Willett Kempton

"The 99.9% solution: Can we displace enough CO2 from large-scale renewable energy to make a difference for climate change and ocean acidification?"

Abstract:

The current state and costs of wind energy are reviewed. Then, we model many combinations of renewable electricity sources (inland wind, offshore wind, and photovoltaics) with electrochemical storage (batteries and fuel cells), incorporated into a large grid system (72 GW). The purpose is two fold: 1) although a single renewable generator at one site produces intermittent power, we seek combinations of diverse renewables at diverse sites, with storage, that are not intermittent and satisfy need a given fraction of hours. And 2) we seek minimal cost, calculating true cost of electricity without subsidies and with inclusion of external costs. Our model evaluated over 28 billion combinations of renewables and storage, each tested over 35,040 h (four years) of load and weather data. We find that the least cost solutions yield seemingly-excessive generation capacity at times, almost three times the electricity needed to meet electrical load. This is because diverse renew-able generation and the excess capacity together meet electric load with less storage, lowering total system cost. At 2030 technology costs and with excess electricity displacing natural gas, we find that the electric system can be powered 90%-99.9% of hours entirely on renewable electricity, at costs comparable to today's but only if we optimize the mix of generation and storage technologies.