Environmental Science & Policy 61 (2016) 53–60

Contents lists available at ScienceDirect

Environmental Science & Policy

journal homepage: www.elsevier.com/locate/envsci

Understanding barriers to decision making in the UK energy-food -water nexus: The added value of interdisciplinary approaches

Candice Howarth[a,*], Irene Monasterolo[b]

[a] Global Sustainability Institute, Anglia Ruskin University, Cambridge CB1 1PT, UK
[b] Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston University, Boston, MA 02215, USA

ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form 23 March 2016
Accepted 24 March 2016
Available online xxx

Keywords:
Water-energy-food nexus
Shocks
Barriers
Decision making
Climate change

ABSTRACT

The nexus represents a multi-dimensional means of scientific enquiry which seeks to describe the complex and non-linear interactions between water, energy, food, with the climate, and further understand wider implications for society. These resources are fundamental for human life but are negatively affected by shocks such as climate change and characterize some of the main challenges for global sustainable development. Given the multidimensional and complex nature of the nexus, a transdisciplinary approach to knowledge development through co-production is needed to timely and effectively inform the decision making processes to build societal resilience to these shocks going beyond the sectorality of current research practice. The paper presents findings from five themed workshops (shocks and hazards, infrastructure, local economy, governance and governments, finance and insurance) with 80 stakeholders from academia, government and industry in the UK to explore the impact of climate and weather shocks across the energy-food-water nexus and barriers to related responses. The research identified key stakeholders' concerns, opportunities and barriers to better inform decision making centred on four themes: communication and collaboration, decision making processes, social and cultural dimensions, and the nature of responses to nexus shocks. We discuss implications of these barriers and how addressing these can better facilitate constructive dialogue and more efficient decision-making in response to nexus shocks.

1. Introduction

Global sustainable development challenges that the world faces such as climate change, financial and macroeconomic instability, green growth, growing urbanization and income inequality, are deeply connected with energy, food and water resources, or the so-called energy-food-water nexus (WEF, 2011; Smajgl et al., 2016; Biggs et al., 2015). These resources are limited yet fundamental for coupled human-natural systems and are depleting at a rate faster than the planet can replenish (FAO, 2012). Human activities have devastating impacts on ecosystems (Millennium Ecosystem Assessment, 2005) and contribute to global scale challenges such as climate change (Smith et al., 2014) with growing evidence demonstrating negative impacts on socio-economic development affecting years of progress in tackling global poverty and vulnerability (World Bank, 2013). The year 2015 reached an important milestone of average global temperatures reaching 1 °C above pre-industrial times (Met Office, 2015) and the last decade was characterised by more frequent and disruptive weather events (e.g. typhoon Haiyan, the Philippines and hurricane Katrina, USA), representing 94% of insurance claims for 2015 and costing over $27 billion (Munich Re, 2016). In addition, increasing uncertainty over energy security and significant volatility in food and energy prices led to increased risk of civil unrest and political instability (Hsiang et al., 2011; Kelley et al., 2015). These have in turn increased social and economic risks of costs of nexus 'shocks' such as flood events, energy blackouts or breadbasket failures (Munich Re, 2012; Hallegatte et al., 2016).

These complex sustainability challenges call for major innovation (Ely et al., 2013; Leach et al., 2012) and reflexive transformation (Stirling, 2014). As a concept, the nexus is supported by a rapidly growing evidence base and a community of practitioners and policy makers, providing a powerful but largely disconnected knowledge base to understand the relationships and trade-offs between the different sectors and disciplines characterising the nexus (Harris and Lyon, 2013; Allan et al., 2015; Stirling, 2015; Kurian et al., 2016; Azapagic, 2015). These have, until recently been viewed as separate and distinct. Researchers, practitioners and policy makers working in and across the nexus have sought to

* Corresponding author.
E-mail address: Candice.howarth@anglia.ac.uk (C. Howarth).

http://dx.doi.org/10.1016/j.envsci.2016.03.014
1462-9011/

characterize, understand and eliminate trade-offs and tensions across and between these sectors (Rasul, 2015; Rasul and Sharma, 2015), whilst simultaneously highlighting opportunities, synergies and common goals (e.g. the UK's EPSRC Sandpit water-energy-food nexus project and the EU's Horizon 2020 Research and Innovation Actions on Societal Challenges). The reason for this is that the use of energy, food and water, and their management, is at the heart of human development and economic activity (Hoff, 2011). The risks associated with the mis-management of these resources has created a substantial social debate under a variety of frames such as sustainable development, sustainability, green economy, natural capital, environmental governance and ecosystem services. The nexus is the latest framing around these issues and provides a natural frame for rethinking sustainability as a complex adaptive system for analysing problems which can be approached more effectively when considered holistically (Yumkella and Yillia, 2015). In this regard, the nexus contributes to the discussion about the identification of more effective measures of economic success to design resilient business strategies (Reynolds et al., 2014), and thus the need to go beyond GDP as an indicator of economic activity (Stiglitz et al., 2010) to account for negative and time dependant externalities of human actions on ecosystems.

We consider nexus *shocks* as low probability, low frequency but high impact events (in terms of physical and economic losses) that span energy, water and food systems (Endo et al., 2015; Howarth, 2016). They impact multiple actors within and across country boundaries at scales that make them complex to understand and to address with implications for integration into decision making processes (Hussey and Pittock, 2012). Moreover, the interlinked nature of the nexus with finance, the economy, policy governance and demographics implies a variety of sources of shocks to the nexus. These can be either endogenous (e.g. the effects of climate change risk on GDP, demographic trends and migration) and exogenous (e.g. financial instability and market bubbles), where correlation of shocks occurring in the same and/or in several dimensions simultaneously increases the risk of stranded assets for both private and public investors and uncertainty about investors' portfolio allocation (Monasterolo and Battiston, 2015).

The most recent catastrophic events and their costs in terms of GDP and human lives (e.g. Hurricane Katrina) show that no sector is immune from these shocks. In an extremely globalized world, single events may induce systemic, cascading effects which can impact several sectors, processes, resources instrumental and fundamental for human development. Thus, addressing this nexus challenge means ensuring timely access to key resources such as water, food and energy to a global population expected to reach 9 billion in 2050, which itself has changing consumption patterns and will reside predominantly in urban areas (UNDP, 2014). Similarly, a methodological framework to analyse the nexus in its multidimensionality accounting for feedback loops and cascading effects is missing despite recent attempts to go beyond the sectorality of research. Therefore, in this paper we explore the application of our findings of a newly developed methodology to study nexus shocks and derive implications for policy making.

2. Inside the water-energy-food nexus

The nexus is defined by a number of elements (Table 1) and can be described as both (i) a descriptive account of interactions and interdependencies between the elements that define it, as well as (ii) a process that enables and supports transition and transformation across sectors and stakeholders. The nexus allows for a more holistic understanding of (un)intended consequences of policies, technologies and practices whilst highlighting areas of opportunity for further exploration. Nexus thinking represents a multi-dimensional means of scientific enquiry which seeks to describe the complex and non-linear interactions between water, energy and food systems, with the climate, to support

Table 1
Key elements that define the energy-food-water nexus.

Theme	Characteristics
Uncertainty	Uncertainty about mutual impacts Policy uncertainty in terms of building resilience Uncertainty around societal changes that influence the nexus
Connectivity	Interconnection and network of relations Time and path dependency of responses Interlinkages
Risk	Complexity Potential systemic effect Potential cascading effect (through society or across the nexus)
Impacts	Cascading, amplifying, nullifying impacts combining discrete but defined sectors
Nonlinearity	A simple system is a process where its components, their interactions and outcomes are known and can be defined (for example where the process starts, how it works and where it ends). Complex systems consist of multiple interacting components, where the relationships between the different variables is not linear. They are usually characterised by "a large number of uncoordinated interactions between [its] elements" (Ladyman et al., 2013) which contribute determining emerging behaviours among heterogeneous agents. The order in which these interactions occur is neither completely casual (random) nor follows a set schedule (Holland, 1995, 1998).
Feedbacks	A feedback can be defined as the reaction from a component or variable of the system that follows an action from a different component of the same system. Negative feedbacks have a balancing effect between two variables or components of the system and usually represent an inverse relationship between them (the action and the reaction move in opposite directions). Positive feedbacks have a reinforcing, amplifying effect between two variables or components of the system and usually represent a positive relationship between them (Forrester, 1961; Sterman, 2000; Mollona, 2008).
Robustness and flexibility	In complex systems, the order is said to be robust, even if the system is perturbed by endogenous forces, it still remains stable due to its fixed structure. A centrally controlled system is more exposed to internal perturbations.
Emergence	Emergent patterns are characteristics or behaviours resulting from a complex system that could not be captured by merely studying its single components in isolation (Holland, 1995, 1998).
Hierarchical organisation	A complex system is usually formed by several different sub-systems and components all interacting one with the others. These are organised in a hierarchical structure where the complex system is at the top and the subsystems are at the bottom.
Independent system	The nexus exists in its own self without the need for human intervention. In fact, human intervention (social) has destabilised complex relationships among different variables in the nexus with social responses aiming to stabilise it
Dependency	Because the environment abides by biological and physical mechanisms, the nexus is characterised by concepts of delay and chaotic behaviours