Managing environmental systems: the water-energy-food nexus

SEI's broad range of expertise in land, air and water systems has provided fertile ground for interdisciplinary research. Some of our most promising work in this regard has focused on the water-energy-food nexus, a topic that is deeply relevant to sustainable development planning and policy.

Most governments have separate agencies to oversee water, energy, and agricultural food production, and they set policies and plan for each sector separately. The same is also true, to some extent, of research on these issues: expertise on energy, water and land use is clustered in separate groups, with limited interaction.

The nexus approach, which grew out of systems analysis, recognizes that water, energy and food are closely linked, through global and local water, carbon and energy cycles or chains. Water, land and energy are also essential resources, but billions of people have limited access to them; and all three are under pressure from supply constraints and rapidly growing demand.

SEI's work on the nexus draws on our expertise in hydrology, agriculture, and water and energy systems analysis, and leverages two powerful SEI-built tools: the Water Evaluation and Planning system (WEAP) and the Long-range Energy Alternatives Planning system (LEAP). It also builds on SEI's on-the-ground research on livelihoods, energy access, sanitation and other issues.

This brief describes our ongoing research on the water-energy-food nexus, starting with key insights from our studies and interactions with stakeholders to date.

- ***Nexus analyses need to jointly address human securities and natural resources within ecosystems.***

In the policy realm, addressing the nexus typically means making connections across sectors: bringing together officials responsible for water and energy, for example, or encouraging decision-makers focused on biofuels production to talk with their colleagues who focus on food production.

Backed by robust data on resource availability and use, these cross-sectoral conversations can be crucial first steps to resolving conflicts and trade-offs, finding synergies, and maximizing the efficiency of resource use. SEI has covered these issues, at the global, national and regional levels; see, for example, Fencl et al. (2012), Benzie et al. (2012), Hoff et al. (2014) and Weitz et al. (2014).

Yet resources are not only for direct human use; the same water that supplies cities, industry and agriculture, for example, may also feed wetlands and provide a habitat for fish. Similarly, demand for land for cities, food and biofuels production often leads to deforestation. Impacts on ecosystems, in turn, affect human livelihoods and well-being by eroding vital ecosystem services (Hoff 2011).

An ecosystems-based approach can help find ways to avoid such negative impacts and actually strengthen ecosystems and the services they provide. For example, an ongoing project in northeastern India has identified multiple potential benefits of afforestation, including carbon storage, improved biodiversity, and new income from carbon markets as well as bamboo and bioenergy production.

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Fishermen on Lake Tana, in northern Ethiopia, near the source of the Blue Nile. SEI is applying the nexus to ongoing development processes in the region.

- ***Along with cross-sectoral interactions, nexus analyses need to examine how systems interact across scales, and the role of factors such as political and social structures, governance and trade.***

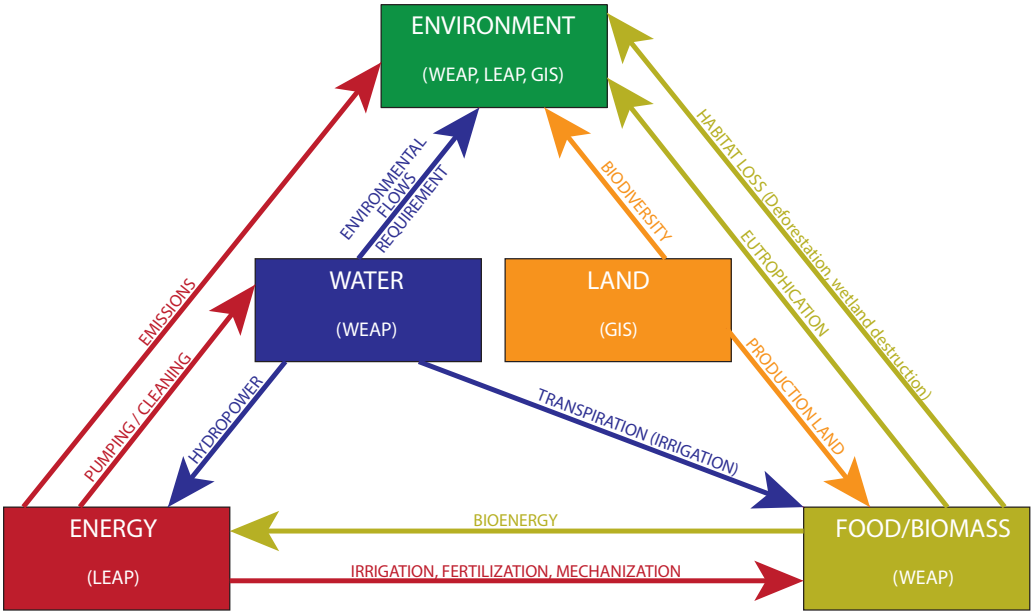
SEI's work to link LEAP and WEAP (see Purkey et al. 2012) has highlighted differences in the temporal and spatial scales at which energy and water systems are typically governed and analysed – e.g. at the national vs. the river basin level, by year vs. by season. Thus, it is essential to identify the appropriate scale for analysis (Granit et al. 2013), and if needed, "translate" data across scales to facilitate cross-sectoral discussions.

Studies also need to examine interactions across scales within and between sectors, to understand how resources are distributed, who gets priority, and how choices at one level affect others. Social network and institutional analysis can shed light on these interactions (Stein 2013).

In fact, a full analysis is likely to span multiple disciplines: our research, which so far has covered areas as diverse as California, Colombia, the Middle East and North Africa, Ethiopia, China and India, has made it clear that even where physical conditions are similar, political, social and economic factors may greatly affect resource demand, trade-offs, and the potential for "win-win" solutions.

- ***If nexus research is to make an impact on policy and practice, it must connect with stakeholders on their terms.***

It's much easier to identify cross-sectoral interactions in research than to address them in practice. To operationalize the nexus, we need to understand conditions on the ground, including the perspectives of different institutions and stakeholder groups, at all relevant scales. Participatory processes are thus crucial, and can produce more viable solutions to resource challenges.



In some cases, however, especially when resources are very scarce, a nexus analysis may not find a win-win option, but just difficult trade-offs (Weitz et al. 2014). The role of science in such situations is not to say what the "right" answer is, but to clarify the choices and ensure that all cross-sectoral impacts, externalities and trade-offs are known and understood. Participatory processes can also help ensure that vulnerable stakeholders have the information and access they need to advocate for themselves, and can foster dialogue across sectors and scales.

But seeking stakeholders' input is not enough. SEI's experience shows that nexus analyses will make the biggest policy impact if they can connect into existing policy processes. For example, a nexus project in the Blue Nile basin is seizing opportunities created by implementation of Ethiopia's Growth and Transformation Plan (see Karlberg and Hoff 2013). SEI is developing scenarios with stakeholders, incorporating local knowledge, and testing them with nexus tools to quantify the links between different sectors, such as the energy requirements for agriculture.

Science is ahead of policy-making and planning in terms of integrated approaches, but trying to draw attention to science in isolation is very challenging. Finding policy and planning "entry points", on the other hand, allows SEI to introduce scientific knowledge and tools to the table when they are likeliest to be useful to stakeholders. This helps build stronger relationships and, at its best, can lead to co-production of knowledge. For example, in studies in Lebanon, Jordan and Egypt (Hoff 2012), close collaboration with stakeholders revealed that social and economic factors, not climate change, were the main drivers of water scarcity, and that governance needed to be improved. Stakeholders also identified locally appropriate strategies to address scarcity, as well as barriers to other solutions.

- ***Many nexus problems have win-win solutions, but some do not. In fact, amid increasing resource scarcity, policy-makers are likely to face many trade-offs that require making value judgments.***

In many places, there is great potential for efficiency improvements and waste reduction – for example, reducing water losses in irrigation systems, or using fertilizer to increase agricultural productivity, so less land is needed to produce the same amount of food or bioenergy crops.

Such approaches can reduce resource use and costs across sectors, and help avoid conflicts. A nexus analysis of proposed Sustainable Development Goals targets, for example, found numerous synergies and potential win-wins (Weitz et al. 2014). Similarly, a nexus analysis of California's Renewables Portfolio Standard found that small changes to the technology mix – e.g. more photovoltaics and less solar thermal power – would make the RPS more viable amid water constraints (Fencl et al. 2012).

Major activities

SEI's work on the nexus is proceeding on multiple tracks. We have several projects focused on specific geographies, as noted above, as well as a comprehensive SEI initiative, launched in 2013, that has brought the different teams together to share tools and insights, collaborate, and work to increase the impact of SEI's nexus work.

The nexus initiative envisions three key roles for SEI: to advance scientific knowledge of cross-sectoral interactions, globally and in specific places; to provide decision-making support and tools to policy-makers and stakeholders working on nexus issues; and to build awareness and understanding of the water-energy-food nexus. These roles correspond to the three pillars of SEI's work: research, policy engagement and communications, and draws on the expertise of a large number of SEI staff.

As part of the initiative, SEI has shaped and participated in numerous nexus-related conferences, seminars and other high-profile events, including moderating a session of the UN General Assembly, presenting SEI's work at a Chatham House expert workshop, hosting a nexus seminar at the Global South-South Development Expo in Nairobi. SEI has also led several discussions of the nexus, at World Water Week 2012 and 2013, the American

Irrigation channels in Jordan, one of several Middle Eastern countries where SEI is using nexus tools to help decision-makers grapple with water scarcity.

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In Colombia's Eastern Plains, the Orinoquia, a nexus approach could help address links between land use choices and biodiversity.

Geophysical Union Fall 2013 conference and the Nexus 2014: Water, Food, Climate and Energy Conference, and other events.

A key goal of the nexus initiative is to produce a package of analytical tools and representative case studies from which we can generalize and transfer solutions across regions. Along with ongoing work, this may include:

• **Conceptual frameworks:** SEI has played a leading role in defining the water-energy nexus and the analytical frameworks used in nexus studies. Most notably, SEI produced the seminal Understanding the Nexus background paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus (Hoff 2011). A follow-up paper produced for Stockholm World Water Week 2013 presented methods and tools to "unpack" the nexus at different levels (Granit et al. 2013). Most recently, on behalf of the Independent Research Forum (IRF2015), SEI developed a nexus-based framework for examining cross-sectoral interactions within the Sustainable Development Goals (SDGs) that directly informed deliberations between the SDG negotiators at the UN (Weitz et al. 2014).

• **Analytical tools:** SEI has been developing widely used water (WEAP) and energy (LEAP) modelling systems for nearly 20 years. With funding from the U.S. National Oceanic and Atmospheric Administration (NOAA), SEI modified the two tools to allow them to exchange information (see Purkey et al. 2012), and demonstrated how the linked tools could be used to address nexus questions through a case study of desalination in California (Mehta and Yates 2012).

In collaboration with several partners, SEI also nested WEAP and LEAP within a cluster of analytical tools now collectively referred to as Climate, Land-use, Energy and Water strategies (CLEWs) by Sweden's Royal Institute of Technology (Howells et al. 2013). SEI and partners have also applied CLEWs in case studies in Mauritius and Burkina Faso. Most recently, SEI has developed a social network analysis methodology that could be widely applied to identify the key actors and institutions who need to be involved in addressing particular nexus issues (Stein 2013).

• **Applying nexus thinking in different geographies:** As already noted, SEI is applying the nexus framework in a wide range of settings, in countries at all levels of development. One of the largest ongoing projects is the Blue Nile study in Ethiopia (see Karlberg and Hoff 2013), which builds on a previous major SEI project, the Green-Blue Water Initiative (see e.g. Rockström et al. 2011). The Blue Nile study uses the integrated WEAP-LEAP platform to support trade-off analysis, taking into consideration the implications of rapid economic development, land conversion, hydropower and biofuel production, irrigation, and ecosystem management.

SEI also has ongoing nexus projects focused on the Middle East and North Africa (several, including one in the Tigris and Euphrates basins); Africa (seven major river basins and beyond, funded by the World Bank); the Mekong Region in Southeast Asia; China; India; the Western U.S., and Colombia (Mariño et al. 2013). This work not only informs national and regional policy-making, but also, in some cases, development cooperation; for example, the India study and some of the Middle East work has been done under the auspices of the German Society for International Cooperation (GIZ).

New research and future pathways

A priority in SEI's nexus work has been to operationalize the conceptual frameworks developed by scientists – to bring the nexus into real-world policy-making and planning. The projects described above provide a start, but SEI is actively seeking out opportunities to do more, in particular with bilateral and other donors who provide entry points into decision-making processes.

Integrated approaches have always been valuable, but this may be a particularly good time to bring the nexus into the policy realm. Concerns about resource scarcity are growing, fuelled by climate change, rapid population growth and the consequences of unsustainable development choices. Science can make a real difference in shifting towards more efficient, sustainable resource use.

The nexus framework is grounded in robust science, yet the work continues: even as we apply nexus tools to policy challenges, we need to keep building scientific knowledge. We also need to keep working to ensure we have clear definitions, well-tested methodologies, and transparent, well-designed integrated models. And we need to expand our perspective, focusing more on integrating socio-economic and biophysical perspectives, and looking across scales, from the local to the global.

Another key task is to better define what is or isn't a "nexus" question. Not all issues are cross-sectoral or cross-disciplinary; a nexus approach must not and cannot replace rigorous sectoral analysis, planning and policy-making. Integration should not be an end in itself – a nexus framework should only be applied when there are strong interlinkages between sectors.

Most of all, we need to ensure that research and analytical tool development around the nexus meets policy-makers' needs: whether they are crafting SDG targets, or managing local resources. For example, we need better tools to quantify cross-sectoral interactions, as well as insights into how institutions and policies account for and manage these interlinkages. We need to improve scientific communication around the nexus, so we can more effectively inform decision-makers. We have made great strides in raising awareness of the problems; looking ahead, we need to contribute more to finding and implementing sustainable solutions.

This synthesis was written by Marion Davis with contributions from Annette Huber-Lee, Holger Hoff and David R. Purkey

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Hoover Dam is a major source of hydroelectric power and irrigation water in the western U.S., but low water levels are a growing concern.

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Stockholm Environment Institute
Linnégatan 87D, Box 24218
104 51 Stockholm
Sweden
Tel: +46 8 30 80 44

Theme leader:
Jennie Barron,
jennie.barron@sei-international.org
Theme co-leaders:
Patrick Büker
patrick.bueker@sei-international.org
Guoyi Han,
guoyi.han@sei-international.org
Charles Young
chuck.young@sei-international.org

sei-international.org
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Twitter: @SEIresearch, @SEIclimate