ABSTRACT: Passage of the California Global Warming Solutions Act of 2006 (AB 32) set the stage for a transition to a low-carbon economy. In addition to greenhouse gas action, drought in California is ushering in an era of unprecedented advances in water resource management. For example, Congressman Jared Huffman’s pending assembly bill would expand investments to reduce evaporative losses in the Bureau of Reclamation water conveyances. Due to the simultaneous demand for greenhouse gas and water action, it is imperative that emerging solutions create synergies and avoid tradeoffs at the energy-water nexus. Photovoltaic structures constructed over aqueducts have been proposed as one novel solution to energy and water management. The objective of this study is to address knowledge gaps on the environmental and economic performance of these solar canals.

Figure 1. Schematic of a solar canal depicting the basic concepts behind the proposed benefits of increased photovoltaic efficiency and reduced evaporation.

Figure 2. Renderings of a solar canal using tensioned cables (Source: Citizen Group).

Figure 3. Schematic of a solar canal depicting the basic concepts behind the proposed benefits of increased photovoltaic efficiency and reduced evaporation.

Figure 4. Annual mean evaporation estimates (mm day⁻¹) using the modified Penman method at National Solar Radiation (NSR) weather stations indicated by circles overlaid onto a thin plat spline interpolated evaporation rate grid.

Figure 5. National Hydrography Dataset major open canals and aqueducts considered in this study. Approximately 4,000 miles of canals and aqueducts.

Figure 6. The water intensity of electricity production in California. Statewide, water savings estimate 90-320 TAF y⁻¹.

Figure 7. Spatial extent of annual idle and irrigated cropland in the Central Valley, California for the year 2011 compared to the year 2015. Source: NASA LandWatch.

Figure 8. The incremental net present value at eight different locations for three different PV systems: conventional ground-mounted, steel truss over canal, and tensioned cable over canal.

Figure 9. The three solar panel support structures considered in our economic analysis. Left: ground-mounted systems. Middle: Steel truss system (Jena, 2015). Right: Tensioned cable system (Ave, 2015).

Figure 10. The net energy produced at eight different locations for ground-mounted “on land” systems and solar canal systems. For the solar canal energy production, the assumption is a 4% increase in panel efficiency.

Energy Production Results
• Mean (across sites) energy production, baseline estimate “over canal” energy production 12 ± 4 GWh mile⁻¹ y⁻¹
• Statewide estimate, 49 ± 16 TWh y⁻¹

GHG savings
• Mean (across sites) baseline estimate “over canal” greenhouse gas offsets 3,400 ± 1,100 mt CO₂e m⁻² y⁻¹
• Statewide, 14 ± 5 million mt CO₂e y⁻¹ based on assumptions:
  o 4,000 miles of open canal in California
  o Canal span 75 ± 25 ft.
  o Panel efficiency increased 4% for “over canal” compared with “on land” scenario
  o 279 mt CO₂e GWh⁻¹ offset (includes both fuel combustion and upstream emissions)

GHG Savings in Context
Potential to offset between 28 to 19 million annual CO₂e grid electricity emissions or between 26 to 54% of the emissions from the imported electricity sector.

Table 1. Statewide Deployment

<table>
<thead>
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<th>Method</th>
<th>Lower Estimate</th>
<th>Baseline Estimate</th>
<th>Upper Estimate</th>
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</thead>
<tbody>
<tr>
<td>Simplified Penman</td>
<td>45 (138)</td>
<td>84 (258)</td>
<td>92 (283)</td>
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<tr>
<td>Pan evaporation</td>
<td>36 (112)</td>
<td>68 (209)</td>
<td>75 (229)</td>
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<td>CIMIS</td>
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<td>69 (212)</td>
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</table>

Water Savings

Economic Performance

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Table 2. Economic Performance

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Figure 11. Greenhouse gas emissions by economic sector reported by the California Air Resources Board.

References:


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