Wiser than the Vikings?
Redefining sustainability in the Anthropocene

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Abstract: Can the concept and science of 'sustainability' offer answers to today's crises? Crucial lessons can be learned from the fates of Viking and Inuit settlers in medieval Greenland. In spite of their advanced technologies and trade systems, the Viking collapsed, whereas the Inuit kept thriving. This case reveals that sustainability can be understood as a dynamic balance of three spheres: 1. biophysical processes (controlled by thermodynamic laws and astrophysical forces) generating life and evolution; 2. human narratives on the meaning of life, death and nature; 3. economic and technological processes ('justified' by those narratives) to access nature's offerings. Sustainability depends on a civilisation's capacity to adapt its narratives and its techno-economic systems to Earth's biophysical realities. The dominant Western narrative (implicitly) defines human progress as controlling life and exploiting nature, justifying ecosystem destruction. However, today emergent practices embrace narratives (re)connecting man with nature, and pioneer in regenerative economics; yet regime institutions keep them from gaining the necessary tract. How can sustainability science help to mainstream these innovative approaches?

Keywords: sustainability science; paradigm; Anthropocene; complexity; epistemology

Introduction

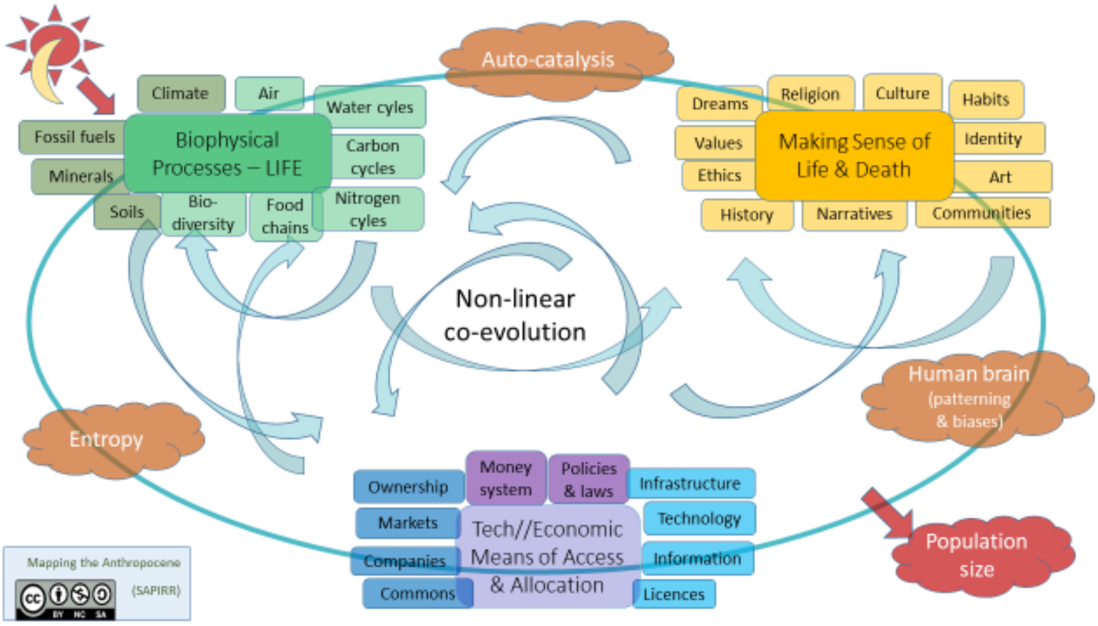
Scientists today agree humans have an impact on Earth's biophysical processes; hence they call our era the Anthropocene. There is some debate on the exact geological implications of the term and on the moral value of giving an anthropocentric name to a geological era (Crist, 2019), but here we use it to highlight the *responsibility* of humans for the state of the Earth ecosystem and the life depending on it. Human agency now takes us into a landscape unprecedented in human history: extreme levels of atmospheric CO_2, species loss at a much faster rate than natural, acidification and plastic pollution of oceans, etc. Sustainability science is conceived as a response to those challenges. The question is whether – or under what conditions – the concept and science of sustainability can help us to achieve the necessary corrections in due time.

Mapping sustainability in the Anthropocene

In his book 'Collapse' J. Diamond (2004) describes how some thousand years ago Vikings settled on Greenland, where an Inuit group also lived. After 450 years the Viking community starved to death, whereas the Inuit stayed alive and well. Their different fates teach us crucial lessons about what makes a civilization (un)able to thrive sustainably. The Viking considered their European way of life superior to the Inuit hunter-gatherer culture. With their bigger and more sophisticated ships they imported materials that were unavailable locally. They turned woods into grasslands, logged trees to build houses and churches, ate meat from the livestock they farmed, not seafood hunted at sea or traded with the Inuit. Archaeological evidence from the last phase of their life on Greenland shows no traces of any fish consumption, but reveals that the Viking ended up eating their calves and even their dogs before finally starving to death.

There is some discussion as to what explains the Viking collapse. Maybe it was caused by the fact that their economic and technological practices extracted resources from the land faster than the ecosystem could regenerate. Or the cause may have been external, such as a cooling climate. But why were the Viking unable to adapt to climate change while their Inuit neighbours did survive? And if their own practices caused their suffering, why did they prefer to hold on to them and die, rather than learn from the Inuit and survive?

Figure 1: Mapping tool for the Anthropocene



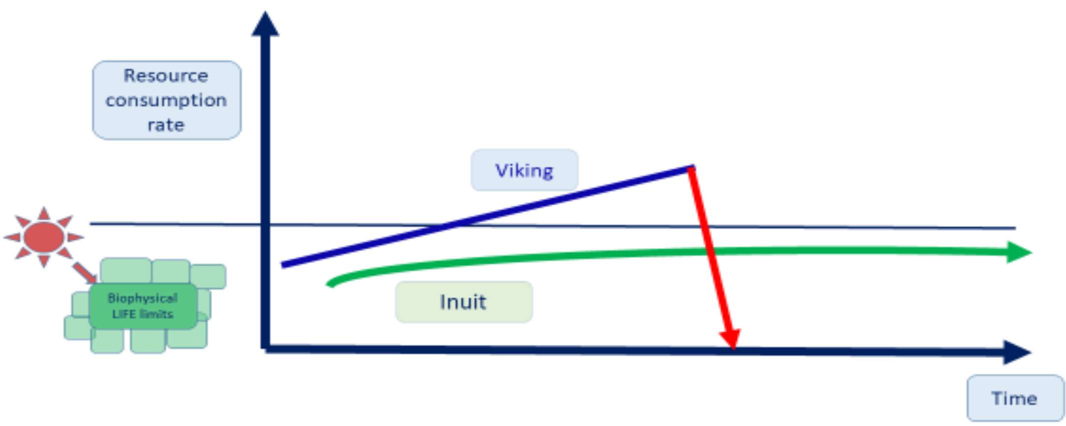
The story reveals the impact of the values and narratives a civilisation embraces. The way a culture defines its identity and its relationship to nature is at least as crucial (if not more) as the sophistication of its economic and technological means. If we map the elements allowing us to understanding the contrasting fates of Viking and Inuit, three spheres appear to be relevant (Figure 1). The first one is the **biophysical, life supporting sphere.** The energy of the sun and the gravity of the moon set in motion hydrological and climatic cycles that create(d) the conditions for life to emerge and evolve. Over millions of years, the interplay between chemical elements and life forms turning solar energy in biomass (photosynthesis) led to the **autopoiesis** (emergence) of soils, plants and animals organised as food chains, bringing about cycles of life and death continuously adapting and evolving. Humanity appeared only recently in this web, and with other species mankind has co-created a huge variety of bio-topographies (Crist, 2019).

The second sphere is the way humans **make sense** of this web of life. Since our **brain** cannot process the chaotic stream of stimuli our environment bombards us with, cultures have evolved as selection patterns, bringing order and meaning in this bewildering, awe-inspiring chaos (Lent 2017). Civilisations descending from ancient Indo-European tribes are built on the basic story that God created man in His image, as the culminating point of His creation. They see nature as God's gift to humanity, a mere resource for man to own and use as he wishes. Western culture today no longer invokes God to justify its objectification of life, but keeps enacting the credo of human supremacy as if it is beyond ethical questioning (Jasanoff 2018). It feels entitled to treat other life forms as matter, not as being worthy of respect. This narrative is so profoundly embedded in language, institutions and technologies, that it is no longer recognised as a deeply political discourse to justify the power man wields over nature; it is now considered a fact, taken for granted. The cosmologies of indigenous peoples, on the contrary, are built on respect for all beings and on restraint in exploiting nature. Their literature on human-nonhuman relations emphasizes reciprocity, kinship and gratitude. The idea that human progress is proportional to the amount of exploitation, destruction and alteration of nature is alien to them (Crist, 2019).

The third sphere concerns **economic and technological (E.T.) means** by which civilisations gain access to nature's offerings and distribute them among their members. Viking E.T.-systems were more complex and so dissipated available energy (in soils, plants…) faster than the Inuit ones, thus fuelling entropy at higher rates (Pogany, 2015). Today's global E.T.-regime dissipates (mainly fossil) energy at rates unseen in human history. It is anchored to money systems, laws, infrastructure, science, policies, etc. It reflects the credo that controlling nature is proof of our progress, lifting us above animals. In the guise of development cooperation and multilateral agreements (which all nations can join as long as they succumb to the basic credo), the West has imposed its vision worldwide, while glorifying this by calling indigenous people 'poor' and 'less developed' – early colonists tellingly called them 'animals'. This Western vision also drives the search for E.T.-systems that further extract value from and pursue mastery of nature (Harari 2015). The narrative is so embedded in systems regulating all aspects of our lives, that it is very hard to change them; many political and business leaders even call it '*unrealistic*' (Latour, 2017).

The Viking history shows that human evolution is not a linear progress (see Figure 2). For quite some time they were successful as traders, builders and farmers. This may have strengthened their sense of superiority, i.e. an escalating feedback which made it even harder for them to recognise their weaknesses and change course. This success reached a tipping point when (in a changing context) doing 'more of the same' did not bring more prosperity. Changing – e.g. by learning from nature or the Inuit – meant questioning their European identity and superiority, and this they could not do. If a civilisation is out of balance with the biophysical context, yet is unable to change its narratives, values and E.T.-means, collapse becomes a likely scenario.

Figure 2: Non-linear development of civilisations

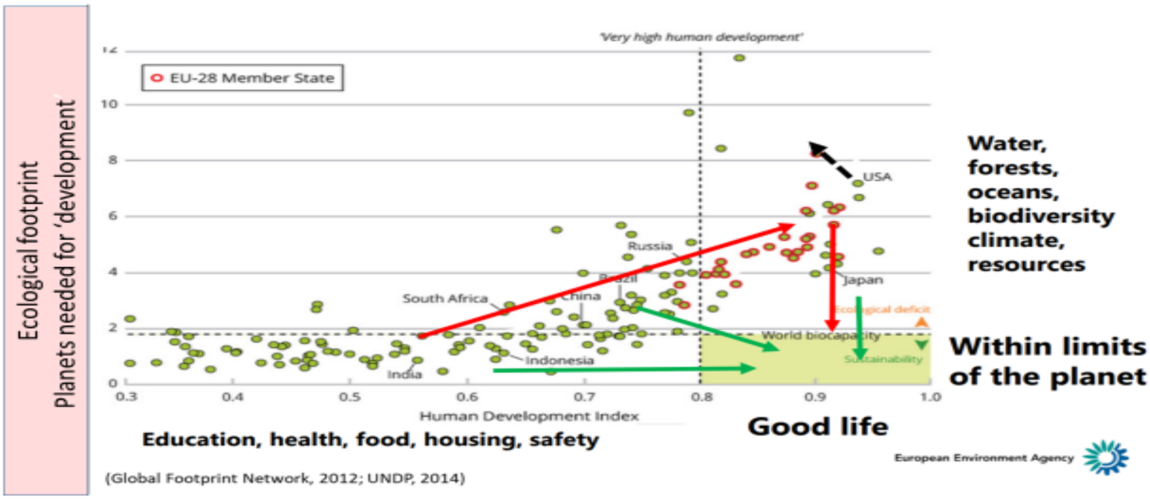


The initial success of a civilisation is also reflected in the growing size of its population. Yet the capacity of a biosphere to regenerate does not grow, as it is determined by the local availability of sunlight and materials (e.g. soils and plants) to store solar energy for human use. Once there are more mouths to feed than the landscape can support, more growth turns into a risk. Only if a civilisation keeps its population in check, it can remain in balance with nature (Crist, 2019).

Diagnosis of our time: are we wiser than the Vikings?

The European Environmental Bureau (EEB) published a graph showing the relation between the United Nations' (UN) Human Development Index (HDI) and the planetary footprint of nations (see Figure 3). The HDI combines metrics on education, life expectancy and income per capita, and is divided in ten steps. The planetary footprint shows how many times a country consumes what the Earth can provide. Not one nation ranking high on development operates within the limits of one planet Earth; most high HDI countries need more than four. To bring all nations to high levels of development *as defined by the UN*, we need at least four planets. This narrative clearly is out of touch with reality (Latour, 2017): the way development is defined does not take into account the Earth ecosystem humans depend on for their well-being, but implicitly embraces the vision of a godlike man, disconnected from Earth. Planetary overshoot is rooted in the view of nature as a divine gift that eternally provides us with resources, absorbs our waste, and flawlessly grows its regenerative capacities to keep up with our growing desires.

Figure 3: EEB graph on Human Development Index and its planetary impact



Current E.T.-systems no longer function as means for human and planetary prosperity. Instead economic growth and technological progress are now the *goal,* while people and planet are used as *resources*. One of the drivers of this means-ends reversal is the money system. Current money is created by banks (fractional reserve banking) in the form of a debt that has to be paid back *with an interest*; this means there is less money around than we collectively owe the banks, and so 'to make money' becomes the aim of all economic transactions (Pogany, 2015; Lietaer, 2011; Snick 2016b). Companies that do not make a profit, go bankrupt. And to keep up with a growing amount of debt-based money, the economy must continuously raise its productivity. Since this always involves (energy captured by) natural processes, planetary overshoot is inevitable: it is in fact designed into the system (Chang, 2011). Moreover, the social inequality between (owners of) the corporations that run the economic-technological system and the majority of mankind is increasing. What can also explain this EEB-graph, is the fact that in Western societal models, education, health care and income are organised by *redistributing* (via taxes) a percentage of economic production. In this system raising the level of development requires even steeper levels of extraction, beyond the limits of planetary and human health.

Economic growth and technological progress are interlinked. As growth exceeds the capacity of the biosphere, and resources get scarcer, research and innovation are needed to keep 'progressing', e.g. by inventing more aggressive technologies for extracting non-human life (like fishing or logging) or materials (e.g. fracking or mining). Growth can also be pursued by reducing the labour cost and making workers more productive; human resource management pursues that. Marketing uses insights in the working of the brain to nudge people towards more consumption. Planned obsolescence is a brilliant marketing strategy if you deny its impact on life. As especially technological R&I requires huge investments and money has to yield a financial return, new technologies in turn fuel economic activity. This escalating loop makes it harder for the E.T.-regime to change course and 'land on Earth' again (Latour, 2017).

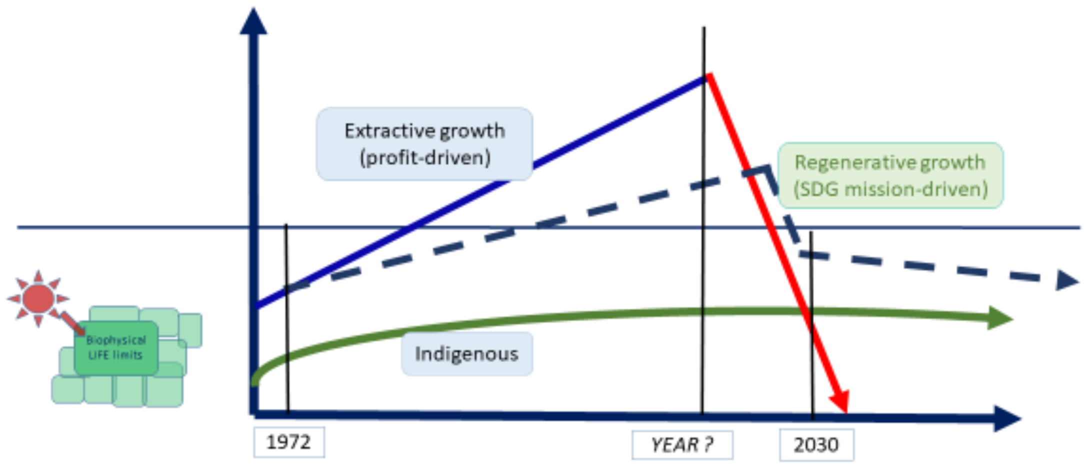
So, are we wiser than the Vikings? Our society is based on the *same* Indo-European belief system that frames man as a godlike creature and nature as a resource to exploit. Science freed itself from the censure of the Church, yet never questioned the credo that man is apart from nature; scientists are even idealised as objective observers and smart managers of the Earth. Modern science does not question the assumption that man has the right to destroy nature or engineer other life forms to pursue his aspirations in total academic freedom (Jasanoff, 2018; Crist, 2019). Our *more advanced* systems have done *more damage* to the planetary ecosystem than the Viking ever did. So, we can only claim to be wiser if we stop doing 'more of the same' before critical thresholds are reached, and if we learn from healthy ecosystems and from indigenous wisdom.

Today there are many signs that this learning is indeed taking place. Citizens and entrepreneurs no longer trust (unethical) banks or corporations to manage their affairs. New models of ownership switch from extractive (pursuing 'value' for distant shareholders) to cooperative businesses, owned by and working for the local community (Kelly, 2012). Biomimicry-based inventions (mimicking the biosphere) increase our natural intelligence and make us understand that 'it is only an investment if it leaves the world better off' (Gorissen, 2019: 2). Entrepreneurs and social innovators design companies that are mission-driven instead of profit-driven, at the service of the common good (Wahl, 2017). A growing group of researchers, political leaders, entrepreneurs and citizens look towards the commons as a sustainable system for governing shared resources (Bollier & Helfrich, 2019, Ostrom, 1990). NGO's and companies learn from the wisdom of indigenous people in the global South, and focus on strengthening their local agro-ecological knowledge and practices (Azurduy, 2019). Local monetary systems are spreading worldwide (Lietaer, 2011). Novel accounting systems no longer externalise the ecological impact of transactions, but reflect the real state of the ecosystem (Bauwens, 2019). The soundness of using GDP as an economic measure is called into question (Raworth, 2017). With (financial and other) support from a community of local users, agro-ecological farmers learn to produce and distribute food sustainably. Sharing initiatives are getting more and more widespread.

The list of initiatives that break away from the old narrative and explore new ones (inspired by nature and/or indigenous wisdom) is growing steadily. This shows our capacity to learn; we are adapting our vision of the good life, learn to find value in restriction and frugality, and diversify our pathways for achieving a quality life with healthy restraint. This desire to change course is visible in the Global Agenda 2030 the UN adopted in 2015. It lists 17 sustainable development goals (SDGs) that are not a choice menu of separate aims, but an interconnected agenda in which each goal must also foster (or at least not damage) the other goals. The agenda has been criticised because it includes economic growth (SDG8); this is seen as a sign that corporations sabotage the

Agenda by having their private goal integrated in it. Yet, what makes the SDGs a strong leverage is that they are proposed as a *global* and *interconnected* agenda, not just for the global South but also for the North. This installs a built-in self-correcting mechanism, for if growth is still defined in a way that threatens other goals (extracting profit at the detriment of justice and ecosystems), it is *not the kind of growth the UN agreed to*. The Agenda can be a leverage for reorienting the economic system; instead of increasing our extractive capacity, SDG8 can only refer to humanity's *growing capacity* to create well-being for all while restoring healthy ecosystems, and to redesign institutions, cities and technologies accordingly (Snick, 2017).

Figure 4. Diagnosis of our time



The diagnosis of our time thus reveals a mixed picture (see Figure 4). No doubt the extractive scenario (the top line) remains dominant and the regime keeps moving towards tipping points (collapsing ecosystems, loss of soils, disturbed climate patterns, mass migration, etc.). On the other hand, an abundant wellspring of niches (the dotted line) explore and learn how we can 'land on Earth' again and live sustainably in an ethical and socially just way. The question is now whether (or under what conditions) the *concept and science of sustainability* can be helpful for our civilisation to leave the extractive model and shift to the regenerative pathway in time.

Does science make us wiser than the Vikings?

Even a superficial look at the literature shows that the sustainability concept is used in often contradictory ways. In broad lines, sustainable development can refer either to efforts to sustain the dominant vision of development and growth (weak sustainability), or to efforts to adapt our vision and allow life on Earth to sustain itself (strong sustainability). The first approach leaves the basic narrative on man's supremacy and his entitlement to exploit nature and other beings unquestioned. It aims at incrementally improving the E.T.-system so as to allow for 'sustained' extraction even in a planetary and social context showing alarming signs of exhaustion and depletion. Weak sustainability 'improves' the dominant E.T.-system without looking at its deeper structural flaws, its false assumptions or questionable ethics.

Strong sustainability, on the contrary, is more like 'learning from the Inuit', for it implies questioning the values inherent in the current system. It does not just treat symptoms of crises, but addresses their root causes. Root in Latin is radix, so this is a more 'radical' approach. It invents regenerative designs, community currencies, commons, and so on., E.T.-tools outside the dominant framework. Their outlying position makes it hard for the regime to recognise or support them; they don't fit the normal narrative, and may be perceived as untrustworthy or subversive. The term 'radical' is often associated with negative connotations that overshadow the ethical concerns and deep respect for life that drive the pioneers. In this complicated, tangled linguistic and institutional field, sustainability science has to find its own position.

Before we look at the impact of the sustainability concept in science, it is useful to first describe the current R&I system in terms of the Anthropocene map (see Figure 1). Historically R&I is embedded in institutions that study (aspects of) only one sphere. Natural sciences specialise in elements and dynamics of the biophysical system. Narratives and values are considered the domain of humanities. The E.T.-sphere is split up among branches of applied sciences (e.g. economics), engineering sciences and disciplines studying specific social institutions (politics, law, etc.). Epistemology and ethics are institutionalised as subdomains of philosophy, not as the capacity and obligation of *all scientists* to reflect on the ontological and normative assumptions of their research. If courses on ethics and worldviews are part of the curriculum of natural and applied sciences, students often see them as an add-on find hardly relevant for their field, not as disciplines that help them to understand how their field can be made more relevant for society.

The current academic system was built (in the Middle Ages, i.e.) during the Holocene, and this has a profound impact on its underlying ontology and epistemology. A paradigm is a set of rules and conventions agreed upon by the scientific community; it defines valid ways to do research and sets parameters for assessing scientific progress. The medieval scientific paradigm was based upon the credo that – as stated in the Bible – God created all that exists, and that creation must reflect God's perfection. Planets were believed to move in circles, since that is the most perfect geometrical form. This premise did not allow to predict planetary movement accurately; such unpredicted phenomena are called anomalies, and they reveal flaws in a paradigm (Kuhn, 1962). Yet, for fear of being excluded from the scientific community, medieval scientists did not reject the normative model, but 'improved' it by adding more circles (epicycles), i.e. by doing 'more of the same'. Astrological maps became extremely complex compilations of epicycles upon epicycles, and so science made progress and grew successful in predicting planetary movements accurately. When Galilei (who had access to a new lens: the telescope) proposed the ellipse as a more appropriate model (eliminating anomalies), he did not *improve* the paradigm but *replaced* it; this is what distinguishes normal scientific *progress* from scientific *revolutions*. Galilei was excommunicated and only rehabilitated 350 years later; yet meanwhile the ellipse has found its way into the academic mainstream, allowing new generations of scientists to 'progress' again.

Universities were not designed in the Anthropocene, but have their roots in the previous era, the Holocene. That started about 12.000 years ago when the climate on Earth stabilised; this meant humans were no longer forced to roam the continents to find food, as in previous eras when ice ages and interglacial periods radically shifted ecosystems. It allowed them to invent agriculture, build settlements and cities, where writing and culture developed. In this stable context, modern scientists assumed reality could be studied in separate units. They studied the impact of changing parameters in one field of reality, while all others (ceteris) were believed to be unaffected (paribus). Scientific progress led to the division of reality in ever smaller sub-specialisms disconnected from the larger picture, i.e. the intertwined and complex dynamics that allow for the evolution of life on Earth. On this small, disconnected scale, it is possible to find regularities and express them in mathematical equations. The *eternal* truth of mathematics feeds the idea that science reveals *objective* truths about reality, laws of nature. Scientific progress was associated with quantitative methodologies, while qualitative aspects of life were dismissed as 'subjective', belonging to the domains of arts and religion, not science. Even in humanities the tendency towards quantitative methods to process 'data' is growing, revealing the power of the Holocene paradigm. Modern economics aims at laws that are called valid 'ceteris paribus'; all aspects that do affect other fields of reality are treated as 'externalities', not to be accounted for.

The splitting up of reality into faculties and laboratories in 'ivory towers' remains the norm today, and the stability assumption lives on. Most scientists and engineers assume that an innovation with a proven positive effect in the laboratory (where other parameters are kept stable), when rolled out at large scale (i.e. by 'bringing it to the market') will lead to a positive impact in society. Applied science and technology are deeply indebted to the specialist approach. In stable contexts causality appears to be linear (if A Then B), which allows scientists to predict and control the outcomes of their experiments (if more A then more B). Since (only) at this small scale stable correlations can be found and outcomes predicted, the current system of technological innovation is in fact a brainchild of the Holocene. The financing of research and innovation is still mostly based on the division between 'pure' science (deemed to discover objective truths about the workings of nature) and 'applied' science (using those insights and exploiting them for improving life and economic growth). The amazing inventions resulting from technological progress can be taken as proof of the (initial) success of this paradigm.

The many current man-made crises are in fact anomalies challenging the Holocene (specialist) paradigm. The debacle with antibiotics – once a great innovation in the laboratory, now one of the major health risks worldwide – was not predicted (and certainly not intended). In their laboratories researchers determined the effect and safety of this medication at the level of the individual patient, yet did not control the real impact of massive dissemination (fuelled by the profit urge of pharmaceutical companies, and affecting consumer expectations and prescription habits) in an interconnected world. It resulted in infiltration of antibiotics in the ground water, undermining the immune system and creating the conditions for mutations that brought superbugs, antibiotics-resistant bacteria. This is a wicked (non-linear) problem: yesterday's solution turns out to be today's problem. Rolling out 'more of the same' is not a solution (given bacterial antibiotic resistance), yet it appears very hard to do 'something else' given the tremendous power and strong institutionalisation of (scientific, pharmaceutical, economic, cultural…) regimes and paradigms.

Many technologies show the same flaws: they are tested in laboratory settings (with a narrow risk analysis) at a small scale (e.g. the individual consumer). The effects of their large-scale dissemination (or 'translation') on the complex co-evolution of life cannot be judged in a laboratory setting, unless the lab is taken outside the ivory tower and brought into complex real-life settings. The availability of a technology may alter people's expectations or habits in a non-predicted way, and this in turn may have a huge influence on the impact the innovation finally has. There is a growing understanding that non-academic actors should no longer be excluded from science. Foreseeing societal impact and judging acceptable levels of (systemic, large scale) risk can only be done in transdisciplinary setting using a complexity lens, i.e. anticipating as much as possible interferences with and feedbacks from other spheres. These feedbacks include not only the effects e.g. of medication on soils, water and evolution (even if mutations cannot be foreseen); they also involve values and narratives, e.g. in terms of our changing expectations concerning health and ageing, our readiness to organise types of care that foster the self-healing capacity of our bodies, our communities and our ecosystem, etc. Plastic, an 'initial success' in terms of consumer comfort, turns out to be deadly for the oceans, those crucial wellsprings of food for countless species and regulators of the climate. The same goes for electronic devices, fertilizers, nanotechnologies, pesticides, cars, etc. Wicked problems occurred not because the techno-scientific system planned them, but because it was (and still to a large extent is) blind to the systemic interdependence and complex dynamics of life. To address the current crises and contribute to Agenda 2030, science, technology, engineering and mathematics are needed, but only if they are embedded in a complexity-based (non-Holocene) paradigm and based on (or inspired by) an ethical, responsible relationship with life on Earth.

The second industrial revolution allowed for large-scale extraction of materials and for the mass production of consumer goods. Since the 1950's this model was rolled out globally (in answer to companies' need for growing markets), and led to what is called 'the great acceleration' (McNeill & Engelke, 2014). It brought world population growth and a comfortable life for many people, but at the cost of massive ecosystem depletion. This makes competition for resources more and more fierce, fuelling geopolitical tensions (Krastev & Frank, 2015). Instead of changing its narratives so as to restore peace (with nature and other humans), Western culture now simply defines human beings as competitors in pursuit of self-interest, and sees education as a leverage for this. At a recent academic congress on 'rethinking global engagement', former EU-president Van Rompuy (2019) stated that 'Europe's projected skills shortage risks being further exacerbated as the global geography of human capital shifts East, and competition to attract talent intensifies. We need popular support for accepting more skilled economic migrants'. In other words, after the grab for Africa we now proceed to the grab for Africa's and Asia's talented children, to be deployed in the economic war of Europe against their countries. This is presented as an evidence, not as a dubious social construct (Crist, 2019; Snick, 2016a).

Many of the world's outstanding academic institutions play a leading role in this 'race to the bottom'. The loss of a stable climate and of stable stocks of almost everything (biodiversity, soils, pollinators, materials…) is at the heart of current societal crises. These cannot be tackled by adding 'epicycles' to the same kind of thinking, but require a new (complexity based) paradigm. The question is now: does the concept and science of sustainability enable the research and innovation system to adapt and embrace such a new paradigm?

Does sustainability science offer new perspectives?

Current crises started reaching the front pages of newspapers only recently (with dramatic fires and school strikes), but the risks have been visible for half a century. As early as 1962 biologist Rachel Carson (1962) warned for ecological damage due to the agro-industrial use of pesticides. Since in 1972 the Limits to growth Report to the Club of Rome was published (and sold thirty million copies in thirty languages), academic, political and economic leaders were *informed* that the extractive scenario is unsustainable (Meadows et al., 1972). Clearly the crises were not unpredicted or unforeseen at all, yet this knowledge did not lead to a real questioning of the system. Often the scientists who warned for the risks were not taken seriously. The assumption that more understanding (through science) allows humans to adapt (and bring societal progress) underestimates the complexity of change, and is blind for the many interconnections that keep the system locked in. Understanding these complex and non-linear dynamics is key for humans to adapt; how to do this with a research systems that is mostly designed to *reduce* complexity?

Yet, in response to the early warnings, pioneers have started to propose adapted scientific approaches. Systems thinking was developed in order to better understand the interdependency between human and natural subsystems and to explore leverages for change (Meadows, 2008; Midgley, 2000). Ecological economics study how economic systems can take entropy into account (Georgescu-Roegen, 1971). Yet, as a whole the academic world has been very slow to accept this holistic paradigm, and remains locked-in to the specialist progress-view. Many researchers and research groups propose new (systemic, transdisciplinary) ways to tackle complex challenges, but these often remain isolated initiatives that do not affect academia as a whole. In general, the extractive economic model (and the technological regime supporting it) is still the main approach, with some 'radical' alternatives as side-branches.

The division of sciences into separate siloes and its institutionalisation in medieval structures in fact makes it very difficult for science to contribute to the co-creation of adaptive pathways for strong sustainability (Chapman, 2015; Crist, 2019). If sustainability is integrated in academia, very often it is (just like ethics) 'neutralized' by reducing it to a new discipline or specialism (often in the natural sciences). It is not taken as a paradigm for all science in the Anthropocene, one that requires it to break out of its siloes and to redefine its aim from 'increasing competitiveness' to 'reinforcing societal and natural wisdom and peace'. Most solutions proposed by the R&I system therefore can only be qualified as weak sustainability. Some examples can illustrate this.

A lot of research in (or for) sustainability focusses on 'green technologies'. Because of their enclosure in disciplines, with a lens focusing on one subsystem and blind for interactions with other subsystems, most solutions are mere improvements of the dominant paradigm, adding social and ecological corrections as epicycles, but leaving the basic model unchallenged. This system-blindness feeds e.g. the belief that replacing fossil energy by renewable energy will allow for continued (or 'sustainable') economic growth. The reasoning is that solar energy is unlimited and imposes no limits to growth. What is overlooked, however, is that to be useful for humans, solar energy has to be captured and stored by material interfaces. Solar panels, grids and batteries are needed to make solar (or any kind of renewable) energy run our machines. Most minerals needed to capture and store renewable energy are scarce and non-renewable; so for all practical purposes, solar energy is *not* abundant but just as scarce as those materials (Pogany, 2015). Switching to green energy may at best solve one problem (CO2 emissions), but at the cost of creating a range of others (mining, pollution, displacement of human and nonhuman populations, geopolitical conflicts over resources or markets, etc.). Moreover, by presenting any kind of renewable energy (including hydrogen) as clean and abundant, societal expectations and consumption patterns may well go up (a rebound effect), leading to an escalation of extraction, transport and pollution, and causing an accelerating destruction of ecosystems.

A solution often put forward to address resource depletion is to find new materials (including mining other planets) to substitute for scarce ones. There is no economist who really believes all resources (minerals, rare earths, metals, …) are renewable on a human time scale. Many of these materials were deposited during the formation stages of our planet, and geochemists have a quite accurate idea of how much of them (including soils) is available in locations where it is economically sound to extract them (i.e. where extraction does not cost more than can be gained from it) (Sverdrup & Ragnarsdottir, 2014). The tipping point for (profitable) extraction of most materials is foreseen around 2030. Those scenarios are based on current extraction rates, and do not take into account the impact of more countries aspiring Western life styles. We are creating cultural addictions that increase the global demand at a much faster rate than (even exoplanet) mining will ever be able to fulfil. So, substitution is not a solution for the problem, but an acceleration (Rosa 2013). It means we are creating expectations and infrastructures that require resources we know will be unavailable in about ten years.

Moreover, we are very busy creating a massive amount of electronic waste with chemicals leaking into the environment; processes like corrosion and osmosis cannot be stopped. This has disastrous effects on the beaches in the South where our old electronics are dumped and plastic washes up. Scientists and entrepreneurs now propose the circular economy as a way towards sustainable growth. This may be a good solution at the scale of a company or sector (extracting *more* value from *more* waste). But since it does not get rid of the growth imperative, the result is only relative decoupling (using less resources per unit of growth), not a decrease in the total use of resources (absolute decoupling). Given the laws of thermodynamics a really circular economy (without waste and dissipation of energy) is impossible on this planet. Launching our machinery in orbits away from the planet is no solution either, as gravity makes old satellites and spent rocket stages collide and disintegrate, increasing the risk for new space crafts to be destroyed by a collision with man-made orbital debris. Given gravity, space debris can only spread further.

It is remarkable that in the lab scientists use rigorous methodologies, but when it comes to judging the impacts of their innovation on society (when rolled out at large scale), their claim is that they *believe* them to be beneficial. They rarely present this as a hypothesis to be put to the test with the same methodological rigour; it is stated as a truth claim. This is complicated by the fact that complex systems may have different behaviours at different scales. Climate change, e.g., makes people suffer from heat waves, and a '*normal*' solution is to produce air-conditioners to stabilise the climate in houses. Since these devices require energy – for mining the materials, for producing, transporting, running the appliances and cleaning up the waste when discarded – they contribute to an increase of gashouse emissions and thus to even hotter summers: a vicious circle. A balanced system at small scale (house) leads to an escalating system at a larger scale (climate). To design a solution that takes into account planetary dynamics as well as human responsibility in the Anthropocene, the first question is: is it better to produce *more* (maybe 'greener') air-conditioners, or on the contrary to *avoid* the production and sales of appliances, and instead focus on ecological ways to keep the climate stable (e.g. reforestation)? Yet today no company (or for that matter research institute) can survive if its aim is to sell as little as possible. The current economic and financial system forces societal actors to conceal systemic risks or ecological solutions (such as reforestation), and to present further growth (consumption) as evidently beneficial. For science to contribute to strong sustainability, its primary focus should be on redefining its paradigm; it should join forces with pioneers in society for co-creating regenerative cultural models and adaptive economic, legal and financial tools. Only under those conditions will it be possible for scientists to make sound judgments about how beneficial new technologies can be, what risks they imply, and how to govern them responsibly and ethically.

Sustainability research hardly ever thematises the growth of the world population as a risk for our chances of survival. Population control cannot be achieved by *imposing* technical solutions, but that doesn't mean it can be neglected as a driver of planetary depletion. The size of the world population influences how much pressure man puts on nature, and for mankind to live in harmony with species that depend on extended wild landscapes, population should shrink to a more reasonable level. Evidently, until the population sets at a lower level, the demographic pyramid will be upside down, with few children at the bottom and a large proportion of older people at the top. This requires a thorough rethinking of aging policies and care systems; yet using a complexity lens reveals more pathways for rethinking policies, enables us to think outside the box of current pension systems and invent new care systems (Snick, 2019). Scientists often treat population growth as inevitable. Others see longevity it as a desirable goal, feeding man's dream of immortality, and do not ask how this impacts demographics (Harari, 2015). Some refer to it as a 'factual' justification for increased extraction, e.g. via industrialised or bio-engineered food production and a more aggressive exploitation and alteration of nature.

All these examples show that although sustainability is appearing on the research agenda, it is approached predominantly from within the Holocene paradigm (i.e. weak sustainability). Even if some universities start with more radical transdisciplinary, systemic approaches, these are not rolled out university-wide. In almost all of higher education the mainstream economic model is still taught as the normal (normative) one, while regenerative inventions are treated as marginal.

A perspective on strong sustainability

Physicist Max Planck once said science advances 'one funeral at a time', meaning that a new scientific truth does not triumph by convincing its opponents, but because these opponents eventually die, and a new generation grows up that is familiar with it. However, climate change and species loss do not wait for retirements, and academia has to step up its efforts. Radically alternative pathways for education – supporting SDGs – are slowly emerging. Since 2016 a Belgian university college (Howest) has developed an educational program for 'Network Economics', training students to set up regenerative entrepreneurial initiatives (including community currencies as a tool). The Copernicus Alliance, a European network of higher education institutions committed to transformational learning for sustainability, offers its members a platform for exchange and mutual learning. Some European research projects on Responsible R&I (RRI) have explored ways to embed strong (i.e. complexity-based, common good-oriented and co-creative) sustainability research in the R&I system (Snick, 2017). But can these initiatives have the needed impact in due time?

In the words of Planck, a new truth can only triumph if a new generation grows up that is familiar with it. So, for our civilisation to shift to a sustainable pathway, a new education is key. Sustainability should no longer be enclosed in a specific field of study, offered to students as a mere option in addition to the 'standard' package. Every young person should understand why the current course of society is like walking in the footsteps of the Viking; they should also learn that today other pathways are being explored, with a sustainable, peaceful world (SDGs) on the horizon. They have to be told that other economic systems exist, even if they are still fragile and fragmented and struggle to be accepted by the (economic, legal, cultural) regime. To keep that information from them and to present the extractive model as the only realistic one is immoral, for it robs them of their freedom to imagine more promising futures. Young people must be freed from the pressure of the extractive and competitive regime, and be allowed to co-create a future in peace and partnership (SDGs 16 and 17) with nature. They should be given the freedom to learn from indigenous wisdom, and be empowered to design regenerative practices.

Typical higher education classrooms are auditoria. Through their very architecture these spaces convey the message that the teacher in the front 'knows' while students (passively, individually) 'learn'. This design is no longer adequate. It is at best suitable for letting students master small (relatively stable) parts of reality that can contribute a part of the complex puzzle we need to solve today. But for education to bring about a radically better society the auditorium – like the laboratory – is no longer the place to learn. We know for sure the future cannot be an extrapolation from the past, as the tipping points threatening our civilisation are approaching faster than foreseen. If young people are to learn how to thrive within nature's boundaries, the best teachers are nature and the indigenous people who for centuries (until Western economies started intruding in their world) lived in harmony with their environment. The best laboratories for exploring the future are the regenerative initiatives and new economic practices that emerge in an SDG-inspired world. They can encourage students to think outside the (academic) box, acquire holistic knowledge, and shape social entrepreneurship supported by regenerative financial, technological and institutional tools. Many of those leverages are yet to be developed, so academia should have a lot to contribute. Higher education for a sustainable future has to be nurtured by four 'placentas' – allowing new life to grow without controlling it:

1. HOPE. Young people today are overwhelmed with scary news about what's wrong with society and nature; they hear that the lifestyle they cherish will no longer be possible. These negative messages lead to reactions of fear and denial. In order for them to open up to alternative futures, an inviting and nourishing environment is needed (Lipton, 2008). Field trips (to nature, to regenerative initiatives or indigenous communities) or service learning therefore are powerful learning settings: they give students hope by showing in real life that the alternative is there and that it is promising (even if still fragile). Universities should stop immediately teaching the extractive economy as the only 'realistic' one, for (in more than one respect) this is a lie, fake news. Student initiatives like Rethinking Economics are important partners in this. Also, the perspective of reducing the human population to a level in balance with the ecosystem should be presented as a hopeful one, and not as undesirable or unfeasible, as this would restrict their freedom to imagine other futures.

2. COMPLEXITY. Young people (and teachers) should be familiarised with systems thinking. This cannot be done by just reading theoretical works on complexity, as it requires skill and daily practice, not unlike learning to use a compass. This should protect them from the fallacies of linear (Holocene) thinking and help them to be more prudent as future leaders, researchers, entrepreneurs and citizens. In the Anthropocene, we have to learn to 'dance with the system' (Meadows 2008) and accept unpredictability as an opportunity to be creative. Learning to 'embrace complexity' can be practiced in playful and fun ways (Booth-Sweeney & Meadows, 2010) and by using mapping tools on various issues in many settings.

3. STORIES help young people to reflect on deep values and (blind) assumptions, and to discover other narratives. Stories do not just speak to the brain, but also to the emotions and the empathy of learners; that makes them into powerful ways to envisioning other futures; they allow learners to *feel* what it could be like, and stimulates both brain halves. Inspirational stories can be about how nature regenerates after the reintroduction of key species (Caroll, 2016), on people learning key lessons about life, or on the people and non-human beings whose history was silenced by a supremacist culture (Kingsolver, 2000 & 2012; Powers, 2018). It can help them to envision a future where the human population is again on a sustainable level and where

people express their love for children in other ways than by putting their own offspring on an already exhausted planet.

4. COCREATION. The term 'Anthropocene' should keep us aware that humans co-create life on Earth together with others species and are responsible for it. Co-creation is an ongoing, iterative and dynamic process of self-reflection and adaptation, especially in an unstable, post-Holocene context (Chapman 2015). Preparing youngsters for the future requires active (not passive) and collaborative (not competitive) learning. Involving students as co-experts in transdisciplinary research projects can be a powerful way to achieve this (FoTRRIS, 2018).

This last paragraph is not to be understood as a final conclusion of a closed set of arguments, but as a proposal (or hypothesis) for further reflection and research. What higher education and research in the future could look like, is itself a matter of co-creation, not an eternal truth.

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