Water-Energy Nexus Challenges & Opportunities in the Arabian Peninsula under Climate Change

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Abstract

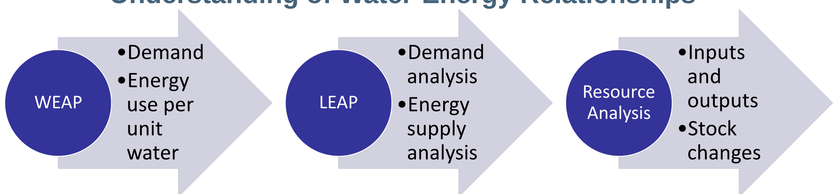
Demand for water in the Arabian Peninsula relies mainly on fossil groundwater resources and desalination. Satisfying water demand requires a great deal of energy as it treats and moves water along the supply chain from sources, through treatment processes, and ultimately to the consumer. Hence, there is an inherent connection between water and energy and with climate change, the links between water and energy are expected to become even stronger.

As part of Abu Dhabi Global Environmental Data Initiative's Local, National, and Regional Climate Change Programme, a study of the water-energy nexus of the countries in the Arabian Peninsula was implemented. For water, WEAP (Water Evaluation And Planning system) models both water demand – and its main drivers – and water supply, simulating policies, priorities and preferences. For energy, LEAP (Long-Range Energy Alternatives Planning system) models both energy supply and demand, and is able to capture the impacts of low carbon development strategies. A coupled WEAP-LEAP model was then used to evaluate the future performance of the energy-water system under climate change and policy scenarios. The coupled models required detailed data, which were obtained through literature reviews and consultations with key stakeholders in the region. As part of this process, the outputs of both models were validated for historic periods using existing data.

The models examined 5 policy scenarios of different futures of resource management to the year 2060. A future under current management practices with current climate and a climate projection based on the RCP8.5; a High Efficiency scenario where each country gradually implements policies to reduce the consumption of water and electricity; a Natural Resource Protection scenario with resource efficiency and phasing out of groundwater extraction and drastic reduction of fossil fuel usage in favor of solar; and an Integrated Policy scenario that integrates the prior two policy scenarios.

Water demands can mostly be met in any scenario through supply combinations of groundwater, desalination and wastewater reuse, with some regional fossil groundwater basins draw to extinction by 2060. While the analysis includes both demand and supply oriented scenarios, the results of the analysis strongly suggest that the region will need to simultaneously purse demand and supply side policies to achieve more sustainable uses of water and energy into the second half of the 21st century.

WEAP and LEAP Are Linked to Improve Understanding of Water-Energy Relationships

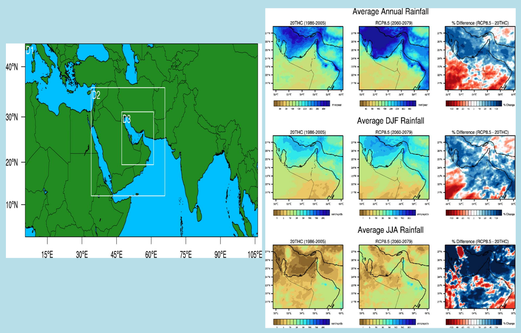


- **WEAP is a decision support framework for water system planning and management**
- **Not a "model" of a water system – WEAP is a *tool* for building models.**

- **LEAP is a scenario-based modeling platform for energy planning and GHG mitigation assessments.**
- **Medium to long-term planning horizons, as well as local, regional, national or global spatial scales**
- **Not a "model" of an energy system – LEAP is a *tool* for building models.**

Modeling Methods: Climate Change

The Baseline and Future Climate are based on results from the Regional Atmospheric Modeling sub-project

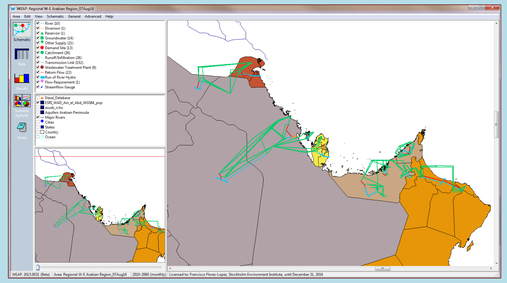


Energy Demand Factors for Water (kWh/m³)

Key Assumption	2000	Scale	Unit
ElectricityFactors			N/A
GWPumping	0.1...		kWH /m^3
MuniWWTreatment	0.8...		kWH /m^3
Desal			N/A
Reuse	1.7...		kWH /m^3

Key Assumption	2000	Scale	Unit
Desal			N/A
MSF	16		kWH /m^3
RO	6.5		kWH /m^3
MED	14		kWH /m^3

The Arabian Region WEAP Model

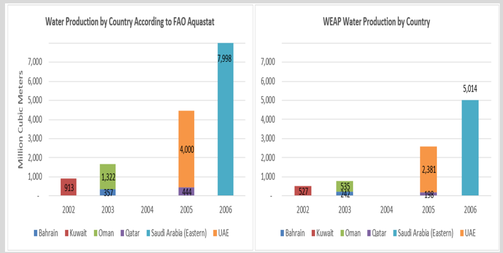


Supply Preference in Regional Model

Source	Type	UAE (Abu Dhabi Region) Indoor	Amenity	Outdoor	Ag.	UAE (Western Region) Indoor	Amenity	Outdoor	Ag.	UAE (Al Ain Region) Indoor	Amenity	Outdoor	Ag.	UAE (Dubai) Indoor	Amenity	Outdoor	Ag.	UAE (Eastern Emirates) Indoor	Amenity	Outdoor	Ag.
Desalination	MSF	1	2	2		1	2	2		1	2	2		1	2	2		1	2	2	
	MED	1	2	2		1	2	2		1	2	2		1	2	2		1	2	2	
	RO	1	2	2	5	1	2	2		1	2	2		1	2	2	4	1	2	2	4
WWTP	Abu Dhabi		1	1																	
	Western Region						1	1													
	Al Ain										1	1									
	East														1	1			1	1	
Groundwater	Abu Dhabi Brackish		4	4	4																
	UpperW Fresh						3	3	3												
	Upper W Brackish						4	4	4												
	West Brackish						4	4	4												
	Western Gravel									1	3	3	3								
	Shallow E Brackish										4	4	4								
	Shallow E Fresh										3	3	3								
	E Brackish										4	4	4								
	E Fresh										3	3	3								
	Eastern Reg													1	3	3	3	1	3	3	3

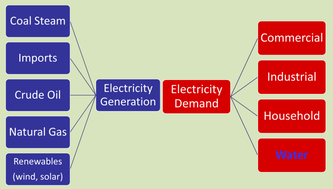
Source	Type	Kuwait Indoor	Outdoor	Ag.	Saudi Arabia (Northern) Indoor	Outdoor	Ag.	Saudi Arabia (Eastern) Indoor	Outdoor	Ag.	Saudi Arabia (Ar Riyadh) Indoor	Outdoor	Ag.	Bahrain Indoor	Outdoor	Ag.	Qatar Indoor	Outdoor	Ag.
Desalination	MSF	1	2		1	2		1	2		1	2		1	3		1	2	
	MED	1	2		1	2		1	2		1	2		1	3		1	2	
	RO	1	2	10	1	2	10	1	2	10	1	2	10	1	3	10	1	2	10
WWTP	Kuwait		1																
	East							1											
	Ar Riyadh											1			1			1	
	Bahrain														1			1	
Groundwater	Dammam North	1	2	1	1	3	1												
	Dammam Center							1	3	1	1	3	1	1	2	1	1	2	1

WEAP Model Validation



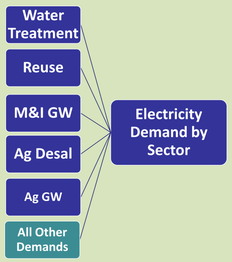
- Water production was underestimated based on direct feedback from regional stakeholders and regional water-energy specialists
- 6 BCM used in the agricultural sector and 3 BCM for municipal, industrial and commercial uses
- Water sources are groundwater, desalination and reuse

Electric Energy Transformation in LEAP



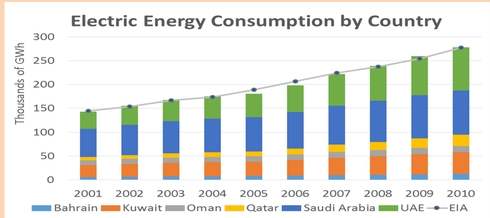
- Electricity demand is currently dependent on per-capita use.
- Transforms this demand to be sector specific (commercial, industrial, household).
- Electric demand by water from WEAP.

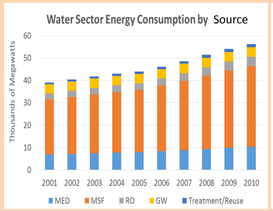
Electricity Demand by the Water Sector

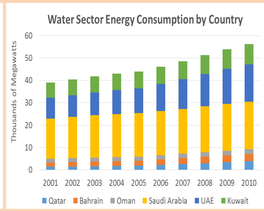


- Excluding Desalination, water primarily uses electricity to treat, pump, and move water.
- Ag Desalination is assumed to use RO technology to treat water to a minimum WQ standard.
- Energy Demand for Ag Water is for pumping.

LEAP Validation



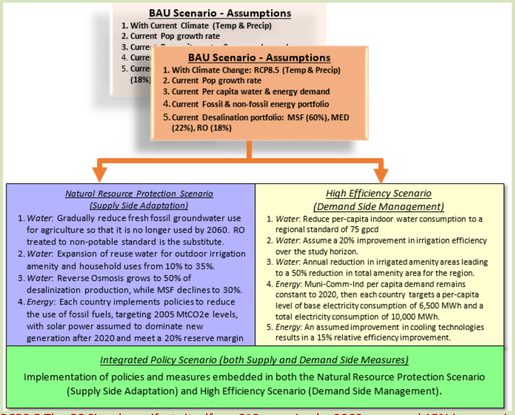




Policy Scenarios

- Scenarios are exploratory, not specific to local policy
- Scenarios address a question such as, "What level of renewable penetration would be required to achieve national greenhouse gas reduction targets; or what level of water use would be needed to meet resource conservation objectives?"
- Scenarios are not predictions but narratives that describe plausible conditions in the Region

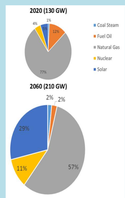
Implemented Policy Scenarios



RCP8.5 The CC Signal manifests itself as ~2ºC warming by 2060, assumed 15% increase in Cooling Degree Days (applied to Service and Residential Demand).
This Warming Induces a 1% increase in electricity demand from 2015 to 2060 (all else being equal).

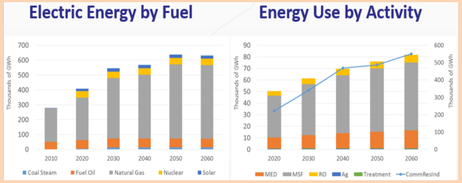
Comparing Results Across the Policy Scenarios

Summary of Scenario Action	Alternative Scenario	Starting Scenario	Cumulative benefits (2020-2060) Water savings (BCM)	Energy savings (TWh)	CO2e reductions (million tonnes)	Total Incremental cost (billion 2015$)	Avoided CO2e emissions from policies ($ per tonne
From climate change, only	BAU-RCP8.5	BAU	-13	-470	1000	47	-
From introduction of improved efficiency & conservation measures	High Efficiency & Conservation	BAU-RCP8.5	49	1600	900	-21	-$24
From introduction of renewable energy and reductions in groundwater withdrawals	Natural Resource Protection	BAU-RCP8.5	0	4200	4200	57	$13.8
From introduction of all sustainable development measures	Integrated Policy	BAU-RCP8.5	49	4400	4000	12	$3.0

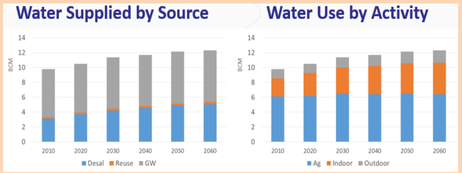


LEAP – Total Energy Demand by All Sectors

Summary for BAU –RCP8.5



WEAP- Water Supply and Demand



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