Research Paper

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A Platform for Trade-off Analysis and Resource Allocation

The Water-Energy-Food Nexus Tool and its Application to Qatar's Food Security

Produced as part of the Valuing Vital Resources in the Gulf series

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The Valuing Vital Resources Series

The Valuing Vital Resources initiative encourages incentives for the sustainable use of energy, water and food through furthering understanding of the economic and societal costs of their interlinked modes of use and production. It involves a series of dialogues, materials and country focused reports to gather and make available international experience in cost-assessments, price reform and related policies. The idea is to provide tools and expert networks that can support countries which currently administer resource prices and are in the process of, or considering price reforms.

This Research Paper

This paper was commissioned as part of the Valuing Vital Resources research series focused on the Arab Gulf region. All countries in the region have a sensitive and interlinked relationship between oil, gas, water and food. This means policy to achieve sustainability in one area must also take into account its effects on others. Many participants in the workshops for this project were interested in how modelling resources in a more integrated way could help improve decision-making based on a better understanding of where value should be more effectively reflected in price. The short case study presented in this paper explains a publicly available and evolving water–energy–food nexus tool. On the basis of Qatar's stated policy objective of increasing national food self-sufficiency, it shows what would happen with 'business as usual' practices if the country were to meet its food security aspirations. The analysis highlights where goals will not be achievable without substantial policy interventions, raising questions over whether current objectives are realistic, and – if they are to be pursued – what needs to be changed to ensure the least damage to other resources or sectors.

Introduction

Water, energy, and food are interrelated systems which face numerous challenges including a growing global population, economic crises, poverty and hunger, and climatic uncertainties. Meeting these challenges requires a paradigm shift and a better understanding of how these three resources form a nexus, with quantifiable interconnections. These developments also need to be incorporated into decision-making processes.[1]

In working towards this goal, the authors have developed a holistic platform (WEF Nexus Tool 2.0©) that aims to support decision-makers in identifying sustainable resource management strategies informed by the water-energy-food nexus. This short case study describes the tool and showcases a sample analysis conducted in Qatar.

The WEF Nexus Tool 2.0©

The tool is scenario-based and attempts to explicitly quantify the interconnections between the three resources, while capturing the effects of population growth, changing economies and policies, climate change and other stresses. It provides the user with the ability to create scenarios for a given country by defining the following inputs:

- **Food portfolio:** identifying local food production levels versus imports, and technologies in agricultural production.
- **Water portfolio:** identifying different sources of water and amounts needed of each.
- **Energy portfolio:** identifying sources of energy for water, and energy for agricultural production.

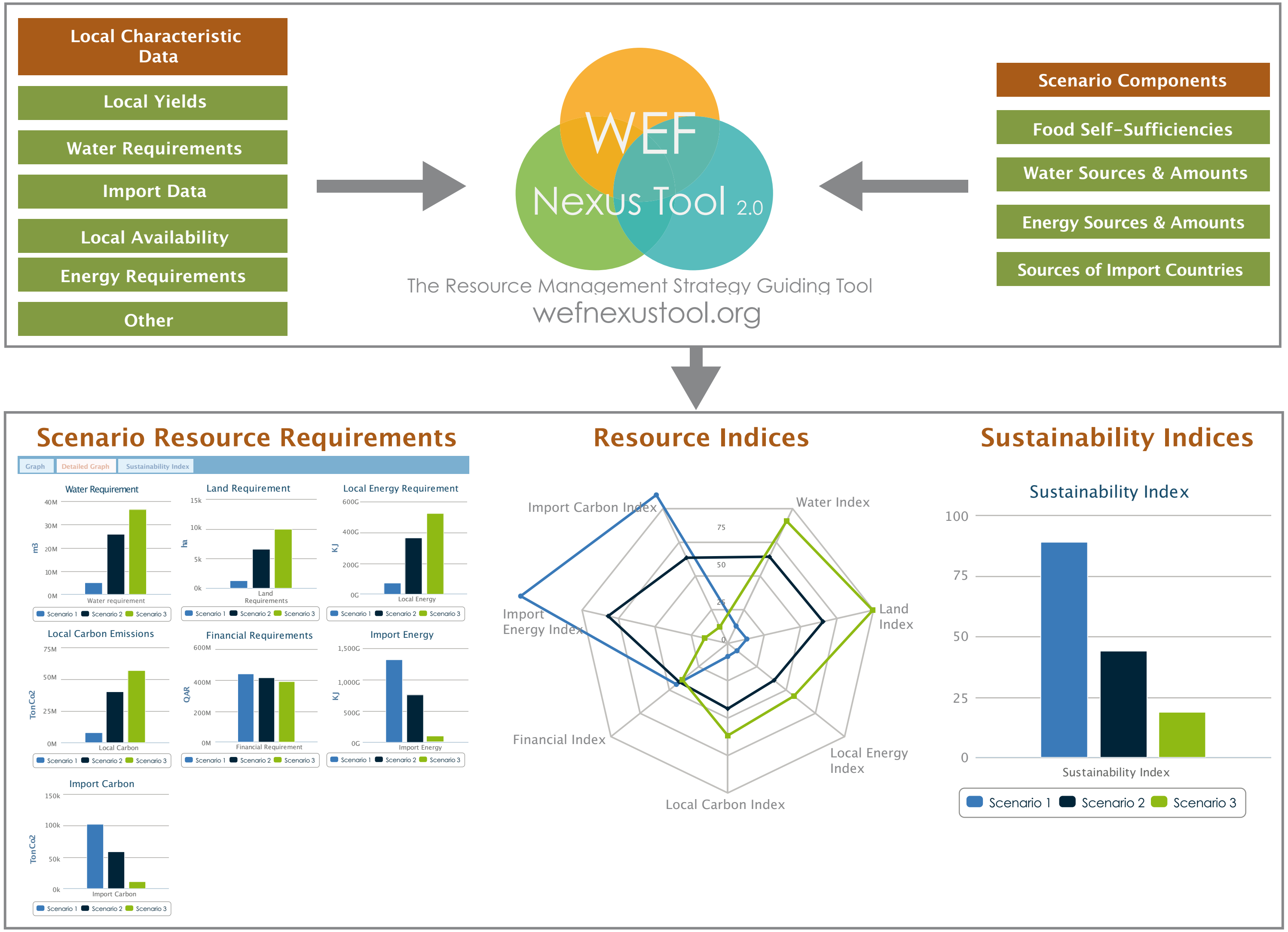
Using the tool, the user can create scenarios consisting of different variations of these inputs and is able to calculate the following outputs for each scenario:

- Water requirements (m^3)
- Local energy requirements (kJ)
- Local carbon emissions (ton CO_2)
- Land requirements (ha)
- Financial requirements ($)
- Energy consumption through import (kJ)
- Carbon emissions through import (ton CO_2)

An overview of the WEF Nexus Tool 2.0 structure is presented in Figure 1.

[1] Rabi Mohtar and Bassel Daher (2012), 'Water, Energy, and Food: The Ultimate Nexus', *Encyclopedia of Agricultural, Food, and Biological Engineering*, 2nd edn. DOI: 10.1081/E-EAFE2-120048376.

Figure 1: WEF Nexus Tool 2.0© structure

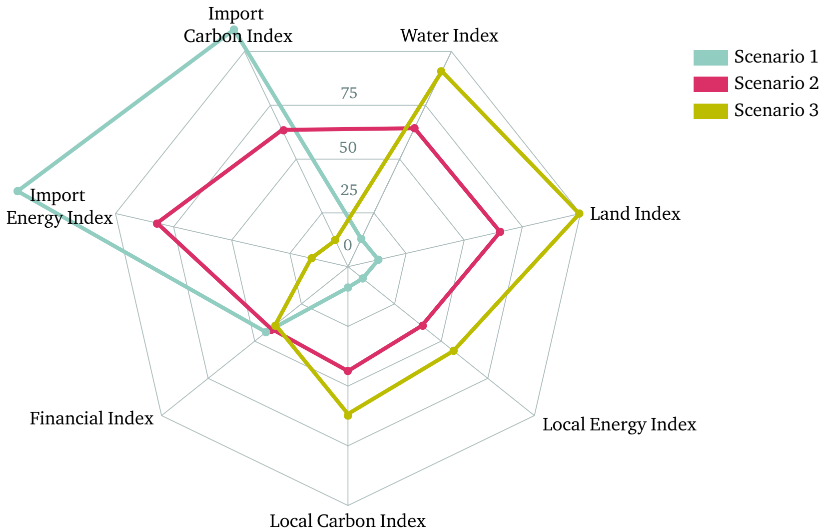


Source: Daher and Mohtar, 2013, wefnexustool.org.

Even though the water-energy-food framework is generic, scenarios created by the tool are site-specific and defined by the local characteristics of the area of study. These may include local yields of food products, water and energy availability and requirements, available technologies and land requirements. The characteristics are defined by the user and allow for the creation of country-specific profiles. The WEF Nexus Tool 2.0© enables users to visualize and compare the resource requirements of their scenarios (Figure 1), and calculate the 'sustainability index' of each scenario in a two-step process.

The first step involves calculating the proportion of resources required, per scenario (m^3 of water, ha of land, etc.), of the total available in the area of study. This step allows calculation of the sustainability index of each of the scenario requirements (for example, water index = water required by scenario/available water resources). Resource indices can be visualized through the web graph, as shown in Figure 2.

Figure 2: Web diagram from WEF Nexus Tool 2.0© showing the resource indices for three possible scenarios



Adapted by Chatham House.

After creating different scenarios, the user is able to compare the resource requirements of each (Figure 1), as well as the resource sustainability indices. Figure 2 gives an example of the visual display of these indices for three hypothetical scenarios (for selected foodstuffs in Qatar) with varying food self-sufficiencies (scenario 1: 10 per cent; scenario 2: 50 per cent; scenario 3: 90 per cent), while retaining the other parameters (water sources, energy sources, countries of import). We can clearly see, for example, how in scenario 1, very little of local resources (water, local energy, land etc.) is consumed, while the country's limits on carbon emissions and energy consumption are exceeded through imports (90 per cent of food products are imported in this scenario). By contrast, scenario 3 consumes more local resources (with self-sufficiency at 90 per cent), requiring all the country's land and almost all current water supply.

In the second step, the user adopts the role of policy-maker by indicating the relative importance of reducing some of the resource requirements in different scenarios, in order to reflect possible national resource allocation strategies. One such strategy could entail giving more weight to reducing carbon emissions and water needs relative to others such as financial, land or energy resources, for a water-scarce country working towards achieving carbon cap commitments. Another could be trying to maintain the highest level of food self-sufficiency without exceeding set financial limits and land requirements.

Prioritizing the importance of reducing each of the resource requirements to achieve a set goal helps users develop possible policy preferences (guided by national strategies) in order to arrive at the optimum scenario. The combination of resource availability/unavailability and preferences for national resource allocation is developed in the Sustainability Index for each scenario (Figure 1).

Qatar's food self-sufficiency goal – a preliminary analysis of land, water and energy needs

In assessing the tool's utility, we ran a preliminary analysis of Qatar's food supply chain system. Qatar currently imports more than 90 per cent of its food and is developing a strategy that would help reduce this reliance on imports. The government's stated aim is to bring the country as close to food self-sufficiency as possible by 2023. Using the WEF Nexus Tool 2.0©, we developed a scenario that allows variation of food self-sufficiency for selected products without altering all other variables (water sources, energy sources, countries of import, etc.). While these analyses require additional verification, they are useful in highlighting the trade-off between increasing local food production and impacts on, for instance, water, energy, financial and land resources.

The tool is flexible in terms of the addition of new technologies. It is split into an admin and a user interface. The admin, represented by the scientist or researcher leading a case study, would have access to all of the 'local characteristic' information (such as consumption values, efficiencies of water desalination and treatment technologies, carbon emissions for different energy sources, countries supplying imports of food products, agricultural technologies, water requirements for different crops etc.). All of these local characteristics can be easily modified, once more refined data or new technologies become available.

Based on 2010 food production levels for eight food products in Qatar – green onions, tomatoes, eggplant, lettuce, carrots, watermelon, cucumber and potatoes – we created a scenario representing an additional 25 per cent increment for each (e.g. if self-sufficiency in tomato production was 10 per cent for 2010, it would be 35 per cent in the scenario). The results show the resources needed to achieve a 25 per cent increase for these food products (Figure 3). Under current (2010) available water and energy technologies and efficiencies, and existing crop yields and trade portfolio, achieving this target would require 206 per cent more water, 382 per cent more land, over 200 per cent more energy and emissions, and a 196 per cent increase in financial resources. The adoption of such a scenario (which may be instigated by national security concerns) will therefore depend on the ability to secure the indicated water, energy, land and financial resources – all of which might require a radical change in production techniques while understanding the local resource constraints.[2]

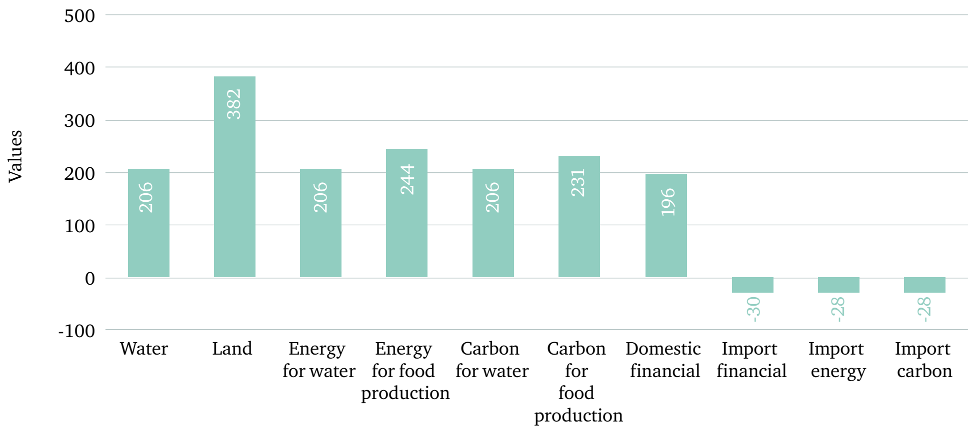
The tool has been tested to assess the impact of additional local food production on water and energy resources as well as land use, financial cost and other suitability indicators, such as carbon emissions. The scenario brings the trade-offs between these vital resources into sharp relief.

[2] Daher and Mohtar (2014, in review), 'Water, Energy, and Food Nexus: A Basis for Resource Planning', *Water International*.

The Qatar example was prepared on the basis of current levels of resource input requirements per unit of output and 'business as usual' trends. Key variables will change for future scenarios, and might include projections for future national consumption of final products, production methods for food, water and energy that could entail fewer resource inputs, land and carbon emissions.

There exists a trade-off between the initial investment needed to achieve a goal of higher food self-sufficiency (to achieve additional security goals) and savings in the future. This trade-off is between the natural physical constraint that makes it imperative to develop a robust trade strategy, and the accompanying goals of increased levels of local food production.

Figure 3: Percentage change in resource needs for a 25 per cent increase in the self-sufficiency of the eight food products



Adapted by Chatham House.

In an attempt to test the existing framework, make it more robust and regionalize the tool's application, we plan to expand its application into different countries in the Middle East and North Africa region. These countries represent unique challenges for the WEF nexus and various socio-political, economic, climatic and ecological dynamics. Such a study would provide an understanding of the landscape of hot spots in the region, and ways to address each according to local conditions and constraints. These scenarios would assess possible ways of achieving food security through maximizing local food production (i.e. using mixed cropping systems, silvopastoral systems, optimizing green water utilization) and trade, while accounting for the different costs and risks associated with each. The existing WEF Nexus Tool 2.0 would be customized for that purpose.

Even though the water-energy-food framework governing the tool is generic, scenarios to be developed must be site-specific and defined by the characteristics of the area of study.

Wider application

The WEF Nexus Tool 2.0 serves as a common platform that brings together scientific know-how and policy input in an effort to identify current and anticipated bottlenecks in resource allocation trends, while highlighting possible trade-offs and opportunities to overcome resource stress challenges.

Accessing the WEF Nexus Tool

The WEF Nexus Tool 2.0© is publicly available and can be accessed, free of charge, at wefnexustool.org. An account can be created and the tool used to build different scenarios for the available countries. Alternatively, the authors can be contacted at info@wefnexustool.com regarding building and administering individual country profiles.

About the authors

Professor Rabi H. Mohtar is the holder of TEES Endowed Professor at Texas A&M University, College Station, USA. He is the Founding Executive Director of Qatar Environment and Energy Research Institute (QEERI) a member of Qatar Foundation, Research and Development and the Founding Executive Director Strategic Projects at Qatar Foundation Research and Development. His research focuses on conserving natural resources (including land, water, air, and biological resources) that face global challenges such as increasing food and water supplies for a growing population. He has received numerous international research awards and honours including the Kishida International Award for contributions to agricultural research and the Distinguished Alumni award from the American University of Beirut, Faculty of Agriculture and Food Sciences. Among many other global leadership roles, he serves on the World Economic Forum's Climate Change Agenda Council (since 2011), the Board of Governors of the World Water Council (since 2012), the advisory board of the UNFCC's Momentum for Change initiative (since 2012).

Bassel Daher is a Research Associate at Texas A&M University. For the last few years, his work has been geared towards creating policy-oriented research in the areas of natural resource management and environmental sustainability. He received his Master of Science in Engineering from Purdue University in 2012. His research has focused on quantifying the interlinkages between water, energy and food systems and developing the platform for scenario assessment and trade-off analysis. He also works on examining the role of climate change, growing population, changing economies, international trade, among others on the three interconnected systems. He continues to look at different water-energy-food nexus challenges across different scales, facing various regions of the world representing different ecozones and socio-economic dynamics.

Acknowledgments

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