



Opportunities and Challenges for Establishing a Resource Nexus Community of Science and Practice

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The American Chemical Society's Division of Environmental Chemistry symposium Toward Creating a Water-Energy-Food (WEF) Nexus Community of Practice, brought together 25 cross-disciplinary speakers in five thematic areas: 1) state of the art models and approaches, 2) WEF Nexus initiatives and case studies, 3) WEF governance and stakeholder engagement, 4) chemical processes and WEF Nexus, 5) WEF education, community, and practice. Discussions included diverse perspectives from different areas of expertise and provided key take-home messages toward building a WEF community of practice. This paper summarizes those messages, drawing conclusions regarding the anticipated challenges and opportunities moving toward establishing a resource-nexus community of science and practice that includes the chemical societies. We define the community of science and practice as a bottom-up approach of formal and non-formal scientists, policy makers, practitioners, technology providers, and civil society members concerned with any aspect of water, energy, food, ecosystem resources allocation, management, governance, and financing. The roles of chemistry and chemical processes in understanding the interlinkages of nexus systems must not be overlooked. Chemistry plays an important role in the circularity of the food and agriculture system, and in providing cleaner energy, cleaner water, and more sustainable food production. The question is how to better engage the chemical society in the WEF nexus moving forward? The paper proposes the resource of health, highlighting major challenges and opportunities in the Water-Energy-Food-Health-Ecosystems (WEFH) Nexus, and highlights future steps for fostering dialogue among this broad, multidisciplinary, multi-stakeholder community toward establishing an inclusive community of science and practice.

Keywords: water-energy-food (WEF) nexus community of practice, resources allocation, resources management, governance, financing, circularity of the food and agriculture system

CHALLENGES AND OPPORTUNITIES

This section summarizes the issues raised at the symposium and deliberated in the WEFH Nexus literature.

Modeling and Tools

The nexus concept is useful for developing integrative indices that require multiple attributes, such as resilience. System Dynamic modeling tools (<https://systemdynamics.org/tools/>) are a good means for teaching systems concepts in the classroom; they allow students to explore scenarios, look at interactions, and design sustainable interventions to the resource nexus. Several types of models exist which offer opportunities for the resource nexus portfolio mix. These include optimization models, system dynamics models, heuristic algorithms, and process-based models, among others (Laspidou et al., 2019; Laspidou et al., 2020). Future nexus work will include complex and simple models, process-based and optimization models, scenario-based models, and more. Each type of model has advantages and disadvantages, depending upon the questions asked, the challenges presented, and the stakeholders involved in its use (Dargin et al., 2019). The System Dynamics Society lists various type of tools for research and education available commercially, open source, stand alone and online tools. Huang and Worboys (2001) were among the first wave of scientists to demonstrate how dynamic modelling and visualization can be conducted on the Internet. The question is how to validate these complex system models. There are no simple, easy solutions with complex systems: they involve a web of interactions that cut across biophysical, social, and political systems. Finding a simple way to validate the models is difficult. Laspidou et al., 2019; and Laspidou et al., 2020 observed that the less traditional but more qualitative methods, social acceptance and stakeholder perspectives, play an important role. Laspidou et al., stated that advanced visualization techniques are important for communicating complex scientific information in layman's term and maintaining citizen engagement.

Regardless of adopted models, we should seek a principled, pragmatic, science-guided framework for complex problem-driven solutions. The framework (or Nexus) of shared tools, such as network analysis for social and physical sciences and their role in WEFH dynamics, is important to facilitate some of the principles that will be used to catalyze actionable solutions (Daher et al., 2019). Several components contribute to the formulation of the framework. As an example, virtual water is a critical component of the Nexus that involves the private sector, the political economy, subsidies, and policies. Virtual water is an important element that must not be overlooked given the quantity of water, transport energy, land use, and land processes that are embedded in each product and production location (Lee et al., 2016). Free food does not exist; someone must pay for it, whether farmer, consumer, or human/ecosystem health. Within this context, soil health and conservation is a major resource to support food security, as such preventing soil degradation as a threat to achieve food security targets. These externalities in the cost of food must be looked at carefully for

they impact the long-term sustainability of human security. Thus, the question becomes **what externalities in the cost of food are appropriate to and should be embedded in the system?** This is a question of geography, geology, space, and time and opens our thinking to the notion that a universal magical solution does not exist. As those externalities vary in space and time, so does our strategies and solutions.

Implementation of the Sustainable Development Goals (SDGs)

The role of the Nexus in implementing the SDGs will become more critical (Stephan et al., 2018). Already, some governments see the interconnectivities as they struggle to implement all 17 goals without compromising the implementation of any single goal. The connection between knowledge and tools is essential to help guide the implementation of the SDGs (Malagó et al., 2021). We must identify those policy makers who are ready to engage in and champion the necessary policy changes that will enable appropriate and integrated national plans for implementing the SDGs. Pappas et al., 2022, presented a modelling for key performance indicators for waste management which encompasses several of the SDGs. Daher and Mohtar (2021) presented a study assessing the government of Morocco plans for water, energy and agriculture plans. They highlighted the need for better coherence at the national level for achieving the national targets.

Water, Water Quality, and Green Water Management

In the future, green water management must include water quality, treatment levels, and the role of chemistry in designing personalized water treatments that keep the end users in mind. Green water is referred to rainwater stored in the soil matrix and responsible for evapotranspiration processes. Green water management is an important aspect of the nexus of water, food, energy, sustainability and recycling, and the circularity of food and agriculture systems (Jones et al., 2021). Effective management of green water can reduce the energy used for pumping and irrigation, save water, and allow sustainable food production (Mohtar and Assi, 2019). Green water management is one of the many approaches that place soils at the heart of the nexus in supporting food security, water security, climate resilience, energy security, reduced emissions, and long-term regenerative solutions. Likewise, regional integration and cropping systems can provide a win-win scenario that considers the water footprint, water productivity, allocation, diet, and other choices using cost-benefit analyses.

Human and Ecosystem Health

Health, in the context of the physical resources of food, energy, and water, is essential in the development of a nexus model. We must develop nexus-inspired health indices and transform the narrative on health from an "implicit burden" on resources into a manageable resource in and of itself. The U.S. Global Change Research Program (USGCRP, 2016) presented a comprehensive account of human health and how it is being impacted by climate change. They

addressed issues of temperature-related death and illness, air quality impacts, extreme weather events, vector-borne diseases, water-related illness, food safety, nutrition, and distribution, mental health and well-being, and health and minority and under represented groups as they are preferentially impacted.

Interdisciplinary Theory

At its core, interdisciplinary theory supports the WEFH nexus principles. Still, there are many theories that must be woven into the theoretical background of the nexus community as we move forward. Generalized, generalizable, and actionable knowledge is important. As we learn more, we must guide the public sector and the community at large using easily implementable and actionable knowledge. This will not be an easy task, especially as we are dealing with a complex system that couples the natural, social, practitioners, and policy domains. Moreover, in academic circles, interdisciplinarity is very expensive: while young professionals are needed to propel the interdisciplinarity of the nexus work, they are often held back by the need to be acknowledged for their disciplinary work and to seek tenure within their own disciplines (Mohtar and Daher, 2019). These concepts are being propelled by the convergence research that emerged recently out of the National Science Foundation as a mean of solving complex societal problems.

THE NEXUS COMMUNITY OF SCIENCE AND PRACTICE

As discussed above, the nexus community should be built from the bottom up and have a distributed organization structure that promotes the Nexus community and discipline while also promoting equity and social wellbeing. We must engage the health community while keeping these principles in mind. Communication and anthropological expertise will be necessary to induce changes in consumption and the ways in which we interact with the resource nexus.

Governance of Nexus Community of Science and Practice

The Community of Nexus Practice of science and practices has an advisory role in the community. The leading core group provides leadership for the network, playing a lead role that facilitates the network's vision and orientation. The CoP should be managed by an executive team responsible who will be responsible for engaging dialogue between all the members.

Sustainability in Nexus Community of Science and Practice

Many communities of practice have chosen to practice sustainable development, which is an offshoot of the standard community development process that considers issues of sustainability at different level economically, socially, and environmentally. The process basically addresses the community's current and future

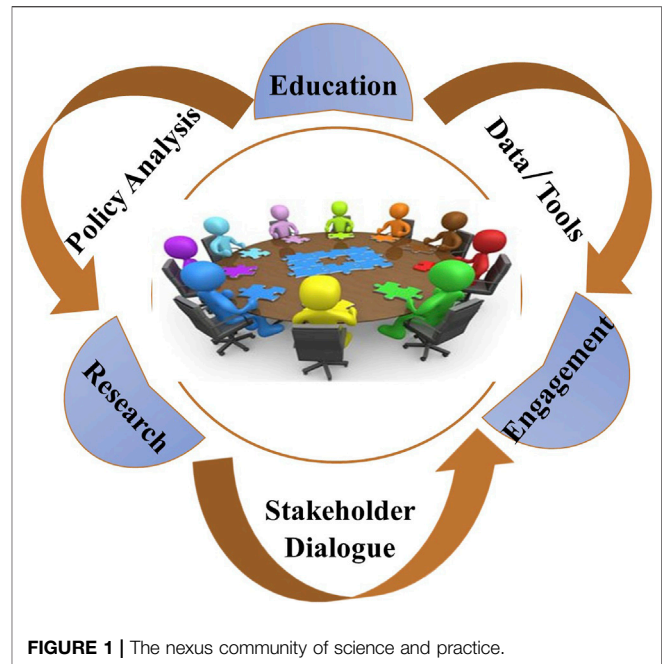


FIGURE 1 | The nexus community of science and practice.

needs for long-term, sustainable development that is not going to compromise later generations.

HOLISTIC, MULTI-SCALE, MULTI-STAKEHOLDERS, NEXUS APPROACH

At this stage, we must consider the principles of a holistic, multi-scale, multi-stakeholder, *Nexus* approach. This begins with an **integrative view** of water, energy, food, and health resources management, which must prevail at all levels and be founded in inclusiveness for all sectors: governance, academic, civil society, and the private sector. We must **define** and **quantify** the interconnectivity between *Water, Energy, Food, and Health* systems to create the tools, data, and knowledge for use in policy and planning. Finally, we must better engage the **private sector** for its role in **supply-chain** management, **mobilization** of resources, **conservation**, and **responsible investment**. Additionally, we must support R&D for **enhanced business opportunities** and **technology development**.

The **Community of Science and Practice** will become a platform for the engagement and dialogue. It will allow multiple tiers of *Education, Research* and *Engagement*, and consider several thematic areas of data policy engagement, including the data, tools, as illustrated in **Figure 1**.

FUTURE AGENDA OF THE COMMUNITY OF SCIENCE AND PRACTICE (COP)

The Symposium was of great interest and raised a wide range of questions. There are remaining questions that need addressing by the WEFH Nexus community including:

1. How do we maintain the Nexus principles given their complexity?
2. What type of representation and modeling will emerge to solve Nexus problems and what type of Data will be required?
3. Do we need special NEXUS professional societies, keeping in mind the distribution of disciplines, geographies, thematics, etc.?
4. Should we publish a new NEXUS Journal?
5. Is it time for a new NEXUS discipline?
6. What needs exist to educate and train a future Nexus/system workforce?
7. How can convergence between opportunities and Nexus-ready graduates be secured?
8. What and how can ACS members and Society contribute to this evolving discussion?
9. What structure would be the most appropriate for a CoP?
10. Can such a community make us more resilient to pandemics and shocks?
11. Who would be interested in funding such an effort? NSF, NAS, AAAS, FAO, IDRC?

12. How can we make the Nexus communicated inclusively?

Whatever the future of the Nexus and Nexus community is, we can say that the genie is out. The system's thinking is here to stay whether we call it "Nexus" or give it some other name.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors participated in a technical session at the ACS annual conference and engaged in a discussions following Mohtar as a speaker. The paper is a summary of this discussion.

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