Chapter 12

The resource nexus and resource efficiency: What a nexus perspective adds to the story

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Abstract

This chapter addresses the resource nexus, a concept that has become quite popular in recent times. It is often framed as water-energy-food nexus and discussed at international organisations, within infrastructure planning units, and actors on the ground concerned with the Sustainable Development Goals (SDGs) of the United Nations. The chapter seeks to clarify the understanding what the nexus is about and proposes a five-nodes nexus including materials and land. We define the nexus as the set of context-specific critical interlinkages between critical natural resources used as inputs into socio-economic systems of provision. Furthermore, we start a discussion on how the nexus fits into the narratives of resource efficiency ad eco-innovation. The chapter argues in favour of complementary strengths of both, and gives an outlook on governance options.

12.1 The Challenge of the Resource Nexus

The narrative of the water-energy-food nexus is nowadays often used to portray the complexity of nature and its interactions with societies.[1] This approach refers to the numerous interlinkages and competing demands for the use of natural resources, perhaps best illustrated by water needed for both energy and food production. Research conceptualizes the nexus as a set of interactions, comprising important drivers for the use of resources. Natural resources serve as direct inputs in the production processes of an-

[1] See also the Future Earth Knowledge Action Network on the nexus at: http://futureearth.org/future-earth-water-energy-food-nexus; the work of the UK nexus network at: http://www.thenexusnetwork.org; or one of the origins: http://www.water-energy-food.org

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other resource or they can substitute the use of another resource. Indirect effects related to specific uses of resources also have to be taken into account because claims for a particular use of one resource can compete with other demands, as in the case of land use for either food or bioenergy production.

Such a systems approach has a long tradition in sustainability research (Wichelns 2017). The nexus debate has emerged only at the beginning of the 2010s (Hoff 2011, Andrews-Speed et al. 2012, 2014) to offer a more integrated approach to studying resource use and management. In fact, nexus terminology is increasingly popular, possibly at risks of becoming a 'buzzword,' as a recent editorial in *Nature* (2016) suggests, and being subject to quite different perceptions from stakeholders (Cairns & Krzywoszynska 2016; Green et al. 2016).

Our contribution takes those uncertainties about what the nexus means as a starting point to discuss a perspective. What can be considered new is, first, **a systemic resource-based approach to environmental challenges** taking into account issues emerging across all resource use patterns rather than originating from one or few selected flows and, second, **a distinct attempt to grapple with social issues on the ground**, such as access to resources and security.

Against the background of research, planning and management often being organized along single 'silos' of water, energy, etc., the aim of the resource nexus approach is to look at the connections between the resources in a more integrated manner. These interlinkages are manifold and complex, as all resources need others as inputs for their production and along value chains to the delivery of goods and services for final consumers. The nexus attracts attention because it provides a holistic and systemic view enabling fresh thinking on emblematic sustainability issues. We shall discuss below how such concept could facilitate adequate innovative solutions, engaging researchers, entrepreneurs and innovators on the ground, dubbed here 'nexus eco-innovations'.

12.1.1 Definition and scope of the nexus

Our contribution defines the resource nexus as the set of context-specific critical interlinkages between critical natural resources used as inputs into socio-economic systems of provision. The nexus can be conceptualized as a set of critical interlinkages between the different natural resources, with human activities shaping the drivers, intensity and efficiency of resource use, and humans and the environment either benefiting or being impacted by the outcomes of resource use. Criticality in such interlinkages may re-

sult from different drivers, such as overusing minimum supply conditions, passing critical threshold values, and indeed numerous tradeoffs. Hydroelectricity may serve as a case where an expected provision of electricity won't occur under conditions of an extended drought, creating knock-out impacts for customers.

Recent nexus scholars (Bleischwitz et al 2017) propose a scope for the nexus that comprises all direct and indirect resource inputs into socio-economic processes at appropriate scales, taking into account:

- Water
- Energy: Fossil fuels and other fuels such as nuclear, REN
- Food: food is seen as a system of provision, as there is usually a series of processing steps between biomass production and consumable food, all of which depend on inputs of energy, water and other resources. In Figure 1, biomass is part of food, energy, and land, illustrating the interlinkages and putting more emphasis on the systems of provision rather than resources itself.
- Land: Land is an ultimately limiting factor of production and serves all environmental functions of support, regulation, provisioning, and cultural services.
- Materials are relevant because:
    - they make up for ~50% of resource use in most industrialized countries (measured in physical units as used in Material Flow Analysis methodology);
    - The costs for manufacturing industry are significant (Wilting & Hanemaaijer 2014) and the potential for eco-innovation enormous;
    - Base metals, critical materials and construction minerals are relevant for the SDGs related to water, energy, and urbanisation; mineral fertilizers are relevant for food production;
    - Materials have been assessed as being important intermediaries of environmental impacts (UNEP 2010: 81).

  We propose to have subcategories for metals and critical materials, construction and industrial minerals and a separate account for mineral fertilizers.

Having such **a five-node nexus** of water-energy-biomass-land-minerals leads to more complexity compared to the majority of previous studies that analyse a two-node or a three-node nexus. In line with recent sustainability research (Liu et al. 2015: 3), it also captures 'a bigger picture' and facilitates bringing in the social dimension. We consider this approach as flexible and open: case studies may focus on a few core critical interlinkages, and may also analyse interlinkages within some of these dimensions, such as biomass, land use and food.

Box 1. The many faces of nexus

The contemporary debate features a number of approaches to the resource nexus with different views on which resources ought to be considered as part of the concept. The most widely acknowledged scope covers *water – energy – food* (Hoff 2011, Slingerland et al. 2011, Bazilian et al. 2011, Lawford et al. 2013). Other studies focus on:

- The *water – energy* nexus (Ackerman und Fisher 2013, Glassman 2011, Howells and Rogner 2014), inspired by the huge amount of energy needed for water pumping and by the impact a drought might have on electricity production;
- Water – energy – food – *land* (European Commission 2012, Ringler et al. 2013, PBL 2014, Sharmina et al. 2016) as main biotic resources originate from land use patterns;
- Water - energy – food and *mineral fertilizer* (Mo and Zhang 2013), pointing at the potential depletion of such resources, their relevance for food security, and their complex supply chain with recovery opportunities from, e.g., waste water;
- Water – energy – *minerals* (Giurco et al. 2014) illustrated by declining ore grades and the high intensity of using water and energy during extraction processes.

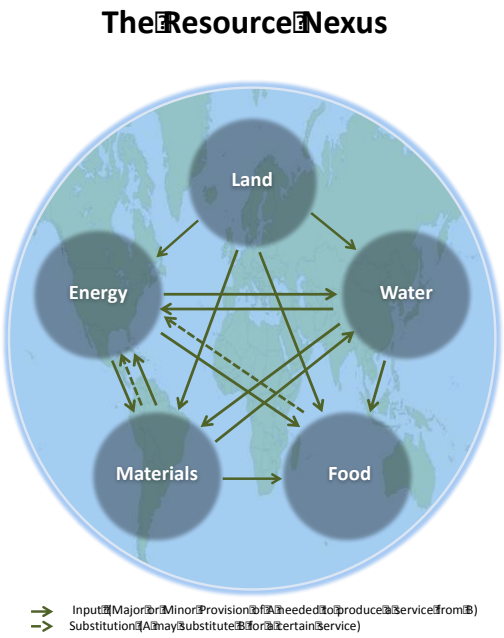
The studies published by Chatham House (Lee at al. 2012) and by the Transatlantic Academy (Andrews-Speed et al. 2012 and 2014) share a wider recognition of resources as manifold inputs into economic processes in line with the approach proposed in this Outlook; so has McKinsey

Global Institute (Dobbs et al. 2012) with a focus on opportunities for some industrial sectors.

There is also a large number of regional case studies, e.g., on India (Rasul 2014), South Asia (Mukherji, 2008, Rasul 2014), and the MENA region (Siddiqi and Anadon 2011), which assess those resource interlinkages that are most relevant in the region. Without being exhaustive here it can be said that the resource nexus concept is fairly often applied on the ground at different scales.

Figure 1 shows the many ways in which the use of key resources interacts. Some nexus issues may be more obvious than others, such as the connection between food and water suggests. Others have become more pressing recently, such as the water inputs needed for energy production when droughts occur.

Fig. 12.1 The resource nexus (Source: Own illustration after Andrews-Speed et al. 2014)



12.1.2 The relevance of the nexus

The nexus challenges are pertinent for many actors, involving private companies, development agencies, infrastructure planning units for water and energy, and international organizations. The challenge for decision-

makers is that all activities that are intended to use a specific resource should be based on the knowledge about the following factors: the estimated inputs needed from other resources in the future, how those may compete with other demands, and what critical events might arise that may put constraints on such supply in the future.

The extended novel narrative of the resource nexus should, therefore, also address:

- The resource interlinkages across use patterns, especially along what is known from consumption research as 'systems of provision' (Ben Fine and Ellen Leopold), i.e., the essential services of public importance;
- Human security, a 'nexus on the ground', and livelihoods of the one billion+ people living below the poverty line;
- Political and economic security, partly as a tool for analysing conflicts related to natural resources within regions or across borders and partly as a tool to assess supply chain securities.

The resource nexus concept becomes relevant for risk assessments especially in water and energy planning, but also for land use planning and for strategic investments. Furthermore, it can be seen as systemic in addressing all relevant issues that can be related to the use of natural resources in societies and across many scales.

12.2 Eco-innovation to address the nexus challenges

12.2.1 Nexus and eco-innovation opportunities

Much of the nexus narrative has been built-up to understand risks stemming from critical interlinkages and how they would affect people. Yet, it is also a compelling narrative for opportunities – and here the narratives of resource efficiency and eco-innovation kick in. Minimizing tradeoffs and exploiting synergies across the use of resources is a common understanding of both nexus approaches and those opportunities. It should also be common ground to avoid waste and making resource use more circular, from business operations onto supply chain management. What needs to be recognized is a wider opportunity of both approaches coming together. In comparison to the nexus with its focus on security especially in fragile regions, the current understanding of eco-innovation has strong bearings in pioneering manufacturing industries and policy actors across the environment and economy – quite often in mature or emerging regions with im-

port dependencies on commodities.[2] The overarching challenge of bringing those two narratives together thus shouldn't be underestimated. Yet it seems promising to try, and it may help turning the bias on risks and threats inherent to the nexus concept into a joint narrative of delivering SDGs and opportunities to eco-innovate. Needless to say any understanding of innovation should include both technological and non-technological innovations introduced by various actors (including public sector and partnerships).

Nexus eco-innovation needs to be a change that addresses critical interlinkages of at least two resources, while not posing additional risks on others. Therefore, it would need to go beyond measures to focus on single materials. One should also strongly consider equity issues and a focus on improving access for deprived actors – giving it a boost in developing and emerging societies. Accordingly, it could be small such as an application of drip irrigation in farming and land use and should typically be related to an SDG. By design it should correct systemic deficiencies and reconfigure system-level structures and dynamics by introducing mutually reinforcing innovations to respond to a nexus challenge. These changes will often include new products or services but, in order to ensure systemic impacts, they have to come with an enabling mechanism. The latter may be co-created by actors on the ground such as farmers or SMEs, by introducing collaborative business models, innovation alliances, and go ahead via ambitious standards and norms, as well as conducive policy and regulatory frameworks. The boundary of nexus eco-innovation should encompass elements in the system to create Schumpeterian dynamics. Innovating together and enabling people may influence the entire system dynamics towards a more sustainable mode of production and consumption. Such eco-innovation needs to internalize changes within innovation systems that usually reside outside innovators' strategy. It will often require new collaborations, often involving public-private partnerships, within and across sectors, value chains and supply chains, and may require adapting regulatory frameworks.

Nexus eco-innovation has to differentiate and compare key resource interlinkages, and likely environmental pressures and impacts associated with alternative eco-innovative solutions. Energy transitions towards a low carbon system have partly underestimated the nexus challenges of dealing with water, land use and the need for materials. The concepts of a circular economy and resource efficiency are very much in line with main aims of

[2] See e.g. the excellent work done by the EU's eco-innovation observatory at: www.eco-innovation.eu

a nexus approach. Some related indicator systems (DMC/RMC) are more narrow and should be widened to capture nexus dimensions. Material flows analysis (MFA), for instance, does neither address water nor land.

Furthermore, due to its broad boundaries, it needs to include both economic and social rationale behind the choices to support one or another innovation pathways. This requires a reflection, collective deliberations and new forms of evidence on how trade-offs between different uses of different resources can be addressed.

12.2.2 Energy transitions

The Paris agreement of 2015 has paved the way for a deep decarbonisation of our economies, i.e., a major transformation of the energy system towards low carbon societies. A nexus eco-innovation approach would underpin such new direction by adding insights on how all alternative energy sources – unconventional fuels, bio-energy, wind and solar – come with additional demand for water and materials and, partly, for land. It is thus of utmost importance to go beyond a 'carbon' indicator and add such nexus dimensions in scenarios, integrated assessment modelling as well as other modelling tools. Nexus modelling tools are emerging (WEAP-LEAP, CLEW, ENV-Linkages, ENGAGE) and should be used for the development of energy transitions, especially if regions are exposed to nexus risks of water stress and food security issues. However, issues of critical materials needed for low carbon technologies point straight forward at the international nexus dimension of any national lead market for clean energy – such national forerunners usually import critical materials and should trace the sustainability of supply conditions. Similar nexus dimensions arise with using bio-energy that may have been produced under conditions elsewhere that are unsustainable for water, land, and food dimensions of bio-energy. It is also worth noting coal production as a source for nitrogen, and thus there is a need to innovate for alternative supply paths for fertilizers.

12.2.3 Implementing the SDGs

It will be decisive to bring both a nexus and an eco-innovation perspective into the implementation of the sustainable development goals (SDGs) launched in 2015. The SDGs are likely to have major implications for future resource markets. However, those implications are mixed. On the one hand, many of the new SDGs will lead to an increase in demand for a number of materials:

- Goal 2: “End hunger, achieve food security and improved nutrition and promote sustainable agriculture” – implies increasing demand for land, mineral fertilisers, water, biomass and food.
- Goal 6: “Ensure access to water and sanitation for all” – implies investments in water supply and a water distribution infrastructure, i.e., increasing demand for materials.
- Goal 7: “Ensure access to affordable, reliable, sustainable and modern energy for all” – is likely to imply increasing demand for bio-energy and renewable energy, plus more traditional energy sources, which again implies more demand for land, biomass, water and materials.
- Goal 9: “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation” – will require more construction materials, metals and other materials.

Adding the promotion of economic growth to it, as well as efforts to eradicate hunger and enhance health, the signals for future demand for resources stemming from the SDGs are clearly upwards. At least for key metals (aluminium, iron ore, copper and nickel, which altogether make up for more than 80% of world production of metals), for construction minerals, for biomass and food, for water, and for arable land, the SDGs are very likely leading to new and additional demand compared to business as usual forecasts (see for food and land use issues: Obersteiner et al. 2016). The situation for energy fuels is less straightforward as climate policy will probably lead to restrictions for using fossil fuels, if political efforts succeed, although major suppliers may not join any future international agreement and have announced plans to expand production. If prices for fossil fuels stay low, efforts to curb demand will be difficult to achieve.

On the other hand, the SDGs also endorse the sustainable production and consumption agenda, and call for global increases in resource efficiency as well as for aims to achieve sustainable and resource-efficient infrastructures by 2030 (Goal 9) and sustainable management and efficient use of all resources by 2030 (Goal 12). Moreover, they aim to “improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation (…)” (Goal 8).

The balance between such expected demand increases and other goals however is not entirely clear, in particular as key terms (such as sustainable management and efficient use of all resources) are insufficiently defined and will leave space for quite different implementation pathways.

Analysing and developing nexus eco-innovations will thus have a key role to play in delivering the SDGs 2 (food), 6 (water), 7 (energy), 9 (infrastructure and industrialization), 12 (sustainable consumption and production) in a more integrated manner. Bringing nexus and eco-innovation closer together, it should clarify trade-offs and identify synergies. A joint approach of the nexus and eco-innovation will also be required to develop principles for a sustainable management of resources (SDG 12) and to understand future dynamics on resource markets and within societies.

12.3 What can policy makers/business/other stakeholders do?

12.3.1 Improving evidence base and policy learning

The resource nexus requires a robust evidence based on interdisciplinary knowledge and diverse expertise actively brought in along the whole policy process. Policies need to encourage collaborative transdisciplinary research engaging various stakeholders in generating and validating context-specific evidence for policy intervention. The dynamic nature of the challenge requires that the evidence base needs to be continuously adapted based on an on-going policy learning process that interprets and prioritizes validated evidence in a transparent way. The complex and emerging nature of nexus requires that the evidence base provides data on critical resource interlinkages as well as other key data on footprints, and incorporates the long-term prospective view by engaging in inclusive foresight methods as well as establishing links with modelling. The establishment of an international open-access database would be a huge step forward. There is a need to integrate the notion of risk and uncertainty in such analysis, while integrating the pre-cautionary principle at the heart of the process.

12.3.2 Shared understanding of the nexus challenges and key projects

Nexus platforms need to involve many stakeholders who bring with them diverse perceptions, understandings and interests that explain how they frame the problem. Various stakeholders will perceive the same problem through different lenses focusing on aspects of technology and infrastructure, environment, economic and business models, policy and regulations, as well as culture and values. All these perspectives are valuable for policy in the context of the nexus and decoupling. Policy processes should directly include nexus issues in a regional or national process to assess the resource base towards implementing SDGs and delivering green growth, a process in which these various frames are transparently presented, explained and supported with the use of evidence. It should help to make risk assessments and better planning, and facilitate key projects on such nexus eco-innovations by comparing successful niches and scaling them up re-

gionally and internationally. This process enriches the evidence base by bringing new stakeholders in, revealing the motivations and positions of stakeholders as well as prepares the foundations for the vision and strategy on how innovation alliances can tackle the nexus issues.

Such key projects may comprise:

- Transboundary river management with better planning for hydropower and co-benefits
- Development of urban green space and urban farming
- Development of business niches with local people at the Bottom of the Pyramid[3] towards eco-innovations with a potential to grow and become interconnected
- Enabling new alliances for collaborations with international companies seeking community involvement and eco-innovation across borders with local benefits
- Engaging with investors, large companies, and international organizations that are under pressure to serve long-term goals with more short-term returns.

12.3.3 Leadership, participation and shared visions of the future

The nexus challenges have the strength of being oriented towards a mid-term horizon of 10 – 30 years, which is in line with planning for water and energy infrastructures, land use, mining projects, and investments for producing capital goods. Key projects as outlined above are important for establishing ties between stakeholders, in particular when the institutions are weak (Acemoglu & Robinson 2012). Overall it requires a strong buy-in from both stakeholders affected by the challenges as well as those who may be instrumental in solving them. The latter may not be directly affected by the challenges, but they may consider their contribution beneficial, if evidence on short-term benefits and co-benefits can be established. Water management, food security, sustainable energy systems, transitions for resource-intensive industries, and sustainable urban development are key areas. Policy and think tanks need to establish and provide a platform for developing future scenarios of dealing with nexus and a shared vision of the future. Indeed, this should add a long-term view too, e.g., the year 2050. The main value added of the process is creating shared visions based on

[3] See e.g. http://www.bopglobalnetwork.org/about-us

various perspectives, and combining potentially conflicting interests into a ‘future project’ by creating short- and long-term incentives for key actors.

12.3.4 Short- and long-term scenarios and transition roadmaps

The overarching vision needs to be translated into more tangible strategies on how to both kick-start the process, identify potential asset losses and sunk investments, and follow up on it in the medium to long term. Planning will need to explicitly recognize the interdependencies between uses of various resources and seek flexible solutions to overcome the current and avoid future lock-ins in the resource- and capital-intensive functional systems (e.g. energy and water supply) that contribute to unsustainable use patterns. Scenarios and roadmaps are examples of strategic tools well suited for dealing with complex challenges of winners and losers requiring both short- and long-term outlooks. They provide a practical framework for developing shared understanding of alternative innovation pathways (scenarios) and contribute a foundation for implementation of complex multi-actor innovation projects (roadmaps). It will be essential to bring new valuation perspectives in such scenarios and roadmaps, in order to identify risks and gains of eradicating poverty and enabling access to key resources for the world’s poor. Research should support these processes via modelling efforts, potentially by soft linking bio-physical tools with macro-economic modelling and applying system dynamics as appropriate.

12.3.5 Systemic policy for nexus system innovations

Policy makers are an important stakeholder in making system innovation possible; one may also consider an ‘entrepreneurial state’ (Mariana Mazzucato). Nexus challenges require an innovative, coordinated and coherent policy response based on a policy mix that both directly supports eco-innovation and also ensures that wider regulatory and policy frameworks favour the sustainability transition. The direct support can be delivered by dedicated market and financial instruments such as resource taxes or resource dividends (Thomas Pogge), allowing a degree of risk in the case of particularly promising investment, whereas the enabling environment can, step-by-step, develop a strong regulatory framework of ‘inclusive institutions’ (Acemoglu / Robinson 2012) as well as removing regulatory barriers, environmentally harmful subsidies and other forms of support that favours actors or technologies that contradict the direction agreed in the vision.

12.3.6 Governance for resource nexus eco-innovations

The resource nexus requires revisiting existing governance structures and mechanisms. Conversely, it also should be applicable if the state is weak

and institutions are weak too – as it is often the case in developing countries. Resource governance[4] thus is an attempt to provide lessons learned especially for resource-rich countries, with key areas such as transparency, accountability, diversification and revenue management. This angle is important and should be enriched with thinking about eco-innovations. Such governance will concern all dimensions of governance, including leadership, strategic deliberation, participation, responsibility and accountability, implementation, and monitoring and evaluation. Resolving nexus challenges require envisaging alternative forms of governance that exist in parallel to, or even substitute, established institutions and organizations. On the one hand, the challenge is to design and implement viable governance approaches that make optimal use of existing capacities and power structures by stimulating collective action on the ground. On the other hand, the challenge may be to innovate and create new governance structures when existing settings do not suffice or are mobilized against the desired change. The latter suggests that design of policy and governance need to take into account the dimension of power and leadership as well as organizational capacity, technical competences and budgets. In the global perspective, the governance catered for the nexus challenges is likely to rely on the regionalized polycentric coordination of collective action towards a global coordination. This regionalized bottom-up perspective complements other planetary governance approaches, such as 'earth system governance' (Frank Biermann) that appear more top-down. Indeed global governance approaches need to combine both bottom-up and top-down.

12.4 Outlook

Amidst lively discussions about the nexus becoming a new buzzword, our contribution provides a nexus definition and suggests a number of core elements for nexus analysis, centred around critical interlinkages to integrate multiple sustainability goals like the SDGs. We suggest new conceptual underpinnings at the interface with human security and strategic choices. A broad scope, illustrated by our five node nexus of water, energy, food, land, materials, remains important for sustainability perspectives in general and for our notion of nexus eco-innovation in particular. A nexus angle can help assess synergies and trade-offs of resource use across different spatial and temporal scales. It is potentially transformative of analytical and policy approaches to resource assessment and governance in the context of supply chain management and wider climate action, and also considering the fact of many countries being rich in some resources while depending

[4] See the excellent work by the Resource Governance Institute at: http://www.resourcegovernance.org/, albeit it is yet weak at nexus eco-innovations.

critically on others. The strengths of the nexus approach may be seen in two regards: enabling a focus towards social issues, and helping to establish alliances beyond the usual environmental policy suspects. Clearly, for world-wide transformations both are indispensable assets.

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