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A systems-theoretical perspective on sustainable development and indicators[1]

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Abstract

The present chapter adopts a normatively distanced perspective on the issue of sustainability and its indicators. Taking our lead from the German sociologist and systems theorist Niklas Luhmann's writings, we argue that the disappointment manifested by many scholars and activists concerning the actual use of sustainability indicators in policy-making comes from a underestimation of the complexity of the modern society. The modern society's complexity lies in its (horizontal) differentiation into several, autonomous, operationally closed subsystems (law, science, the economy, the mass media, etc..) structured around a binary code (legal/illegal, tradable/ non-tradable, new/old…). These different subsystems are open and structurally coupled to each other but not to their natural environment. The relation between society and nature is mediated by technology. Social systems observe each other with indicators, which are condensations of expectations with respect to the social environment. They make use of indicators if they change their structures and programs according to their own observations and they are influenced by indicators if they react to the way they are themselves observed by their environment. The recent burgeoning of sustainability indicators, sustainability impact assessments methods and practices, etc., can be sociologically interpreted as the progressive emergence of a new functional system structured around the sustainable/unsustainable binary code. Whilst being a further diversification of the modern society, such a process would however overcome the current trade-off between complexity and sustainability, responsible for the coming ecological disasters.

1. Introduction

With the publication of the Brundtland report in 1987 (WCED 1987) and, more solemnly, at the United Nations Conference in Rio in 1992, the (world) society (Luhmann 1997) formalised a new way of observing itself and, in so doing, institutionalized a new self-description. From then on, society was to regard itself as "unsustainable". During the three decades following World War Two, the possibility of a nuclear war between the two opposing blocks had already given rise to a worldwide anxiety about the prospect of humanity destroying itself through the obliteration of its living environment. Likewise, a new way of observing the relations between society and the

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natural environment had become apparent in the early seventies, with several now almost legendary publications such as "The Limits to Growth" (Meadows, Meadows, Randers and Behrens III 1972), "Blueprint for Survival" (Goldsmith, Allen, Allaby, Davull and Lawrence 1972), "The Population Bomb" (Ehrlich, P. 1972), "The Closing Circle" (Commoner, B. 1971), and other less famous manifestos. At the end of the eighties, following the collapse of the communist block, the world society was confronted to a new challenge: becoming at once fully global and fully developed. The challenge was that development, as it was understood, could not become global without putting in peril its ecological basis but, at the same time, development that could not be extended to the whole humanity was not considered real development. A new model of development was to be imagined that could be shared by all people immediately without jeopardizing the future. This was called "sustainable development". As a result, at the 1992 UN Conference on Environment and Development, in Rio-de-Janeiro, 178 countries adopted the Agenda21 action program by which they committed themselves to a host of resolutions and actions deemed able to put the world society on the path of sustainable development. Among these measures was the identification and use of indicators (see Dahl's chapter). The use of indicators for assessing sustainable development is called for at several places in Agenda 21. It is mentioned in particular in chapter 8 ("Integrating environment and development in decision-making"), with article 8.5 stating that: «Countries could develop systems for monitoring and evaluation of progress towards achieving sustainable development by adopting indicators that measure changes across economic, social and environmental dimensions". (This, incidentally, is one of the earliest mentions of the so-called 'three pillars of sustainable development'.) Indicators were also called for in almost every chapter of section 1 ("Social and Economic Dimensions"), in chapter 35 ("Science for sustainable development") and in article 40.4 where one reads that "Commonly used indicators such as the gross national product (GNP) and measurements of individual resource or pollution flows do not provide adequate indications of sustainability. Methods for assessing interactions between different sectoral environmental, demographic, social and developmental parameters are not sufficiently developed or applied. Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems". As a consequence, from 1992 onwards, we have witnessed an important intellectual and financial investment in the production and discussion of indices of sustainability and sustainable development and the development of conceptual frameworks for the cognitive and normative integration of those indicators in the assessment of progress towards SD. Despite undeniable achievements in both domains (as this book testifies), there is a widely shared sentiment amongst researchers and activists in sustainable development that this increase in "ecological communication" has not delivered the expected (officially, at least, by the countries that endorsed the Agenda 21 program) changes in political and economical practices (Gudmundsson, H., Lehtonen, M., Bauler, T., Sebastien, L., & Morse, S. 2009 ; Lyytimäki, J., Gudmundsson, H., & Sørensen, C. H. 2014 ; Lyytimäki, J., Tapio, P., Varho, V., & Söderman, T. 2013). It is nowadays common knowledge that the relation between information and decision is not the simple, linear, straightforward one assumed by the rationalist theory of decision. In this context, indicators, even if not explicitly mobilized in the policy-making process, can and do influence it in several ways

(Boulanger 2007; Gudmunsson 2003). The success of the somewhat naïve calls for "evidence-based policies" – admittedly, in less obfuscate domains than sustainable development – has not come without criticisms (Saltelli and Giampietro 2017). We have recently come to a more realistic, less utopian understanding of the relations between knowledge in general, indicators in particular and policy-making. We now know that the path from evidence-based policy to policy-based evidence is short, and at times the two are difficult to distentangle (Saltelli and Giampietro 2017). Yet we still lack a theoretically-based interpretation of the adequacy or otherwise of indicators generally and this is even more the case in sustainable development. Various classifications of the types of indicators (descriptive, normative, etc.), of theirs use or misuses, of their influences, consequences, etc. are mostly derived from inductive reflections and, on the whole, they lack the consistency and explanatory power of observations which one would have if a general theory were to be available. On the other hand, one may think that the way in which these issues have been dealt with so far has been overly influenced by what some have called "unreflected normativity"[3] (Irwin 2006). If there is no shortage of reflections that are anchored in Habermas' or other philosophers' perspectives on communicational rationality, the ethics of discussion, on deliberative democracy and on democratic participation, we will probably never have too much of that kind of "reflected normativity". Yet, what is probably lacking the most at this moment is an uncompromising "reflected positivity". What do we mean by that? We invite our reader to follow us in an analysis which takes its lead from a thinker who can be considered the anti-Habermas par excellence: the German sociologist Niklas Luhmann. Luhmann's absence of claim to normativity - a position that could be described as ambitious modesty (King and Schüt 1995) - should enable us to adopt an "... analytically sceptical but not dismissive perspective" (Irwin 2006, p. 300) on the whole SI industry. The excessively (?) abstract nature of Luhmann's theories allows us to escape the traps of an overly "politically correct" view point as well as, hopefully, put aside for a moment our own axiological commitments. Hans-Georg Moeller maintains that"…Luhmann's social theory is the best description and analysis of contemporary society presently available" (Moeller 2012, p. 3). Without going as far as Moeller, we note that a growing number of sociologists find in Luhmann's writings one of the deepest, far-reaching and sophisticated sociological theories of society.

The present chapter is organized as follow: as introduction, we briefly present Luhmann's vision of modern society as functionally differentiated, his theory of systems as the unity of a distinction system/environment, and the concepts of autopoeisis and operational closure. We conclude this section with a characterization of sustainability as a problem specific to modern society that has to accept a trade-off between the necessary reduction of the complexity of its environment and its environmental sustainability, an avenue already explored by Vladimir Valentinov. The next section deals in more detail with the way functional subsystems are structured around a binary-code that regulates all their communications. It introduces the concept of "structural coupling" which describes the relations they maintain with each other and gives an interpretation of indicators as structures (i.e. condensation of expectations) used by systems in observing each other and observing how others observe them. This enables us to formalize in a system-theoretical way

[3] And we don't clear one's name from the grievance.

the difference between use and influence of indicators. We then turn to the problem of the structural couplings (if any) of society with its non-social environment. We argue that the reduction of its complexity is taken care of by technology, in fact by a whole machinery of reduction of the complexity of natural non-living and living systems or aggregates. This leads to the question of the reference class of sustainability indicators: is it nature as such or technologies and therefore decisions on technological choices and their risks? Going back to indicators, we show that they are also technological beings and therefore complexity reduction devices, as "forms" in Spencer-Brown sense and as punctuations (discretizations) of continuous processes. After having summarised some of the ideas and arguments presented in the whole chapter in a section devoted to the Ecological Footprint, we conclude with some prospective considerations on the possible emergence of a new fully autonomous autopoietic functional system in charge of the survival of the world society (as a functionally differentiated one) thanks to the handling of the binary code "sustainable/unsustainable" and its programs (sustainability assessments methods and models) and structures (indicators).

2. Why (or how) is modern society un-sustainable?

While the world society that began observing itself through the sustainable/unsustainable distinction was not wholly developed, it was nevertheless roughly "modern". At least, there was a universal consensus on the fact that it was impossible not to be modern because there was literally no alternative unless one decided to exclude oneself from world society. But what did "to be modern" exactly mean? Few words have been as thoroughly discussed and commented than "modernity". In some way, it has been the main – if not the only – concern of sociology since it inception. This has been true for its founding fathers (Emile Durkheim, Karl Marx, Vilfredo Pareto, Max Weber, Ferdinand Tönnies…) and it remains so for most pro-eminent contemporary scholars such as Talcott Parsons, Anthony Giddens, Zygmunt Bauman, Alain Touraine, Jürgen Habermas, and Niklas Luhmann. They have all emphasized and analyzed different facets of modernity but its most often acknowledged and highlighted singularity, compared to any other society, is its mode of internal differentiation. In particular, with the exception perhaps of Durkheim and Parsons, no other sociologist has given more attention and importance to the internal mode of differentiation of modern society than Luhmann. According to him, societies can be differentiated from one another by the existence or non-existence of a principle of internal differentiation and, if any, by the nature of the principle of differentiation at work. He distinguishes four principles of differentiation: segmentation, centre-periphery, social stratification and functional differentiation. It is the latter which characterizes the society which gradually formed within Europe during the sixteenth to eighteenth centuries. Modern society is differentiated in functional sub-systems: law, economics, politics, science, religion, education, mass-media, art, etc. This does not mean that other forms of internal differentiation have completely disappeared – for instance, being a plurality of national states, the world political system is still structured in a segmentary way – but the dominant and structuring principle of modern society is the differentiation into sub-systems organized around the fulfilment of a societal function: economy deals with scarcity; politics provides collectively binding decisions, science is in charge of the production of knowledge, education ensures the preparation of psychic systems

for communication, etc. These different functions, formerly closely intertwined, gradually broke apart from each other and are nowadays performed by different, specialized systems. It is therefore a fully functionally differentiated society that began to observe itself through the distinction “sustainable/un-sustainable” and to combine this with two other already established distinctions: global/local and developed/underdeveloped. It is then very natural to assume that there is some relation between functional differentiation and un-sustainability. In order to understand why, or more exactly, in what way a society composed (mainly) of functionally differentiated systems compromises its ecological basis, it is necessary to clearly appreciate both the systemic and the social character of the functional sub-systems. The systemic character is summarized by two (somewhat pedantic) concepts: operational closure and autopoeisis.

Contrary to almost the entire tradition in systems theory, the founding principle of Modern Systems Theory and Luhmann’s in particular, is not the whole-parts relationship but the distinction system-environment. Luhmann used to say that a system is not a unity, nor a totality but a difference, or, more exactly, the unity of a difference system-environment. Systems are flow of operations that connect and interlink with one another over time, with the result of perpetuating a system-environment distinction of its own. In other words, the system continuously reproduces itself as distinguished from its environment with its own elements as building blocks This is the phenomenon of autopoiesis (Maturana and Varela 1980). For instance, consciousness (which Luhmann calls "the psychic system") is the uninterrupted flow and mutual linking of thoughts in one’s mind, and what constitutes the identity of a "psychic system" (as consciousness) is the singularity of its thoughts compared to anyone else’s. The same is true for what constitutes a human organism as a biological system, which enables its immune system to preserve it as a unique living entity, different from any other (except a perfect twin) and explains the rejections that occur after an organ transplant.

Systems are operationally closed. A system can "act" only inside its own boundaries. It is incapable of intervening directly on the operations of other systems and in return, they are unable to interfere with it. In other words, no system can intervene in the autopoiesis of another system. According to Luhmann, this is true even for the political system of modern society. It cannot – unless it renounces to be modern – decide in place of science on what is true or not about the world and the communist experience has shown that it cannot without much trouble abolish the difference between political and economic operations. Operational closure does not mean closeness to their environment. On the contrary, operational closure is a correlate to causal opening to the environment. The relationship between a system and its environment will be discussed in more detail hereafter with the concept of structural coupling.

The operations of autopoietic systems are recursive, that is to say, they are based on the results of previous operations. The operations of the system at any time depend on its present state, which is the outcome of its past operations, and on the present state of its environment. In other words, the system is always a mixture of self-reference and other-reference. The self-reference functions as a binary code which decides, during the interval between t and t + 1, on the acceptance or rejection

of the operation to come. It presupposes the ability to observe itself, which amounts to recapitulating the sequence of its past operations and characterizing them.

What makes systems social is the nature of their operations. Social systems consist of communications, and only communications[4]. Communication events are essentially, but not exclusively, linguistics. A monetary transaction, a vote, a decision (inasmuch as it is not confined to the consciousness of the person who takes it) are communications. Functional systems constitute environments for each other, of which they are distinct but with which they maintain relationships. The economy is an environment for politics, the legal system, science, arts, education, the mass media, etc., and they in turn are environments for politics, economy, the legal system, and so on. More generally, functional systems, as belonging to society, constitute for each other a societal environment, an environment made only of communications, differently coded than their own. In addition to its societal environment, each subsystem (and society in general) is facing an extra-societal environment consisting of non-social systems or objects, in which Luhmann puts human beings both as living organisms and as psychic systems: the bio-physical environment (which is not a system for Luhmann)[5].

We can now be somewhat more specific about sustainability and sustainable development: it has to do with the relation between social systems (systems made of communications) and their non-social environment, which is not made of communications but of bodies, minds and thoughts for the human environment, and a lot of inert matter, energy and living systems for the bio-physical one. The *raison d'être* of the differentiation of society in functional sub-systems is the reduction of the complexity of this environment. Modern system theory (as opposed to classical system theory) maintains that for any system, its environment is more complex than itself and that any system has to reduce this complexity in order to survive. No system can handle the full complexity of its environment. It would be quickly overwhelmed if it tried to do so. Since modern society reduces the complexity of its non social environment by differentiating itself in sub-systems, it does so at the expense of an increase in its own complexity. It follows that, as Vladimir Valentinov (2014) elegantly puts it, there is a "trade-off between sustainability and complexity". The complexity of human beings is reduced by "slicing" them in as many parts as the functional systems to which they participate, a slicing responsible for the feeling of alienation and meaninglessness that accompanies modernity. As for the complexity of nature, it is reduced through technology. This trade-off obtains at the level of the causal relations between systems and their environment, which is the domain of what (modern) system theorists call "structural couplings".

3. Binary coding, structural couplings and indicators

Functional systems have all their communications shaped by a binary code: true/untrue for the scientific system; payment/non payment for the economy; government/opposition for policy; information (i.e. new)/non information (i.e. old) for mass media; legal/illegal for law, etc.

[4] One would be tempted to add observations except that observations are communications too.
[5] To which Luhmann sometime adds technology. More on technology shortly.

« A code must fulfil the following requirements: (1) it must correspond to the system's function, which is to say, it must be able to translate the viewpoint of the function into a guiding difference; and (2) it must be complete…. The code must completely cover the functional domain for which the system is responsible. It must therefore (3) be selective with regard to the external world and (4) provide information within the system. (5) The code must be open to supplements (programs) that offer (and modify) criteria to determine which of the two code values is to be considered in any given case. (6) All of this is cast into the form of a preferential code, that is, into an asymmetrical form that requires a distinction between a positive and a negative value. The positive value can be used within the system; at the least, it promises a condensed probability of acceptance. The negative value serves as a value of reflection; it determines what kinds of program are most likely to fulfil the promise of meaning implied in the positive code value. » (Luhmann 2000a, p.186). If the binary coding determines the ultimate meaning of communications for the functional subsystems, it is at the level of programs that they open themselves causally to their environment. Programmes are guidelines, methods, criteria that allow the code to be applied. Theories and methods are science's programs; for the legal systems these are norms, constitutions, etc.; political parties' programs are parts of the program of the political system in democracy, and so on. The nature of the relations between functions, codes and programmes for the different functions system is synthesized in Table 1.

Table 1. Synthetic representation of the main functional systems according to Luhmann. (Adapted from Moeller 2006, p.29).

System	Function	Efficacy	Code	Program	Organizations
Law	Elimination of the contingency of normative expectations	Regulation of conflicts	Legal/illegal	Laws, constitutions, Etc.	Courts
Politics	Making collectively binding decisions	Practical application of collectively binding decisions	Government/opposition Power/no-power	Political parties' programs, Government's programs	Parties
Science	Production of knowledge	Supply of knowledge	True/false	Theories, methods	Laboratories, universities
Religion	Elimination of contingency	Spiritual and social services	Transcendence/Immanence	Holy scriptures, dogmas	Churches, sanctuaries in general
Economy	Prevention of shortages	Satisfaction of needs	Payment/non-payment	Budgets Investments	Firms
Etc. (Mass media, Education, Health…)					

The execution of functional programs necessitates resources supplied by the social environment. Therefore, every functional system is dependent on the others. The political system needs (growing) financial resources for satisfying (ever growing) demands from the other systems. The economy needs laws to ensure that contracts are being honoured or that sanctions are applied; all systems need competent individuals able to execute their programs and they expect the education system to provide them. And all need the mass media because "Whatever we know about our society, or indeed about the world we live in, we know through the mass media." (Luhmann 2007, p.1), etc. These kinds of linkages between systems are called "structural couplings". « …coupling mechanisms are called structural couplings if a system presupposes certain features of its environment on an ongoing basis and relies on them structurally….structural coupling is a form, too, and a two-sided at that, and that means it is a distinction. What it includes (couples with) is as important as what it excludes. Accordingly, the forms of a structural coupling *reduce* and so *facilitate* influences of the environment on the system.» (Luhmann 2004, p.382).

Indicators are structures[6] that systems use in order to observe their environment. They condense expectations with respect to it. More precisely, the systems expect that things do not change too quickly or too radically in their environment (otherwise the indicators would have to be permanently changed), but also that these expectations could be invalidated (otherwise they would not monitor it in this way). Changes (positive or negative) can occur and it is important for the systems to be informed sufficiently early to react, possibly by adapting theirs programs and structures (including, if necessary, their indicators). Functional systems observe each other in conformity with their own (binary) codes and structures, according to their structural couplings with their environment. For the economic system, something has meaning if it relates to actual or possible payments (markets, prices…); for science, if it consists of statements open to verification so that they can be classified *in fine* as true or untrue; for politics, what matters is how it connects to the government/opposition or majority/minority distinction and what are the consequences in the perspective of future elections, which depends on public opinion (through which it is structurally coupled with the system of the mass media) and so on. Viewed in terms of structural couplings, the GDP, even if made of economic data, is a political indicator, not an economic one. Through the GDP, and the distinction growth/stagnation, the political system (and perhaps other systems as well) monitor its structural coupling with the economy. The same is true for other seemingly economic indicators such as the unemployment rate. The distinction growth/stagnation is particularly important for the political system because its budgetary resources are closely dependent on (are structurally coupled with) the level of economic activity. The political system's legitimacy and the credibility of its programs are indexed on economic growth which makes possible both the reduction of unemployment and the response to the growing demands made on it as a welfare state. As for the economic system, it observes itself through markets (notably the stock markets of which the Dow Jones is the leading indicator) that provide a representation of the economy as a whole to its various subsystems and it concentrates its external observations on

[6] Luhmann uses the term « structure » in a different way than most sociologists. A « structure » consists of expectations a structure holds with respect to its environment. Learning, for instance, means changing one's expectations, changing one's structures.

its political and legal environment with indicators of safety of investments in the countries of the world, of competitiveness, of taxations levels, of trade-unions influence, and so on[7]. The political system observes itself in the mirror of public opinion[8] (through which it is coupled to the mass media); the scientific system has its h-index and G-index; and so on.

Functional systems observe each other but they also know that they are being observed. They observe how others observe them and may be "irritated" (that is, stimulated) by it. An interesting example of the process of mirroring observations with resulting consequences for the observed system is given by the performance indices of the education system, such as, for example, the PISA indicator of the Program for International Student Assessment OECD, the Shanghai Academic Ranking of World Universities, or the QS World University Ranking (QSWUR). The success of these rankings is understandable when one considers the coupling of almost any other system with the education which need to recruit people with sufficient skills to ensure their own performance and meet the expectations that families, who want the best possible career prospects for their children, maintain towards the school. About the role of rankings on Americans' law schools, Espeland and Sauber (2012) remark: « Law school rankings have influenced almost every aspect of legal education, despite the fact that they were initially denounced by most administrators and by virtually all of the professional organizations associated with legal education. They have changed which schools students apply to and attend. They have changed how resources are distributed within the schools; for example, schools have shifted money from need-based to merit-based scholarships in order to raise their median LSAT scores and improve their rank. Rankings have also changed the work routines and career paths of many administrators; career service personnel, for instance, now spend much more time tracking down students to find out if they are employed—a key component of the ranking formula—often at the expense of additional individual career counseling or networking with employers. » (Espeland and Sauder 2012, p. 89).

In the language of system theory, the distinction between use and influence of indicators can be stated as follow: A system *uses* an indicator if it changes its structures and programs according to its own observations. Conversely, it is influenced by an indicator if it adapts its programs in reaction to the way it is observed by the systems in its environment.

4. What structural couplings: with nature or technology?

Functional systems observe their societal environment with a particular focus on their structural couplings. In the SD domain, we are concerned with non-social environments, which are, according to Luhmann, human beings, nature and technology. We will leave aside here the important question of the structural couplings between society and the human beings[9] and focus on the society-nature-technology relations. Whilst the topic has not been investigated in these terms by Luhmann, there are some indications that he considered that modern society's coupling

[7] For a comprehensive list of the various indexes used by functional systems to observe each other, see Bandura (2008)

[8] See « Die öffentliche Meinung » in Luhmann (2000b). For a French translation, *cfr*. Luhmann (2001)

[9] It is a topic explored in details by Luhmann, for the most part with the concept of « interpenetration ».

with nature was nowadays mediated by technology[10]. In his last opus, he wrote: "The structural coupling of the physical world and society can no longer be captured by the concept of nature… The nature concept is replaced in this context by the paired concepts energy/work and energy/economy. Technology consumes energy and performs work and in this manner links physical givens with society. » (Luhmann 2012, p. 322).We have mentioned Valentinov's (2014, 2017) analysis of the sustainability problem as a trade-off between societal internal complexity and full awareness of the complexity of its environment. We think necessary to add to Valentinov's analysis[11] a consideration of the role technology is playing as a medium between society and nature, but also in some way between human beings and nature. As an organism, the human individual is coupled with its ecological environment through its perception and motion organs but nowadays it rarely has access to a genuine, pristine natural environment. The air humans breathe, the water they drink, the food they eat, the scenery they contemplate are so modified by technologies that it is almost impossible to disentangle what is nature and what culture. What is important about technologies is that they are the most powerful and pervasive complexity reduction machinery the social systems make use of in their relation with nature. At the more abstract level, technology is driven by the distinction "work/ doesn't work". This distinction supposes selecting some causal forces operating in the environment and transforming or diverting them in order to make them work as (or in) an artefact: "...what is called technology is a functioning simplification in the medium of causality. We could also say that within the simplified area strict (functioning under normal circumstances, recurrent) couplings are established. This is, however, possible only if interference by external factors is to a large extent excluded. Technology can therefore also be understood as the extensive causal closure of an operational area." (Luhmann 2005,p.87). Abstracting or insulating some mechanisms or processes from their original context of functioning constitutes a reduction of the complexity of nature that has already been dramatic in its consequences with rather simple substances like DDT and can be still more so with "high technologies" such as nuclear plants, GMO's, nanotechnologies, etc. It is tantamount to cutting, as with a scalpel, in the complex network of interacting factors and feedbacks of which natural (and especially living and ecological) systems are made of. The distinction "works or not" boils down to "successful or unsuccessful reduction of complexity", or to "controllable or uncontrollable states of affairs". Yet, "we also know… that complexity itself can be captured in no reduction, can be represented in no model. Even if it works, we must also expect something to be left over. "Successful" reduction thus amounts to harmless ignoring. » (Luhmann 2012, p. 317). The problem is that, sometimes, what looked first as "harmless ignoring" reveals itself to be quite risky if not definitively catastrophic. The burning of fossils fuels, the spreading of DDT, the handling of asbestos, the habit of smoking, etc., are but dramatic examples of such mistakes. If all important relations between society and its bio-physical environment are mediated by technology, it follows that the issue of environmental sustainability

[10] The status of technology in Luhmann's writings is unclear. Luhmann didn't consider technology as a system or at least, not as a social or autopoeitic one (Chaskiel 2008), but see Reichel (2011).

[11] In a recent article written with Spencer Thomson, Valentinov does in fact consider technology, albeit only at the micro-level of the firm (Thomsom and Valentinov 2017).

can be stated in terms of technological risks[12], which means in terms of decisions regarding which technology to adopt (and, beforehand, to develop), and this for any organization, whatever the functional system it belongs to. As Bartelmus (chapter TK) remarks, there has been much GDP bashing in the SI (and SD) community and sometimes for good reasons, but if we agree that the couplings of functional systems with the bio-physical environment are mediated by technology, there is no particular reason for blaming the economy more than any other system for society's un-sustainability. Of course, not all functional systems are coupled at the same degree to technologies. The scientific system, the health system or the mass media – not to mention the army – certainly make a more intensive use of energy and materials than the legal system, religion or arts but all contribute to the environmental crisis. Yet, it is the economy and economic growth in particular that is most generally blamed for it. This was already apparent in the Agenda 21 program, which focused mainly on indicators complementary or alternative to GDP and was more than neutral with respect to technologies. In fact, most references to technologies in the document concerned transfer of technologies from developed to developing countries, as if the technologies of developed countries were more benign than the ones of less developed countries. Because the economy, like any social system, consists of – and only of - communications and observations, it cannot directly intervene in the functioning of ecosystems. Payments as such have no impact on the bio-physical environment of society. The financial system, which is a sub-system of the economy, gives a clear demonstration that economical communications can be totally disconnected from any linkage with the material world (precisely what many activists blame it for!), except through the information technologies they make use of. On the other hand, the simple idea of giving more importance to one or another functional system at the expense of others in the fate of the whole society is totally foreign to Luhmann's perspective (Luhmann 1987). There is no overarching system and no "determination in last instance". The economy is what it is because all other systems are what they are and they are all structurally coupled to energy and material through their use of housing, transportation, information processing… technologies. Technology is indeed one the three factors taken in consideration in the IPAT identity but the SD community is divided as to which factor to highlight: T, A or P[13]? Actually, several of the founding fathers (or grand fathers) and mothers of our contemporary ecological consciousness such as Oswald Spengler, Lewis Mumford, Rachel Carson, Jacques Ellul, Gunther Anders, Fritz Schumacher, Ivan Illich, Bertrand de Jouvenel and others thought that the role of technology and of the technological mindset in the coming environmental crises was deeper than the responsibility of the economy or the politics.

[12] Technology is of course one the three factors taken in consideration in the IPAT identity. However, it is more often than not the A factor more than the T one or the P one which is emphasized in the SD community.

[13] In chapter TK, Spangenberg distinguishes between "modificationists" and "transformationists". It is tempting to assimilate the former to T-champions and the latter to A-ones. But things are not that simple: there can be modificationists and transformationists in both camps.

5. Indicators as reduction of complexity

What is true of technology in general is also true of indicators, because they are (information) technologies. Like all technologies they reduce complexity, and they do so in two important respects:

1. Indicators are observation devices, but what is observing? According to George Spencer-Brown (1969) observing is the unity of a distinction and an indication. You cannot observe something until you distinguish it from something else (at least, everything else) and focus on one side of the distinction, which is then called indicated or "marked", and leaving the other "unmarked". The unity of a distinction and an indication is called a "form" (Fig. 1). < INSERT FIG1 HERE ABOUT > It is important to be aware that both sides of the distinction are important, even if only one is focused on. The marked side makes sense only in reference to the un-marked one. For instance, the "risk" in a risk/safety distinction is different from the same word in a risk/danger distinction. As Luhmann (1992, 2005) shows, the two lead to very different observations. Indicators are "forms" also, they focus only on the marked space and leave as much if not more of the "world" unobserved, including the operation of distinction itself. For instance, in the SD community, GDP is blamed (once again) for leaving "un-marked" a lot of (supposedly) important non-monetary phenomena. Of course, this is true as it is true of any observation. GDP divides the world in monetized and non-monetized things and it is important to understand that both sides of the distinction are important. It is the unity of the distinction that matters. There must be some non-monetized things in the world in order to make sense of the monetized ones. Therefore, by attempting to bring back on the monetized side (the indicated one) as many elements from the non-monetized one (un-marked) as possible, we run the risk of abolishing the distinction itself and therefore of condemning oneself to being unable to observe anything. It is only at a second level of observation that the system (or another one), making use of another distinction, is able to observe the first observation, and discover its contingent character. The distinction sustainable/unsustainable can thus be considered the leading distinction of a second-order observation of the first-order observation using the developed/under-developed form.
2. Indicators digitalize (make discrete) analogous (continuous) processes. To be useful for binary coded systems and for decision-making in organizations, indicators must reduce the complexity of a continuous phenomenon to a very limited number of significant (for the user) categories (an operation sometimes called punctuation), if not simply to the binary code itself. It is particularly true in SD where the set of values of observations should be separated in two subsets: sustainable and unsustainable. This is in many cases (if not all of them) an obvious reduction of the complexity of the nexus of mechanisms and processes of positive and negative feedbacks[14]. Yet it is indispensable: without threshold values for ppm of GHG in the atmosphere (445) or for the increase in average temperature at a given

[14] Analog communication is of a higher level of intrinsic complexity than digital communication. However the latter is of a higher logical level. See Wilden (1980). Especially chapter VII « Analog and Digital Communication : on Negation, Signification and Meaning ».

horizon (+ 2 degrees Celsius), the mission of the parties at the United Nations Convention on Climate Change would be impossible. The "punctuation" of continuous processes for usability in policy-making can only very rarely be based only on scientific evidence. It involves taking account of uncertain social consequences whose assessment mixes necessarily scientific and normative considerations and there is necessarily some arbitrariness in this. It is at this stage that participation of the public can be the more legitimate and effective (Bell and Morse Chapter TK). As Bell and Morse write in their introduction: « The indicator community did not suggest that SIs should be expert impositions, and neither should we pretend that there can only be one set of 'true' SIs that apply. Rather they are emergent from process, and hence can be contestable. This goes against the grain of science and for some it is an uncomfortable and maybe even unacceptable position. To suggest that we do not have the 'truth' and the best or only way to represent that 'truth' is to play into the hands of those who wish to dominate with their own agendas. »

If reducing complexity is unavoidable, the challenge is to determine the level and scope of reduction necessary and sufficient for "irritating" society's functional systems. In that respect, one can wonder if we are not going too far in an excessive reduction of complexity with some "mashup" indices (Ravaillon 2010) of SD. Throughout the Agenda21 and almost all of the literature that followed, GDP is criticized not only because of its blindness to environmental damages but also because it gives an inaccurate and partial vision of the psychological comfort of people ("well-being"). Hence, the development of indexes that attempt to capture in one figure as many sectors of the bio-physical environment as possible together with the human state of well-being. We refer here to various attempts to enrich the GDP with environmental and welfare dimensions such as with the Index of Sustainable Economic Welfare, the Genuine Progress Indicator, the Genuine Savings Index, the Happy Planet Index, etc. Pretending to condense in one single index the complexity of two of the non-social environments of society, that is, the human being as an arrangement of organic and psychic systems, and the bio-physical environment in all its diversity, constitutes a formidable challenge in terms of reduction of complexity. It is also being oblivious to the complexity of the social world to believe that there exists something like a central agency inside society able to steer on such a basis the whole system's relations with its environments, or otherwise, that each functional subsystem can extract from them the required and relevant information it needs to adapt itself. Both assumptions are false, Luhmann argues. Indeed, by pointing only to the economic system or to the political one (but giving it the mission to steer the economy), "Beyong GDP" indices assume either that it is possible to reduce the complexity of society to only one of its sub-systems: the economy or the political system or, still worse, that society exists outside or above its subsystems and the organizations that belongs to them. There is no overarching principle or centre in contemporary society that could play the role God, the King, the nobility or empires' capitals played in past societies.

The case of the Ecological Footprint

An indicator is intended to transform data into information, for instance data about rising temperatures and about GHG emissions are transformed into information on the relation between

human production and consumption patterns and global change. However there is no such thing as information, period. « Information is a purely system-internal quality. There is no transference of information from the environment into the system. The environment remains what it is. At best, it contains data. » (Luhmann 1989, p. 18). It follows that each system considers the data about temperatures and GHG emissions differently: some ignore them altogether; others can be irritated by them but only on the basis of their own codes and programs. Take for instance the Ecological Footprint indicator (Wackernagel chapter TK). It is interpreted in a totally different way by the scientific research system and by the system of the mass-media. The science system cannot but look at it with the lenses of its binary code: true/untrue. Yet, whilst born of the scientific system, the EF doesn't convince everyone in the scientific community (van de Bergh and Verbruggen 1999, Kitzes & al. 2009, Giampietro and Saltelli 2014, Galli & al. 2016). Still, and despite its uncertain scientific status, the EF can be considered a success story: a Google search done at the 02/02/2015 date delivers about 1.760.000 references, compared to 461.000 for the Index of Sustainable Economic Welfare, 448.000 for the Genuine Savings Index and 272.000 for the Genuine Progress Indicator. This can be attributed to its endorsement by several NGO's (WWF, the New Economic Foundation, Redefining Progress…) but also to some idiosyncratic features of the index which make it well suited to the need of the system of the mass-media. The (general) mass-media system whose internal code is information/no-information (which boils down to new/old) has been interested in the EF and could easily include it in its autopoeisis for several reasons that are worth exploring a bit. First of all, like the GDP's growth rate or the unemployment rate, it is a quantity and Luhmann (2000, p.28-29) observes: "Quantities are a particularly effective attention-grabber. Quantities are always informative, because any particular number is none other than the one mentioned - neither larger nor smaller. And this holds true regardless of whether one understands the material context (that is, whether or not one knows what a gross national product is […]). The information value can be increased in the medium of quantity if one adds comparative figures, whether they be temporal (the previous year's rate of inflation), or factual, for example, territorial. So quantification can generate sudden moments of insight without any substance and simultaneously more information for those who already have some knowledge. ». But, of course, this is not enough. Almost all indicators are quantities (more or less) but not all of them receive the same attention from the general mass-media. The second characteristic of the EF, which makes it well-suited to the mass-media requirements, is its multi-level relevance. Because it can be computed at the levels of the household, the city, the region, the country and the world, information is given a local if not a personal reference and this feature has greatly contributed to the surfacing and diffusion of the ecological topic in society's communications. Referring to the diffusion of the ecological concerns, as Luhmann explains, "The speed with which this complex of topics has been introduced and spread is certainly due partly to protest movements operating in close collaboration with the media, but above all to the mass media themselves. Many selection criteria come together in this context: high figures, a steady supply of disasters, events triggered by technology and therefore contingent, ideological and political conflicts about the appropriate attitude to adopt. Then there are the local and at the same time supralocal relevance and the largely invisible form of threat… » (Luhmann 2013, p. 317).

6. Conclusion: an emerging sustainability functional system?

In a functionally differentiated society whose systems are articulated around a binary coding, which system is able to take care of the ecological question? This is the question posed by Luhmann in 1989 by publishing "Ecological communication". Three years after the publication of this book, at the United Nations Conference on Environment and Development, world society formalized its self-observation with the categories sustainable / unsustainable described itself as unsustainable. There is no trace of the sustainability concept and therefore of the sustainable / unsustainable distinction in Luhmann's 1989 opus, nor even in the two articles published around or just after the Rio Conference addressing the ecological issue (Luhmann 1992, Luhmann 1993). We have no clue that could let us believe that Luhmann foresight the birth of a new functional sub-system. Yet, the burgeoning of indicators, (and the controversies about them), conceptual frameworks, and assessments methods that followed the 1992 Rio conference can be interpreted as the possible emergence of a new functional social system, striving to find its place next to the extant incumbent ones. This means that an additional row would have to be inserted in Table 1 with, in the "code" column, the distinction "sustainable/unsustainable", and in the "Program" one: indicators and Sustainability Impact Assessment frameworks and methods. This new system's function would be to take care of the survival of humanity and of its living environment and its efficacy would be assessed in terms of sustainable human well-being. Therefore, whilst being a further diversification of the modern society, the coming of this new system would however overcome the current trade-off between complexity and sustainability, responsible for the coming ecological disasters. In the "Organizations" column we would probably see institutions like the I.P.P.C. perhaps with a more participatory component. Being distinct from science, politics, or law, etc., its basic binary code "sustainable/unsustainable" would not be reducible to true/false, power/no-power or legal/illegal, or any other distinction used by the social systems in its environment. As for sustainability indicators, for instance, they would still have to be underpinned by scientific theories, methods and observations but their logic would nevertheless remain distinct from the scientific one, if only because they involve a risk evaluation component foreign to pure scientific communication. Of course, structural couplings would have to be established with the other systems and the "ecological communication" would have be understood and translated in their own semantics. In order to be effective, the sustainability function system should be able to trigger new applications of the "true/false", "government/opposition", "tradable/non tradable", "legal/illegal", etc., but in no ways try to substitute its own code to theirs. In short, it would have to accept a functionally differentiated society and respect the autonomy of the other systems. As a social system, it would also be a meaning-constituted one, made of communications only. It would not (and could not) communicate with the bio-physical environment but only with other social systems. It would focus on the decisions taken in the organizations of the other functioning systems: the state, administration and parties for the political system; firms and corporations for the economic system; universities and research centres for the science system; hospitals for the health system and so on, and screen them with its sustainable/unsustainable sieve. All this is already on the way, more or less, and only the future will tell if it will continue but there exist temptations to return to a less differentiated society, with science, politics or even religion taking an hegemonic position and, in the very name of

sustainability, pretending to decide alone what is collectively binding or not, legal or illegal (for science or religion) ; true or false, legal or illegal, transcendent or immanent (for politics),etc. The risk exists also that a sustainability functional system, once fully developed, becomes able to claim the superiority of the sustainable/unsustainable distinction over all others binary codes and also in the name of human survival as preeminent value, erodes the autonomy of the others social systems and gives rise to a differently structured society, possibly far away from what we understand today by « sustainable development ». This means that even if we are impatient with the slowness with which the incumbent systems (mainly the political, the economical and the educational one) react and adapt to the messages of our indicators; we maybe have to refrain the temptation to deprive them of their autonomy and to put under (our?) control.

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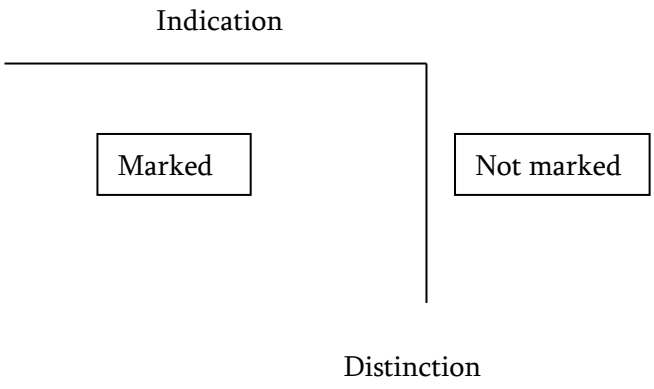

Fig. 1. Form as the unity of distinction and indication. Source : Spencer-Brown (1969)