Water-energy nexus

Measuring integration – towards a water-energy-food nexus index

How do you measure whether a country is advancing towards integrating water, energy and food production? Gareth Simpson and Marit Berchner propose a new water-energy-food nexus index.

Water, energy and food are three of the key pillars upon which humanity exists and develops. But these pillars are not independent, as illustrated in Figure 1. Rather, a multitude of connections and trade-offs exist between them. For instance, water is utilised in agricultural irrigation and food processing. Water is also essential for energy generation, be it directly in the case of hydropower or indirectly in coal mining. Energy is utilised in the pumping of water and for the mechanisation of various agricultural activities. The nexus approach to sector management seeks to understand the linkages, dependencies, and trade-offs associated with the core elements within the particular nexus.

The regulatory custodians of water, energy and agriculture, often reside in separate departments. With a lack of coordination between them, these departments can (and do) promote conflicting programmes that inadvertently threaten the security associated with an adjacent sector. One of the reasons for this lack of coordination is that a general understanding of the nexus dynamics is limited. While research on the nexus has mainly focused on a qualitative examination of the linkages and dependencies between the sectors in the nexus, what is lacking to date is a quantitative indicator or index assessing the performance of the sectors in relation to each other. A number of indicators currently exist for each of the three individual resources within this Water-Energy-Food (WEF) nexus. Many of these sector-specific indicators are reported upon by the World Bank and United Nations. These indicators, however, describe isolated pieces of information, and thereby neglect the interconnections between sectors.

It is therefore proposed that a composite indicator, or index, be developed to report on the WEF nexus. This index should ideally be based upon quantitative data, and must ultimately be represented by a single numeric indicator, whereby different cities, regions or countries can be compared and evaluated. The WEF nexus index for, e.g. a country, could then be calculated on an annual basis in order to assess progress in sustainable development, as it relates to these three vital sectors. Similarly, mitigation scenarios could be tested in order to establish achievable and measurable goals to improve the WEF nexus index over time.

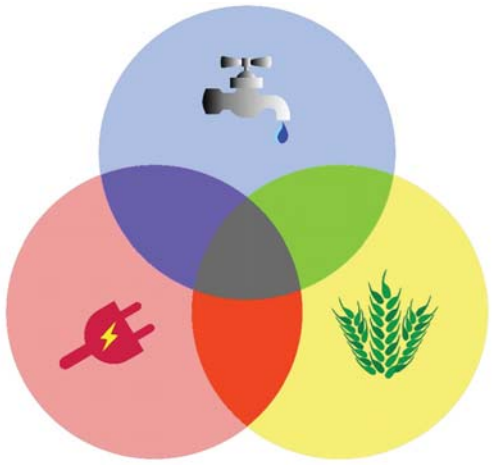

Figure 1: A schematic representation of the Water-Energy-Food nexus.

It is proposed that the WEF nexus index be calculated using two key existing indicators from each sector: one representing a country's sustainability level in terms of that sector; and a second one representing that nation's population's vulnerability in terms of that resource in the WEF nexus. These components are intimately connected, since a country's sustainability has a major impact on its population's vulnerability.

The three 'human vulnerability' indicators are the key targets for their respective United Nations Sustainability Development Goals (SDGs):

SDG 2 (Zero hunger),
SDG 6 (Clean water and sanitation for all), and
SDG 7 (Affordable and clean energy).

The six parameters which constitute the WEF nexus index for the case of South Africa are presented in a radar chart, termed the WEF nexus hexagon, in Figure 2. This is a visual representation of the numeric WEF nexus index. The WEF nexus index for South Africa is 0.728. This ratio is the average of the six indicators presented in Table 1. For comparison purposes, Germany's WEF nexus index is 0.877. Based on the presentation of data in this

figure, South Africa is relatively self-sufficient in terms of cereal production, the prevalence of undernourishment is relatively low, and a large proportion of the population has access to improved drinking water sources and electricity.

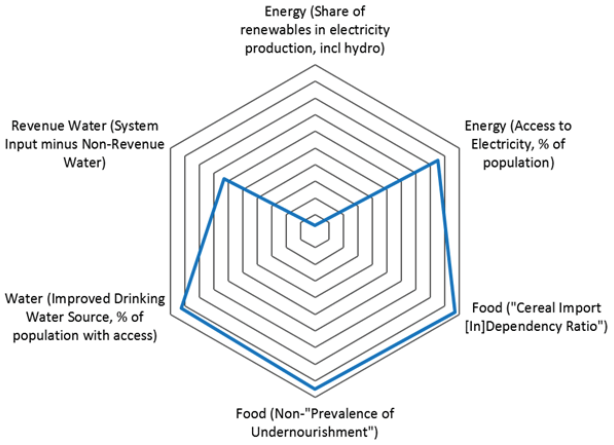

Figure 2: The WEF nexus hexagon for South Africa

Regionally, South Africa is one of the most advanced countries in terms of achieving the targets set in the three relevant SDGs. Ongoing developments such as population growth, urbanisation and changing dietary patterns however result in the goals never being achieved absolutely, but rather that they are dynamic and in need of continuous monitoring. The proposed WEF nexus index can support the monitoring process and draw attention to strengths and weaknesses associated with the sectors in focus, and the policies that are being implemented.

For instance, although the proportion of non-revenue water, which is the sum of unbilled authorised water, commercial losses and real or physical losses, in South Africa (36.8%) is very similar to the world average (36.6%), this still represents a staggering volume of water. The goal of reducing the proportion of non-revenue water must remain a key national goal.

The sector that lowers the WEF nexus index for South Africa most significantly is the energy sector, which is due to this sector being dominated by coal. South Africa is the seventh largest producer of coal in the world. The Council for Geoscience estimates that South Africa has a run-of-coal reserve of about 66.7 billion tons. Eskom, the national utility, purchases approximately half of the locally produced coal, and about 90% of this country's electricity is generated by means of coal-fired power stations. Only a little more than 3% of South Africa's electricity is generated by means of renewable sources.

When considering the influence of coal in South Africa, its impact upon agriculture and water is significant. The Bureau for Food and Agriculture Policy explains that, "At the current rate of coal mining in Mpumalanga, it was calculated that approximately 12% of South Africa's total high potential arable land will be transformed, while a further 13.6% are under prospecting by the mines in Mpumalanga." These statistics indicate that current and future mining enterprises could soon have a negative impact upon agricultural production, as well as long-term implications for food prices.

It is estimated that there are about 5 000 endorheic wetland pans in the Mpumalanga Province alone. This is the second smallest province in South Africa. The change in land use due to mining represents a loss of cultivated land for food production, and will have a negative impact on water quality and biodiversity in the wetland system. Once an opencast mine is rehabilitated, its pre-mining land capability will never be restored. Similarly, some of the hydrological drivers of the wetland ecology will be irreparably removed. Yet in a country such as South Africa, where there is such a large dependence on coal, to stop developments such as this mine would be tantamount to switching the lights off on a national level. Further, the coal industry in South Africa employs about 90 000 people. There is thus a dilemma between business as usual and sustainable development.

Similar to the loss of high potential arable land, biodiversity and wetland systems, the hundreds of operating and derelict, ownerless mines in the country result in water pollution because of acid mine drainage. Water bodies such as the Olifants River have been significantly impacted in terms of quality (and quantity) by extensive coal mining within its catchment area. These factors, combined with the high proportion of non-revenue water, and South Africa being a water scarce country, yield a potential crisis within the WEF nexus.

The WEF nexus hexagon, together with the aforesaid impact of coal mining on the WEF Nexus, shows that in addition to seeking to reduce the level of unaccounted-for water in the country, a key focus must be to develop clean energy technologies, and in particular renewable energy. South Africa is endowed with massive potential in terms of solar and wind power generation. The South African Department of Energy's Integrated Resource Plan, released in November 2016, recognises this, with the base case allocating 55 000 MW for new renewable energy to be delivered between 2020 and 2050. This comprises of 37 400 MW of wind and 17 600 MW of solar photovoltaic power generation.

There are, however, some concerns regarding the constraints that are specified regarding the annual delivery of renewable energy.

The WEF nexus index, together with its visual presentation as the WEF nexus hexagon, can serve as a tool to illustrate how sustainable development is advancing in the water, energy and food sectors, particularly when their linkages are taken into account. The WEF nexus index, being a quantitative ratio, enables comparisons across different geographic entities or within one geographic region over a period of time.

Especially if supplemented with qualitative information, this index can assist researchers, regulators, consultants and NGOs in identifying strengths, weaknesses, opportunities and threats within the interdependent sectors. This can lead to the development of policy recommendations which take into account the interconnections between sectors, and which encourage dynamic progress towards the achievement of the SDGs.