EXHIBIT 1

Xcel Energy – Colorado

2017-19 RE-TOU & RD-TDR Study and Evaluation Plan

Introduction

Pursuant to Section VII.E. of the Non-Unanimous Comprehensive Settlement Agreement, Proceeding No. 16AL-0048E (the "Settlement Agreement"), Xcel Energy (the "Company) is submitting a Study and Evaluation Plan ahead of the specified November 15, 2016 date, to interested Pilot and Trial Program Stakeholder Group (the "Stakeholder Group") participants for solicitation of review and feedback.

In the Settlement Agreement, the Settling Parties agreed to the implementation of two new residential time varying rate schedules by the Company in Colorado:

1. **The Residential Energy Time-Of-Use Service Schedule ("RE-TOU") Trial**
2. **The Residential Demand – Time Differentiated Rates Service Schedule ("RD-TDR") Pilot**

These two rate schedules have been approved starting on January 1, 2017, and will be available to residential customers in Colorado starting as early as April 1, 2017, depending on the timing of customer enrollment. The Company is expected to file an Advice Letter on December 2, 2019, which will include results from the RE-TOU trial and is intended to inform the Commission whether the RE-TOU requires modification prior to implementing the final RE-TOU for all residential customers.

Evaluation results from the RE-TOU trial will therefore be a critical input to the Advice Letter and thus, it's imperative that the evaluation design and plan be based on industry best practices, inclusive of lessons learned from previous similar rate designs, and the result of a collaborative effort between the Company and the Stakeholder Group.

In the settlement agreement, parties agreed that "Public Service will pursue similar budgets, marketing opportunities, participant characteristics, and goals for participation of voluntary trial participants in the Schedule RE-TOU service as the Schedule RD-TDR pilot." This document will refer to the RE-TOU as a "trial" and the RD-TDR as a "pilot." Any evaluation activities required by the RE-TOU advice letter timeline will also be mirrored in the RD-TDR pilot. [1]

The purpose of this Study and Evaluation Plan is to:

- Describe the various methods of achieving effective measurement and verification ("M&V") of rate trial and pilot results, including relative merits and risk;
- Discuss the Company's assumptions and analysis; and
- Propose a recommended M&V plan for consideration.

[1] Per the Settlement, Schedule RD-TDR tariff will end January 1, 2022, unless explicitly otherwise changed by the Commission. Schedule RE-TOU does not have an end date, unless explicitly otherwise changed by the Commission. The Company may continue to collect and study data for customers on these schedules beyond the anticipated end date of this Evaluation Plan.

Ultimately, the final Study and Evaluation Plan will serve as the basis for a competitive Request for Proposal, scheduled to be released in November 2016, which will solicit bids from 3rd party vendors to conduct the evaluation activities throughout the life of the trial and pilot.

Study Objectives

It is the intent of this research to:

- Quantify the relative impacts of the RE-TOU and RD-TDR rates on customers' bills as compared to the current R rate;
- Assess impact on the Company's revenue recovery;
- Assess how various customer groups within the Residential class change their consumption behavior in response to the proposed rates. In particular, to understand how their energy use and peak demands change, particularly during summer peak periods;
- Attempt to understand with statistical significance how these rates affect targeted population segments; specifically low income, seniors (65 years of age or older), renters in multi-family buildings, and those with end-use technologies such as solar, electric vehicles, and smart thermostats;
- Analyze how impacts may differ depending on household characteristics such as whether the home is occupied during peak hours, low v. high load factors, geographic location, energy usage, and adoption of end-use technologies such as central air conditioning, storage, electric heat, electric water heaters, as well as others;
- Measure and track customer satisfaction, customer preferences, attitudes, understanding and drivers for participation, as well as customer acceptance;
- Determine participating customer demographics, major household appliances, energy use patterns and other behavioral changes, and technologies adopted to help reduce or shift energy use / bill costs and how these characteristics potentially impact the efficacy of the trial and pilot rates; and
- Reduce sample bias in recruiting, and measure and adjust for any participation sample bias that remains.

Recommended Study & Evaluation Plan Summary

This section provides a summary of the Company's recommended Study and Evaluation Plan. A detailed discussion of the Company's decision process, as well as relative merits, risks, and cost implications associated with different approaches, is included in the Methodology section of this document.

Both RE-TOU and RD-TDR will be voluntary rate schedules. While the Company intends to recruit from a diverse and representative sample of customers, inherently, participating customers are more likely to exhibit characteristics that are associated with early adopters. That is, they're likely to more engaged and informed about their energy bills and household energy usage, and ultimately, may be more willing or able to shift usage to off peak periods as a result of the rates, or have a larger appetite for risk. Savings results from a voluntary rate would thus be expected to be greater than what might be expected from the general population (and what might be expected from the final RE-TOU if deployed to all residential customers as planned in 2019).[2] In order to reduce this bias, the Company suggests recruiting across a wide swath of customers in all regions

[2] Sacramento Municipal Utility District's 2014 SmartPricing Option's study found that TOU impacts were 43% lower when offered on an opt-out basis when compared to opt-in results. The assumption that opt-in impacts are likely to be greater than opt-out impacts is widely supported among time-varying rate literature. See Nexant's 2015 Time-of-Use Pricing Opt-in Pilot Plan for the CA Statewide TOU Pilot Design Working Group and The Brattle Group's *Dynamic Pricing & Demand Response* presentation to the IPU's Annual Regulatory Studies Program (Faruqui, 2016).

and energy usage strata (with different geographies and energy usage strata receiving equal levels of encouragement) and also recruiting intensely within distinct customer populations to maximize the chances that a greater cross-section of customers will volunteer. Additionally, the Company may investigate methods for extrapolating trial and pilot results to a larger population.

To estimate energy and bill impacts for all non-solar customers,, the Company recommends utilizing a randomized post-enrollment approach for control group assignment to minimize voluntary bias and reduce differences between test and control groups. Maintaining similar test and control groups will be critical since rate trial and pilot impacts will be assessed by comparing energy usage, peak demands and bill savings between the two groups.[3]

To assign customers to the control group, the Company recommends utilizing a "recruit & deny" approach. After customers have opted to enroll in the rate, control group participants will be randomly selected and denied participation in the trial and pilot until the end of the trial/pilot period. Control group customers will receive a bridge interval meter, but not the rate. Additionally, the Company recommends utilizing incentives to encourage participation in subsequent surveys, which will be important to track changes in household appliance / technologies saturation and/or energy behavior changes. The method and frequency of incentives will be finalized after the selection of a 3rd party evaluation vendor.

Per Section II.A.1 and II.B.1 of the Settlement of the 2017-2019 RE Plan (Proceeding No. 16A-0139E), under Option B of the Small Solar*Rewards Program, capacity and REC incentives will be allocated to customers under the RD-TDR pilot. Thus, a post-enrollment control group selection approach won't be possible for new solar customers interested in enrolling in the RD-TDR. An alternative design must be considered for RD-TDR solar participants.

The Company proposes to utilize a pre-enrollment matched control group approach for new solar RD-TDR customers where a new solar customer who chooses to enroll in the RD-TDR will be matched with a new solar customer (who turned down participation in either the RE-TOU or the RD-TDR) based on PV system size, pre-enrollment monthly energy use, and household characteristics. This matched solar customer will then be assigned to the RD-TDR solar control group.

Similarly, both new and existing solar customers who sign up for the RE-TOU will be matched with a corresponding new or existing solar customer, based on PV system size, pre-enrollment monthly energy use, and household characteristics. While a "recruit & deny" approach would be possible for RE-TOU solar customers, the Company recommends using the same matched control group design as is being used for RD-TDR solar customers to be able accommodate as many solar customers as possible, and to ensure results between RD-TDR and RE-TOU solar customers are comparable.

Rate Descriptions

The following section describes the trial and pilot rates, as outlined in the Settlement Agreement (unless otherwise noted), and provides the baseline parameters for subsequent trial and pilot design features.

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[3] The fundamental statistical approach to quantifying the effect of participation on an outcome is to compare the average change over time in the outcome variable for a treatment group (those participating in the new rate) with the average change over time for a control group (those not participating in the new rate). The efficacy of the study is dependent on both the ability to control for differences between the treatment and control groups and how the groups are selected.

Participation

Participation in both rates will be voluntary and each participant will receive a "bridge meter" that will allow the Company to measure electric usage on a 15 minute basis.

Participants are allowed to opt-out of either rate prior to the end of the seventh billing cycle, after which point they must participate for a minimum period of 12 consecutive months, unless service is no longer required by the customer.

Residential Energy Time-of-Use Service Schedule (RE-TOU)

The RE-TOU rate schedule is structured as three different time periods with a differential between the summer and winter rate schedules. The summer period is defined as June through September and the winter period is defined as all other months. Table 1 and Table 2 show the time periods included in the tariff as well as the proposed rates.

Table 1. RE-TOU Time Periods

	Time
On Peak	2 PM through 6 PM MT (weekday, non-holiday)
Shoulder	9 AM through 2 PM and 6 PM through 9 PM MT (weekday, non-holiday) and between 6 PM and 9 PM MT (weekends and holidays)
Off Peak	9 PM through 9 AM MT

Table 2. RE-TOU Rates

	Summer	Winter
On Peak	$0.13814	$0.08880
Shoulder	$0.08420	$0.05413
Off Peak	$0.04440	$0.04440

Note: Rates shown are energy only, exclusive of fuel and rider costs.

The RE-TOU trial customers will be capped at 30,000 participants over a three year period starting in 2017 through 2019 as shown in Table 3. [4]

Table 3. RE-TOU Trial Participation Goals and Caps by Year

Cumulative Number of Participants	2017	2018	2019
Goal	10,000	14,000	18,000
Cap	10,000	20,000	30,000

Residential Demand - Time Differentiated Rates Service Schedule (RD-TDR)

The RD-TDR is a demand rate with a differential between the summer and winter rate schedules for the Generation and Transmission demand component of the rate structure. The summer period is defined as June through September and the winter period is defined as all other months. Billing demand for the Generation and Transmission Demand Charge will be the measured hourly demand used between 2:00 pm and 6:00 pm Mountain Time on all non-holiday weekdays. Billing demand for the Distribution Demand

[4] This cap limits the number of customers who can participate in Schedule RE-TOU using bridge meters on a trial basis.

Charge shall be the measured hourly demand used at any hour during the month. Table 4 shows the proposed rates.

Table 4. RD-TDR Rates

	Rates
Distribution Demand	$3.65
Generation & Transmission Demand – Summer	$9.73
Generation & Transmission Demand – Winter	$6.81
Energy Charge per kWh	$0.00461

Note: Rates shown are energy only, exclusive of fuel and rider costs.

The RD-TDR will be capped at 18,000 participants over a five year period starting in 2017 through 2021 as shown in Table 5. Unless expressly changed by the Commission, this pilot will terminate on January 1, 2022.

Table 5. RD-TDR Pilot Participation Goals and Caps by Year

Cumulative Number of Participants	2017	2018	2019	2020	2021
Goal	10,000	14,000	18,00,0	NA	NA
Cap	10,000	14,000	18,000	18,000	18,000

Targeted Participants[5]

In addition to seeking voluntary participants from a diverse and representative sample of the population (across geographic regions and varying levels of energy usage), the Company also plans to actively enroll participants in the following specific segments:

1. **Low income segments** – In order to identify how these rates may potentially impact this subset of the population, the Company will study a segment of the low income population. Low income participants will be limited to 500 customers per rate and will be subject to a "hold harmless" provision such that the customer will pay no more than the lower of the same customer's bill under either of the rate schedules or the current R rate schedule.
2. **Solar customers** – Pursuant to Section 5 of the Settlement Agreement, excess energy production from solar customers will be treated differently under the RE-TOU rate. Additionally, solar customers taking the RD-TDR pilot rate under the Solar*Rewards Option B will be allocated 51 MW over the 3 year period according to the schedule shown in Table 6. [6]

Table 6. Solar*Rewards Option B (RD-TDR) MW Caps by Year

	2017	2018	2019
Annual Capacity	9	18	24

[5] The Company was asked to consider including a separate sample target bucket for households that are occupied during peak hours. Company research indicates that a large majority of households will fall into this category and thus, it's reasonable to assume statistically significant results can be achieved for this segment utilizing customers recruited from other targeted customer segments (particularly the All Others category which the Company has expanded for the RE-TOU specifically to ensure this segment is captured sufficiently). See the Target Sample Section for more detail.

[6] Allocated capacity not used for Schedule RD-TDR in any year will roll over for general Solar*Rewards availability.

3. **Smart Thermostats** –Smart thermostats can be programmed to reduce and/or shift HVAC energy usage from on-peak to off-peak periods, and thus provide a potentially valuable benefit to customers on the new rates and lead to greater savings impacts.
4. **Electric Vehicle (EV) owners** – The Company believes this segment will be likely to achieve sizeable savings on either the RE-TOU or RD-TDR if they're able to shift charging to off-peak periods. It will be critical to understand exactly how and to what extent these price signals affect behavior change and what the implications are for larger grid reliability and operations. Due to the relatively small EV market in Colorado, the Company will limit EV participation targets to 500 per rate and control group.
5. **Senior Citizens (65 years of age or older)** – Senior citizens, similar to low income customers, are another potentially vulnerable group—many of whom live on a fixed income—and may be unable or unwilling to shift electricity consumption to off-peak periods. This group also may be less familiar with, willing, or able to acquire new technologies that could assist them in controlling their usage. It will be important to understand the extent to which this group may experience hardship under either of the two rates to inform long term rate design.
6. **Renters** – Renters may be less likely or unable to change behavior due to the lack of adequate economic incentives to invest in new household technologies to shift consumption to off-peak periods and/or uninterested in changing behavior if landlords cover utility costs. In the latter case, a TOU or demand charge price signal could be dampened or ineffective. Without changing energy behaviors, customers could see bill increases. It will be important to study the extent to which customers in these situations respond to price signals. [7]

Methodology

The following section describes various methodological considerations and approaches to accurately quantifying change in energy usage and peak period impacts over a specified pricing period, as well as the Company's recommendation for the evaluation approach to the RE-TOU and RD-TDR rates.

Self-Selection Bias

Both the RE-TOU and RD-TDR will be voluntary rates. While the Company intends to recruit from a diverse and representative sample of customers, inherently, participating customers are more likely to exhibit characteristics that are associated with "early adopters." That is, they're likely to more engaged and informed about their energy bills and household energy usage, and ultimately, may be more willing or able to shift usage to off peak periods as a result of the rates, or have a larger appetite for risk. The potential predisposition inherent in groups that are opting in or volunteering for participation can be referred to as self-selection or voluntary bias. Changes in energy usage from a voluntary rate would thus be expected to be greater than what could be expected from the general population (and what could be expected from the final RE-TOU if deployed to all residential customers in 2020).

There are several approaches to addressing this potential voluntary bias:

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[7] Given that several populations including but not limited to low income, seniors and renters may be groups that could be difficult to reach and with whom to communicate, the Company may also consider testing the efficacy of various levels of encouragement, education, and communication strategies to determine the optimal approach for minimizing potential harm and/or maximizing energy saving behavior changes.

1. **Monetary incentives**. Customers who don't typically exhibit "early adopter" behavior, and thus represent a wider swath of the overall population, may be incentivized to participate with a monetary reward. These incentives could be provided either upfront at the time of sign up or throughout the study period in incremental payments during the study, paid after completion of study milestones such as customer surveys, or some combination.[8] However, previous studies have shown that the significant costs associated with this approach don't always lead to increased participation.[9] Furthermore, providing an initial sign up incentive may risk reducing the effectiveness of the rate price signals (i.e., customers may feel as though they've already gained enough from the incentive that they either don't care as much about saving more or potentially paying more).
2. **Bill protection**. This approach would guarantee customers the lower of either their bill under the new rate or what it would have been otherwise on the current R-rate.[10] This is the approach agreed to in settlement for low income participants. While customers might be more willing to sign up because of the reduced exposure to risk, similar to the issue with providing monetary incentives, this may simultaneously reduce the efficacy of the rate price signals. One approach to mitigating this reduced price signal is to offer bill protection for a longer period, such as on an annual rather than monthly basis.[11]
3. **Diverse and Intense recruitment**. Ensuring that recruitment is evenly distributed across both geographic regions and those with varying levels of energy usage will maximize the possibility of encouraging adoption across a diverse population representative of the overall customer base. Additionally, the more intensely a given customer sample is recruited (i.e., in the form of marketing outreach such as emails, bill onserts, etc.), the more likely customers who aren't usually early adopters will be to sign up for the rates.
4. **Extrapolation of results.** There are a number of previous TOU studies where participation was mandatory[12] for a representative sample of customers. While there may be differences in geographical and customer / household characteristics, these previous findings can be utilized in conjunction with study results to adjust the results of the study such that inferences about projected savings can be made for a more diverse distribution of customers.

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[8] Pacific Gas & Electric used large monetary incentives (~$200) to recruit a representative sample of customers into its 2015 TOU Pilot Rate.

[9] Sacramento Municipal Utility District's 2014 SmartPricing Options Pilot found that the offer of an In-Home Device (with some implicit monetary value) resulted in only a slight impact on acceptance rates and that choice models estimated that these impacts were not statistically significant.

[10] Focus groups conducted to pre-test the launch of Southern California Edison's (SCE) 2016 TOU Pilot found that customers perceived risk of higher bills under the TOU rate plan and that bill protection was viewed as a more effective measure than monetary incentives to mitigate their concerns. Thus, SCE utilized bill protection, instead of monetary incentives to encourage pilot participation. Pacific Gas & Electric and San Diego Gas & Electric also provided bill protection in their pilots.

[11] Oklahoma Gas & Electric's 2011 TOU Pilot utilized annual bill protection as a way to encourage participation and mitigate price dampening.

[12] Sacramento Municipal Utility District's 2014 SmartPricing Options Pilot included default rate options. Opt-out rates over the two year study period were relatively low, ranging from 4-7.7% and customer acceptance was high (92.9%-97.8%).

Recommendation:
Given that monetary incentives and bill protection may potentially reduce the effectiveness of the pilot price signals in the tested rates, the Company recommends addressing voluntary bias for non-low income participants by recruiting across a wide swath of customers in all regions and energy usage classes (with different geographies and energy usage stratas receiving equal levels of encouragement) and also recruiting intensely within distinct customer populations. Additionally, the Company recommends potentially investigating methods for extrapolating study results to a greater population, but any such extrapolation will ultimately be left to the discretion of the chosen vendor. Any extrapolation that occurs will also include a narrative explaining any limitations in using such a technique. For low income participants the company will offer bill protection and recommends recruiting intensely within set customer samples.

Experimental Design & Analysis

The fundamental statistical approach to quantifying the effect of participation on an outcome is to compare the average change over time in the outcome variable for a treatment group (those participating in the new rate) with the average change over time for a control group (those not participating in the new rate). The efficacy of the study for conclusions on energy savings and bill impacts is dependent on both the ability to control for differences between the treatment and control groups and how the groups are selected. Other elements of the study, such as customer understanding and acceptance of the rate designs, do not require comparison to control groups to draw conclusions.

The following are several methods for controlling differences between treatment and control groups:

1. **Randomized Control Trial (RCT).** RCTs are widely recognized as the industry best practice standard for experimental design, within both the wider research community and the community of those that study time varying electric rates.[13] A random sample minimizes bias and allows for simplified administration and group assignment. Control group allocations are made after customers have tried to voluntarily enroll in the rates. Those assigned to the control group are either denied or delayed participation. This approach ensures that the treatment and control groups are likely to be comprised of customers who volunteered to participate in the study thus provide comparable results.

   The drawback to post-enrollment selection of control groups is that it may cause potential customer dissatisfaction. Customers may react negatively to losing a perceived opportunity for bill savings as a function of being placed in the control group.
2. **Quasi-Experimental Matched Control Groups**. This approach can be used when randomization is not feasible or reasonable. The goal of the method is to reduce bias due to pre-enrollment existing differences by matching each participant with a control customer based on known characteristics (such as energy use, PV system size, load shape, demographics, etc.). While this method can result in a very close match in pre-enrollment characteristics between treatment and control groups, the match based on unmeasurable characteristics (such as propensity to volunteer for a new rate being studied) remains unknown. The impact of these unmeasurable characteristics on the results is difficult to assess, since the differences can't be quantified. This option will not result in as robust results as an

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[13] Cappers, Peter, Annika Todd, and Charles Goldman. *Smart Grid Investment Grant Consumer Behavior Study Analysis: Summary of Utility Studies.* Lawrence Berkeley National Laboratory, 2013.

RCT, but is the best option for any situation where the control group has to be selected from a pool of customers who chose not to participate.[14]

3. **Randomized Encouragement Design (RED).** In this design, customers are selected randomly from the same population and some are offered participation while others aren't. Participation isn't expected from all customers but those who are offered the option to participate are considered to be in the treatment group. The control group is made up of customers who received less encouragement or no encouragement. Initial savings are calculated by comparing the change in usage between the treatment and control groups, and reflect a weighted average of those who participated and those who declined participation. Later stage savings are determined only for those who participated.[15] Both the RED and the RCT control for selection bias and allow for estimation of effects of those who participated; however, as the name suggests, in the RED, the behavior of randomly-chosen groups who were subjected to different levels of encouragement to participate can be observed. Testing different levels of encouragement is not a main objective for the Company's test; thus, the RCT is considered the more appropriate approach in this case. Additionally, RED designs typically require high acceptance rates in order to be effective, which may or may not be expected for the Company's voluntary rates.
4. **Difference in Differences.** This analysis approach is a widely used and relatively reliable method of quantifying change in energy usage and peak period impacts over a specified pricing period while controlling for pre-study differences. Savings are approximated based on a direct comparison of treatment and control groups during the participation period and for a time before participation (the "pre-study" period). This method allows for the calculation of the differences in energy use corrected for any pre-existing differences between the treatment and control groups. Unfortunately, due to the lack of residential interval metering, the Company won't have access to pre-study interval data[16] which limits the effectiveness of utilizing a Difference in Differences approach.

Recommendation For Non-Solar Segments:
Utilize a randomized control trial with a post-enrollment assignment where customers are recruited to participate in either the RE-TOU or the RD-TDR, and then randomly assigned to the control group. This approach eliminates any bias in the estimation of impacts from systematic non-measureable differences between test and control group.

Recommendation for Solar Segments:
Per Section II.A.1 and II.B.1 of the Settlement of the 2017-2019 RE Plan (Proceeding No. 16A-0139E), under Option B of the Small Solar*Rewards Program, capacity and REC incentives will be allocated to customers under the RD-TDR pilot. Customers who sign up for the RD-TDR will be receiving a REC incentive specifically designed for that rate. Randomly selecting these customers to be part of a control group and thereby changing the financial dynamics of their contracts, including Solar*Rewards REC incentive,

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[14] Marrin, Kelly and Craig Williamson. "Matched Control Group Methods: What's your propensity?" WLRA Spring 2013 Conference, Boise, ID.

[15] Sacramento Municipal Utility District's SmartPricing Options Pilot utilized a RED to determine impacts for opt-out TOU pilot groups and all CPP pilot groups.

[16] The majority of Xcel Energy customers in Colorado have AMR meters which only provide aggregated monthly usage data, not interval data which is necessary to calculate peak demand savings.

won't be possible under the current settlement agreement. Thus, a post-enrollment control group selection approach won't be possible for new solar customers interested in enrolling in the RD-TDR. An alternative design must be considered for RD-TDR solar customers.

The Company proposes to utilize a matched control group approach for new RD-TDR solar customers where a new solar customer who chooses to enroll in the RD-TDR will be matched with a new non-participating solar customer (who elected to stay on the R rate) based on PV system size, pre-enrollment energy use, and household characteristics. This matched solar customer would then be assigned into the control group. In order to ensure that test and control groups are as similar as possible, the Company recommends that RD-TDR matched control group customers be recruited from *new* solar customers only, since it's possible that existing solar customers may differ from new solar customers.

Similarly, both new and existing solar customers who sign up for the RE-TOU will be matched with a corresponding new or existing solar customer, based on PV system size, pre-enrollment monthly energy use, and household characteristics. While a "recruit & deny" approach would be possible for RE-TOU solar customers, the Company recommends using the same matched control group design as is being used for RD-TDR solar customers to be able accommodate as many solar customers as possible, and to ensure results between RD-TDR and RE-TOU solar customers are comparable.

Table 7 illustrates how solar customers will be recruited and allocated in either rate.

Table 7. Solar Customer Sample Design

	Recruiting Pool	Control Group Allocation
RE-TOU	New & Existing Solar Customers	Matched
RD-TDR	New Solar Customer Only	Matched

While there may be some differences between solar customers who sign up for the rates and those who don't (i.e., self-selection bias), this will be mitigated by the matching process to some extent. We can also assume that solar customers as a whole are by definition early adopters (more willing to take risks, engaged with their energy use, etc.) and that the self-selection bias is smaller when compared to the overall differences between solar customers and the general population. Thus, considering the limitations of the solar decision making process described above, the Company believes this to be a reasonable approach.

Control Groups Considerations For Non-Solar Customers[17]

In a post-enrollment control and test group assignment scenario (as described in the proceeding section, above), some prospective customers who are interested in enrolling in the trial or pilot are assigned to the control group instead. Control group assignees will be provided a bridge meter to enable the Company to track their interval energy use (and build a baseline to compare against the treatment groups

The following are several methods for handling control group assignments:

1. **Recruit & Delay.** Those customers who are randomly assigned to the control group are told that they can participate in the rate, but their participation will be deferred. This approach retains the benefits of the RCT design, eliminating any bias due to differences between the test and control

[17] Solar control groups will be matched to solar test groups and provided bridge meters. Customer appeasement won't be necessary, as with other control group customers under the post-enrollment selection approach.

groups, but can mitigate negative customer reactions to not being allowed to participate. This approach works best when the delayed participation is for the duration of the study, but for this three year study, that would not be feasible – a deferral of one year might be the most customers would probably be willing to accept. A significant drawback to this deferred enrollment is that it will likely entail significant administrative efforts to ensure that the control group is consistently being replenished when control customers eventually roll onto the rates. It also does not necessarily eliminate potential customer dissatisfaction[18], since many customers would have to wait. Tracking and managing this flow of participants will be critical to ensure participation stays under the allowed rate enrollment caps, particularly towards the end of the study. Additionally, this method may increase the risk of potentially reducing the robustness and consistency of the control group data, or introducing new potential for bias (say, if customers recruited in the later years are different than customers recruited in earlier years).

2. **Recruit & Deny.** This approach would simply deny customers enrollment and place them in the control group.
3. **Recruit & Deny and provide incentives.** Customers are denied enrollment, recruited into the control groups, and provided monetary incentives. Presumably, if customers are volunteering to participate, they believe they can benefit by shifting energy usage and realizing cost savings. Providing monetary rewards could help offset the perceived loss in potential savings.

Recommendation For Non-Solar Segments:
The Company recommends utilizing a recruit & deny approach. After customers have opted to enroll in one of the rates, control group participants will be randomly selected and denied participation in the rates until the end of the trial/pilot period. While customers could react negatively to losing out on potential savings, with no potential risk for losses, the Company believes that most would be willing to understand the necessity of a control group in conducting any trial and/or pilot and accept control group participation.[19] However, the Company recommends utilizing some method and frequency of incentives to encourage participation in subsequent surveys, which will be important to track changes in household appliance / technologies saturation and/or energy behavior changes.

Sampling Plan

Power Analysis[20]

Power refers to the likelihood of finding statistically significant savings when savings actually exists and depends on the level of confidence, magnitude of the savings, and inherent variability in the energy usage

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[18] Sacramento Municipal Utility District's (SMUD) 2014 SmartPricing Options Pilot found that satisfaction ratings for respondents in the deferred pilot control groups were equal to or greater than satisfaction in the control group (i.e., the recruit and delay method did not in some cases negatively impact satisfaction with SMUD services).

[19] In late October, the Company fielded a survey with 401 residential Xcel Energy customers in Colorado and asked them how they would react to being placed in a control group. Results indicate that 6% would be angry; 2% would be angry and take no action; and 4% would be angry and call to complain.

[20] The Company contracted with DNV GL (an independent consulting firm) to conduct a statistical power analysis or hypothesis test across the targeted customer segments in order to determine target sample sizes. A full description of this analysis is included as Appendix A.

data. This section focuses on the Company's methodology and assumptions used to determine the latter two concepts, in order to determine the appropriate sample size.

If an energy usage dataset has significant variability, and a relatively small expected savings due to rate participation, large sample sizes would be required to determine with certainty that savings can be attributed to the test, and not just noise (variability) in the energy usage data. Alternatively, if an energy usage dataset is relatively uniform (i.e., low variability), and a relatively large change is expected due to rate participation, smaller sample sizes would be necessary to attribute savings to rate participation.

To study the impact of the RE-TOU, the dataset of most interest is the average summer weekday daily on-peak energy used between 2:00 pm and 6:00 pm on non-holidays from June through September. To determine effects of the RD-TDR, the dataset of most interest is the maximum demand during summer weekdays between 2:00 pm and 6:00 pm on non-holidays from June through September.[21]

Mean & Variance

The Company plans to actively enroll participants in the following specific segments: low income, enabling technology, EV owners, private solar adopters, seniors, renters, and the general population. The following describes how data was gathered for each segment to determine energy usage mean and variance.

- For non-EV and non-solar segments, DNV-GL used the Company's existing residential load research sample[22] to calculate the mean and variance for both the average summer weekday on-peak energy and the system peak hour demand.
- For the EV population, a sample of 20 customers with residential EV charging data was utilized.[23] Unfortunately, EV load data was only available for the vehicle charging, and did not include interval data for the rest of the house. Because mean and variance estimates that are inclusive of the load for the whole house were needed, we combined the means and variances for the charging loads with the means and variances from the load research sample. While this does not specifically reflect the energy use of customers with EV charging, it is a reasonable proxy for what typical household loads would be if EV charging was added, particularly for an energy measure that is averaged across the four months.
- For solar customers, DNV-GL used the Company's existing residential solar load research sample.[24] This includes two pieces of load data: (1) the amount of solar energy generated on one channel; and (2) the net load delivered to or from the Company's system. The underlying load for these

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[21] For the purposes of the power analysis, DNV GL focused on summer weekdays between 2:00 pm and 6:00 pm on non-holidays from June through September. However, the Company will also be interested in studying impact on overall demand and energy use regardless of time period.

[22] As part of ongoing load research efforts, the Company maintains a representative sample of Colorado customers that have meters that collect interval data. This is a randomized sample that is stratified by energy usage and weighted by each stratum's representativeness in the overall population.

[23] In 2013, the Company conducted an Electric Vehicle Demand Response Pilot in Colorado with 20 customers which allowed for the collection of residential charging load interval data.

[24] Starting in 2015, similar to ongoing load research efforts, the Company started collecting interval data to study a representative sample of Colorado solar customers. This solar sample employs the same stratified random sample design used in the general population load research sample.

customers is the amount of solar generated minus the amount delivered to or from the Company's system, calculated in each hour. So for this population, DNV-GL used the mean and variance of the net load.

Expected Savings Size

A critical component of determining target sample sizes, is estimating what the expected savings size will be. There are a number of TOU studies performed by other utilities from which we can benchmark and determine an appropriate estimate of the expected reduction for the RE-TOU. Expected peak reduction is assumed to be a function of the ratio of peak to off-peak prices.[25] Xcel Energy's peak to off-peak price ratio, including fuel and riders is roughly 2.3. The average peak reduction achieved in studies performed in the United States (shown in Table 8) that had peak to off-peak ratios of 2.0 to 2.5, is 7.8%. Thus, the Company believes that 7.8% is a reasonable estimate for what the RE-TOU may achieve for those without enabling technologies. The average peak reduction achieved in studies that had In-Home Devices ("IHDs") or enabling technologies was 11.0%. The Company believes this to be a reasonable estimate for what the RE-TOU may achieve for those with smart thermostats.

[25] This relationship, or degree of substitution, between demand response in two pricing periods in response to a change in the ratio of on peak to off peak prices is called in some TOU studies the *elasticity of substitution*. It is often used as a parameter in other models of customers demand for electricity such as: the Constant Elasticity of Substitution (CES) used in the California Statewide Pricing Pilot and others; or the Addilog demand model used in the evaluation of TOU pricing in Ontario Canada.

Table 8. Energy TOU Rate Designs and Achieved Peak Reduction

Utility (Year of Study)	Type of Enrollment	Peak Hours	Peak / Off Peak Price Ratio	Peak Reduction
Ontario, Canada (2015)*	Default	12-17	1.5	3%
PECO (2015)*	Opt-in	15-18	1.7	6%
PG&E TOU (2015)	Opt-in (E-6)	13-18	2.0	15%
Statewide Pricing Pilot (2005)**	Opt-in	15-19	2.0	5%
SMUD SmartPricing (2015)***	Opt-in, IHD offer	17-19	2.0	12%
SMUD SmartPricing (2015)***	Opt-in	17-19	2.0	9%
SMUD SmartPricing (2015)***	Default, IHD offer	17-19	2.0	6%
Connecticut (2014)	Opt-in	13-18	2.0	3%
Xcel Energy (2013)	Opt-in	14-20	2.5	7%
Xcel Energy (2013)	Opt-in w/ IHD	14-20	2.5	15%
Ireland (2010)	Opt-in	17-19	2.0	10%
SRP (2012)	Opt-in	14-20	3.4	9%
SRP (2012)	Opt-in	16-18 (from base)	5.2	20%
SRP (2012)	Opt-in	16-18 (from TOU)	5.2	20%

*TOU prices applied to generation services only. Price includes distribution charges.

**Results for CPP-F Normal Weekday Summer which reflect energy reduction achieved on normal non-CPP weekdays during which a TOU was applied.

***Off peak prices were tiered. Price ratios are calculated based on the average of the two tiers.

Industry research on the impact of demand rates on residential customers is more limited. Publicly available results are shown in Table 9. Given the small sample of data points, that most of the results are over 30 years old, and extreme variance in results, the Company plans to use the same assumed expected savings size as the RE-TOU which is believed to provide a conservative estimate that will ensure results will be statistically valid.

Table 9. Demand Rate Achieved Peak Reduction[26]

Utility	Average reduction in Max demand
Arizona Public Service (1981-2015)[27]	3-4% average; 10-20% among engaged
Norway (2006)	5%
North Carolina (1978-1983)	17%
Wisconsin (1977-1978)	29%

[26] Hledik, Ryan, *The Brattle Group*. "Rolling Out Residential Demand Charges." EUCI Residential Demand Charges Summit, May 2015.

[27] *Direct Testimony of Charles A. Miessner On Behalf of Arizona Public Service Company*. Docket No. E-04204A-15-0142.

Attrition

Inevitably, some portion of customers will move or decide to opt-out of the rate. If a customer moves or opts out, the current approach is to remove the customer from either the treatment or control groups. Attrition has significant implications not only for maintaining the robustness of treatment and control groups (ensuring sample targets are met throughout the study life), but also for projecting bridge meter requirements. While there is uncertainty related to the actual attrition that will occur, the Company can draw from previous experiences to determine a best possible estimate. As shown in Table 10, in the Company's SmartGridCity Boulder pricing pilot, 14% of customers moved each year. We expect that there is some correlation between move rates and the percentage of the population that rents housing. Rental rates in Boulder are much higher on average than in the rest of Colorado (50% v. 34%, respectively).[28] Thus, we assume that move rates for the overall population will be somewhat lower than was found in the Boulder pilot. SMUD's 2014 Smart Pricing Options Pilot found an annual move rate of 12%. While Sacramento County has as higher renter population than Colorado, the Company believes this estimate to be a conservative approximation to ensure desired sample targets, especially when triangulated with the Company's 2016 Home Use Study survey results that determined 12% of customers move each year.

Table 10. Review of Annual Move Rate Estimates

Study	Annual Move Rate*	Renter Rates**
2013 SmartGridCity, XE Boulder	14%	50% Boulder
2015 TOU Pilots, CA Statewide IOUs	10-20%	44% CA Statewide
2014 Smart Pricing Options, SMUD	12%	42% Sacramento County
2016 XE CO Home Use Study	12%	34% CO Statewide

*Move rates that were reported over cumulative years were converted to annualized rates

** As reported in the 2010 US Census

The Company assumes that same portion of opt-out customers that was found in the SmartGridCity Boulder Pricing Pilot--approximately 4%--can also be applied to the new trial and pilot rates. [29] That assumption is based on the fact the SmartGridCity Boulder Pricing Pilot was also an opt-in voluntary rate. Collectively, this means that 16% of customers will leave the trial and pilot each year for a total attrition rate of 35% over 30 months (April 2017 through September 2019).

Sample Ranges

As discussed previously, expected savings assumptions can have a considerable impact on estimations for targeted sample size and choosing the optimal savings assumption involves balancing the ability to detect savings with study costs. If we underestimate savings, and participating customers achieve larger savings, then our results will likely be more precise but cost expenditures will be greater than necessary. If we overestimate reduction, and participating customers achieve lower savings, then we risk reducing precision and potentially not finding statistically significant results.

Table 11 demonstrates this relationship. If we assume that the expected savings are 3% (the minimum savings achieved in previous studies with peak to off-peak ratios of 2.5:1), then our total sample target would be 135,742 (see Table 8 for a review of TOU study achievement). This target wouldn't be possible under current participation caps (please see Table 3 and Table 5). If we assume that expected reduction is 15% (the

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[28] 2010 US Census.

[29] Sacramento Municipal Utility District's 2014 SmartPricing Options Study found an opt-out rate of 5.9% for TOU customers with no IHD option.

maximum change achieved in previous studies with peak to off-peak ratios of around 2.5:1), then our total sample target would be 6,874, much lower than the Company's proposed sample. Please see the section Expected Savings Size for more detail.

Table 11. Participant and Control Targets

Estimated Energy Reduction During Peak	RE-TOU	RD-TDR	Control	Total Sample
3%	56,030	56,030	66,168	178,228
5%	21,338	21,338	24,988	67,664
7.8% (proposed)	9,840	9,840	11,340	31,020
10%	6,701	6,701	7,614	21,016
15%	3,990	3,990	4,396	12,376

Note: Table assumes 11% as the estimated energy reduction for IHDs.

Target Samples

Based on the results from the power analysis and the assumptions described above, the following participation targets shown in Table 12 would be required.

Table 12. Number of Participants and Control Targets

Pilot Rate	Low Income*	Solar	Electric Vehicles***	Smart Thermostat	Renters	Seniors	All Others	Total
Energy Reduction Assumption	NA	7.8%	7.8%	11.0%	7.8%	7.8%	7.8%	
RE-TOU	500	1,500	500	820	1,630	1,630	1,630	8,210
RD-TDR	500	1,500	500	820	1,630	1,630	1,630	8,210
Control	500	3,000	500	820	1,630	1,630	1,630	9,710
Total	**1,500**	**6,000****	**1,500**	**2,460**	**4,890**	**4,890**	**4,890**	**26,130**

*Low income sample targets are pre-determined per Section VII.G of the Settlement Agreement.
**The solar control groups will be selected using a matched group design and thus each rate requires its own control group.
***Electric vehicle participation won't be capped but the Company will limit marketing and recruitment to achieve only the targeted sample frames

Table 13 shows sample targets accounting for a cumulative attrition rate of 35% over the life of the 30 month evaluation period for the RE-TOU trial (see Section Attrition for details).[30]

[30] The RD-TDR is scheduled to continue through 2022. For the purposes of the Study and Evaluation Plan, the Company will focus on the first three years for both rates.

Table 13. Number of Participant and Control Targets, Including Attrition

Pilot Rate	Low Income*	Solar	Electric Vehicles***	Smart Thermostat	Renters	Seniors	All Others	Total
Energy Reduction Assumption	NA	7.8%	7.8%	11.0%	7.8%	7.8%	7.8%	
RE-TOU	770	2,311	770	1,263	2,511	2,511	2,511	12,647
RD-TDR	770	2,311	770	1,263	2,511	2,511	2,511	12,647
Control	770	4,621**	770	1,263	2,511	2,511	2,511	14,958
Total	2,311	9,243	2,311	3,790	7,533	7,533	7,533	40,253

*Low income sample targets are pre-determined per Section VII.G of the Settlement Agreement.
**The solar control groups will be selected using a matched group design and thus each rate requires its own control group.
***Electric vehicle participation won't be capped but the Company will limit marketing and recruitment to achieve only the targeted sample frames

As mentioned previously, per Section II.A.1 and II.B.1 of the Settlement of the 2017-2019 RE Plan (Proceeding No. 16A-0139E), under Option B of the Small Solar*Rewards Program, 51 MWs of capacity and REC incentives will be allocated to customers in 2017-19 under the RD-TDR pilot. If Option B capacity is fully utilized, it will equate to roughly 9,000 new solar customers. Each year, unused Option B capacity will roll over into the Option A Solar*Rewards program. The Company is obligated to reserve 9,000 of the 18,000 RD-TDR cumulative 2019 participation cap for these Option B solar customers. This means the 12,647 total RD-TDR sample target identified in Table 13 may not be possible to achieve and that adjustments must be made.

Table 14 shows desired sample targets that have been adjusted to fit under the 9,000 RD-TDR 2019 cap. The RD-TDR renters and seniors segments have been revised such that the total target non-solar sample equals 9,000.

Additionally, the Company was asked to consider including a separate sample target bucket for households that are occupied during peak hours. Company research indicates that a large majority of households will fall into this category. According to the Company's 2016 Home Use Study, 61% of residents are either retired, stay at home parents, or work from home. According to a recent Company panel survey conducted in late October of 2016, 77% of customers said someone was home during peak hours 2pm to 6pm.

It's reasonable to assume statistically significant results can be achieved for this segment utilizing customers recruited from the All Others category as well as other targeted customer segments. To ensure that this segment will be sufficiently captured, the Company will double the sample target for the All Others category for the RE-TOU and control groups, and will attempt to achieve similar targets for the RD-TDR to extent allowed under the Option B capacity restriction.

The Company believes these targets to be the most reasonable balance that complies with the Settlement Agreement, allows for the study of many customers segments of interest / concern, and provides the greatest opportunity to achieve statistical precision. This sample plan is contingent on the Company's abilities to recruit and install 43,938 meters before June 1, 2018 (the start of the 2018 cooling season) which equates to roughly 3,138 meter installations per month over 14 months (April 1, 2017 through May 31, 2018).

Table 14. Number of Participant and Control Targets, Adjusted for RD-TDR Solar Cap Compliance and Expansion of "All Others" Category

Pilot Rate	Low Income*	Solar	Electric Vehicles ***	Smart Thermostat	Renters	Seniors	All Others	Total
Energy Reduction Assumption	NA	7.8%	7.8%	11.0%	7.8%	7.8%	7.8%	
RE-TOU	770	2,311	770	1,263	2,511	2,511	5,022	15,158
RD-TDR	770	2,311	770	1,263	1,843	1,843	2,511	11,311
Control	770	4,621	770	1,263	2,511	2,511	5,022	17,469
Total	**2,311**	**9,243**	**2,311**	**3,790**	**6,865**	**6,865**	**12,555**	**43,938**

*Low income sample targets are pre-determined per Section VII.G of the Settlement Agreement.
**The solar control groups will be selected using a matched group design and thus each rate requires its own control group.
***Electric vehicle participation won't be capped but the Company will limit marketing and recruitment to achieve only the targeted sample frames

Other Sampling Considerations

Segment Overlap

Many customers segments will invariable overlap with others. For example, some customers are likely to have EVs and solar, and many customers with solar and/or EVs may also have smart thermostats. Interactions between these different technologies will likely have impacts on the customer's ability or willingness to shift energy usage. Other than the low income segment, which is capped at 500 per rate/control group and will receive first priority treatment, the Company plans to allocate customers into the varying sample segments using the following prioritization:

- As discussed previously, RD-TDR solar treatment groups will receive a REC incentive specifically designed for that rate will be matched with a control group. Thus, RD-TDR solar customers, regardless of whether they exhibit other characteristics of interest, will by definition be allocated to the RD-TDR solar segment. To ensure RD-TDR and RE-TOU solar groups are comparable, RE-TOU solar customers will be given similar preferential treatment.
- EV adoption in Colorado is still fairly low[31] and while the Company anticipates EV customer acceptance of a TOU rate to be high given the potential cost savings when shifting charging time, the study will require many EV owners to enroll in the rates in order to achieve target sample sizes. Thus, any customer who doesn't own rooftop solar and owns an EV will be allocated into the EV test and control groups until the sample targets are fulfilled.
- Smart thermostat customers who don't have solar or EVs will be allocated into the smart thermostat test and control groups.
- Company research indicates that roughly 25% of customers are aged 65 or older.[32] If senior customers have solar, EVs, or smart thermostats they will be allocated first to those technology

[31] According to the 2016 Alliance of Automobile Manufacturers, there are 6,924 EVs in Colorado as of September 16, 2016. http://www.zevfacts.com/sales-dashboard.html

[32] 2016 Home Use Study

categories. After target samples in those categories have been filled, remaining customers aged 65 or older would be placed in the Seniors category.

- Renters who don't exhibit any of the above mentioned characteristics will be placed into the renters bucket. According to the 2014 U.S. Census, roughly 34% of Colorado customers rent their homes.
- All other customers will be allocated into the All Others category.

Using this method of prioritization and allocation, the segments with the lowest priority (renters and "all others") will invariably exhibit disproportionate characteristics. For example, the "all others" category will likely have a larger than representative portion of those who aren't seniors, and own their homes.

Additionally, some customers will likely have attributes that are relevant to multiple categories. When conducting the final analysis in 2019, the Company will plan to aggregate all participants with similar attributes together to assess the ultimate impact of the new rates on all customers reflecting a particular attribute.

Smart Thermostat TOU Services

Some smart thermostat manufacturers have developed or are in the process of developing services which can integrate with local utility TOU rate plans. These services can automatically adjust and help customers minimize electricity use when energy prices are most expensive. It's anticipated that smart thermostats with this additional functionality would lead to greater expected savings. At a minimum, the Company plans to ask smart thermostat owners in the study what type of device they have, how they use it, and track this going forward for future analysis.

Customer Research

Customer research will be a critical component throughout all stages of the trial and pilot process, including customer enrollment, meter installation, evaluation, and ongoing feedback. This section describes the Company's preliminary plans for customer research, though further refinements or additions may be made.

Customer Intake Form

The Company plans to collect essential customer information during the sign up process from all customers volunteering for the trial and pilot (including those assigned to the treatment and control groups) through an intake form.[33] This form will request information that will be critical to the evaluation of results not only to understand the relative impacts each characteristic may have on the customer acceptance, or willingness or ability to shift usage in response to the new rates but also to provide a comparison to known characteristics of the Company's overall population. If participants differ significantly from the general population, it will be useful to note those differences and make adjustments to potential extrapolations in the context of a default rate.[34] This intake form will be a pre-requisite for participation ask customers about topics including but not limited to the following:

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[33] The Company currently collects some broad household information from customers who sign up for paperless billing. If possible, the Company will attempt to leverage this information and avoid duplication of efforts.

[34] The Company plans to leverage existing customer research surveys to understand the general customer population for comparison, such as the Home Use Study, and the Attitudes, Awaresness, and Usage (AAU) Study. These are performed every two years with a random sample of the general population in Colorado, and assess appliance / technology saturations, as well as energy efficiency behaviors.

- Contact information
- Housing characteristics
    - Home type
    - Square footage
    - Age of home
    - Owner / Renter status
    - Household size
    - Age of occupants
    - Need for ongoing medical equipment that requires electricity
- Appliance & Technology Saturation (including but not limited to)
    - Smart Thermostats
    - Rooftop Solar
    - Electric Vehicles
    - Central Air Conditioning/Room Air Conditioning/Swamp Cooling
    - Refrigerators
    - Smart/Programmable Dishwasher (ability to delay start)
    - Smart/Programmable Washing Machine (ability to delay start)
    - Electric Heating - Baseboard or Use of Space Heaters
    - Electric Hot Water Heater
    - Energy Storage
    - Pumps (sump, pool and/or hot tub)
    - Other Electric Appliances/Machines (computers, TVs)
- Behavioral characteristics
    - Number of people home during 2-6 pm
    - Energy efficiency behaviors[35]
- Demographics
    - Age
    - Income
    - Gender

Ongoing Customer Research

Regular communication and feedback processes throughout the life of the trial and pilot will be important to ensuring smooth programmatic performance and limit any potential customer dissatisfaction. Frequent feedback will allow the Company to improve processes and / or change communication tactics. Additionally, the Company plans to measure and track through surveys – behavior changes, customer understanding of the rates and changes in their bill, as well as general acceptance / satisfaction with the new rates and experiences.

While the Company agrees that periodic surveys will be important and necessary, the Company also believes

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[35] To augment information gathered in the intake form, the Company plans on utilizing known participation data in previous DSM or renewable programs from Company databases.

it will be critical to balance the need for customer information with survey fatigue. Survey fatigue can reduce response rates and, if customers are annoyed, could also bias results. It will be crucial to achieve sufficient survey responses—including at the end of the pilot—which will become increasingly difficult as time goes by as it is, let alone with survey fatigue. Additionally, over-surveying may risk influencing customer behavior and compromise the validity of the load impact estimates by reminding customers that they're being studied. This is called the "Hawthorne Effect," where the knowledge that one is being studied causes a change in behavior that wouldn't necessarily occur if the intervention were offered without the subject's knowledge that they were being studied. Ultimately, the Company recommends deferring to the selected evaluation vendor to advise on an approach that will balance survey frequency with survey fatigue to achieve maximum response rates and collect the customer data necessary to attain study objectives

The Company currently plans to survey customers according to the minimum following schedule:

- Post customer enrollment
- Post summer peak season, annually

Timeline

The following table describes the high level milestones for RE-TOU and RD-TDR rates.

Table 15. RE-TOU and RD-TDR Milestones

Milestone	Date
Stakeholder Meeting (1)	October 27, 2016
Stakeholder Meeting (2)	November 2, 2016
Stakeholder Meeting (3)	November 4, 2016
Stakeholder Meeting (4)	November 9, 2016
Final Study & Evaluation Plan Provided	November 15, 2016
M&V Request for Proposal Issued	December 7, 2016*
Stakeholder Meeting (5) – discussion of customer enrollment campaign	December XX, 2016
M&V Evaluator Selected	January 2017*
RE-TOU and RD-TDR marketing campaign begins	February 1, 2017*
Year 1 Evaluation Report (June 2017- May 2018)	Fall 2018*
Year 2 Evaluation Report (June 2018 – May 2019)	Fall 2019*
Advice Letter	December 2, 2019
Year 3 Evaluation Report (June 2017- December 2019)	Spring 2020*

*Subject to change

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ATTACHMENT A

DNV GL

Power Analysis

DNV·GL

Memo to:
Louise Wood, Xcel Energy

From: Craig Williamson
Date: September 23, 2016

Power Analysis for Residential TOU Pilot
This memo explains the statistical power analysis done by DNV GL to estimate the sample sizes required for Xcel Energy's Residential Time-of-Use (TOU) Trial. We first give a general description of statistical power, and how it can be used to estimate sample sizes needed for designed experiments such as the Residential TOU trial. Lastly, we detail the calculations done for the Xcel Energy Trial and the inputs to those calculations, as well as some caveats based on the data used for the calculations.

The power of a statistical hypothesis test is the probability that the test will detect a difference between two groups (find statistical significance) given that an actual difference of a certain magnitude is there. This is different from calculating confidence intervals and precision, since it is specifically for a hypothesis test. Calculating sample size based on target precision of the savings uses the variance of the estimator, just like power analysis, but it calculates the sample size needed to achieve a target confidence interval size.

The power calculations we used assume that there will be two groups: a treatment (or test) group, and a control group. The test group will receive a treatment (be put onto a TOU rate), and the control group will not. The two groups will be as similar as possible. The Xcel Energy Trial will be testing two different rates: an energy TOU rate (RE-TOU) and a demand TOU rate (RD-TDR). All of the power calculations are the same for the two rate test groups.

For a hypothesis test, we first establish the null hypothesis, which states there is no difference between the two groups. We then test this null hypothesis against the alternative hypothesis, which states there is a difference. The test uses probability to determine how likely it is that the difference between the two groups is due simply to chance under the null hypothesis. If the two are different enough to convince us that the difference is not due to chance, then the null hypothesis can be rejected.

The inputs to the power calculation include values for alpha and beta, and a minimum effect size as well as estimates of the mean (average) and variance of the measure of energy use that is being tested. For this Trial, the customer summer weekday average daily on-peak energy is the primary interest. This is the average kWh/day that a customer uses between 2:00 pm and 6:00 pm on non-holiday weekdays from June through September. The effect size, and the mean and variance estimates, are all on-peak summer kWh/day.

DNV GL provided a spreadsheet tool to Xcel Energy which allows for input parameter adjustments, and in turn shows the resulting required sample sizes. The input parameters are:

- **Alpha level of the test** – This is usually set to 5%. This is the probability of a Type I error for the test, usually assuming a two-sided test. A Type I error is concluding that there are significant savings when in reality, there are not.
- **Beta level** – This is usually set to 20%. This is the probability of a Type II error for the test. A Type II error is concluding that there are no savings when, in reality, there really are savings. 1-Beta, commonly 80%, is the probability of detecting statistically significant savings, also called the power of the statistical test.

- **Effect size** – The power depends on the size of the effect. The effect size is the minimum savings that can be detected with, say, 80% power. The effect size can be expressed as an absolute number (i.e., kWh savings) or a percent of the average value.

The formula for the sample size required to detect a minimum effect size - expressed as a percent of the mean - and assuming a direct difference estimate (no pre-treatment data) is:

$$n = \left(\frac{\left(z_{1-\alpha/2} + z_{1-\beta}\right)\sqrt{2var(X)}}{eff * \bar{X}} \right)^2$$

Where the *z* values are from the normal distribution, *X* is the energy variable (average summer weekday on-peak energy), and *eff* is the percent effect size. If the effect is specified in kWh rather than as a percent, the denominator then becomes the effect size.

Populations for this Trial and Pilot

There are five populations that are being studied for the Xcel Energy TOU rates. One population is the low income customers, for which the sample size has already been set during negotiations with stakeholders. The other four are No Technology, Smart Thermostat, EV Owners, and Solar. In order to accurately predict the required sample sizes for the rates, we need accurate estimates of the mean and the variance of summer weekday on-peak energy for each of these populations. Since we do not know in advance which customers will be part of the rates, we must make assumptions about who will be in it, and use the best estimates available for the means and variances of those customers. Because the rates are voluntary, there is no way to pre-determine who will sign up. The inherent limitation of a voluntary rate is that the accuracy of the sample sizes will depend on how well the estimates of the means and variances reflect the eventual rate population.

For the No Technology and the Smart Thermostat populations, we used Xcel Energy's existing residential load research sample of 223 customers to calculate the mean and variance for both the average summer weekday on-peak energy and the system peak hour demand. Because Xcel Energy's existing load research sample is designed to represent the entire residential population, these estimates should be good predictors of the mean and variance for the customers in these two rate groups, as long as there is not a systematic difference between those who sign up for the rates and those who do not. Because we cannot control who volunteers for these rates, this is the most reasonable estimate we can make. However, if the volunteers turn out to be predominantly lower use or higher use customers, the effect sizes here may not reflect what will be detectable when the study is completed.

For the EV Owner population, we used Xcel's EV sample of 20 customers with EV charging data. Unfortunately, the EV load data was only for the vehicle charging, and did not include the rest of the house. Because we needed mean and variance estimates for the total household load, we combined the means and variances for the charging loads with the means and variances from the load research sample. While this does not specifically reflect the energy use of customers with EV charging, it is a reasonable proxy (and the best option, given the available data) for what typical household loads would be if EV charging was added. It may be that customers with EV charging tend to have different non-charging household use than the general population, which would result in different mean estimates. Also, there is likely correlation between the charging load and the household load, but without the household use for the homes with EV charging, we cannot adjust our variance estimates to account for this. Lastly, having only 20 EV charging customers means that the mean and variance estimates are not very precise, which will make the estimated sample sizes less precise as well.

The Solar customers were from a separate load research sample, which had two channels of load data: the amount delivered to the customer on one channel, and the amount fed back into the Xcel Energy system

from the customers in the other. The net load for these customers, which is the load that will be billed on the TOU rates, is the amount delivered minus the amount fed back, and calculated in each hour. For this population we used the mean and variance of this difference. This is a large sample (205 customers) and is representative of the existing population of solar customers. If the new solar customers coming online, (which are expected to make up the TOU rate sample) are similar to the existing solar customers, then the mean and variance estimates will be accurate and appropriate. In addition, we assumed that the TOU rate will be applied to the net energy use, as is the current residential rate.
The effect size for the solar group also required special consideration. While we could come up with reasonable percent effect sizes for all groups, using a percent for the Solar group was not appropriate. The TOU rates will encourage customers to shift a portion of their energy use from on-peak to off-peak, but that portion should be a percent of the customer's total household energy use. If a customer might shift 10% of their on-peak energy, for example, that is assumed to be 10% of their total energy use. However, the net metered interval data only reflects the portion of the customer's load that is served by Xcel Energy, not what they get from their solar panels. Applying a percent effect size to the on-peak (i.e., net metered) energy for the solar customers would result in an effect size that is way too small. For this reason, we used the kWh effect size from the No Technology customers for the Solar customers. This was the best proxy available for the Solar customers' total household energy use.

Based on all these considerations, Table 1 below shows the required test group sample sizes for each of the groups, based on the average summer weekday on-peak energy and the system peak hour demand. The numbers were calculated using alpha=5% and beta=20%, meaning the power (i.e., the chance of detecting the effect if it is in fact there) is 80%.

Table 1: Required Test Group Sample Sizes

Customer Segment	Reduction Type	Mean	Variance	Minimum detectable savings	Sample Size-simple difference
No Tech Groups (Gen Pop, Renters, Peak Occupancy, Seniors)	Average On-peak Summer Weekday Energy	6.19	24.1949	0.4827	1630
	System Peak	2.11	3.4902	0.1645	2026
EV group	Average On-peak Summer Weekday Energy	6.88	24.9134	0.5363	1360
	System Peak	NA	NA	NA	NA
Solar - based on fixed value	Average On-peak Summer Weekday Energy	2.10	22.2631	0.4827	1500
	System Peak	2.08	4.2770	0.1620	2560
Smart Thermostats	Average On-peak Summer Weekday Energy	6.19	24.1949	0.6808	820
	System Peak	2.11	3.4902	0.2319	1019