Sustainability and techno-science: What do we want to sustain and for whom?

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Abstract: We analyse the relationship between the mainstream framings of sustainability and techno-scientific innovation. Focusing on sustainability, we discuss the need to shift from predicting and promising what to do (in the future) to a political resolution of how we want to live together (in the present). Next, we turn our attention to techno-science, examining the normalising forces emerging from the modern framing of sustainability and the strategies that standardise the envisioning of our techno-scientific future, and the risks and promises of innovation. Concentrating on two emergent technologies, along two main drivers of innovation: optimisation (for new pathways of 'sustainable' competitiveness and consumption) in the field of smart technologies, and substitution (for new resources) in the field of synthetic biology. Finally, we provide some suggestions about the role of complexity and quality vs. efficiency and functionality, for reopening the democratic debate about what is to be sustained and for whom.

Keywords: sustainability; techno-science; innovation; post-normal science; optimisation; substitution; smart technologies; synthetic biology; wonder; power; control; urgency.

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1 Introduction

In a recent paper, we have analysed some of the main contradictions and paradoxes arising within a dominant, inherently modern framing of sustainability (Benessia et al., 2012). This framing assimilates the aims and goals of sustainability with those of the mainstream economic paradigm of growth and relies on techno-scientific innovation in order to describe, confront and solve our present human predicaments (environmental, social, economic, cultural and political).

We have outlined and discussed four main paradoxical intrinsic loops in this approach.

- First, the scientific prediction of the future as a precondition for responsible action in the present, whereas the possibility of foreseeing future developments is precluded precisely by our greater scientific and technological power to act and transform.
- Second, the reliance on techno-scientific silver bullets in order to tame the problems arising from the very introduction of techno-scientific processes and products into our socio-ecological systems.
- Third, the appeal to scientific experimental evidence in order to (rationally) support a course of action, whereas the definition, detection and measurement of scientific evidence are intrinsically value-based processes, namely they crucially depend on our course of action.
- Finally, calling for global mobilisation, but claiming, to this end, the need for specialised expertise to work in isolation, despite the fact that specialised knowledge can only trigger (specialised) technical fixes (Funtowicz and Strand, 2011).

These contradictions and paradoxes are all interlinked and they can be considered as epistemic and normative diversions from the needed radical change in our collective being and agency. In this sense, by persisting in a contemporary version of the modern framing, we ironically remain *waiting for sustainability* as the characters in Beckett's play (Beckett, 1952), keeping ourselves occupied

- with unsolvable controversies about quantitative risk estimates (Sarewitz, 2004)
- with the quest for empirical evidence of linear causal relationships within complex systems characterised by radically uncertain dynamics (Dupuy, 2004)
- with the search for techno-scientific silver bullets and the disappointment and sorrow about the unintended consequences of their implementation (Barstow et al., 2010; Perrow, 2011).

We have delineated a way out of the contradictions arising from this type of fatal framing error by recognising the vivid and self-evident presence of harm and structural violence perpetrated on humans and other beings *today*, and therefore by encouraging an epistemic and normative shift from scientifically searching *what* to do, to politically choosing *how* to.

This type of transformation entails a collective commitment to the present and an extension of epistemic and normative rights: resorting to a new kind of *praxis* developed through the hybridisation of sustainability science with a variety of practices and knowledge arising from different (non-scientific and scientific) contexts, and challenging the modern divisions between facts and values, evidence and ideology, humans and other forms of life.

In our previous work, we have considered the concept of techno-science as a given, a fixed point of reference in relation to which the notion of sustainability could be dynamically examined. In this paper, we would like to deepen our reflection along these lines, by lifting this constraint on the notion of techno-science: analysing its own cultural, political and social dynamics, and therefore considering how the discourses about sustainability and techno-science interact and co-evolve.

The definition of sustainability becomes even more uncertain and ambiguous, as both influencing and being influenced by the mutable boundaries of techno-science. On the one hand, the dominant modern discourse about sustainability, in all its known contradictions, is functional for maintaining the techno-scientific path-dependent trajectory on its track despite its ever more manifest and conspicuous drawbacks. On the other hand, as we will see, the issues of 'What to sustain?' and 'For whom?' are deeply modified by the main drivers of the techno-scientific enterprise.

As we explore further, the unchallenged economic policy aims of growth, productivity and competitiveness – reinforced in the ongoing crisis both in Europe and in the USA – are fundamental ingredients of this whole scenario. If we keep these goals as givens for improving and extending human welfare on this planet, then we (continue to) face the paradox of sustaining a steady increase in our global resource consumption within a closed, finite system, with limits to its stocks and bio-geo-chemical resilience (Elser and Bennet, 2011; Rockström et al., 2011).

The issue becomes even more complex, as the technological and ideological lock-ins of our hyper-complex life-supporting systems lead us to deal with a double-bind scenario, quite painfully clear in the wake of the latest economic, financial and political emergency: we cannot keep growing indefinitely in the way we have so far, but if we do not keep growing, we jeopardise economic stability not only of future generations, but also – more decisively – of present generations.

The dominant discourse about a way out of this situation comes from the grand narrative of techno-scientific innovation, which serves a double purpose. As the first line of reasoning reads, in this unfavourable equation, we need to take into account an essential hidden variable, which Malthus proverbially overlooked: natural supplies might be limited, but human creativity is *unlimited*, and so is human power to decouple growth from scarcity, improving efficiency in the use of natural resources and ultimately substituting them altogether, with substantially equivalent technological optimised artefacts.

Techno-scientific innovation allows then for a 'sustainable growth' through the optimisation and the substitution of our means, and through the deployment of suitable silver bullets, protecting us from the complexity of socio-ecological problems as they arise. Second, techno-scientific innovation is taken as the mainstream solution in order to keep sustaining the growth of states' economies in a hyper-saturated market, by opening up new pathways of competitiveness and consumption, to be filled with new, constantly upgraded, products and services.

Sustainability can then become a useful metaphor of the contemporary world and the current human predicament, as we witness a trajectory from its institutional discovery as a global issue in the 1992 Rio Conference, when it was associated with diversity, participation and precaution, to the recent Rio + 20 Conference when it becomes merely an adjective of growth (Brand, 2012).

In this paper, we discuss this complex scenario of co-production of visions, narratives and hopes, by exploring the dynamic relationship between sustainability and techno-science. We will first examine the path-dependent trajectory of techno-scientific innovation and focus on how the modern discourse of sustainability is functional for its stability. We will then invert our perspective and analyse how the contemporary techno-scientific enterprise profoundly challenges the nature of the world we want to sustain, and the 'we' that we want to sustain it for.[1]

We will explore these normalising forces against their cultural, institutional and political context, by concentrating on two emergent technologies, along two main drivers: optimisation for new pathways of sustainable competitiveness and consumption in the field of smart technologies, and substitution for new resources in the field of synthetic biology.

As we will see, following Thomas Gyerin's pragmatic approach to science and ideology (Gyerin, 1983), the inherent contradictions at the intersection of techno-science, sustainability and growth can be taken as an effective repertoire used by technocratic elites to articulate their needs, interests and visions, enlarging their symbolic and material resources and defending their authority. When fully acknowledged, this range of arguments and imaginations about the future can become a useful map to navigate in the present, exploring the limits of the current framings and devising new epistemic and normative routes for a collective learning path.

2 Innovation for a sustainable future: normalising the goods and bads of techno-scientific enterprise

Since the emergence of the Modern State, science has provided the privileged form of rationality and legitimacy for decision-making and action. The republic of scientists, emerging from the reversible and emendable laboratory science of the early ages of Galileo, Newton and Hooke, was founded on the ideal of a certain, objective and exhaustive knowledge production (Shapin and Shaffer, 1985). This type of modern knowledge was meant to "speak truth to power" (Wildavsky, 1979), creating the conditions for ideally complete, rational and robust decision-making processes, intended as exhaustive logical demonstrations.

Science was then identified with liberal democracy by authors such as Robert K. Merton and Karl Popper, and with mainstream economic orthodoxy with its aura of quantitative certainty and rational decision-making.

With the fundamental transition from disciplinary, applied laboratory science to the current market-based, open-field techno-scientific direct experimentation, this mode of knowledge production, based on the sole requirement of integrity assurance by peer-review, faces a deep and irreversible crisis. The *post-normal* scenario of uncertain facts, disputed values, high stakes and urgent decisions (Funtowicz and Ravetz, 1993) is now more than ever intrinsic in our way of proceeding through life, matter and energy manipulation. Complexity recognition, knowledge quality assurance and public accountability are in fact not merely desirable, but also urgently needed.

Nonetheless, most often, an essentially modern framing is still applied to inherently post-normal issues, as an effective strategy to maintain the current business-as-usual balance of power. This framing is based on a set of normalising strategies and narratives to externalise the bads and support the goods of innovation.

Radical uncertainty and the intrinsic blending of facts and values can be normalised in two different ways. The first standardising strategy consists in asking only questions that can be answered by scientific quantitative reasoning. This procedure enables the translation of uncertainty and complexity in the statistical language of risk assessment, thus narrowing the decision-making processes within the norm of modern rational demonstration. This approach evokes Mullah Nasruddin's lamppost story, in which the drunk man looks for the lost keys at night under a lamppost because it is the only place where there is light.

Furthermore, the notion of objectivity can be standardised by enforcing a homogeneous epistemic culture in regulatory processes: if the values and interests at stake in shaping what is considered as relevant knowledge are shared by the members of the closed regulatory community, they do not stand out, they are neutral within a seamless background (Hardin, 2004). Overall, the process of evaluation of the socio-environmental impacts of techno-science becomes then a bureaucratised technical fix, incorporating only the values that are legitimised by the institutions involved (Tallacchini, 2009).

The modern framing of sustainability, with all its inherent contradictions, provides a set of values that can be highly functional to these two homologising notions. If predicting the future in order to act responsibly, thus sustainably, is taken as a fundamental normative assumption, then the normalised notion of certainty provided by risk assessments becomes essential for decision-making. On the other hand, if efficiency is considered as crucial in order to make our processes and products sustainable, then complexity becomes a burden on the road to sustainability, and the standardised normative processes ensured by homogeneous epistemic communities become indispensable.

Complexity and controversy are removed not only in taming the risks, but also in justifying the benefits of techno-science. Indeed, the visions and promises of innovation are in turn standardised along four axes, intimately connected to the modern model of sustainability and functional to each other. Four standard techno-scientific imaginaries are implemented as sophisticated epistemic marketing devices: wonder, power, control and urgency. A frame of reference defines an abstract space in which the complex and multifaceted concept of innovation can be projected and analysed, in terms of what we want (wonder), we can (power and control) and we need (urgency) to obtain from our contemporary techno-science, in order to sustain growth. These imaginaries are cultural and socially implicit constructs; the fundamental constituents of a structure that redefines the modern ideals of science as a privileged knowledge system, and technology as a primary instrument of action; a set of initial conditions or relevant facts that determine the normative choices as inevitable consequences (Jasanoff et al., 2007; Jasanoff and Kim, 2009). Given these initial conditions, techno-scientific enterprises do not start with a question, but with an answer that needs to be substantiated; a promise to be fulfilled in a near but undetermined future: new *optimised* products, more efficient and performing, enabling us to extend consumption while stabilising our demand of energy. New techno-scientific implementations will enable us to manipulate more effectively matter, energy and life, and to *substitute* the products of evolution by more efficient artefacts.

This process of standardisation of the bads and the goods of techno-science on the way to a sustainable growth constrains the public imagination and debate regarding our current predicament within the future-oriented dichotomy of (controllable) risks and (deferrable) promises. We will now examine how this reduction of the space, time and quality of the democratic dialogue about our (techno-scientific) needs and aims has emerged in the path-dependent trajectory of innovation.

3 Sustaining growth: the path-dependent trajectory of innovation

The definition of innovation as the engine of economic, social and environmental wealth is the last semantic step of a pervasive and articulated narrative of progress that can be traced back – along a co-evolving epistemic and normative trajectory to the emergence of the Scientific Revolution and Modern State. Within this narrative, we ask science and technology to fulfil (at least) three essential functions: to extend or at best to *sustain* our well-being, to *preserve* us from the possible adverse consequences of our acting towards this goal and to *contain* the unfavourable events, should they arise despite our efforts to avoid them.

The technological and ideological constraints on the trajectory of innovation lead us today to identify the stability and the extension of our well-being with the economic aims of consumption growth and markets competitiveness (Jackson, 2009).

In the EU 2020 Strategy, innovation is considered as fundamental to achieve and foster a "smart, sustainable and inclusive growth" (European Commission, 2010a), where 'smart growth' means "developing an economy based on knowledge and innovation" (European Commission, 2010a). But what is sustainable growth?

The European Commissioner for research, innovation and science, Máire Geoghegan-Quinn, provides the following definition of innovation in a short video interview at the Lisbon Council in 2010:

> "Innovation means that we bring all the wonderful scientific research that we have, all the way along a chain, until we get it into products, we sell it on the market. We develop products and create products that the markets are there for, and the people will want to buy. That is, at the end of the day, how we can develop research to retail." (Geoghegan-Quinn, 2010)

The European Commissioner evokes here a standard imaginary of wonder, based on the modern ideal of scientists as explorers of the unknown, opening the doors of our perception to the most remote phenomena and making them techno-scientifically accessible. Highly functional to the needs of economic growth, the wonder of innovation is defined in terms of new technologically mediated experiences to make and corresponding retail products and services to buy. Therefore, in this context, innovation helps sustaining growth by perpetually providing new and desirable products and services, fostering consumption and consequently creating new market opportunities and jobs (Frey and Osborne, 2013).[2]

This line of reasoning can be found in the program of one of the seven flagship initiatives at the core of the European Union 2020 Strategy, defined as 'Innovation Union'. The aim of this initiative is

> "to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs." (European Commission, 2010b)

Quite ironically, this set of assumptions and arguments are based on a rather time-worn model. In the 1945s influential report 'Science, the Endless Frontier', the first American presidential science advisor Vannevar Bush provided the political vision establishing science-based technology as the cornerstone of progress and economic growth.

> "To create more jobs we must make new and better and cheaper products. We want plenty of new, vigorous enterprises. But new products and processes are not born full-grown. They are founded on new principles and new conceptions, which in turn result from basic scientific research. Basic scientific research is scientific capital. Moreover, we cannot any longer depend upon Europe as a major source of this scientific capital. Clearly, more and better scientific research is one essential to the achievement of our goal of full employment." (Bush, 1945)

The idea that technological innovation would become a powerful engine of economic growth in the post WWII era was anticipated by the Marxist scientist and historian John Desmond Bernal who described science as "the second derivative of production" (Ravetz and Westfall, 1981).

If the founding model is clearly the same, the context in which this model is applied is radically different. At the end of the War, the American people were ready to welcome the great expansion of production with the enthusiasm for the newly born culture of mass consumption. The horizon of resource scarcity and environmental degradation was still very far and thus not visible. Finally, as the geographical frontiers to conquer were over and Europe lay exhausted in the ruins of war, the USA could rely only on themselves and on the 'endless frontier' of their scientific and technological development.

Quite differently, in the tight race for ever new market shares that characterises our era, European techno-scientific development has to hold the pressure of the global market.

> "We need to do much better at turning our research into new and better services and products if we are to remain competitive on the global marketplace and improve the quality of life in Europe." (European Commission, 2010a)

Compared to the post war scenario, the challenge to emerge and expand has now turned into a struggle for economic survival. Sustaining growth implies then a fundamental urge for a 'wonderful' and competing techno-scientific innovation. In a lecture given at the

Lisbon Council in 2010, the EU Commissioner Máire Geoghegan-Quinn expresses this tension (Geoghegan-Quinn, 2012):

> "There is no shelter for un-competitive firms or economies. Competitiveness is the new law of economic gravity, which no one can defy."

Innovation only can hold the weight of this law:

> "And now it is [scientific] knowledge and ideas that drive competitiveness, not tangible assets."

Indeed, the knowledge and the ideas evoked here are clearly not referring to the search for a new worldview, still firmly anchored to the one of Vannevar Bush, but they imply a substantial transition from 'basic scientific research' conceived as normal, curiosity-oriented science creating common knowledge, to big, industrial, goal-oriented techno-science-producing corporate know-how, defined as innovation.

The early stages of this trajectory are well described by US President Eisenhower in the warnings of his Farewell Address to the country, pronounced in 1961:

> "Today, the solitary inventor, tinkering in his shop, has been overshadowed by task forces of scientists in laboratories and testing fields. In the same fashion, the free university, historically the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research. Partly because of the huge costs involved, a government contract becomes virtually a substitute for intellectual curiosity. For every old blackboard there are now hundreds of new electronic computers."

The process of transformation from modern science and technology to innovation occurs in parallel to the growing crisis of credibility and legitimacy of a knowledge system grounded on the Cartesian ideal of prediction and control.

In most recent years, not only economic but also environmental and social crises proliferate, and the EU 2020 Strategy invokes innovation as the 'only answer' (European Commission, 2010b) to address and solve the most pressing societal challenges: "combating climate change and moving towards a low-carbon society" (European Commission, 2011a) and finally to manage the problems of "resource scarcity, health and ageing" (European Commission, 2010b).

The limits in our use of matter, energy and life have become sharply evident, and the need for a steady consumption growth can only be sustained by the drive of innovation. In this imaginary of power, techno-science can indefinitely extend the boundaries of our individual and collective being and agency, through the *ad libitum* manipulation of living and non-living resources, endlessly enhancing the quality and the duration of human life.

The contemporary origin of this imaginary of power can be traced back in the transition from nuclear power as a weapon of mass destruction to the first techno-scientific emancipating promise, providing unlimited energy to people and nations. In 1953, when Eisenhower gave his celebrated lecture on the 'Atoms for Peace' (Eisenhower, 1953), Vannevar Bush was not far away on the horizon. Nuclear power became the paradigmatic new and emergent technology of the post-WWII era, promising new sources of progress. It was the beginning of the trajectory to an emerging type of Modernity, in which science and science-based technology became not only the 'second derivative of production' but the main engines of economic growth and prosperity.

The New York Times (17 September, 1954) reported a speech given the day before by the Chairman of the US Atomic Energy Commission, Lewis Strauss to the National Association of Science Writers (Strauss, 1954).

> "Our children will enjoy in their homes electrical energy too cheap to meter...will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age."

Strauss's message resonates with Francis Bacon's posthumously published text 'The New Atlantis' which can be regarded as a founding stone of the standard imaginary of power. In his writing, Bacon describes a Utopia of wealth, happiness and security based on scientific advancements:

> "We have also engine-houses, where are prepared engines and instruments for all sorts of motions. There we imitate and practice to make swifter motions than any you have, either out of your muskets or any engine that you have; and to make them and multiply them more easily, and with smaller force, by wheels and other means: and to make them stronger, and more violent than yours are; exceeding your greatest cannons and basilisks." (Bacon, 1996 [1627a])

His unfinished manuscript ends with a visionary list of "*wonders* of nature, in particular with respect to human use" (Bacon, 1627b). Here are a few examples:

> "The prolongation of life.
>
> The retardation of age.
>
> The curing of diseases counted incurable.
>
> The altering of complexions, and fatness and leanness.
>
> Versions of bodies into other bodies.
>
> Making of new species.
>
> Instruments of destruction, as of war and poison.
>
> Drawing of new foods out of substances not now in use.
>
> Deception of the senses."

Bacon (2012) (1620) anticipated that all this could be achieved by the use of the new tool of experimental and inductive science. In *Novum Organum* (2012 [1620]) he explained why: "Human knowledge and human power come to the same thing, for where the cause is not known the effect cannot be produced" (Aphorism 3). Useful knowledge for Bacon is knowledge about cause–effect relationships enabling us to avoid or induce the causes of what harms or benefits us, respectively.

The dialectic between power and control, the founding pillar of the Cartesian ideal of mastering nature, is established here. The three main axes of modern imaginaries are therefore in place: the wonders of nature can be mastered by the power and control of the scientific method. Scientific knowledge takes charge of predicting the causes and the consequences of our (technological) action in a certain, objective and exhaustive way.

The governance of contemporary techno-science is still based on this triad: in order to safely drive the wonderful and powerful engine of innovation *in vivo*, outside of the organised and simplified boundaries of experimental laboratories, we need to control risks and ethical concerns through what we have defined as standardised certainty and objectivity. In the imaginary of *control*, radical uncertainty, indeterminacy and ignorance are, most commonly, improperly translated into quantifiable risks and managed through the tools of statistical analysis and numerical simulation, *as if* exhaustive matter-of-facts predictive technologies. The consequences that lie outside of quantitative and statistical models, therefore, unpredictable and unforeseen, are defined as *unintended*, conceived as anomalies and confronted within the same framework, through more and newer techno-scientific instruments. Recent crises, ranging from the 2010 Deepwater Horizon accident in the Gulf Mexico to the Fukushima nuclear disaster in 2011, illustrate the vulnerability to corruption of complex technological systems and the hubris of quantitative-based experts who ignored what they chose to ignore.

This last step is made possible by a standard imaginary of *urgency,* based on a morally binding necessity to bypass any delaying post-normal knowledge production and decision-making process, in favour of a silver bullet techno-scientific and technocratic approach. In this future-oriented imaginary, lack of time and high stakes produce allegedly compelling mono-causal framings, in which techno-scientific expert creative knowledge emerges as a *deus ex machina* from the modern imaginaries of wonder, power and control. Geo-engineering, biofuels and biotechnology for food production are commonly evoked and debated in this specific scenario, by different lobbies, as mitigation and adaptation technologies for a variety of socio-ecological issues, ranging from climate change to global hunger to energy instability and crisis.

In this framework, innovation is thus needed to provide a "smart, sustainable and inclusive growth" in two ways. First, by creating not only new products and services, but more significantly, by opening new pathways of consumption. Second, by promising to decouple growth from scarcity, optimising and substituting our means, while taming complexity and the risks of failures through effective *ad hoc* silver bullets.

Overall then, as innovation becomes essential for sustaining growth and for plain survival, the trajectory of techno-science is stabilised within an abstract space of standard imaginaries, despite its inherent contradictions and paradoxes. This four-dimensional space can be defined in analogy with one of the highest peaks of modern science, Einstein's theory of relativity. The first three axes – wonder, power and control – can be associated with the spatial dimensions of a space–time relativistic manifold. They represent the fundamental coordinate system of the modern imaginary of progress, and they are in correspondence and in defence of the three founding pillars upon which it is based: objectivity, certainty and exhaustiveness. The fourth axis, urgency, introduces a temporal dimension, which influences and is influenced by the first three. In analogy with relativistic physics, the different epistemic framings and decision-making processes connected with sustainability can be seen as *points*, constantly evolving on four dimensional locally flat manifolds, the modern charts of an intrinsically curved, post-modern atlas.

The attempt to normalise the inherent complexity of choosing a sustainable path for our species can then be interpreted as a way of globally flattening the intrinsically curved space of our current techno-scientific experimentation on socio-ecological systems. The normalising system can be locally functional, but the global complex atlas is doomed to fall apart when the different charts are placed in relation to each other.

We will now discuss the second set of arguments of our paper: the ways in which two key drivers of techno-scientific enterprise, optimisation and substitution, challenge the questions of "What do we want to sustain?" and 'For whom?'

4 Optimisation: being smart

In the fall of 2008, in the middle of the global financial crisis, the US multinational company IBM launched one of its most ambitious global campaigns, based on the idea of building a 'smarter planet'.[3] On 8th November, a few days after Barack Obama's election, IBM Chairman and CEO Sam Palmisano presented his narrative of smart innovation in a 15 min speech at the US Council of Foreign Affair.

In his talk, the planet as a whole – considered both as a matter of facts and as a matter of concern (Latour, 2005) – is described as a single highly complex and interconnected socio-technical system, running at a growing speed and demanding more energy and resources. Climate, energy, food and water need to be efficiently managed in order to meet the challenge of a growing population and a globally integrated economy. A number of sudden and unexpected wake-up calls such as the crisis of the financial markets need to be recognised as the signs of a discontinuity that needs to be governed.

The leaders of both public and private institutions have to acknowledge this radical change and seize the opportunity of techno-scientific innovation to "change the way in which the world works" (Palmisano, 2008). The planet is thus conceived as a complex machine that will cease to function if not governed with the appropriate tools and techniques.

Once the crisis scenario is presented, the IBM narrative of innovation moves to the resolution at hand: we have *already* the technological power and control to turn our predicament into an opportunity. If we are willing to embrace the change and technologically upgrade our way of living, *we can* fix our problems and bring the planet back to a sustainable track. Barak Obama's pragmatically optimistic message 'Yes, we can' is purposively evoked by IBM as a way to reach the public sector as an economic partner.[4] The difference lies in a semantic shift from the electoral 'we can', ostensibly calling for a collective democratic awakening, to the frankly business oriented 'we can', invoking a technological renewal.

The world as a global techno-economic and socio-ecological system is too complex to be governed sustainably by using only human instinct and experience (Palmisano, 2013).[5] Leaders of firms, cities and nations become then responsible for choosing the most effective optimising techno-scientific means, so that the system can be self-governed in the most efficient way. Anticipating by two years the narrative of the Innovation Union, Palmisano invokes 'smart growth' not only as possible and desirable, but also as required and urgent, if we want to prevent further sudden collapses of our life-supporting systems on the one side, and if we want to sustain our competitiveness on the globalised market on the other.

> "It is obvious, when you consider the trajectories of development driving the planet today, that we are going to have to run a lot smarter and more efficiently – especially as we seek the next areas of investment to drive economic growth and to move large parts of the global economy out of recession […]. These mundane processes of business, government and life – which are ultimately the source of those 'surprising' crises – are not smart enough to be sustainable." (Palmisano, 2008)

The implicit assumption is, of course, that the tools required are techno-scientific and that IBM will deliver them for a new *smarter* leadership.[6]

As the boundaries of our finite, physical world become more and more evident in the transition to an era of resource scarcity, we are provided here with a solution coming from the ICT (Information and Communication Technologies) innovation: the apparently *boundless* universe of digital information, virtual connectivity and computational power allow us to optimise our life and become efficient enough to secure consumption growth. These three fundamental axes of the new technological revolution are articulated *via* the terms 'instrumented', 'interconnected' and 'intelligent', which all together define the notion of 'smart'.

Instrumented reflects the indefinite proliferation and diffusion of the fundamental building blocks of the digital age, the transistors (up to one billion per human at the infinitesimal cost of one ten-millionth of a cent). As all these transistors become *interconnected*, anything can communicate with anything else. In this vision, we can thus monitor and *control* our planet with unprecedented precision and capillarity by converging the realms of the physical, the digital and the virtual *things* (Vermesan et al., 2011).[7] Finally, everything can become *intelligent*, as we are able to apply our ever-increasing computational *power* to sensors, end-users' devices and actuators, in order transform the ocean of data that we collect into structured knowledge, and then into action.

In this emerging (and controversial) narrative of the Big Data (Brynjolfsson and McAfee, 2014; Krugman, 2014; Crawford, 2013; Hardy, 2013), the modern ideal of "science speaking truth to power" (Wildavsky, 1979) and the pristine separation between facts and values in our decision-making processes are ideally preserved by technologically enhancing our power to objectively, exhaustively and precisely collect, represent and analyse countless amounts of data, as facts upon which a rational decision can be made.

Three framing epistemic and normative assumptions, emerging from the imaginaries of power and control, need to be set in place in order for this modern narrative to be functional. First, the inherent complexity of the interaction between socio-ecological and technological systems has to be reduced to a measurable set of complicated and therefore simplified structured information. Second, the needed 'facts' have to be defined in terms of supposedly relevant data, filtered through the appropriate information technologies. Third, the *quality* of our decision-making processes has to be completely disentangled from the normative sphere of values, equated to the computational power to distinguish data from noise, and to assign them a meaning, in order to transform them into an operationalised notion of knowledge.

A first contradiction emerges, as the very same technologies invoked to fix our problems increase exponentially the level of complexity they are supposed to manage. Moreover, in this perspective, human beings are relieved of any kind of responsibility, as the arising systemic crisis is imputed to the ineluctable increase of socio-technological complexity. Our only commitment becomes allowing our machines (and the companies that produce them) to keep optimising our life.[8]

More radically, in this scenario, not only the 'things' about which decisions need to be taken, but also the 'we' who gather around those 'things' is fundamentally transformed. Indeed, the ultimate consequence of this set of assumptions is that the most effective decision-maker is *in itself* the merging of a physical, a virtual and a digital being: a cyborg or a robot. The IBM's supercomputer named Watson, a 'deep question answering' machine, which outsmarted his predecessor Big Blue by winning the US TV game 'Jeopardy!' is a clear implementation (or an early incarnation) of this idea

(Thompson, 2010). Watson is conceived and proposed as the best weapon to decide in highly complex and urgent situations, ranging from financial transactions, to clinical and diagnostic decisions, to the management of mass emergencies.

In 2010, Palmisano ended his speech at the Royal Institute of Foreign Affairs in London with these words:

> "Let me leave you with one final observation, culled from our learning over the past year. It is this: building a smarter planet is realistic precisely because it is so refreshingly *non-ideological*." (Palmisano, 2010)

The overarching epistemic, normative and ultimately metaphysical framework of efficiency for a smart and sustainable growth is presented as a modern, inevitable consequence of progress for the common good. If our world is a slow, obsolete and congested socio-technical machine ruled by the laws of thermodynamics instead of those of governance, then (the promise of) a techno-scientific innovation to optimise its functioning becomes objectively needed.

5 Substitution: being synthetic

In the grand narrative of innovation, not only our infrastructures, lifestyles and decision-making processes have to become smart, but also the complex and unpredictable universe of the living needs a deep revision. Significantly absent in the cosmology of smart innovation, the *bios* we coexist with and we depend upon can and has to be restructured for extending the limits in our use of resources and for surviving to our own development.

If the principle of efficiency is a 'refreshingly non-ideological' and rational choice, then the process of industrial standardisation has to be applied also to the microscopic world of organic and inorganic matter, both conceived as Cartesian *res extensa*, and an inert substratum to act upon in the most productive and controlled way (Mackenzie et al., 2013).

The promises of the emerging technologies such as biotechnology and nanotechnology were articulated within this narrative since the beginning of the 1980s. The first were aimed at optimising agriculture processes and products, the second were proposed as a Pandora's box for building a plethora of materials *ex novo*, even promising to optimise the second law of thermodynamics, or entropic law, through direct manipulation at the atomic scale (Drexler, 1986). Both technologies have reached (and for many have passed) their maturity without bringing the promised results (Rose and Rose, 2012), while prompting numerous and unexpected public controversies; they are still financed, supported, regulated and fully embedded in the trajectory of innovation, but it is the new synthetic biology, which catalyses most hopes and fears, public and private funding.

Synthetic biology is a multifaceted innovation, established on a specific combination of the imaginaries of power and control. It is grounded on a unifying and utopic vision, developed over the course of 20 years, designating a variety of techno-scientific procedures. They range from

- advanced biotechnology, based on systemic gene manipulation and control, to
- open source modular bioengineering, producing and sharing standard building blocks, to construct biological devices, to
- the synthesis of new kinds of organisms (Delgado et al., 2012; Fox Keller, 2009).

We will concentrate here on this last conception of synthetic biology, as another exemplary case of co-evolution between the modern model of sustainability and the trajectory of innovation.

In May 2010, nine years after the first sequencing of the human genome in its entirety, the US scientist-entrepreneur Craig Venter announced the creation of Synthia, the first 'synthetic cell' in a crowded pressroom at the J. Craig Venter Institute:

> "We are here today to announce the first synthetic cell, a cell made by starting with the digital code in the computer, building the chromosome from four bottles of chemicals, assembling the chromosome in yeast, transplanting it into a recipient bacterial cell and transforming that cell into a new bacterial species. So this is the first self-replicating species that we've had on the planet whose parent is a computer." (Venter, 2010a)

Synthia is defined as *synthetic* because the genetic code that constitutes its genome has been conceived using a digital coding model and then synthesised in a laboratory. It is labelled as such even though, as many have objected, the organic material of the recipient cell belongs to a natural bacterium (*Mycoplasma capricolum*), and the digital template for the synthesis of its code has been obtained from the sequencing of another bacterium (*Mycoplasma mycoides*).

Venter's designation of Synthia as the first artificial life form has been contested as a techno-scientific hype, an exaggerated claim for marketing reasons. However, while clearly promoting his research with bold statements, his definition can be more fruitfully interpreted in terms of two founding principles, demarcating synthetic biology as a leading innovation to sustain the future. First, the essence of life can be identified with the DNA macromolecule, defined as encoded information, which can be not only sequenced (read) but also chemically synthesised (written). Second, the genome of an organism can be conceived as a genetic program; "the software of life" (Venter, 2010b), which univocally determines the phenotype of the corresponding cell and thus unambiguously decides (in Venter's words, 'boots up') its identity (2010b). Both principles are founded on the idea of life as *embodied* information, and on computation as the essential metaphor for its understanding. This conception is grounded, both in theory and in practice, on the evolution of information technologies and on the increasingly powerful and cheap procedures of DNA sequencing and chemical synthesis (Le Fanu 2009).

The heart of the whole process lies *in between* the two latter operations, the techno-scientific *locus* in which we can deterministically modify and enhance the living processes, reprogramming life for our needs. What we technologically bring back to the wet universe of the living is an optimised, more efficient version of the natural evolution of species. The power of our techno-scientific means allows us then to control *at will* (and ideally eliminate) the inherent complexity of the *bios*, conceived as a burden of evolution.

In a long interview given by Craig Venter and two of his closest working partners – Hamilton Smith and Clyde Hutchinson III – to the American science writer Will Hylton for the New York Times, we read:

> "We're also trying to re-engineer the genome in a much more logical fashion", Venter said. "We're doing it in the form that, if there was a God, this is how he would have done it". "Evolution is very messy", Smith added. "We're trying to clean it up", Venter said." (Hylton, 2012)

The *laws* of evolution need then to be 'cleaned up' from their redundancy, rationally redesigned and replaced by optimised *programs*, making life more predictable, controllable and productive: in other words, evoking the narrative of ICT innovation, smarter. The implicit normative assumption, in perfect analogy with Sam Palmisano 'non-ideological', objectively needed smarter planet, is threefold: first, the world needs to be logical; second, being logical implies predictability and efficiency, and third, complexity has therefore to be eliminated.

Here, while the metaphysical implications on the identity and substance of the *bios* lie in the background of the smart revolution, ontological substitution becomes not only possible and desirable but also needed. Venter's research aims at identifying the minimum genome to sustain a life form. This genome is conceived as a *chassis*, a template of standard information in which one can add specific genes to obtain the desired phenotypic functions. The result of this process is the promise of organisms *on demand*, simplified and optimised, satisfying our needs and fixing our damages: hyper-efficient algae to produce biofuels, synthetic bacteria to clean entire ecosystems, hyper-selective vaccines and drugs to eradicate our diseases, hyper-nutrient food products to end starvation (Hylton, 2012).

Four centuries along the trajectory of modern science, the "*wonders* of nature, in particular with respect to human use" (Bacon, 1627b) are finally at hand. The techno-scientific task is to remove the *natural* complexity of the living beings because they represent an unwelcomed burden of evolution. The redeeming promises of innovation can then be fulfilled and the scarcity of natural resources can be *substituted* with the abundance of synthetic resources.

The idea of solving the dilemma of unlimited growth within a finite system by completely substituting our natural resources with substantially equivalent, techno-scientifically enhanced artefacts was expressed by Solow (1973):

> "If it is very easy to substitute other factors for natural resources, then there is, in principle, no problem. The world can, in effect, get along without natural resources." (Solow, 1973)

A few decades later, the controversial economic ideal of *complete substitution* is embedded in the trajectory of corporate techno-science. Coupled with smart optimisation, this principle grounds the contemporary dominant model of sustainable development.

In October of 2011, the European Parliament's Science and Technology Options Assessment Unit (STOA) presented the results of a workshop on the technical, socio-economic, legal and ethical issues of bio-engineering in the 21st century, with the eloquent title: 'Making perfect life'. One of the main challenges for the governance of synthetic biology was expressed as follows:

> "Can we make synthetic biology a building block to a sustainable future by standardising life?" (STOA Workshop, 2011)

Craig Venter's conception of private profit for the public good, synthetic biology and the eradication of complexity are here proposed as the possible founding pillars of the European innovation policy for a sustainable future.

6 Concluding remarks

We have examined the relationship between sustainability and techno-science at the intersection with economic growth; exploring how the modern framing of sustainability is functional for keeping the trajectory of techno-scientific innovation on its track. When applied to innovation, the normative perspective of modern sustainability helps in standardising the goods and the bads of techno-scientific advancement.

The wonders and power of techno-science will enable us to move from scarcity – of market shares and resources – to abundance – of digital gadgets, data and synthetic replacements, while predicting and controlling the side-effects on the way. Moreover, the drive for sustainability helps securing the ideal of progress, by shifting it from the possible and desirable enhancement of our wealth to the urgent and needed defence of our increasingly precarious *status quo*.

Then we have reversed our line of reflection focusing on the ways in which techno-science modifies and determines the *object* and the *subject* of sustainability. The questions, What do we want to sustain? and For whom? are deeply challenged by the techno-scientific ideals of indefinitely optimising life, extending the definition of natural resources and substituting them by rationally designed artefacts.

In the fields of smart technologies and synthetic biology, innovation not only promises solutions and generates concerns, but more significantly, it assumes, promotes and requires a specific epistemic, normative and even ontological framing of the world, in the name of growth and sustainability. This vision redefines our relationship with life-supporting infrastructures and processes, and with the other living beings (including the humans) that we implicitly integrate or dismiss in the meaning of 'we'.

In this techno-scientifically grounded universe, complexity is the main obstacle to overcome for securing a sustainable future, using the power of our best techno-scientific silver bullets. The *smart* Leviathan of the ICTs eliminates the analogic complexity from our economic, political and social life, and the *synthetic* Leviathan of the new life sciences restores logic in the chaos and redundancy of biological evolution and provides rationally designed organisms on demand.

This program of radical standardisation of life, in its foundations and in its manifestations, triggers some open questions about our current and future condition. Do we think that it is feasible and desirable to give up quality for functionality (Funtowicz and Ravetz, 1992) and to subordinate living to functioning? Do we believe that it is the only possible solution for our current predicament?

An implicit set of assumptions narrows our space, time and democratic imagination about the change we are facing:

- we identify the trajectory of techno-scientific innovation as an end and not a means (Van den Hove et al., 2012)
- we take the model of growth as the only possible path

- we consider complexity as a useless burden to drop off on that path. It reminds us of another key passage of Dwight Eisenhower's Farewell Speech to the Nation (Eisenhower, 1961):

> "The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present – and is gravely to be regarded. Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite."

The warning is still valid, and the relationship between sustainability, techno-science and democracy has to be deeply innovated if we want to live fruitfully and peacefully with the very same complexity that gives us the opportunity to decide for our future and to commit to our present.

A first step is to acknowledge that the project of modernity has lost its momentum and that the need to create a 'successor program' (Toulmin, 1990) is an essential task of our time. It must be essentially different from the existing paradigm because the world has changed and we have changed, precisely because of the transformative power of the modern ideals and technologies. It seems to us that the successor program cannot be a new blueprint, founded on certain substantiated claims, but a suite of processes, programmed and spontaneous, based on socially robust learning practices, to explore and experiment how to live together before even attempting to plan and decide what is going to become of us.

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Notes

[1]Allenby and Sarewitz distinction among three levels of technology enables us to make sense of the ambiguities and contradictions involved in the promises of innovation (Allenby and Sarewitz, 2011).

[2]Examples abound on innovation making jobs redundant: see Brynjolfsson and McAfee (2014) and Frey and Osborne (2013).

[3]IBM "Let's build a smarter planet" campaign by Ogilvy & Mather, won the 2010 Gold Effie Award.

[4]The overall rationale of the campaign can be found at http://s3.amazonaws.com/effie_assets/2010/4625/2010_4625_pdf_1.pdf

[5]"Executives have traditionally regarded experience and intuition as the keys to formulating strategies and assessing risks. That type of thinking might have worked in an earlier time of information scarcity, but not in the time of Big Data" (Palmisano, 2013).

[6]The technoscientific narrative of a corporate marketing initiative such as the one we are considering depends intrinsically on its function of selling goods, as products and services, and it could then be considered as less representative of a deeper political, economic, cultural and existential transition. However, within the path-dependent trajectory from normal science to industrial techno-science, the same narrative of innovation can be found in private firms and in public institutions, as in both cases the goal is to preserve the overarching model of competitiveness and consumption growth, and to survive in it. In this sense, the difference between public and private becomes marginal as in both cases the subject of the narrative is not the institution proposing it, but the *kind of world* that implies the given innovation as the only possible sustainable trajectory. As we have seen, IBM does not talk about its products or services, but it describes a universe in which its technological presence becomes essential.

[7]This technological framework is commonly defined as the Internet of Things (Vermesan et al., 2011).

[8]Other relevant exemplifications of this kind of narrative are the HP project for "The Central Nervous System for the Earth" (http://www.youtube.com/watch?v=qMGyQGTpMFs) and the CISCO and NASA partnership into the global non-profit research and development organisation 'Planetary Skin', http://www.planetaryskin.org/