

High Level Group

Innovation Policy Management

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship



"THROUGH RESILIENCE THINKING TOWARDS SUSTAINABILITY AND INNOVATION"
Recommendations for policy makers in the EU

Brussels, February 2016

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Note to the reader

This report was produced by the independent, tripartite, Working Group on Resilience Management and the Circular Economy working under the aegis of the High Level Group on Innovation Policy Management. Its members – senior civil servants drawn from the European and national administrations, experts and managers from leading innovative companies and prominent scholars from academia – have participated in its work in their personal capacity.

While there have been broad discussions and many areas of agreement among the participants in the group, the recommendations for action and all ideas for further consideration have not been agreed upon in detail by all members. The final version of the report is therefore written under the responsibility of the Secretariat.

Executive summary

Europe needs to take the global leadership of a new model of economic development to provide well-being to its citizens, focused on the twin objectives of equity and full sustainability.

Therefore, applying resilience thinking as a transitioning model towards an economy built on circularity would have a positive and overarching impact on social, cultural, economic and environmental sustainability. Resilience thinking acknowledges that human activities now shape the biosphere from local to global scales. At the same time, human societies are fundamentally depending on the life-supporting biosphere for survival and well-being.

Concrete recommendations for further action in this direction are presented to the EU institutions and Member States, notably on the notion of making sustainability through resilience thinking an overarching EU policy principle; on applying the principles of resilience thinking to boost social innovation and increase citizen's well-being; and by simultaneously stimulating competitiveness by means of an equally overarching innovation policy.

Key issues identified to achieve sustainable and resilient societies, prosperous for all are:

- Targeted and innovative funding coming from both public and private sources;
- Adequate and coherent innovation-triggering policy framework not resulting in a lock-in;
- Creation of semi-protected niches for frontrunners and incentives for best performers;
- Shared engagement and buy-in of all key stakeholders through collaborative governance.

The expert group operates with the following definitions of key concepts:

- **Resilience:** The capacity of a system to absorb shocks so as to maintain essential functions and develop towards a sustainable state.
- **Sustainability:** The normative goal of society, understood as managing resources in ways that promotes equity and welfare in current and future generations.
- **Circular Economy:** The transition from a linear economic model to a circularity-based model where resources are kept in use for as long of possible, reducing the generation of waste, improving resource efficiency and developing a sustainable economy through innovation.

Foreword

In its Blueprint on 'Inspiring and Completing European Innovation Ecosystems', the tripartite, independent High Level Group on Innovation Policy Management (HLG) recommended that the EU should maintain its global leadership in ecological sustainability, both from public and private angles. However, the HLG noted that sustainability has additional dimensions to be managed coherently: economic sustainability, such as the creation of comparative advantages and employment, or social and cultural sustainability, an integral component of welfare societies and of national identities.

One cannot deal with present and emerging problems with solutions from the past. This understanding opens a vast space for scientific research and innovation in markets and societies, bringing competitive advantage and employment, and it can lead to new insights in systemic risk and in ways of addressing it. Though, not only academic research needs to be involved, also 'experts in the field' must participate, i.e. those operating in these systems which have acquired a practical understanding to complement academic research.

An innovative European policy approach is now, due to convergent crises, even more urgent to ensure the twin objectives of competitiveness and ecological, economic and social sustainability, which can only be achieved through comprehensive and courageous innovations. Recognizing that long-term social and economic sustainability cannot come at the price of eroding the capacity of the life-supporting biosphere is a key insight. The urgency of a new approach becomes even more evident considering that the transition towards more sustainability in most industrialised countries is slowed down by inappropriate and incoherent policy frameworks, by dis-functioning in the financial sector and by uncertain or slow transition in some traditional industries.

The advances of research and technology offer solid opportunities to deal with a number of challenges, though one should neither overlook the importance of social innovations, nor the fact that not every innovation is in the end sustainable. Also global governance tackling global issues remains weak and mired in traditional inter-national methods. Because of its long experience with multi-layered governance, the EU could position itself to lead the required change processes, for itself and the global interest, as it has done on climate change.

In order to ensure a level playing field in the Single Market, to avoid unfair competitive practices based on lower standards, and to stimulate companies to follow this lead, public authorities need to maintain appropriate policy and regulatory framework conditions. The EU recently adopted package on the so-called circular economy is one step on the way to do so.

The effects of the financial crisis are still felt today in Europe and have shown the lasting need to maintain sustainable, resilient and adaptive ecosystems, systems that are as self-sufficient as possible, with mechanisms able to prepare for external changes or shocks, absorb and amortize them in a way that the ecosystem as a whole is not substantially affected.

The HLG believed that resilience thinking and practice offers an innovative way to describe and understand the complex dynamics that are triggered when we change one parameter without taking account of the whole system. Instead, we need to consider restoration, stressor reaction, self-adaptation, or self-restoration, evolution. Resilience thinking seeks to understand the life cycles and complexity of systems (including the innovation systems) in order to better manage them, placing specific issues within a comprehensive context. Adaptation should be understood as a component of resilience, the ability of the system to change or assume different behavioural properties when reacting to the stimuli

I. The circular economy concept by the European Commission

On December 2nd 2015, the European Commission adopted the new Circular Economy (CE) package aimed to support a smart, sustainable and inclusive growth. The European Commission has introduced four legislative proposals on waste recommending amongst other measures new EU-wide targets for waste recycling, a binding landfill target, the promotion of economic tools to discourage land filling, and harmonized calculation methods for recycling rates in the EU. These proposals came together with an action plan addressing a vast range of issues such as food waste reduction, development of quality standards for secondary raw materials, rules on fertilisers, strategy on plastics and action on water reuse. Other proposals include measures to promote re-use and stimulate industrial symbiosis, as well as economic incentives for producers of greener products and recycling practices.

The package has been prepared by a team of Commissioners comprising Vice-president Franck Timmermans, Vice-president Jyrki Katainen and Commissioners Karmenu Vella (Environment, maritime affairs and Fisheries) and Elzbieta Bieńkowska (internal Market, Industry, Entrepreneurship and SMEs) aiming at increasing collaboration between the main policy areas concerned with Circular Economy. The new project defends a more inclusive approach throughout the value chain process, “closing the loop” of full product lifecycles.

The Circular Economy initiative aims for a transition from a linear model based on the idea that resources are abundant and cheap to dispose of, to a circular economic model: “Circular economy systems keep the added value in products for as long as possible and eliminate waste. Transition to a more circular economy requires changes throughout value chains, from product design to new business and market models, from new ways of turning waste into a resource to new modes of consumer behaviour”. This implies “full systemic change, and innovation not only in technologies, but also in organisation, society, finance methods and policies.”¹

Circular Economy remains the most encompassing initiative and most far-reaching project to date where resilience thinking is being used as a catalyst for economic sustainability. The European Commission’s action plan seeks to “support the circular economy in each step of the value chain—from production to consumption, repair and remanufacturing, waste management, and secondary raw material”. The Circular Economy is a unique attempt to develop sustainable economy in Europe, as part of a broader strategy that impacts all policy domains. The concept of resilience in the European economy can indeed reach many other sectors of activity such as agriculture, chemicals or environmental ecosystems.

The European Commission notes though that the transformation to a circular economy can “never come about simply as a result of legislation: we need a combined approach, where smart regulation is blended with market-based instruments, innovation and incentives.” The HLG believes that such combined approach can only materialize when establishing clearer linkage and coherence between a circular, sustainable economy, research and innovation policy and other policies (energy, digital, and others) so to promote a sustainable transition.

With this package, the European Commission attempts to bridge the gap between the multiple steps in the value chains of different industry sectors with a transversal and comprehensive

¹ Towards a Circular Economy: A zero Waste Programme for Europe, Communication from the European Commission, COM/2014/0398, 2014

approach of sustainability and circular economy. The package contains broad commitments on long-term strategies such as eco-design or the development of eco-innovation projects.

Yet, the Circular Economy package fails to fully address a truly comprehensive understanding of systemic change as it falls short on the social dimension of sustainability. Building a bridge between jobs, growth, sustainability, and citizens' well-being can only be achieved through a mixture of radical and incremental innovation both in economic and social systems.

By its very nature, a Circular Economy can only be achieved by building in parallel the working conditions for developing both public and private research and innovation. These two objectives must be seen and developed as twins. Without the framework conditions for widespread and sometime radical innovation there will be no circular economy emerging, only a dysfunctional one with increased regulatory burden and decreasing employment and competitiveness. A silo approach risks increasing production costs in the EU for the sake of environmental sustainability with negative outfall for competitiveness and employment.

II. The concept of resilience

1. General definition of resilience

The resilience approach views humans as part of the biosphere, and assumes that the resulting intertwined social-ecological systems behave as complex adaptive systems. This means that change is unavoidable, often non-linear, and sometimes irreversible. Resilience thinking addresses the complex interaction of social-ecological systems and “emphasizes the need to understand and manage change, particularly unexpected change”² in order to address pressing sustainability challenges such as human long-term well-being.

2. Working definition of the working group

Our working definition of resilience hinges on multi-disciplinary scientific approaches and collaboration among stakeholders. It also relies on 7 key principles defined in the Annex section of this report that range from the management of slow variables and feedbacks to the means to promote polycentric governance systems.

Resilience is a concept for understanding and managing change in integrated and complex systems. It can be helpful to guide processes towards sustainability: ecological, political, economic, and societal. Resilience thinking is thereby a means to an end, not the end itself; it can be understood as notion/paradigm and tool for how a system can deal with (internal, external) shocks, and manage a transition towards a more desirable and sustainable setting, for instance a circular economy. Resilience is an overarching, inclusive concept bridging different types of silos and stretching across various sectors and policies – thereby echoing the European Commission's envisaged “combined approach”.

² Biggs Reinette, Schlüter Maja, Schoon Michael, Principles for building resilience. Sustaining Ecosystem Services in Social_Ecological Systems, Cambridge University Press, 2015, p 7

Generally speaking, resilience refers to a system's capacity to handle change and shocks. This implies a system's capacity to absorb shocks so as to maintain essential functions and develop towards a sustainable state. This system can be ecological as well as political, economic, or societal – or most likely, these systems interwoven. Lastly, resilience thinking offers insights into questions relative to governance and policy management in highly complex, multi-layered and turbulent environments such as the EU's. Resilience-thinking-based policy has the capacity to understand the inter-acting elements of complex economic, ecological and social systems, how they self-organize and change over time and how they can be influenced through multiple interventions to maintain, adapt or transform to desirable equilibriums. Accordingly, any major or strategic policy alignment should benefit from the help of resilience thinking.

With its flexibility, a resilience thinking-based approach provides a toolbox to improve innovation policy management and ensure that governance and regulatory systems can adjust and become more sustainable, depending of the disturbance they face. It is a pragmatic approach to help meet the objectives of national and international agendas such as Sustainable Developments Goals, including improved human well-being, COP 21 agreements, the revised Circular Economy package and the broader objectives of climate change. The resilience concept informs policy maker on how a systemic change in organisations, society, finance methods and policies can be realised in an inclusive and comprehensive way.

3. The relationship between resilience and sustainability

Resilience thinking is based on systems theory. In a strive towards sustainability it is helpful to consider the social (including the economic and cultural) and the ecological (environmental) aspects as one integrated system: a social-ecological system. Society is ultimately dependent on goods and services from ecosystems and, *vice versa*, all ecosystems are influenced by human activities. Resilience thinking provides a conceptual framework, based on empirically founded research on systems characteristics, for navigating social-ecological systems towards sustainability. Resilience thinking is a framework that help us understand and manage how society can face uncertainty and unexpected change in shifting development to new pathways. Resilience thinking provides the explanatory tools to consider and apprehend the numerous intertwined sustainability challenges of society and its dependence on the biosphere and develop innovation in policy management.

III. Recommendations

The old resource intensive model of growth is unsustainable. New production methods, driven by digitalisation, automation and flexibility are inevitably on the move and will have far reaching economic and social effects which need to be coached by the European Commission and national governments. The EU's and the national governance structures are equally important in a multi-layered system such as the EU.

Innovative forms of collaboration between stakeholders, in the first place European Council and European Commission, national governments, corporations (large and SMEs), and research centres are needed to properly answer the challenges of a new paradigm shift.

Embedded in the global objective of circularity, the Circular Economy provides a challenging framework to deeply transform the rationale behind Europe's economy. There is a clear will to engage all components of society in a global effort towards sustainability but it has become clear that this new policy direction requires new forms of governance. If the European Commission's Communication on a Circular Economy points in the right direction, it still needs completion.

Prosperity and sustainability cannot be achieved without building resilient systems that promote radical innovation in economic policy, corporate strategy, and in social systems and public governance. A series of recommendations have therefore been developed to show how resilience thinking can guide this new policy development.

Recommendation 1: Sustainability through resilience thinking must become an overarching EU policy driver

Shifting towards a more sustainable economy model requires moving away from the traditional silo approach to favour a holistic comprehension of EU policies. An approach based on resilience thinking can serve as a tool to a common effort to move towards a new paradigm.

Following the example of the White Paper on the Single Market, achieving sustainability through resilience thinking must become the overarching objective of EU policies. The HLG already indicated the urgent need for mechanisms to overcome systemic fragmentation, duplication and even contradiction, in the design and implementation of policies inside EU institutions, between Member States and EU institutions, but also between companies and public authorities and between administrations and civic societies, and to strengthen and broaden impact assessment.

Many areas such as energy, the digital economy, agriculture, transport and others are concerned with sustainability challenges. Sustainability inevitably affects all policy domains, regulatory and funding mechanisms and requires a change of mind sets and of operations in the whole EU policy making system, from units upwards to the European Commission itself and outside in Council working groups, the Councils, up to European Council itself.

Implementing sustainability as a core driver of sectorial policies requires nothing less than system change. The nomination of Vice-Presidents with responsibility for policy strategy and coherence, and not to forget for mentoring, and the senior advisors for innovation and for sustainability, offer the European Commission a useful tool to enhance policy coherence.

Improved impact assessments, real stakeholder engagement throughout the process, and innovation policy management will help enhance the efficiency and quality of EU regulations, if they are needed to achieve desirable objectives; other methods of public steering should be considered equally. Horizontal and vertical alignment of policies will bring greater coherence to the legislative framework and engage different policy domain into a common effort.

Recommendation 2: Apply the principles of resilience thinking to boost social innovation

Without social innovation, the realisation of the Circular Economy will be more difficult and lead to resistance. The CE, just as any other complex innovation ecosystem policy, must never only focus on boosting the market and competitiveness, but must equally aim at improving the life and overall well-being of citizens. Social inclusiveness must be a direct component of the sustainability strategy through social acceptance and buy-in for resilience and innovation.

The European Commission needs to scale up its efforts to engage the civic society but also regional and local authorities, creating broad consensus that its policy proposals can bring renewed prosperity and sustainability for all. As the HLG Blueprint has stated, social innovations encompass novel strategies, concepts, ideas and institutional arrangements that help boost the social well-being of citizens and maintain the welfare state.

To give the impetus to a new innovation policy management, the European Commission must include the social dimension in its strategy, in particular science and education policies. It should also consider the effects of its policies on national social protection systems and which innovations may be needed to maintain and improve their functioning. Social innovation is a widespread and powerful force to shape societies, and plays a crucial role in addressing problems of inequality, poverty and uneven initial endowment.

Without a strong stimulus at all levels of stakeholders Europe risks becoming a mere follower of innovative policies instead of being the front-runner of the innovation sector. The quadruple helix innovation model refers to an innovation concept where government, academia, industry and the citizens collaborate together to drive structural changes beyond the scope of what an organization could achieve on its own³. It encourages the input of a knowledge democracy to stir up innovation policy, align agendas and create new windows of opportunity. The right catalyst could in that sense give Europe the means to overcome risk aversion and lead to breakthrough initiatives towards sustainability and innovation policy management. Improving EUs long-term competitiveness in the global arena can only be done if it is based on enhancing – not eroding – the capacity of the biosphere. Resilience thinking provides a sound and flexible framework for guidance.

Communities share a variety of interests that must not be considered competitively but in a comprehensive and inclusive way. Resilience-based policy is an efficient tool to address several intertwined issues and bring a wide variety of benefits for stakeholders. For example, in a time of budgetary constraints for many public authorities, a better cooperation between public and private stakeholders can help overcome budget pressure and a lack of innovation capacity, while improving public services for citizens. The focus on eco-innovation must therefore always go hand-in-hand with social innovation and should itself have as objective the maintenance of the welfare state and social inclusion in parallel with acting within the capacity of the biosphere locally, regionally and globally.

³ Dublin Declaration on Open Innovation, 2014

Recommendation 3: Innovate the governance of sustainability through resilience thinking

Introducing a new policy call for a new form of governance and management. The European Commission's call to adopt a full systemic change and innovation not only in technologies, but also in organisation, society, finance methods and policies must be followed by innovative policy approaches in house and in the EU as a whole. One cannot build an electric car with the production methods designed for internal combustion cars; the same is valid for public policy.

In line with resilience principle n°7 (Annex) that promotes polycentric governance systems, the collaborative governance model favoured by the HLG can provide a satisfactory framework to implement new forms of policy management. "Collaborative governance is a relatively new concept and refers to a governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programmes or assets"⁴. It supports a more inclusive policy design and to push for consensus among discordant political interests. The search of a compromise at the early stage of the policy process will increase its chances of successful implementation.

To support the incubation of innovations and novel business models, as well as the transition towards new businesses, an adequate policy framework must be combined with a fine balancing in order to avoid over-regulation, poor quality regulation, and lock-ins. The objective of collaborative governance is to have a stable regulatory framework that also allows a certain flexibility to solve ad-hoc problems often difficult to address in a timely and appropriate fashion when respecting the traditional legalistic logic. Rigidity of purpose does not imply rigidity of methods, and a 'one size fits all' approach does injustice to the wide variety of conditions and needs in the EU.

Therefore, instead of initiating the lengthy process of new policy developments that would likely have unclear outcome and questionable efficiency, the emphasis needs to be put on the better deployment of existing policy framework and efforts to increase policy coherence and alignment. Such adapted and responsive policies should then provide incentives for the best performers, stimulating innovation and out-of-the-box thinking and an overall shift towards evaluation of benefits before anything else. Instead of producing more and more regulation, a better enforcement can improve inter-operational coherence of existing legislations.

Innovation policy management cannot be achieved without better cooperation with scientific institutions and agencies. Better regulation requires understanding and assessment of regulatory impacts; hence, scientific data needs to be better integrated into the policy process. While respecting the precautionary principle, cost-benefit analysis should be applied to impact assessments in order to move away from a problem- to a benefit-focused approach.

Recommendation 4: Create semi-protected niches for frontrunners to experiment

Innovation often happens in a very disruptive way, overtaking the existing legislative framework that often lacks sufficient flexibility to adapt to these rapid changes. As a result, many promising innovations run the risk of being banned and eliminated off the market. In

⁴ Ansell, et al. (2008): Collaborative governance in theory and practice, in: Journal of Public Administration Research and Theory, Vol. 18, No. 4

order to overcome the aversion for innovation, experimental spaces should be dedicated for a safe development of innovative solutions. Special legal provisions or even exceptional exemptions of law can help boost the innovation potential of promising industries.

To adopt a new economic paradigm and shift towards a sustainable economy, efforts must be invested in the transition process. To encourage frontrunners industries, semi-protected niches must be created to foster innovation and create transitional areas. A certain independence from the regulatory framework will offer more flexibility for creativity thinking and favour risk-taking projects. This will help create a favourable environment for frontrunners to experiments and unfold their potential while building up strong innovative networks.⁵

Recommendation 5: Transition funding and public procurement for innovation

Innovation policy demands an important amount of funding capacity to support Research and Development or transition costs for industries. Yet there has never been in history such research capacity as today. The European Commission has announced a 650 million euros plan under the Horizon 2020 programme to support transition towards its circular economy plan. Moving towards sustainability requires many important structural changes and a high capacity of adaptation. The question remains however how to manage and finance the transformation process from the old industrial paradigm to the new one in each sector and country. Public funding can serve a double objective, to support industries with innovative initiatives and to help other sectors adapt to the new economic model.

Public funding should be used to speed up development and implementation of new technologies by supporting innovative solutions, more precisely, socially and eco-innovation driven initiatives with a multiplying cross-over effect. Structural funds can provide a push to develop ground-breaking projects that can then be scaled up to an entire sector. This means that more focus should be put on the carrots than on the sticks. More and clearer incentives are needed for corporations that are forerunners in sustainability.

For industries at risk or with difficulty to adapt to a new economic system, an assisting phasing out or transformation processes, including industrial reconversion and re-training of workers, as done successfully for the coal and steel industry under the ECSC Treaty, should be put in place. However, the focus should clearly be on promoting the best companies to expand instead of helping the unsustainable ones to survive. Specific grace periods could however help sensitive sectors adapt to new requirements and to finance the costly research required. Therefore the European Fund for Strategic Investments should be widened to include specific industrial challenges for the circular economy which otherwise would delay the system change and cause harm to Europe's economy and ecology.

Public procurement mechanism offers a promising framework for the scale up of innovative initiatives. Given the importance of the public sector in the European Union, the promotion of public procurement can provide a solid framework for the expansion of innovation policies. Public procurement can initiate a levelling upwards across the single market and bring rapid transversal benefits by impacting other economic sectors. A better cooperation of engaged actors could also lead to higher user engagement and co-creation initiatives, putting into practice the objectives of the quadruple helix model for sustainability.

⁵ Rotmans, Jan / Loorbach, Derk (2009): Complexity Theory and Transition Management, in: Journal of Industrial Ecology, Vol. 13, No. 2, p. 184-196

Recommendation 6: Avoid lock-ins & provide dynamic standards and targets

A smart legislative and policy framework based on resilience thinking must enable stakeholders to benefit from new opportunities without being paralyzed by unnecessarily rigid targets and objectives. Standards and targets should be subject to constant re-evaluation and evolution in order to avoid regulatory lock-ins.

Setting up interim targets will provide industries more space to modernize and innovate and increase their chances to develop competitive advantages. Sector-focus targets are a concrete tool to avoid the one size fits all policy effects that could potentially hinder the global innovation capacities of certain policy domains. New targets should set up a minimum and a maximum objectives to engage industries into a broader effort while encouraging front-runners to develop competitive edges.

To follow on the collaborative governance scheme, tripartite groups should be installed to monitor the efforts made towards a sustainable economy. The European Commission and European Council representatives, with research centres officials, business delegates and Member States should gather to monitor progress made towards new policy objectives through a system of peer-review. National and European experiences have shown that such groups are able to develop alignment of views, coherence of analysis and creativity to find widely accepted solutions. It allows also to move away from a too legalistic approach and to develop progressive indicators and dynamic standards, which are a way to stimulate innovation and to develop competitive advantage in markets.

Recommendation 7: Develop sector-specific, resilience-thinking based policies

The elaboration of policies to realise a circular economy needs to take account of fundamental differences between business-to-consumer sectors, business-to-business sectors, and between the agro-food, forestry and fisheries sectors, the manufacturing industries, and infrastructures. Each sector requires a specific but complementary approach, developed with collaborative methods and bottom-up.

In the agro-food, forestry and fisheries, sector there is a lot to gain from refined use of and support to the multi-functional landscape. Furthermore, the circular economy policy needs to take into account the evolution towards digital farming, because it can achieve higher levels of sustainability than present regulations, many of which will need over time a fundamental revision to take account of new scientific and market developments. This opens a direct link to the objectives of digital sector policy making and the key issue of data protection and ownership.

Moreover, in this sector biosciences and new gene techniques will play an important role in assuring higher productivity, though raising questions of intellectual property rights and in some cases of ethics. These should not be politicised but dealt with by knowledgeable, multi-disciplinary expert groups.

In the manufacturing industries, the same questions regarding the digital economy are equally important to be solved in the context of the Digital Union. A bridge and cross-fertilisation between the two is therefore necessary. With resilience thinking-based policies such as eco-innovation, each sector can help reduce the environmental pressure on natural resources and the ecosystem and pave for the way for a sustainable economic model. Finally,

the logistics and infrastructures sector (transport, ICT, energy networks) all have a role to play in a circular economy to ensure innovation and competitiveness. Again, a collaborative and bottom-up approach will bring rapid and many benefits to the EU.

One must ensure however that a sector approach does not lead to adverse effects on fair competition or on cross-fertilisation.

Annex: The key principles of resilience in social-ecological systems

Principle 1 – Maintain diversity and redundancy

Diversity and redundancy are two key attributes that define and deeply impact social-ecological system's ability to respond to change and to deal with uncertainty. A diversified and multicultural economic environment may be expensive in terms of complexity but increases the reliability of ecosystem services and the potential for learning and innovation. The challenge is to find the balance between these costs and benefits when investing in diversity and redundancy.

Diversity is important for resilience because it provides options for responding to change and disturbance. Evidence suggests that systems with many different components are generally more resilient than those with few or less heterogeneous components. Diversity has three components: variety (how many different elements); balance (how many representatives of each elements); and disparity (how different the elements are from each other). Diverse actors with different roles are critical for resilience, with overlapping functions and different strengths in performance during different phases of development. A function lost by the decline of certain elements can be compensated by other elements less affected by disturbance.

Redundancy describes the replication of elements or pathways in a system and is determined by the number of elements that perform a particular function similarly. It potentially provides “insurance” for system functioning, by allowing some elements to compensate for the loss or failure of others. The presence of multiple systems with similar functional roles provides redundancy and allows for substitution among elements, thereby providing “insurance” through a functional compensation. Redundancy is valuable where elements providing redundancy differ from each other in their responses to disturbance. These differences increase the chance that some elements will persist and continue delivering particular ecosystem services in the face of change (designed redundancy).

Principle 2 – Manage connectivity

Disturbance can negatively affect the supply of resources of an economic system. Stronger connectivity, e.g. structure and strength with which economic and human resources migrate or interact within an economy or a given system, can facilitate recovery after a disturbance and ensure resilience. However highly connected systems increase the potential for disturbances to spread; this might be reinforced depending on the structure connecting systems components. Given the context connectivity should be encouraged or controlled.

Connectivity refers to how parts of a system interact with each other i.e. nature and strength of interactions between components. Connectivity in general, facilitates the flow of energy, material or information. In particular, the strength and structure of connectivity may safeguard against disturbances either by facilitating recovery of the system or by constraining the spread of a disturbance. Instead of facilitating recovery from a disturbance, connectivity may also enhance the resilience by acting as a barrier to the spread of disturbances (this capacity is usually maximised in moderately connected systems that are highly heterogeneous). However, explicit empirical data on impact of connectivity on resilience remains scant.

Principle 3 – Manage slow variables and feedbacks

Changes in controlling slow variables may lead a system to shift from one regime to another. These changes are often large and rapid and can have a huge impact on human societies. The challenge here is to identify and manage the key slow variables and system's feedback processes that ensure the desired configuration. It is important to understand slow variables and feedbacks underlying different social-ecological configurations and monitor changes to help to ensure resilience.

Systems consist of and are affected by a multitude of variables that change and interact on a range of timescales. Some are slow, in that they change much more gradually than other fast variables. In most social-ecological systems, a limited set of key variables and internal feedback processes interact to control the configuration of the system. Such controlling variables generally change relatively slowly. Variables controlling configuration of a system are typically slow variables. A central aspect of maintaining the resilience of goods and services in a system, in the face of disturbance and change, therefore involves identifying and managing key controlling feedbacks that underpin and control the configuration of social and ecological systems. Feedbacks occur when a change in a particular variable, process or signal leads to changes in a system that eventually loop back to affect the original variable, process or signal. Feedbacks can either be reinforcing by create changes of the same type, or dampening, when they counteract similar changes. This is important for resilience because there are limits to how large a shock or change a system can be exposed to and still recover and keep functioning in the same way. Critical limits in controlling slow variables typically correspond to points at which previously dominant feedbacks in a system disappear, new feedbacks emerge or minor feedbacks become dominant. At this point, changes in internal feedback processes cause the system to reorganise, often abruptly, into a different configuration, where the system is structured and functions in a different way.

Principle 4 – Foster complex adaptive systems thinking

The social-ecological systems that provide goods and services to society can be viewed as complex adaptive systems (CAS). They are highly interconnected and likely to endure nonlinear changes, uncertainty and surprises. A CAS-based management may enhance resilience. However it may also compromise resilience if complexity is not effectively communicated or when CAS thinking is not able to evolve with changing contexts or is inequitably shared. CAS thinking can be fostered notably by tolerating and embracing uncertainty, investing critical thresholds and recognizing barriers to cognitive change; and by adopting systems framework built on these parameters. Key questions for the future relate to communicating CAS thinking and assessing the relation between CAS thinking, power and its organization and institutional barriers that may exist.

Social-ecological systems that provide goods and services to society can be viewed as complex adaptive systems (CAS). CAS are made of many interacting components that are individually and collectively adaptive to change, enabling them to self-organise and evolve, and often yielding emergent properties. Key CAS properties are: a high level of interconnectedness; potential for non-linear change; uncertainty; and a multiplicity of perspectives within social ecological systems. Such features make aspects of CAS highly uncertain, therefore challenging to predict and control.

Understanding CAS is important for managing them, though some elements of their uncertainty are difficult to predict and require adaptive management approaches that can account for these uncertainties. Resilience of a social-ecological system is partly driven by decisions taken by actors within the system. Understanding these systems, then, requires an understanding of how these actors think. One way to understand such systems is through mental models used to interpret and understand the world and decide on appropriate actions. Management that views social-ecological systems as CAS is thought to enhance resilience by emphasising holistic approaches, the management of multiple goods and services and trade-offs in an integrated way and managing the lags and feedbacks. Fostering CAS thinking does not necessarily influence the resilience of services but changes and adapts the cognitive foundations and paradigms underpinning management processes and decisions. This would be a first step towards management actions that can foster resilience. Many examples suggest that management practices that optimise the provision of a narrow set of goods and services on the basis of linear reductionist worldviews tend to undermine resilience in the face of change.

Principle 5 – Encourage learning

Learning should be fostered to enhance the resilience of goods and services, notably by influencing governance and decision-making. Mobilizing financial and human resources, developing social networks and implementing long-term monitoring, can support effective learning. However learning can be undermined because of its cost and because of a failure in taking in account asymmetrical power relations or in setting the appropriate scale for learning activities.

Since knowledge of CAS is always partial, enhancing the resilience of goods and services requires continuous learning about social-ecological systems that provides these services. Recognising complexity in social-ecological systems brings with it the assumption that knowledge on these systems is always partial, and that knowledge requires renewal otherwise it will become obsolete. Three key approaches to managing social-ecological systems that aim to support learning are: adaptive management, adaptive co-management and adaptive governance.

Learning in adaptive management is based on the scientific approach of articulating alternative hypotheses, experimentation and evaluating these hypotheses. Adaptive co-management is the combination of adaptive management with sustained interactions between stakeholders. Lastly, adaptive governance emphasises the development of social norms and cooperation, organisational structures and the role of bridging organisations to match the scale of decision-making to the scale of ecological processes. These approaches recognise that knowledge is incomplete and that uncertainty and change are inevitable and require management. Experience has shown that learning can enhance resilience primarily through its influence on governance and decision-making processes. Such learning in support of decision-making is achieved through a variety of both planned and unplanned processes, including active experimentation and monitoring, multi-actor collaboration and through inter-generational interactions with the environment.

Principle 6 – Broaden participation

Participation refers to the engagement of relevant stakeholders in the managements and governance process. It includes both information and devolution of power. Participation may be used from the identification of problems to policy implementation or monitoring of results. Participation is also a way to ensure transparency and trust building, and participate to legitimacy of decisions.

Participation of diverse stakeholders is thought to build trust that improves legitimacy of the knowledge base and decision-making; to promote understanding of system dynamics; and notably to improve management's capacity to detect and respond to shocks.

Principle 7 – Promote polycentric governance systems

In polycentric governance systems there are multiple and coordinated interacting autonomous bodies creating and implementing rules within a specific policy arena and geography. Polycentricism may provide institutional sources for enhancing resilience, including policy/institutional diversity, improved connectivity between groups and new levels of participation at different levels of inclusiveness and various degrees of collaboration. The challenge is now to learn more about how inclusiveness and degree interact and how they lead to different outcomes in different situations. These factors may influence how polycentricism can succeed, or fail.

Governance, in this sense, refers to deliberation and decision-making among groups of people in the act of self-ordering their relationships. Each governing authority has the autonomy to make and enforce rules within a policy area for a specific region. In an ideal polycentric system, each individual governing body interacts and links with other authorities both horizontally and vertically to achieve a balance of collaboration and autonomy. Polycentric systems improve resilience by: 1) providing opportunities for learning and experimentation; 2) enabling broader participation; 3) improving connectivity; 4) creating modularity (allows governance bodies to reduce exposure to failures and losses of collaborators through a degree of independence – provide opportunities for successful experimentation to spread and failures to remain isolated); 5) improving potential for response diversity; 6) building in redundancy; and 7) increasing accountability and improving fit between resources and institutions. These characteristics are linked with the other resilience principles, discussed earlier.

Polycentric and collaborative policy making requires: fostering ability to evolve in concert with the context of the system to transform; networking of institutional entrepreneurs more than individual leaders; and anticipating and when possible create windows-of-opportunities and which is collaborative and adaptive.

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