

Design of a Weather- Normalization Forecasting Model

Project Proposal

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1.0 Context

Northern Virginia Electric Cooperative (NOVEC) is an electricity distributor headquartered in Manassas, Virginia. NOVEC provides power to nearly 150,000 customers across six counties – Prince William, Stafford, Loudon, Fairfax, Fauquier, and Clarke. NOVEC’s service territory constitutes a fraction of each of these six counties, wherein it is required to provide power to meet any customer demand. In order to meet energy demand, NOVEC purchases power from PJM Interconnection, a regional power supplier, in two ways: long-term bulk purchases and spot purchases. Bulk purchases occur up to five years in advance and are meant to satisfy estimated demand over this time period. In the event bulk purchases are insufficient to meet any demand over this timeframe, spot purchases provide the energy to cover the difference and flexibility to materialize hours or days before delivery. Temperature fluctuations, mainly during the summer months, are a significant contributor to increased power demand in excess of the bulk purchase amount. Bulk purchases offer economies of scale and are more cost efficient than spot purchases which constitute a higher premium for accommodating unscheduled orders on short notice.

In order to minimize the amount of ad hoc purchases without overcompensating for their avoidance with excessive bulk purchases, NOVEC has developed a forecasting model that estimates future energy purchases over a 30-year horizon. While bulk purchases do not necessitate forward planning for 30 years, existing statutes do require this length of forecast. NOVEC leverages forecast model insights to inform the magnitude (kilowatt-hours) and length of bulk energy purchases from PJM. Economic metrics included in the model seek to characterize the basic load by capturing economic growth or decline in the Northern Virginia area. The basic load is the energy requirement based solely on the size and typical consumption of customers, the number of which changes with time. To reasonably determine the size and growth rate of customers, local weather data is collected and used to remove the effects of weather on historical energy purchases. This is known as weather normalization.

Normalizing for the weather allows NOVEC to determine changes to their service-base, which provides necessary insight for capacity planning (such as infrastructure), in addition to deriving reasonable estimates of future energy consumption. Rather than predicting the weather patterns for the future, the model uses the long-run average value for a given time period as determined from historical data. Historical power consumption since 1983, weather data since

1963, and economic forecasts at the state and county level are all inputs to the model. The output of the model is a monthly power demand forecast over a 30-year horizon.

2.0 Problem Statement

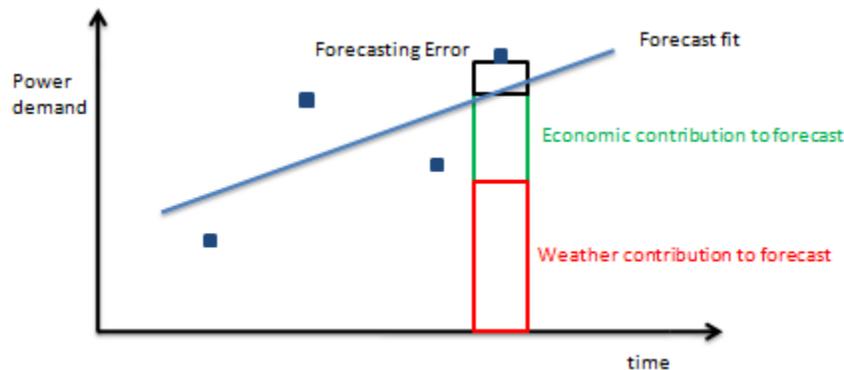
In order to predict future power demand, the model performs weather normalization for 50 years of hourly weather data and evaluates economic data provided by Moody's economic forecast. Each of these factors can be evaluated at the state, county, or Washington, D.C. metropolitan area. Accordingly, each data set must be weighted to correspond to the impact it would have on NOVEC's service area and thus power demand. For instance, Prince William County data would be more heavily weighted than those for Clarke County since NOVEC's territory in Prince William is much larger than in Clarke County; therefore, economic factors would impact the basic load differently.

In accounting for these variables, NOVEC believes that the current model may no longer be the best available and that a new weather-normalization method may better reflect recent changes in weather trends. Improving the accuracy of the forecast would limit the amount of power that NOVEC has to buy beyond the bulk amount, thus decreasing costs. NOVEC requests analytical support to develop a new weather-normalization forecasting model or to determine that the existing model is the best available.

3.0 Scope

The purpose of this project is to develop a new weather normalization methodology to improve NOVEC's forecasting model by more accurately predicting future power demand. However, in order to develop a methodology to normalize for weather, the economic factors contributing to changes in power demand must also be accounted for in the analysis.

Notional Forecasting Methodology



The figure above gives a notional representation of the weather-normalization forecasting method. The forecast, which is fit to historic power demand, is made up of some combination of weather impact, economic impact, and error. In accomplishing the goal of changing the weather-normalization methodology, the weather's contribution to this model must change. As the weather contribution changes, either the economic contribution or the forecasting error must also change. Thus, in order to effectively develop a new weather normalization method, the economic factors must also be addressed.

The model will take into account historical data as inputs: customer and energy purchase totals by month starting from 1983 and hourly weather data starting from 1963. These data sets provide us with a plethora of data that will necessitate extensive evaluation. The weather data alone contains over 400,000 records detailing hourly measurements of temperature, dew point, humidity, wind speed, and precipitation. Furthermore, historical energy purchases provide over 6,000 data entries on total customer demand. In these historical data, some records are blank or contain errors, a problem that will have to be mitigated by this project through data validation. Additionally, this analysis will leverage Moody's state, county, and Washington, D.C. metro economic data starting from the 1970s. In particular, per sponsor guidance, data relating to employment and housing stocks will be used to predict the growth or decline of NOVEC's customer base, though other metrics are available for analysis. Moody's economic data includes projections of econometrics across varied scenarios, only one of which is currently used to inform NOVEC's forecasts. Testing the model under additional scenarios offers a means to

conduct sensitivity analysis and inform the sponsor's decisions with some measure of risk related to modeling assumptions.

4.0 Preliminary Requirements

NOVEC needs to gauge 30-year energy requirements at a monthly resolution to inform bulk purchase negotiations. Historic and projected total energy purchases must maintain an ability to characterize customer growth by type, residential or non-residential. In order to more accurately depict growth, NOVEC needs to be able to strip out the effects of weather; this is the ultimate purpose of the study and dictates a requirement to develop a methodology that will more accurately remove weather-effects. This will provide a better interpretation of the base load exerted by a dynamic customer base as well as reasonable estimates to how this base is changing.

Results of this study must also be able to synchronize with NOVEC's existing forecast model. To accomplish this, insights must be summarized within the context of two variables, heating- and cooling-degree days, which quantify cold and hot, respectively, temperature's impact on observed load. To assess the quality of the methodology to strip out weather-effects, the sponsor also requires an ability to report the error associated with output.

Although not required, a newly developed forecast model developed in conjunction with the weather normalization routine would be evaluated for enduring use at NOVEC. An ideal model for such consideration would need to be robust to changes in temperature and economic trends.

Based on these factors, the following requirements were derived:

1.0 The project shall deliver a weather-normalization forecasting model (WNFM).

1.1 The WNFM shall accept data inputs.

1.1.1 The WNFM shall accept as an input at least 51 years of historical weather data.

1.1.2 The WNFM shall accept as an input at least 31 years of historical power demand data.

1.1.3 The WNFM shall as an input Moody's economic data.

1.2 The WNFM shall output a weather-normalized power demand forecast.

1.2.1 The WNFM shall output a heating day variable.

- 1.2.2 The WNFM shall output a cooling day variable.
- 1.2.3 The WNFM shall output a monthly power demand forecast for a 30 year time horizon.

2.0 The project shall deliver an error report that evaluates the accuracy of the WNFM.

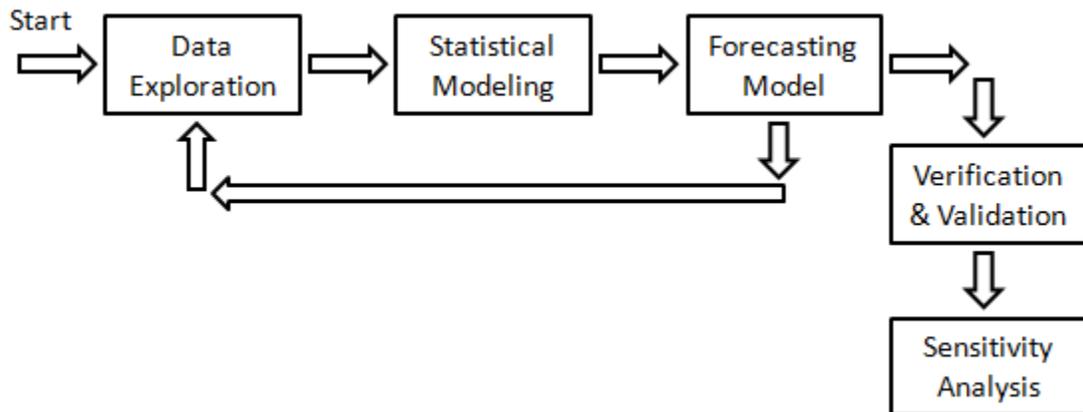
3.0 The project shall deliver documentation for the WNFM.

3.1 The WNFM documentation shall include detailed description of the modeling process.

3.2 The WNFM documentation shall include detailed description of how to use the model.

5.0 Technical Approach

An overarching approach to accomplish the study’s intent comprises a general sequencing of objectives. The flow chart below shows the high-level steps to complete the weather-normalization forecasting model. After Data Exploration and Statistical Modeling, the Forecasting Model will be constructed. At that point, our project will utilize an iterative methodology in order to modify the dynamics between weather-normalization and economic parameterization procedures. This will allow us to increase the accuracy of the forecasting model as well as observe the relationship between input data and end results. Concluding model development, Verification and Validation will be conducted with input from the sponsor. Assuming that we have time, Sensitivity Analysis will also be performed by varying the model parameters.



Each of the study phases introduced above is discussed in more detail below.

1) Data Exploration

- Identify and amend data gaps and inconsistencies.
- Determine diminished correlation of weather over long periods of time. Consider removing or lowering weighting of older weather data from the 1960s; entire data set is averaged in current model.
- Evaluate trends and empirical distributions in weather and economic data by plotting histograms, time series plots, and x-y scatter plots over varied timeframes.
- Utilize smoothing technique that accounts for seasonality of weather in addition to overall economic and meteorological trends.
- Investigate whether variable transformations are needed.

2) Statistical Modeling

- Determine best combination of explanatory variables to predict monthly energy purchases; selected by statistical significance at 95% significance level.
- Provide 95% confidence intervals for independent variable parameters as well as for predicted values.
- Aggregate hourly weather data into monthly data to correspond to power load data.
- Select model based on goodness of fit test.

3) Simple Forecasting Model

- Determine different options for weighting economic factors; current method uses service area in proportion to county size.
- Incorporate Moody's Economic projections using results from statistical model.

4) Verification and Validation

- Verify model consistency; ensure model is implemented as designed.
- Validate with NOVEC's power demand data from 2011-2012; serves as basis for comparison to current weather normalization methodology.

5) Sensitivity Analysis

- Vary weather parameters; test for impact of change in trends.

- Vary economic variable weights.

The goal is to improve their current modeling capability by quantifying a relationship between total monthly energy purchases, temperature, and relevant economic factors relatable to sales growth which will then be used to inform the 30-year monthly forecast model.

6.0 Expected Results

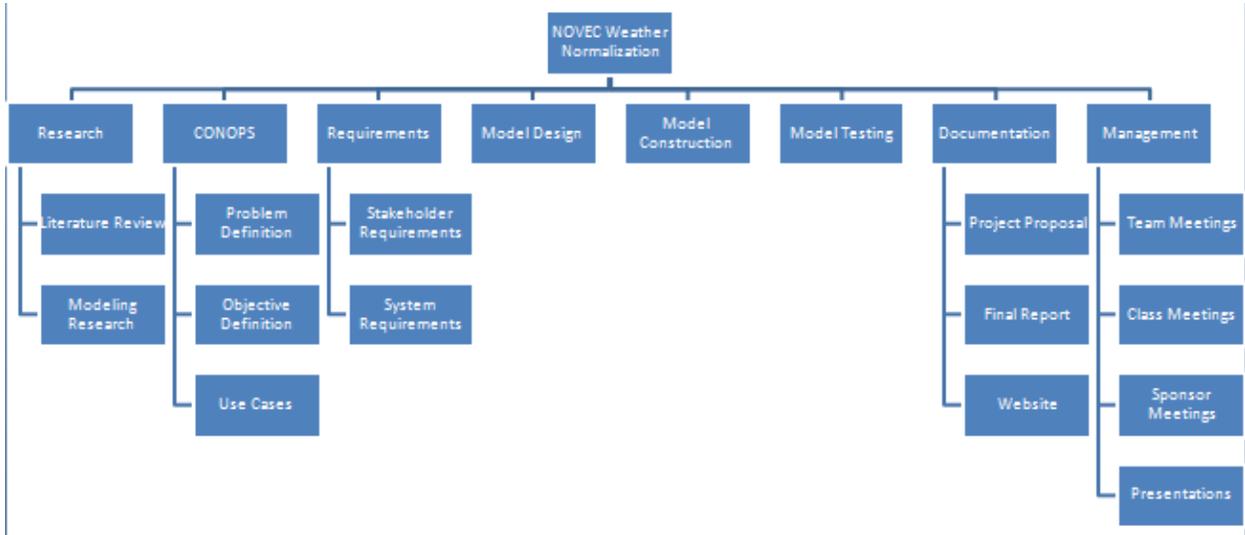
At this point in the study, our expectations are limited to a qualitative description as it would be imprudent to recommend anything more without first informing an opinion with supporting analysis. To this end, our expected results are to establish a weather normalization model that produces a monthly demand forecast with a 30-year time horizon that is more accurate than the current NOVEC model. Alternatively, the result of our analysis could be to determine that NOVEC's current weather-normalization method is sound and cannot be improved upon. Ultimately, NOVEC's need for analysis stems from sequential investment decisions that are obscured by uncertainty, primarily from the stochastic evolution of the economy and weather patterns. Given the complexity of the issue at hand, and the time constraint imposed by this analysis' suspense, we expect to assist in the characterization of this uncertainty and deliver a robust methodology that will improve NOVEC's ability to filter weather-effects from energy demand. It is also our intention that this methodology will be adaptable to accommodate relevance in light of any changes in data collection or knowledge management processes. We plan to maintain a simple approach that will be robust to any new information that would advocate its revision, such as the marginal cost benefits associated with energy purchased over different intervals.

Our model is anticipated to decrease the amount of error currently seen in NOVEC's forecasting model and we mean to report this error in the output as a range of likely values as opposed to a single value; we expect this to provide more meaning to the decision as it adds a distinguishes courses of actions by an additional measure of risk. Ultimately, however, we have no expectation at this time as to the exact content of the 30-year forecast results.

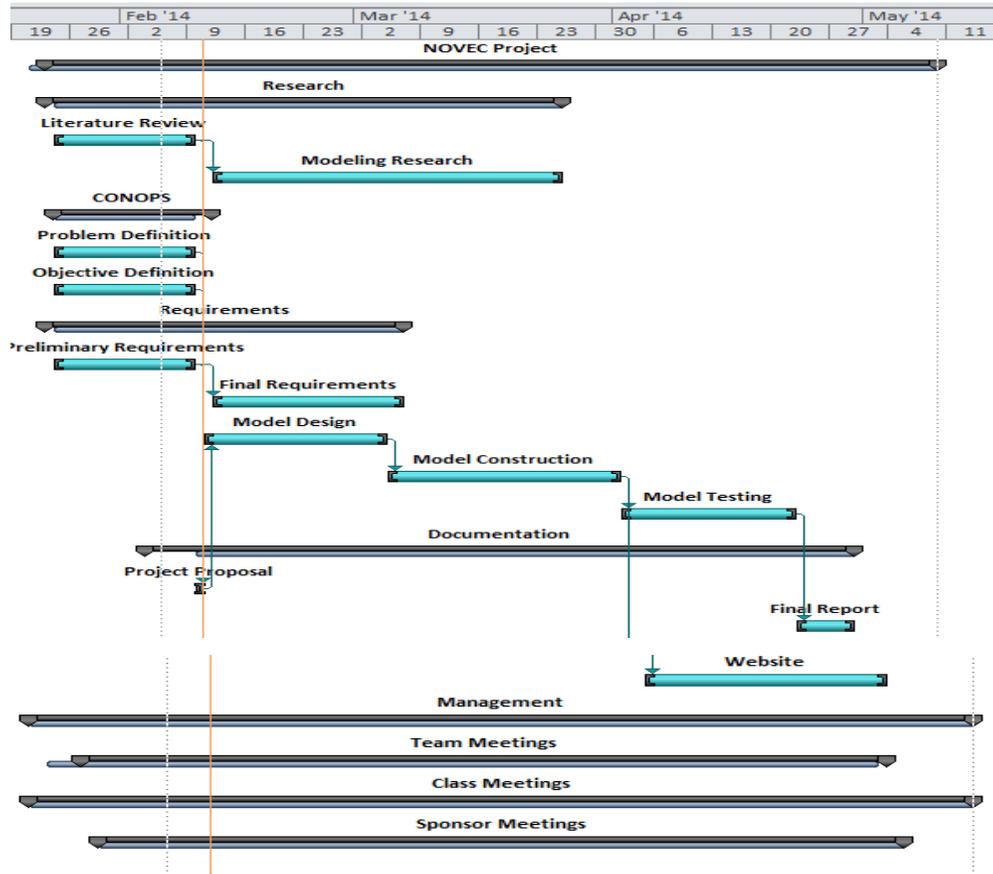
7.0 Project Plan

Our project plan includes a Work Breakdown Structure (WBS), a project schedule, and earned value graphs. The earned value graphs are based on timesheets based on the WBS.

NOVEC Project WBS



NOVEC Project Schedule



NOVEC Project Earned Value Chart

