

LNRCC
Programme

RESEARCH
REPORT

UAE Water-Energy Nexus

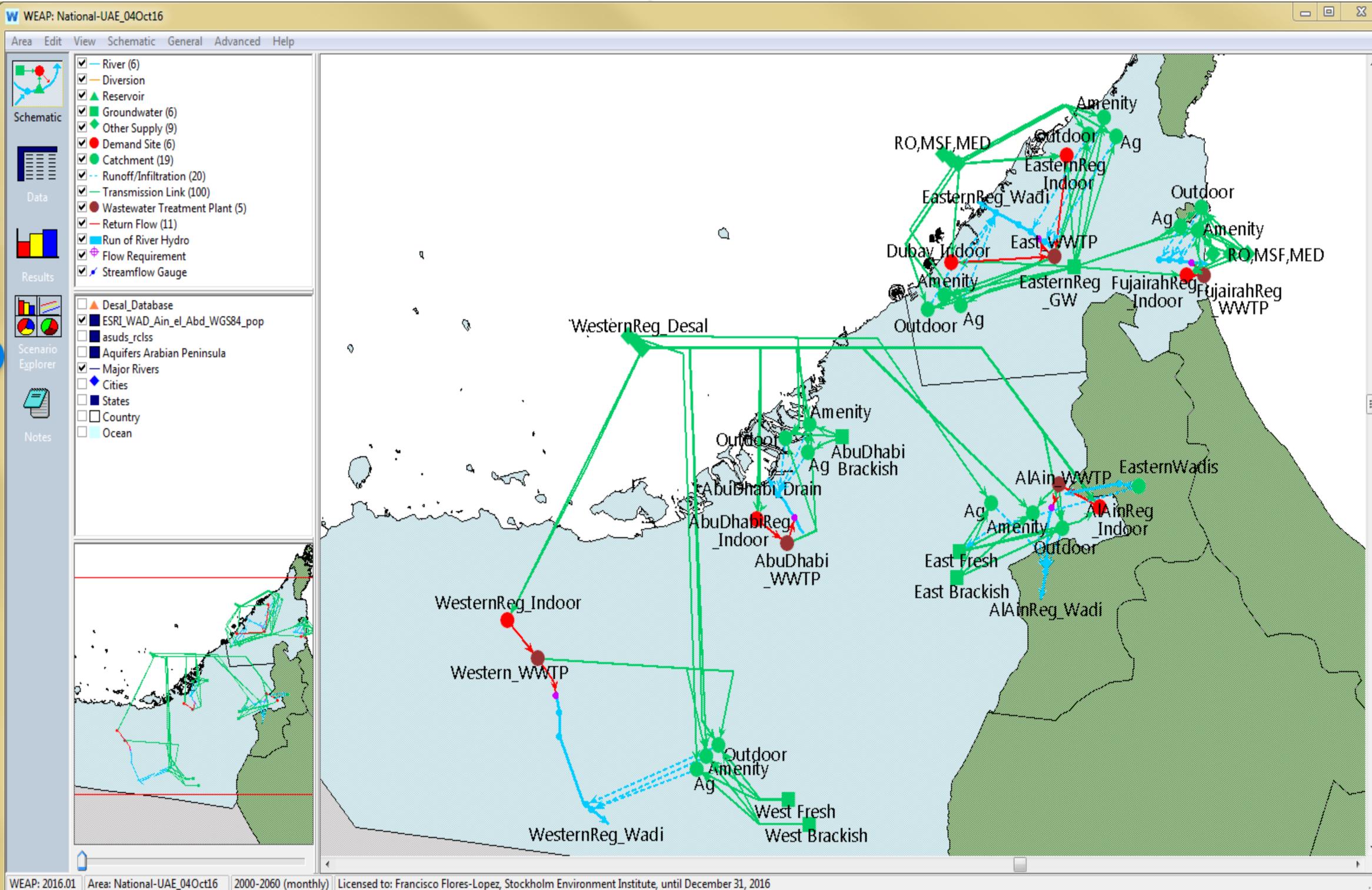
Stephanie Galaitsi, 14 March
2017

Project Goal & Objectives

Goal: Examine water and energy access vulnerabilities in the UAE until 2060 due to risks from the anticipated demographic and climatic changes

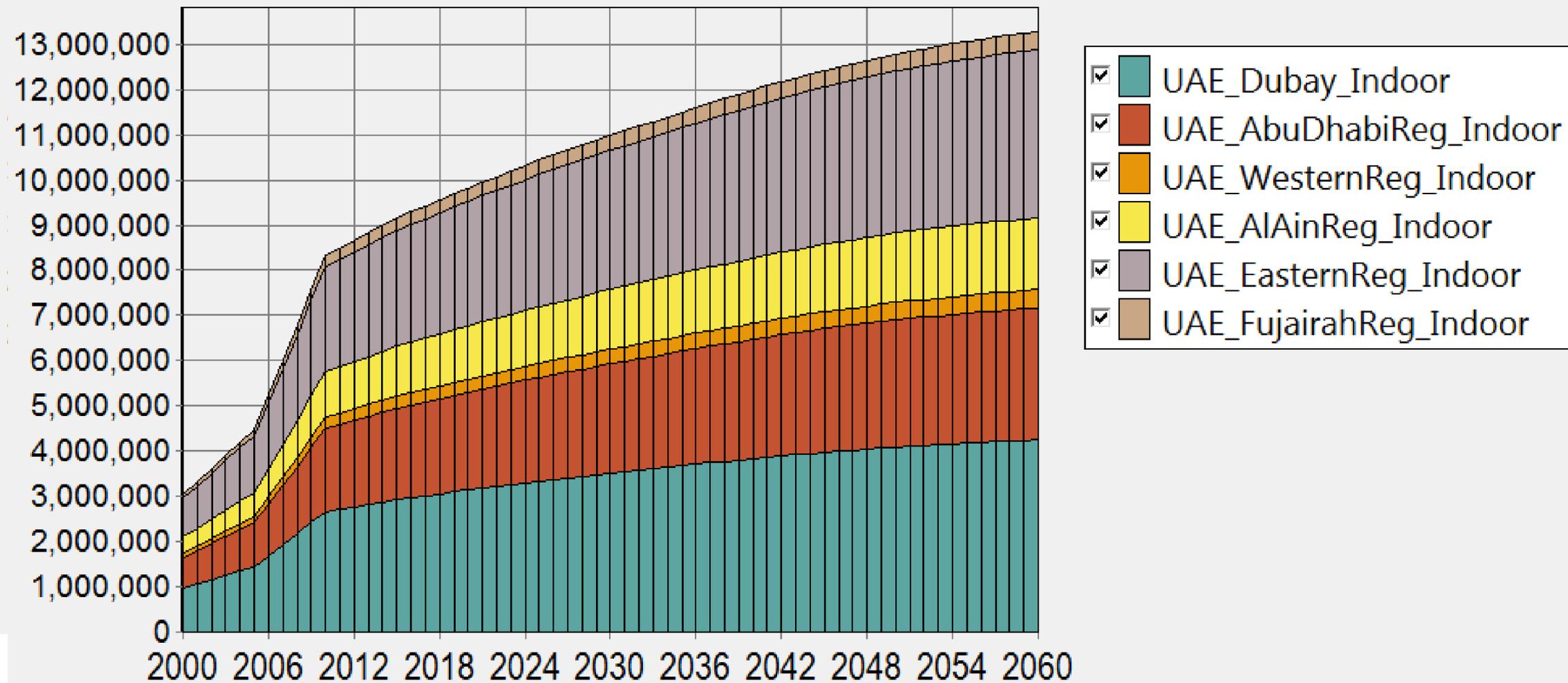
- ✓ **Objective #1:** *Build* coupled water-energy models for the UAE
- ✓ **Objective #2:** *Define and quantify* a set of policies consistent with a sustainable development vision minimizing climate change impacts
- ✓ **Objective #3:** *Analyze* alternative development scenarios under climate change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

The UAE WEAP Model Overview



Data Population for Indoor Water Demand

Demand Site Annual Activity Level ▾



- Population over time[#] (shown in graph)
- WEAP models indoor water demand as a function of population
- Water models water consumption (water that does not then flow to a WWTP) as a percentage of demand

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

Water Sources for the UAE WEAP Model

Water sources include:

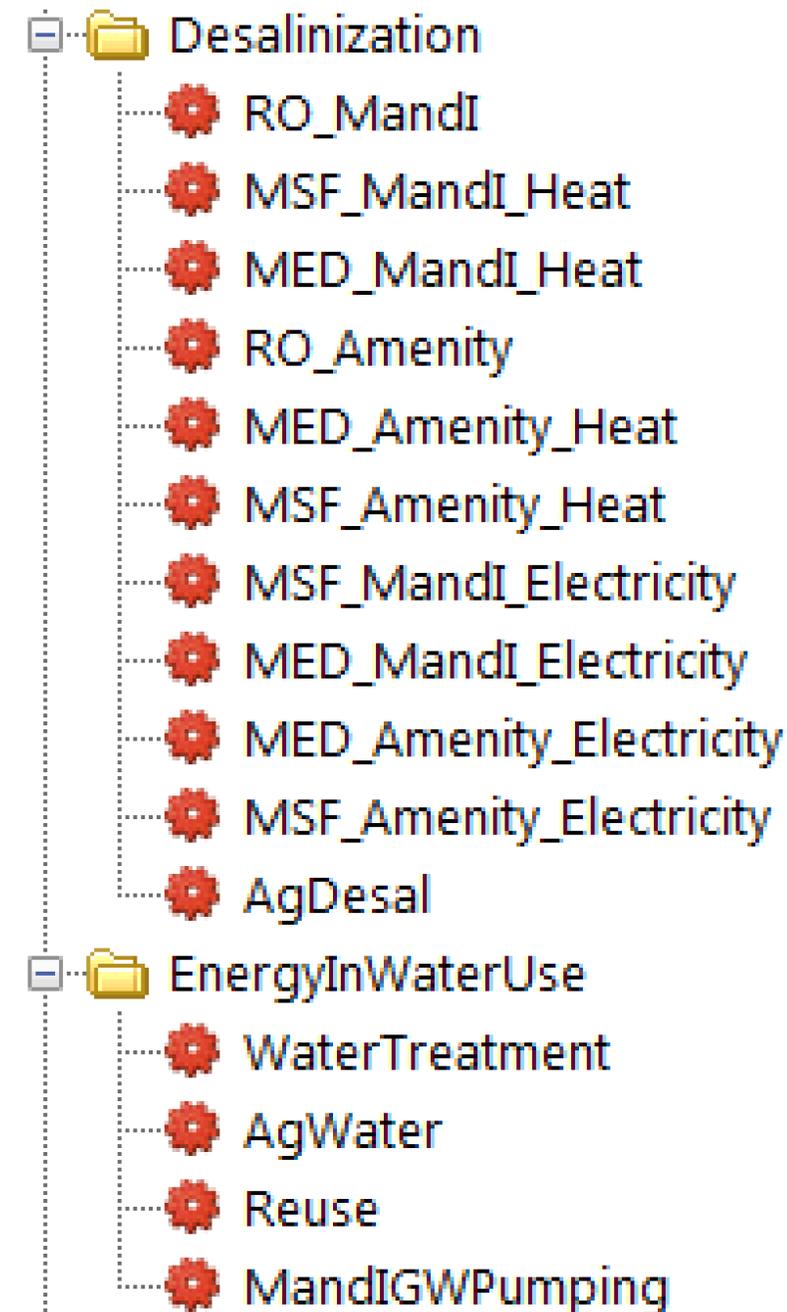
- Groundwater (Fresh and/or Brackish)
- Desalination (“Other Supply”) as Reverse Osmosis (RO), Multi-Stage Flash (MSF), and Multi-Effect Distillation (MED)
- Treated Wastewater for outdoor non-potable use.

All sources have energy implications (kWh/M³)

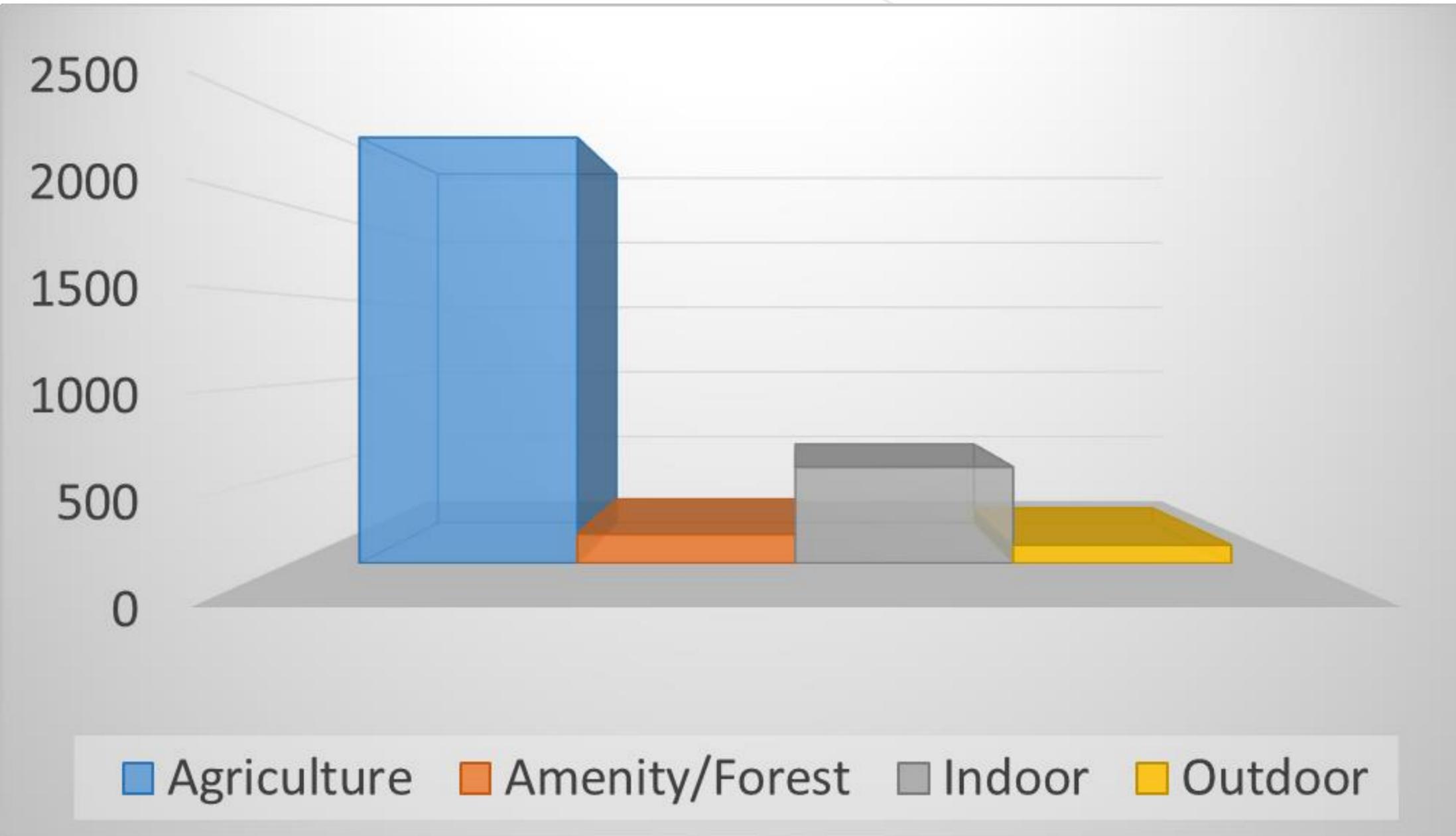
Energy Demand factors for Water (kWh/m³)

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

- User defined variable within WEAP calculates the energy demand of water consumption
- Energy demand is in electricity use (kWh per m³ water)



UAE WEAP - Water Demand by User Type (MCM)

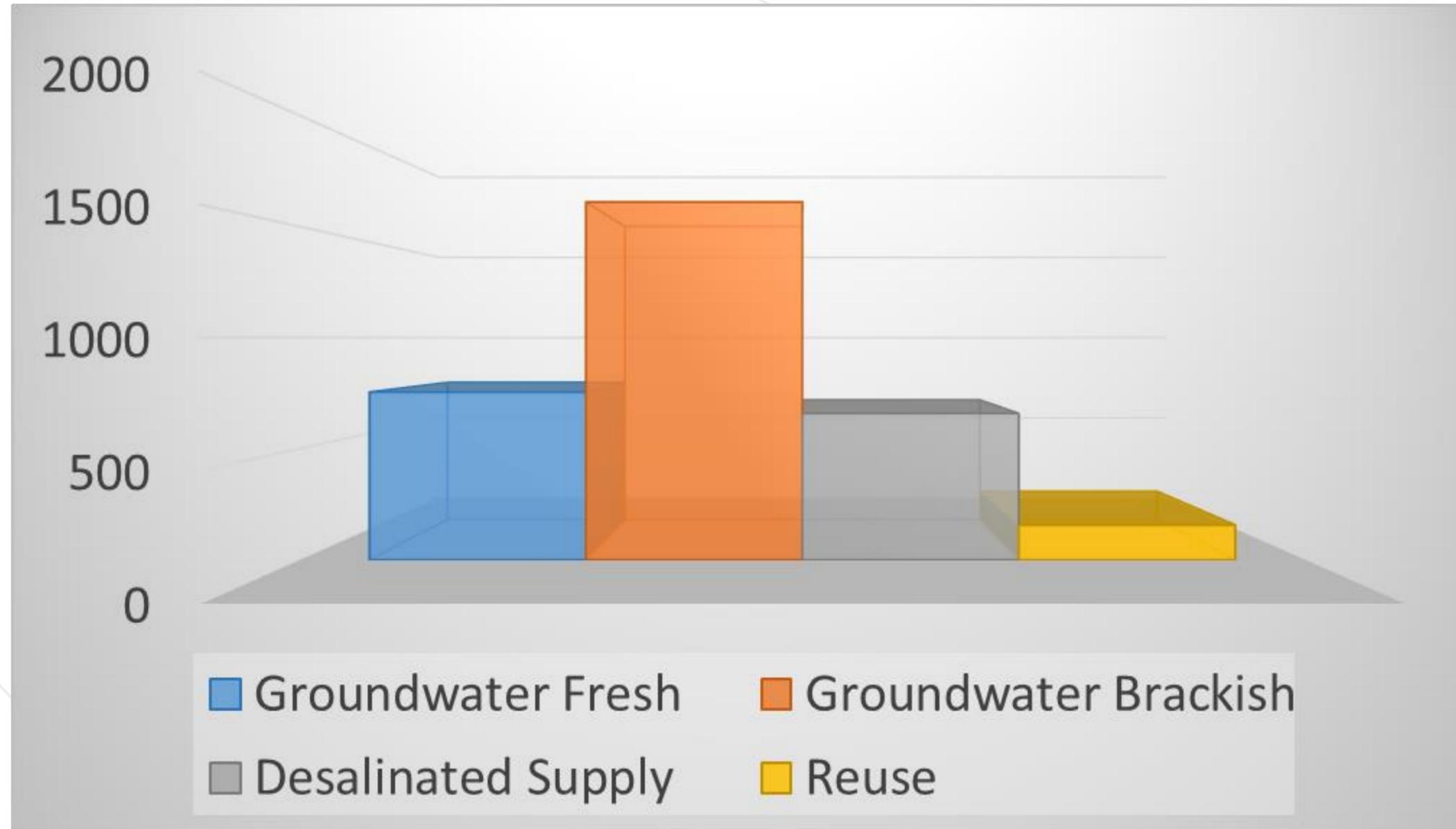


- Demand Sites represents Indoor water demand (domestic, commercial, government & industry)
- Catchment areas determine water demand with 3 types of catchments: Agriculture, Amenity and Outdoor Household use.
- Agriculture catchments further divided into land use categories:

UAE_AbuDhabiReg_Ag

- DatePalms
- Fodder
- Vegetables
- Other

UAE WEAP MODEL VALIDATION – Water Supply Delivered by Source (MCM)



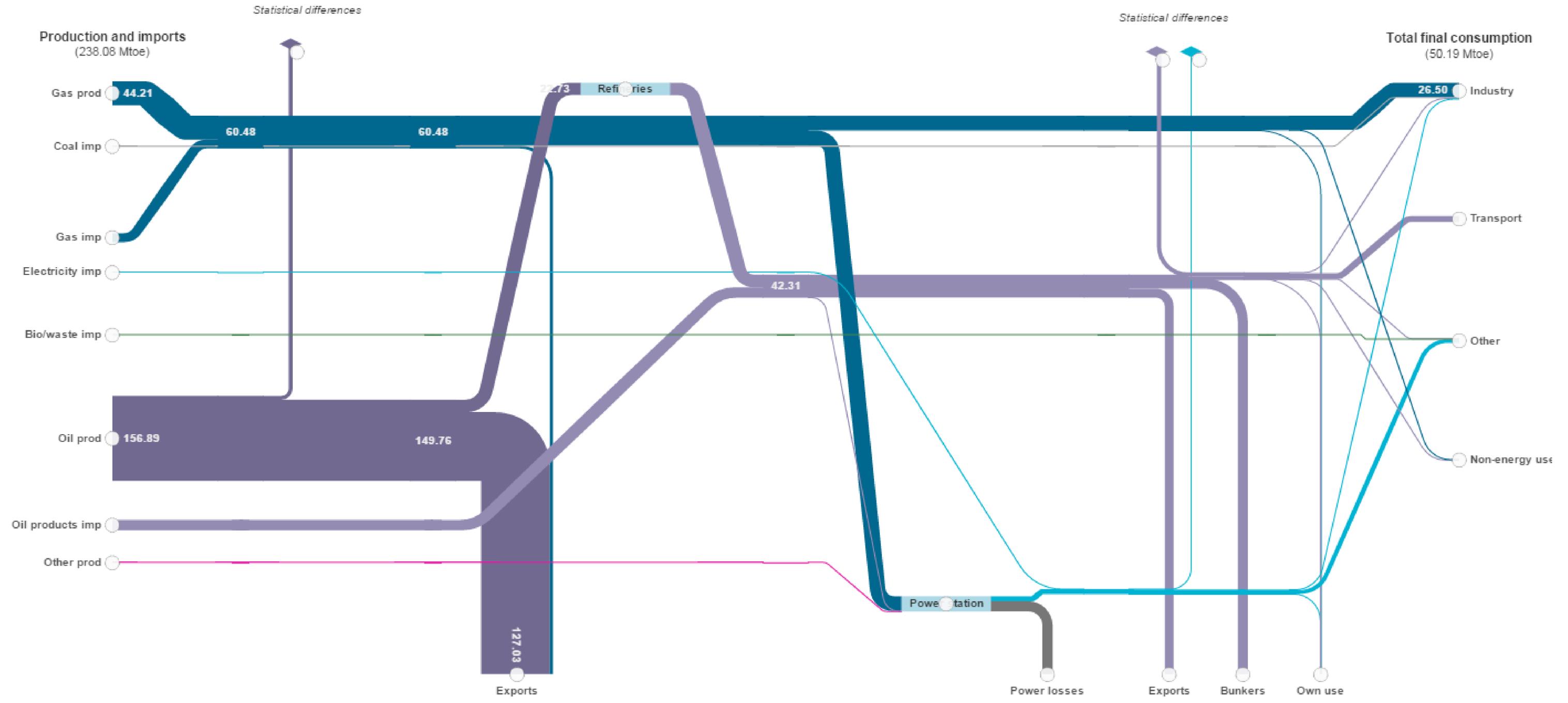
- 2005 total water supply
- 2005 FAO Aquastat reports 3,998 MCM of total water withdrawal
- Water sources are groundwater, desalinated and reused
- Total desalinated supply delivered of (138 RO, 387 MSF, 132 MED MCM)
- Fresh groundwater supplies 23% of total water supply delivered in 2005

2005 Total Water Supplied Simulated by WEAP : ~ 3,200 MCM

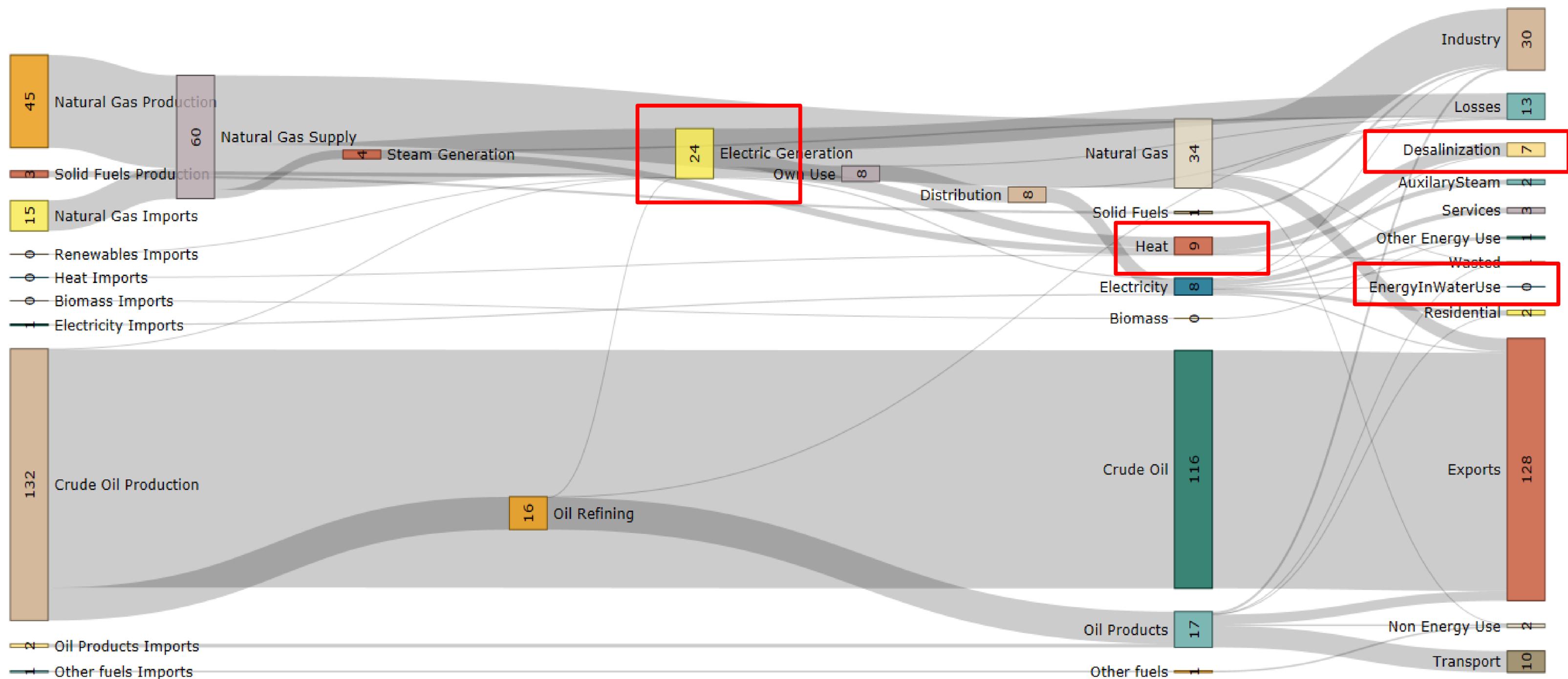
2013 EIA Estimate of Total Energy in UAE

United Arab Emirates
BALANCE (2013)

Millions of tonnes of oil equivalent



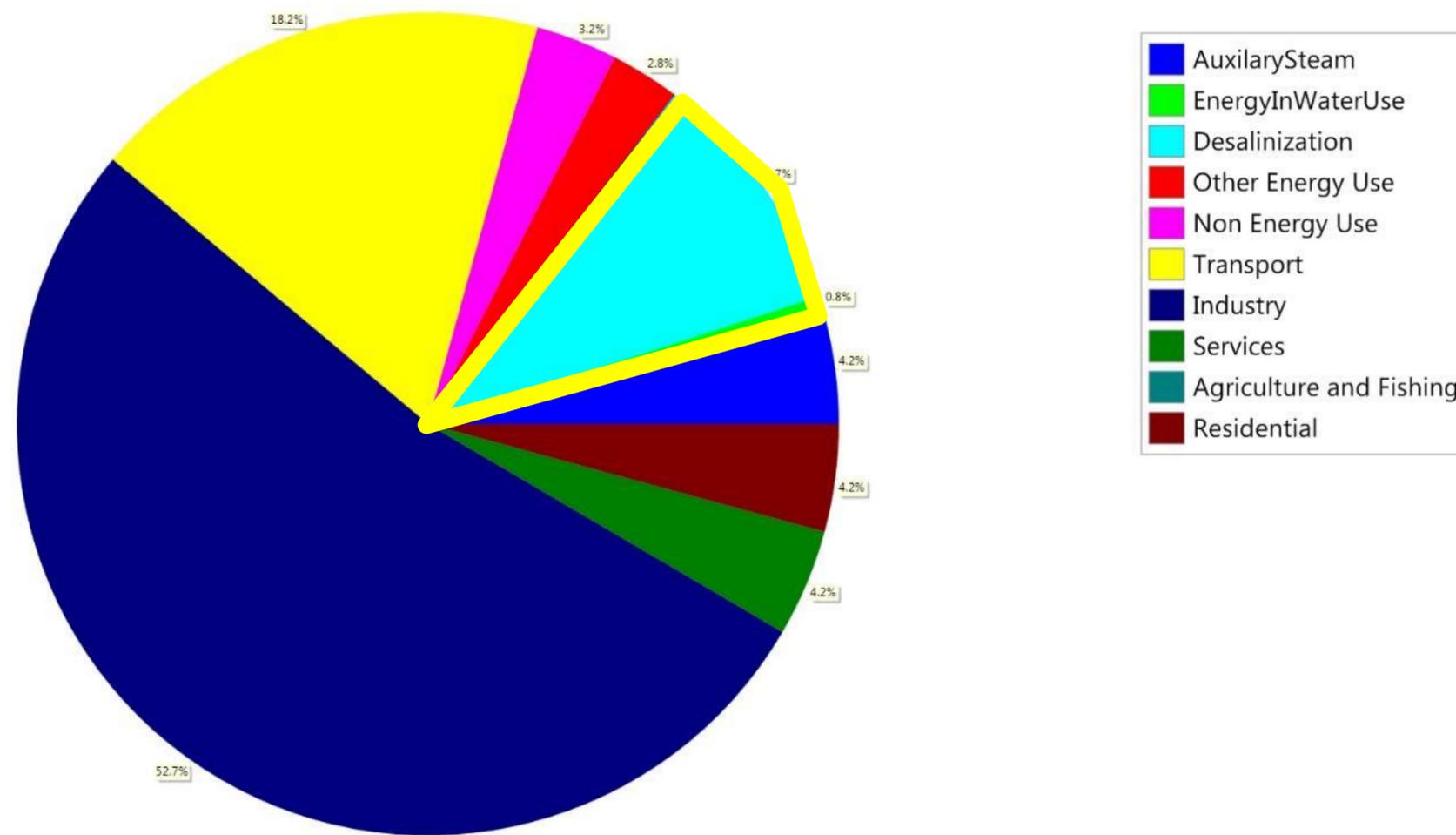
2013 LEAP Simulated Total Energy



Total Energy Use in 2013 (660 TWh)

Total Energy Demand Final Units
Baseline Scenario, All Fuels

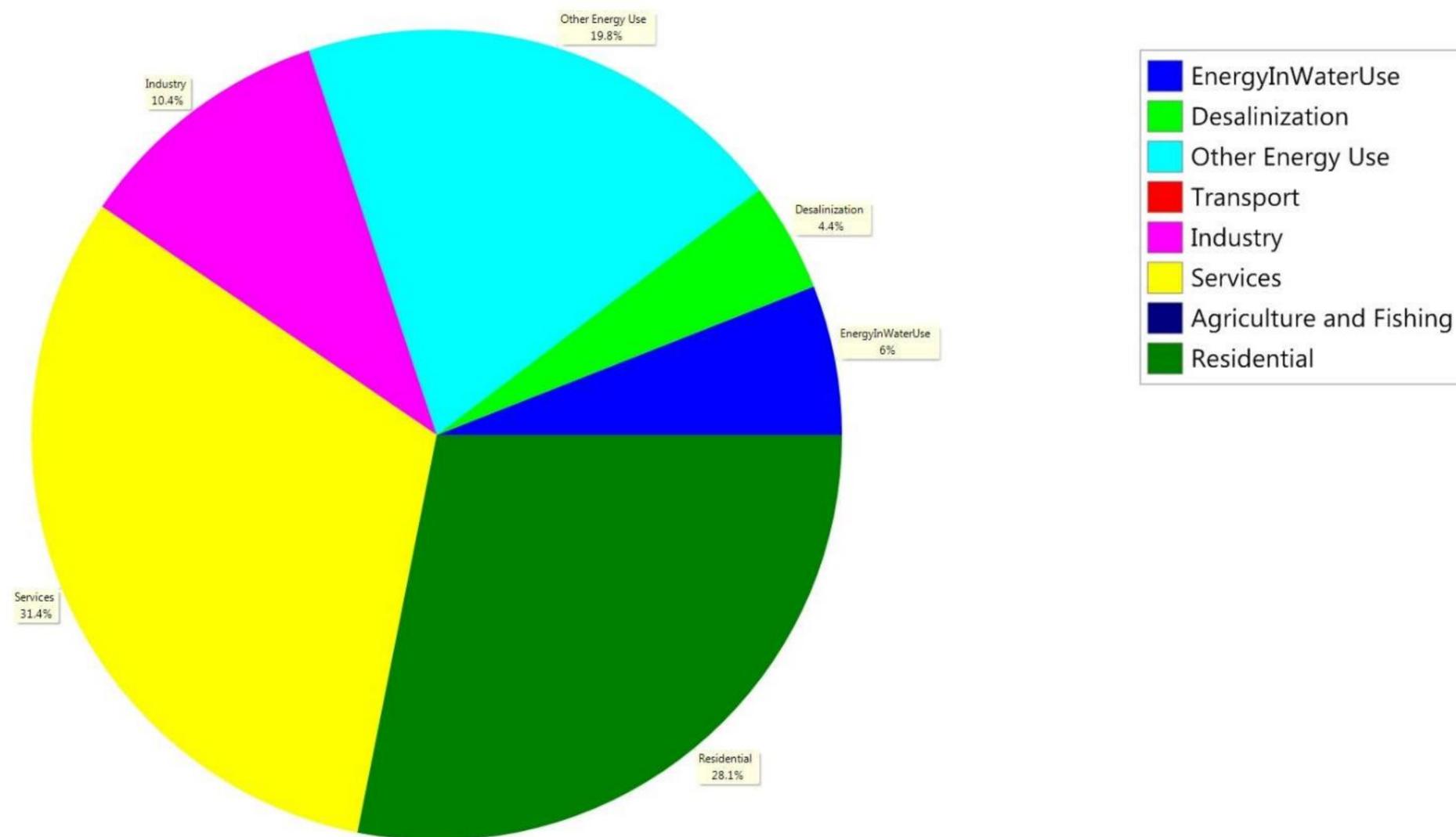
2013 = 663.95



- Desalinization is about 10% of total energy use.
- Water sector is less than 1% of total energy use.
- Largest Energy Use Sector is Industry at a little more than 50%

Electricity Demand by Use Sector (80 TWh in 2013)

Energy Demand Final Units
Baseline Scenario, Electricity



IEA 2013 Final Consumption = 91 TWh

- Electric Energy Demand by Water Sector is 10% of total electricity use.
- Desalinization 4% of electricity use.
- All other Water Activities are 6%.

BAU

- Historic climate data
- Population growth but constant per-capita resource use
- Outdoor, Amenity, and Agricultural Water demands fluctuate with climate.
- No policy scenarios are considered

BAU with climate change

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

Characteristics of Policy Scenarios

Characterization of Scenario				
	Energy Supply	Energy Demand	Water Supply	Water Demand
Efficiency (Demand Side)		Flatten peak electricity demand for space cooling 20% decrease in per capita electricity demand		Indoor per capita use reduced Irrigation efficiency Reduction in amenity areas Water loss reduced
Natural Resource Protection (supply)	Renewables favor new generation capacity (primarily solar) Caps on fossil fuels		Eliminate fresh GW use. RO substituted, MSF declines Increase in treated WW for irrigation	
Integrated Actions	Combines the Efficiency and Natural Resource Protection Assumptions			

Characterizing costs and environment benefits in the Policy Scenarios

- **Costs addressed within a cost levelization framework**

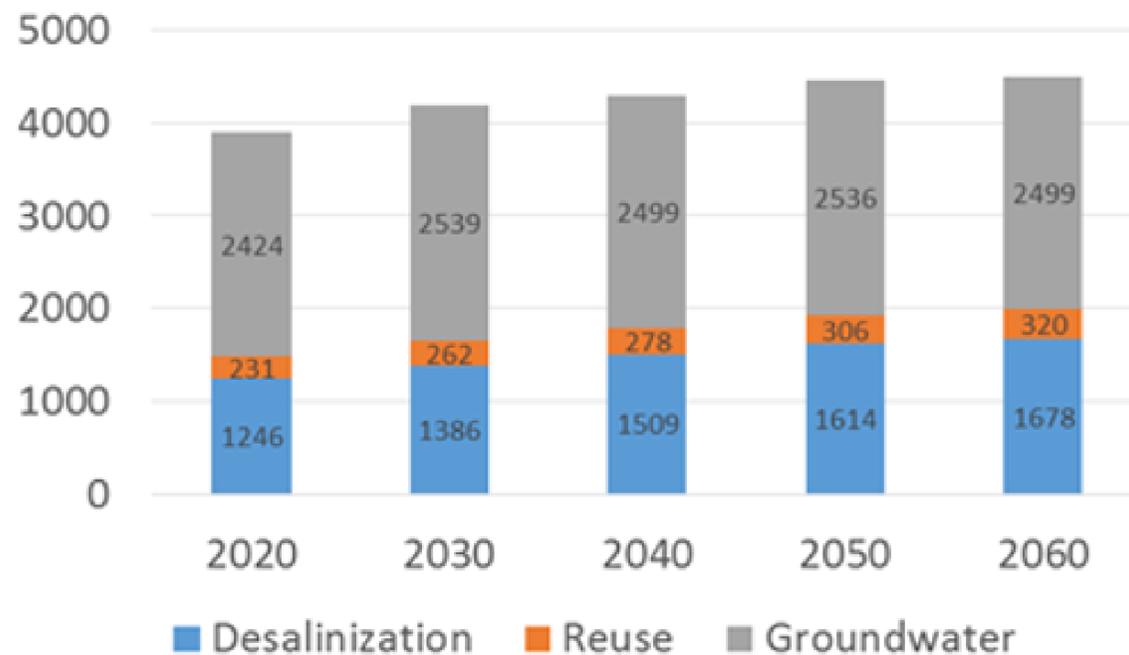
- ✓ Costs aimed at reducing per capita water consumption
- ✓ Costs aimed at reducing greenhouse gas emissions

- **Environmental impacts**

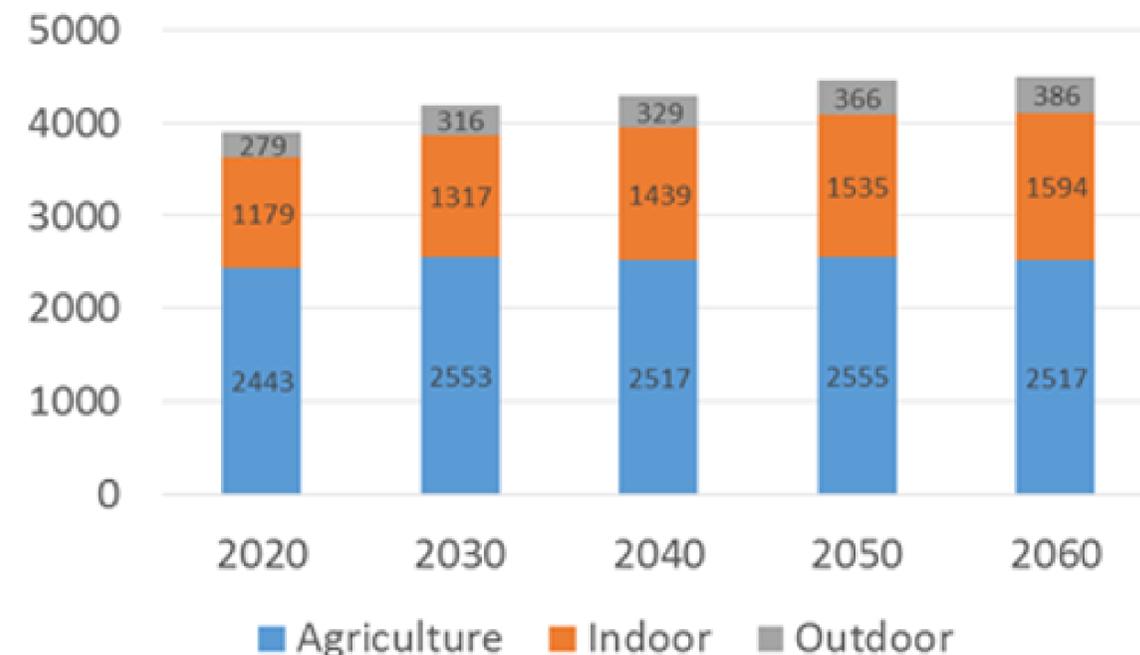
- ✓ Water-related impact metrics for each scenario are focused on fossil groundwater and desalinated water consumption levels
- ✓ Energy-related impact metrics for each scenario are focused on greenhouse gas emission reductions, electricity savings, and fossil fuel savings.

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

a) Water supply (MM3)



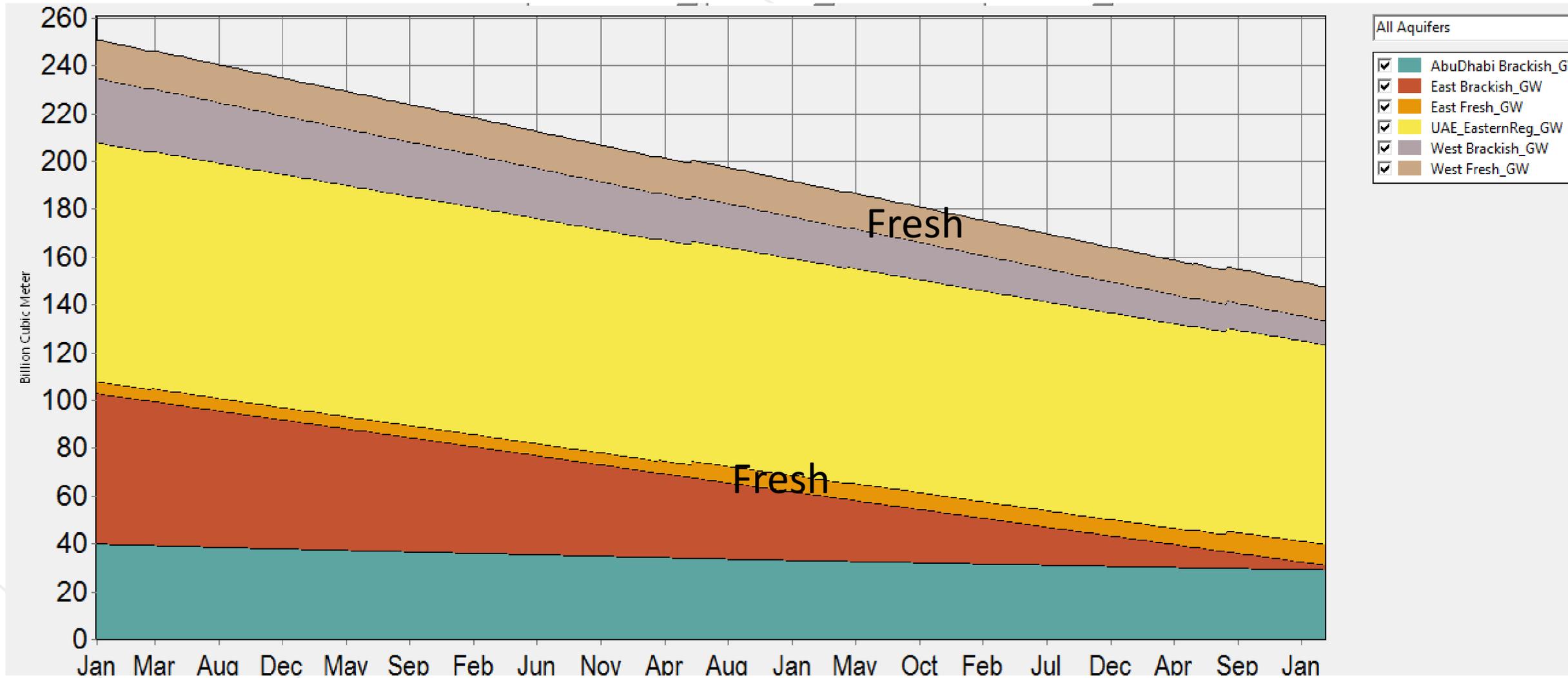
b) Water demand (MM3)



- Total water demand grows from 3,800 MCM in 2015 to 4,500 MCM 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

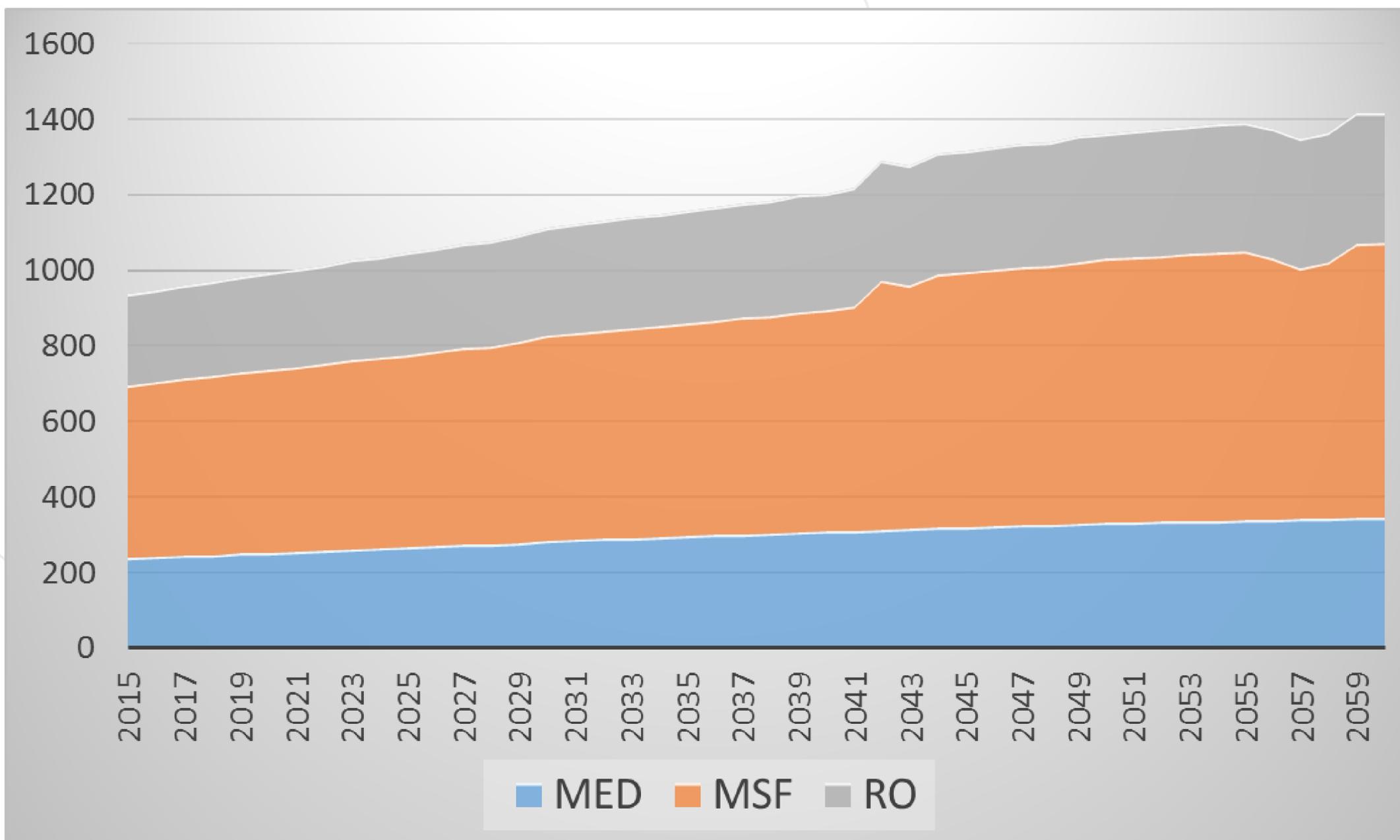
* *The Effect of Climate Change on Demand is on outdoor, Ag, and Amenity uses*

WEAP – Groundwater Storage for *BAU-RCP8.5* (BCM)



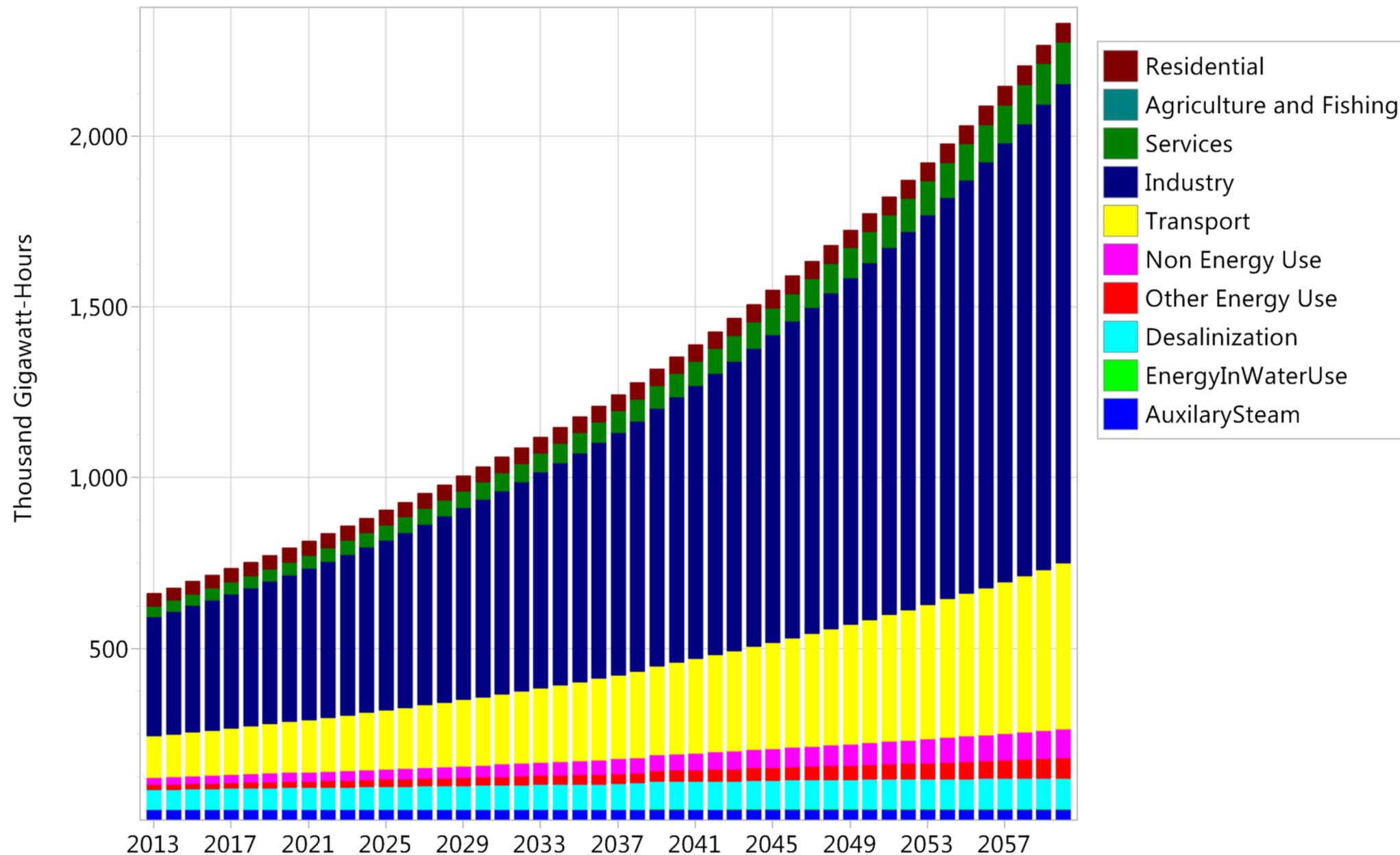
- Freshwater aquifers are preserved.
- Brackish aquifers are not fully depleted over time
- These 2 aquifers, Abu Dhabi Brackish & Eastern Region, stay steady
- Depleted aquifers have no ocean water intrusion

WEAP – Desalinated Water Supply for *BAU-RCP8.5* (MCM)



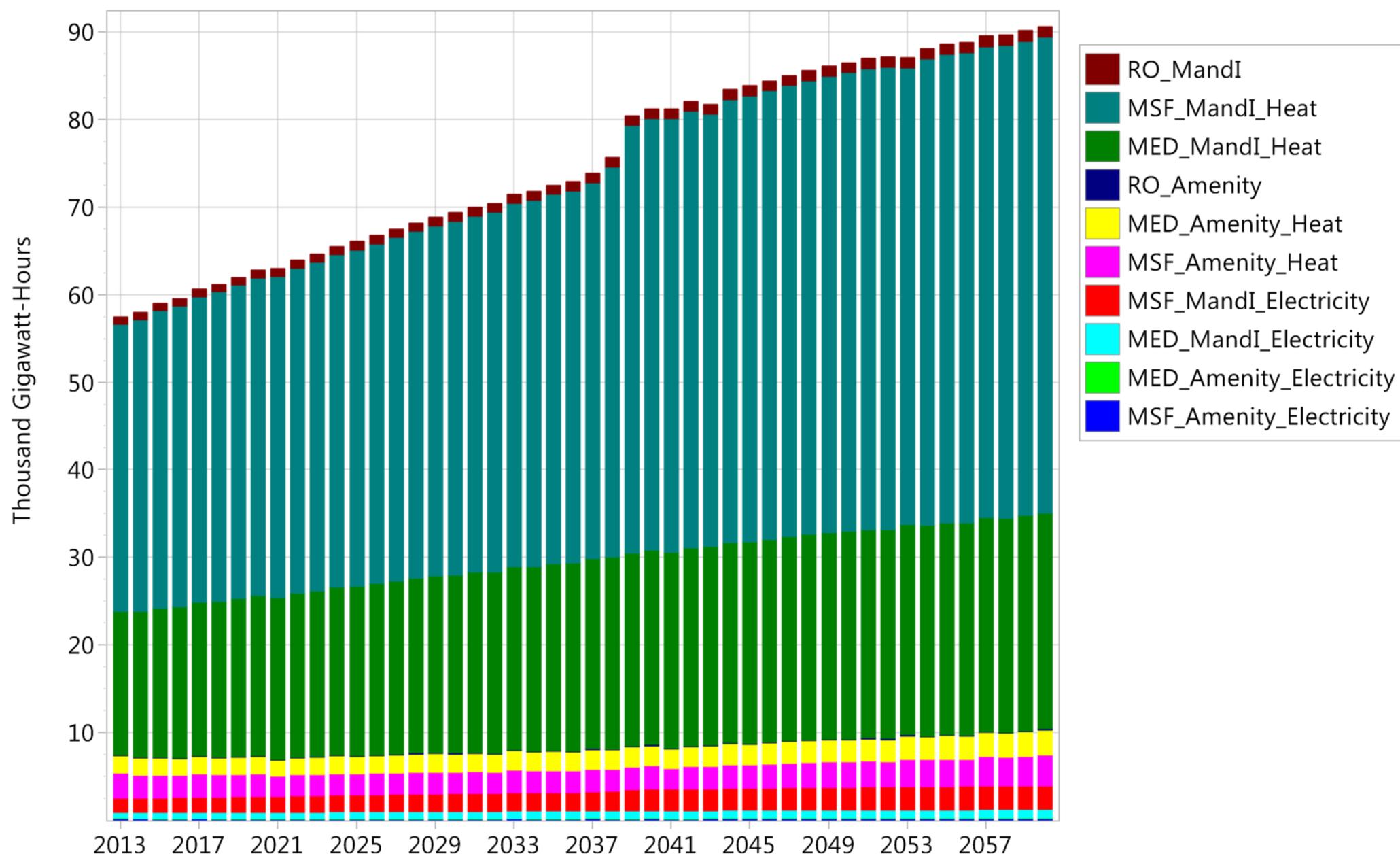
- Desalinated water production is proportional to population growth and water demand
- Reverse Osmosis increases to meet agricultural deficits due to lack of groundwater availability
- MED and MSF keep a steady growth rate

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



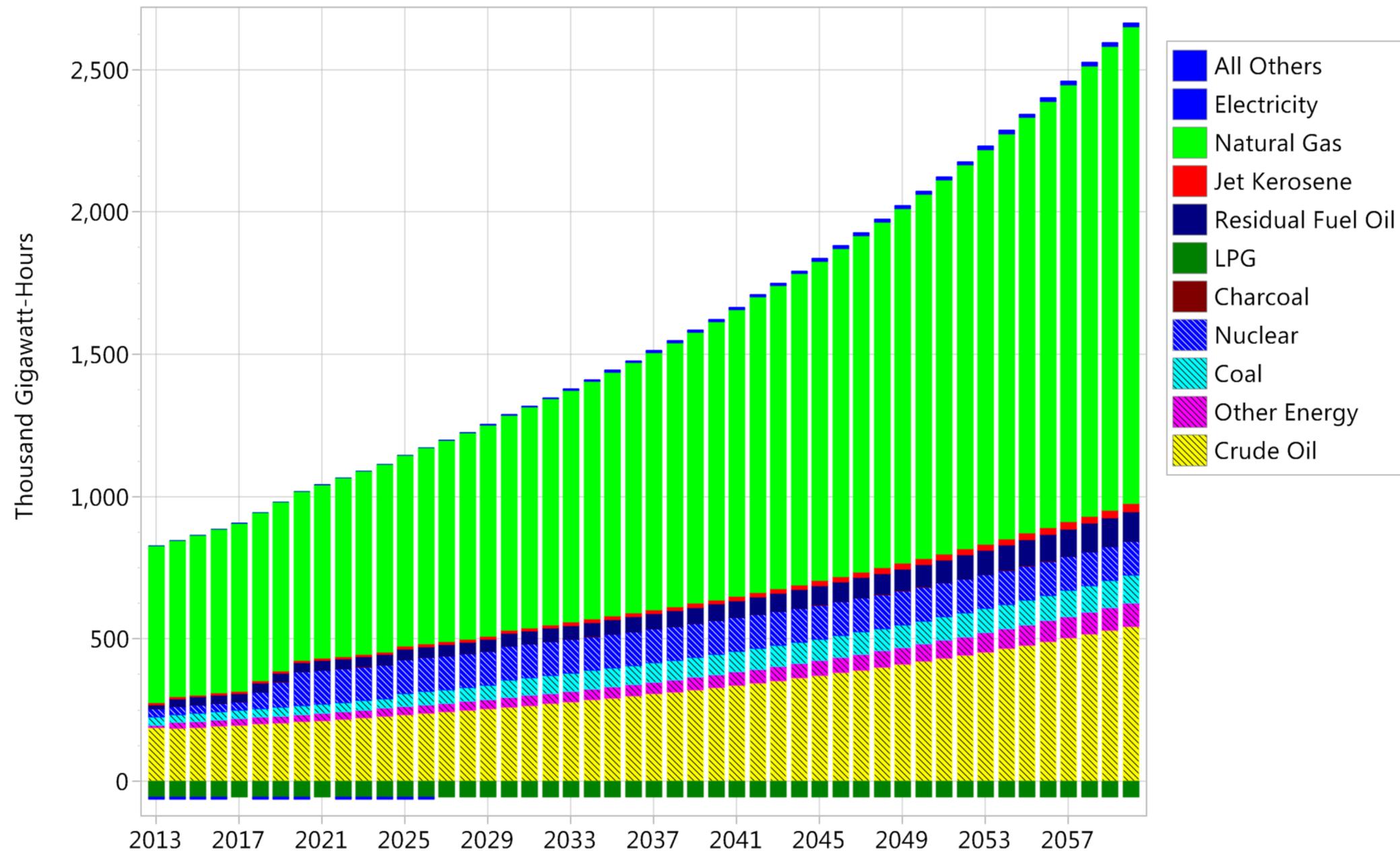
- Industrial Sector is largest user of energy, followed by transport.
- Desalinization represents about 8.5% of total energy demand in 2013; declining to 4% by 2060.
- Excluding Desalinization, Energy use by water sector is a small fraction of total energy use.

LEAP – Energy Demand for Desalinization by Type (*BAU-RCP8.5*)



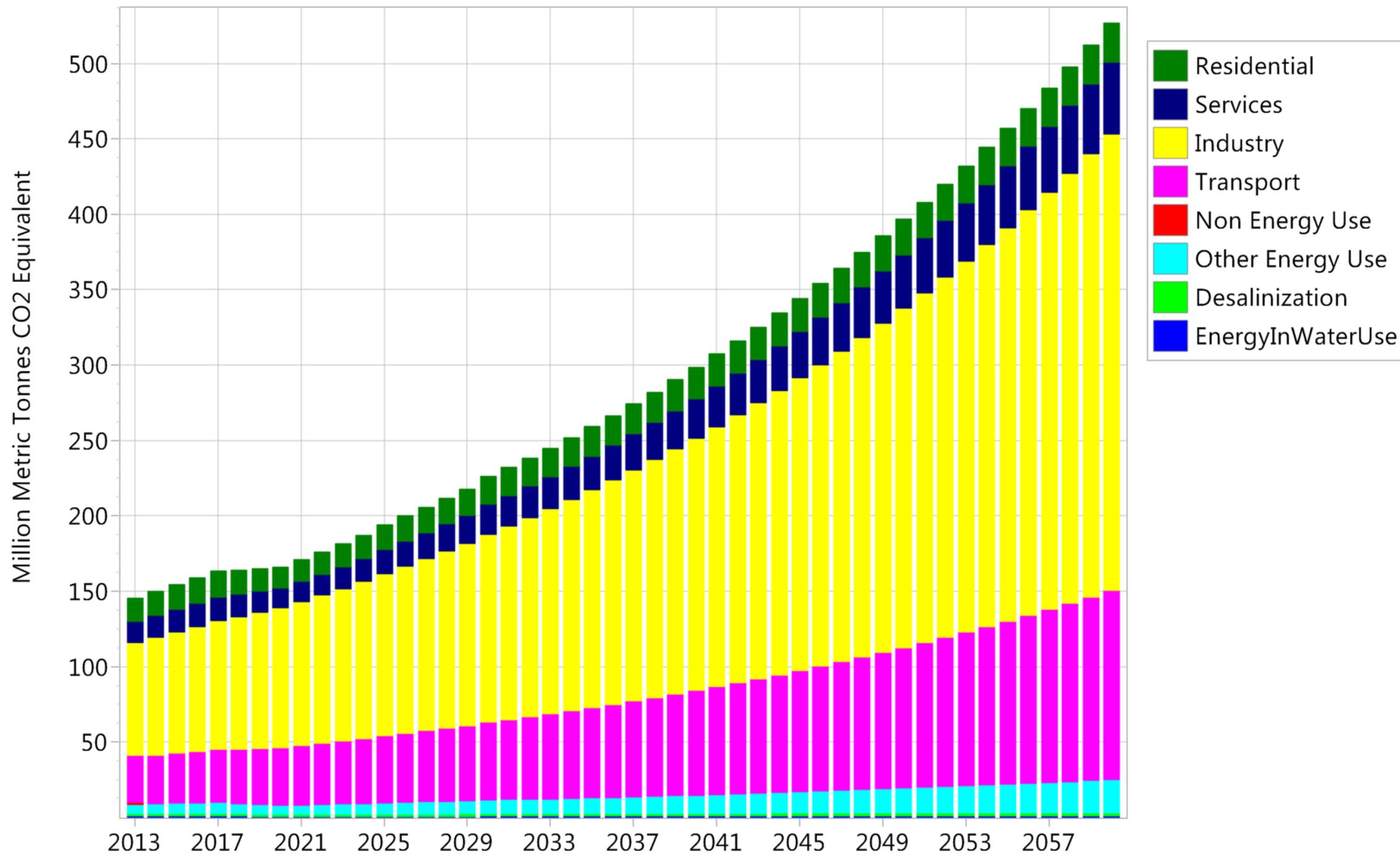
- Largest Energy Use are MSF and MED technologies, used to generate water for Municipal, Industrial, and Service Sectors.
- Note that this energy is largely derived through Nat Gas Combined Cycle, co-generation.

LEAP – Energy Supply by Fuel Source (*BAU-RCP8.5*)



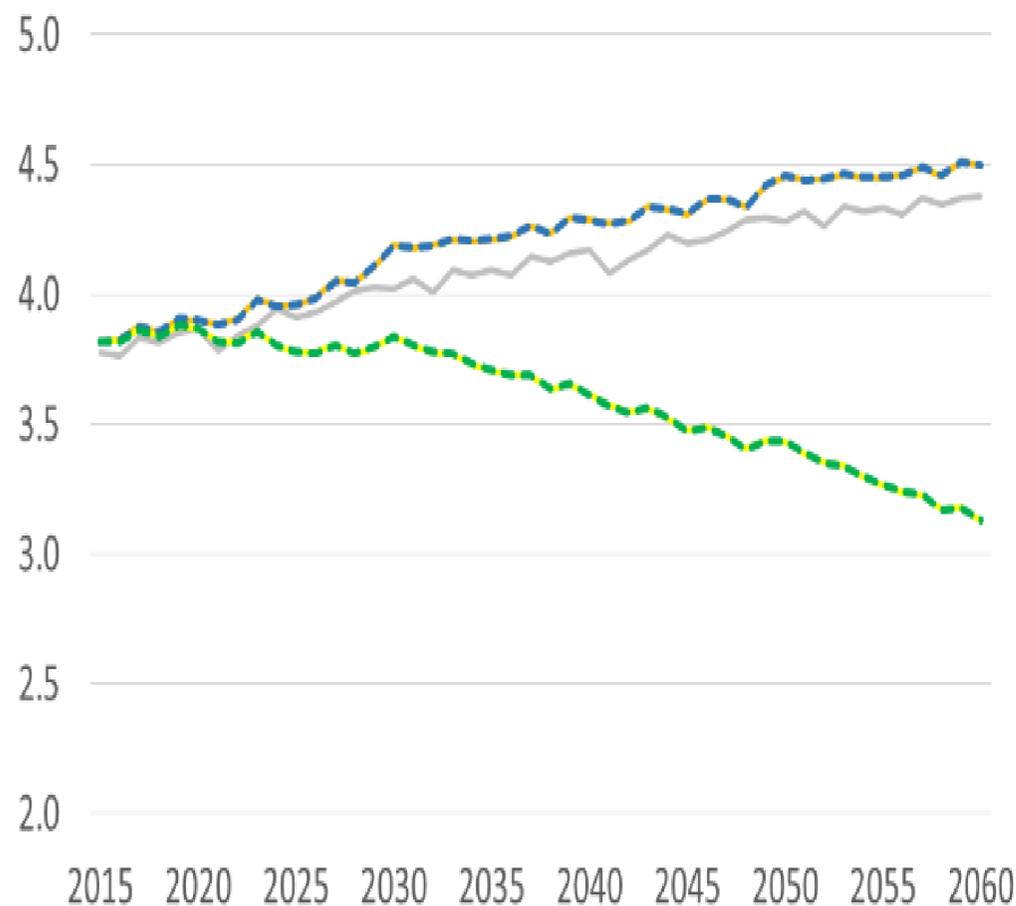
- BAU scenarios assume future fuel sources follow current trends (dominated by Natural Gas).
- Nuclear Power makes up about 10% of total generation by 2060.
- Renewables are not a significant source of energy.

100-Year GWP: Direct (Demand) plus Indirect (Transformation) Emissions (*BAU_RCP8.5*)

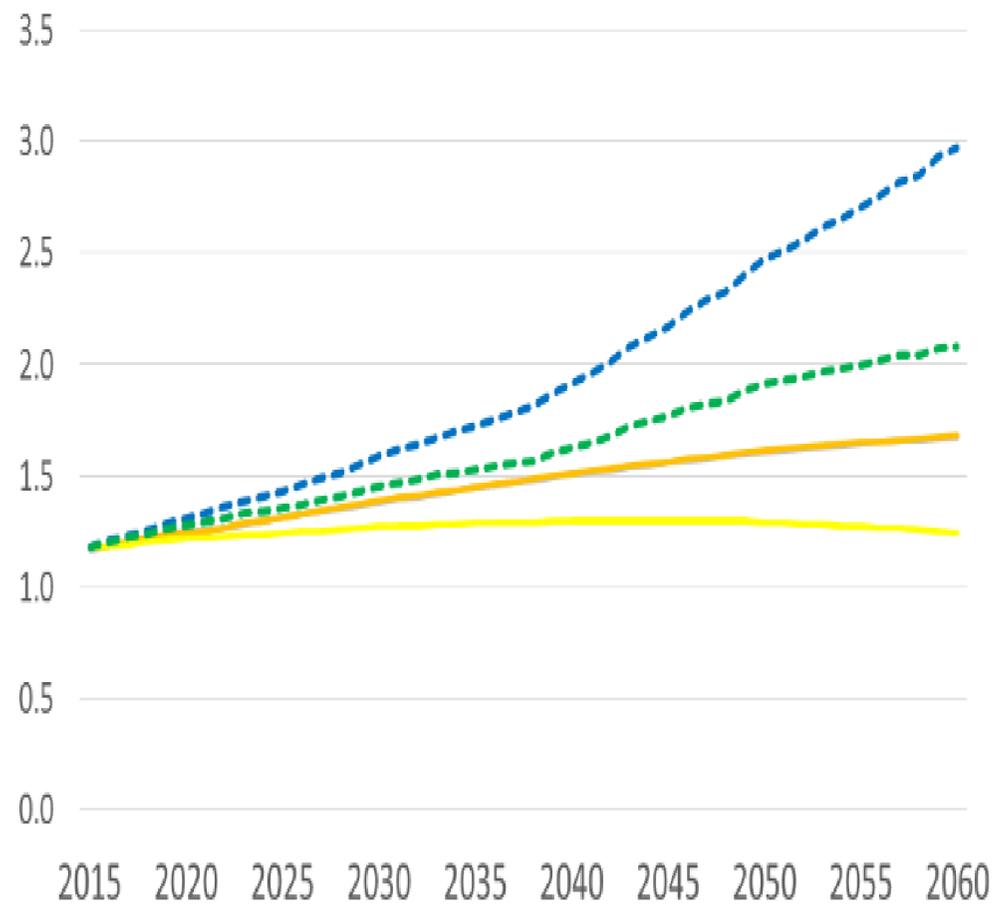


Annual water supply, all scenarios

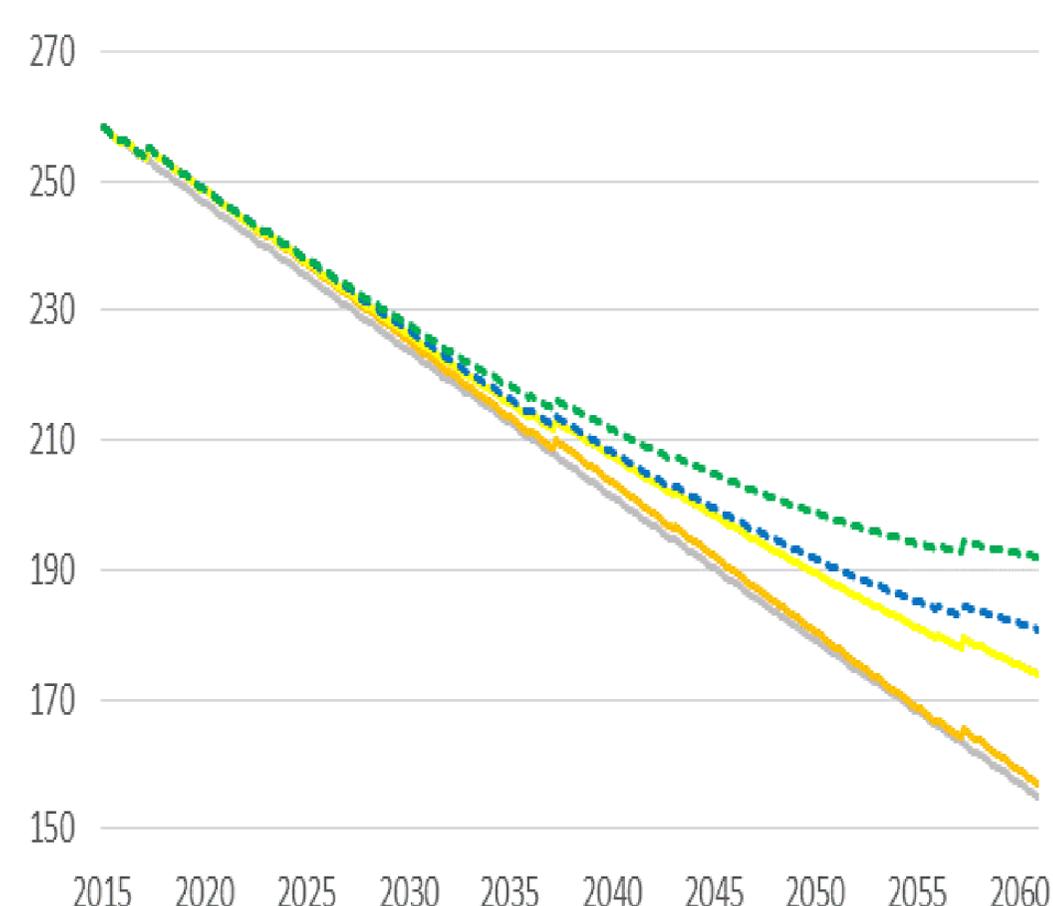
All uses



From Desalination



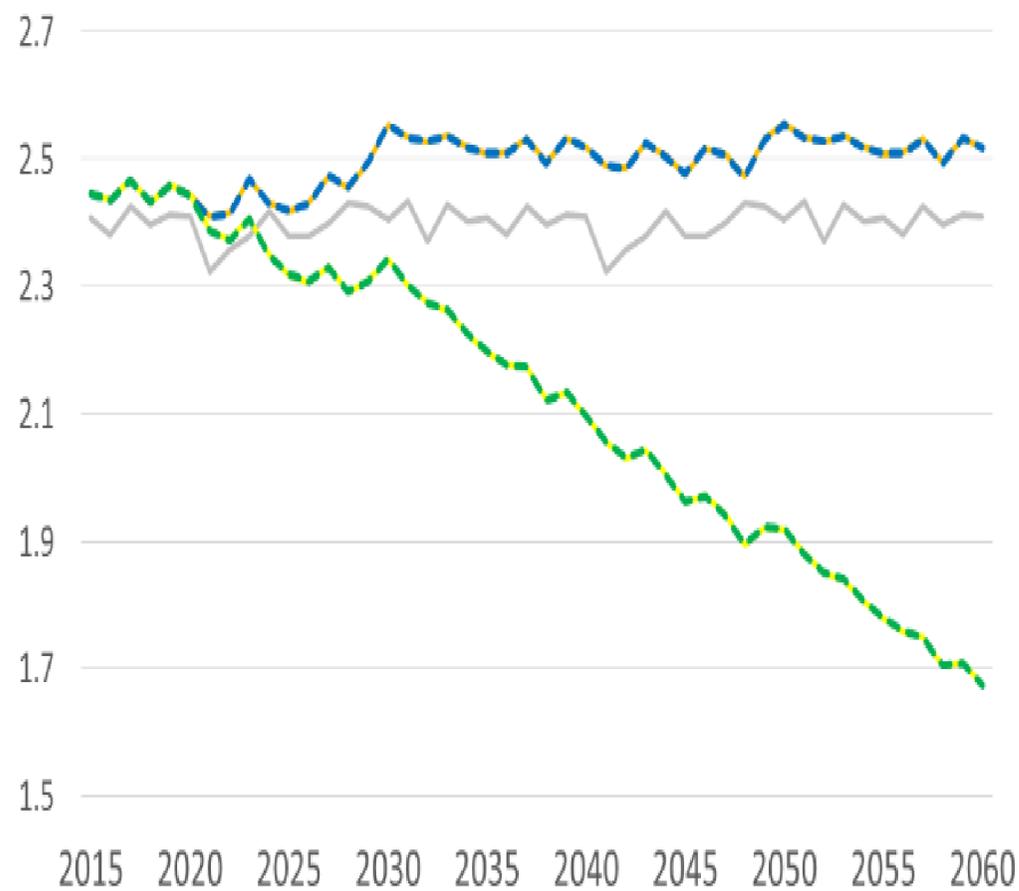
Total groundwater storage



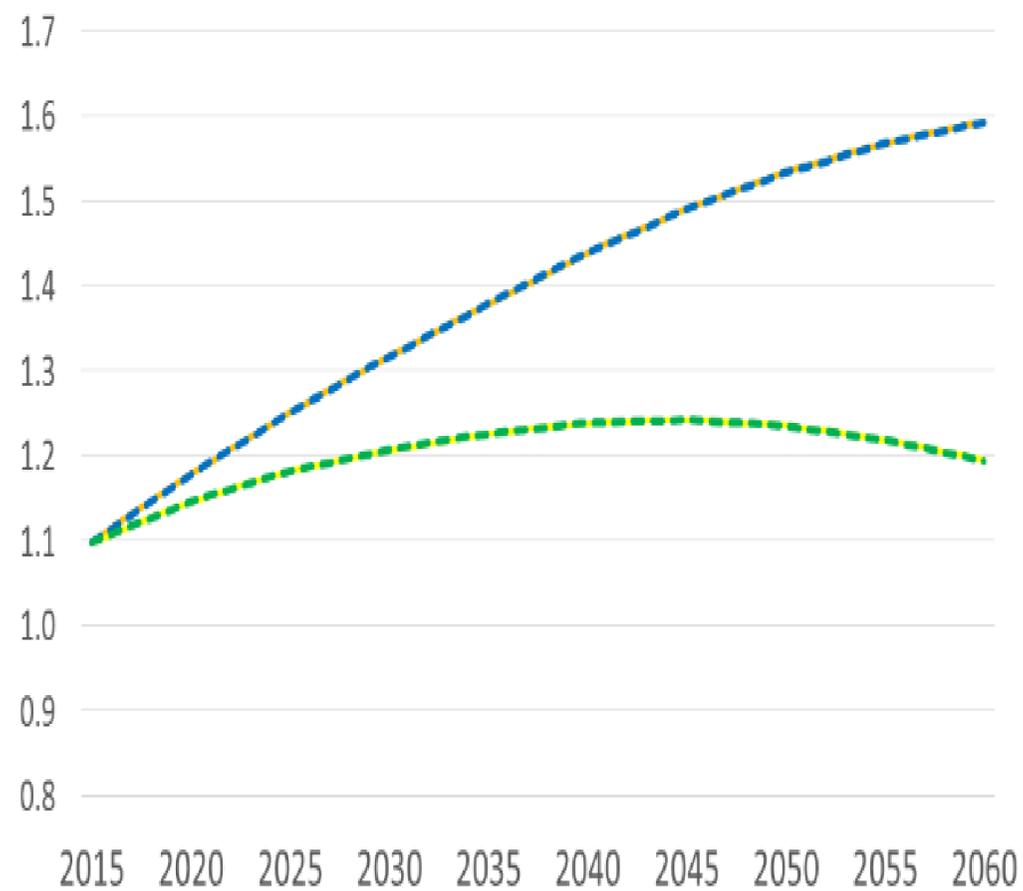
— Baseline — BAU_RCP8.5 — High Eff - - - Nat Res Protection - - - Integrated

Water demand, all scenarios

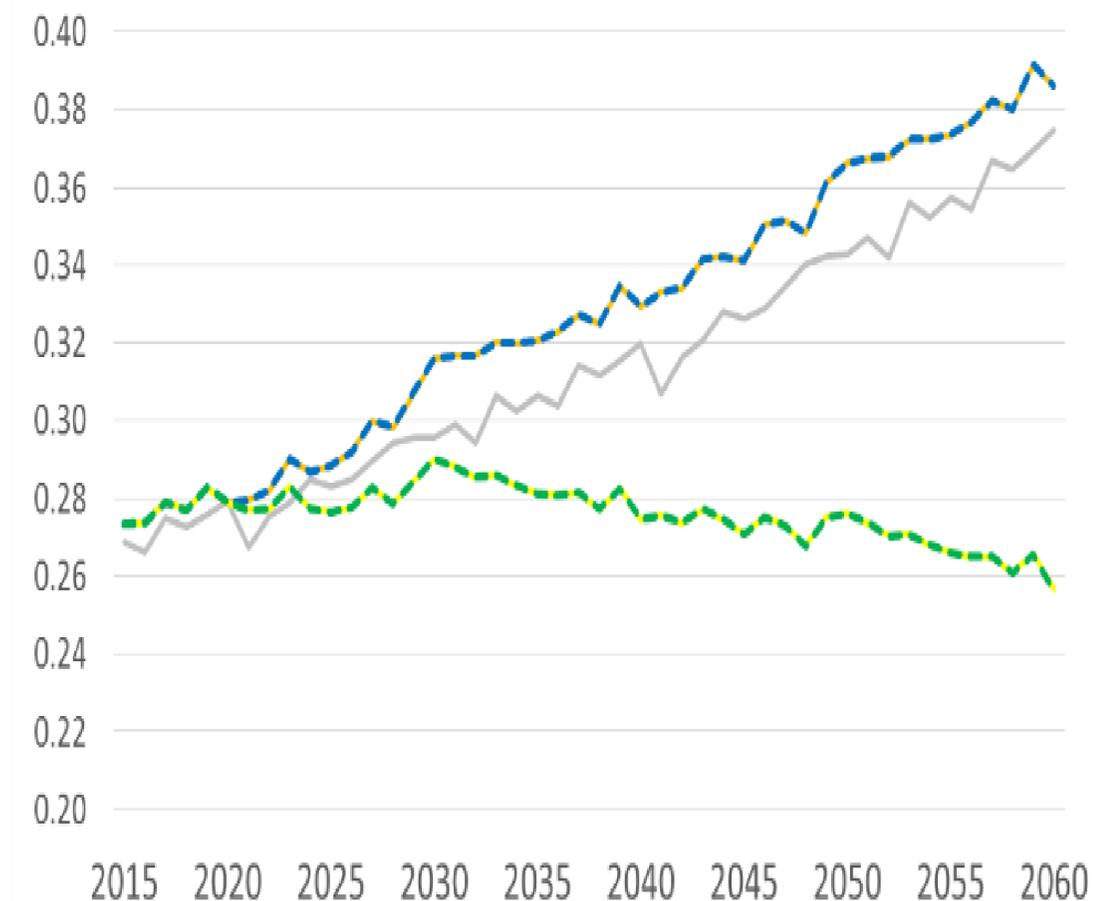
Agriculture



Indoor



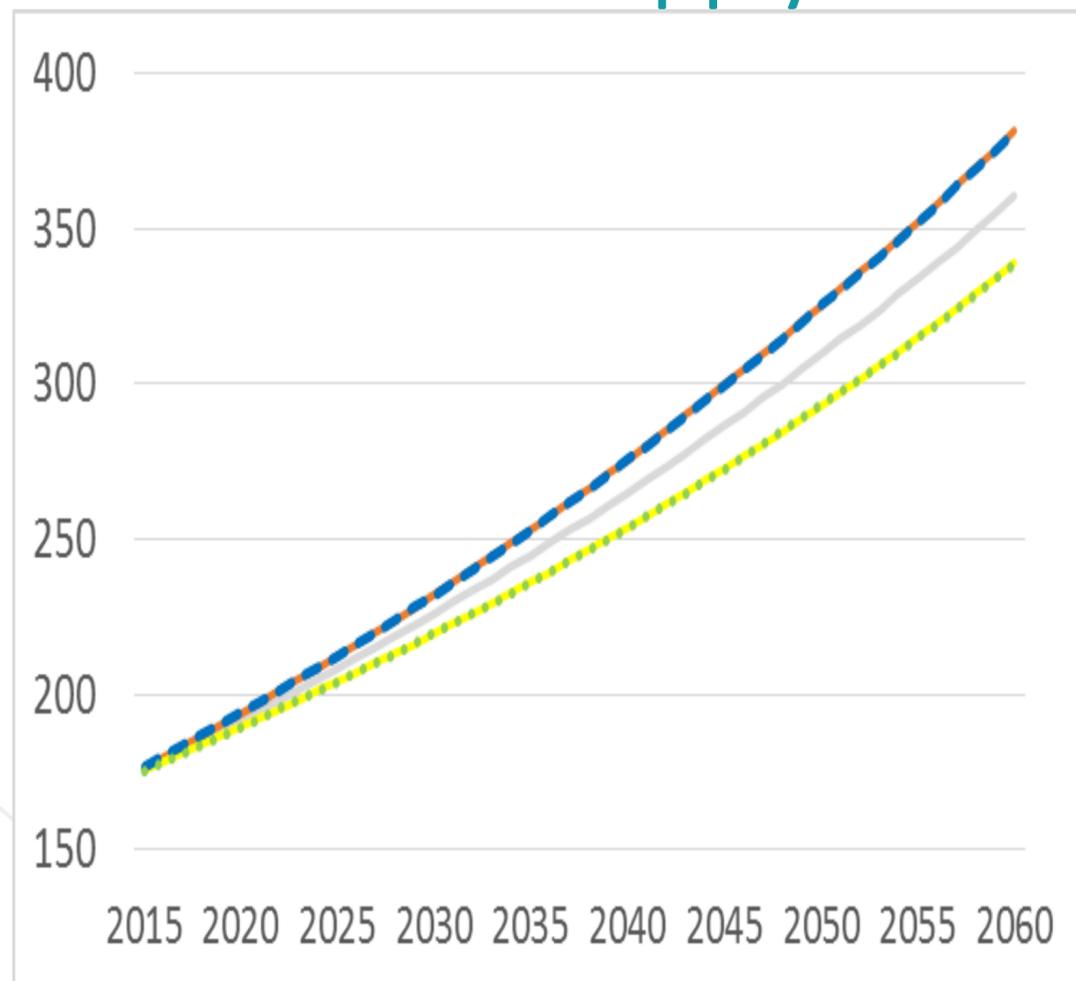
Amenity, other Outdoor



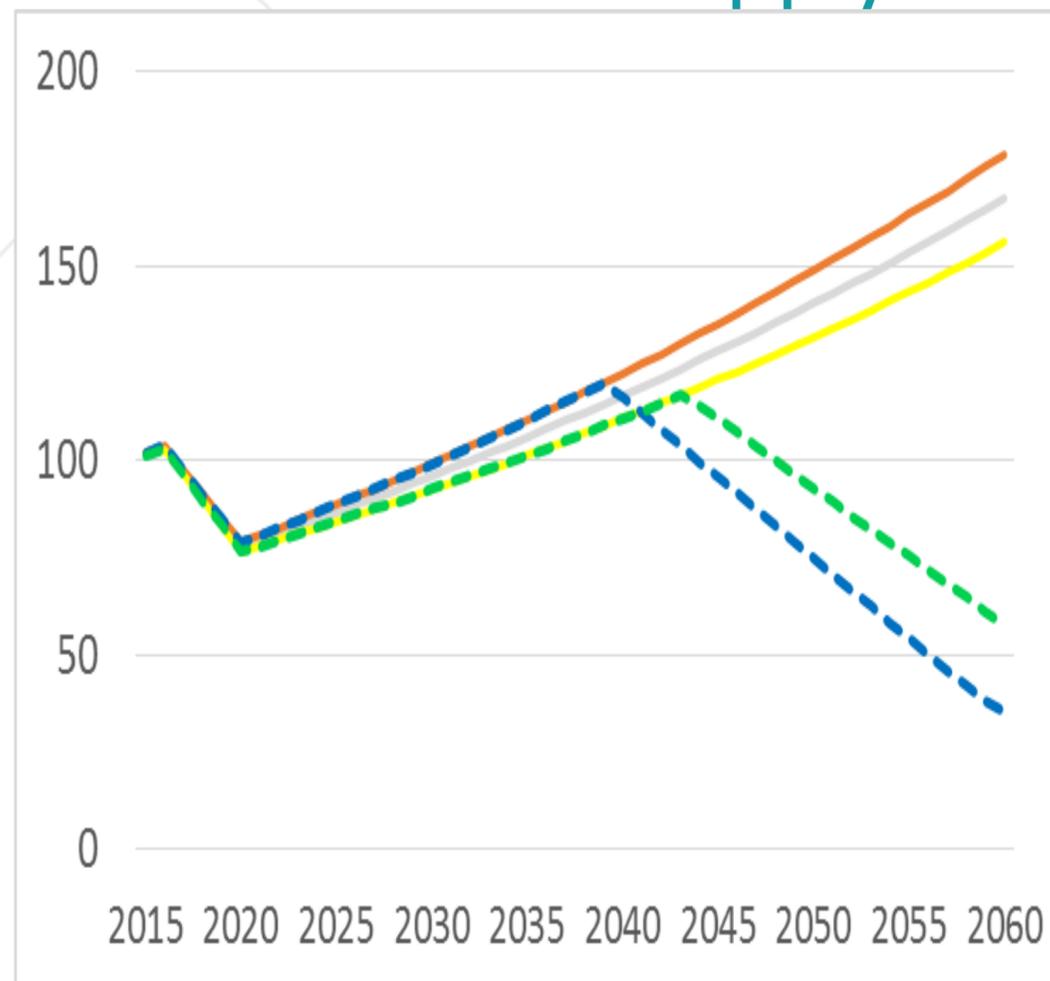
— Baseline — BAU_RCP8.5 — High Eff - - - Nat Res Protection - - - Integrated

Electricity supply, all scenarios

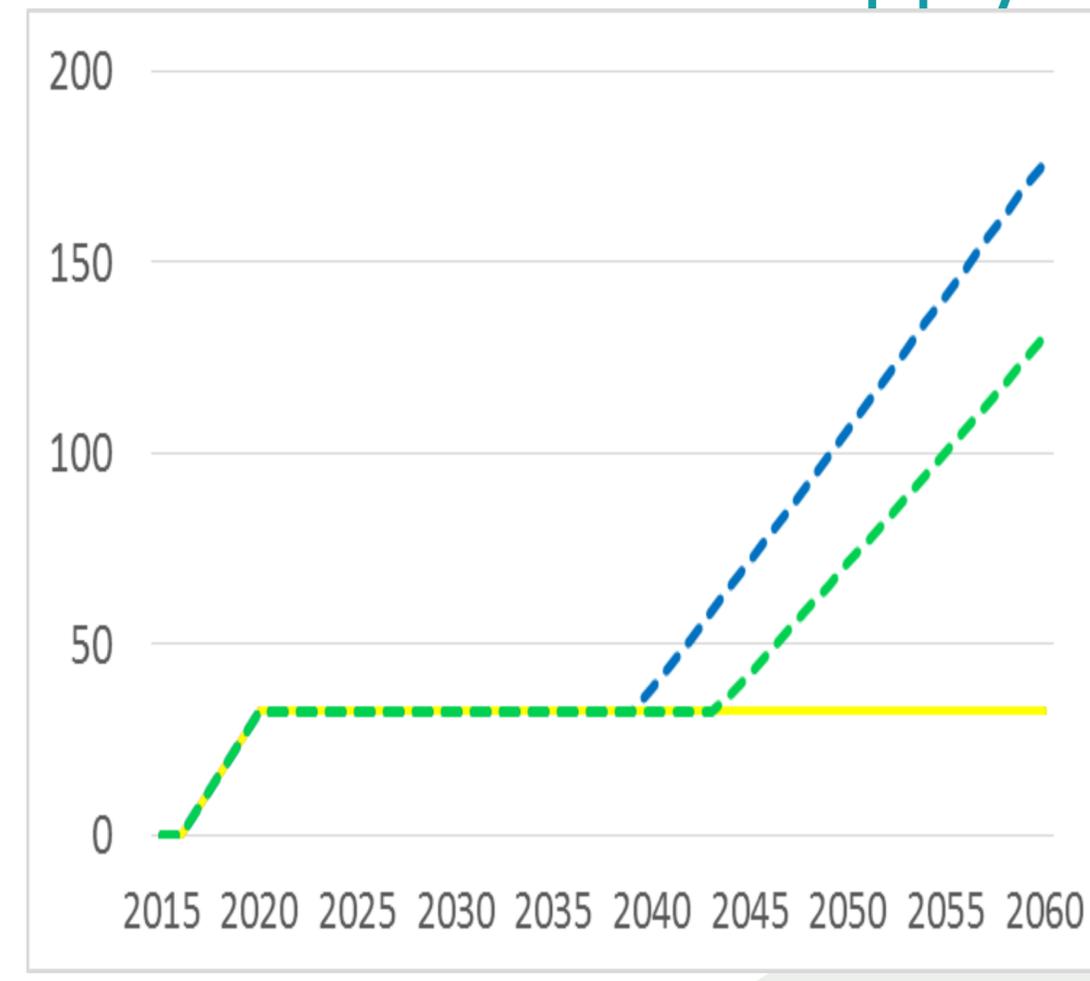
Total Supply



Fossil-Fired Supply



Solar and Nuclear Supply



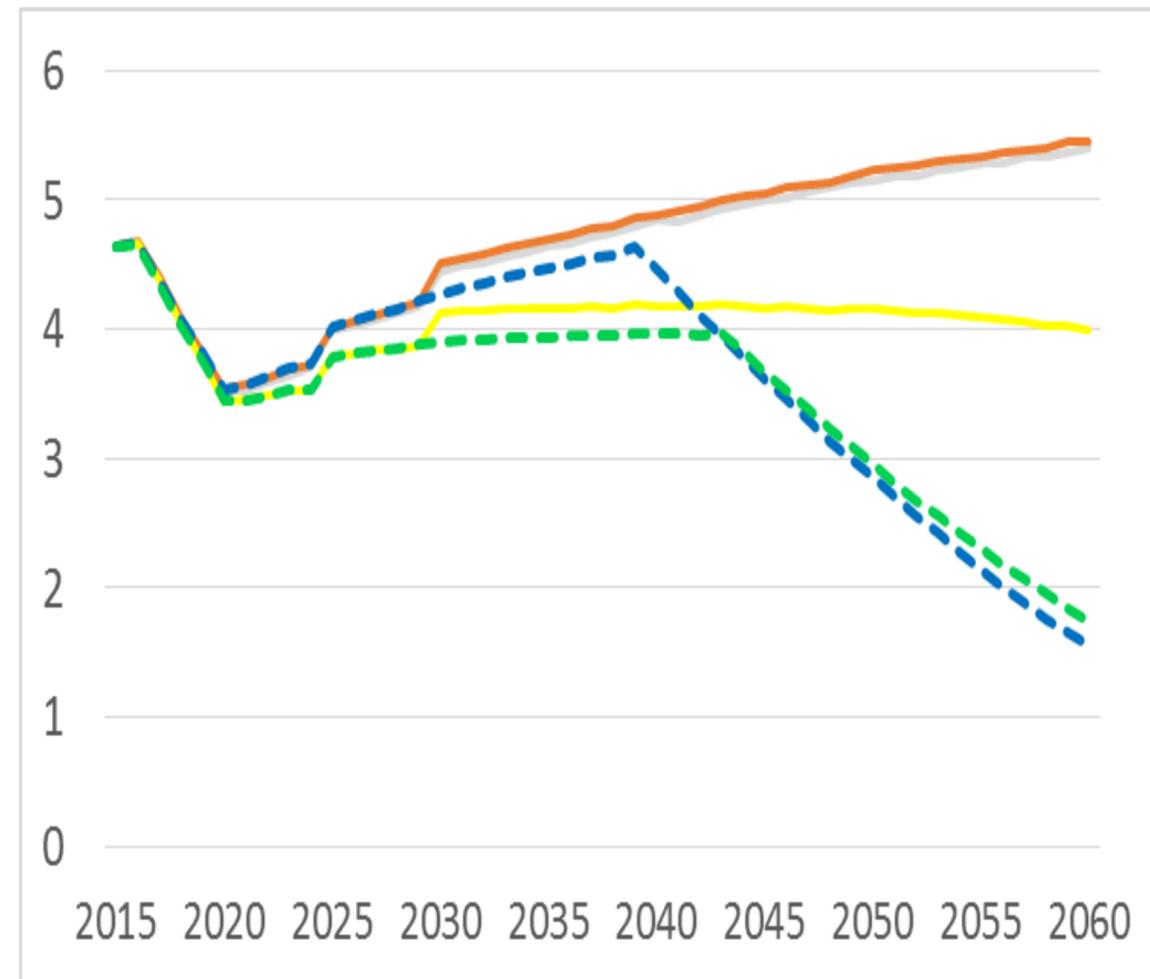
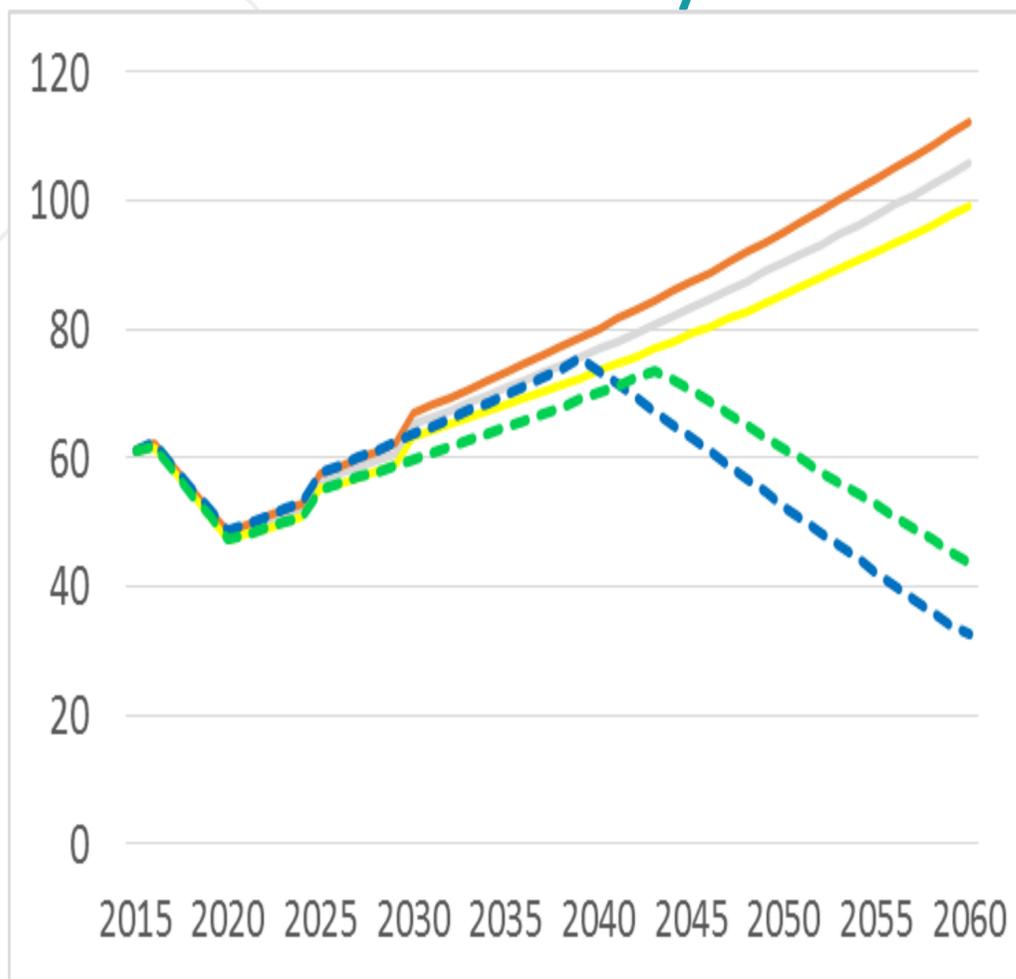
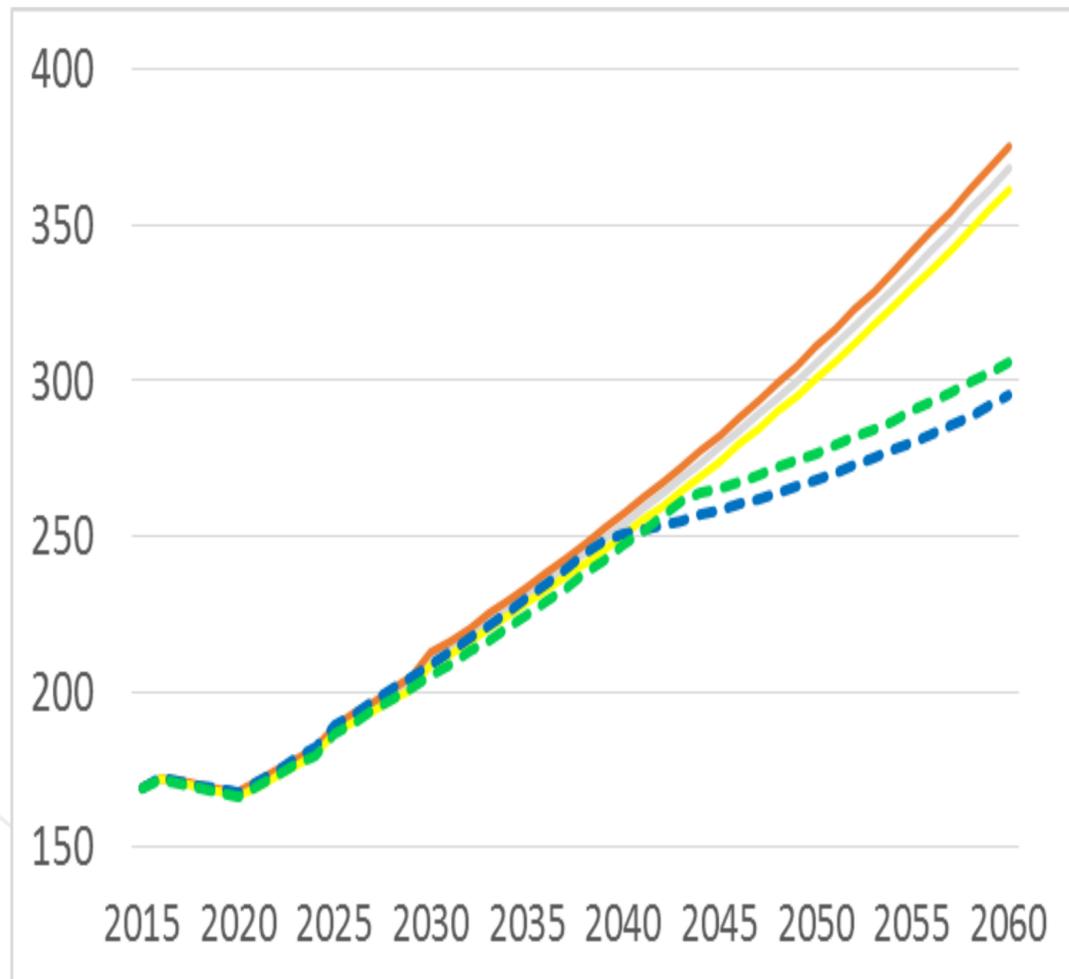
— Baseline — BAU_RCP8.5 — High Eff - - - Nat Res Protection - - - Integrated

CO₂ Emissions, all sources, all scenarios

Demand and Transformation

Total Electricity Gen.

Water-Related Emissions



— Baseline — BAU_RCP8.5 — High Eff - - - Nat Res Protection - - - Integrated

Impact	Alternative Scenario	Starting Scenario	Cumulative benefits (2015-2060)			Total Incremental cost (billion 2015\$)	Avoided CO2e emissions from policies (\$ per tonne)
			Water savings (BCM)	Fossil fuel savings (GWh)	CO2e reductions (million tonnes)		
From climate change, only	BAU-RCP8.5	BAU	-5	-470	-138	4	NA
From introduction of improved efficiency & conservation measures	High Efficiency & Conservation	BAU-RCP8.5	28	1600	283	-3	-\$10.2
From introduction of renewable energy and reductions in groundwater withdrawals	Natural Resource Protection	BAU-RCP8.5	0	4200	933	12	\$13.2
From introduction of all sustainable development measures	Integrated Policy	BAU-RCP8.5	28	4400	845	3	\$3.4

Water and Energy Overview for Policy Scenarios:

- Findings:
- This analytical framework can conduct a water-energy analysis under various scenarios, including exploring future emissions
- Green growth initiatives can be achieved in a cost-effective manner that also will increase the resilience of the water-energy nexus under climate change.
- Diversification of the energy portfolio will be necessary to achieve environmental targets, such as GHG stabilization or even reduction.

For further information, please contact Marco
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