

Introducing MINE

Faber, M., Frick, M., Zahrnt, D. (2019) MINE Website, Introducing MINE, accessed on 20 January 2019, www.nature-economy.com

Abstract

The MINE website explores the interplay between nature and economy. Focusing on such fundamental concepts as time, thermodynamics, evolution, homo politicus and justice, a new outline of economic activity emerges *within* nature. The dominant approach of Mainstream Economics, which considers nature as a subsystem of the economy, is thus replaced by a broader and more integrated framework.

The visual map and its links between concepts provides an orientation. The visitor can approach the content from their own starting point and follow their own path to discovery. Each concept starts with the historical background and moves on through theory and practice.

The research behind MINE began in the 1970s at the University of Heidelberg, Germany, in an interdisciplinary group spearheaded by Professor Malte Faber, including scientists from economics to mathematics, physics and philosophy. The research has contributed 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.

1. History

Ancient Philosophy

In ancient times, typically in hunter and gatherer societies and later in agricultural economies, land was the source of all goods.

Ancient Philosophers in the European tradition have dealt with the issue of nature even before Socratic times. In his work *Politeia* (1971), Plato deals with the problem of the sustainability of a city. He argues that the increase in needs leads to a shortage of land and raw materials (see Manstetten 2018 for details)

Considerations of word economics, a term deriving from the Greek word *oikonomia*, illustrates how important land was viewed. Oikonomia is composed of the Greek words *oikos* and *nomos*; *oikos* means household, including humans and animals as well as buildings, stables, and nowadays tools for agriculture. The word *nomos* is an ancient Greek word for law. “The expression *nomos* is derived from the Greek verb *nemein* which means to pasture or graze. How are the law and the pasturing or grazing of domestic animals correlated? Among the oldest orders which humans had to establish among themselves was the division of pasture areas and the allotment of fertile lands by a higher authority, for example a lord or a council assembly. *Nomos* is therefore the law in the sense of the establishment of principles for the concrete ordering of the division and allotment of rights and goods within a human society. The ordering of division and allotment is always associated with the questions: Who has claim to what? Who deserves this, who deserves that? Who is to receive more, who less? In other words, when is a partition just and when is it not? Reflections on *nomos* lead to questions of a just legislation – *nomos* belongs in the sphere of justice” (Faber and Manstetten 2010: 16). These reflections show how closely the Greeks have considered the connection between land, justice and sustainability [see concept SUSTAINABILITY & JUSTICE].

Physiocracy

The first well-developed modern economic theory was the *Physiocracy*. This concept is a direct translation from the French word *Physiocratie* which in turn was derived from the Greek words *physis*, English – nature, und *kratía*, English – government; thus, physiocracy means government of nature. The French founders of Physiocracy considered land (including all resources of nature) to be the essential source of wealth because only land could manufacture food and materials; the production of goods required raw materials. The

two main representatives were the French economists François Quesnay (1694 – 1774) and his pupil Anne-Robert-Jacques Turgot (1727 – 1781). They were followed by Adam Smith (1723 – 1790) who became the founder of Classical Economics. The Classical Economists also regarded land as being of importance. David Ricardo (1772 – 1823) developed a theory of rents of land, and Robert Malthus (1766 – 1834) became famous not only as an economist but also as a public figure, for in his theory of population he viewed land as the ultimate restriction for growth [ABSOLUTE & RELATIVE SCARCITY]. His pessimistic views were much debated in public and led to economics being referred to as a dismal science.

Classical Economics

The starting point of Classical Economics in the eighteenth century was also a biophysical approach to production. But In contrast to the physiocrats, the classical economists distinguished capital into fixed and circulating capital; the former contained land (including minerals and energetic materials such as coal), tools, machinery, buildings, installations (such as ports, canals), and means of transportation. The latter included raw materials, intermediate material within the production process, and finished production goods in stores. This division of capital was the beginning of a shift away from the biophysical condition of production to the production factors of capital and labour.

This process continued rapidly after 1870 with the rise of the Neoclassical revolution; the latter is the basis of present Mainstream Economics. The “physical approach to production of capital goods and to manufacturing as the materials-processing activity disappeared. The neoclassicals developed a new vision of the economy based on analytical mechanics. They rejected the classical cost-of-production theory of value and formulated value theory in terms of scarcity and diminishing marginal utility (corresponding to the scarcity and diminishing marginal productivity of the land). The difficulty, of course, was what to do with the materials, food, tools and machines which were produced and not given at the outset as an original endowment (and the support this gave to the cost-of-production approach). The result was a static equilibrium theory of prices” (Christensen 1990: 77).

Mainstream Economics

One of the main founders of Neoclassical Economics which is the basis for Mainstream Economics was Leon Walras (1834 – 910). He (1874: 213) “assumes that an individual capital good yields a flow of outputs just like ‘a field grows a crop year after year’. And ignores the flows of materials and energy [THERMODYNAMICS] that are converted into the crop and the materials and the energy needed in industrial processes. He eliminates raw

materials by vertically aggregating production into an instantaneous one-stage transformation of original factors into final output. Once capital goods are assumed to be like land in terms of yielding positive marginal products, it is merely one more step to assuming that the economy does not need land or resources since capital can substitute for resources (see Solow 1978)” Christensen 1989: 78).

Mainstream Economics did not deal systematically with environmental or resource issues until the beginning of the seventies. This changed with the publication of Meadows et al. *The Limits to Growth* in 1972 and the oil crisis in 1973; both events led to “the establishment of two separate and largely disjoint fields of inquiry and prescription – Natural Resource Economics and Environmental Economics” (Commons 2003: 83) in Mainstream Economics. Both areas employed the same analytical framework and tools as Mainstream Economics.

Ecological Economics

In the 1980s, more and more economists and ecologists had become dissatisfied with the way Mainstream Economics dealt with the environmental crisis and the increasing scarcity of resources. “The 1990s saw the emergence of Ecological Economics. Ecology is the study of living organism in relation to their organic and inorganic environments. The ‘eco’ in Ecology has the same root as the ‘eco’ as in economics, which...is *oikos* for household. If economics is the study of human housekeeping, ecology is the study of nature’s housekeeping. Ecological Economics came into being as the result of the conviction on the part of some ecologists and some economists that to properly understand human housekeeping, and its implications for nature’s housekeeping, it was necessary to locate the study of human housekeeping in the study of nature’s housekeeping. Ecological Economics starts, that is, from the idea that humans are part of nature and that the economic and environmental systems are interdependent” (Faber and Manstetten 2010: 87).

For an extensive survey of the history of the relationship between nature and economics see concept HISTORY OF THOUGHT.

2. Theory

First, we give a summary of the methodological foundations of Mainstream Economics, demonstrating its strengths. However, its weaknesses have come under closer scrutiny over past decades (Section 2.1). Three deficits include the lack of an adequate treatment

of nature, justice and time (Section 2.2). Finally, we present a summary of the field of Ecological Economics.

2.1 Mainstream Economics

Methodological foundations

Mainstream Economics started to develop its methodological approach in the mid 19th century by orienting itself according to the natural sciences, in particular physics. “When a discipline seeks to capture reality using its own specific systematic methods (whether to generate theoretical knowledge or to facilitate action), various steps are necessary to do so:

1. Empirical information about the reality is selected and processed in such a way that it can be represented and utilised within the system of the discipline concerned. If, for example, we are working within the system of neoclassical economics, information about scientific laws or human behaviour can only be utilised to a limited extent or else in highly stylised form. Drawing on the influential definition provided by Lionel Robbins (1932: 15), the neoclassical economic system refers to those human behaviours that involve actions based on choice to deploy scarce means which have alternative uses. Other human behaviours, such as responsible action using the human faculty of judgement, cannot be usefully analysed within this system. The material, life-world object of economics, consisting of volumes and prices, is expressed in the form of quantity of goods, prices, costs and benefits. Scientific laws or regularities are integrated only in heavily stylised form [THERMODYNAMICS]. For example, technical constraints on production are depicted in the context of productive functions. Elements of these constraints that are crucial in relation to environmental and sustainability problems, such as the ubiquitous occurrence of co-production (i.e. the generation of unwanted additional products such as waste products), are systematically ignored, however (Baumgärtner et al. 2006: Chapter 7) [JOINT PRODUCTION].

2. A system of axioms that helps generate a simplified picture of reality – in other words, a model – is then devised in order to explore the laws or regularities that describe the changes in the data concerned. In neoclassical economics, for example, these include certain assumptions about economically active individuals that are conceptualised axiomatically as egoistic rational maximisers of utility (*homines oeconomici*) with given preferences [HOMO OECONOMICUS & HOMO POLITICUS].

3. Finally, the law-based relationships within the system are analysed. Interrelationships are often formulated in mathematical terms. The aim is generally to establish causal relationships: relations of cause-and-effect are sought, and their significance examined in relation to both the individual elements and the system as a whole.

Systems of this kind exist in the classical sciences as well as in economics. They are, in the first instance, constructs that are underpinned by the theoretical cognitive interests relating to a particular sphere of human knowledge” (Klauer et al. 2018: 38).

Mainstream Economics is largely free of the normative considerations that are required for environmental interventions. Normative principles needed for these are human rights (Faber and Manstetten 2014: Chapter 6), justice, political freedom, obligations towards future generations, inherent values of living beings. These are not considered by a descriptive social science such as Mainstream Economics.

Strengths

One major result of this approach is that all macroeconomic variables can consistently be deduced from the individual behaviour. This approach allows us to develop the theory of general equilibrium which connects all consumers and producers within all markets and all periods. It enables economists to determine simultaneously the value problem and the quantity problem, i.e. finding all prices and all amounts of resources employed and goods produced. The general equilibrium approach explicitly recognises the intertemporal interdependence of the many parts of an economic system in an internally consistent fashion (for the following see Faber and Proops 1986: 295 f.). These positive features have been made possible by defining the boundaries of the corresponding problems in terms of individual preference orderings, technology, resource and legal and political institutions. A central result of general equilibrium analysis was to show that Adams Smith’ invisible hand can be proved mathematically and value free.

However, general equilibrium was developed for many economic actors and thus for the case of perfect competition. The seminal book *Game Theory* by John von Neumann and Oskar Morgenstern (1944) developed a complimentary approach of economic analysis, allowing consideration of an arbitrary number of economic agents from one to infinity. The latter case delivers the same results as those of a general equilibrium theory, while one agent corresponds to the case of monopoly, two to duopoly and few to oligopoly.

A further advantage of this neoclassical approach, which contrasts with the experience in other social sciences, is that general equilibrium theory and game theory have given Mainstream Economics a common language and a consistent set of concepts, exhibiting

formal elegance. During the second half of the 20th century the neoclassical approach gained acceptance in more and more economic areas, such as international trade, monetary theory, capital theory, public finance, micro foundations of macroeconomics, and development theory.

General weaknesses

However, during the last quarter of the 20th century, a growing awareness arose of the weaknesses of the neoclassic approach and its reduction. Why did this happen? One main reason is that the better the boundaries of the problem are defined, the more tractable the corresponding model is and the more completely characterised the set of solutions; i.e. the nearer the model is to closure, the less ambiguous are the solutions. The obvious drawbacks have been that economic theory has become divorced from economic history; invention and innovation can only be addressed through the introduction of ad-hoc assumptions. This drawback initiated the field of Evolutionary Economics [EVOLUTION].

Interdependencies between economy and politics cannot be analysed in Mainstream Economics. This deficiency was the reason that the area of Public Choice was developed during the 1960s [HOMO OECONOMICUS & HOMO POLITICUS].

The application of general equilibrium theory to problems of resource depletion and environmental degradation has been mainly in terms of “internalizing externalities” [JOINT PRODUCTION] in a narrow sense. To some extent, Mainstream Economics attempted to cope with this drawback in its fields Environmental and Resource Economics established in the seventies. However, since the same methods are employed as mentioned above, this has not been not been an adequate solution. This failure led to the establishment of the field of Ecological Economics.

2.2 Lack of adequate treatment of nature, justice and time in Mainstream Economics

From the perspective of authors interested in a broader perspective on economic activity, society and nature, the critique of Mainstream Economics has been framed along the following three fundamental deficits. These are (Faber 2008),

- first, the lack of an adequate conceptualisation of nature,
- second, a failure to handle the question of justice and

- third, a failure to deal with the dynamics of time.

These three deficits contributed to the rise of the establishment of Ecological Economics and explain how Ecological Economics differs from Mainstream Economics.

Nature

“To be fair to Mainstream Economics, the criticism that it fails to conceptualise nature in an adequate manner can be said to apply to all modern sciences. The natural philosopher Friedrich Wilhelm Joseph Schelling (1775 – 1854) put it this way at the beginning of the 19th century: ‘All modern European philosophy since its beginning with Descartes (i.e. since the 17th century; the author) has one common failing in that nature is not present in it.’ (1809/1997: 28 f.; our translation). At first glance, one can only wonder at this statement, for since the time of Francis Bacon (1561 – 1626), all philosophies and natural sciences placed nature at the centre of their explanatory systems. What does it mean then to say that nature does not appear in this philosophy or this science? Where it is omnipresent?

To answer these questions, we first have to clarify what nature means in this context [TELEOLOGICAL CONCEPT OF NATURE]. In everyday life, nature is understood as the part of the world not made by human hand. In our normal experience, nature is something independent. This independence of nature has led some philosophers and poets, particularly those belonging to the romantic movement, like Goethe, Wordsworth [HISTORY OF THOUGHT], Novalis, Schelling and Thoreau, to perceive nature as the independent basis of life in all its forms. In their view nature has an aim in itself and is constantly at work developing higher life forms [BASICS OF LIFE] so that beings are ultimately able to reflect on themselves. The experience of nature as a fountain of life and development beyond human planning led these thinkers to an attitude of universal gratefulness. In contrast, as Schelling noted, the representatives of modern science in their majority seemed blind to this independence of nature. These sciences were concerned solely with the task of searching for laws that determine nature, in order to command natural processes. For them, nature was no longer something independent. Instead, nature was nothing more than material for humans and their wants.

This approach still forms the basis of modern natural sciences as well as of Mainstream Economics. For example, let us consider the founder of modern economics, Adam Smith (1723 – 1790). He assumed that nature would not impose any limits on the endeavour to increase productivity further and further through division of labour and technical progress. Karl Marx (Petersen and Faber 2018) followed on from Adam Smith in his hope that material wealth could be increased indefinitely. In the communist economy, Marx expected to find an economy that is able to give everyone what they want. It never occurred to either

Smith or Marx that nature, which provides the raw material for this wealth, might resist this human striving for continuous growth. Today, nature is viewed in Mainstream Economics solely as a provider of resources and services. Nature as such does not appear. Bertram Schefold, (2000; our translation) one of Germany's leading economists, stated: 'As an editor of a series of hundreds of classical works on economics, I have not found one single [economics] book in which nature is at the centre of political economy.'

'Nature' is no concept of economic theory. It is only viewed as something like other economic concepts such as production, consumption, land, labour, and utility which supply us with a restricted relationship concerning nature" (Faber 2008: 3).

Justice

We will show that this neglect of the constraints of nature has implied that justice is equally dispensable in Mainstream Economics. (The argument in this section was developed at length in Faber and Petersen 2006.) From a philosophical point of view, justice [SUSTAINABILITY & JUSTICE] relates to the idea of a good life for society: A just society is one whose members are able to live a good life, which also implies that a good life is in harmony with nature [TELEOLOGICAL CONCEPT OF NATURE]. The notion of a 'good life' is a holistic concept which pertains to all important dimensions of social development, i.e. to politics, culture, education and the economy as well as to human interaction with nature [INDIVIDUAL, COMMUNITY & ENTIRETY].

Early on, the classical economists narrowed down this wide notion of justice by reducing it to a question of income distribution. On this basis, it was logical to increasingly neglect the problem of justice over time. Their argument runs as follows: If the social income is high enough and distributed in such a way that all humans can satisfy their wants completely, i.e. if we are in a state of affluence, then justice vanishes as an issue [SUSTAINABILITY & JUSTICE]. Such a state of affluence seems to be feasible if one presupposes the possibility of indefinite growth, i.e. if one assumes that material wealth can be increased arbitrarily. In the 18th century, this vision was formulated with wonderful clarity by the Scottish philosopher David Hume (1711 – 1776). Hume wrote about a state of affluence: 'It seems evident that in such a happy state every other social virtue would flourish and receive tenfold increase; but the cautious, jealous virtue of justice would never once have been discussed.' (Hume 1777/1975: 183f.). 200 years later in 1930, John Maynard Keynes (1967: 366) wrote: "...the *economic problem* may be solved, or be at least within sight of solution, within a hundred years. This means that the economic problem is not – if we look into the future – *the permanent problem of the human race* (italics from the original). Hume,

Marx and Keynes all thought, if sufficient goods are available, then the problem of justice no longer exists.”

Time

We turn now to the third deficiency of Mainstream Economics. Some of the best economists of the second half the 20th century noticed that their method of modelling time [BASICS OF TIME] is inadequate. The well-known neoclassical capital and growth theorist Robert Solow (1985: 330) even wrote ironically: “There is a single universal model of the world. It only needs to be applied. You can drop a modern economist from a time machine – a helicopter, maybe, like the one that drops money – at any time, in any place, along with his or her personal computer, he or she could set up in business without even bothering to ask what time and which place.” Path dependency, invention, technical innovation [EVOLUTION] and irreversibility [IRREVERSIBILITY] are not handled sufficiently. For example, Paul Samuelson (1983:36) noted: ‘In theoretical economics there is no ‘irreversibility’ concept, which is one reason that Georgescu-Roegen (1971) is critical of conventional economics’ [THERMODYNAMICS]. All the various attempts of Mainstream Economics to come to terms with time were summed up by one of the leading economic theorists of the 20th century, John Hicks (1965:47), who remarked: ‘The more precise capital theory became, the more static it became....’ This is why John Hicks turned away from Mainstream Economic capital theory and became one of the co-founders of neo-Austrian capital theory (Stephan 1996, Faber et al. 1999), where time is at the forefront of the analysis” (Faber 2008: 2-4).

Having explained the three deficits of Mainstream Economics, nature, justice and time, we shall now turn to Ecological Economics.

2.3 The field of Ecological Economics

“From a broad perspective, an interest in nature, justice and time constitutes the defining characteristic of an ecological economist: This interest forms a unifying bond between ecological economists.

The central goal of Ecological Economics is to contribute to justice in the wider sense as defined above. For Ecological Economics, justice means the idea of a good and sustainable life, not only for humans but for all beings [SUSTAINABILITY & JUSTICE]. A just human social order includes the stipulation that it preserves itself and its natural foundations of its existences. If we are interested in justice, we should also be prepared to

act to bring about justice in the real world. It is for this reason that Ecological Economics is by its very essence research orientated as well as action-orientated. As a consequence, ecological economists should be willing to advise government and society. The question of sustainability requires that particular attention be given to time [BASICS OF TIME]. This is a specific characteristic of Ecological Economics: Different time spans, short, medium and long-term perspectives as well as irreversibility [IRREVERSIBILITY] must be reckoned with in nature, economy and politics.

Normative perspective

From a normative perspective, Ecological Economics views nature [TELEOLOGICAL CONCEPT OF NATURE] and justice [SUSTAINABILITY & JUSTICE] as closely connected. Ecological Economics is an attempt to consider economics and nature according to the prerequisite that an independent 'dignity of nature' has to be respected in addition to the dignity of humans (Huber 1990: 233).

This idea that the dignity of humans and the dignity of nature must simultaneously be respected can be considered the defining norm of Ecological Economics. No trade-off exists between the dignity of nature and anything else: There is no price for the dignity of nature. Viewed in this way, the task of Ecological Economics seems at first sight to be rather simple: Take care of nature and justice when giving advice and be sure that time frames are considered.

Complexity of the task

However, this rule of thumb leads to great complications, for Ecological Economics has norms which go much further than those of Mainstream Economics, therefore ecological economists are confronted with a much more complex world. The world of Ecological Economics deals explicitly with the constraints of nature, for it acknowledges that in reality there are limits to the growth of real income. Hence, questions of just income distribution can neither be dispensed with by attaining boundless affluence, as the philosopher David Hume suggested, nor can they be diffused by unlimited economic growth, as Mainstream Economics proposes, because growth is definitely limited by the constraints of nature. Hence, questions of just income distribution can neither be dispensed with by attaining boundless affluence, as the philosopher David Hume suggested, nor can they be diffused by unlimited economic growth as Mainstream

Economics proposes, because growth is definitely limited by the constraints of nature. From this follows: increasing environmental degradation and scarcity of resources on the

one hand and increasing conflicts regarding income distribution on the other hand seem to lead an adviser into a veritable minefield of insurmountable obstacles: hence, questions of sustainability seem to be unsolvable” (Faber 2008: 4). As was argued in Becker et al. (2015) to overcome this difficulty it is necessary to give the ecological dimension of sustainability [SUSTAINABILITY & JUSTICE] much more priority than it is at present the case.

3. The MINE Project: Focus on Fundamental Concepts

This chapter introduces the MINE Project by outlining the 15 fundamental concepts that help us to understand the interplay between nature and economy. The fields Environment (3.1), Time (3.2) and Humanity (3.3) structure these concepts.

Note that each concept begins with a descriptive abstract that also form the entry points on the MINE website.

The origins of MINE

In the 1970s, researchers at the University of Heidelberg began work on long-term economic issues. In the early 1980s, they extended their studies to include environmental and resource issues. To meet the complex challenges of environmental protection and resource use, they formed an interdisciplinary team of researchers from economics, mathematics, physics, philosophy, and other disciplines. This group came together to build a shared understanding of the interplay between nature and economy. Their core belief was that interdisciplinary research could lead to new perspectives. They were interested in conceptual work, developing new methods and its application. Their work formed the basis of the field of Ecological Economics, and they used it to advise several governments on policy. “The substance and style of the research along with the interdisciplinary dialogue that went on within the research group bore all the characteristics of a distinct school of research, described by some as the Heidelberg School of Ecological Economics ... whose main geographical locus shifted from Heidelberg to the Helmholtz Centre for Environmental Research – UFZ in Leipzig after Malte Faber became Professor Emeritus” (Klauer et al. 2017: xvi) in 2004.

This set the challenge to preserve the web of knowledge and people that are fundamental to in-depth interdisciplinary research. At the same time, digitalisation created new standards of media consumption, reading, working and communication. The traditional ‘reader’ can in part be reconceived as a ‘user’ who chooses among a vast range of options, has a shorter attention span, and wants to learn while being entertained. This posed new

demands for preserving and presenting the publications of the Heidelberg School in an accessible and communicative format.

MINE is the solution to this challenge as it presents the research in an interactive and visual way, connecting people, research and ideas to affect real change around the world.

MINE addresses students, researchers, journalists, and decision makers. Readers can choose their own, individual path of discovery across the platform.

Structure: fields and concepts

MINE includes 15 fundamental concepts that correspond to the fields *Environment*, *Time* and *Humanity*. The original texts from 40 years of research have been supplemented, combined and restructured according to the following template:

Abstract

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

A key objective of MINE is to reveal the links between these concepts by examining and working through the concepts from a variety of perspectives. It only became possible to relate the individual concepts to one another after all of them were developed. The material in MINE is diverse since it deals with the connections and interrelationships between nature, the environment in particular, and the economy. Both areas and their relationships are considered in terms of time scale. This requires us to devote special attention to the concept of time.

Environment

The field *Environment* builds on the foundation of life in ecosystems and economic activity, which means energy. The use of energy implies that more than the good itself is necessarily produced; hence there is always joint production. Further, we have to ask what nature is and the basics of life. Finally, we deal with concept of scarcity which is the reason that living beings have to be concerned with their own subsistence. Thus, the field *Environment* is covered by the following concepts: THERMODYNAMICS, JOINT PRODUCTION, TELEOLOGICAL CONCEPT OF NATURE, BASICS OF LIFE: STOCKS, STORES AND FUNDS AS WELL AS ABSOLUTE AND RELATIVE SCARCITY.

Time

The second field is *Time*. This 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. The field *Time* is covered by the concepts BASICS OF TIME, IRREVERSIBILITY, EVOLUTION, and IGNORANCE. Finally, one concept – dealing with long-run aspects – remains. It employs all of the concepts of MINE for successful environmental politics. It is called ENVIRONMENTAL POLITICS: THE STOCKS FRAMEWORK AND THE ART OF LONG-TERM THINKING and integrates various concepts into a practical model for policy consultation. It is based on our experience in advising governments during four decades.

Humanity

The third field is *Humanity*. The reader may ask why we speak of humanity and not justice. The reason is that justice is a narrower concept than humanity. Here we deal with images of humankind and three interests of human beings. Living together demands certain qualities, namely sustainability, justice, responsibility and power of judgement. The field *Humanity* is addressed in the following concepts: HOMO OECONOMICUS & HOMO POLITICUS; INDIVIDUAL, COMMUNITY & ENTIRETY; SUSTAINABILITY & JUSTICE; RESPONSIBILITY, and POWER OF JUDGEMENT.

3.1 Environment

1. Thermodynamics

“But – a fact hard to explain – loud though the noise caused by the Entropy Law, the second law of thermodynamics, has been in physics and the philosophy of science, economists have failed to pay attention to this law, the most economic of all physical laws.” Georgescu-Roegen (1971: 280)

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.

This concept 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 CO₂, waste water, dust etc.

Related concepts: JOINT PRODUCTION; SUSTAINABILITY & JUSTICE; IRREVERSIBILITY; TIME; EVOLUTION

2. Joint Production

From a thermodynamic point of view, there is no industrial production of a good that does not manufacture at least one waste product. The practical implication of this phenomenon, called joint production, is the essence of our environmental problem.

While an awareness of joint production (i.e. combined production of at least two goods) played a key role in the early years of classic 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 this concept 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 which 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.

Related Concepts: THERMODYNAMICS, HOMO OECOMICUS & HOMO POLITICUS, ABSOLUTE & RELATIVE SCARCITY, EVOLUTION

3. Basics of Life – Stocks, Stores and Funds

How do the basics of life evolve according to our present modes of production, distribution and consumption?

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 other concepts a Teleological Concept of Nature, Thermodynamics and Irreversibility, enables us to operationalize the concept of life. This concept helps us grasp the intertemporal relationships between stocks, stores and living beings.

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

Related concepts: TELEOLOGICAL CONCEPT OF NATURE; THERMODYNAMICS; IRREVERSIBILITY; EVOLUTION; BASICS OF TIME; ABSOLUTE & RELATIVE SCARCITY; INDIVIDUAL, COMMUNITY & ENTIRETY

4. Absolute and Relative Scarcity

The strength of Mainstream Economics lies in its analysis of the price system of an economy which allows an encompassing examination of economic interdependencies. However, it also reveals the weakness of Mainstream Economics. Goods and services that have no price are ignored. Thus, the origin of the environmental crisis is revealed.

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 results in a positive price. Goods with no price are not scarce. However, many pollutants have no price, therefore they are not dealt with. 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.

This concept 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.

Related concepts: HOMO Oeconomicus & HOMO Politicus; RESPONSIBILITY; BASICS OF LIFE; BASICS OF TIME; IRREVERSIBILITY

5. Teleological Concept of Nature

The scientific method of the modern era has created our current environmental crisis. This approach alone will not take us out of this crisis. Instead, we must take recourse to other approaches. We regard the teleological approach as suitable.

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*, 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/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 concept reintroduces the teleological approach to generate new perspectives and fruitful questions to help secure the foundation of natural life. Since this concept is purely theoretical one, it does not give a practical example.

Related concepts: BASICS OF LIFE; BASICS OF TIME; THERMODYNAMICS; EVOLUTION; INDIVIDUAL, COMMUNITY & ENTIRETY

3.2 Time

1. Basics of Time

“What then is time? I know well enough what it is, provided that nobody asks me; but if am asked what it is and try to explain it, I am baffled.” Augustine

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.

This concept introduces several conceptions of time, tracing the line 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 world view. *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.

This concept argues that this broad view of time culminates in a stocks 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.

Related concepts: IRREVERSIBILITY; EVOLUTION; BASICS OF LIFE; IGNORANCE; ENVIRONMENTAL POLITICS

2. Irreversibility

“You can turn an egg into an omelette, but you can’t turn an omelette into an egg.” Saying

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. So, a good definition of irreversibility is: A process is irreversible if it is not possible to reverse it.

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.

Related concepts: THERMODYNAMICS; EVOLUTION; BASICS OF TIME; BASICS OF LIFE

3. Evolution

"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change." Charles Darwin

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.

Related Concepts: IGNORANCE, BASICS OF TIME, JOINT PRODUCTION, POWER OF JUDGEMENT, IRREVERSIBILITY, TELEOLOGICAL CONCEPT OF NATURE

4. Ignorance

Kant gives us three fundamental questions: "What can I know?", "What shall I do?" and "What can I hope for?" Let us start by looking at the first!

The phenomenon of ignorance was an issue in Greek philosophy as early as Plato's first dialogues (e.g. Meno). The importance of the consciousness 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 results 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.

Related concepts: JOINT PRODUCTION; RESPONSIBILITY; POWER OF JUDGEMENT; EVOLUTION; BASICS OF TIME; ENVIRONMENTAL

5. Environmental politics – The Stocks Framework and the Art of Long-Term Thinking

“Politicians give advisers little of their time, often not more than five minutes. How can advisers cope with this challenge?” Administrator of the Environmental Protection Agency, Washington D.C., USA.

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.

Related concepts: BASICS OF TIME; BASICS OF LIFE; SUSTAINABILITY & JUSTICE; HOMO OECOMICUS & HOMO POLITICUS; POWER OF JUDGEMENT; IGNORANCE

3.3 Humanity

1. Homo Oeconomicus and Homo Politicus

Homo oeconomicus poses the question, If I don't act in my own self-interest, who will act for me? Homo politicus, on the other hand, asks, If I don't act in the interest of others, who am I?

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.

This element 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.

Related concepts: SUSTAINABILITY & JUSTICE; POWER OF JUDGEMENT; RESPONSIBILITY; INDIVIDUAL, COMMUNITY & ENTIRETY, BASICS OF TIME

2. Power of Judgement

As Kant put it, an 18-year-old can be a good mathematician with talent and hard work. But he won't be able to be a good physician or politician because these professions require the 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 groundbreaking *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 an 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.

Related Concepts: HOMO OECOMICUS & HOMO POLITICUS; RESPONSIBILITY; IGNORANCE; JOINT PRODUCTION; ENVIRONMENTAL POLITICS

3.. Responsibility

"The price of greatness is responsibility." Winston Churchill

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 this concept 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.

Related Concepts: POWER OF JUDGEMENT; HOMO OECONOMICUS & HOMO POLITICUS; IGNORANCE; INDIVIDUAL, COMMUNITY & ENTIRETY; SUSTAINABILITY & JUSTICE; JOINT PRODUCTION

4. Individual, Community and Entirety

We do not picture our readers solely as researchers or students of science or the humanities, but as anyone in the fields of politics, management, economics, education and the media who has an interest in ecological questions. What we have to offer is a studium generale. Faber and Manstetten (2010: 2).

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 element 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. To begin with, note 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 element 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.

Related elements: TELEOLOGICAL CONCEPT OF NATURE, BASICS OF LIFE; HOMO OECONOMICUS & HOMO POLITICUS; IGNORANCE; SUSTAINABILITY & JUSTICE; POWER OF JUDGEMENT; RESPONSIBILITY; ABSOLUTE & RELATIVE SCARCITY

5. Sustainability and Justice

Justice is more than a just income and a just distribution of wealth because it is a central condition for sustainability. Why is this so? Justice within a generation and between present and future generations is a precondition for sustainability.

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 and just dimensions, while the ecological dimension is largely ignored. Ecological Economics focuses on the latter one.

This concept 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.

This concept serves 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 (Schneidewind and Zahrnt 2013; Zahrnt and Zahrnt 2016).

Related concepts: HOMO OECONOMICUS & HOMO POLITICUS; RESPONSIBILITY; POWER OF JUDGEMENT; BASICS OF LIFE; TELEOLOGICAL CONCEPT OF NATURE; ENVIRONMENTAL POLITICS

4. Literature

The content of MINE originates from scientific work published in books and peer-reviewed journals. Quotes are indicated by a special typographic style.

The project team would like to thank the publishers **Edward Elgar**, **Elsevier**, **Routledge**, **Springer** and **Taylor & Francis** for granting a reproduction permission.

Furthermore, we want to express our gratitude to Bernd Klauer, Reiner Manstetten, Thomas Petersen and Johannes Schiller for supporting the MINE Project and granting the permission to use parts of the content of their book “Sustainability and the Art of Long-Term Thinking.”

We are indebted to Prof. Joachim Funke, Ombudsman for Good Scientific Practice at Heidelberg University and the legal department at Heidelberg University, for their advice and support.

The main sources of this concept are the following publications:

Faber, M. and R. Manstetten (2010) *Philosophical Basics of Ecology and Economy*. Routledge, London and New York. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical or photocopying, recording or otherwise without the prior permission of the publisher. The material is reproduced in MINE with permission of the Licensor through PLSclear (**Ref. No: 8528, licenced 03.01.2019**).

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