LNRCC Programme

RESEARCH REPORT

Regional Water-Energy Nexus & Climate Change

Day 2, 14 March 2017

SEI STOCKHOLM ENVIRONMENT INSTITUTE

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Climate Change Research Group

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مبادرة أبوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

Project team

The Regional, National Water-Energy Nexus sub-projects and Al Ain water resource & climate change is being carried out by a team from the Stockholm Environment Institute (US-Center) and the National Center for Atmospheric Research (NCAR)

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Project Goal & Objectives

Goal: Examine water and energy access vulnerabilities across the Arabian Peninsula until 2060 due to risks from anticipated demographic and climatic changes

- ✓ **Objective #1:** *Build* coupled water-energy models for the Gulf region
- ✓ **Objective #2:** *Define and quantify* a set of policies consistent with a sustainable development vision minimizing climate change impacts
- ✓ **Objective #3:** *Analyze* alternative development scenarios under climate change relative to water, energy, and environmental impacts.

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Water and Energy Models are Linked to Examine Water-Energy Relationships

Water
- Demand
- Energy use per unit water

Energy
- Demand analysis
- Energy supply analysis

Resource Analysis
- Inputs and outputs
- Stock changes

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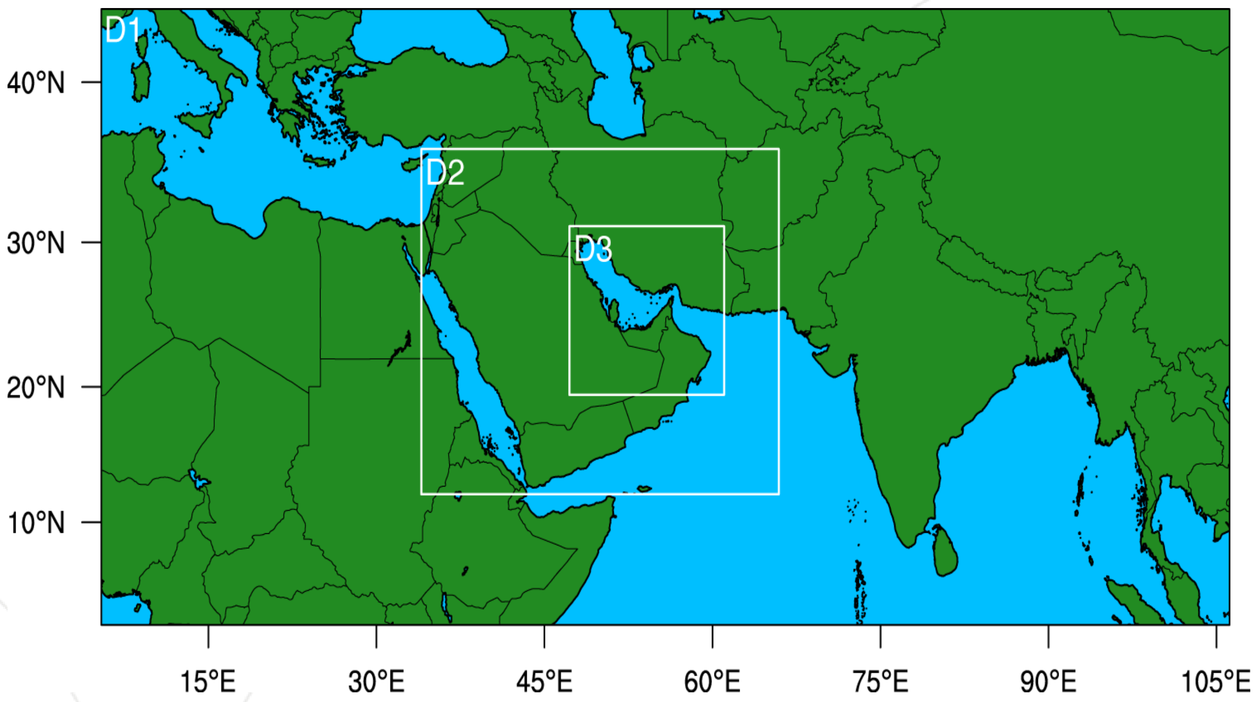
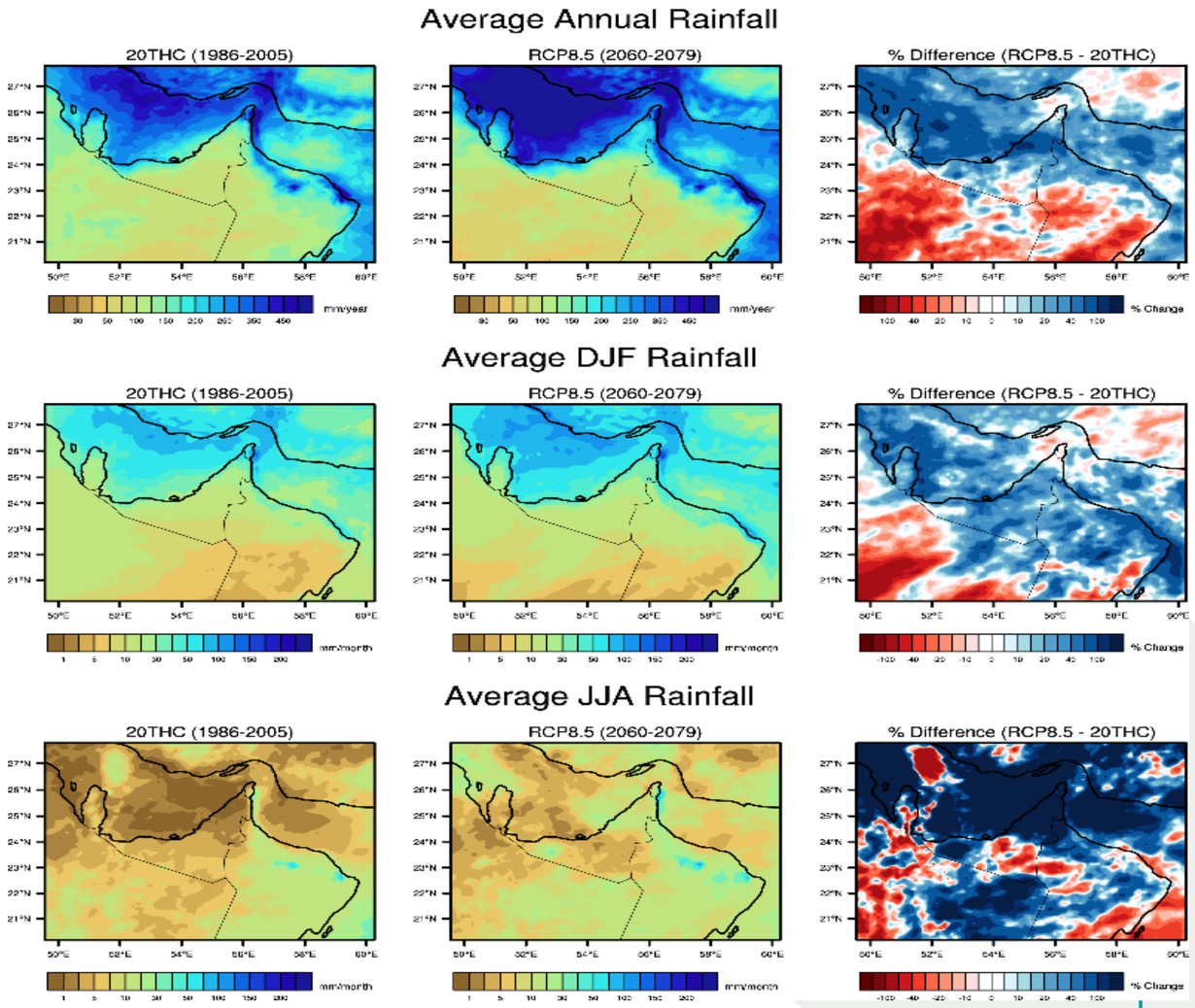
Modeling Methods: Climate Change

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





- **Decision support framework for water system planning and management**
- **WEAP is a *tool* for building water system models.**
- **Demand, supply, priorities and constraints**

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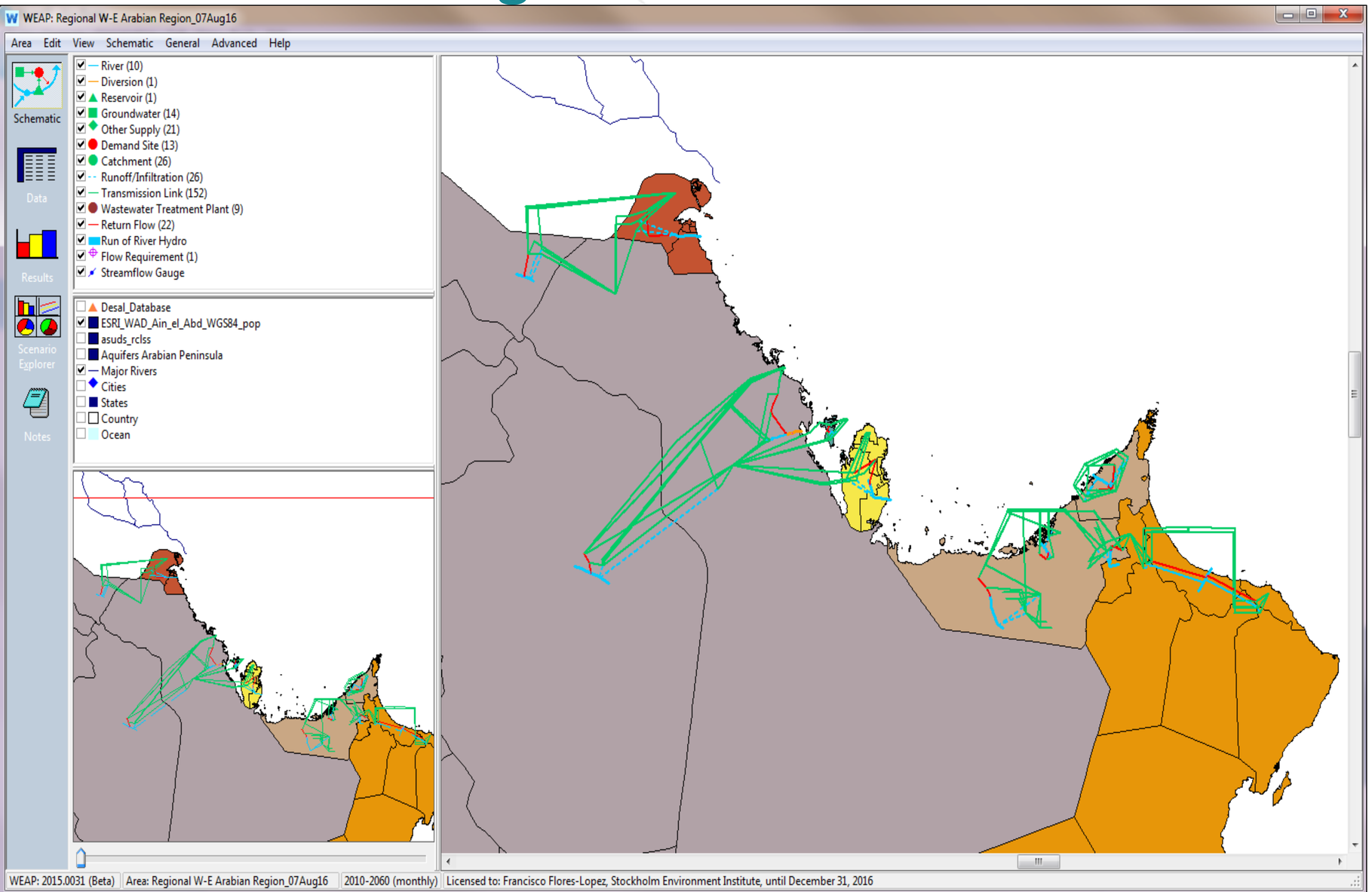
The Arabian Region WEAP Model Overview



Countries in the model: Bahrain, Kuwait, Qatar, (Eastern) Saudi Arabia, UAE, and (Northern) Oman

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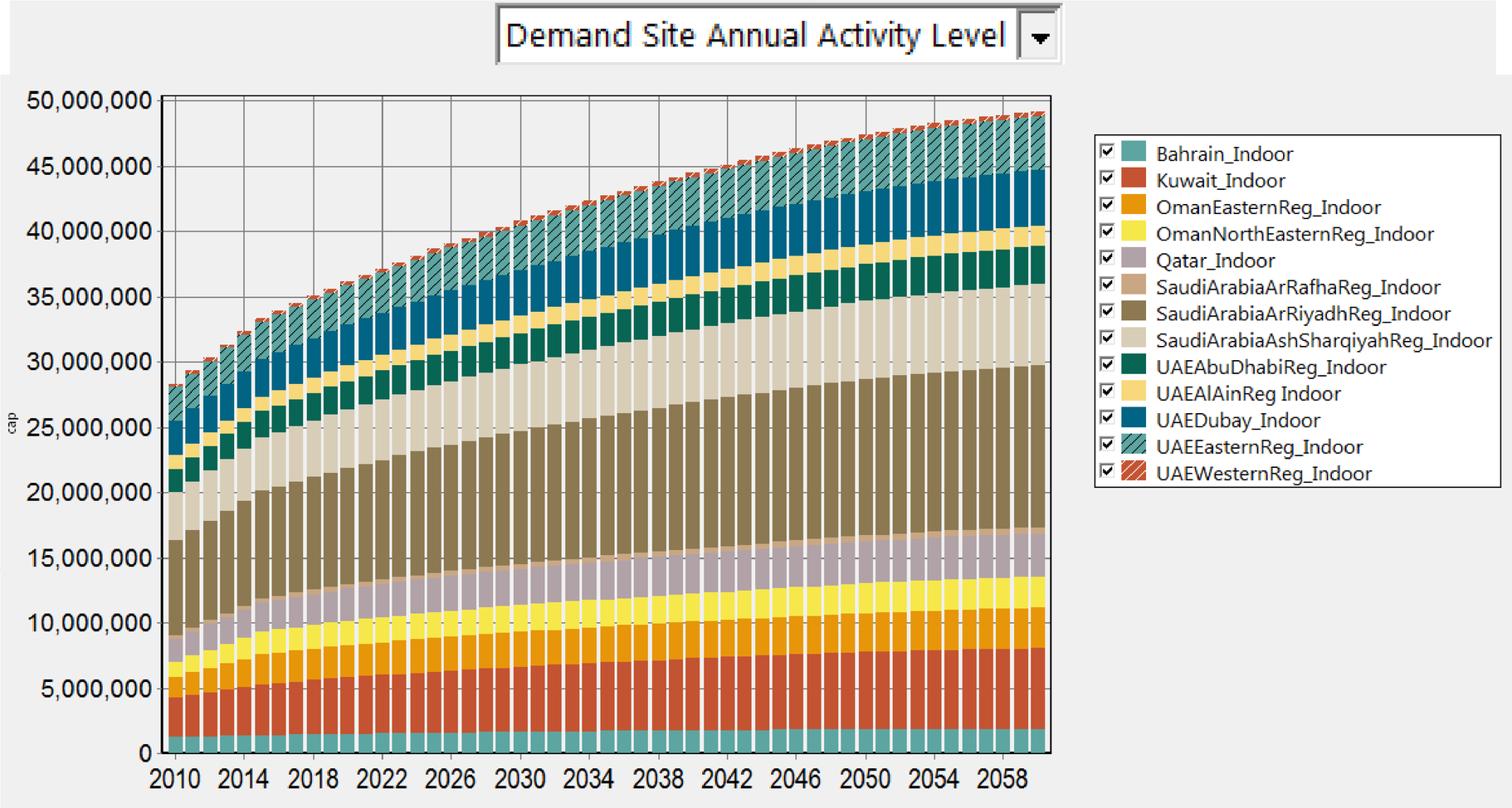
Population Projection for Indoor Water Demand



#: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, custom data acquired via website.

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Water Sources for the Regional WEAP Model

Water sources include:

- Groundwater (Fresh and/or Brackish)
- Desalination ("Other Supply") as Reverse Osmosis (RO), Multi-Stage Flash (MSF), and Multi-Effect Distillation (MED)
- Treated Wastewater for outdoor non-potable use.

All sources have energy implications (kWh/M^3)

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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

- WEAP calculates the energy demand of water use
  - GW Pumping
  - Potable and Waste Treatment
  - Reuse

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

- Energy demand is in electricity use (kWh per m^3 water)

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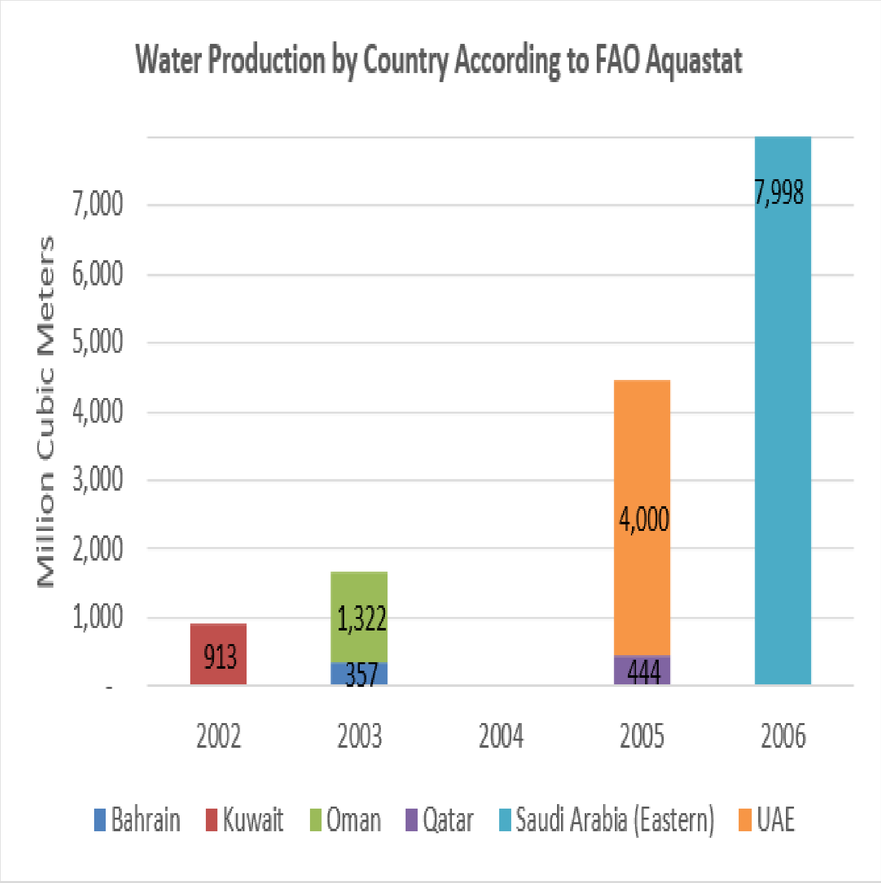
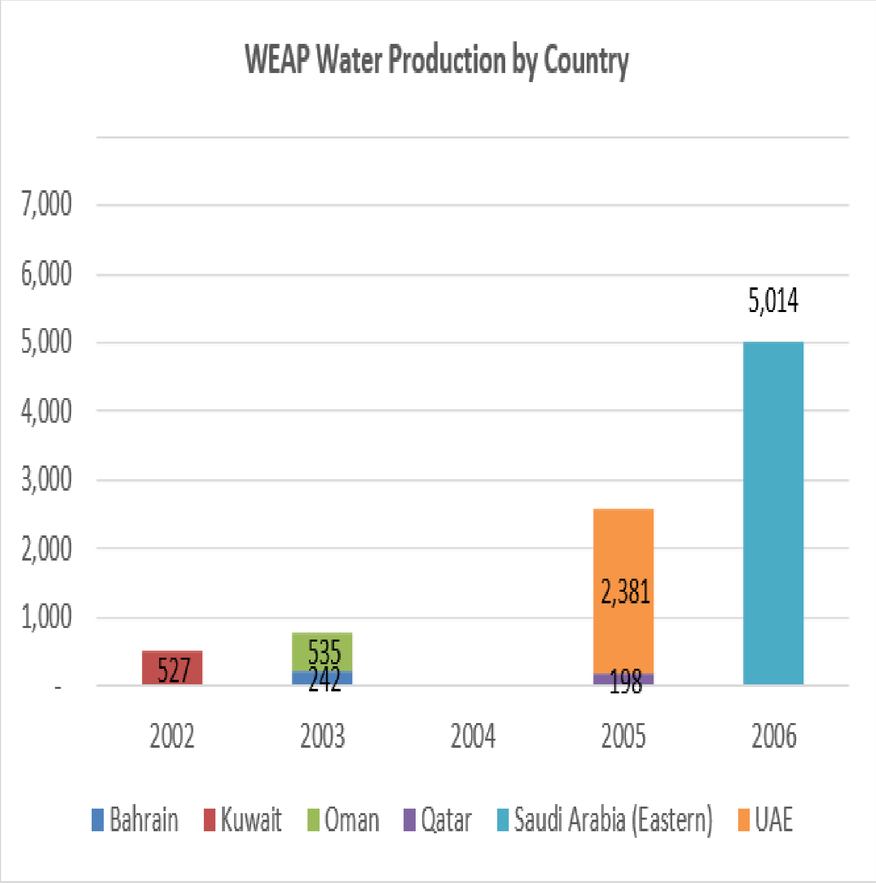
WEAP MODEL VALIDATION – Water Production (Supply Delivered) in the Arabian Peninsula (MCM)





- Water production was underestimated based on direct feedback from regional stakeholders and regional water-energy specialists
- Total annual water use in the Arabian Peninsula (non-Gulf regions excluded) were estimated to be about 9 BCM
- 6 BCM used in the agricultural sector and 3 BCM for municipal, industrial and commercial uses
- Water sources are groundwater, desalination and reuse

Total Water Supplied in Historic Period: ~ 9,000 MCM
Data period induced period 2002 through 2010

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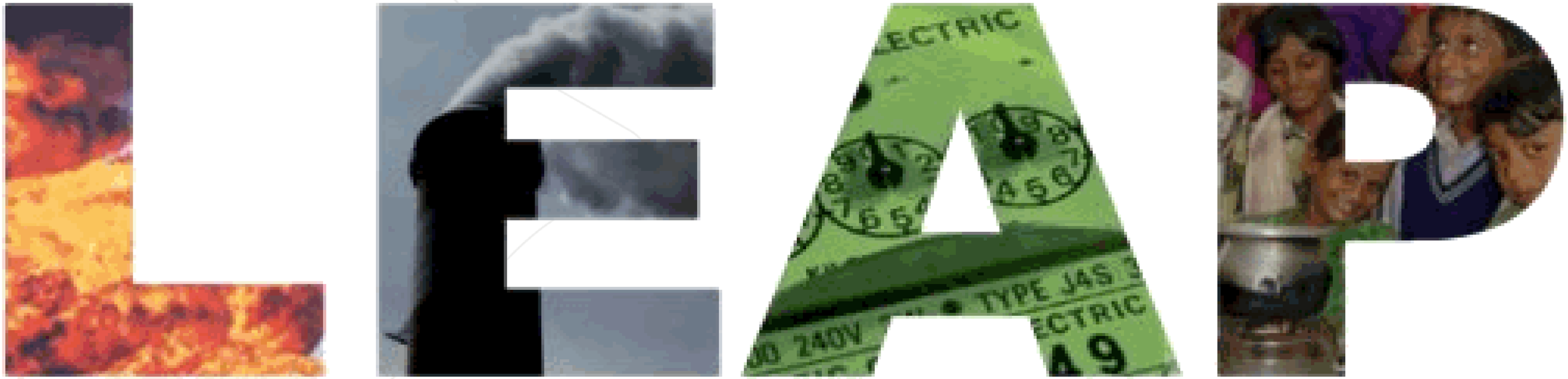

- **LEAP is a scenario-based modeling platform for energy planning and GHG mitigation assessments.**
- **LEAP is a *tool* for building energy system models**
  - **Energy generation, available fuels, demands**

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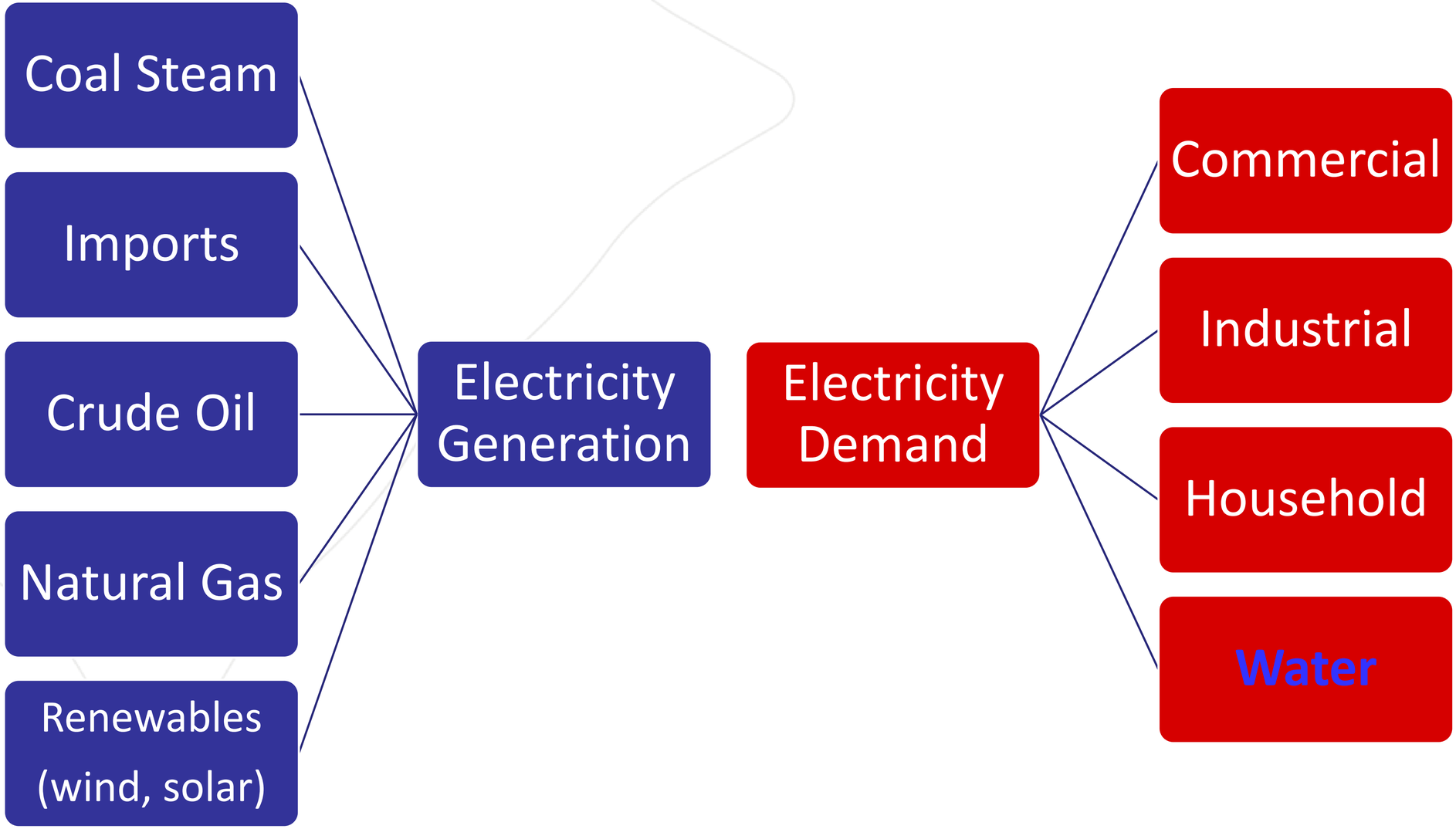
Electric Energy Transformation in LEAP



- Information for energy balance.
- 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

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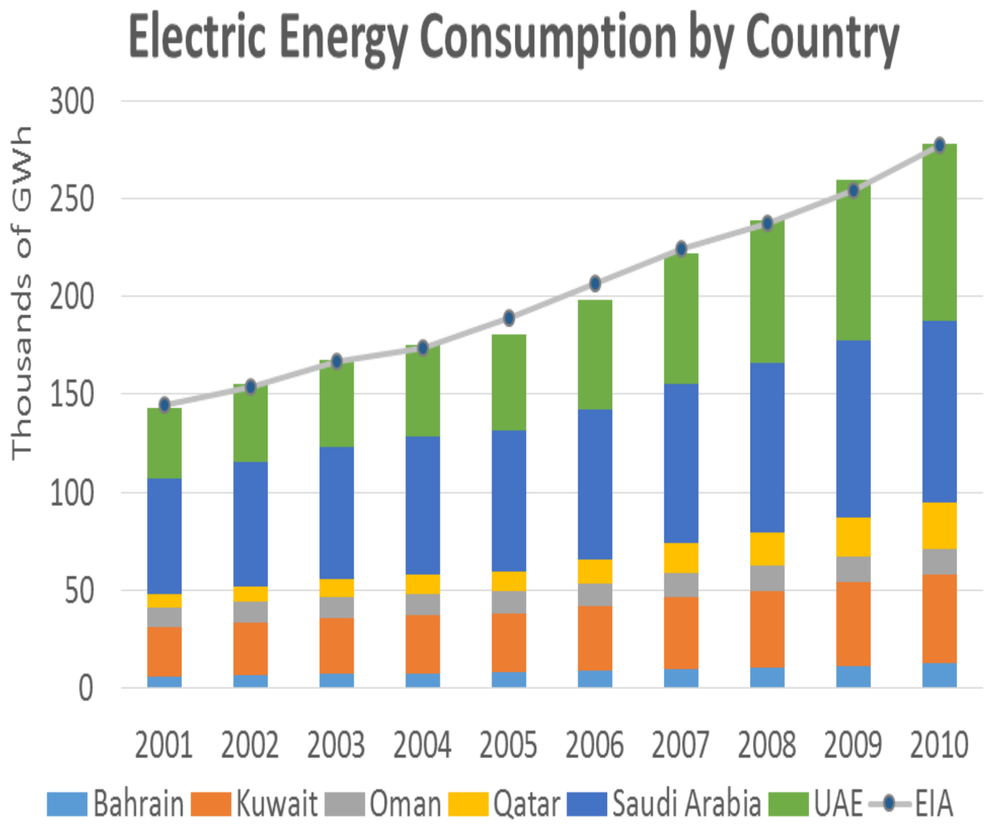
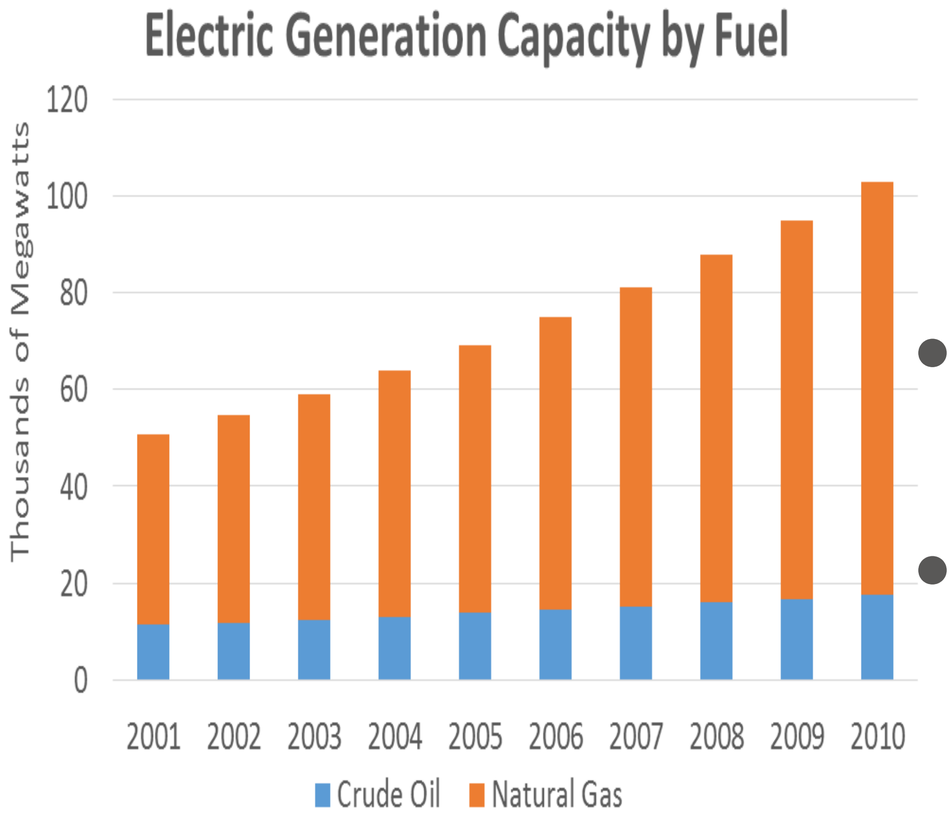
LEAP VALIDATION: Electric Energy for the Arabian Peninsula





- Left: Historic electric energy consumption by country and modeled by LEAP (bars) and the estimate of the annual energy consumption for the same six countries from the IEA
- Right: Electricity capacity by fuel source in MW
- Note that solar and wind are less than 0.1% of total production through this period

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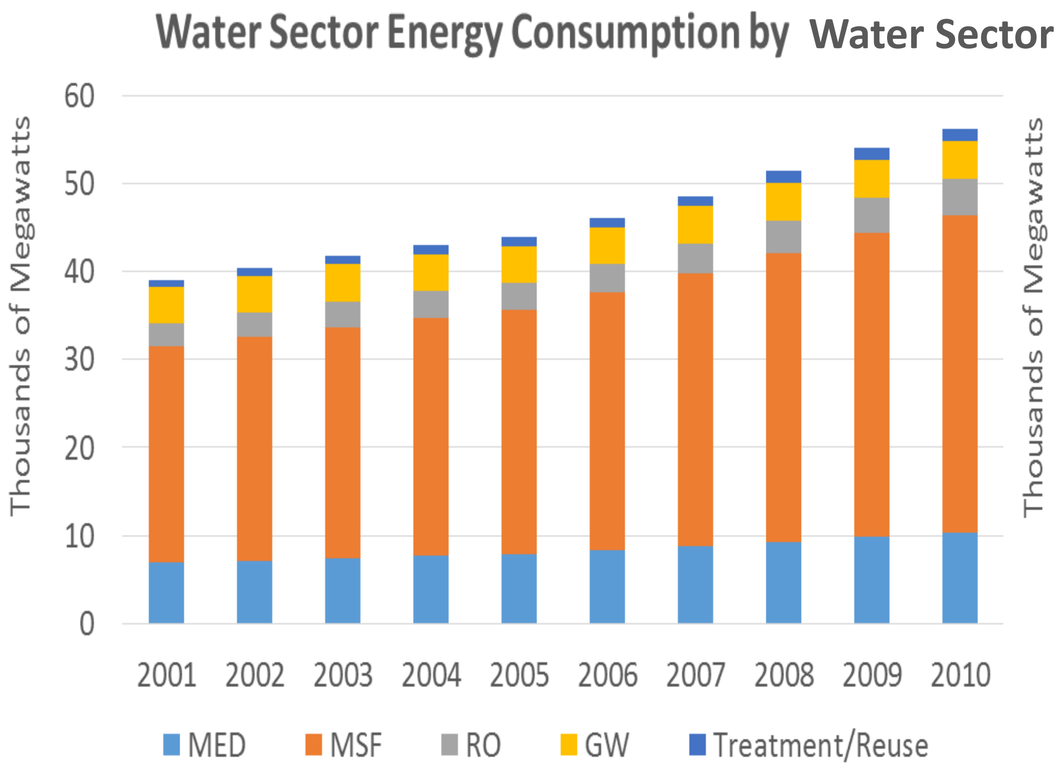
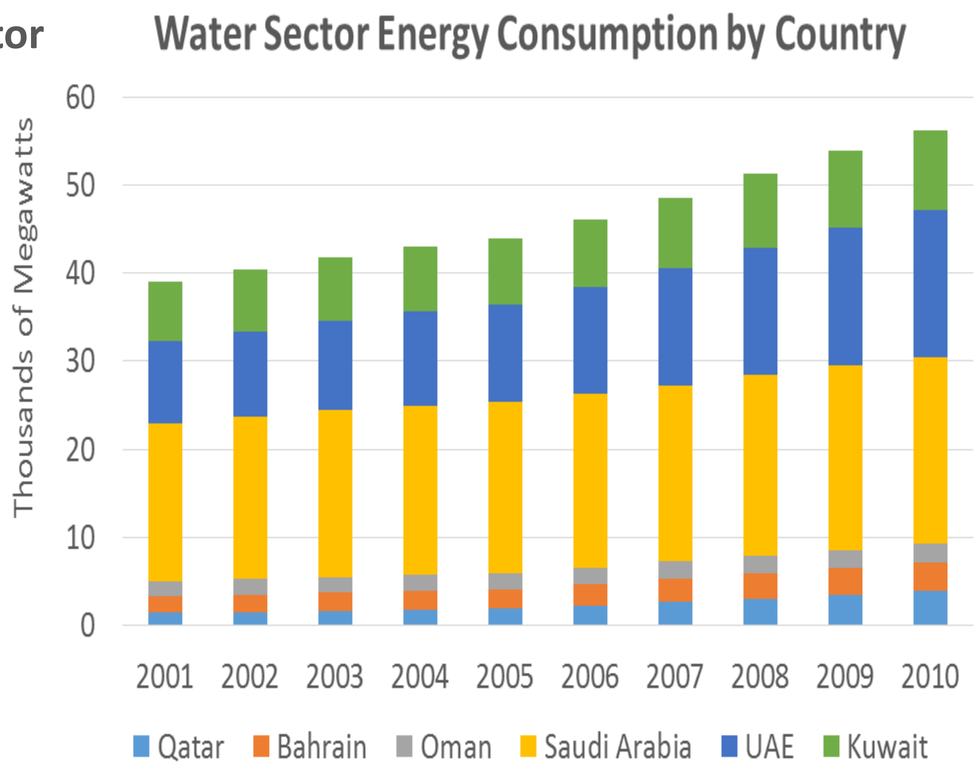
LEAP VALIDATION: Energy Consumption by Water Sector for each technology type and for each country





- Water Sector Energy by use type (left) including desalinization technology; groundwater pumping; and WWT and distribution
- Country level energy demand by country

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Overview of Scenarios

Five scenarios were implemented to explore the links between water and energy in the UAE, and the implications of climate change. These Include:

- The BAU with and without Climate Change Scenarios (*BAU and BAU-RCP8.5*)
- Policy Scenarios that tier off the *BAU-RCP8.5* scenario:
  1. *High Efficiency*
  2. *Natural Resources Protection*
  3. *Integrated Policies*

BAU without Climate Change (*BAU*)

- Historic climate data is used in the Business-As-Usual (BAU) Policy Scenario
- BAU includes population growth but constant per-capita resource use (e.g. m^3/person; kWh/person)
- Outdoor, Amenity, and Agricultural Water demands fluctuate with climate.
- No policy scenarios are considered in the BAU Scenarios

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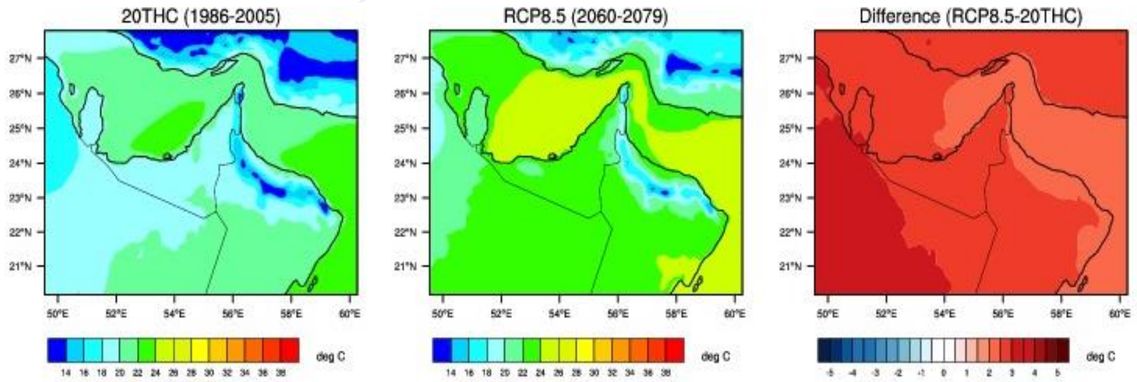
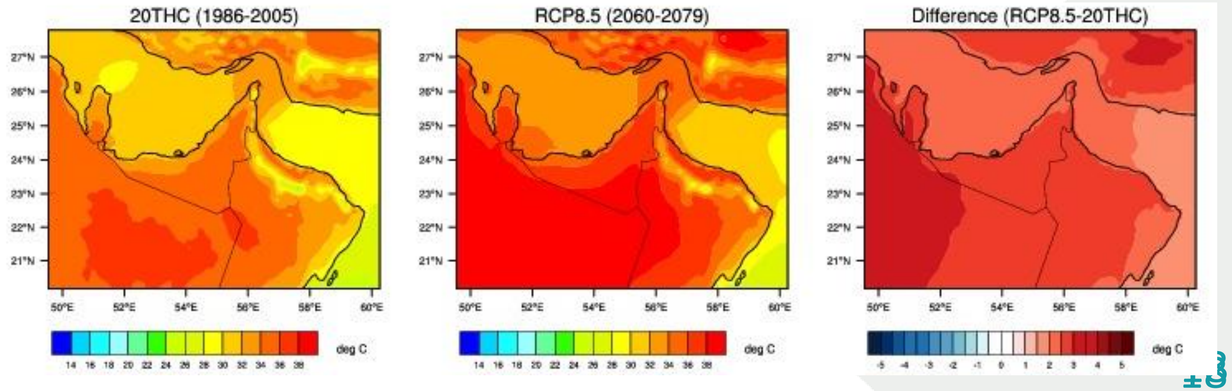
BAU with Climate Change (*BAU-RCP8.5*)

- Same characterizations of the BAU, except for climate
- Climate change is modeled using RCP8.5; results from the Regional Atmospheric Study, which projects a mean annual increase in temperature of about 2°C warming by 2060

Dec, Jan, Feb



Jun, Jul, Aug



Characteristics of Policy Scenarios

Characterization of Scenario				
	Energy Supply	Energy Demand	Water Supply	Water Demand
Efficiency (Demand Side)		Reduce peak demand through improved efficiency.		Indoor use halved by 2060 Outdoor and irrig. ag use 66% of current amount by 2060
Natural Resource Protection (supply)	Renewables favor new generation capacity (primarily solar)		RO in favor of Thermal Increase in Treated WW. Eliminate Fresh GW USE. 50% reduction in brackish GW Use 2050	
Integrated Actions	Combines the Efficiency and Natural Resource Protection Assumptions			

Comparing Results Across the Policy Scenarios

- BAU's and policy scenarios are run through 2060 with implementation of policy actions starting on 2020 and are fully implemented by 2060
- Because of uniform nature of the scenarios (in terms of country-level adaptations), we focus our analysis on regional results rather than on a country-by-country basis
- We used a *'social cost'* approach to our analysis, which focuses only on the costs associated with energy and water production, using a *'levelized cost'* approach to each fuel type and water production method. A socialized cost approach does not attempt to quantify any of the benefits of water or energy productions, as the benefits are complex and simply beyond the scope of this project

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Water and Energy Overview for *BAU and BAU –RCP8.5*

The two BAU scenarios are run through 2060

Finding: Climate change, primarily through warming, increases water supply requirement by 3% by 2060, reflected in the BAU-RCP8.5 scenario

Finding: electricity demand increases by 15% by 2060 driven by the higher heat index (leading to an increased demand for seasonal cooling)

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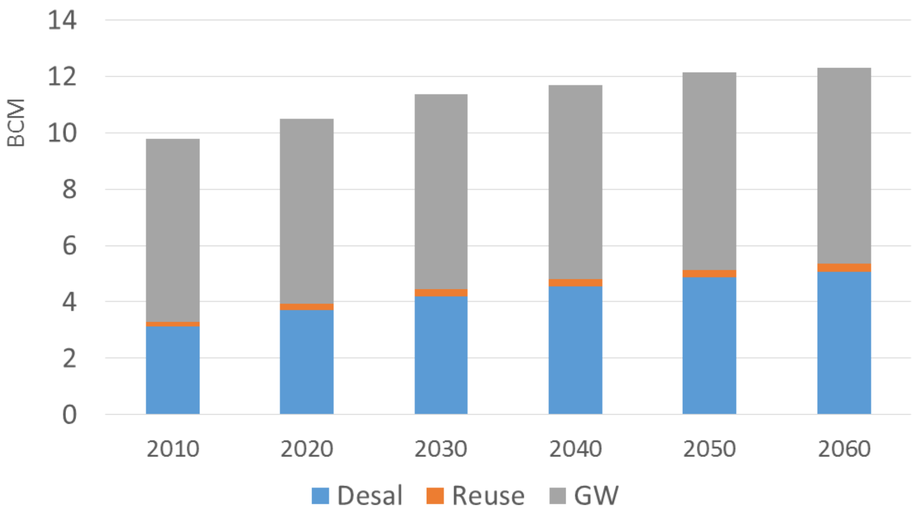
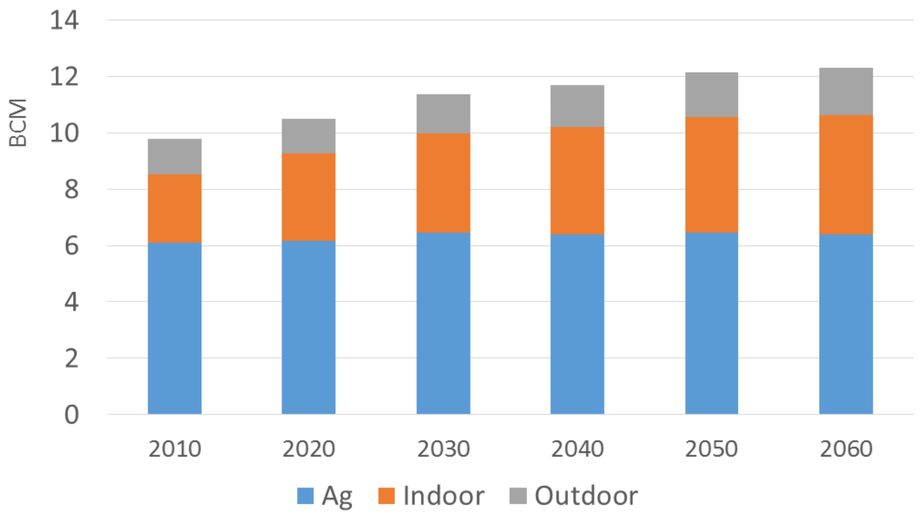
WEAP- Water Supply and Demand Summary for *BAU –RCP8.5*

Water Supplied by Source



Water Use by Activity



- Total water demand grows from 10 BCM in 2010 to 12.2 BCM in 2060
- Indoor demand has the largest increase with a growth of 45%
- Outdoor household water demand grows slightly as population grows, as does agriculture demand

** The Effect of Climate Change on Demand is on outdoor uses*

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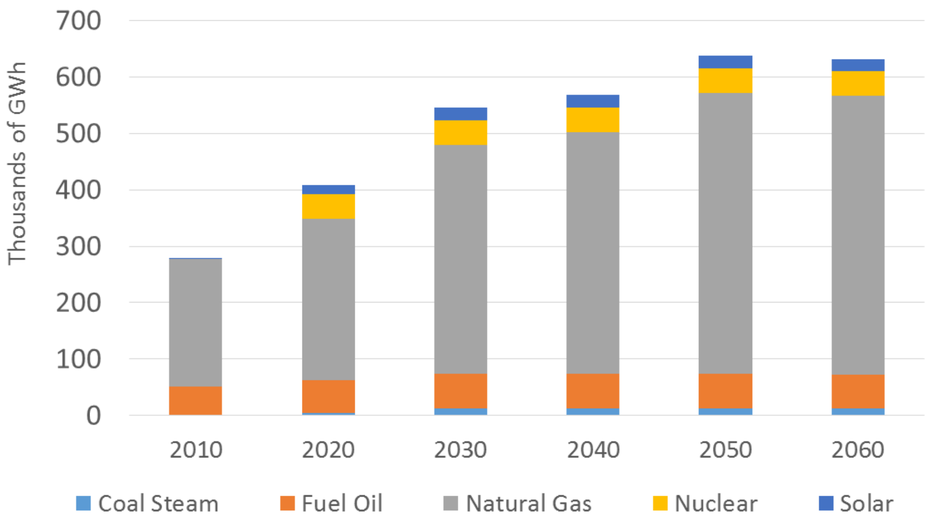
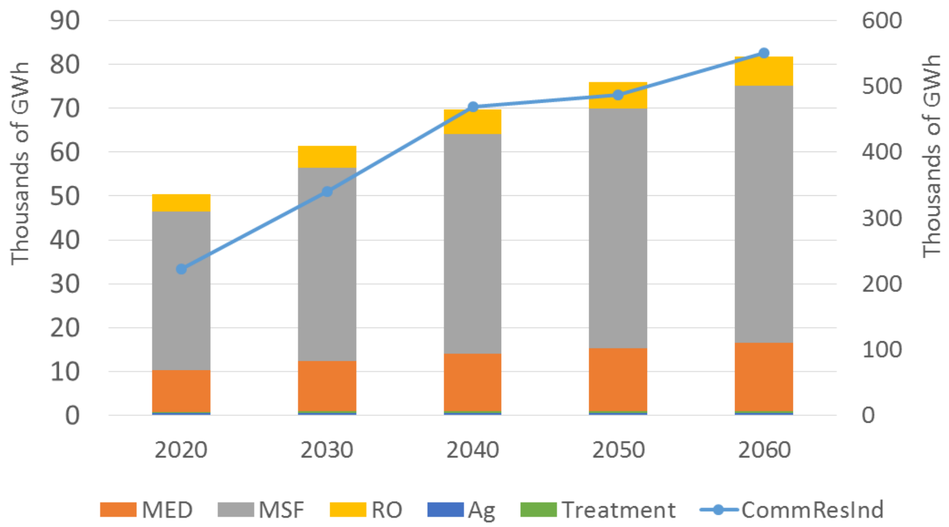
LEAP – Total Energy Demand by All Sectors (*BAU-RCP8.5*)

Electric Energy by Fuel



Energy Use by Activity



- Total energy use more than doubles.
- Natural Gas Continues to Dominate. Renewables are small fraction
- MSF main desal technology.
- Water related energy demand uses ~15 to 20 % of total energy with majority for desal.

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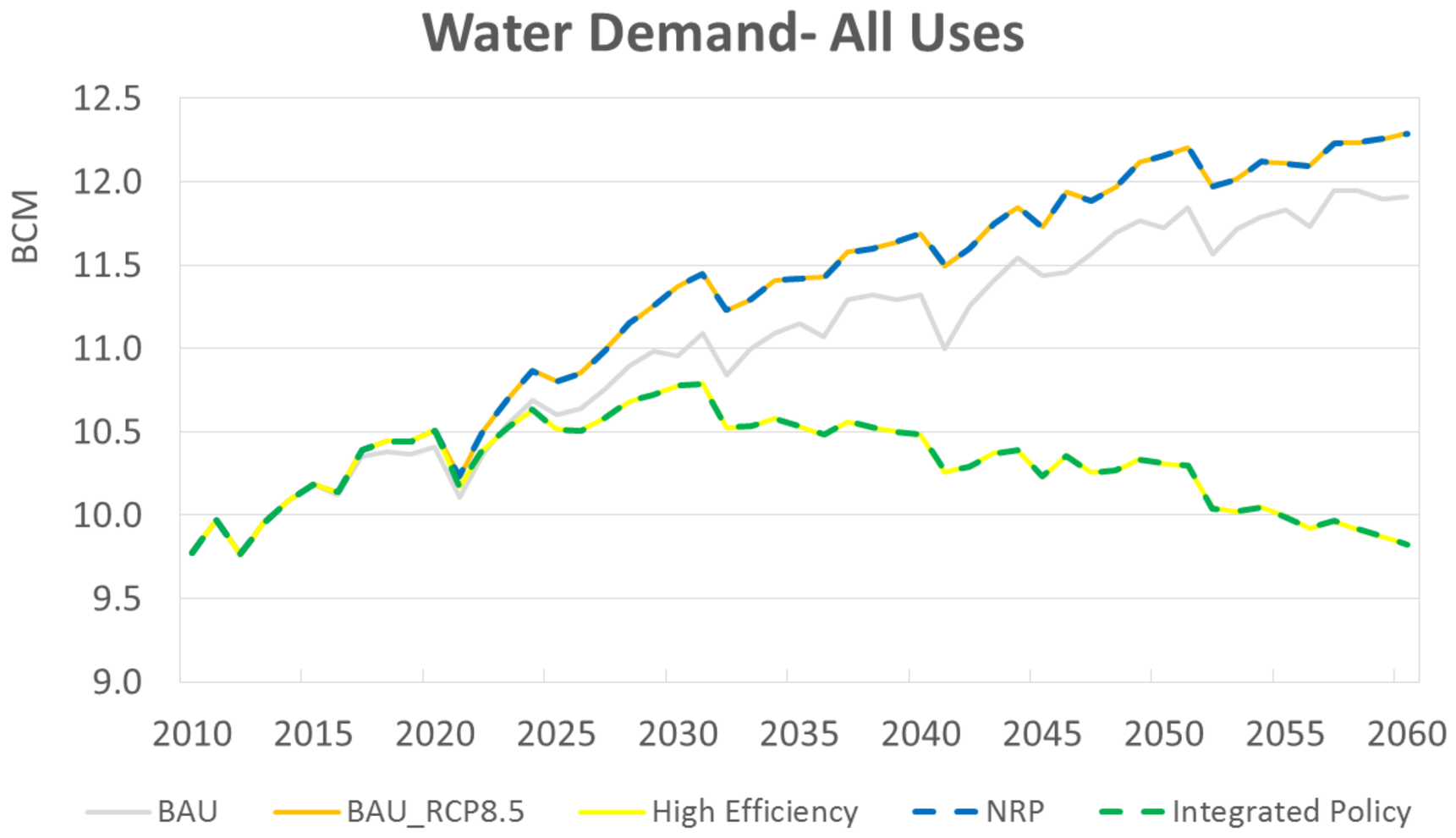
Comparing Results Across the Policy Scenarios



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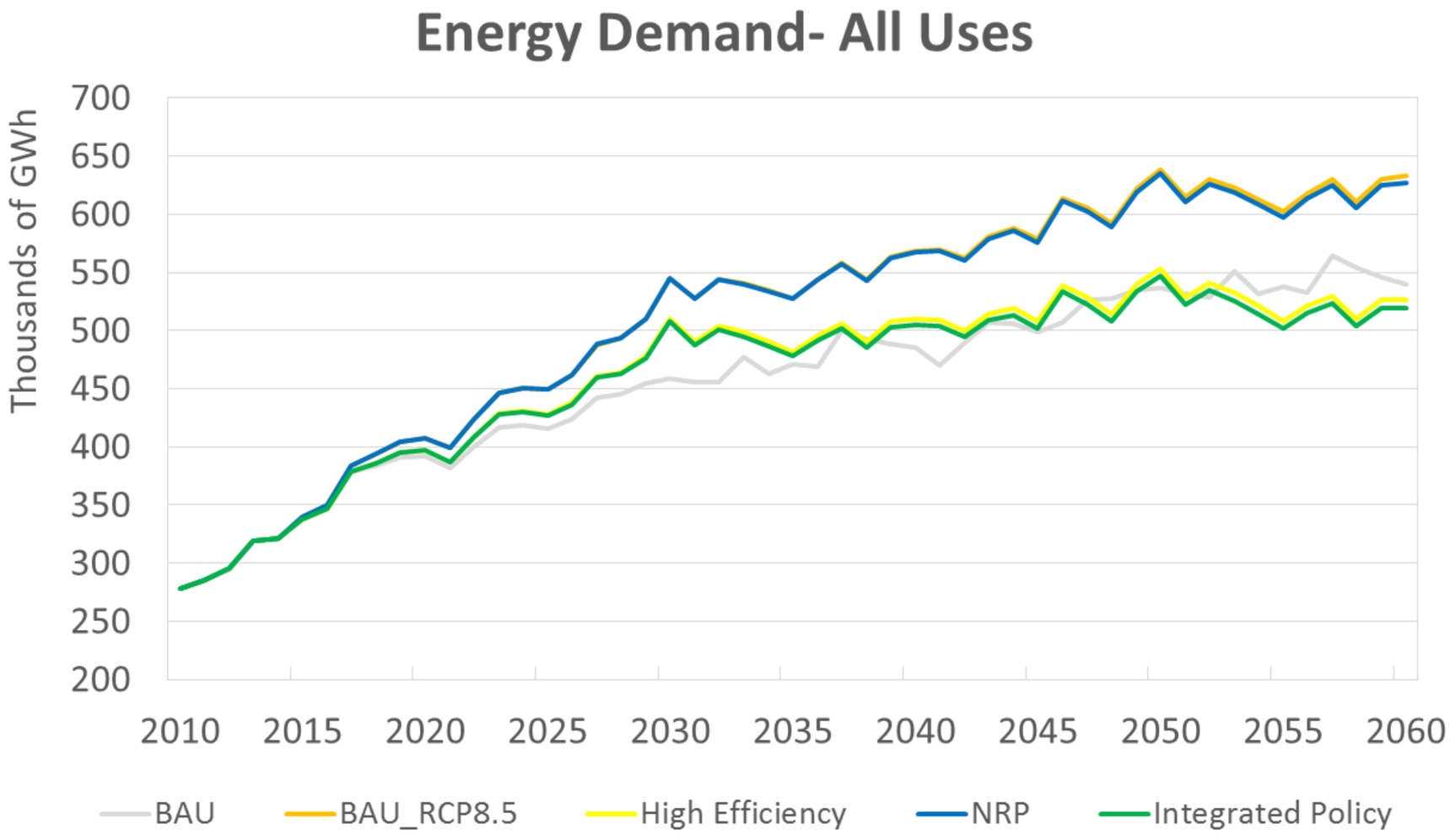
Comparing Results Across the Policy Scenarios



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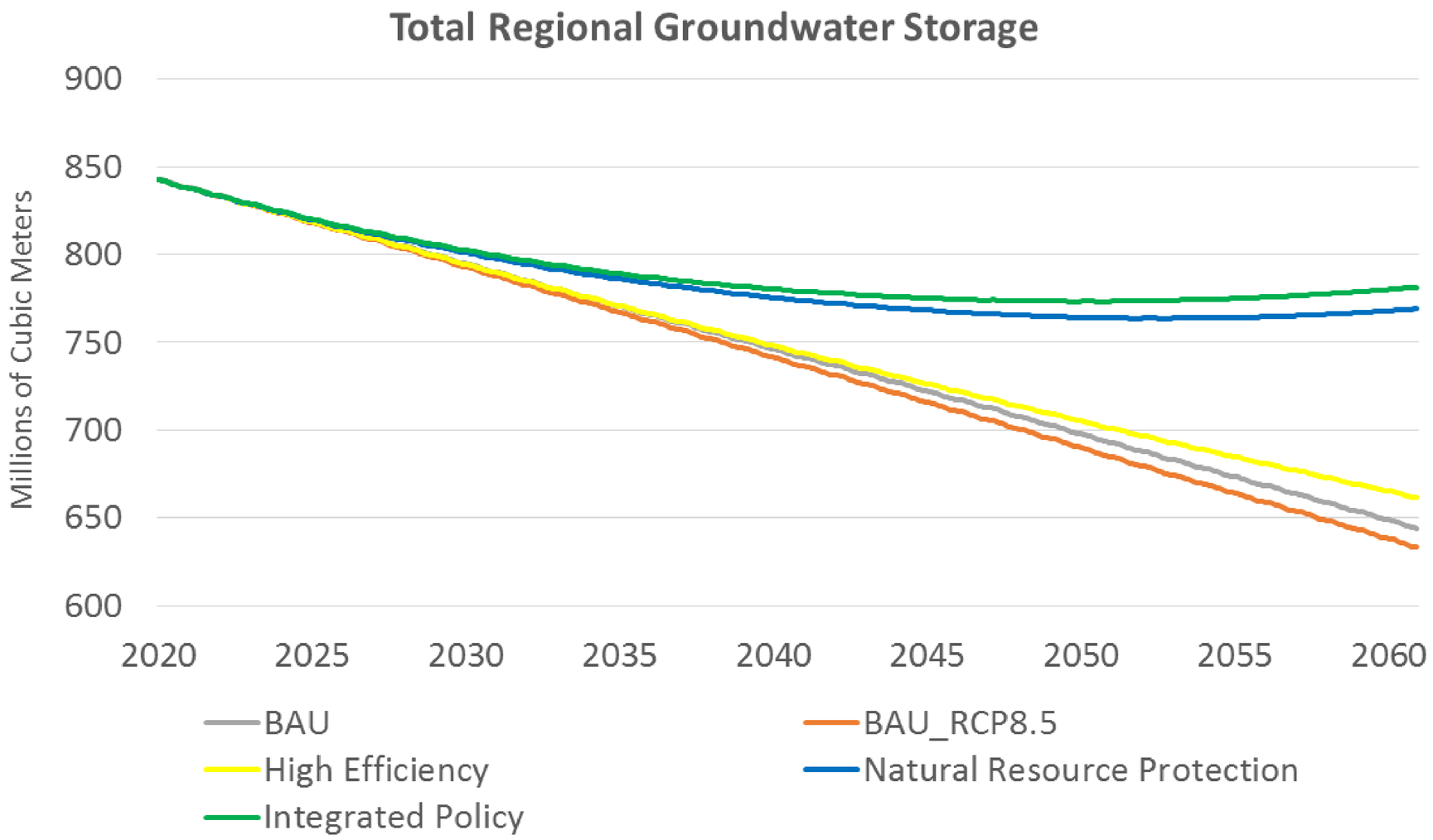
Comparing Results Across the Policy Scenarios



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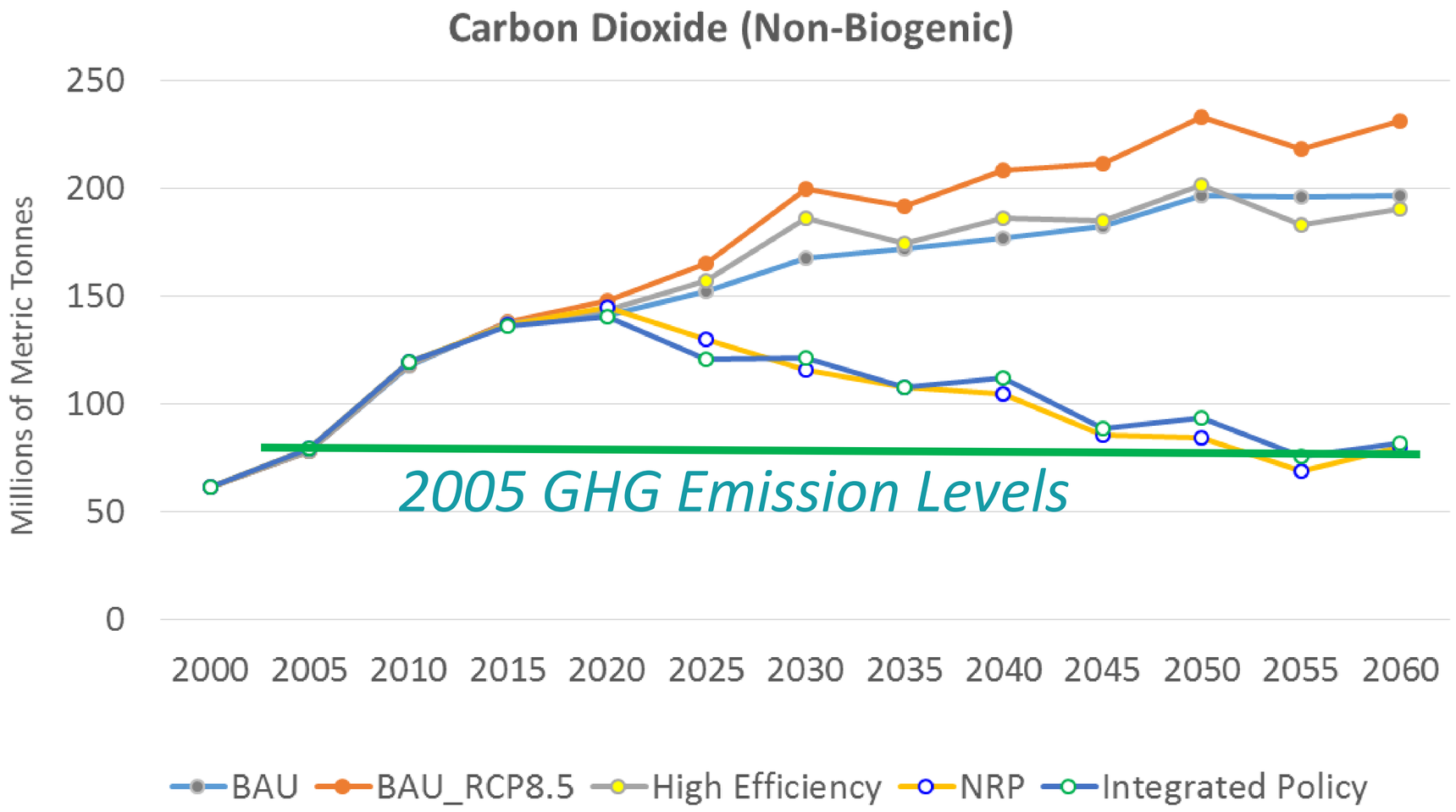
Comparing Results Across the Policy Scenarios



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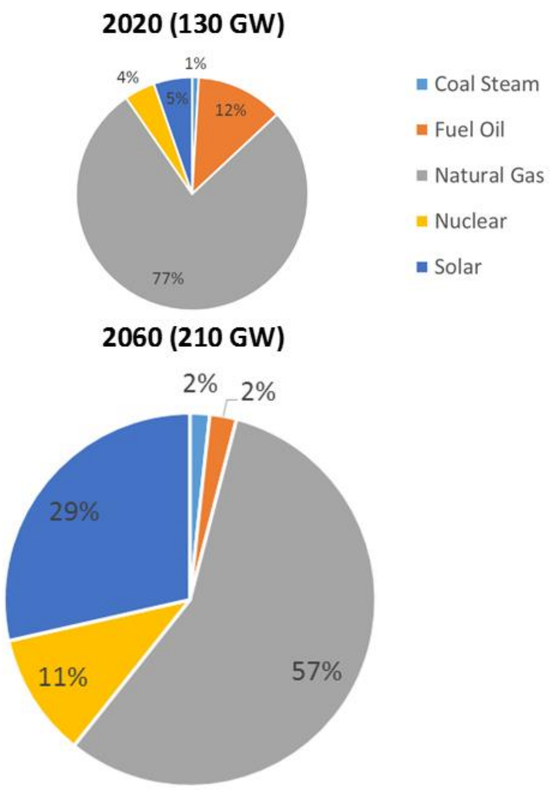
Comparing Results Across the Policy Scenarios

Summary of Scenario Action	Alternative Scenario	Starting Scenario	Cumulative benefits (2020-2060)			Total Incremental cost (billion 2015$)	Avoided CO2e emissions from policies ($ per tonne
			Water savings (BCM)	Energy savings (TWh)	CO2e reductions (million tonnes)		
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

Generation Capacity for Integrated Policy Scenario



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Highlights and Lessons Learned

- Reductions in regional water use are likely more attainable than regional energy use.
- Policy-makers will need to decide the importance of preserving fossil groundwater versus its exploitation in the short term.
- While desalinization is costly in terms of energy-use, it is often co-generated and therefore care must be taken when accounting for water's share of the energy footprint.
- we have developed a limited set of future policy scenarios that apply broad, region-wide assumptions to demonstrate the merits of those policies and the flexibility of the framework to rapidly explore alternative policy scenarios. These policy scenarios should be expanded to study other assumptions and adaptations.

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THANK YOU!

For further information, please contact Marco Vinaccia (LNRClimateChange@ead.ae)

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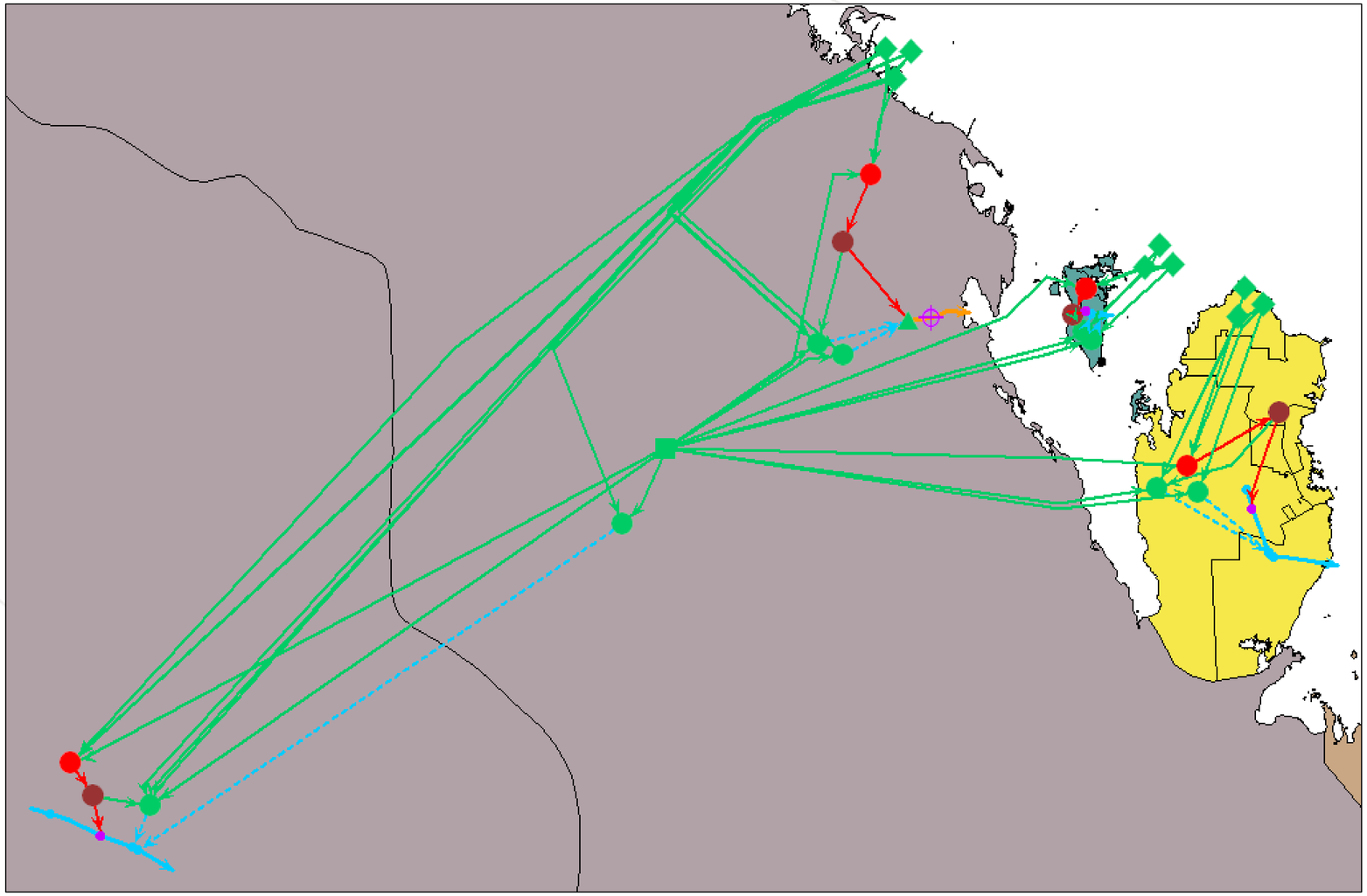
Central Dammam Aquifer System (Bahrain, Qatar and Eastern Saudi Arabia)



- Shared Central Dammam Aquifer between Bahrain, Qatar, and Eastern Saudi Arabia
- Each country has its own desalination system
- RO desalination and groundwater supply agriculture
- Each country has separated crop demands
- Bahrain and Qatar have their own WWTP; Eastern Saudi Arabia has two systems.
- Amenity and Outdoor catchments source water from WWTPs

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Supply Preference in Regional Model

Source	Type	UAE (Abu Dhabi Region)				UAE (Western Region)				UAE (Al Ain Region)				UAE (Dubai)				UAE (Eastern Emirates)			
		Indoor	Amenity	Outdoor	Ag.	Indoor	Amenity	Outdoor	Ag.	Indoor	Amenity	Outdoor	Ag.	Indoor	Amenity	Outdoor	Ag.	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			Saudi Arabia (Northern)			Saudi Arabia (Eastern)			Saudi Arabia (Ar Riyadh)			Bahrain			Qatar		
		Indoor	Outdoor	Ag.	Indoor	Outdoor	Ag.	Indoor	Outdoor	Ag.	Indoor	Outdoor	Ag.	Indoor	Outdoor	Ag.	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

Water Sources for the Regional WEAP Model

- Groundwater
  - DammamNorth_GW
  - UAEEasternReg_GW
  - OmanEasternReg_GW
  - WesternGravelAq_GW
  - DammamCenter_GW
  - UpperWFresh_GW
  - UpperWBrackish_GW
  - WestBrackish_GW
  - WestFresh_GW
  - AbuDhabiBrackish_GW
  - ShallowEBrackish_GW
  - ShallowEFresh_GW
  - EastBrackish_GW
  - EastFresh_GW

- Other Supply
  - BahrainDesal_MED
  - BahrainDesal_MSF
  - BahrainDesal_RO
  - KuwaitDesal_MED
  - KuwaitDesal_MSF
  - KuwaitDesal_RO
  - OmanDesal_MED
  - OmanDesal_MSF
  - OmanDesal_RO
  - QatarDesal_MED
  - QatarDesal_MSF
  - QatarDesal_RO
  - SaudiArabiaAshSharqiyahRegDesal_MED
  - SaudiArabiaAshSharqiyahRegDesal_MSF
  - SaudiArabiaAshSharqiyahRegDesal_RO
  - UAEEasternRegDesal_MED
  - UAEEasternRegDesal_MSF
  - UAEEasternRegDesal_RO
  - UAEWesternRegDesal_MED
  - UAEWesternRegDesal_MSF
  - UAEWesternRegDesal_RO

Water sources include:

- Groundwater (Fresh and/or Brackish)
- Desalination ("Other Supply") as Reverse Osmosis (RO), Multi-Stage Flash (MSF), and Multi-Effect Distillation (MED)
- Treated Wastewater for outdoor non-potable use.

All sources have energy implications (kWh/M^3)

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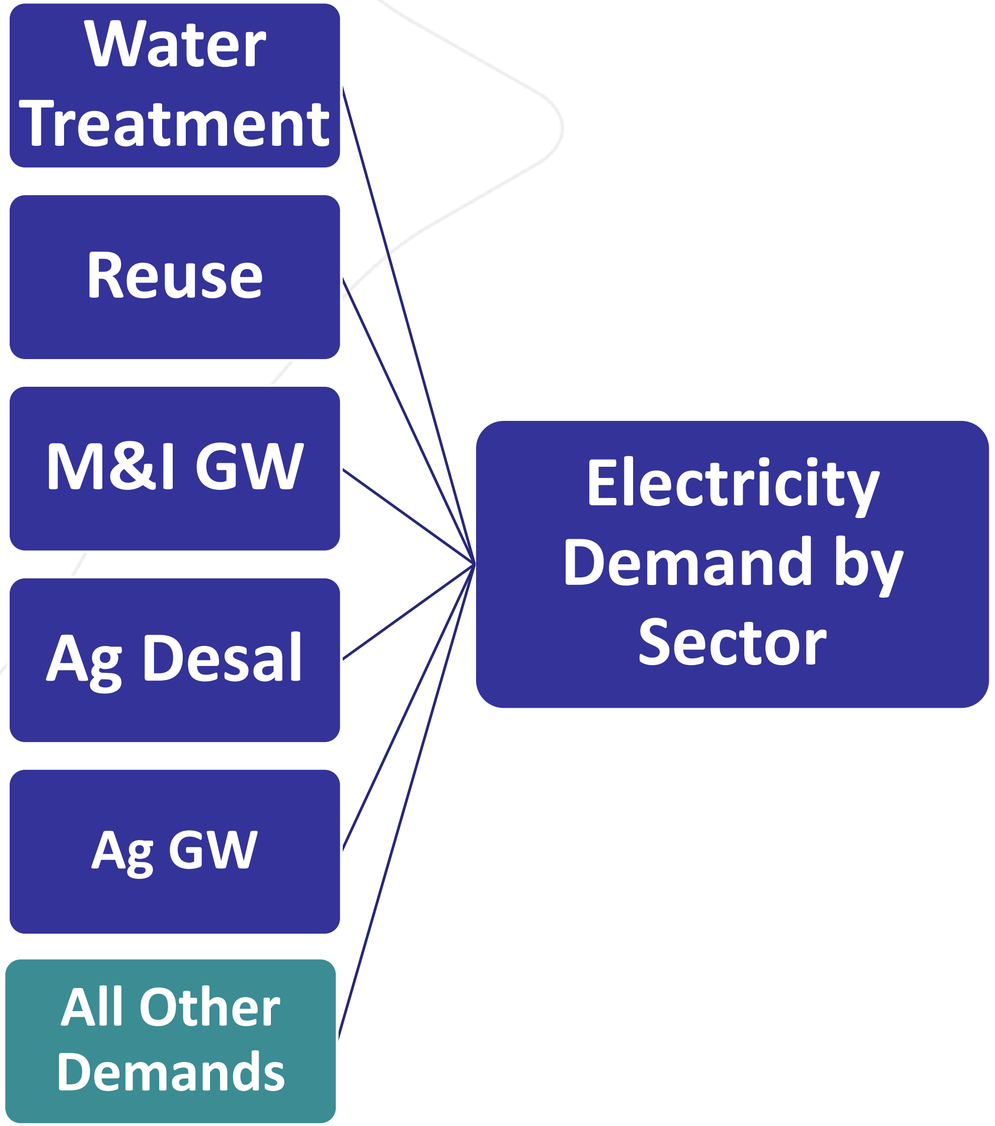
Electricity Demand by the Water Sector



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

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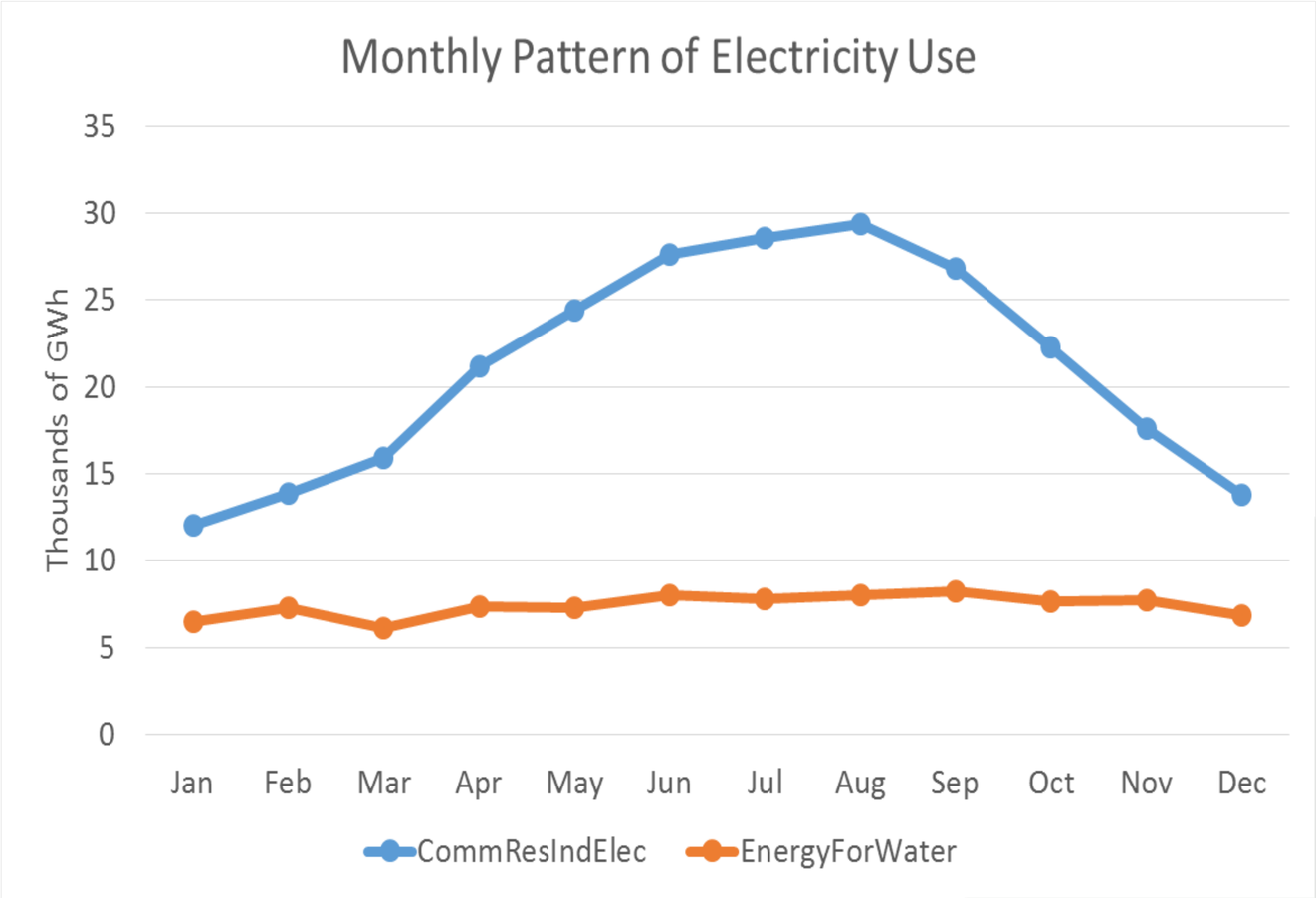
LEAP VALIDATION: Average Pattern of Monthly Electricity and Energy for Water Use

- Monthly average pattern of residential, commercial, and industrial electricity use (blue line) and electricity use associated with water related activities, including pumping, desalinization, water treatment, and reuse (orange line)



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