**Thermodynamic potential of membrane-based atmospheric water harvesting**

Water scarcity is a global problem that requires a suite of technologies to address, as no single solution will fix the problem. For example, the best solution for equatorial coastal regions may be drastically different than that in arid remote communities. Atmospheric water harvesting (AWH) is a budding field that aims to capture water vapor from the ambient air. While these processes require more energy, they allow for decentralized water production which bypasses the monetary, and emissions costs associated with transportation. Further, AWH generally provides highly pure water with little need for additional treatment.

Primary methods of atmospheric water harvesting include membrane systems, sorbent systems, dew plates, and fog harvesting. Of these, membrane and sorbent systems aim to concentrate water vapor from the ambient air, while dew and fog methods capture water directly from the ambient air. Through an exergy analysis, we find that the ideal energetics of obtaining water highly varies with the ambient environment, ranging from 0 (humid) to over 300 (arid) kJ/kg. This contrasts with water desalination which varies much less, from about 0.1 (low salinity) to over 3 (concentrated brine) kJ/kg. Current AWH technologies suffer from at least one of the following three: capacity, efficiency, or yield. Membrane systems have the potential to achieve high efficiency water harvesting, especially in arid environments. Through an ideal system comparison, we show that the use of membranes in an open system has a niche geographic region of optimality. These systems, when compared to dew plates and MOF-801 sorbents, are most effective in cold (T<315K) and arid (RH <35%) environments. In these regions, the 2nd law efficiency has a limit of approximately 50%.