Ground Truth Analysis of North Dakota’s aECI

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This report is one in a series of short ground-truth efforts that seek to understand historical residential sector energy consumption trends observed in state specific simulations using the proposed Performance based State Efficiency Program (PSEP) metric. Initial simulations of the PSEP metric used historical data to estimate the number of years that the state would have made progress with respect to weather adjusted energy consumption intensity (aECI), where progress is defined as a downward slope over the five year period that ends in the evaluation year. Over the period from 1985-2007, North Dakota would not have performed well, with only one progress year detected according to the PSEP methodology (Figure 1).

North Dakota has an abundant supply of low cost energy, and energy efficiency has not been a high priority in the state. The state has historically had very few residential energy efficiency programs and ranked at the bottom of the 2009 ACEEE energy efficiency scorecard. In part due to a lack of interest in energy efficiency, North Dakota has one of the highest rates of increase in their aECI, mostly driven by a steady increase in per capita electricity consumption.

![Figure 1: Map displaying the number of progress years noted for each state from 1985-2007.](image)

Analysis
North Dakota’s Weather Adjusted Energy Consumption Intensity (aECI)


For additional information on the PSEP metric:
NRDC webpage: [http://www.nrdc.org/globalWarming/cap2.0/energybargain.asp](http://www.nrdc.org/globalWarming/cap2.0/energybargain.asp)

2 Unless otherwise stated, the energy data used in this report are from the Energy Information Agency of the U.S. Department of Energy’s State Energy Data System (SEDS).
• North Dakota’s aECI has substantially increased over the period of 1985-2007 with occasional periods of decreased consumption (Figure 2).
• In 1995, the five-year slope of adjusted ECI was negative with 80% significance, signifying a progress year.
• In 1985 and 1994, the five-year slope was slightly negative but did not pass the hypothesis test.

Figure 2: Adjusted ECI for North Dakota from 1980-2007 with progress years noted (top) and the corresponding five-year slope of aECI with 80% confidence intervals (bottom). This index uses state-specific moving average heat rates as described in the PSEP revised methods.\(^3\)

\(^3\) Throughout the report, MBtu represents one million Btu.

\(^4\) The analysis of aECI trends presented in the figure uses state-specific moving average heat rates as described in the PSEP revised methods. HDD and CDD calculations use data from the National Climatic Data Center (NCDC) and assume a base temperature of 65°F; while more accurate base temperatures would be preferable for the analysis, these data are not readily available.
ECI by Fuel Type
The ECI disaggregated by fuel type (Figure 3) clearly shows that residential electricity consumption has steadily increased, while consumption of other energy sources has remained relatively flat. This rise in electricity consumption is the driving force behind the state’s rising aECI.

![Figure 3: Residential ECI in North Dakota by fuel type from 1975-2007](image)

North Dakota has witnessed one of the fastest increases in residential electricity consumption in the country, with an estimated linear increase of 0.7 MBtu/cap/year per year from 1985 to 2007. The following analysis investigates possible explanations for this rise: the lack of electrical efficiency programs, a consistently low price of electricity, a strong economy based in part on energy production, demographic shifts in the state’s population, an increase in electrical heating and cooling appliances, and changes in the state’s electrical grid mix.

Energy Efficiency
Historically North Dakota has implemented very few residential energy efficiency programs. In the past few years, with the help of the 2009 American Recovery and Reinvestment Act, the state has offered an energy efficient appliance rebate program, and three of the state’s 21 utilities and electric cooperatives have begun to offer energy efficient rebate and loan programs to residential consumers. Additionally, a public energy policy commission was founded in 2008 to create a state energy plan, which incorporates goals to encourage energy efficiency and establish a statewide energy building code. These programs and policy

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6 North Carolina State University, “Database of State Incentives for Renewables and Efficiency (DSIRE): North Dakota” reviewed June 2010: [http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=ND](http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=ND)

recommendations offer hope for reduction in energy consumption in the future; however the lack of electricity efficiency programs and priorities prior to 2007 offers a partial explanation for North Dakota’s rapidly increasing residential electricity consumption.

Though North Dakota has not focused on electricity efficiency programs, the Division of Community Services has administered a low-income weatherization program through the DOE’s Weatherization Assistance Program since the start of the program in 1976. Federal funding for the program has steadily increased from $1.7 million in 2001 to $3.7 million in 2009. The weatherization program may have affected electricity consumption and helped to maintain the flat trends in residential use of fuel oil and natural gas; Oak Ridge National Laboratory is currently conducting a full evaluation of the program to assess energy savings.

Electricity Price
The price of energy can affect consumption patterns. North Dakota has one of the lowest prices of electricity in the country. Between 1985 and 2007, North Dakota has witnessed a steady decline in the price of electricity coupled with a steady rise in disposable income (Figure 4). As would be expected, there is a strong correlation between the decreasing electricity prices and the increasing per capita electricity consumption in North Dakota (Figure 5). A study of electricity billing and consumption data performed by Synapse Energy Economics, Inc., shows that in 2007, despite North Dakota residents consuming more electricity per capita than many other states, their average monthly bills and percentage of annual income spent on electricity were equal to or lower than nearly all comparison states (Table 1). Additionally, low energy prices have hindered energy efficiency programs in the state, as many potential electricity efficiency improvements are not economical. Though low electricity prices may not be causing the growth in electricity consumption, they are certainly not limiting the use of electricity.

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9 Personal communication with Bruce Hagen, Residential Energy Specialist, North Dakota Division of Community Services, June 21, 2010.
11 Energy Information Agency (EIA), “Historical 1990 through Current Month Retail Sales, Revenues, and Average Retail Price of Electricity by State and by Sector (Form EIA-826),” downloaded June 2010: http://www.eia.doe.gov/electricity/page/at_a_glance/sales_tabs.html
Figure 4: Indexed trends of ECI, disposable income, housing units, and price of electricity and natural gas in North Dakota from 1980-2007

Figure 5: Per capita electricity consumption versus electricity price adjusted to year 2000 USD.

\[ y = -2.4369x + 99.388 \]

\[ R^2 = 0.6279 \]
Table 1: Comparison of State Residential Electricity Consumption Profiles
(Source: Synapse Energy Economics, Inc)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>North Dakota</td>
<td>7.30</td>
<td>1077.9</td>
<td>$78.70</td>
<td>8,500-10,500</td>
<td>$36,082</td>
<td>2.62%</td>
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<td>South Dakota</td>
<td>8.07</td>
<td>990.7</td>
<td>$80.00</td>
<td>7,000-8,500</td>
<td>$35,760</td>
<td>2.68%</td>
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<tr>
<td>Iowa</td>
<td>9.45</td>
<td>885.5</td>
<td>$83.60</td>
<td>6,500-8,000</td>
<td>$34,916</td>
<td>2.87%</td>
</tr>
<tr>
<td>Minnesota</td>
<td>9.18</td>
<td>832.4</td>
<td>$76.40</td>
<td>8,000-10,500</td>
<td>$41,105</td>
<td>2.23%</td>
</tr>
<tr>
<td>New York</td>
<td>17.10</td>
<td>603.9</td>
<td>$103.30</td>
<td>5,500-9,000</td>
<td>$46,364</td>
<td>2.67%</td>
</tr>
<tr>
<td>Vermont</td>
<td>14.15</td>
<td>592.2</td>
<td>$83.80</td>
<td>7,500-9,000</td>
<td>$37,483</td>
<td>2.68%</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>10.87</td>
<td>724.8</td>
<td>$78.70</td>
<td>7,000-9,500</td>
<td>$36,272</td>
<td>2.61%</td>
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<tr>
<td>California</td>
<td>14.42</td>
<td>579.6</td>
<td>$83.60</td>
<td>1,500-7,000</td>
<td>$41,805</td>
<td>2.40%</td>
</tr>
</tbody>
</table>

Notes:
[1] EIA 2009. Current and Historical Monthly Retail Sales, Revenues and Average Revenue per Kilowatthour by State and by Sector (Form EIA-826)
[2] Residential revenue divided by the number of residential customers in each state. The data are based on EIA 2009.

Economy
Though economic growth and energy consumption in the residential sector are not consistently correlated, the growth in North Dakota’s economy may be contributing to state’s increasing energy intensity. From 1998 to 2008, North Dakota’s GDP steadily increased at an average rate of 3.3%, which exceeds the national average of 2.5%. Recently, a substantial portion of the state’s economic growth is attributed to the development of the state’s energy industry, particularly the production of crude oil, coal and wind power. Though this economic growth would more directly affect the energy consumption of the commercial or industrial sectors, some effects may trickle down to the residential sector, such as increased purchasing power to buy more electric appliances and the electricity to serve them. Additionally with a growing economy fueled in part by energy production, both the cultural pressures and the market incentives to encourage energy conservation are largely absent.

13 Personal communication (email) with Zachary Weis, State Energy Engineer, North Dakota Division of Community Services, August 26, 2010.
15 In a 2009 interview with Forbes magazine, ND governor Hoeven stated, “Our No. 1 focus has been and continues to be economic development. When we came into office at the end of 2000, we started right then with a very aggressive economic development plan . . . We targeted five industries for growth, industries where we have natural advantages in North Dakota: value-added agriculture, advanced manufacturing, technology-based businesses, energy and tourism.” Zumbrun, Joshua, “What’s North Dakota’s Secret?”, Forbes.com, referenced August 2010, http://www.forbes.com/2009/06/30/north-dakota-hoeven-business-energy-economy.html
Household Size
Another driver of the increased electricity consumption could be the drop in household size. Presumably, a household with fewer people would consume more energy per capita than a household with more people. North Dakota has seen a 17% decline in the average household size from 2000 to 2009. The estimated household size of 2.06 people per household in North Dakota in 2009 is substantially lower than the average US household size of 2.38 people per household, and the 17% decline in household size is substantially higher than the national average decline of 10% from 2000 to 2009. This drop in household size may be contributing to the disproportionate rise in electricity consumption in the state.

Urban Population
Another distinct demographic shift in the state has been the transition of much of the rural farming population to the larger cities of Fargo, Bismarck and Grand Forks. Data from the 1980, 1990 and 2000 census reports suggest that the rural population of the state has been decreasing, and the urban population has been increasing, while the total population has remained the nearly the same (Figure 6). Fargo, West Fargo, Bismarck and Grand Forks have all seen substantial population increases; in total from 1980 to 2008, the population of these cities has increased by over 69,000 people (Figure 7). These increases likely account for most of the 88,000 people who have left the rural areas. Though the correlation between an increasing urban population and electricity consumption is unclear, the implied lifestyle changes that may accompany the shift, such as increased use of computers and other appliances, might account for increased electricity consumption.

Figure 6: Rural and urban population shifts in North Dakota from 1980 to 2009

17 Based on the 2000 census and the most recent population estimates for 2009, North Dakota’s population has increased from 642,195 to 646,844 people, while the number of households has increased from 257,152 to 313,332 houses. Dividing the population by the number of households results in an average household size of 2.49 in 2000 and 2.06 in 2009. This represents a reduction of 17% in household size from 2000 to 2009. [US Census bureau, “State and County Quickfacts” Downloaded June 2010: http://quickfacts.census.gov/qfd/states/38000.html]
19 The state’s total population has decreased by approximately 6,000 people from 1980-2008
20 Thomas Brinkhoff: “City Population: North Dakota”, reviewed June 2010: http://www.citypopulation.de/USA-NorthDakota.html (Based on data from US Census)
Age Distribution

An additional demographic shift, specifically an increase in the population’s average age, can increase per capita residential energy use.\textsuperscript{21} This effect is outside the influence of energy policy makers, and it may therefore be reasonable to correct the ECI trend to account for demographic changes in age distribution within a state. An initial analysis indicated that the effect was small in most states and that the demographic age shifts were similar from state to state following a trend that is consistent with an aging baby boom generation. These shifts in the age distribution of North Dakota’s population could account for a 4%, or 0.17 MBtu/cap/year per year, increase in the aECI from 1990-2007 (Figure 8). As the electricity load grows at approximately the same rate as the total aECI, this underlying load growth would result in an increase in residential electricity consumption of approximately 0.10 MBtu/cap/year per year. This demographic driven growth alone could explain approximately one seventh of the estimated 0.7 MBtu/cap/year per year growth in per capita electricity consumption in the state. A correction for the age distribution effect has not yet been incorporated into the PSEP method, but it may be included in a future version of the metric.

\textsuperscript{21} This is based on data analyzed from the Residential Energy Consumption Survey (RECS) database, which can be found at http://www.eia.doc.gov/emeu/recs/. A fuller explanation of the demographic analysis will soon be released in the PSEP final report on our website.
Figure 8: Distribution of North Dakota citizens by age (bottom); relationship between age and dimensionless ECI based on analysis of RECS 2005 data set (top right); impact of changes in the age distribution on ECI (top left) demonstrating that from 1990-2007 ECI would have increased by ~3% entirely due to shifts in the age of the state’s population.

Household Heating Distributions
Increasing electricity consumption could also be due to an increase in electric heating. Based on RECS data from 1993, 1997, 2001, and 2005 for the West North Central Census division (which includes North Dakota), there was both a decrease and a subsequent increase in the number of households reporting that electricity was their primary heating fuel (Figure 9). The RECS data show similar patterns in the primary equipment used for household heating (Figure 10). Between 2001 and 2005, there were increases in central electric furnaces, built-in electric heaters, and portable electric heaters. The net impact of these changes is an increase in electricity consumption, which is consistent with the above fuel type results. Focusing
exclusively on the increase in electric heaters, the impact on primary electricity consumption is roughly estimated to be 0.8 MBtu/cap/year.\textsuperscript{22,23,24} This corresponds to over 100\% of the observed growth in primary electricity from 2001-2005. This appears to overstate the effect that an increased use of electric heaters has on electricity consumption, but it nevertheless highlights the large effect that a relatively modest change in the rate of electric heating can have on per capita electricity consumption. The reason for the overestimate may be linked to the fact that the estimate neglects changes in electricity consumption associated with a switch from other heating systems (e.g. central gas furnaces also use electricity to deliver heated air, so a switch from gas to electricity involves a reduction in electricity for air handling that is not included in our estimate). While an increase in the use of electric heaters could cause a substantial increase in the electricity consumption of the state, a regression analysis showing a weak and slightly negative correlation between electricity consumption and annual heating degree days suggests that year-to-year variations in the demand for heating do not explain much of the electricity use in the state (Figure 11).\textsuperscript{25}

\textbf{Figure 9:} Proportion of households reporting primary heating fuels: West North Central Division (RECS 93, 97, 01, 05).

\begin{itemize}
\item \textsuperscript{22} North Dakota has approximately 300,000 households, from the RECS estimate of heating equipment an increase of 8 percentage points occurred between 2001 and 2005, this corresponds to 24,000 new electric heaters, or ~6,000 per year over four years. According to the EnergyStar Furnace Savings calculator, a furnace with 95\% conversion efficiency would consume about 86 MBtu/year in Fargo. In total, this represents about 0.8 MBtu/cap per year of primary energy consumption.
\item \textsuperscript{23} US Census bureau, “State and County Quickfacts,” downloaded June 2010: http://quickfacts.census.gov/qfd/states/38000.html
\item \textsuperscript{25} Though the total aECI used in the PSEP metric is adjusted for weather (HDD and CDD), the disaggregated energy sources, including electricity consumption, used in this paper’s analysis are not weather adjusted.
\end{itemize}
Figure 10: Proportion of households reporting primary heating equipment: West North Central Division (RECS).

Figure 11: Linear regression between per capita electricity consumption and annual heating degree days\textsuperscript{26}

AC Penetration
Another potential driver of electricity consumption is the adoption of air conditioning. Again, based on the regional data from the RECS 2001 and 2005 surveys, there has been an increase in air conditioner penetration from 91.3% to 95.8% (Figure 12). Based on a rough estimate, the impact is minor in North Dakota. The small increase in air conditioning units would only account for 0.025 MBtu/cap/year, but could

\textsuperscript{26} Degree day data is from the National Climatic Data Center (NCDC): http://www.ncdc.noaa.gov oa/mpp/freedata.html
explain approximately 5% of the witnessed increase in electricity consumption. The minimal effect of air conditioning is further supported by the extremely weak correlation (0.02%) between electricity consumption and annual cooling degree days.

Figure 12: Penetration of air conditioners in residential housing in 2001 and 2005 for the West North Central Census division (Source: RECS).

Grid Mix Shifts
Finally, if the average heat rate for North Dakota were increasing over time, this could explain some fraction of the overall increase in primary energy associated with electricity consumption. The average heat rate did increase between 1975 and 1985; however, since that time, the heat rate has remained relatively flat (Figure 13). In recent years, the state has made considerable efforts to encourage the development of wind energy, which is reflected as a slight decrease in the heat rate starting in 2003. Aside from the largely coal-based grid mix allowing for the production of cheap electricity, the grid mix of the state does not seem to be a driver of the increasing electricity consumption.

27 North Dakota has approximately 300,000 households, from the RECS estimate of AC penetration an increase of 4.5 percentage points occurred between 2001 and 2005, this corresponds to 13,500 AC units, or ~3,375 per year over four years. According to the EnergyStar AC Savings calculator, an AC unit with a SEER (seasonal energy efficiency ratio) of 10 (the low end of efficiency ratings for that period) would consume about 1437 kWh/year in Fargo. In total, this represents about 0.025 MBtu/cap per year of primary energy consumption.
30 Both the data for heaters and air conditioners is regional data; North Dakota could have potentially different trends. Bruce Hagen at the North Dakota Division of Community Service mentioned that he had seen a substantial increase in the number of air conditioners used in North Dakota in recent years. It is likely that the saturation of air conditioners is lower in North Dakota than in other states in the West North Central region, such as Missouri.
**Figure 13:** Grid mix in North Dakota by fraction of total electricity production and dimensionless heat rate; most of the state’s electricity is produced using coal

**Conclusion**

The observed rapid growth in North Dakota’s residential electricity consumption is likely due to a combination of factors. Most prominently, the extremely low cost electricity has made energy efficiency efforts in the state of low priority. Additionally, demographic shifts toward an older and more urban population with smaller household size could potentially increase consumption. Though it is unclear to what extent the use of electric heating equipment has increased in the state, due to the state’s high number of heating degree days, a small percentage change in the number of heaters can affect a large change in the residential energy consumption. The increased use of air conditioners could also potentially contribute to the electricity consumption; however, due to the low number of cooling degree days, a small increase in air conditioning units would not have a substantial effect on the total electricity consumption.

Though North Dakota has historically performed poorly in the PSEP metric, the state has considerable opportunity for improvement. Starting in 2008 and 2009, both the state and the utilities have become more interested in energy efficiency programs, and have both made policy recommendations and enacted appliance rebate programs. Perhaps these and expanded energy efficiency efforts will enable North Dakota to significantly reduce their per capita energy consumption in the coming years.