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CORRIGENDUM

Corrigendum: The energy and emissions footprint of water supply for Southern California (2015 *Environ. Res. Lett.* **10** 114002)

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Due to a mistake in transcription of figures, incorrect units were displayed in figures 4–7. All units of carbon emissions per unit water should be in tonnes CO_2e per acre-foot (t CO_2e/AF). Figures 4–7 have been corrected to display the correct units and the associated text of the results and discussion sections has been corrected accordingly. The main results and conclusions of our study are not affected by this error.

3. Results

The conveyance of water constitutes the largest component of LADWP's and IEUA's water supply carbon footprint, followed by treatment and distribution (figure 4). The result is due to their reliance on imported water from the Metropolitan Water District (MWD), which is pumped over great distances to Southern California. For supplies typically transported over short distances, such as recycled water and desalted groundwater, the treatment phase comprises the largest portion of the footprint. In order to ensure sufficient quality for non-potable use, recycled water treatment for the two utilities includes, aeration, microfiltration, and disinfection.

For LADWP, the most energy and emissions intensive water comes from the SWP (West and East Branch), followed by local recycled water (figure 4). This is an interesting finding as SWP-West and recycled water have carbon footprints of 0.88 tCO_2e/AF (0.71 tCO_2e/dam^3) and 0.87 tCO_2e/AF (0.71 tCO_2e/dam^3) respectively, countering the assumption that local sources necessarily have a lower carbon footprint. LADWP's emissions intensity for both recycled water and groundwater is approximately twice that of IEUA's, due to the latter's greater use of electricity from hydropower, solar and biomass sources (figure 2). The third most emissions intensive source for LADWP is water from the Colorado river aqueduct (CRA). Although more energy intensive than recycled water, the CRA mainly uses electricity generated from hydropower, which reduces its emissions footprint. The least intensive water source, both in terms of energy and emissions, is water from the Los Angeles Aqueduct, which is gravity fed and therefore requires no net energy to transport the water.

For IEUA, water from the SWP and the CRA is the most energy and emissions intensive (figure 2). In contrast to LADWP, local sources have a smaller footprint because of the cleaner grid mix. However, in the case of IEUA the desalted water has a higher footprint than recycled water (figure 4). This is because the treatment phase is highly energy intensive due to the reverse osmosis and ion exchange used to remove nitrates and total dissolved solids. Surface water requires a relatively small amount of energy for transport and treatment, with emissions largely in the distribution phase.

3.1. Spatial-upstream versus statewide average (e.g eGRID) approach

The fact that the carbon footprint of LADWP's local recycled water is higher than that sourced from the Colorado river was made evident by the spatial-upstream approach used in this study. With respect to broadly comparing the spatial-upstream approach with the statewide average approach, the former resulted in higher emissions profiles for the water supplies of the two utilities (figure 5). Specifically, the spatial-upstream approach resulted in an increase in the weighted average of the emissions intensity (tCO_2e/AF) for both LADWP (+6%) and IEUA (+7%). Increases in emissions vary by water source. Emissions intensity for the CRA actually decreased by 7%. Differences in grid mixes can further be seen in the distinctions between IEUA's and LADWPs groundwater and recycled water emission footprints, because embodied energy for the water sources is similar. However, IEUA's groundwater and recycled water increased by 18% and 2% respectively, while LADWP's increased by 65% and 79%.

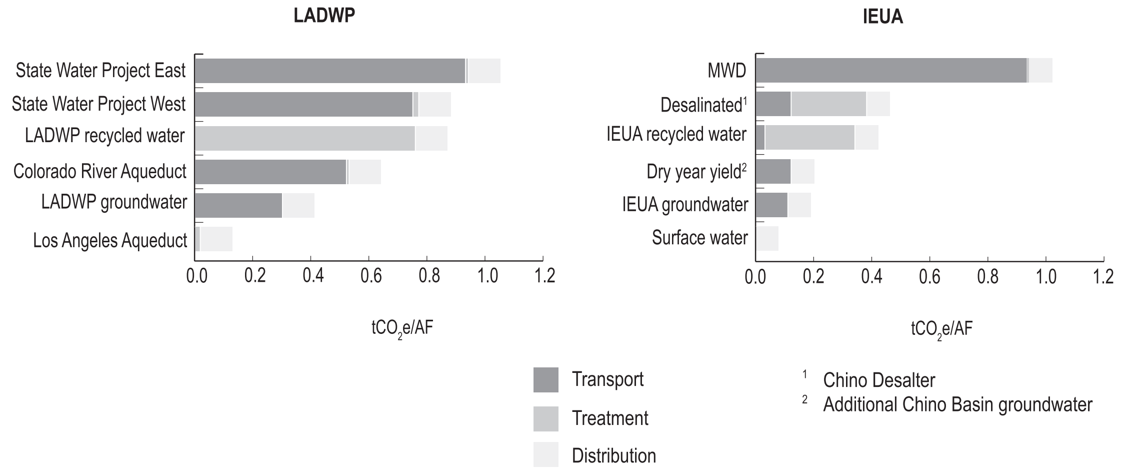

Figure 4. Comparative emissions burden for LAWDP and IEUA water sources. Greenhouse gas emissions (tonnes CO_2e per acre foot) are listed for each water source with the shading indicating which operational phase of water supply the emissions are attributable to.

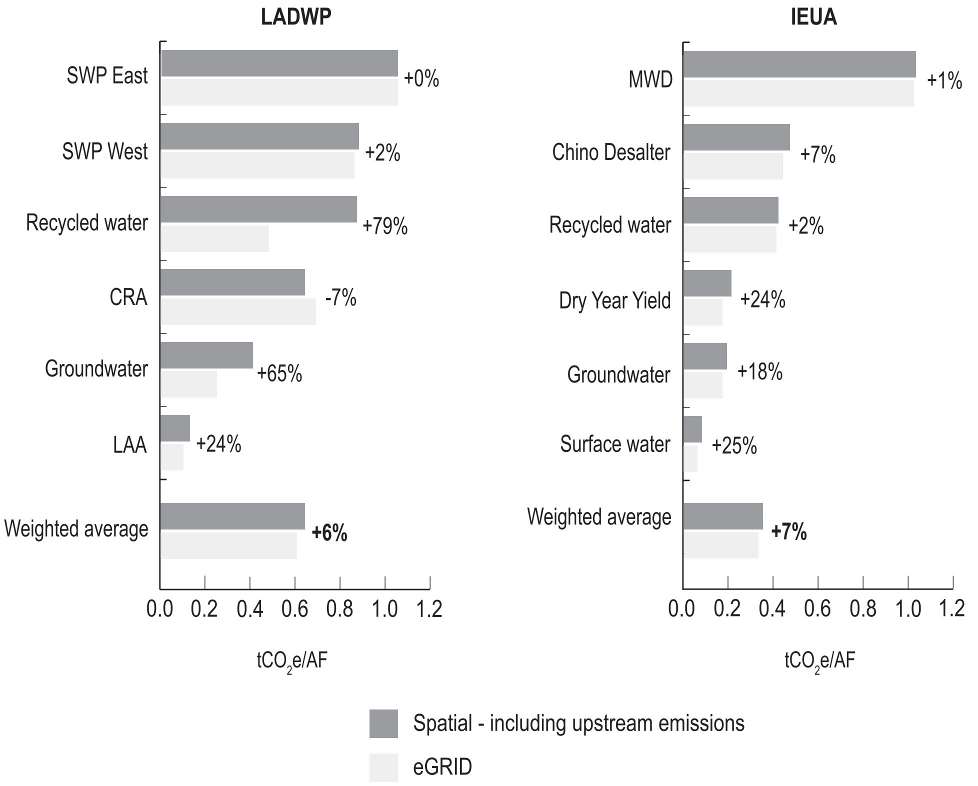

Figure 5. Comparing emissions of eGRID (Statewide average) versus spatially-explicit approach. For each water source, emissions intensity (tCO_2e/AF) is compared using a spatial method with upstream emissions included and the conventional approach, using a regional emissions factor from eGRID's CAMX subregion.

The overall higher carbon footprints of both utilities are primarily due to the inclusion of upstream emissions. Figure 6 illustrates the impact of upstream emissions. For example, including upstream emissions in the statewide approach resulted in a 28% and 30% weighted average increase for LADWP and IEUA respectively. Sources dominated by transport (MWD, SWP, CRA) have greater absolute differences on a tCO2e/AF basis. The MWD carbon intensity increases by 29% and the SWP East and SWP West increase by 28%, but the smallest increase is the LAA at 9%.

In terms of comparing the spatially-explicit approach with the statewide approach without including upstream emissions, for both utilities the overall emissions footprint is significantly lower (figure 6). LADWP's average emissions intensity decreases by 38% due to its heavy reliance on the SWP and CRA, where over 50% of its water supply is sourced.

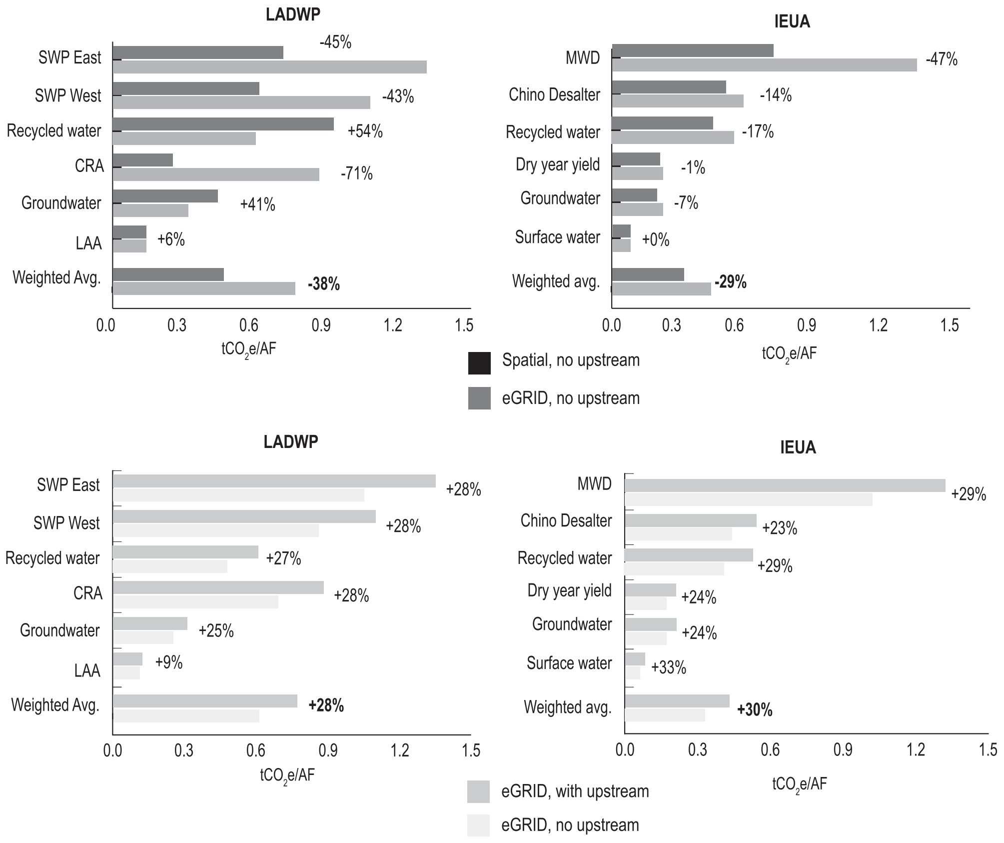

Figure 6. Relative impact of spatial and upstream emission factors. (a) Emissions intensity for each water source using eGRID generation profiles and spatially-explicit generation profiles, with the percentage indicating the percent difference using 'eGRID with no upstream' as a base case. (b) Emissions intensity for each water source using eGRID generation profiles and varying the inclusion of upstream emissions factors. The percentage shown indicates the percentage difference using 'eGRID with no upstream' as the base case.

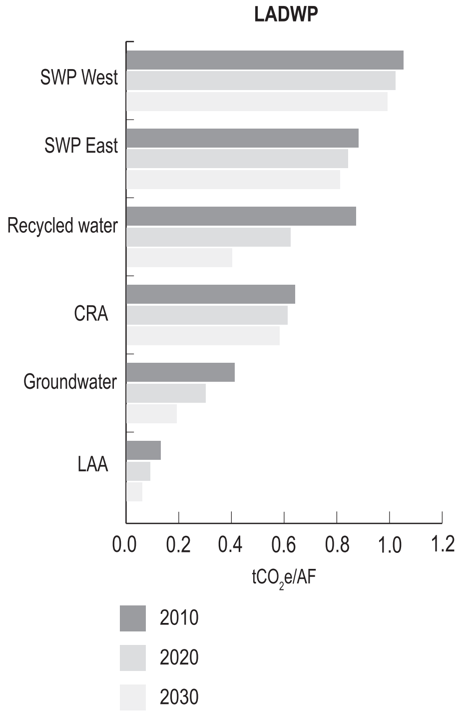

Figure 7. Projected impact of grid mix changes for LAWDP. The projected carbon intensity (tCO_2e/AF) of each LADWP water source based upon electricity generation source projections (LADWP 2011) for 2010, 2020, and 2030.

Emissions intensity of the SWP water falls by 40% and the CRA emissions falls by 70% as the eGRID CAMX emissions profile effectively underrepresents the proportion of electricity generated by hydropower used to transport the water. However, this is not the case for local sources of water (LAA, groundwater, recycled water) which shows increases in emissions intensity due to reliance on LADWP's relatively dirty electricity generation mix. This has important implications as the City of Los Angeles looks to expand efforts to generate more supply through recycled water, stormwater capture, and groundwater replenishment. All IEUA sources of water show a decrease in emissions intensity using a spatialized emissions factor, resulting in a 29% decrease in the weighted average (figure 6).

4. Discussion

The environmental sustainability of local water supply (in terms of carbon footprint), therefore, hinges on the electricity grid mix used to treat and distribute water. To gain a sense of just how influential the local grid mix is consider the example of LADWP and its proposed transition away from coal and towards a cleaner grid mix. Using LADWP's forecasted generation sources for

2020 and 2030 (LADWP 2011) and Integrated Resource Plans from relevant utilities, we calculated future GHG emissions to understand how LADWP's energy transition impacts the carbon footprint of its water supply system (figure 7). In this scenario, LADWP decreases its coal generation from 40% in 2010 to 28% in 2020 and to 0% in 2030. Meanwhile, the percentage of renewable generation increases from 18% (2010) to 40% (2030) and the percentage of natural gas increases from 30% (2010) to 50% (2030). Under this scenario, the reduction in carbon intensity of local water sources (LAA, groundwater, recycled) is especially pronounced (54%). Imported water, by comparison, is reduced just by 6%, 8%, and 10% for the SWP East, SWP West, and CRA, respectively. LADWP could follow IEUA, which was able to mitigate the emissions associated with recycled water and groundwater by self-generating more of the electricity needed to power its local water treatment plants. Of course, in addition to the grid mix, the energy intensity of the technology has to be considered as well. This is especially the case with desalination, which is highly energy intensive and even with a relatively clean energy grid, would have a considerable carbon footprint. Other considerations also include the extent to which efficiency improvements throughout the various phases of water pumping and transport, treatment, and distribution may yield greater overall emissions reductions as result of economies of scale.