvin, Rudolf Clausius and others founded a new field of physics, thermodynamics, which focuses on the study of energy.

Although energy is one of the most important economic production factors, thermodynamics does not play a key role in Mainstream Economics. However, energy is necessary for every production process and has an impact on nature because it creates environmental damage. Its use leads to irreversible loss of coal, oil and gas. This is the reason why the founder of Ecological Economics Nicholas Georgescu-Roegen focused on thermodynamic considerations in his pioneering work *The Entropy Law and the Economic Process* (1972).

This concept explains the consequences of the two fundamental laws of thermodynamics: (i) Energy can neither be created nor destroyed, but only transformed. (ii) To give an example of the second law: Heat will by itself always transfer from a hotter to a colder body, like a heated stone will give up its heat to the cooler air surrounding it.

Thermodynamics lays the foundation for an understanding that every industrial production process yields joint products, at least one of which is a waste product. This fact is easily communicated to the public, heightening awareness of the danger of our mode of production.

A practical example is the production of steel by using coke and iron ore. The output is not only steel but also the remains of the manufacturing process, such as CO_2, wastewater, dust etc.

2. Joint Production

While an awareness of joint production (i.e. combined production of at least two goods) played a key role in the early years of classical economics and Marx' thinking, it later fell into oblivion. Environmental crises have brought it back into practical and theoretical discussions. When physicists proved that industrial production is always attended by the manufacture of at least one waste product, they also highlighted the general relevance of this concept for environmental issues. Their proof is based on the first and second laws of thermodynamics.

The added value of the concept *joint production* is that it shows that the Mainstream Economics' theory of externality is an ex post approach, while the Ecological Economics'

concept of *joint production* provides an ex ante approach. The former recognizes environmental degradation only after it has occurred, whereas the latter focuses on it right from the start.

An example from the soda-chlorine industry illustrates a process that evolved over 250 years. New technologies and products were invented due to resource scarcity. Over the course of time, pollution from the new technology was increasingly recognised, leading to environmental legislation. Thus, we can develop a "triangle of causation": Resource scarcity initiates technological invention; this in turn produces environmental pollution that must be regulated by politics. This process leads to new technological innovation, which produces new resource scarcities and new environmental pollution. This is how the textile industry led to the soda-chlorine industry and finally to the production of CFCs (Chlorofluorocarbons) which have destroyed the ozone layer.

3. Basics of Life – Stocks, Stores and Funds

Life and forms of living beings began around 4 billion years ago. However, the terms *stocks* and *stores* have only developed as scientific concepts over the course of the last two centuries, while the term *fund* came into use even more recently (Georgescu-Roegen 1971). A fund can be understood as a source of services for one or more species of living beings.

While Mainstream Economics does not focus on the origins of life, this is a basic concern of Ecological Economics. To understand life, we need concepts which focus on its temporal structure and are suitable to examine the interaction between the dynamics of coupled systems made up of natural and economic components.

A central concept is that of a stock, hence this concept develops a general theory of stocks, applicable in ecology and economics. Some stocks are used as stores in ecosystems and economic systems. Crucial questions for sustainability are: When do stores become scarce? How can they be replenished or substituted by other stores? To answer these questions, we need a third concept, a *fund*. Essential for a fund is that it maintains itself, and that it gives services to other living beings.

Take an apple tree, for example. Its services are material and immaterial, be they shelter or aesthetic services. Drawing on three concepts and heuristics, a Teleological Concept of Nature, Thermodynamics (Section 4.1) and Irreversibility (Section 4.2), enables us to operationalize the concept of life. The heuristic *Basics of Life – Stocks, Stores & Funds* helps us grasp the intertemporal relationships between stocks, stores and living beings.

As a practical example, we use the three concepts to describe the development of oxygen in the atmosphere and its consequences for life on earth.

4. Absolute and Relative Scarcity

Thomas Robert Malthus (1766-1834) introduced the notion of absolute scarcity of nature into classic economic thought. He maintained that a population grows faster than the food required to sustain the population, and that will eventually lead to a decline in the population.

In contrast, Mainstream Economics focuses on relative scarcity, which defines a good as scarce in relation to other scarce goods. A scarce good carries opportunity costs which, in turn, result in a positive price. Goods with no price are not scarce. However, many pollutants have no price; therefore, they are not dealt with (see concept *Joint Production*). In contrast, Ecological Economics focuses its analysis on the damage caused by these pollutants.

We show why the concept of *relative scarcity* is too narrow to secure the natural basis of life. For example, ground water is irreversibly lost, and climate change causes draught and flooding. In contrast, Ecological Economics is very much aware of the absolute scarcity of natural goods: A good which cannot be substituted with another is absolutely scarce. Ecological Economics focuses its analysis on non-priced goods.

It is necessary to recognise that many services provided by the environment become absolutely scarce in the long run, therefore we must take precautionary measures now.

To illustrate our critique, we examine the concept of relative scarcity in the context of the present loss of biodiversity.

5. Teleological Concept of Nature

Aristotle employed the teleological approach to explain the world. The adjective *teleological* is derived from the Greek word *telos*, which means "aim". The teleological approach was used until the middle ages. It was largely abandoned in scientific discourse in favour of causal analysis.

However, as Immanuel Kant (1724-1804) argued in his *Critique of Pure Reason* (1787/1923), normal scientific discourse must be enhanced if one wishes to understand life, for living things cannot be explained purely mechanically but must be interpreted *teleologically*, i.e. one must ask, *what is it for?* In everyday life we ask, what is the nectar in apple blossoms for? The proximate answer is because the nectar attracts bees, which pollinate the flower. The nectar fulfils a certain purpose for the living thing. In this vein, we want to bring the question *what is it for?* back into scientific discourse: What is the purpose of nature? What is the purpose of life? (Faber and Manstetten 2010: 85). Mainstream Economics views nature only as an environment that is used as a supplier of resources and a receiver of waste and pollution from economic activity, be it extraction, production or consumption.

In contrast, Ecological Economics has developed a teleological concept of nature which allows us to formulate a concept of nature so encompassing as to enable us to develop a conceptual basis for Ecological Economics.

This text reintroduces the teleological approach to generate new perspectives and fruitful questions to help secure the foundation of natural life. Since this heuristic is a purely conceptual one, it does not give a practical example.

4.2 Time

The second area is *Time.* It is one of the most difficult philosophical concepts. We deal with it in our concept *Basics of Time.* Time gives rise to irreversibility and evolution. Last but not least, time is the main source of our ignorance. Finally, we present one more concept, one dealing with long-term aspects, namely Environmental Politics*: The Stocks Framework and the Art of Long-Term Thinking*. It employs all the concepts of MINE for successful environmental politics and integrates various concepts into a practical model for policy consultation.

1. Basics of Time

Whereas our concept of space seems well established, perhaps 'hard-wired' into our brains, time is altogether more elusive. Since Aristotle (or even before), the nature of time has been a source of contention among philosophers, both pure and natural.

Mainstream Economics employs a restricted view of time, which in turn leads to a simplified analysis of long-term developments. This holds particularly for the interplay between nature and the economy. Ecological Economics, in contrast, employs a wider view of time.

Basics of Time introduces several concepts of time, tracing its development from ancient philosophy to political decision-making. *Chronos*, which can be found in Aristotle's and Newton's writings, reflects a linear, objective understanding and is at the core of the modern scientific worldview. *Kairos*, adopted from the name of a Greek god, signifies the right moment to act, meaning a subjective interpretation of when to act with limited knowledge or even in the face of ignorance. Both *chronos* and *kairos* are important to understand and make use of the inherent dynamics of evolutionary processes.

Basics of Time argues that this broad view of time culminates in a stock's perspective, which provides an indispensable tool for political advisors and decision-makers.

Our first example comes from Tolstoy's *War and Peace* in which patience and time lead to an outcome that seemed impossible at the outset. The second example concerns German water policy where a slow build-up of production stocks leads to social support of the innovative policy and ultimately to the long-term protection of water.

2. Irreversibility

During the 19th century, new insights into the concept of irreversibility were developed with the founding of thermodynamics. It turned out that an understanding of time irreversibility requires a thermodynamic underpinning.

In the second half of the 20th century, the physical chemist Ilya Prigogine discovered ground-breaking insights regarding irreversibility in self-organising systems, such as biological plants. The economist Georgescu-Roegen introduced the physical concept of irreversibility into Ecological Economics. Mainstream Economics has a flawed view of temporal irreversibility in production theory since it neglects important thermodynamic considerations, for instance it generally assumes that all goods can be substituted by others.

Ecological Economics argues that a thermodynamic understanding of irreversibility is necessary to adequately analyse the interplay between nature and economy. For ease of understanding, let us assume that time is reversible. Accordingly, time has the same status as a spatial variable; hence, time can move in two directions, into the past and into the future. Thus, its direction is not uniquely defined and past and future can be treated symmetrically. However, as soon as we experience real time, we note that we are only able to move in one direction, namely from the present to the future, for we cannot return to the past. Therefore, a good definition of irreversibility is: A process is irreversible if it is not possible to reverse it. Although this is a tautology, it is revealing.

Thermodynamic irreversibility restricts economic actions in time (Georgescu-Roegen 1971). Only those actions are possible that are not restricted by the two laws of thermodynamics. Hence, thermodynamic irreversibility is a constraint for economic action.

A practical example of irreversibility is the burning of a piece of coal. Once burned, you can never turn it back into coal.

3. Evolution

Darwin's seminal book on biological evolution has triggered an ongoing debate on evolution, in biology and in general. Not until the 1960s did Mainstream Economics start to take up Joseph Schumpeter's ideas of evolutionary thought for economic analysis in one of its branches, Evolutionary Economics. However, Mainstream Economics did not emphasise the relevance of his ideas for environmental problems. Ecological Economics, on the other hand, uses the concept of evolution as a key to diagnose, analyse and treat environmental and resource problems.

We show the fruitfulness of the concept of evolution by examining predictable and unpredictable processes, inventions and innovations, ignorance and novelty. For instance, the concepts of genotype (the gene structure of a living being) and phenotype (the realization of a living being) can be employed not just in a biological context but also in a physical and economical context. This broad view of evolution is useful for two reasons: (i) Several concepts first introduced in natural science are useful because they provide economics with a physical foundation. (ii) The way natural science has treated time and irreversibility offers important

lessons to economics, for many economic actions have irreversible consequences, like the use of groundwater which cannot be replaced if it is extracted too fast.

Our example of the soda-chlorine industry shows an evolutionary process in an economy over the course of 250 years. First, new technologies and products are invented due to resource scarcity. Second, increasing pollution caused by the new technology is recognized, and third, environmental legislation is implemented, leading to new inventions, and so on. Hence new questions lead to new answers in an evolutionary way.

4. Ignorance

The phenomenon of ignorance was an issue in Greek philosophy as early as Plato's first dialogues (e.g. Meno). The importance of an awareness of ignorance is illustrated by the famous Oracle of Delphi: It acknowledged Socrates as the wisest of all human beings because he said, "I know that I know nothing".

Mainstream Economics is particularly strong in dealing with risk and, to some extent, uncertainty. In contrast, Ecological Economics focuses on the boundary between what we know, what we know that we do not know, and where we are even unaware of our lack of knowledge. To this end, we outline different forms of ignorance, such as personal and social, open and closed, reducible and irreducible ignorance. This concept enables us to improve our understanding of natural processes and our political decision-making

The example of joint production shows how manufacturing one good result in at least one waste product. Various joint products, however, can go unrecognized for a long time, with detrimental effects. Responsible action therefore demands that we deal explicitly with ignorance.

5. Environmental Politics

In ancient philosophy, practice existed only to create space for the wise to contemplate theory. In the ideal of modern science, however, science is an abstract system of cognition, providing the basis for technological control of nature.

The stocks framework is an attempt to overcome the gap between theory and practice between academics and practitioners. In contrast to Mainstream Economics, Ecological Economics emphasizes the role of time in politics by examining the dynamics of economic, social and environmental stocks and their relationships. Stocks may be material or immaterial, such as a social institution like legislation.

Our applied example examines the development of sustainable inland shipping policy in Germany. To this end, we proceed in seven steps, starting with the policy aims and relevant facts known about German inland shipping. This enables us to identify the relevant material and immaterial stocks associated and their dynamics. In doing so we can summarise the normative demands placed on German inland shipping policy by the general principle of

sustainability and formulate concrete goals. Finally, we propose concrete policy recommendations for the transportation system.

The last chapter describes the stocks framework as a school of long-term thinking. It shows how a practitioner is able to learn to deal with issues over long timescales.

We note that this concept is almost identical to chapters 12 and 13 of the book *Sustainability and the Art of Long-Term Thinking* by Klauer et al. (2017).

4.3 Humanity

The third area is humanity. Here we deal picture of humankind, power of judgement, responsibility, individual, community and entirety, sustainability and justice.

1. Homo Oeconomicus and Homo Politicus

Mainstream Economics began considering human behaviour during the 17th century with the work of Thomas Hobbes. Its present assumption about behaviour is mainly that of *homo oeconomicus*: Human beings act according to their self-interest in a rational manner, hence they are utility maximisers.

The concept of *homo oeconomicus and homo politicus* examines the model of *homo oeconomicus*, analysing its accomplishments and shortcomings. Criticism from different disciplines such as Ecological Economics maintains that this is a one-sided view of human behaviour. A fundamental deficit of this tenet is that nature, justice and time do not receive the attention they deserve. We develop a further concept of humankind by drawing on political philosophy: *homo politicus*. *Homo politicus* is characterised by an interest in justice, common welfare and the sustainability of the natural basis of life. *Homo politicus* does not replace *homo oeconomicus* but rather complements him since both concepts contain essential dimensions of human behaviour. This twofold approach allows a better explanation of human behaviour as observed in reality and leads to better predictions.

Our practical example examines the passage of legislation on a waste management system in Germany during the 1980s and 1990s. The example reveals that officials were not acting exclusively as *homo oeconomicus*, but also as *homo politicus*. Indeed, these officials pursued long-term goals of justice, sustainability and the protection of the common good. It is generally recognised that the new waste management system was a breakthrough in German environmental policy and has since been adapted by other countries due to its success.

2. Power of Judgement

The concept of the power of judgement goes back to the Greek word *phronesis* which means prudence. Aristotle dealt with it, and in the 19th century Kant wrote his ground-breaking *Critique of the Power of Judgement*.

Mainstream Economics traditionally is good at modelling predictable situations as well as situations with calculable risk. However, environmental issues generally evolve over the long-term, which entails surprise and ignorance. To this end we need concepts hitherto not employed by Mainstream Economics; in particular we need to consider the concept of the power of judgement. Although this is a philosophical concept, we all are aware of it in everyday life. It is the ability to react intuitively in a new situation. A judge or a doctor who is confronted with a new case needs the capability of power of judgement to pass adequate judgement or find an appropriate treatment. Ecological Economics makes use of the power of judgement.

This concept enables us to discuss, in a non-scientific but nevertheless rational manner, long-term problems, evolutionary in nature, and our confrontation with uncertainty and ignorance.

An example of the power of judgement is the application of the precautionary principle which protects us from the consequences of actions that otherwise would take us completely by surprise. The example of Fukushima shows how that catastrophe could have been avoided had the power of judgement been applied.

3. Responsibility

The concept of responsibility was addressed in philosophy, in particular by Aristotle, Kant and Weber. This concept offers an overview of the philosophical understandings of responsibility, building up an approach that can deal with high complexity, the occurrence of novelty and irreducible ignorance.

When dealing with responsibility, Mainstream Economics limits itself to responsibility for an individuals' wellbeing. Ecological Economics, however, focuses on responsibility for society and the environment as well.

What is responsibility? Responsibility causally links the consequences of an action to the actor. Legal responsibility must be distinguished from moral responsibility. We differentiate individual responsibility from collective responsibility. Finally, we introduce political responsibility and political-ethical responsibility. Ascribing responsibility in this differentiated way helps reduce complexity, for it shows who is responsible for what and to what extent. This allows us to distinguish between reality and wishful thinking. The added value of the concept of *responsibility* is that it presents different dimensions of responsibility. Further, it allows us to analyse complex environmental and resource issues.

The examples of joint production, like water pollution, lead to an important conclusion: A top-down approach does not suffice to deal with environmental problems. We need a bottom-up approach: Individuals must assume their responsibility alongside the community and political actors.

4. Individual, Community and Entirety

The interests of human beings have been considered in different reflections throughout the history of humankind. Philosophers, theologians, political economists and famous literary

writers have examined the different interests, like Thomas Hobbes, Adam Smith, Immanuel Kant, Alasdair MacIntyre and Johann Wolfgang von Goethe, to name a few.

The challenge of this concept is to develop a framework which focuses on three interests of a human being: interest (i) in the individual, i.e. in him or herself, (ii) in society and (iii) in entirety.

While Mainstream Economics focuses mainly on the individual, Ecological Economics is concerned with all three interests.

The behaviour of living beings issues from their needs. In contrast to non-human beings, human beings can and do reflect on their needs. This opens up alternatives, e.g. to postpone the satisfaction of certain needs in favour of other needs. Reflection that leads to a decision operates within the sphere of rationality, a sphere different from that of needs. This explains the observation that the development and behaviour of human individuals is far less predictable than the development of non-human beings.

In contrast to Mainstream Economics which focuses on needs and preferences, our standard of choice in this concept focuses on the term *interest*. Interest is linked to needs, but it is separated by reflection, and thus human beings gain distance to move beyond what they directly perceive. The concept of interest, contrary to that of needs, is orientated toward longer periods of time. This element opens new perspectives for long-term environmental research, in particular concerning sustainability.

Our practical examples show how difficult it is to deal adequately with interests. This is particularly true for interest in entirety.

5. Sustainability and Justice

Justice has been a well-established notion since antiquity – see e.g. the *Politeia* by Plato. As Socrates noted, a just state and a just soul is governed by reason, not by human desires. The notion of sustainability arose in public discourse with the *Report of the Club of Rome on the State of Humanity: The Limits to Growth* (Meadows et al. 1972). When referring to the natural basis of life, we mean the resources provided by nature that are necessary to support human life and cannot be substituted by man-made artefacts.

Sustainability has three dimensions: the economic, what is just, and the ecological. Mainstream Economics and public discourse focus on the economic und just dimensions, while the ecological dimension is largely ignored. Ecological Economics focuses on the latter.

This element presents a conceptual framework for sustainability and justice. The concept of justice is developed in terms of distributional justice and in the sense of order justice (a sort of constitutional justice) as well; the latter is crucial for solving environmental problems. We show how closely sustainability and justice are interrelated.

Sustainability and justice serve as a bridge between the general concepts of sustainability and justice and their concrete components. One major outcome is that the growth paradigm turns out not to be the solution but an obstacle to achieving a sustainable world.

As a practical example, we show how we can achieve a sustainable world. It is very unlikely that we will be able to decouple economic growth from environmental burden. It is crucial that we attain sufficiency in society, for sufficiency identifies what is enough to live a good life.[22]

5. Outlook

MINE can be viewed as the result of two different but closely connected ways of approaching the interplay between nature and economy. The development of concepts and heuristics in our research has always been followed by their application in the context of policy advising. This process has time and again brought us new insights which made us aware of the necessity for further theoretical research. This, in turn, resulted in further concepts and heuristics. This cycle of finding new areas of research engendered by our advising activities and again applying the newly found concepts to consulting obliged us to maintain an openness in our investigation. As a result, this procedure led to an inherent dynamic over the course of many years. Of course, this result also holds for our project MINE itself: It practically demands to be expanded. Therefore, we would like to name some of the topics that are predestined to be worked on in the future: resilience, flexibility, stability, confidence, and freedom. We will continue our work, of course, and we hope that others will join us.

Finally, we want to note that our approach benefited from the study of classical texts of thinkers like Plato, Aristotle, Hobbes, Rousseau, Smith, Kant, Goethe, Malthus, Hegel, Wordsworth, Marx, Keynes, Schumpeter, Heidegger, Georgescu-Roegen and Sen. Reiner Manstetten states in the introduction to his most recent book (2018: 19f), "It became clear that it was possible to address topics and perspectives through the medium of these texts that had hardly received any attention in daily discourse. That was possible due to an exercise that can be termed *detachment.* Engaging with ideas whose nature and the culture in which they originated prove that they are far from all our immediate preoccupations creates, practically by itself, a certain distance from the daily influx of opinions, individual sentiments, habits of thought and prejudices." (Our translation.) What Manstetten says here about his work could equally be said about our own.
The online tool is expected to go live in January 2019: www.nature-economy.com

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[22] Schneidewind and Zahrnt 2014; Zahrnt and Zahrnt 2016.

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