Simulation Matching Demand With 100% Wind, Water, and Solar Supply Plus Storage Across all Energy Sectors in NEW ZEALAND With NO Added Hydropower Turbines

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Figure 1. Five-year (60-month, 2050-2054) time-series comparison for New Zealand of computer modeled (a) monthly-averaged total wind-water-solar (WWS) power generation versus the sum of load met across all energy sectors (electricity, transportation, heating/cooling, industry, agriculture/forestry fishing) plus losses plus changes in storage plus shedding, (b) breakdown of load plus losses plus changes in storage plus shedding into individual components, and (c) breakdown of WWS power generation by generation technology.

Figure 2. Same as Fig. 1, but with hourly results for a 30-day period during the 5-year simulation.

The model used was the LOADMATCH grid integration model (Jacobson et al., PNAS 112, 15,060-15,065, 2015). It used a 30-second time step. Supply matched demand every 30 s for all 5 years, accounting for the
intermittency of WWS and extreme weather events. Results here are shown in the monthly average and hourly average. Total annual average load met in 2050 with 100% WWS in New Zealand was 17.6 GW, a reduction of ~43.6% from the business-as-usual (BAU) case due to (a) the higher work out to energy in ratio of electricity over combustion (27.7%), (b) eliminating energy in the mining, transporting, and refining of fossil fuels and uranium (8.94%), and (c) additional end use efficiency improvements and reductions in energy use beyond BAU (6.91%).

Table 1 gives the installed capacity and storage requirements for the system. No hydropower turbines beyond those installed in 2015 were assumed.

![Table 1](image)

CSP = concentrated solar power; PHS=pumped hydropower storage; CW+ice= chilled water storage plus ice storage; HW=hot water storage; UTES=underground thermal energy storage in rocks, where heat is obtained from solar thermal collectors; UTES-elec=UTES storage in rocks, where heat is obtained from excess WWS electricity. In addition, hydrogen was produced (266 Gg-H/yr) and stored (2.92 Gg-H tanks) for use only in transportation. Battery electric vehicles were also used in transportation.

![Figure 3](image)

The cost of energy replacing retail electricity was 8.8 (7.2-11.1) ¢/kWh in 2013 USD. The cost of all energy was 9.24 (7.3-12.0) ¢/kWh. The system capital cost was $152 (123-180) billion. Costs include electricity generation; heat, cold, electricity, and hydrogen storage; hydrogen electrolysis and compression; and short- and long-distance transmission; and distribution.
Citations: