Playing Together in the Sandbox: A Collaborative Model for Estimating Regional Impacts from Codes and Standards

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ABSTRACT

In the Northwest, recent code upgrades have dramatically increased the efficiency of buildings built, while recent changes in appliance standards promise to positively affect the stock of appliances going forward. The significance of these changes underscores the importance of transparently estimating resulting savings. While the savings from incentivized measures are routinely measured, historically only a handful of experts have estimated regional codes and standards savings using incomplete data sources and highly specialized knowledge.

To increase the transparency of savings attributed to codes and standards, and to increase the number of analysts capable of conducting the analysis, Bonneville Power Administration (BPA) undertook a project to develop a regionally consistent methodology to track the savings from codes and standards. The resulting methodology meets several objectives necessary to be regionally relevant and useful. These include:

- Modularity of analysis tasks for efficiency of development time and resource, for transparency, and to facilitate continual improvements to the data sources and algorithms over time.
- Flexibility in definition of baseline and efficient cases (for example, code-to-code, practice-to-practice analyses) to accommodate the reporting and analysis needs of a variety of stakeholders
- Provisions for identification of model strengths and weaknesses to inform the prioritization of process improvements as resources become available.
- A software architecture that provides a portable, transparent product usable and modifiable by a core group of regional stakeholders.

This paper reviews this methodology and the challenges encountered in its development. This methodology can serve as a model for other regions to estimate codes and standards impacts and can support the development of new codes and standards. [1]

Introduction

Energy codes and appliance standards have become increasingly important sources of energy-efficiency savings. However, to fully capture and benefit from these impacts, analysts need a transparent methodology, used consistently, to quantify this valuable resource.

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In the Northwest, three organizations—the Bonneville Power Administration (BPA), the Northwest Energy Efficiency Alliance (NEEA) and the Northwest Power and Conservation Council (the Council)—partner together in a unique collaboration. The Council estimates the power needs for the region, and develops a Power Plan for the region every five years. This Power Plan is the basis for BPA's targets for energy efficiency. NEEA and BPA work together to meet the region's power needs by acquiring energy efficiency. BPA and the region's public utilities provide rebates and incentives, while NEEA develops and implements market transformation savings programs. All three organizations required a way to consistently and transparently track these savings: the Council to use in their regional Power Plans, BPA to apply to their targets and future load forecasting, and NEEA to track their net market effects. Despite this, all three organizations were counting and tracking savings from codes and standards in different ways.

The Council's five-year Power Plan uses a frozen baseline, meaning that as new codes and standards are established, the savings from these new codes and standards are applied towards meeting the goals laid out in the Plan, rather than increasing the baseline. Programmatic savings that are used to incent measures are adjusted throughout the five-year period, based on changes to codes and standards, new data and market shifts. However, the Power Plan's baseline against which achievements towards the goals are determined remains constant.

The Council methodology does not consider causality as a metric for whether or not savings from energy efficiency count towards the goals. The reason for this is that all energy efficiency in the region is a resource that meets regional power needs. The Northwest has a 30 year history of developing energy efficiency resources collaboratively, making it difficult to determine "who caused what".

Regional utilities, the Council, BPA, the Energy Trust of Oregon (ETO) and NEEA have all played different roles in advancing building codes and appliance standards over the past 30 years. The Council developed the Model Conservation Standards (MCS) in the early 1980s, and BPA provided significant resources for Washington state to adopt the code, including paying incentives on the homes built under the new code for the first few transition years. BPA also funded numerous staff in Washington to provide the expertise needed for a successful implementation of these first codes. Local utilities, including Tacoma Power, Springfield Utility Board and Mason Public Utility District #3, have been actively involved with inspecting and helping to implement the energy code. It has only been in the last year that Springfield Utility Board stopped providing inspections for the energy code for all commercial buildings built in their territory. NEEA – funded by regional utilities, BPA and the ETO – has provided the primary support from the utility community for the energy code since NEEA's inception in 1997, including providing training on the energy code, funding positions at the state level to provide information and support to builders and building inspectors, and developing code packages to increase efficiency over time. NEEA, utilities and the ETO have pushed new building practices and technologies forward in the market, making them more likely to be adopted into codes and/or standards. The Council and NEEA have both been actively involved in appliance standards at the national level, attending hearings and providing expert opinion and data to support the case for increasing levels of energy efficiency.

States, national agencies, and other codes and standards stakeholders use various methods and different baseline definitions for counting savings from codes and standards. This variation has made it difficult to understand what impacts a new code or standard has on the electric grid and what part of those impacts to considered a power resource.

In order to develop a consistent regional methodology, BPA worked with Navigant to develop and document a regional approach to quantify savings from codes and standards in a consistent and transparent manner and meet the needs of stakeholders including NEEA, the Council, regional utilities, and regulatory agencies. The methodology addresses data coolection on buildings, appliances, and regulations; building and appliance stock turnover modeling; and energy analysis of buildings and appliances.

This paper describes the challenges of developing a model in collaboration with several stakeholders and outlines the methodology for the Codes and Standards Impact Quantification (CSIQ) Analysis that was ultimately developed.

Challenges

While the benefits of a consistent regional method were clear, the challenges of developing the method required significant effort from multiple parties. The first challenge was defining the scope of the methodology. The Navigant/BPA team did not want the methodology and vision to be constrained by data availability, particularly since one objective of this effort is to increase and improve regional data collection. The team needed to think big, yet also balance with the budget and time constraints of this project. This led to the development of a methodology that would produce an initially useful, yet basic, model that could be scaled up over time as data became available.

The second challenge was to meet the various stakeholder needs from the project. For example, the various parties involved define baselines differently. For state agencies, the important metric is savings going from previous code to current code ("code-to-code"), as defined by their legislatively-determined goals. In contrast, the Council, BPA and NEEA count savings as the reduction in energy consumption from current practice in the market to a new code or standard ("current practice-to-code"); these new codes or standards are not always more efficient than current practice.

Additionally, it was difficult to distill a complex methodology into a coherent and transparent document. For the methodology to be useful for the region, the document describing it needed to be readable by a broad audience yet specific enough to guide the model development. The methodology met these challenges through the following:

- **Allow improvements over time:** The methodology focuses on providing a framework and a process to guide into the future, but allows improvements to occur incrementally as budget and time allow and better data becomes available.
- **Allow flexibility in assumed baselines:** Because various stakeholders required different baselines, the methodology is not prescriptive on what baselines to assign, but can accommodate multiple ways of incorporating baselines.
- **Describe key decision points and considerations**: The methodology distilled the process to balance the conflicting needs for 1) substantive guidance for the next phases of the project and 2) a document and methods that are accessible to a broad audience.

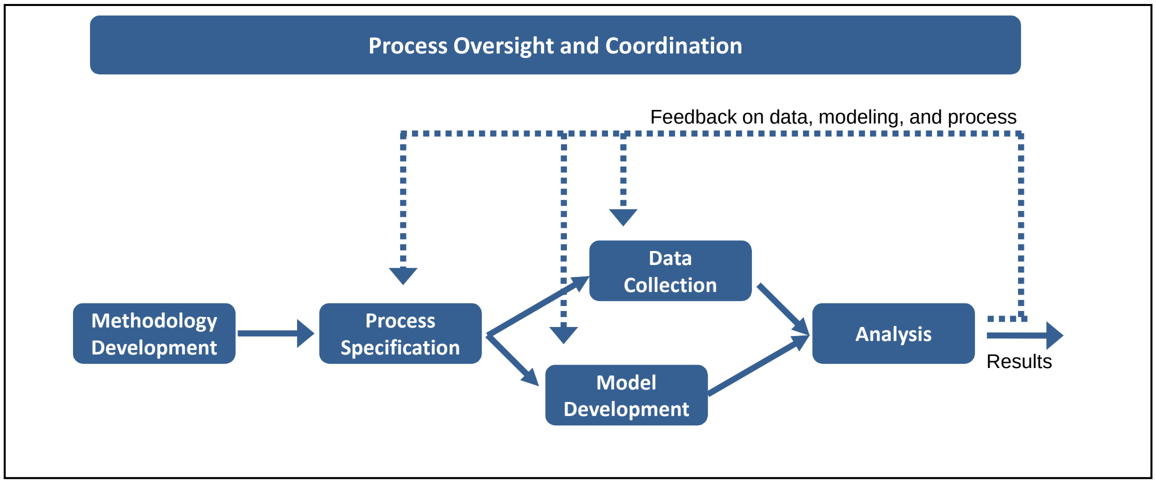
Additionally, the methodology specifies requirements of activities and products to encourage an efficient effort, a transparent model, and a strategic approach to model refinement over time:

- **Model oversight**: A regional organization will provide the necessary process oversight and coordination to ensure that all parties work together efficiently and that feedback from modelers and stakeholders informs future iterations of the CSIQ Analysis.
- **Coordination and clarity of data collection:** Model data specifications (e.g., categorization of building types and equipment types) provide guidance on regional data collection efforts such as residential and commercial building stock assessments. Consideration of the CSIQ Analysis in the coordination of regional data collection efforts will inform the sample sizes and stratifications of surveys, data field definitions, and the granularity of data collected. For example, the categorization of buildings by business type and vintage should be consistent across building stock assessments conducted by NEEA and building stock forecasts developed by the Council.
- **Modularity of modeling tasks:** The model consists of discrete tasks, with explicit data flows between tasks. This modularization of the process allows for the distribution of tasks among analysts – quite possibly at different organizations – for efficient use of expertise and time. It also allows the model oversight entity to target specific aspects of the analysis for improvement through an ongoing, iterative refinement process.
- **Standardization of datasets and analyses:** The methodology prescribes input templates that will standardize the structure and format of datasets and analyses. This will facilitate the sharing of data between different modelers, particularly between the appliances and the buildings modelers (in general, different people). The development and use of templates will greatly increase transparency and the ability to integrate the process.
- **Identification of data gaps and uncertainties:** Inevitably, analysts will encounter data gaps, both of scope and of quantity. When developing assumptions to overcome these gaps, analysts must document any assumptions made and highlight uncertainties in data sources and analysis methods. This provides further transparency of results, which stakeholders can use at the regional level to prioritize future improvements in analysis and supporting data collection efforts.

Collaborative Process for Modeling, Analysis, and Improvement

The team intends for the full model described by this methodology to be built gradually, over several years, by multiple parties. Therefore, it was important to begin with the specification of an ongoing process of model design, development, execution, and improvement that would allow for continuous improvement in these conditions. A regional organization such as BPA or NEEA will provide the overarching oversight and coordination of efforts. Modeling efforts begin with the development of the methodology (described in this paper), which is then used to specify the datasets, models and reporting capabilities to be built. Once developed, the datasets and models are used to conduct an analysis. In addition to results, a key output of the process is feedback from the developers as to the strengths and weaknesses of each part of the full model and datasets. The coordination and oversight entity would use this feedback to prioritize updates and improvements for future iterations of the process. Figure 1 illustrates this process.

Figure 1. CSIQ Analysis Process Diagram



Source: Navigant Consulting 2011

Methodology

At a high level, the CSIQ Analysis answers the following question: what is the expected incremental energy (electricity and natural gas) impact of a set of changes to building codes and appliance standards in the region? This change is the difference in estimated regional energy consumption between two cases: a baseline pre case, and a post case that considers the changes to codes and standards. The following sections describe key features and requirements of the models. Following this discussion, Figure 2 illustrates this process schematically.

Pre and Post Case Definition

Different stakeholders may have different baseline definitions and methods for predicting outcomes of changes in codes/standards; the model must be flexible enough to consider a variety of pre and post scenarios.

The pre case (or baseline) may be defined as:

- an existing code/standard;
- an observed current practice;
- an estimate of current practice; or
- a baseline defined for regional planning purposes.

The pre case drives the data requirements in the model. Baselines defined as existing codes and standards require only building and appliance stock information and codes and standards specifications. However, baselines defined as current practice will require the characteristics of the existing building and appliance stock: for example typical levels of insulation of buildings and efficiency levels of appliances.

It is also important to note that the pre case for a given vintage cohort of buildings may change over time. For example, grocery store hours of operation increased between the 1970's and 1990’s. Within all buildings, subsystems such as lighting and HVAC will turn over many times over the life of the building.

The post case may be defined as the new code or standard or an estimate of what the practice will become as a result of the changes to codes or standards. For a post case defined as the new code or standard, building and appliance models are simply brought up to code to establish the post case inputs; The post case defined as the estimate of what practice becomes is complicated to determine, as future practice may exceed the code or standard’s stringency or compliance may be lower than expected. The analyst must use professional judgment to make reasonable estimates.

For changes to codes or standards that are increases in stringency, there are two classes of responses for the analyst to consider. The first is that new codes/standards affect only those sites (or appliances) not meeting the new code/standard, and that non-compliant characteristics are brought up to code/standard. The second response is that the characteristics of all sites (or appliances) shift towards a higher efficiency level. For example, a new efficiency standard for water heaters may simply force only those customers who would have bought the lowest efficiency model to buy a more efficient model. Alternatively, changes in the marketplace due to changes in regulation may influence all customers to purchase an even higher efficiency model than they would have otherwise purchased.

Separate Analyses for Buildings and Appliances

A key decision made in the development of the CSIQ Analysis was to separate the analyses for the buildings and appliances. There were two options considered: (1) analyze appliance impacts within the building analysis; or (2) conduct separate analyses of buildings and appliance/equipment and integrate results from the two analyses at the end of the process. The team chose to keep the building and appliance analyses separate for the following reasons:

- Accurately modeling internal heat gains on an appliance-by-appliance basis in buildings would require a level of data collection in buildings far greater than current building survey efforts.
- National appliance data sources that track market share do not track what types of buildings appliances end up in, or how they are used—while market share data is useful for the appliance analysis, it would not provide the level of detail required to model appliances in buildings.

This approach creates two analysis tracks: a building track and an appliance track. This allows for a bottom-up approach to building analysis (analysis of individual buildings, and results scaled up to the regional building population) and a top-down approach to appliance analysis (scaling observed regional sales volume by estimated energy consumption per appliance), which is in line with the best practices for both of these types of analyses individually.

While the appliance analysis is separate from the building analysis, the appliance analysis does affect the calculated building impact: appliance details (saturation, energy consumption) inform the representation of internal heat gains in the building simulation, and changes to the internal heat gains (as a result of changes to appliance/equipment efficiency) will affect HVAC loads. To address this, sensitivities to internal gains (e.g., ΔkWh of cooling / ΔkWh in appliance loads in conditioned spaces) are determined as part of the building analysis, and applied to appliance/equipment end-use impacts to determine overall impacts.

The determination of whether a particular code provision or appliance standard should be addressed through the building or appliance track is more complicated than a simple distinction between codes and standards. For example:

- Some building systems are affected by both codes and standards – for example, lighting and HVAC standards impact the efficiency of products as manufactured, while codes impact the installation of those products within a building. Lighting and HVAC are included in the building analysis because they are the dominant and interactive energy consumption components within the complex building system.
- Some code provisions address equipment that are not typically modeled directly through building simulation – for example, water heater or compressor provisions. This equipment would be assessed through the appliance path if the expected lifetimes of the appliances/equipment are shorter than the expected building lifetime and replacement of these products would not be considered a building retrofit/alteration.

Data Collection

Successfully developing robust estimates of the impacts of codes and standards requires a diverse set of data collection activities. Building characteristics for each building type, of each vintage, will be necessary. Furthermore, the characteristics of buildings will also vary by analysis period as buildings evolve over time, due to retrofits and usage changes. For building representation, sample sizes and stratification for regional data collection will determine the statistical significance of results. At the current levels of data collection, statistical significance at the building type level or at the service territory level is unlikely.

Appliance stock turnover models require appliance populations by efficiency level and age. For example, a model capable of forecasting clothes washer stock turnover and increase going forward requires the population of clothes washers in the region, disaggregated by vintage and efficiency factor, as well as estimated lifetimes. The difference in efficiency of replaced and new appliances relative to current purchasing trends determines the impact of appliance standards.

Data sources. The full report to BPA (Firestone et al. 2011) identifies potential data sources for the CSIQ Analysis. The data needs of this modeling project are large, and it is worthwhile to understand all of the past, current, and planned data collection activities done in the region to best utilize existing data and to inform the development of future data collection efforts to serve multiple purposes. The types of data required for this model are:

- **Building characteristics**: construction type, building systems, and building usage
- **Building stock**: construction records or surveys for historical representation, coupled with regional economic and employment forecasts by sector for future representation
- **Appliance stock**: by efficiency level
- **Appliance efficiency impacts**: data on appliance usage and energy consumption

- **Codes and standards specifications**: Building codes vary by state, and, in some cases, by cities or counties. Appliance standards are primarily specified at the federal level, although some states have more rigorous appliance standards.

Analysts must develop data sources in tandem with the CSIQ models. As data becomes more available and more granular, models that are more detailed become possible.

Input Development

After collecting building and appliance data, this data must be assembled into two analysis cases: a pre case and a post case. Each case is a set of input parameters used directly for building simulation and energy analysis to determine energy consumption for that case. For example, building simulation models use data from building surveys, and the appliance stock model uses appliance saturation and shipment data.

Building model selection. For the building analysis, there is a choice between modeling specific buildings based on building surveys and using prototype building models. Modeling specific buildings has the advantage of directly using building survey data and using a sampling approach (i.e., a sample of buildings in the region is used to estimate the impacts on all buildings in the region). This requires the analysis of hundreds of buildings to capture the diversity of building stock in the region. Using prototype models has the advantage of requiring fewer building models—typically 10 to 20—analyzed repeatedly for each climate zone.

A sampling approach is preferred when the pre case is defined as current practice, rather than existing codes and standards, because the same amount of survey data is required to inform the descriptions of the building prototypes as would be needed for the sampling approach. Additional efforts would be needed to calibrate building prototypes so that their energy performance characteristics, not only their building characteristics, match that of the surveyed buildings. Therefore, each surveyed building would need to be analyzed regardless of approach. However, for simpler analyses that only consider energy impacts from one code/standard definition to another (i.e., “code to code” analysis), using packaged prototype models offers a compact and straightforward method of analysis.

New and existing buildings will need to be modeled. New buildings must be modeled to capture the impacts of codes and standards on new construction. Existing buildings must be modeled to capture the impacts of codes and standards on retrofits/alterations. Existing buildings must also be modeled to determine HVAC interaction factors to apply to impacts identified in the appliance path. Building models must be developed along three dimensions: building type (e.g., small office, hospital), building vintage (e.g., built between 1980 and 1990), and analysis period (e.g., evaluation of code/standard changes between 2000 and 2005). Additional dimensions to consider include state, climate zone, and HVAC system type (where building characteristics vary significantly by these factors). The impacts determined through analysis of each of these building models must be scaled by the amount (typically square footage) of new construction.

Impact and Turnover Analysis

Building stock model. The building stock model tracks the quantity of new construction, alterations, and demolitions (by square feet) in the region. The granularity of the building stock data must, at a minimum, match the granularity of the analysis. For example, building stock data must be disaggregated by building type, location, and the building vintage (for alterations). In the Northwest, the Council currently develops these forecasts, using proprietary data sources such as FW Dodge and Global Insights for historic and current quantities of new construction, alterations, and demolitions during each time. Analysts can use regional economic forecasts to forecast future construction activity.

Estimating the square footage of retrofits/alterations affected by codes/standards will be a significant challenge. Many of these retrofits may be too insignificant to be captured by proprietary data collection efforts, yet are still affected by codes or standards. Furthermore, some, but not all, codes or standards may affect a given retrofit. For example, a lighting retrofit would not require building shell improvements but both lighting and building shell provisions would affect an addition. Where data are not commercially available, the analysis of retrofit/alterations may require the leveraging of other regional research efforts on this topic or primary research to review building permits and interview market actors. While the retrofit analysis capabilities in the region are currently undeveloped, retrofits likely represent a large portion of total codes/standards impacts, particularly during times of slow new construction development (including the current economic downturn).

The results of this building stock model will be scaled to the population of buildings in the Northwest (during Results Integration), as determined by the building stock model.

Building impact analysis. Building analysis determines the energy impacts of code/standard changes on a single building's lighting and mechanical systems. The building simulation models produced during the input development phase of the CSIQ Analysis are analyzed to estimate building energy consumption in the pre and post cases. Codes/standards details are typically analyzed through building simulation but engineering analysis is appropriate in certain cases.

The building analysis must also determine the HVAC interaction factors of each building type/vintage, so that they can be applied to the appliance/equipment end-use impacts. Running the building simulation several times with varying internal heat gains and observing the effects on the HVAC system will indicate this relationship. Separate HVAC interaction factors may be determined for different load schedules (for example, based loads, daytime loads, nighttime loads). Interaction factors are expressed as the change in HVAC energy consumption (kWh or therms) per change in internal heat gains (kWh).

Appliance impact analysis. Appliance impact analysis determines the energy impact of code/standards changes per appliance. Secondary sources such as engineering analyses, metering studies, or impact evaluations can provide appliance impact estimates. Results from studies from other times or regions (e.g., Department of Energy analyses in support of federal standards rulemakings, impact evaluations in other regions) may need to be adjusted to reflect current conditions in the region. For example, if there has been a significant conservation effort for a measure in the Northwest, the baseline may differ from the national average to reflect regional conditions. In addition, climate specific assumptions such as water inlet temperature, outside air temperature, and humidity may need to be modified to reflect the climate zones of the

Northwest. These impacts are then multiplied by the estimated stock of new appliances each year, which is determined through estimates of existing appliance stock and appliance stock turnover.

The U.S. Department of Energy's National Impact Analyses (NIAs) provide a thorough template for conducting the appliance standards analyses, using shipment/sales data, a stock turnover model, and usage assumptions. These analyses use historical shipment data and product lifetime decay functions to estimate the population of appliances by efficiency level and vintage for each year, from the 1980s to the 2040s. The future appliance population estimates include estimates of demand growth over time for both baseline and efficient scenarios.

Results Integration

The final phase of the CSIQ Analysis is to aggregate the building and appliance/equipment results to determine the total regional impact of a change in codes and/or standards from the baseline. The results integration is not an analysis task. Rather, it is the straightforward multiplication of impacts by affected square footage (building impacts) and by HVAC interaction factors (appliance impacts), followed by the addition of these building and appliance impacts. The remaining steps are:

- Scale building impacts (of individual buildings, from the building analysis) by the regional quantity (square footage) estimates of new construction and of existing building alteration (from the building stock model).
- Apply HVAC interaction factors (determined in the building analysis) to appliance impacts by building type/vintage (determined in the appliance analysis).
- Add building, appliance, and HVAC interaction impacts together to get total results.

The sampling error of the building impact analysis can also be assessed at this point. If building survey data has been used in the analysis, the survey sample sizes by building type, location, and vintage will be used to bound sampling error at various layers of aggregation (state, building type). These estimates of sampling error will enable users to understand at what level of granularity they can reliably report results. For example, a large sample size may result in an acceptable sampling error range for results at the building type level, while a smaller sample size may only result in acceptable sampling error range at the state level. This type of error analysis would not be possible for the prototype approach.

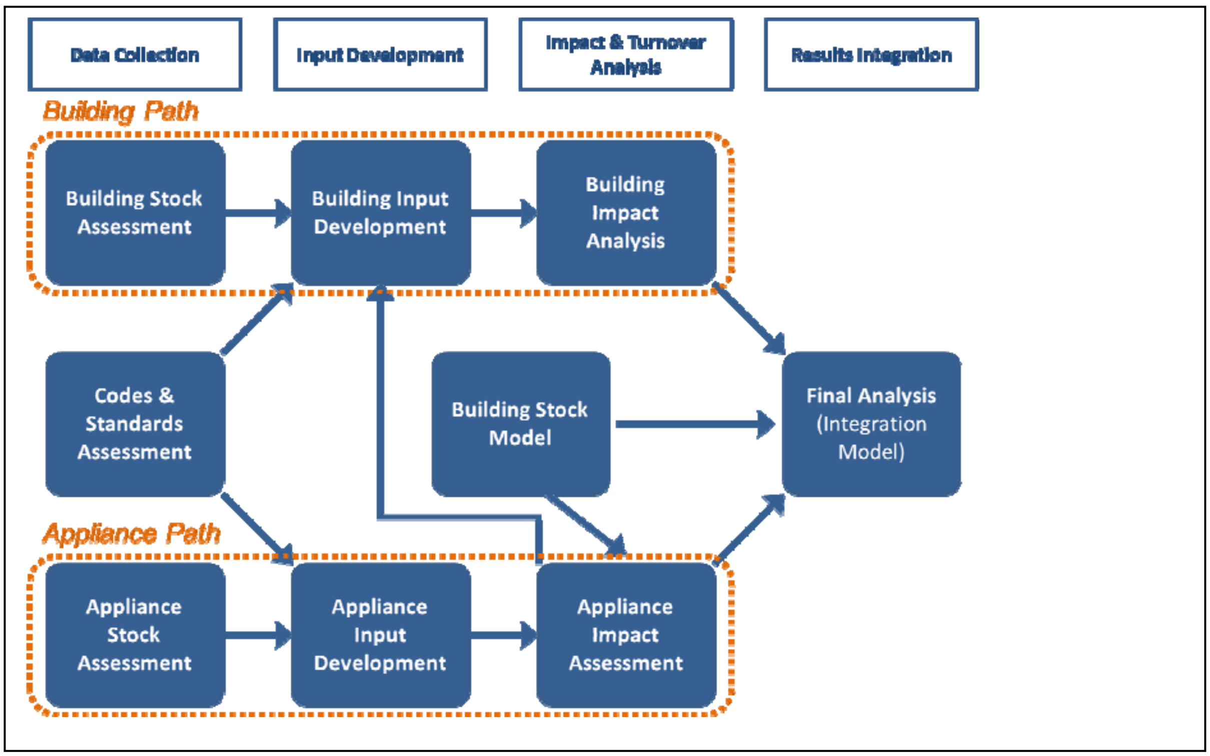
At geographic levels of granularity below the state level, an additional source of uncertainty is building stock forecasts. While these forecasts may be accurate at the state level, they may not be proportionally distributed across utility service territories, and in a small service territory, actual construction activity may vary significantly from state level forecasts. For example, residential construction patterns may be significantly heterogeneous across service territories. Using a forecast that is proportional to the state-level forecast may not be appropriate for such small areas.

Functional Tasks of the CSIQ Analysis

To initiate model specification, the team divided the CSIQ Analysis into its functional tasks. Each task must have clearly defined data inputs, assumptions, methods, and outputs (standardized during the specification process) to enable each task to stand alone as a separate model or analysis, yet seamlessly feed its results into the next task in the CSIQ Analysis. These intermediate results provide transparency to the process. As described previously, the modular approach allows the CSIQ oversight entity to target specific aspects of the analysis for improvement through an ongoing, iterative refinement process. This modularization of the process also allows for tasks to be distributed across analysts for efficient use of expertise and time.

Figure 2 presents a diagram of the CSIQ Analysis. Each blue box represents a discrete task within the process, and arrows represent data flows from one task to another. The orange dashed box (labeled "Building Path") indicates the tasks required for the building analysis. NEEA currently does these tasks. The orange dashed box (labeled "Appliance Path") indicates the tasks required for the appliance analysis. The DOE NIAs address these tasks for many appliances. The remaining appliance analysis efforts beyond the NIA are to distribute appliance populations across the building population and then to determine the HVAC interactive effects of appliance end-use impacts. Figure 2 illustrates this process.

Figure 2. The Codes and Standards Impact Quantification Analysis Schematic



Source: Navigant Consulting 2011

While this process was designed for the Northwest, the authors expect that the methodology is generically appropriate to all regions. However, modules within the process would need to be designed with regional data availability in mind. For example, Northwest regional entities collect and compile extensive regional building stock data, which forms the foundation of the building path analysis in Figure 2. Regions with less extensive data would need to determine early on how to approximate the characteristics of their building stock over time. Historically, this has been limited to code-to-code analyses[2].

Conclusions

This project initiated the process of estimating the Northwest regional energy impacts of changes to codes and standards. It addresses the challenges to providing sound, regionally consistent impact estimates and provides a high-level plan for specifying and constructing the models. The CSIQ Analysis will be capable of estimating impacts from actual codes and standards changes and can also be used as a planning tool to help regulators design effective codes and standards. This method could be applied to other regions to address the universal needs of attributing savings to organizations, forecasting regional power needs, and designing codes and standards that meet regulatory energy savings objectives.

References

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[2] For example, Tolkin et al. (2010) described a code-to-code analysis of residential code upgrades and stretch code introduction in Massachusetts.