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Evaluation of the effectiveness of an energy efficiency program for new home construction in eastern North Carolina

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ABSTRACT

This paper reports on the evaluation of the effectiveness of an energy efficiency program in eastern North Carolina. This subject program is focused on improved construction methods for residential housing. The program incorporates proven energy saving technologies, construction procedures, onsite inspections, and design construction methodologies in new residential construction. The analysis compared the energy usage associated with the houses built in conjunction with the energy efficiency program (test group) with similar new residential construction unrelated to the program (control group). Several statistical methods were employed to establish differences between the energy efficiency program participants and the control group. The analysis provides significant support for the effectiveness of this energy efficiency program and supports the suitability of similar efforts for inclusion in plans for renewable energy offsets and energy efficiency standards.

1. Introduction

Energy efficiency is an important means of realizing the triad of established objectives of energy policy [1] the most immediate direct environmental benefit of improving the efficiency of energy use is a reduction in the use of resources and well as a reduction in the emission of many air pollutants [2]. Approximately 40% of the energy used in the United States is associated with residences and commercial buildings. Recent deregulation of electricity and rapidly increasing demands for energy coupled with reduced supplies has resulted in dramatic increases in energy costs [3]. In recent years many studies have been conducted to evaluate energy savings and energy efficiency programs in the United States, Canada, Japan, Slovenia, India, New Zealand and other countries around the world. Some researchers focused on the commercial energy use while others focused on the residential energy use [4–15], both groups found energy savings associated with implementation of energy efficiency programs. However, in his study Herring [16] has a different opinion and challenges the view that improving the efficiency of energy use will lead to a reduction in national energy consumption, and whether it is an effective policy for reducing the national CO2 emissions.

This study was undertaken to assess the value of energy efficiency initiatives towards meeting a possible renewable portfolio standards (RPS, described below) energy efficiency goal as a result of state legislation. Specifically, the study compared the energy usage of residences constructed under the auspices of a county-centric energy efficiency program for new residential housing to a sample of residences constructed using traditional new residential methods within three surrounding counties. In undertaking this study, the researchers hoped to identify a measure of comparison between one of the regions longest standing residential construction energy efficiency programs and traditional residential construction. Additionally, in undertaking this study, it was anticipated that the results would provide a basis for programmatic efforts of energy conservation serving as a tool to reduce the need for new energy producing infrastructure and reduce related green house gas emissions such as RPS might require.

The country-centric energy conservation program [17] has been in place for thirty years and is currently used by over ninety builders within the test county. In the last year, it has influenced design and construction practices for more than 320 homes. Since its inception the program has been involved with construction of 6275 single family homes, 21 commercial buildings, and 5000 multifamily units. Recommendations are made to constructors based on computer based analysis of parameters such as house orientation, number of windows, total volume, etc., and it also features physical verification of energy efficiency features at several stages during the construction process.

To assess the efficacy of the program and to quantify the impact of the program as a potential RPS offset, the authors gathered and analyzed energy usage data from homes built under the energy

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saving program compared to homes in the region which were built without the benefit of the energy efficiency program. Such a credible and robust study of the possible impact of demand-side management and energy efficiency measures was seen to be an essential tool for formulation of a policy for least cost mix of demand reduction and generation measures needed to supply the customer base consistent with the provisions of the RPS.

2. Background of the study

The residential housing sector is a major energy consumer in most countries. In the United States, this sector uses approximately 21 EJ (Exa = 10^{18}) of site energy per year. This amounts to approximately 20% of all energy used in the nation. Moreover, American households consumed fully 35% of all national electricity production (3660 billion kWh) and strongly depend on natural gas for heating [18–20]. Further, supplying energy to the residential sector in the U.S. generates fully 18% of its greenhouse gas emissions. Despite improvements in refrigerator, furnace efficiency, and insulation technologies as well as on-going improvements to building codes related to energy, many Americans' lifestyle changes have put higher demands on heating and cooling resources. The average U.S. home size has increased significantly, from 139 m^2 in 1970–214 m^2 in 2005 [20]. The two-person household in a large home has become more common, as has central air conditioning: 23% of households had central air conditioning in 1978 and that figure rose to 55% by 2001. Also, miscellaneous electric end-uses in households has been rapidly expanding since 2000, largely offsetting efficiency gains in the conventional end-uses of heating, cooling and water heating [20].

On a national level, the US Department of Energy (DOE) [21] has formulated a National Action Plan for Energy Efficiency that recognizes energy efficiency initiatives as "critically underutilized in the nation's energy portfolio." The DOE plan suggests that energy efficiency is a plausible approach to reducing the demand for new energy infrastructure investments and related environmental and security concerns. The plan recognizes two decades of national experience with efficiency programs that could be broadened and expanded. This National Action Plan has been endorsed by the American Public Power Association [22].

Energy efficiency programs also present an opportunity in relation to the developing renewable energy requirements. The 2007 Annual Energy Outlook, [23] found that since 2006, twenty-three states have adopted a renewable energy program. Ralls [24] reports twenty-eight state renewable programs beginning with Iowa in 1983 with some states having multiple programs that are municipality based. These programs are clarifying what resources qualify and what targets are appropriate for renewable electricity generation or capacity. States such as Nevada and North Carolina are incorporating energy efficiency programs as a part of the state's renewable energy target.

A nationalized approach to renewable energy seems to remain on the horizon per the Energy Policy Act of 2005.

While the US Senate version of energy bill provided specific RPS language, the signed law was free of a national mandate. According to Ralls [24], regional energy interests are best able to evaluate the specifics of an RPS initiative in conjunction with policy objectives and cost-benefit analysis for consumers. With the general intent that the US should provide citizens with reasonably-priced, reliable and sustainable energy and electricity service, a federally mandated program may not be implemented in lieu of flexibility based on availability of diverse renewable sources in the geography of a given region. Consequently, the state or municipal level appear to be the point for initiating and maintaining effective and equitable RPS legislation. Several recent studies have indicated the potential value of including conservation programs as an element of an RPS. La Capra Associates [25] reported that including energy efficiency as an "eligible RPS resource" would "dramatically" reduce the cost of the RPS, i.e., a 25% energy efficiency component would result in a $500 million dollar savings over the cost of a renewable resource supply only. Similarly Givens [26] indicated that including energy efficiency within the RPS will "…reduce the need for new infrastructure such as power plant sites and transmission lines." He further pointed out that energy efficiency has an immediate and continual reduction in CO_2 emissions, i.e., greenhouse gas emissions. Intuitively, cost-avoidance results are a large contributor to the appeal of energy efficiency programs such as RPS. For Givens, RPS-type programs are valuable when sustained and when the standards result in long-lasting improvements to building design, building construction and building maintenance. When energy efficient programs permit reduced energy cost while maintaining existing and even improved levels of service and life style, the goal of energy producers, regulators and environmentalists should be met [23,27]. La Capra [25] anticipates the energy efficiency potential of the state will be sufficient to meet twenty-five percent (25%) of anticipated REPS targets if included in RPS legislation.

3. Sampling methodology

The study was focused on determining the efficacy and influence of the energy saving program benefits (test data) in residential construction as compared to traditional, non-energy efficient construction (control data). Applicable utilities supplied energy consumption data consistent with customer release. Utilities' customers provided data used to derive residential energy efficiency as described below.

Data were collected by means of survey and analyzed using statistical methods of comparison. The baseline or control data points came from three counties in North Carolina that surround the test data county. The control data locations were selected for their distance from the energy efficiency program's sphere of influence (at least one county separation) and data availability. Both the test county and the regional utilities provided electricity usage and supporting information from monthly energy consumption historical records. No within the test county local control group was used in order to avoid data that might reflect any carry-over influences or effects of the energy efficiency program. For example, some influences of the energy efficiency program were thought to carry-over into non-participating residential construction even though the constructors did not formally participate in the program.

Survey questions were developed from the U.S. Department of Energy's residential energy consumption survey [28], and sent by mail to selected houses. The questionnaire contained eleven sections covering the household characteristics, energy usage, fuel type, and house characteristics. These sections of the questionnaire

Table 1
List of survey sections.

1	Household characteristics
2	Basic housing characteristics
3	Kitchen appliances
4	Other appliances
5	Water heating
6	Space heating
7	Air conditioning
8	Quality of construction
9	Solar orientation
10	Home design
11	Miscellaneous