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Economics of household wind turbine grid-tied systems for five wind resource levels and alternative grid pricing rates

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ABSTRACT

Households in the USA state of Oklahoma serviced by investor owned electric utilities that have smart meters may select to be charged based on either a traditional meter rate schedule, a smart meter schedule, or they may install a household grid-tied wind turbine and be subject to a different rate schedule. The objective of the research was to determine the economic consequences of installing microgeneration grid-tied wind turbine systems (6 kW; 10 kW) given alternative pricing structures for households at five unique locations with different wind resources. Twenty years of hourly wind speed data, and hourly electricity use data for representative households, were obtained for each location. The annual household electricity cost among the five locations ranged from $894 to $1199 for the smart meter rates and $870–$1191 for the traditional meter rates. The estimated annual cost of $5389 for the least costly household grid-tied 6 kW wind turbine system, is five times greater than the annual cost of purchasing from the grid. If external consequences of electricity generation and distribution are ignored, given current and proposed rate structures and prices, household wind turbine electricity generation systems are not economically competitive in the region.

1. Introduction

Prior to the introduction of rural electrification, windmills used to pump water were common in rural areas of the USA Great Plains. Windmills are still common in remote areas that do not have access to the grid. Wind turbines for electricity microgeneration are manufactured by private companies, and advertised for sale to rural on-grid households in the region. The economics of grid-tied household wind turbine electricity generation systems for the region have not been fully explored. Economics depends on a number of factors for which data are readily available such as investment cost, price of grid electricity, and type of metering system. However, a comprehensive economic analysis also requires information that is more difficult to obtain, such as hourly information regarding site-specific wind speed.

The USA state of Oklahoma is located in the southern Great Plains. The unique Oklahoma Mesonet weather system has recorded 20 years of hourly wind data for more than 100 sites across the state. The geography and climate of the state is quite diverse ranging from an elevation of 110 m, 132 cm of annual rainfall, and average wind speed of 2.8 m/s at Idabel in the southeast, to an elevation of 1267 m, 46 cm of annual rainfall, and average wind speed of 5.5 m/s at Boise City in the northwest [1]. The western half of Oklahoma is located in America's wind corridor [2]. The prevalence of wind inspired the line "… where the wind comes sweeping down the plain …" in the musical play named after the state [3]. Seventeen percent of the electricity generated in the state is produced by large commercial wind turbines [4]. Development of the commercial wind turbine sector has been aided by a state subsidy of $0.005 per kWh produced by systems with rated production capacity of one megawatt or greater [5] and by a federal investment tax credit of 30% [5].

Household wind systems are not common in the state. A 2009 census survey found that 20 Oklahoma farms reported an installed wind turbine for on-farm use [6]. There are about 80,000 farms in Oklahoma [7]. Thus, these data suggest that 0.025% of Oklahoma farms have a farm-based wind turbine system. Some Oklahoma

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farms purchase electricity from rural electric cooperatives. However, much of rural Oklahoma is serviced by investor-owned electric utilities that are natural monopolies. In the USA, rates charged by investor-owned public utilities are regulated by state authorities. The Constitution of the State of Oklahoma provides the Oklahoma Corporation Commission (OCC) with the authority and responsibility to supervise, regulate, and control Oklahoma investor-owned electric utilities [8]. The OCC is charged with the responsibility of insuring adequate service, preventing unfair charges to the public, protecting the utilities from unreasonable demands, and enabling a fair return to investors [9].

Electric meters measure the quantity of electricity removed from the electrical grid at the metered site. Traditional (accumulation) meters measure total consumption and do not provide information of when the energy was used during the time period of interest [10]. Historically, rates approved by the OCC followed from the technical constraint imposed by traditional meters and billing systems. OCC rates approved for one utility to apply to farms and households with traditional meters are shown as alternative I in Appendix A [11]. A fixed price per kilowatt-hour (kWh) is charged independent of the time of day the electricity is consumed. The regulated prices are assumed to be greater than the marginal cost at off-peak load times, and lower than the marginal cost at peak load times.

Introduction of alternative pricing systems to more nearly align prices with marginal costs has been limited by the prevalence of traditional meters [12–14]. Smart meters provide a way of measuring site-specific information, allowing regulators to permit utility companies to charge different rates based on time of use. Different rates for different hours of the day may be used to incentivize reductions in use during traditional peak time periods. Theoretically, smart meters that enable two-way communications between the utility and their customers, facilitate real-time monitoring of electricity flows, and enhance both the technical and allocative efficiency of electricity markets. Smart meters enable the utility to charge different rates for different times of the day. Alternative II rates as shown in Appendix A have been approved for one utility by the OCC [11] for Oklahoma users that have smart meters [15]. Customers that have smart meters may select either the alternative I or alternative II pricing system subject to 12 month contracts that may be renewed each year.

Fig. 1 illustrates marginal costs for hypothetical base load and peak load situations. Base load is assumed to be generated by the lowest cost fuel source, which, in Oklahoma, if externalities including the consequences of carbon released into the atmosphere are ignored, is coal. During hot summer afternoons, for example between 2 p.m. and 7 p.m., when electric powered air conditioners are operating near capacity, electricity use peaks [11]. During the peak-load period, use may exceed base load plant capacity. In Oklahoma, most requirements in excess of base load are generated by natural gas powered plants. If the external consequences are ignored, the marginal cost of using natural gas is greater than the marginal cost of using coal (Fig. 1). For example, in October 2015 the cost of producing one kWh from coal was 61% as much as the cost of producing one kWh from natural gas [16].

The economics of a grid-tied household wind turbine microgeneration system depends in part on the grid electricity pricing structure in effect for the household. Prior to 2014 the OCC required Oklahoma utilities to make net metering available to all customer classes [17]. For net metering scenarios, each rate block during a billing period (assumed to be one month) is treated separately. The consumer is charged for the difference between the total electricity removed from the grid during the block and the total electricity provided to the grid during that block for the month. However, the consumer is not compensated if household production during a block exceeds household use during the same block. The household is charged for the net electricity withdrawn from the grid, that is, the total removed minus the total provided to the grid during the billing period. However, to participate in net metering, the household could be required to provide net excess generation to the grid at no charge [18]. Smart meter (Time of Use (TOU)) net-metering charges to the household are determined by each block (on-peak and off-peak) for each billing period (monthly).

There are several issues associated with net metering that influence aggregate economic efficiency. If households are reimbursed at the full retail rate, the net effect is that on average the utility will pay more for electricity from net metering households than for electricity from power plants. Net metering requires that

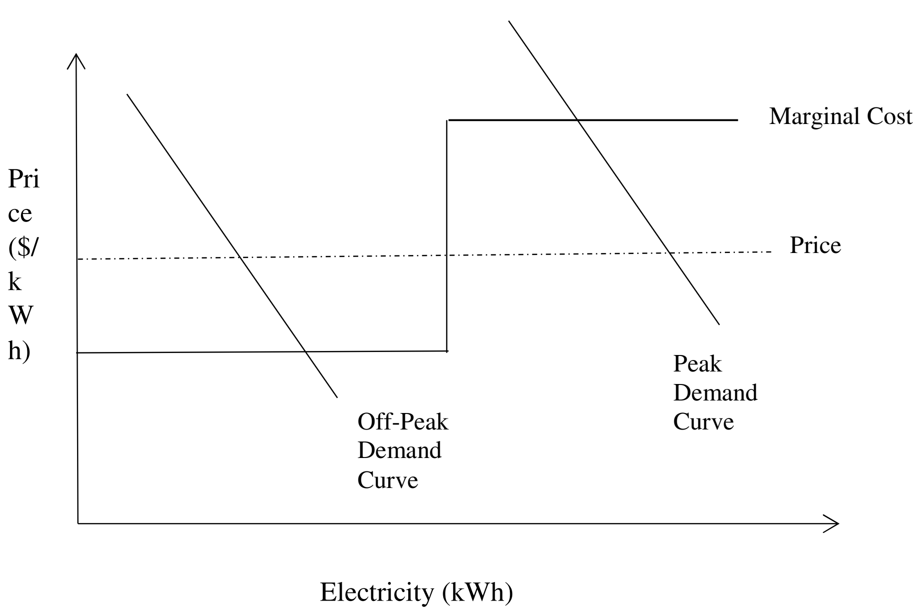

Fig. 1. Household electricity marginal cost, peak demand, and off-peak demand.