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Energy sector adaptation in response to water scarcity

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1. Motivation

Integrated assessment models (IAMs) have largely ignored the impacts of water scarcity on the energy sector and the related implications for climate change mitigation. However, significant water is required in the production of energy, including for thermoelectric power plant cooling, hydropower generation, irrigation for bioenergy, and the extraction and refining of liquid fuels [1,2]. With a changing climate and expectations of increasing competition for water from the agricultural and municipal sectors, it is unclear whether sufficient water will be available where needed to support water-intensive energy technologies (e.g., thermoelectric generation) in the future. Thus, it is important that water use is incorporated into IAMs to better understand energy sector adaptation to water scarcity.

2. Method description

Recently MESSAGE has been updated with the capability to quantify the water consumption and withdrawal requirements of the energy sector. MESSAGE accounts for water use in resource extraction and fuel conversion processes, in heat and intermittent power generation plants as well as several cooling technologies for thermal power plants. These new capabilities have been used to quantify water consumption, water withdrawal, as well as thermal pollution associated with pre-existing climate change mitigation scenarios.

The following equation [3] is used to express water withdrawal or consumption intensity *i* (e.g., m^3/kWh net power output) as a function of heat-rate (how efficiently the plant converts heat to electricity), and cooling system type.

$$i = \alpha \cdot (\varepsilon - \beta) + \delta$$

Where:

- ε represents the heat-rate (kWh heat/kWh net power output),
- α represents how efficiently the cooling technology utilizes water (m^3/kWh heat)
- β represents other heat outputs (heat content of electricity and other heat losses such as with flue gases; kWh heat/kWh net power output),
- δ represents water requirements other than for cooling (m^3/kWh net power output).

3. Water implications of Energy-Use

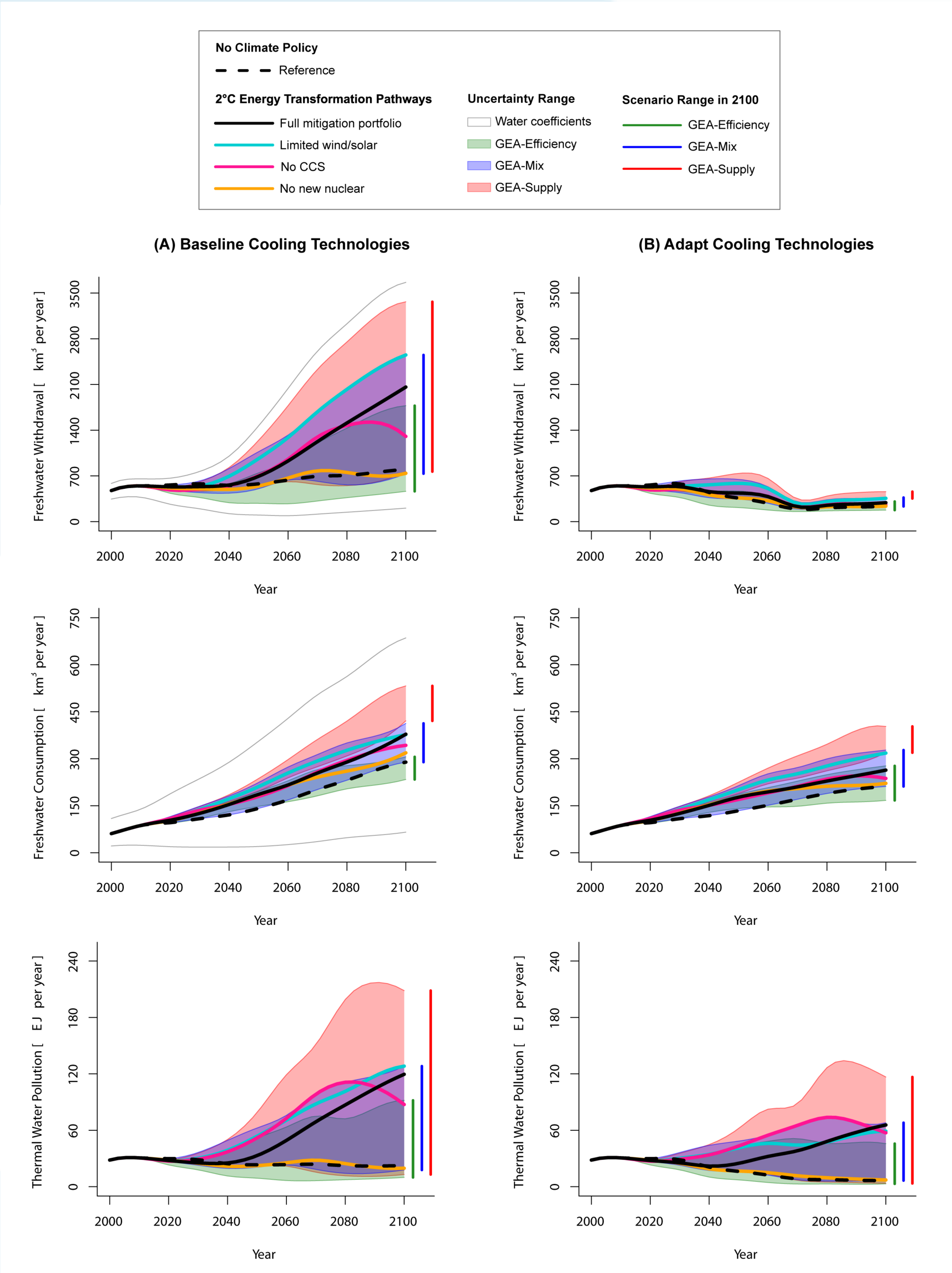

Figure 1: Global water impacts across the 2°C and reference scenarios for the two thermal power plant cooling technology cases: (A) baseline cooling technologies; and (B) adapt cooling technologies (transitioning away from once-through cooling)

4. Key findings

1. Water use across climate stabilization cases can vary greatly depending on the energy technology portfolio. Uncertainties associated with technology specific water withdrawals are small compared with those surrounding consumption.
2. Large scale deployment of low carbon thermoelectric technologies (e.g., nuclear, CSP or carbon capture and storage) can result in significant water use increases.
3. A transition to more water efficient cooling technologies results in substantial reductions of water withdrawals. Further reductions in water consumption can presumably only be achieved with large scale deployment of dry-cooling technologies and parallel upscaling of wind and photovoltaic electricity generation.
4. Thermal pollution, which poses a threat to aquatic ecosystems, can only be avoided by transitioning away from *both* fresh- and sea-water based once through cooling systems.

5. Regional Implications

1. Industrialized regions benefit from anticipated stagnation in regional energy demands and a transition away from water withdrawal intensive thermal power generation.
2. Rapid demand increases in conjunction with end-use electrification in developing regions necessitates upscaling of thermoelectric power generation. Nuclear, CCS and CSP are critical in this process. Latin America greatly benefits from the expansion of hydropower.
3. The expansion of nuclear power generation using once through cooling in PAO (seawater), SAS (freshwater) and MEA (seawater) significantly increases thermal pollution and its associated impacts on aquatic ecosystems.

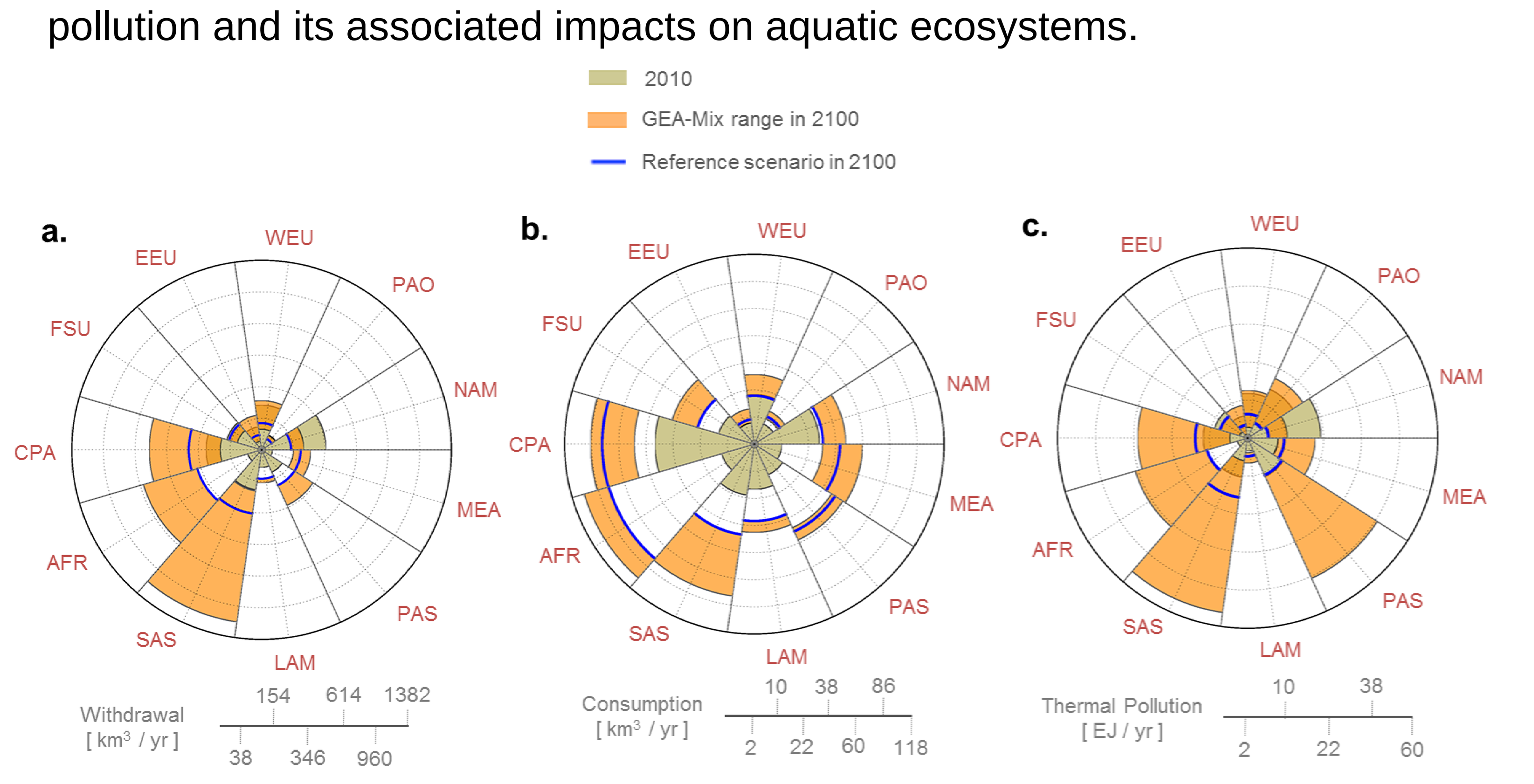

Figure 2: Regional results obtained for a. withdrawal, b. consumption and c. thermal water pollution across the climate change mitigation pathways and reference scenario

6. References

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