CONCEPTUAL OVERVIEW
Regional Water-Energy Nexus & Climate Change

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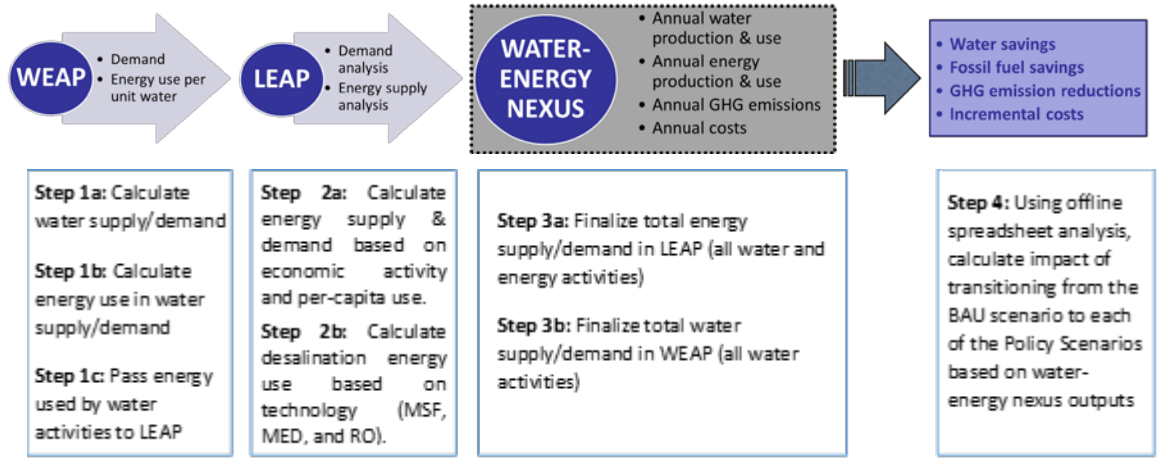
Under climate change, several key trends in the Arabian Peninsula suggest the importance of addressing water and energy in an integrated and proactive way. First, climate change has already begun to affect rainfall and temperature patterns across the region, as established by the LNRCCP's Regional Atmospheric Modeling sub-project. Second, regional socioeconomic growth trends indicate that the population in the region's hyper-arid environment is likely to continue increasing and will require additional energy-intensive desalination capacity to satisfy increasing water demands. Third, new energy and water technologies can increase production efficiency for both resources, if introduced within a water-energy integrated framework. Finally, a water-energy nexus strategic approach could help to inform future technology research, development, demonstration, and deployment at several centres of excellence in the region.

The vulnerability of the region's water resources to climate change was explored within a "water-energy nexus" framework. The water-energy nexus is simply a way to considered water resource vulnerability as part of an integrated water and energy system, rather than as an independent resource. Water is used in all phases of the fuel cycle, from extraction of energy resources like natural gas and oil, to energy production and electricity generation. Energy is required to extract, convey, purify, and deliver water to various types of end users in the economy. It is also used to treat municipal and industrial wastewater. Until recently, energy and water have been viewed as separate planning challenges. Any interactions between energy and water have typically been considered on a case-by-case basis. However, changing demographics, large-scale development initiatives and increased reliance on desalination have recently motivated attention on the connections between water and energy infrastructure. It is a particularly useful framework to apply in the assessment of water resources vulnerability to climate change on the Arabian Peninsula.

The overall goal is to better understand the water-energy nexus challenge in the Arabian Peninsula region in the face of climate change and socioeconomic development. The major research questions underlying the methodological approach were twofold. First, what would be the future benefits - as measured in water savings, energy savings, greenhouse gas emission reductions – associated with various scenarios that aim to promote efficiency and conserve natural resources under climate change? Second, what would be the costs

associated with shifting to such scenarios and away the current baseline development trajectories?

Figure 1: Sequence of steps used to analyze the regional water-energy nexus under climate change



Addressing the goal and research questions required an analytical framework capable of accounting for water, energy and climate interactions in an integrated way. On the water side, the Water Evaluation And Planning (WEAP) system was used; on the energy side, the Long Range Energy Alternatives and Planning (LEAP) system was used. WEAP and LEAP are integrated modeling tools that can track water and energy resources associated with extraction, production, and consumption, throughout the region's economy, including seawater desalination, groundwater pumping, and the transmission of water. Moreover, the models have been coupled (i.e., outputs of one model are used as the inputs to the other) to enable an analysis of the interplay between water management and energy management policies under changing future conditions. A planning period of 2010 through 2060 was considered in the analysis. **The results of the LNRCCP's regional atmospheric modeling and desalination studies were incorporated into the analytical framework of the regional water-energy nexus study.** An overview of the analytical sequence is sumamrized in Figure 1.

The validated water-energy nexus model was used to analyze the costs and benefits of several policy scenarios that could promote resilience of water and energy systems in the region in the face of climate change. Establishing a plausible policy scenario framework is fundamental for using the coupled model to explore challenges and opportunities for transitioning to more climate-resilient development paths. This scenario framework consists of five scenarios: a "Business-As-Usual scenario, without climate change"; **a "**Business-As-Usual scenario, with climate change"; a "High Efficiency and Conservation scenario"; a "Natural Resource Protection scenario"; and an "Integrated Policy scenario".

The results of the study confirm that green growth objectives that will increase the resilience of the water-energy nexus in the region under climate change. Moreover, this can be achieved cost-effectively. Specifically, the pursuit of an economic diversification agenda (as has been prominently reported recently by some countries in the region) employing a green growth framework can lead to significant environmental benefits. These benefits can be achieved at net economic savings in the case of a scenario emphasizing energy/water efficiency investments (-$24.0 for each tonne of CO2e avoided), and at modest economic cost in the case of a scenario emphasizing renewable energy investments ($13.8 for each tonne of CO2e avoided). Taking advantage of the synergies across efficiency and renewable green growth strategies achieves maximum benefits at very low cost ($3.0 for each tonne of CO2e avoided).