Envision Charlotte: Billed Electric-Energy Savings and Corresponding Emissions Reductions

Final Report

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Reviewed by Envision Charlotte Measurement Committee

Executive Summary

Between 2010 and 2016, 61 commercial buildings in uptown Charlotte participated in Envision Charlotte. As a part of this effort, all participating buildings received shadow electric meters that were installed in parallel with their actual revenue meters. Data was provided to kiosks in each building as well as to an online portal. Envision Charlotte started to track billed energy[1] savings after Duke Energy had completely installed these shadow meters just prior to the start of Q3 2012. Figure 1 shows the trend in aggregate billed energy from mid-2012 through the culmination of the program at the end of 2016. This graph shows the aggregate energy consumption based entirely on actual site electricity usage as read from the meters. No normalizations or adjustments have been applied. This data is compared to a baseline energy consumption value computed in 2010. Table 1 summarizes the overall change in billed energy consumption, and Tables 2 and 3 present corresponding information about the equivalent number of homes powered and the estimated cumulative reduction in energy bills. Tables 4 through 6 summarize the corresponding emissions reductions.

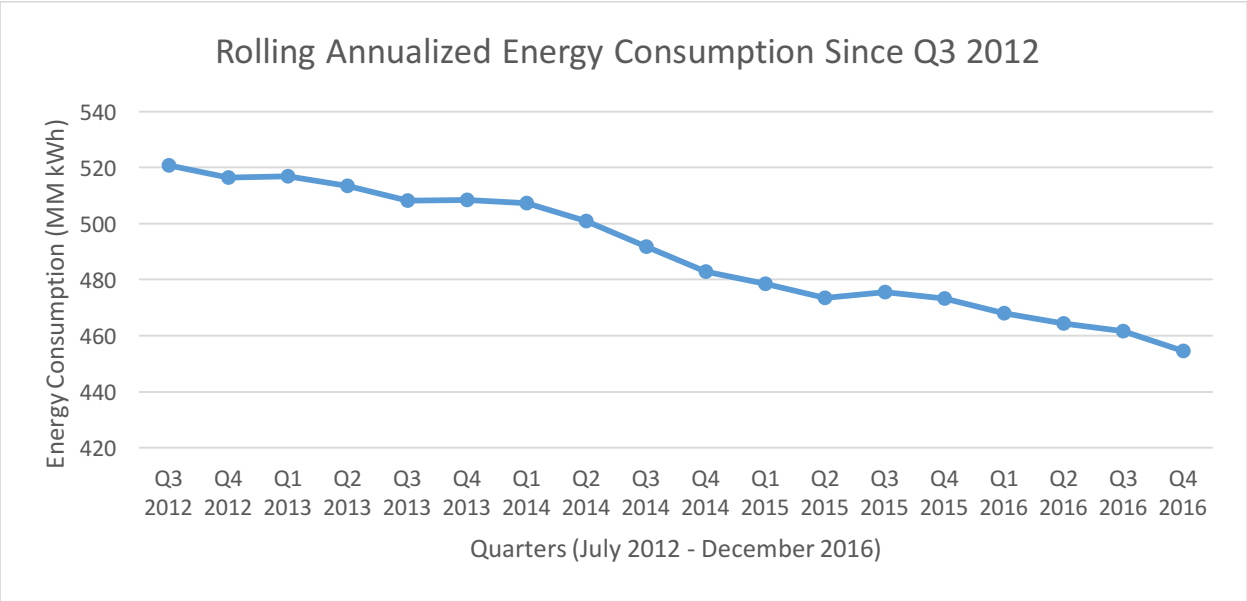

Figure 1: Annualized energy consumption trend for the 61 participating Envision Charlotte buildings throughout the entire program. The dot shown for each quarter reflects the annualized energy consumption in the year ending on the last data of that quarter. Thus, for instance, the value shown for Q3 2012 corresponds to the aggregate energy consumed between October 1, 2011 and September 30, 2012.

[1] Throughout this document, the term "energy" refers entirely to site electric energy consumption.

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Table 1: Billed Energy Savings

Baseline: Billed energy consumption estimated for the 12-month period ending December 31, 2010	562.18 MM kWh
Final: Billed energy consumption estimated for the 12-month period ending December 31, 2016	454.45 MM kWh
Percent reduction	19 %

Table 2: Equivalent Number of Homes Powered[2]

Equivalent Number of Homes Powered Annually	9,964 homes

Table 3: Estimated Cumulative Reduction in Energy Bills[3]

Estimated Cumulative Billing Reduction Since Q32012	$25.74 MM

Table 4: Estimated CO_2 Emissions Reduction Summary

Baseline: CO_2 emissions estimated for the 12-month period ending December 31, 2010	296,830 tons
Final: CO_2 emissions estimated for the 12-month period ending December 31, 2016	239,949 tons
Percent reduction	19 %
Equivalent number of elephants	12,928
Equivalent number of cars removed from the road	11,003

Table 5: Estimated NO_x Emissions-Savings Summary

Baseline: NO_x emissions estimated for the 12-month period ending December 31, 2010	469,154 lbs
Final: NO_x emissions estimated for the 12-month period ending December 31, 2016	379,250 lbs
Percent reduction	19%
Equivalent number of elephants	10

[2] This is the number of homes that could have been powered by the aggregate savings in 2016 alone.
[3] Note that the savings reflected in this analysis resulted from a variety of measures undertaken within the 61 buildings, and thus significant investment was likely required in many cases. Given the nature of this activity, information about such investments is confidential and thus a return-on-investment cannot be computed. Information in the public domain, however, suggests that a number of the 61 buildings invested significantly in energy savings projects during the measurement period.

Table 6: Estimated SO_2 Emissions-Savings Summary

Baseline: SO_2 emissions estimated for the 12-month period ending December 31, 2010	586,092 lbs
Final: SO_2 emissions estimated for the 12-month period ending December 31, 2016	473,780 lbs
Percent reduction	19 %
Equivalent number of elephants	13

Energy-Savings Analysis

In May 2015, UNC Charlotte was requested to prepare energy-savings reports for Envision Charlotte using data provided confidentially by Duke Energy under the terms of an existing Master Research Agreement. With the approval of Envision Charlotte's Measurement Committee, the team compared aggregate billed energy consumption without using any weather or occupancy normalization procedures. UNC Charlotte used the following process:

1. **Baseline Computation:** UNC Charlotte computed the baseline energy-consumption value by summing electric meter data from all 61 participating buildings over a one-year period. This baseline was computed using the same data set utilized for Duke Energy's Smart Energy Now program, with additional billing data for two Duke Energy buildings that were excluded from the Smart Energy Now program.
2. **Reduction Computation:** On a quarterly basis beginning in the third quarter of 2012, UNC Charlotte provided an aggregate energy-consumption value recorded over the previous 12 months for the 61 participating buildings. Prior to Q3 2015, this value was computed using 15-minute interval data provided by Envision Charlotte's shadow meters. Due to communications issues with some of these meters, all analysis from Q4 2015 onward was completed using monthly billing data provided directly by Duke Energy.

Please note the following assumptions:

- **Baseline Data Set:** The original Smart Energy Now data set contains 2010 billing data for only 52 of 61 buildings. The remaining seven buildings have the following anomalies:
    - Two Duke buildings were not included in Smart Energy Now
    - 3 have data sets beginning in February 2010
    - 1 has a data set beginning in December 2010
    - 1 has a data set beginning in January 2011
    - 1 has a data set beginning in September 2011
    - 1 has a data set beginning in January 2012

These minor variations result primarily from factors such as the date upon which the buildings were initially occupied, e.g. the Duke Energy Center and 1 BAC. *To accommodate for these variations, UNC Charlotte has computed an annual baseline value using the first 12 months of available data for each building.* For ease of public communications, the Envision Charlotte Measurement Committee decided to refer to this baseline as the annual energy consumption in 2010. This annualized baseline actually contains values recorded over the following time intervals:

- 54 buildings use data beginning in January 2010 (includes the addition of the two Duke buildings not in the original Smart Energy Now data set)
- 3 buildings use data beginning in February 2010
- 1 building uses data beginning in December 2010
- 1 building uses data beginning in January 2011
- 1 building uses data beginning in September 2011
- 1 building uses data beginning in January 2012

Figure 2 provides a graphical summary.

- **First Comparison of Data to Baseline:** UNC Charlotte began comparing to the baseline in the third quarter of 2012. This decision reflects the fact that Q3 2012 was the first complete quarter in which all of the 61 buildings were officially participating in Envision Charlotte.

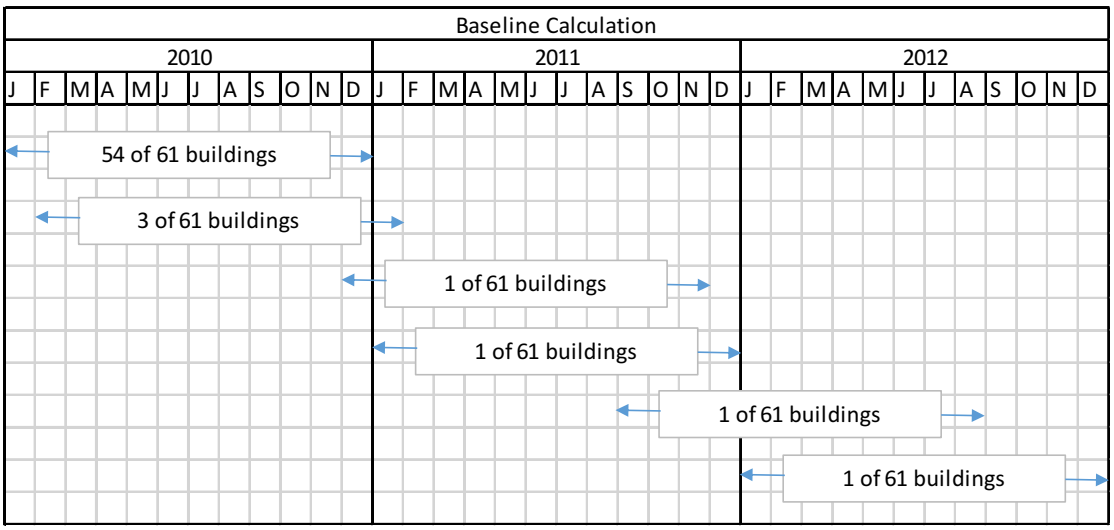

Figure 2: The chart above shows the time period for which data was pulled for each of the 61 buildings when computing the baseline.

Comments on the Sources of Energy Reduction

In the years since the Envision Charlotte project began, the commercial real-estate market in the uptown core has obviously undergone changes. Given the nature of Envision Charlotte, it is impossible for the Measurement Committee to fully understand the multitude of reasons why energy consumption decreased. Certainly, some reduction can be attributed to changes in behaviors by both building operators and occupants, but it is impossible to quantify the precise amount. Furthermore, it is also impossible to quantify the exact impact of various capital improvements made within the Envision Charlotte buildings since confidentiality agreements prevent us from obtaining such information. A search of documents in the public domain shows that several buildings, such as Charlotte's Old City Hall,[4] invested significantly to achieve their savings. In the case of Old City Hall, for instance, the project was financed at least in part using an Energy Efficiency & Conservation Block Grant. It is likely that many buildings made similar investments, but information about private-sector buildings is much more difficult to obtain in the public domain.

It should also be noted that at least two of the 61 buildings experienced material reductions in their occupancy during the course of this study, and these reductions did contribute to the reported savings. Confidentiality agreements, however, do not allow us to disclose their exact contribution to the overall reduction. It should be further noted that other significant changes in occupancy – in either direction – may have occurred during the time frame of this study. Since we can only rely on data available in the public domain, it is impossible for us to account for all of these changes. It is important to note, however, that multiple sources site the steady drop in vacancy rates in Charlotte, which were approximately 7.5% in Q1 2016 after reaching a high of approximately 15% in 2010[5,6]. The consistent rise in occupancy is a trend that traditionally accompanies a rise in energy consumption, and thus this result is extremely encouraging. Anecdotal evidence also suggests that occupant density has increased in uptown Charlotte since 2010, but the author was unable to find a documented source to corroborate this observation.

Comments on the Equivalent Number of Homes Powered Annually

We computed the number of homes that could have been powered in 2016 by the equivalent savings recorded in that year. This was computed by dividing the annual reduction by the electricity consumption in the average American home. According to the EIA[7], the average home used approximately 10,812kWh in 2015. Thus,

[4] http://www2.apwa.net/Documents/Advocacy/APWA%20CASE%20Study%20OCH%20(2).pdf
[5] Cushman & Wakefield Office Snapshot Q12016, http://www.cushmanwakefield.com/~/media/marketbeat/2016/04/Charlotte_Americas_MarketBeat_Office_Q12016.pdf
[6] JLL Skyline, https://skyline.jll.com/
[7] https://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

$$\text{Number of Homes Powered in 2016} = \frac{(562.18 - 454.45)\times 10^6 \text{kWh}}{10{,}812 \text{ kWh/home}} = 9{,}964 \text{ homes}$$

Comments on the Estimated Reduction in Energy Bills

We computed the estimated reduction in energy bills assuming a median utility rate of \$0.073/kWh[8]. The billing reductions are cumulative, and we thus assumed that each building continued consuming the same amount of energy it had in its baseline year. Thus, we determined the cumulative reduction in 2013-2016 as well the reduction in the second half of 2012. As noted previously, this value should be treated at face value. Recall that many of the 61 buildings likely invested heavily to achieve their savings, and thus a more complete economic analysis would examine a weather and occupancy adjusted return-on-investment. We do not have sufficient information to compute such a value. The data does suggest, however, that the commercial real-estate community in Charlotte likely did find good reason to invest in appropriate energy-savings measures.

Emissions-Reduction Analysis

In May 2016, the Envision Charlotte Measurement Committee adopted a procedure for calculating emissions reductions from the energy-savings efforts in its 61 participating buildings. This section describes the process for calculating these emissions reductions.

Calculation Procedure

1. **Baseline Computation:** As described previously, the baseline energy consumption for the 61 participating buildings was 562.18 million kWh in 2010. The corresponding emissions of various gases and particulates can be calculated using rates published in the EPA's comprehensive Emissions & Generation Resource Integrated Database (eGRID). According to eGRID, electricity generation in North Carolina is responsible for producing emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) at the following rates:
    a. CO_2: 1055.9975 lb/MWh
    b. SO_2: 1.0425 lb/MWh
    c. NO_x: 0.8345 lb/MWh

    Thus, energy consumption in the baseline year resulted in the following total emissions:

    a. CO_2: $1055.9975 \frac{\text{lb}}{\text{MWh}} \times 562{,}180 \text{ MWh} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 296{,}830 \text{ tons}$
    b. SO_2: $1.0425 \frac{\text{lb}}{\text{MWh}} \times 562{,}180 \text{ MWh} = 586{,}092 \text{ lbs}$

[8] This is the median rate reported to the author by Duke Energy via email correspondence on March 27, 2017.

c. NO_x: $0.8345 \text{ lb per MWh} \times 562{,}180 \text{ MWh} = 469{,}154 \text{ lbs}$

2. **Reduction Computation:** At the end of the program on December 31, 2016, the energy consumption in the previous 12 months had been 454.45 million kWh. Using the same emissions rates provided above, this consumption resulted in the following emissions:

   a. CO_2: $1055.9975 \frac{\text{lb}}{\text{MWh}} \times 454{,}450 \text{ MWh} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = 239{,}949 \text{ tons}$
   b. SO_2: $1.0425 \frac{\text{lb}}{\text{MWh}} \times 454{,}450 \text{ MWh} = 473{,}780 \text{ lbs}$
   c. NO_x: $0.8345 \frac{\text{lb}}{\text{MWh}} \times 454{,}450 \text{ MWh} = 379{,}250 \text{ lbs}$

   Thus, the emissions reductions between the baseline year and the 12-month period ending December 31, 2016 were as follows:

   a. CO_2: 56,881 tons
   b. SO_2: 112,312 lbs
   c. NO_x: 89,903 lbs

3. **Number of Removed Cars:** To help understand the impact of the avoided CO_2 emissions, UNC Charlotte determined the number of cars that would need to be removed from the road in order to achieve the same emissions reductions. According to the EPA, the typical passenger vehicle emits about 5.17 short tons of carbon dioxide in one year. Given this fact, the total number of cars that would need to be removed from the road in order to achieve the same emissions reductions is calculated as follows:

$$\frac{56{,}881 \; tons}{5.17 \; tons/vehichle} = 11{,}003 \; vehicles$$

4. **Weight of Avoided Emissions:** To help understand the impact of the avoided emissions, UNC Charlotte determined the number of elephants having an equivalent weight. In this case, we computed the number of elephants corresponding to the reductions in CO_2, NO_x, and SO_2, respectively. According to the interpretation of multiple academic publications cited by Wikipedia, the weight of an average adult male Asian elephant is 4.4 short tons (8,800 pounds). This was the value used for our computations. In the case of CO_2 reductions, for instance, we computed as follows:

$$\frac{56{,}881\ tons}{4.4\ tons/\text{elephant}} = 12{,}928\ \text{elephants}$$

Notes and Assumptions

There are several elements to note from the above calculations:

1. Emissions rates were taken from the EPA's comprehensive Emissions & Generation Resource Integrated Database (eGRID). The most recently published eGRID, which uses 2012 data, is available online at https://www.epa.gov/energy/egrid . For specific details, see 'egrid2012_data.xlsx', Tab 'ST12', row 33 for North Carolina specific power plant emission rates.
2. The resource mix for electricity generation in North Carolina (and the United States in general) continues to evolve, with most emissions rates on the decline. New technologies such as scrubbers are also helping to decrease emissions rates. To isolate the effect of Envision Charlotte's activities and to avoid any additional confusion, we have elected to use the 2012 eGRID emissions rates in all published reports.
3. Information about average tail pipe emissions from passenger vehicles is available online from the EPA at the following location: https://www.epa.gov/sites/production/files/2016-02/documents/420f14040a.pdf
4. Information about the average weight of an adult male Asian elephant can be found here:

Disclaimer

All analysis presented herein was performed by researchers at UNC Charlotte using raw data provided confidentially under the terms of a Master Research Agreement signed with Duke Energy. Under the terms of said agreement, Duke Energy allows only publication of aggregate energy information for all Envision Charlotte participants. Duke Energy did not participate in any of the analysis and is not responsible for any results presented herein. Furthermore, it should be noted that Envision Charlotte and Smart Energy Now *are not the same*. As described herein, Envision Charlotte is accounting for all billed energy savings within the 61 participating buildings between the middle of 2012 and the end of 2016. This encompasses far more savings than the behavior-based savings encompassed by Smart Energy Now. Additionally, Smart Energy Now included only data through August 2013 and thus Smart Energy Now entails a far shorter evaluation period. This document does not intend to suggest that the energy savings reported by Envision Charlotte resulted solely from energy efficiency or behavior change; rather, a multitude of factors contributed, and behavior change was one portion of the savings reflected in this report.