NAVIGANT

ComEd Commercial AC Tune-Up Research Detailed Plan

Detailed below are the specific tasks, activities, deliverables, and schedule associated with commercial air conditioner (AC) tune-up research.

Introduction

This detailed research plan describes the proposed methods that Navigant will use to verify the energy savings reported for AC tune-up measures in the AirCare Plus Program and the deemed measure savings for different tune-up activities listed in the Illinois Technical Resource Manual (TRM). Navigant proposes to conduct this research in three stages, (1) an engineering analysis and ride-alongs, (2) a billing analysis, and (3) a metering study. The results from each stage of the study will inform the subsequent stages. Navigant will coordinate with ComEd and CLEAResult to gather necessary data and to coordinate the field work research components.

Background for Research Prioritization

The Illinois Technical Advisory Committee's proposed evaluation priorities identified an Illinois-based study for the AC tune-up measure as a high priority research item. Based on the current version of the IL TRM v6, the energy savings for the AC tune-up measures can be calculated in two ways: (1) conducting pre-tune-up and post-tune-up tests of energy efficiency, or (2) using the deemed savings factors listed for different tune-up components.

The current deemed savings percentages in the IL TRM (ranging from 0.22% to 14.76%) are substantially lower than those claimed by the AirCare Plus Program tracking data. The tracking data for PY8 and PY9 of the AirCare Plus Program shows an average percentage change in energy efficiency ratio (EER) of about 21% for AC tune-ups. Navigant also found the percentage savings claimed by the program was greater than similar field studies conducted in other jurisdictions across the country.[1,2]

Navigant also notes that field measurement of an AC unit can be prone to many uncertainties and variabilities. The methodology used to measure the pre-treatment and post-treatment EER relies on a limited set of measurements and built-in assumptions that exclude the measurement of key parameters such as total power input. As a result, it is important to ensure that the test methods and algorithms used for quantifying AC tune-up savings accurately reflect actual energy savings.

Overall Study Goal

The impact evaluation research goals for the for this effort are to: (1) verify both the measure savings and test-in, test-out efficiency measurements; and (2) propose updates for deemed savings for different AC tune-up activities for the Illinois Technical Reference Manual (TRM).

[1]Central Air Conditioning in Wisconsin, published by Energy Center of Wisconsin (ECW Report Number 241-1) in May 2008, specifies a 5% ± 4% energy savings from AC tune-ups.
[2]Review of Recent Commercial Roof Top Unit Field Studies in the Pacific Northwest and California, New Buildings Institute, October 8, 2004, suggests a 5% -11% energy savings due to refrigerant charge adjustments.

Research Questions

The key research questions that will be answered by this study are listed below by research stage.

Stage I: Engineering Analysis and Ride-Alongs

- Is the methodology and instrumentation used for performing tune-ups and calculating in-field measurements of energy efficiency accurately representative of in-field energy use? Are there other instrumentation or methodologies used by HVAC contractors in other jurisdictions that could provide measured test results that are accurate and representative of field operation?
- How accurate are pre-treatment and post-treatment energy efficiency ratio (EER) and energy saving calculations using the data collected by service technician while performing the tune-ups?
- How can the tracking data be used to provide additional information on the magnitude of savings, for different building types, climate zones and cooling capacities?

Stage II: Billing Analysis

- What is the magnitude of the tune-up savings as shown in customer billing and AMI data?

Stage III: Metering Study

- What are the savings factors associated with the specific tune-up actions (e.g., refrigerant charging, condenser clean up) for commercial customers?

This research will improve the accuracy of the reported results on energy savings associated with commercial AC tune-ups. Specifically, this study will help ComEd and its customers in ensuring that measure savings reported in the tracking data and the savings factors reported in the IL TRM accurately reflect the actual measure energy savings.

Summary of Evaluation Research Activities

To verify the measure energy savings, Navigant plans to conduct several analyses including engineering analysis, evaluation of AC tune-up procedures, billing analysis, and, if warranted to further reinforce the results from other analyses, a metering study. Table 1 below shows the different activities that are planned for this research study.

Table 1 Research evaluation activities and general timelines

Activity	Rationale	Timing
Data Request	Requesting (1) Customer AMI or billing data from ComEd; and (2) tune-up measurements by service technician from CLEAResult	Summer-Fall 2018
Literature Review	Review studies on energy savings from commercial AC tune-ups	Summer 2018
Engineering Analysis	Use engineering calculations to evaluate energy savings due to specific tune-up activities. Used to determine the benefit of an AMI-based regression analysis.	Summer 2018
Contractor Ride-Alongs	Evaluate the methodology used for administering tune-up and calculating energy savings based on pre- and post-treatment measurements	Summer – Fall 2018
Analysis of customer energy consumption data (including AMI data)	Verification of measure energy savings based on a regression analysis of consumption data	Winter 2018
Metering Study	Will be conducted if the results from the energy consumption data analysis are not statistically significant.	Summer 2019

Methodology

Navigant will conduct the research study in three stages. Considering the costs involved in doing a metering study, Navigant will first conduct a series of lower-cost analyses using secondary literature review, contractor ride-alongs, and engineering analysis in Stage 1. In Stage 2, Navigant will conduct an energy consumption data regression analysis (using AMI data as appropriate) to estimate measure impacts. If the results from the regression analysis are not statistically significant, the only remaining option is to do a third stage metering study to determine measure impacts. If the results from the second stage analyses are statistically significant, then Navigant will not perform a metering study. The staged approach will help the research remain cost-effective and yet produce meaningful results. This detailed plan is outlined in Table 2.

NAVIGANT

Table 2. Summary of Tasks, Deliverables, and Timeline

Tasks	Activities	Data Needs	Deliverables	Timeline
Stage I	**Engineering Analysis and Ride-Alongs**			
Task 1: Tracking data characterization and TRM review	• Tracking data review • TRM review	• Program tracking data	• None	3 weeks
Task 2: Kick off meeting, data request and literature review	• Kick-off call • Request data • Literature review	• Secondary data, spot measurements and operating parameters	• None	10 weeks
Task 3: Engineering analysis	• Engineering calculations of energy savings due to various tune-up activities	• None	• Memo with findings from literature review and engineering analysis	6 weeks
Task 4: Contractor ride-alongs	• Interview contractors for developing ride along protocol • Evaluating process followed by service technicians for performing tune-ups	• CY2018 pipeline projects	• Memo with findings from contractor ride-alongs	11 weeks
Stage II	**Billing Analysis**			
Task 5: Energy data regression analysis	• Regression analysis in R	• Customer AMI or billing data	• Memo with findings from AMI or billing data analysis	12 weeks
Stage III	**Metering Study**			
Task 6: Metering study	• Conduct pre-treatment and post-treatment field measurements for energy use.	• CY2019 pipeline projects	• Detailed metering plan, memo • Memo describing the results	28 weeks
Final report	• Report writing	• None	• Presentation(s) • Final Report	8 weeks
Time to Complete the Project			**12 months (without metering study); 19 months (with metering study)**	

Stage 1

Stage I of the research plan includes the following tasks:

- Task 1: Tracking data characterization
- Task 2: Kick-off meeting, data request and literature review
- Task 3: Engineering analysis
- Task 4: Contractor ride-alongs

Task 1: Tracking Data Characterization and TRM Review

In preparation of the research study, Navigant first reviewed the tracking data for the AirCare Plus Program for PY8 and PY9 and characterized the energy savings based on building type, cooling capacities, and as a percentage of the annual building electricity use. For developing these characterizations, Navigant used the publicly available data provided by the U.S. Energy Information Administration on electrical energy utilization index for different building types, and the IL TRM on typical floor areas for different building types to estimate the annual building electricity use for each building type. Based on the pre-treatment and post-treatment EER values in the PY8 and PY9 tracking data, it appears that, on average, the AC tune-up measure saves approximately 2.2% of the total annual building electricity use. Low-rise offices comprise approximately one third of the installations in the tracking data and the AC tune-up savings are higher at about 3.4% of the annual building electricity use. Navigant anticipates the savings percentage to be higher during the summer months, where the energy use by ACs constitutes a greater part of the total building energy use. Given how small the AC tune-up energy savings are as compared to the total annual building electricity use, Navigant plans to focus its customer AMI or billing data analysis on installations that received a tune-up in the cooling season.

Navigant also plans to review the equations and procedures specified for this measure in the IL TRM. If any issues are identified, Navigant will highlight them as part of this research study and provide recommendations for updating the TRM, to the Technical Advisory Committee, stakeholders, and Vermont Energy Investment Corporation (VEIC).

Task 2: Kick Off Meeting, Data Requisition & Literature Review

On May 1, 2018, Navigant organized a kick-off call with ComEd and CLEAResult to discuss the potential approaches for the research study and sources of data. During the call, Navigant discussed the availability of customer AMI data, the instrumentation for performing tune-ups, and the availability of secondary data collected by service technicians. In preparation of that meeting, Navigant forwarded a list of 450 customers from PY8 and PY9 for which it sought the AMI data. Following that meeting, Navigant received literature on the Field Diagnostic Services Inc. SA Mobile Efficiency Index (EI) methodology which is used by CLEAResult for calculating the energy savings from AC tune-ups.

The methodology described in the instrumentation literature requires the measurement of suction temperature and pressure, liquid line temperature and pressure, return air dry-bulb temperature, return air humidity ratio and outdoor air dry-bulb temperature along with compressor performance data and engineering assumptions to calculate the operating coefficient of performance (COP), cooling capacity, and power input. Due to concerns of simplicity and practicability, the methodology requires only a small set of measurements and does not mandate the measurement of electrical power input to the compressors and fans. Instead, the methodology estimates the compressor power input based on compressor performance coefficients (compressor maps) and assumes a constant power input value for fans and controls (based on a set percentage of compressor power input). While the methodology

provides a simple way of calculating savings from a tune-up, there are concerns about how accurately the results match with the measured energy savings.

To address these issues, Navigant plans to identify methodologies and instrumentation used for calculating energy savings from tune-ups as a secondary goal of this research study. This plan includes a deeper literature review comprising tune-up programs conducted in other jurisdictions and field reports. Navigant also requested secondary data from CLEAResult on the specific tune-up activities carried out at each installation and spot measurements taken while doing the tune-up. Navigant will use this data to inform the verification analysis comparing energy savings reported in the tracking data and the IL TRM. The findings from this literature review of field reports and instrumentation will be documented in a memo that will be delivered to ComEd after completion of Task 3 – Engineering Analysis. Navigant also plans to set up monthly calls with ComEd and CLEAResult to discuss the progress and seek feedback on the research study.

Task 3: Engineering Analysis

Navigant plans to model the performance of a vapor compression cycle subject to commercial AC operating conditions to evaluate the improvement in EER due to specific AC tune-up activities. Navigant will use compressor and fan performance data of models typically used in commercial AC equipment for this analysis. Manufacturers of commercial AC equipment and compressors typically provide fan and compressor performance data in their product specifications. The energy savings associated with cleaning of condenser and evaporator coils, and adjustment of refrigerant charge levels, can be calculated using such data.

For estimating the impact of cleaning of coils, Navigant will first review technical literature to determine the difference in air resistance between a clean and dirty or fouled heat exchanger coil. Using the difference in the air resistance, Navigant will evaluate the decrease in brake horsepower associated with cleaning the heat exchanger coil. If the commercial AC model number or fan performance information is available as part of the secondary data collected by service technicians, then Navigant will use that information for this analysis.

To evaluate the impact of refrigerant charge adjustment, Navigant will review the spot measurement data provided by CLEAResult and technical literature to determine the operating temperatures and pressures of a commercial AC unit under two operating conditions: (1) a system charged to manufacturer specifications, and (2) a system that is either undercharged or overcharged. Using the pressure and temperature data, Navigant will calculate the operating COP, cooling capacity, and power input based on compressor performance maps for commercial AC models that underwent a tune-up. If model numbers are not available, Navigant will use data of compressor models typically used in commercial AC equipment.

The results from this analysis will be used as a validation for the other analyses that will be carried out as part of this research study. This analysis will help in defining the range, accuracy and uncertainties of the billing analysis and the savings factors associated with different tune-up activities. Note, the results from this analysis will depend on the quality, quantity, and timely availability of data from CLEAResult. Navigant anticipates receipt of the data in July 2018.

Task 4: Contractor Ride-Alongs

Navigant will conduct contractor ride-alongs to evaluate the procedure used by service technicians in performing AC tune-ups. As a first step, Navigant will discuss with CLEAResult the steps followed by service technician in conducting tune-ups. Navigant will draft a protocol for the evaluation process. The

protocol will also include interview questions for the implementers on data collection and measurements related to different tune-up activities. While the service technicians perform the tune-up and record the measurements for pre-tune-up and post-tune-up tests, Navigant staff doing the ride-alongs will measure the total power input, airflow rates, dry-bulb temperatures and humidity (the flow rate, dry-bulb temperature and humidity will be recorded for outdoor, return and supply air streams). The total power input will be recorded using power meter data loggers. For split systems, the total power input to the indoor and outdoor units will be recorded separately and added. The airflow rates, dry-bulb temperatures and wet-bulb temperatures (or relative humidity) will be recorded using hotwire anemometers, temperature sensors and psychrometers. Using the measurements Navigant will calculate cooling capacity and EER for the pre and post tests, and compare the savings with that reported by the contractor using their instrumentation. The availability of these additional measurements will be beneficial in validating energy savings from the tune-up activities. Additional details on the instrumentation, methodology and data collection will be provided in the ride-along protocol.

Another goal for conducting the ride-alongs is to assess whether service technicians are collecting high quality data using well-calibrated instrumentation that could be used for developing accurate estimates of measure energy savings.

Navigant plans to reach out to ComEd and CLEAResult in July 2018 to coordinate tune-ups for about 30 installations in the summer of 2018. Coordinating this task with CLEAResult will depend on the availability of AC tune-up projects scheduled to be conducted in CY2018.

Stage II

Stage II of the research plan includes the following tasks:

- Task 5: Energy data regression analysis

Task 5: Energy data regression analysis

Depending on data availability, Navigant plans use either AMI interval data or billing data to evaluate savings for AC tune-up participants using regression analysis with a pre-program matching (RPPM) approach.[3] The logic of matching is that for each measure participant, energy consumption in the summer before measure implementation will be compared to that of all customers in the available non-participant pool with data over the same period.[4] The customer with energy use most similar to a participant's energy use over the summer before the program enrollment will be used as the match. Since this measure is for commercial and industrial customers, Navigant will also consider matching based on building type. The participants who receive a tune-up will form the treatment group, while their non-participant matched pair will form the control group. Both treatment and control groups will have a pre period (energy use data before the measure was implemented) and a post period (energy use data after the measure was implemented) Navigant will either use billing or AMI data depending on the available data. If the available AMI data are sufficient to get statistically significant results then Navigant will use AMI data for the regression analysis. Otherwise, Navigant will convert the AMI data to monthly billing data, combine it with the billing data for customers that do not have AMI meters, and use these aggregate data for the regression analysis.

[3] Ho, Imai, King, and Stuart (2007). Ho, Daniel E., Kosuke Imai, Gary King, and Elizabeth Stuart. 2007. Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Political Analysis* 15(3): 199-236.

[4] The term 'non-participant' refers to customers who are either enrolled in the AirCare Plus program but did not get an AC tune-up measure or are not enrolled in the AirCare Plus program.

Navigant plans to estimate savings for PY9 or CY2018 AC tune-up participants. The pool of potential matches will include non-participants from PY8, PY9 and CY2018 or other customers who are not enrolled in the AirCare Plus Program. Navigant will first evaluate whether the measure non-participants in PY8, PY9 and CY2018 are sufficient to form matched pairs with the participants. If the non-participant pool is insufficient, then Navigant will reach out to ComEd to obtain energy use data for commercial customers who did not participate in the AirCare Plus Program Navigant may also explore alternative evaluation methods that do not rely on a matched control group, such as a pre-post participant model.

After matching, Navigant will run a regression model similar to the one below to estimate program savings. This is a variant in Navigant's standard Lagged Dependent Variable (LDV) model which is used in many program evaluations for ComEd modified to use daily data.

$$ADU_{kt} = \beta_1 Treatment_k + \sum_j \beta_{2j} Month_{jm} + \sum_j \beta_{3j} Month_{jm} \cdot PREkWh_{km}$$

$$+ \beta_4 BuildingType_k + \beta_5 Zip_k \omega_t + \varepsilon_{kt}$$

Where,

ADU_{kt}	=	Daily energy use by household k on day t
$Treatment_k$	=	A binary variable taking a value of 1 if customer $k$is a participant and 0 otherwise
$Month_{jm}$	=	A binary variable taking a value of 1 in month m, when $j = m$ and 0 otherwise
$PREkWh_{km}$	=	The daily electricity use by household k during the most recent month before household k (or its match) enrolled in the program that is also the same calendar month as day t. For instance, if household k enrolled in August 2018, the value of $PREkWh_{km}$ for June 2018 is June 2017
$BuildingType_k$	=	The building type of participant k
Zip_k	=	The zip code of participant k
ω_t	=	A vector of daily weather variables
ε_{kt}	=	Model error term

As noted, this task is dependent on availability of AMI or billing data for the year that the measure was installed and the previous year. After completing this task, Navigant will provide a memo highlighting the findings of this analysis.

Stage III

Stage III includes a metering study that may be conducted based on the results obtained from the Stage I and Stage II analyses.

Task 6: Metering Study

Navigant will facilitate a discussion with stakeholders on the results of Stage I and II to determine if a metering study is a sufficient priority. This research plan only includes a brief overview of the metering study. If stakeholders agree on the need for a metering study, Navigant will provide a more detailed metering study plan, covering the sample size, participant selection criteria, and methodology.

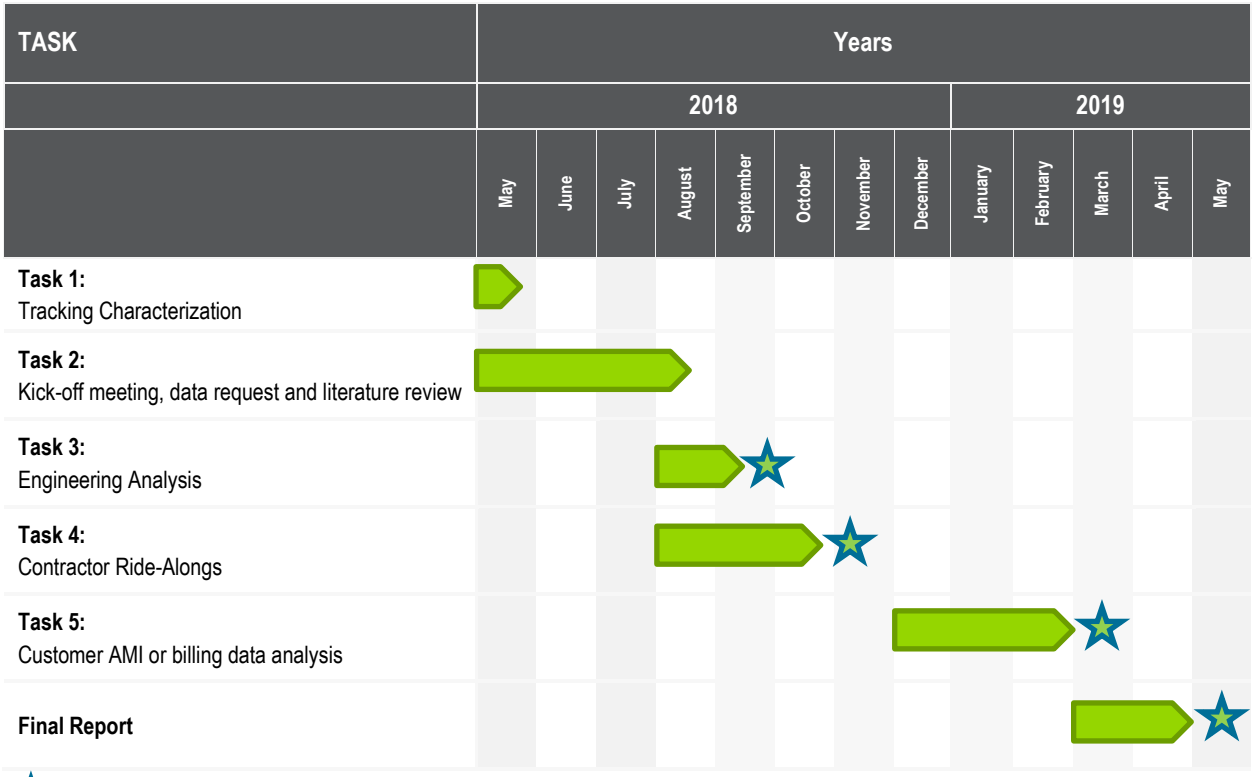
The metering study will cover a sample of approximately 50-70 installations where power measurement data loggers will be installed starting from three months before the scheduled tune-up (if possible) to three months after the tune-up. The difference in the energy use data between the three months of pre-treatment and three months of post treatment, adjusted for the weather, will help in providing a representative estimate of AC tune-up energy savings. Additionally, based on what specific tune-up activities are carried out at each installation, Navigant will also be able to determine the savings associated with specific tune-up activities.

The results from this analysis will be reinforced with the Stage I and Stage II analyses to provide a holistic savings estimate for commercial AC tune-ups. Selection of participants for the study will depend on availability of installations scheduled to receive a tune-up in CY2019. Navigant anticipates receiving this data by March 2019.

Schedule

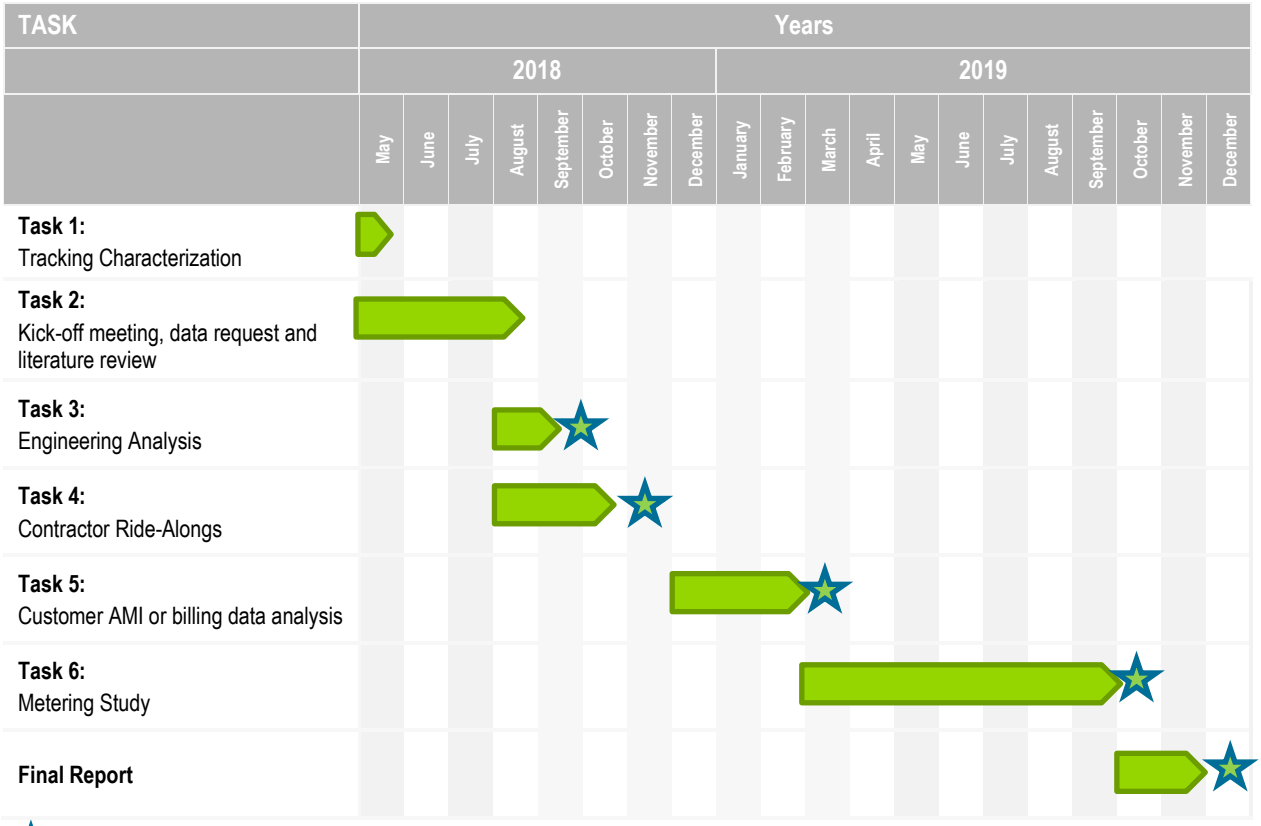
Two timelines are possible depending on whether Navigant conducts a metering study. Figure 1 below shows the timeline without a metering study. Under this scenario, Navigant anticipates completing all the research tasks by April 30, 2019. Figure 2 shows the timeline if a metering study is conducted. Under this scenario, Navigant anticipates completing all the research tasks by November 30, 2019. Both timelines are approximate, and adjustments to the stated deadlines are possible.

Figure 1. Project Schedule by Task – Scenario I, no Metering Study



represents deliverables also indicated in Table 2

Figure 2. Project Schedule by Task - Scenario II, Including Metering Study



represents deliverables also indicated in Table 2