



FoTRRIS

Fostering a Transition towards Responsible Research and Innovation Systems

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EU Politics for sustainability: systemic lock-ins and opportunities

Club of Rome – EU Chapter

Member of the Advisory Board of the FoTRRIS project



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Since 1972 European leaders have issued policies aimed at safeguarding the wellbeing of ecosystems and the prosperity of all people. Yet the threats have since increased steadily. In terms of system dynamics this indicates a lock-in, mechanisms that make the system veer away from its stated goal. A systemic analysis of EU policies and their (lack of) impact reveals various factors driving the socioeconomic system; a transition in each of them is required for politics to really change course. Four drivers determine the dynamics of the socioeconomic system: technical, social, eco-monetary and paradigmatic. EU policies mostly address the technical driver without taking into account the leverage of the three others. Yet the growing focus within EU research policy on Responsible Research and Innovation (RRI) may offer strong opportunities for transition.

The EU facing big challenges

The origins of the European Union can be traced back to the second World War, a global scale catastrophe. To prevent future wars, European leaders set up economic cooperation among their national states. For several decades this ‘unification of the market’ brought prosperity and a long period of peace to the states involved. The dream was that by enlarging the EU, more and more countries would be able to enjoy the same socioeconomic wellbeing. Yet, today this political project appears to be arriving at turning points.

1. Unequal economic realities among European countries threatens the internal cohesion. Geopolitical conflicts with countries looking for EU support at our eastern border lead to military escalation with Russia. Lack of economic perspective in many countries worldwide causes mass migration and makes young people vulnerable to the call of radical or terrorist organisations. All this raises doubts about the effectiveness of the EU’s ‘soft’ approach to security, and the call for military investments is heard (Krastev & Frank, 2015). Yet, the causes of these threads can all be traced back to the very economic model, in which competitiveness and private or national interests are (structurally) given priority over global concerns and solidarity (Snick, 2016b).

The very economic model the EU heralds as the source of peace and prosperity, is in fact contributing to increasing global insecurity (Snick, 2016a).

2. Ecological threats such as climate change, pollution and mass extinction may be even more dangerous conditions, and no increase in weapons or military intervention can avert them. Scientists call the current era the 'antropocene', indicating that it is human (industrial) activity which today impacts the planetary ecosystem. Again, a model that once seemed to bring prosperity in fact is shown to be a serious threat that may jeopardize our survival. Scientists found that the extreme drought that killed ten million Ethiopians in the early 1980s was caused by the pollution haze in industrialized countries keeping the water-laden tropical air from moving northward (Gibson-Graham, 2006, p. ix).
3. Thirdly, the economy is confronted with increasing scarcity of primary materials. Even sand, the second most frequently used raw material (after water) is being depleted at a fast rate, while the mining of sand destroys beaches and marine ecosystems, especially in the global South (Platt, 2016). Economic growth is confronted with the limits of planetary resources, and models that conceive of economics within the boundaries of the planet are tentative and not fully established or embedded in laws and institutions. By depleting natural resources unprecedented wealth was created in some countries, but the prediction that through a trickledown effect this would lead to prosperity for all has been falsified (Picketty, 2014). Yet, politics still hang on to the current model in which fighting poverty is made dependent on the creation of more material wealth (by increasing productivity).

Today these 'big challenges', diverse as they may be, all are recognised as complex and intertwined. In other words, our socio-economic model is reaching tipping points where what once seemed to be beneficial, at a larger time scale appears to threaten our very wellbeing and survival. Therefore, doing 'more of the same' may well turn out to be disastrous, and the call for an urgent paradigm shift is voiced by many researchers, citizens, politicians and business leaders. The EU is responding to these challenges in different, often contradictory or ambiguous ways. We will look at two of these responses, viz the Circular Economy and Responsible Research and Innovation. They will be analysed from a systemic perspective in order to better understand under what conditions they may really foster a transition towards a more sustainable economic model.

The Circular Economy as a response to material scarcity

The EU reactions to big challenges are often ambiguous and even contradictory. On the one hand the EU propagates environmental conservation and social inclusion, yet at the same time invests even more in regulations, trade agreements and innovation programs with a view to increasing competitiveness and reinvigorating the very

economic model that causes inequality and natural depletion. Although European policy stresses the importance of nature conservation and social justice, it still believes these to be reconcilable with a linear (growing) economic model, even though it is obvious that a model requiring growth in a non-growing planet can only lead to a fierce rat race and ruthless competition for scarce resources and the exploitation of human labour (Snick, 2016b). This indicates a lock-in that undermines ecological and social policies.

It is therefore a hopeful sign of resilience that inside the corporate world there is a growing willingness to acknowledge this change of context and to explore innovative ways of doing business. Loss of available resources (entropy) encourages the industry itself to innovate. An example is the Circular Economy (CE), a movement which receives quite some EU attention and support even if it is still far from being the 'new normal'. The CE is meant to replace a linear-extractive model in which economic production follows the path of mining, producing, consuming and throwing away as waste. Instead it proposes a model in which goods and materials are kept in circulation as long as possible, and waste eventually is recycled as a primary resource for new products. But even political support to the CE can remain an ambiguous or superficial response to the current tipping points. Not only is it still seen as a 'side track' or a niche rather than as the standard for all economic activity, but it is also considered a smart way to refuel competitiveness and growth. Yet, it is obvious that if a company wants to 'grow' its productivity by using waste as a resource, this requires a growing influx of waste, and so at a larger scale this model remains extractive (albeit less visible at first sight). The CE focuses on technical solutions that are expected to allow the industrial economy to continue growing in a 'sustainable' way (which may indicate that the 'sustainability' of the industry is still considered more crucial than that of the planetary ecosystem on which human life depends). It is clear that circular production cannot safeguard planetary wellbeing as long as it has to occur at increasing rates (growth), and so the CE - for it to really become circular - widens the horizon to include sharing initiatives, putting 'access to services' before 'buying products' (i.e. social innovation). This inevitably entails the emergence of alternative business models (or corporate goals) that aim at community benefits rather than private profit, and imply less noxious concepts of and indicators for economic 'growth'. In turn these innovative business models open up a space for community oriented monetary systems (monetary innovation).

So the CE may well be the leverage of a more radical transition (Snick, 2016b). If the aim of the CE really is to halt the depletion of resources, then decreasing production and consumption (or 'degrowth' of material throughput) is an even more powerful way to get there. However, in the current economic system a company that does not increase its productivity may well be forced out of the market. So for a CE to become the 'new normal', innovative economic models and financial tools - translated into legislation and taxation adapted to the current context - will be necessary (Capra &

Mattei, 2016). This will require research and innovation not only on technical questions (e.g. “how to make mobile phones that last longer and use less energy, how to make sure they are easily repairable and recyclable...?”). Companies in the CE are faced with questions that are beyond technical innovation. How can citizens be motivated to buy ‘sustainable’ products rather than the ‘extractive’ ones (that may be cheaper), or to repair them or otherwise give them a second life, or to eventually bring them back to be recycled? If the dominant market mechanism allows companies to make a profit by selling (increasing numbers of) products and so rewards them for increasing the ‘dissipation’ of resources, then what ‘mechanisms’ is needed to allow the CE to close the circle again and counteract this dissipation? If citizens are contributing to the closing of the loop, e.g. by sharing, repairing or recycling their ‘stuff’, then that turns them into ‘prosumers’, i.e. at the same time consumers of the products and participants in the ‘production’ of user value. If their efforts to make resources go round longer is considered crucial for the CE, then how is their ‘work’ to be valorised and protected? All current legislation is built on the extractive model, whereby a producer will try to make a maximum private profit by selling his products to a consumer. In this model, planned obsolescence is not some deviant nasty trick, but a clever marketing instrument that allows a company to bolster its profits. To increase productivity a company has to pay labour as little as possible. So most EU legislation is intended to limit the excesses of extraction and exploitation, yet does not question the extractive and exploitive model itself. Initiatives in which consumers and producers ‘cocreate’ value therefore have no adequate legal frameworks and may even be suspected of illegal pursuits (Orsi, 2012). These examples show that an evolution such as the Circular Economy, promising as it may seem from a technical point of view, is ineffective in the face of big challenges as long as it is not supported by innovations in the economic, social and legal domains (Von Hippel, 2005, p. 2-3). Without social, economic and legal innovation, the economy will not be able (or not be *allowed*) to remain within planetary boundaries. Now companies are rarely specialised (or skilled) in social or legal innovation, so for ‘saving our resources’ they will need to work together with other actors, citizens’ initiatives, civil society organisations, (social) scientists or public services and politicians. All of them have a specific ‘expertise’ that is crucial for the CE (and so for EU politics) to really turn the tide. This ‘transdisciplinary approach’ also appears to be the most effective way to deal with large epidemics (such as Ebola) in the South, where complex community structures and traditions have a large impact on the spreading of the disease; fighting the epidemic by focusing exclusively on specialist medical institutions or health systems may therefore make the epidemic worse (Piot, 2016, p. 484). Coping with the complex challenges of today is no longer the exclusive domain of one specialist (or technical) discipline, but requires collaboration and innovation with what is called the quadruple helix: scientists, citizens, business and politics as four equally important sources of expertise (Dijkgraaf, 2012, p. 23).

Responsible R&I as a potential leverage for innovating politics

The EU also encourages research and innovation to find solutions to the big crises. Specifically the concept of Responsible Research and Innovation (RRI) is coined to denote R&I that deals with sustainability and is structured around six themes: ethics, gender equality, citizen engagement, education, open knowledge and governance. A growing percentage of the EU budgets for R&I are allocated to RRI programs. Yet, the question how 'responsibility' is to be defined, and who exactly is responsible for what and how the six principles are to be put into practice, remains a matter of debate. Few research institutions will be ready to admit that what they normally do is 'irresponsible', and contributing technical solutions for greening products or medical techniques for beating epidemics definitely cannot be considered as 'unethical' in itself.

Yet, as a lot more research has gone into technical (green, medical...) innovation than in the innovation of economic models, governance or social management, there is a real risk that researchers will already consider their research 'responsible' if they contribute just the technical part, leaving the economic and social questions to other disciplines. Since these other dimensions (social, legal and economic innovation) are not integrated from the start into the innovation projects, there is a real risk of a lock-in. For example 'green' technical innovations - e.g. cleaner cars - may be 'co-opted' into the dominant economic and consumption model; since consumers may (be made to) believe that it is less harmful to drive a 'clean' car, they may tend to drive it more (causing social change in the *wrong* direction), and the net effect of this technical innovation at a larger scale may be neutralised or even negative. Also, as long as there are no clear specifications of what exactly is to be considered RRI, the concept may be diluted and exploited as an additional access to research funding. For example, can the search for life on other planets be considered RRI? Does it contribute to solutions for the great challenges, and if so can it be argued that this solution will be efficient and timely? Does it suffice that (a survey revealed that) most people find the quest for extraterrestrial life the most fascinating question about the universe, to claim that this research is therefore contributing to a big societal problem or is based on 'citizen engagement'? If research to increase the competitiveness of - say - the weapon industry is performed without fraud, does that make it 'ethical' (and therefore RRI)? Do efforts to attract more women to this line of research prove its 'gender-sensitiveness' (and therefore make it RRI)?

Yet, given the political decision of the EU to orient the majority of its R&I budget towards RRI (Galiay, 2016), this concept may offer a real opportunity to foster the transition. Yet, the above examples make it clear that this will only be the case if the concept and practice of RRI as a driver of transition is more clearly delineated, and differentiated from R&I within the current (specialist) paradigm, embracing one of the themes of RRI as a mere cosmetic addition. We will propose a framework to

explore under what conditions RRI can effectively contribute to solutions for big challenges. This proposal is currently being investigated by the FoTRRIS-project¹ (financed within Horizon 2020). This is not to imply that R&I policy is the only or even the main road to sustainability; in fact the challenges are so complex and so intertwined that no single approach can ever pretend to bring the sole answer, and academia is only one strand in the quadruple helix of transition (Dijkgraaf, 2012). Since transition requires integrated change (or innovation) processes in four domains (technical, social, economic-monetary and legal), research into how this can be accomplished will certainly be an important leverage.

On the EC website we learn that Responsible R&I has been launched with a view to “better aligning both R&I process and outcomes with the values, *needs* and expectations of society. Responsible research and innovation is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of *inclusive and sustainable* research and innovation. In practice, RRI is implemented as a package that includes multi-actor and public engagement in research and innovation, enabling easier access to scientific results, the take up of gender and ethics in the research and innovation content and process, and formal and informal science education.” (italics AS) In the Horizon 2020 program, RRI is promoted via both actions on thematic elements of RRI (public engagement, open access, gender, ethics, science education), and via integrated actions that for example promote institutional change to foster the uptake of the RRI-approach by stakeholders and institutions².

Key concepts in this description are the ‘needs of society’ as well as ‘inclusive and sustainable’ innovation. It is of course a crucial question how the needs of society are to be delineated. In the light of the current big crises, one of the needs for human society is to be able to reproduce itself (and allow future generations to survive). So the development of solutions for the ecological and social crises and of alternative models leading to a sustainable and inclusive socioeconomic system is certainly needed. Yet, the concept of RRI as it is described above can be interpreted in a minimalistic (or ‘weak’) way, e.g. by focusing on just one thematic element of RRI, whereby research projects that do not aim at sustainability or inclusiveness take additional steps to, say, enable access to the scientific results. In its more ambitious approach, however, integrated actions for RRI can foster institutional change with a view to including diverse stakeholders into innovative models for sustainable and inclusive outcomes. In the current context of big challenges, this more ambitious (or ‘strong’) reading of RRI offers tremendous opportunities.

¹ The FoTRRIS-project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement Nr. 665906. This communication reflects only the author's view and the EU is not responsible for any use that may be made of the information it contains.

² Source : <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation>.

What would such an ‘integrated action’ or ‘institutional change’ have to look like in order to really contribute to a transition - in response to the lack of sustainability and inclusiveness of the current socioeconomic system? Since today’s challenges are recognised as complex systemic crises, solutions have to take into account the dynamics of complex systems. Since most R&I institutions today are based on a specialist rather than a systemic paradigm, it can be argued that RRI will require specific institutions and intellectual and legal infrastructure for tackling crises in a transdisciplinary way. Insights about how these ‘RRI-institutions’ have to function to really serve their purpose are still tentative. In the literature we find analyses of different ways to tackle big challenges, comparing classical (specialist, technical) approaches with more transdisciplinary ones. These analyses are a source of insights into how effective RRI should be conceived, organised and valorised (Piot, 2016).

Proposal for a conceptual framework for RRI

The proposal that will be presented here is mainly based on literature and on systemic analysis of various policies and projects. This proposal will be further tested in the FoTRRIS-project³. FoTRRIS proposes the concept of ‘Community Oriented Responsible R&I’ (or ‘CO-RRI’) as a synthesis of the crucial characteristics of Responsible R&I developed in collaboration with citizens, CSO’s, companies and public services for common wellbeing. This orientation towards (local) communities is what distinguishes FoTRRIS from many other RRI-projects. For R&I to take responsibility in the face of the big challenges, it should also integrate six thematic lines: citizen engagement, gender, governance, education, open access and ethics. FoTRRIS considers public engagement not as a feature that is added in later stages of the RRI-process, but as a building block of RRI itself. RRI is not possible without deeply democratising R&I. Solutions for the big challenges can only succeed if they imply society and recognise the innovative competences of citizens in communities as a basic building block of RRI. Yet, to integrate this community based innovation – in which citizens are recognized as peers – into the current R&I landscape requires specific infrastructure, methodologies and policies. This FoTRRIS aims to develop.

Responsibility means ‘contributing to solutions’

R&I has always been an important driver of economic growth. Today the world is facing big ecological and social crises, and in many parts of the world the economy is struggling. It is agreed that *Responsible* R&I should aim at solutions for these challenges. However, what is to be understood by this ‘responsibility’ and who is responsible for what is still a matter of debate. What we do know is that current threats are complex systemic problems at a global scale. Therefore RRI must adopt a

³ See <http://fotrris-h2020.eu/>

systemic approach to understand the root causes of these phenomena. This will allow it to foster sustainable solutions and to reveal what policies can restore planetary and social wellbeing. RRI should be a catalyst of change allowing the global society to work together towards a new, more viable system. This avoids tackling only certain drivers of the crises while blinding us for others, and aggravating the crisis while making us believe we solved it. RRI is responsible insofar as it *justifies* what aspects of complex socio-economic and ecological dynamics it takes into account for tackling big challenges (Ulrich 1987). Given the global scale of today's crises RRI has to take the *planet earth* as a relevant context. RRI contributes to research and innovations that respect or restore planetary ecosystems sustaining life, and pursue equal access to healthy ecosystem services for all (including future generations and other species).

A common denominator for the crises: Anthropocene

Scientists call the current era the Anthropocene since human economic activity influences the dynamics of the planetary system and leads to problems like climate change, oceanic pollution, soil erosion and mass extinction threatening human survival. This comes as a shock since for centuries politicians and economists predicted that growing economic productivity (combined with social legislation) would bring wellbeing for all. Yet with spreading industrial activity we see the depletion of natural ecosystems and unequal access to increasingly scarce resources. This entails loss of economic perspective in many regions of the world, mass migration, geopolitical tensions and security threats, problems our political and social institutions are not prepared for. Moreover, since the 2008 crash the economic engine itself is faltering in many countries. At first sight this seems to make it hard to address the crises. Yet, if the current economic model causes the threats it is unjustified to believe that 'more of the same' will cure them. These unpredicted outcomes (anomalies) reveal that the current paradigm is untenable, and lead to the emergence of alternative practices and paradigms.

R&I has long been driving economic growth. It provided innovations allowing companies to increase their competitiveness by increasing resource throughput at a lower cost. It brought innovation *within* the very economic model that is today identified as the driver of planetary and humanitarian crises. In a sense R&I is co-responsible for these problems as it sustained or invigorated an extractive and competitive economic model. The emergence of RRI means the science community assumes this responsibility. For RRI to lead to solutions for the threats, it must necessarily include innovation of the economic model itself. RRI contributes to economic growth within planetary boundaries. How this can be conceptualised and organised is itself a matter of learning and innovation. RRI must include research on - and innovation of - the economic model so as to contribute to social justice and planetary wellbeing.

Planetary boundaries determine the conditions for RRI

RRI should pursue 'economic growth' that guarantees a dignified and healthy life for all beings within the boundaries of the planet. It therefore has to acknowledge the basic laws of the planetary system and find new economic models to bring prosperity in a planet that is a semi-closed thermodynamic system. This means:

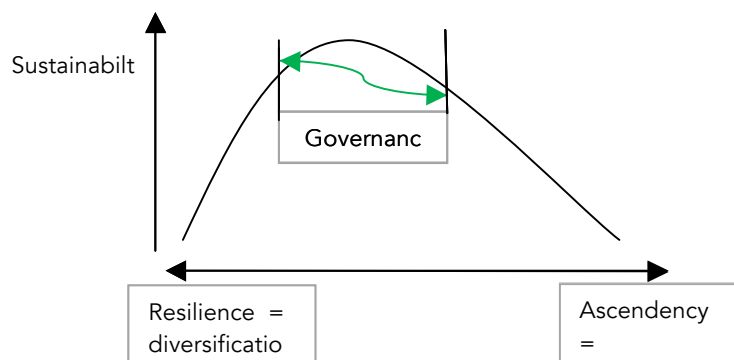
- a. There is **no exchange of matter** with the surrounding space. Growth of productivity in one place inevitably causes depletion and/or pollution in other places. Most economic theories do not include this fact in their mental models and treat the effects as 'externalities' or 'side effects'. Since this type of economic activity is rolled out globally, externalising is no longer possible. The backlash comes in the form of climate change, depletion, pollution and mass migration. This feedback forces RRI to recognise the planetary context as the real basis for justified economic models.
- b. There is **exchange of energy** with the surrounding space. The best-known source of external energy is the sun. Solar heat is distributed unevenly between the earth's equator and poles, fuelling weather systems that in the course of evolution have created ecological niches (climate zones, ecosystems, soils...) and spurred other energy sources (wind, water...). Plants turn solar energy into carbon and feed other forms of life, produce useful materials and yield energy. The yearly influx of solar energy determines the amount of renewable energy and (plant) matter that is available for economic use.
- c. There is always an **increase of entropy** (or disorder). Entropy refers to the degree in which energy or matter are dissipated and become unavailable for use. In the evolution of Earth it is solar energy that creates order (life, available energy) and keeps the planet from reaching maximum entropy (death). In the course of evolution pockets of (mineral or fossil) materials have formed that are available for use. But once extracted and dissipated in the environment it is hard to retrieve them in a useful form and they may even become harmful. E.g. plastic once dissipated in the ocean is no longer available for economic purposes and - eaten by fish - impairs marine and human health. Efforts to 'restore order' always require higher inputs of resources and energy, so at a large scale speed up overall entropy. Products can be recycled but their quality always degrades (entropy); up-cycling (restoring internal order) requires extra resources and increases overall (external) entropy (Roddier, 2016).

For human survival it is crucial to change socioeconomic systems to restore internal order (increased prosperity for people and other beings) while keeping overall entropy low. RRI fosters this by building knowledge on socioeconomic practices that are more adapted to planetary laws and by promoting economic models that guarantee access to a quality life for all people and restore planetary ecosystems.

Evolutionary framework for RRI: growth, collapse and emergence

RRI is to provide answers to crises that threaten life as we know it. Throughout (pre)history, life on earth has gone through several extinctions after which new forms of life emerged. The best known is the ecosystem collapse in which the dinosaurs died out. These were 'successful' animals, capable of a huge throughput of matter and energy. This however made them extremely dependent on (food from) specific ecosystems, and unable to adapt timely to a sudden change in the context. Small, more adaptable mammals survived and eventually evolved into new (emergent) forms of life. Human systems can learn a lot from studying the way natural systems react to changes in the context and can thrive by imitating those (biomimicry). Research on the sustainability of complex flow systems reveals that this depends on three structural elements (graph 1).

Graph 1: Curve of sustainability of complex flow systems (Goerner et al, 2009)



Firstly, it requires resilience, i.e. the capacity to choose alternative paths to pursue its goal in case of a crisis. If a farm grows diverse crops with varying harvest dates, it will survive if a storm ruins one crop. But if an ecosystem just consists of small niches competing for energy, resources may get dissipated and make the system stagnate. So a second element is ascendency, i.e. the capacity to process larger amounts of energy and reducing overhead. Agro-ecology uses combinations of crops that allow for maximum productivity on a given surface, selecting plants (e.g. basil, tomato and grape) that among them optimally share light, water and nutrients and yield plural crops on one plot of land. Reducing diversity (selection) raises ascendency, moving the farm (system) towards the curve's apex. But too much streamlining leads to a tipping point where chances of success decrease again. Monocultures are hyper-ascendant. They extract resources while excluding other flows that can replenish them, and in case of a collapse no alternative paths are available. Resilience and ascendency depend on opposed parameters (much versus little diversification) that must be balanced. So the third factor is governance, the capacity of a system to adjust resilience or ascendency in response to context changes. These correcting feedback

loops have to be active before the system is too far on the downward slope, keeping it within a 'window of viability' (around the curve's apex). When (socio-technical) regimes get too ascendent and collapse, the system often veers up by the emergence of resilient ('alternative') niches. This implies that CO-RRI (up-scaling niche innovations in response to great challenges) should no longer be valorised using the instruments (such as Intellectual Property Rights) of the regime that contributed to the crises in the first place. In evaluating RRI-projects the number of patents should no longer be used as a (positive) indicator for success.

Research reveals that all kinds of sustainable systems can be compared to dynamic networks keeping a balance between these two opposite features (Ulanowicz, 2015). Their ability to efficiently maximize throughput depends on streamlining processes that are adapted to (and successful in) a given context (internal order, increasing external entropy). Their resilience on the other hand depends on their capacity to allow for divergent processes, maintaining a degree of freedom that diminishes efficiency but increases adaptability. Sustainable systems in all kinds of contexts show a surprising consistency in their degree of order at around forty percent, whereas divergent pathways account for sixty percent of their flows. The dinosaurs' hyper efficient adaptation to a very specific context explains their collapse once this context changed, while small mammals' resilience and adaptability allowed them to survive and enabled the emergence of new life forms that were better adapted. As these life forms get successful (efficient), they in turn have an impact on their context, leading to changes that again require adaptability. Keeping the system's ascendancy and resilience within a window of viability is what is needed to avoid large collapses, and this requires governance. Governance for sustainability means maintaining the right balance between freedom (60% adaptability) and order (40% efficiency).

The current economic infrastructure is extremely efficient at maximising energy throughput, turning other forms of life and planetary resources into means for economic growth far beyond the yearly renewable influx. This socio-technical regime is strongly institutionalised on a global scale and very slow to adapt. Yet as a response to dramatic and threatening context changes, small niches of alternative socioeconomic practices are emerging worldwide, more in tune with the laws of the planet and oriented towards local or global wellbeing. The sustainability of society depends on its capacity to upscale resilient initiatives; research in process ecology suggests that sixty percent of socioeconomic transactions should be enabled through innovating pathways while efficiency accounts for forty percent. RRI aims at up-scaling more adapted socio-economic approaches and at designing R&I infrastructure that assures high resilience in the long term (Goerner et al. 2009). RRI also has to develop governance models (innovative legislation and taxation) that allows the system to break out of this political lock-in and restore the balance between ascendancy and resilience.

RRI is required in response to a historical lock-in

RRI is needed to design economic models and legal frameworks that guarantee the prosperity of all life while respecting the yearly influx of resources and causing minimum entropy. Economics is a human activity shaped by political and scientific decisions that are in turn influenced by historical events and evolutions. Yet socio-cultural processes also crystallise into institutions and habits that are less adaptable. These institutions tend to be seen as realities to be taken as a 'given' rather than as a process based on choice and values. RRI focuses again on economics as a societal *function* and fosters the emergence of more adapted infrastructure, practices and value systems. The economic function can be described as the wise allocation of scarce resources to the wellbeing of all. As the earth is a dynamic system shaped by fluctuating energetic, thermodynamic and evolutionary factors, this requires *ongoing* research and innovation. It forces humankind to constantly find more adapted ways to allocate (renewable) resources available at a given time and place to the needs of all. The current economic system is dysfunctional since it destroys life sustaining ecosystems and increases social inequality while pursuing its own growth. RRI must clarify what drivers explain this escalation and what leverages can bring timely change.

A historically unique event has steered economic processes on a path away from 'normal' planetary laws. Stocks of billions of years of solar energy (in fossil form) were found. This sped up economic activity to a degree surpassing many times the annual influx of energy and resources. It spurred the creation of infrastructure based on (diminishing) stocks of non-renewable energy; this led to centralised, industrial production units whose aim is to make a profit by selling a maximum amount of products at the lowest cost. The greenhouse gasses released in the process exceed the absorbing capacity of the planet; this capacity comes from plants (photosynthesis) which depend on complex ecosystems that are themselves degraded by economics. This historically 'unique' economic infrastructure appeared efficient in a context of fossil energy, but brought dramatic context changes that ask for an urgent change. However, it is so strongly institutionalised that the term 'economy' today is mainly used to refer to this system (and its infrastructure), which makes it hard even to think of economics again as a function. The economy is seen as a sector whose growth is deemed more important than the thriving of people and planet, a total means-end reversal. Achieving the aim of prosperity again will require the 'degrowth' of this infrastructure and the 'regrowth' of our capacity to fulfil the economic function. RRI has to restore the economic function which the current (fossil based) infrastructure does not serve, and explore innovative (resilient) means and infrastructure to realise this. RRI aims at 'regrowth', i.e. increasing (again) our capacity to sustainably allocate resources to the needs of all while keeping entropy low.

RRI allows adapted monetary systems to emerge and upscale

Debates on RRI always end up in the question whether there is enough money to solve ecological, geopolitical or social problems. Money is an agreement within a community to use something as a means of exchange in a systematic way. Saying 'there is no money for sustainable development' in fact means 'the current agreements do not allow us to allocate available resources to human and planetary wellbeing'. So for RRI to restore the economic function it has to change the 'agreements' that are used to allocate resources, and contribute to the innovation of the financial system. Therefore, it is crucial to understand the lock-in of current money.

Industrial scale production was made possible by the centralisation of capital and power. National governments gave private companies (banks) the sole power ('fiat') to create money and to impose rules for financial transactions. Today money is created virtually when banks write out a loan (digits on an account) to be paid back by the debtor with an interest. As digits are unlimited in number debt can grow endlessly. Economic actors however cannot repay debts by adding digits to the bank's account, but have to 'make money' in the real economy on a non-growing planet. Money is thus systemically imbalanced, since (virtual) outflow is larger than (real) available inflow. That makes it 'scarce by design' and urges economic actors to exploit human and natural resources, extract profits from speculation on resources and worry more about price than about social or ecological value. 'Making money' becomes the primary aim of business transactions and organisations, at the detriment of the wise allocation of smart resources to the needs of all (the economic function), i.e. a means-ends reversal.

The monopoly of this money creates a lock-in for it is often seen as 'given' rather than an agreement that has to be (re)designed for the common good and the wellbeing of all. It makes pursuing self-interest *seem* more rational than fostering common wellbeing, and diminishes our adaptability. If CE-companies use waste as a raw material this should decrease entropy; yet as companies are required (by scarce money) to make profits (financial 'results'), they need growing flows of waste (increasing extraction). Taxes raised to restore the common good (e.g. poverty alleviation, health care, nature conservation...) are payable only in money that disrupts common goods. Governments expect businesses to respect ecological and social rules yet force them to compete for extractive money, a *double bind* explaining behaviour like tax evasion or information distortion.

In the industrial era 'work' has been narrowly defined as 'being employed' for (private profit of) a company rather than as 'contributing' to the wellbeing of the community. The term 'income' since then denotes a monthly payment on one's account instead of 'access to collective (human or physical) resources or services needed for a quality life'. This narrow view has been institutionalised in legislation

and social security systems, and still today has a negative impact on the status, wellbeing and empowerment of people (mainly women) who take care of future generations or communities. The profit-drive entails a scarcity of and competition for jobs. Available human resources are left unused (unemployed) while work for social or planetary wellbeing is left undone. To restore the economic function, concepts like 'work' and 'income' will have to be redefined.

Today more cooperative financial systems (such as gift economy, local currencies, social crowdfunding, ethical investments or interest-free loans) are emerging worldwide, mobilising resources to meet community needs which the private profit market does not meet or for which governments do not have (scarce) money. Local communities set up exchange systems of mutual aid that serve goals like elderly care and social cohesion or a cleaner and greener environment. These initiatives increase access to resources (i.e. regrowth of 'income') without fuelling exploitation. In response to poverty they valorise all human talents that contribute to community or planetary wellbeing without exclusion or exploitation, respecting the needs of next generations. Ethical companies use combinations of local and national currencies to make goods and services accessible to people in poverty. Yet since cultural and linguistic habits are hard to change, the economic potential of these initiatives is not recognized, resources remain unused and needs unmet. RRI has to turn these initiatives into catalysts of change by making them visible, raising awareness of their value and fostering political support. RRI should foster the development of exchange systems that valorise and exchange resources and lead to regrowth of the economic *function*. It has to support the valorisation of all roles needed for human wellbeing and thus foster gender equality. It should also build knowledge on innovative monetary systems that emerge in response to the crises, and investigate what governance they need and how communities can integrate them in their economic fabric.

The concept of 'regrowth' is visualised in table 1. Since currently overshoot day falls in August, we can say that the current system uses 150% of the renewable resources, and since the majority of the world population (estimated at 80% for the sake of the argument) lives in poverty, these resources serve only 20% of the population. If the economy could allocate 100% of the resources to 100% of the population, the economic function would be better fulfilled (regrowth of economic function). If further decoupling and other RRI allow us to use less than 100% of resources (allowing natural ecosystems to restore and build buffers) for more than 100% of the population (foreseeing population growth in future generations), regrowth goes up again.

Table 1 : Modelling the impact of various scenarios on economic function and social/ecological wellbeing (exempli gratia)

Economic function Scenarios	Used % of Yearly Available Resources = R	Allocation by means of	For % of World Population's Wellbeing = P	P/R-Ratio = Regrowth index	Impact on context
Current situation	120 Planet overshoot	Monopoly of scarcely designed (extractive) money	20 - Worldwide competition	20/150 = 0,13	Social, ecological and geopolitical threats
Continued growth & private profit	125 Increasing entropy	Competition & speculation for financial profit	15 - Capital Accumulation	15/125 = 0,12	Lock-in aggravation of crises
Inclusive & green growth	110 External entropy	Competition with (patented) clean products and services	25 Social corrections	25/110 = 0,23	Slowing down crises, no systemic solutions
Regrowth supported by RRI	100 Entropic degrowth	Innovative financial rules & community currencies protecting common goals	100 Solidarity & cooperation	100/100= 1 Baseline	Access to (commons based) resources to fulfil all functions
Sustainable Regrowth	80 Further decoupling	Commons-based RRI up-scaling & fostering uptake of new economic paradigms	105 = Including next generations with population growth	105/80= 1,31 Regrowth	Restoring ecosystems, social justice & prosperity

RRI decentralises commons-based knowledge

Scientific insights on emergence of order in complex systems reveals that most domains of human behaviour cannot be regulated by reductive systems. Reductionism breaks down complex systems into their constituents parts and try to predict the outcome of the whole based on the knowledge of the basic elements, like a clockwork. However, this does not allow to account for non-linear (or chaotic) processes in which chance plays a role and which turn out to determine almost all of human behaviour. So for RRI to facilitate the resilience of complex human socioeconomic systems, it should build on the knowledge of how order (or 'life') emerges in complex dynamic systems. From observing how live ecosystems reach states of relative stability and order, RRI can then create the circumstances in which this learning can be applied to socioeconomic adaptation (Sapolsky, 2011). In terms of R&I this means that specialist (or reductionist) knowledge is not able to produce

solutions for problems (or create order and control) in a complex dynamic system like the planetary ecosystem. Adaptability and emergence of new order appears to come from bottom-up input, converging over time into new, self-organised and self-adaptive structures that appear to be more accurate than specialist – centralised – knowledge is able to produce (Surowiecki, 2004). This insight is a basic building block for CO-RRI. For innovation processes to result in self-adaptive and self-correcting solutions adapted to the complex dynamic (non-linear) ecosystem of (life on) the planet, it needs infrastructure where this collective, bottom-up adaptive capacity is facilitated and fostered. Local communities have embedded (indigenous) knowledge of local needs and resources, and can create solutions for local manifestations of global crisis based on short feedback loops, allowing for rapid adaptation. For certain aspects of these solutions, more distant connections are also needed, but in diminishing degrees. This means that decentralised infrastructure to foster local solutions to global threats (or ‘glocal’ RRI), supported by a smaller number of institutions at the meta-level, is what is needed for rapid adaptability.

Fossil-based infrastructure typically centralises production of goods or services for consumers. In line with this top-down approach classical R&I sees citizens as *objects* of knowledge or *users* of innovations. R&I is embedded in highly specialised institutions requiring a centralisation of resources and money. These institutions are themselves seen as economic actors making money with patents or spin-offs. Scarce money puts them under pressure to generate incomes, steering their activity towards lucrative (high entropic) sectors. Innovative initiatives emerging in response to big crises are more decentralised. In line with (thermodynamic) planetary laws they rely on renewable resources that are available locally in varying quality or quantity. New allocation systems foster the use of these resources for the needs of the community. The ‘market’ of private profit driven initiatives does not lead to collective wellbeing, while high order (ascendent) state services have trouble steering away from the industrial, centralised model. Therefore, emergent alternatives invest in a new kind of public space where resources are allocated to the common good while involving citizens as ‘prosumers’, producing as well as consuming the services they co-create. This space for economic regrowth is called ‘the commons’, a concept that delineates where resilience is to be found today, and therefore crucial for RRI.

Local communities and cities appear quicker to adapt than the private market or the state (Gibson-Graham, 2006, p. 165). They are big enough to be able to pool (human and physical) resources and design their own allocation systems for the common good. They are small enough to allow for short feedback loops, since there is a more direct contact with citizens in their daily environment. Cities have more freedom and flexibility for different policy departments to join forces in innovative initiatives than the state. Citizens can be more easily motivated to engage in work for their community as they feel the positive impact of their efforts and have access to the results. Commons are seen as the level with the highest resilience and adaptability.

That makes them into 'real life' (urban or rural) labs for RRI. The number of 'resilient city' networks today is large, including labels such as Smart cities, Sharing cities, Climate friendly or Green cities, Covenant of Mayors etc. These networks too often receive support from the EU; their innovative capacity is a crucial resource for RRI.

Emergent initiatives can hardly upscale for lack of adapted legal and institutional leverages. Current legislation is based on the assumption that economic relations are essentially exploiting and pursue private profit; this is institutionalised by business legislation. Environmental and social legislation curbs excesses of exploitation and makes the competitive model (seem) more 'just' (Capra & Mattei, 2015). Commons however are built on relations of cooperation (Orsi, 2012). Commoners pool their resources with a view to increasing collective wellbeing, blurring the lines between owner and renter, employer and employee or producer and consumer. Existing legislation does not offer adequate models to formalise those new relations, and they risk being suspected as attempts at increasing exploitation while evading state control. For the economy to reach a level of sixty percent 'resilient' transactions, leverages at higher (legal and political) levels are urgently needed. This involves specialist knowledge developed by RRI. To raise societal adaptability this knowledge cannot be privatised but must itself be a common good. RRI-infrastructure to strengthen the potential of regrowth initiatives should be based in the public space uncovered by private market and state. Commons initiatives should be seen as real life laboratories where citizens, CSO's and companies experiment with more adapted practices and models. Local, decentralised RRI-infrastructure (which we will call 'hubs') is needed to help them to upscale by exploring higher (political, monetary or technical) leverages, systematise the expertise they co-produce and make it freely accessible to society.

RRI co-designs by integrating different types of innovation

Traditional R&I institutions are built on specialist, non-systemic mental models. This explains why economic science for centuries could deny physical laws, why money is seen as a given rather than a social construct, and why many people believe solving great challenges can lead to growth. Economics rely on mathematics for scientific robustness. However, calculating economic functionality in a complex dynamic flow context (Earth) implies an enormous number of variables that defy linear proof or mathematical calculation. Therefore, economists use a limited number of quantifiable parameters such as money, productivity or jobs, and neglect others. Economic laws are valid *ceteris paribus*, i.e. *supposing* other factors remain unchanged. If economic (financial) success is measured with bank money as the only unit of account, 'more' (profit, productivity) will seem 'better,' even though in our planet growth leads to increased entropy and *loss* of economic functionality.

Initiatives emerging today use a more integrative, holistic approach. Social innovation – redesigning economic relations including care and community work – is combined with monetary and technological innovation; their innovative governance models and ownership regimes make functions accessible to more people while using less natural resources. If you want to put up a picture, you need a hole made in the wall (access to a function), not a drill (product ownership). Commons allow access to functions by pooling resources. Local Exchange & Trade Systems or Mutual Aid Networks encourage people to ask a neighbour to drill the hole in return for some other help to the community. Tool libraries give access to machines owned by (someone in) the community and define rules and regulations for use. Up-scaling these niches also requires changing the socio-technical regime, for established institutions think in terms of producing goods rather than of increasing functionality. In the Circular Economy (CE), the concept of selling function instead of products is being explored. Interestingly, if a company sells a function (e.g. light instead of lamps, washing capacity instead of washing machines) it is in the interest of the company to make its products last as long as possible, and the systemic driver for ‘planned obsolescence’ disappears automatically. However, as long as the company is forced (by economic and financial models) to make a profit, it may be in the interest of the company to urge consumers to burn the lamps day and night or wash as often as possible, causing other externalities (in terms of energy, water, etc).

In socio-economic institutions of the industrial system, functions are mostly organised in silos with specific goals and means. The function of ‘transport’ e.g. is translated into ‘things’ like roads, harbours, a logistics sector or car industry requiring growth etc. In terms of function, however, transport could mean ‘the capacity to bridge the distance between people and what they need with low entropy’. Urging the car industry to sell cleaner cars is not functional as (without financial innovation) more cars have to be sold. If however twenty families share a car, access to function is offered with less resources. CSO’s that ask a local farmer to bring baskets of food to the community once a week increase prosperity (easy access to local food– i.e. mobility function fulfilled - more free time, less cars in the street...) and lower the entropy. If participants in this kind of commons are valorised with (local money allowing them to buy) train tickets, functionality and ‘mobility’ go up again, including for people in poverty. Technology can create ICT-tools to facilitate access or develop renewable and low tech products or tools. Low tech is easier to share with and disseminate in regions in the world that have fewer specialised R&I institutions and therefore contributes to economic regrowth on a global scale. Economic RRI is needed to investigate how goods and services can be made available without urging companies to accumulate capital; examples are P2P models (Troncoso & Utratel 2015), B-corp or Economy of Communion. The conditions that would allow community currencies to strengthen local economies or the indicators that are needed to monitor regrowth in a complex context should be investigated. In order for

the commons economy to upscale, this expertise must be made available to society by RRI-hubs exchanging knowledge and making it freely accessible. RRI-hubs are needed to mediate between specialist R&I institutions and the ‘real life laboratories’ of citizen or city initiatives by providing methodological frameworks that focus on socioeconomic functions as well as on technical and legal preconditions, allowing them to map in a transdisciplinary way leverages needed to upscale emergent solutions. They should integrate social, economic-monetary and technological leverages into new governance models and paradigms. By sharing their methods and results, they foster the uptake of RRI for transitions at regional, national or transnational scales. Table 2 visualises relevant partners for these hubs.

Table 2 : Stakeholder analysis for CO-RRI-hubs

Positive power = (current) leverage for systemic impact	high	Pioneers in regime/expert institutions <ul style="list-style-type: none"> - Academic sustainability research - Legal experts for sharing economy - Circular economy, biomimicry R&I... - Benefit corporations, Economy of communion movement... <p>→ Partners for knowledge co-creation</p>	CO-RRI local hubs (with regional clusters & www-platform) mediating between real life laboratories and Pioneer experts <p>Developing strategic partnerships with</p> <ul style="list-style-type: none"> - Systems analysts, Future Earth Research... - RRI-community, P2P- network ... - Research network on community currencies - Associations of cities and communities...
	low	Financial growth oriented (in regimes and niches) <ul style="list-style-type: none"> - Classical for-profit companies - Technological innovation for growth - ‘Sharing’ companies to raise private profit (Uber, AirBnB...) <p>→ Invite and encourage to learn</p>	Real life labs <ul style="list-style-type: none"> - CSO’s (transition towns, ecovillages, LETS...) - Cities (Smart, Sharing, CO2neutral, Ville Ravie...) - Prosumers (Community Supported Agriculture, Car sharing initiatives, Cohousing projects...) <p>→ Partners for knowledge co-creation</p>
		Low (sub-systemic goal= own growth)	High (systemic goal= regrowth)
		Innovative potential = Capacity for shifting paradigm towards common good & regrowth	

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