Kinetic energy in the atmospheric boundary layer greatly exceeds present world energy demand. Onshore wind energy is also currently the cheapest form of new electricity generation in the United States of America and is cost-competitive in most areas of the world. An expanded role for wind energy derived electricity generation is thus an obvious pathway to achieve climate change mitigation efforts. Scenarios from international agencies indicate that this virtually carbon-free source could supply 10–31% of electricity worldwide by 2050. In previous research we considered these projections for increased installed capacity within Intergovernmental Panel on Climate Change Representative Concentration Pathway (RCP) climate forcing scenarios, and showed dependent on the precise RCP followed, pursuing a moderate wind energy deployment plan by 2050 delays crossing the 2 deg C warming threshold by 1–6 years. Using more aggressive wind turbine deployment strategies delays 2 deg C warming by 3–10 years, or in the case of RCP4.5 avoids passing this threshold altogether (Barthelmie and Pryor, 2014).

Here we address three other components of building a feasible roadmap for expanding wind turbine (WT) installed capacity within the contiguous USA. We discuss the technical issues and a robust framework for assessing uncertainty in terms of:

(i) The overall stability of the wind resource under climate non-stationarity. The ‘power of the wind’ scales with the wind speed cubed. Alterations in local and regional climates may impact the geographic distribution and/or the inter- and intra-annual variability of the resource and/or operating conditions. Using simulations conducted with the WRF model we show that the wind climate over parts of CONUS that have installed wind turbines is relatively stable over the current century and lay out a roadmap that can be employed to examine other aspects of wind turbine operating conditions.

(ii) The feasibility of expanding installed capacity while avoiding land-use conflicts. Herein we develop wind energy scenarios to increase installed capacity that focus on replacing older WT with higher name-plate power production WT (via ‘repowering’) and show that using existing technology quadrupling of installed capacity can be achieved without need for additional land.

(iii) The system efficiency of electricity production under expanded installed capacity. Wind turbines work by extracting kinetic energy from the air and converting it into electrical power. Thus, some disturbance of the flow field and reduction in wind speeds (i.e. wind turbine wakes) is inevitable. Here we present simulations that quantify the degree to which wind turbine array-array interactions limits system-wide efficiency under the repowering scenarios and also examine the scaling of local climate impacts with installed capacity. Using very high resolution WRF simulations we show quadrupling WT installed capacity results in only minor downstream climate impacts beyond the grid cells in which WT are located, and a modest decrease in the overall efficiency of electrical power production.