Executive Summary
The cost of displacing fossil fuels: Some evidence from Texas

What energy technology will likely be used when fossil fuels are no longer dominant? More importantly, what will be the cost of that alternative "backstop" energy supply? The higher the cost, the longer will fossil fuels remain viable as an energy source. A higher cost of energy at the time of transition also implies that more total fossil fuels will have been used by then, regardless of the prior trajectory of fossil use. This has implications for the total stock of emissions likely to be released by fossil fuel combustion. Finally, a higher cost of the backstop technology will imply there is more of an "energy crisis" around the transition time.

We examine these issues using data from the ERCOT ISO in Texas and cost and price data from the Energy Information Administration. The ERCOT ISO is suitable for our purpose since it is relatively isolated from neighboring grids, and wind power was almost a quarter of its total generating capacity at the end of 2016.

No matter what technology is used instead of fossil fuels, bulk electricity storage will also be required. We argue that the current cost of pumped storage is a reasonable lower bound for costs that could be attained by other bulk electricity storage technologies after further R&D. We therefore contrast wind plus pumped storage with nuclear plus pumped storage as alternative means of meeting ERCOT hourly loads for 2016. Both systems also included natural gas open cycle turbine (GT) capacity equivalent to 10% of maximum hourly demand as reserve capacity and to provide ancillary services.

We found that the wind plus storage system required almost double the storage of the nuclear plus storage system. The reason is that storage has to serve two functions in the wind system. As in the nuclear plus storage system, it has to cope with variations in demand. In the wind system, however, storage also is needed to offset the large daily and seasonal fluctuations in wind output. The high cost of storage then implies that the wind plus storage system is more costly even at unrealistically high weighted average cost of capital (WACC) values, which normally would be expected to greatly disadvantage capital-intensive nuclear generation.

This result has an important implication. It is often argued that storage would solve the problems with wind generation – its intermittency, non-dispatchability, and generally negative correlation with system load. Our result implies, however, that far from making highly variable and uncontrollable sources of generation more competitive, storage would in fact better advantage stable and controllable generation. With storage, such sources can be used to continuously and reliably supply the average load at low cost.

When we allow natural gas combined cycle (CC) and open cycle turbines (GT) to be included in the cost minimizing system, the natural gas plants can provide backup for the wind or nuclear plants at lower cost than pumped storage. Overall system

costs are, of course, much lower, especially for recent natural gas prices in the United States, which are very low by historical standards. In fact, the cost of natural gas generation is currently so low that, at a realistic WACC of 7.5%, natural gas prices would need to be more than triple the 2016 average value before any capacity other than CC or GT would be included in the minimum cost system.

At a WACC of 7% or above, the cost minimizing solution over some range of natural gas prices involves wind and natural gas with no nuclear or storage. At still higher natural gas prices, nuclear is added. Eventually, as already stated, once natural gas prices are high enough to eliminate natural gas from the system (except for GT contributing emergency backup capacity), only nuclear and storage remain. The fact that the cost of a wind plus natural gas system is less than the cost of nuclear plus natural gas, but nuclear plus storage is less costly than wind plus storage might appear contradictory. The explanation, however, is that wind needs much more backup capacity than does nuclear. When that backup is expensive storage, the system with wind has higher cost, but when it is less costly natural gas plant, the combined system including wind can have lower cost.

The fact that a wind plus natural gas system includes more natural gas to backup the variable wind output also means that wind capacity is much less effective at reducing natural gas use, and thus emissions, than is nuclear generation. At a WACC below 7%, nuclear rather than wind displaces natural gas generation as natural gas prices rise. Where the transition is from natural gas to wind, the reduction in natural gas use is on the order of 30%, while when nuclear displaces natural gas the decline in fuel use is more like 50%.

A related point is that we find that increases in the cost of natural gas have very little effect on the total amount of fuel used until the price is high enough to trigger the entry of wind, or especially nuclear, generation into the system. A given percentage increase in the price of natural gas raises costs by around 40 times the percentage that it reduces natural gas use.

We also found that wind was included in the minimum cost system for a fairly narrow range of natural gas prices (about 3.15–3.7 times 2016 prices for a realistic WACC of 7.5%). Furthermore, for these prices, constraining wind capacity to zero does not raise total costs by very much. Although it would slightly delay the exit of natural gas capacity from the system, it also advances the use of nuclear. As a result, the ultimate effect on natural gas use and CO_2 emissions (especially cumulative emissions) would be trivial to non-existent.

Finally, we also noted that greater uncertainty about the potential marginal net damage from CO_2 emissions might also favor the use of more nuclear power in the short term by increasing its option value. In particular, if new information reveals a greater urgency to transition away from fossil fuels for environmental reasons, this will be much easier if there is more nuclear and less wind capacity in the system.