



# Methodology for Quantifying the Energy Impacts of Building Codes and Appliance/Equipment Standards in the Northwest

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# 1 Introduction

Codes and standards are a significant source of energy savings in the Northwest, and since 1980, an estimated 40 percent of conservation energy savings in the region have come from codes and standards.<sup>1</sup> Codes and standards are mandated by federal, state, and/or local governments, and often interact in complex ways, such as when the implementation of a new federal appliance standard has implications for the energy savings resulting from a state building code. The Northwest region would greatly benefit from a comprehensive, transparent, and regionally accepted methodology for assessing energy savings from codes and standards. Such a methodology could be used for retrospectively quantifying the energy savings from past codes and standards efforts as well as forecasting the potential savings from proposed codes and standards changes.

Bonneville Power Administration (BPA) engaged Navigant Consulting, Inc. (Navigant) to develop a high level methodology for quantifying the energy savings from changes in building codes and appliance standards in the Northwest. The methodology presented in this document is part of a multi-stage process to develop, implement, and refine a set of data collection and analysis activities. This overarching process is referred to as the **Codes and Standards Impact Quantification (CSIQ) Process**, and the set of data collection and analysis activities (the part of the overarching process in which energy impacts are actually quantified) is referred to as the **CSIQ Analysis**.

## 1.1 CSIQ Process Goals and Objectives

The ultimate purpose of the CSIQ Process is **to develop and implement an agreed-upon method to quantify the energy savings of codes and standards** (including electricity, natural gas, and potentially other fuels) so they can be tracked or used to guide policy decisions regarding possible future codes and standards. The CSIQ Process can be thought of as the roadmap for the overarching regional effort that will result in the development, use, and refinement of the CSIQ Analysis in which energy savings are actually quantified. The Northwest Energy Efficiency Alliance (NEEA) currently estimates regional impacts from nonresidential new construction building codes in an analysis developed by Mike Kennedy Associates; the CSIQ Analysis described in this document expands upon the existing efforts to include savings from non-residential retrofits, residential building codes (for both new buildings and retrofits), and both residential and non-residential appliance and equipment standards, enabling the CSIQ Analysis results to capture the full spectrum of energy savings possible from codes and standards. In addition to this overarching goal, Navigant together with regional stakeholders and subject matter experts identified the following objectives for the CSIQ Analysis to be developed through the CSIQ Process:

- **Usable by multiple parties:** The CSIQ Analysis must be flexible enough to accommodate the goals of multiple parties, which may include BPA, the Council, NEEA, the states, and utilities. Each party likely has different preferences regarding baseline and alternate scenarios (e.g., code-to-code, practice-to-practice, practice-to-code), time frames (e.g., retrospective analysis vs. assessing the potential impacts of future code/standard changes), and/or geographic levels of interest (e.g., regional, state/city, and utility service territory levels).<sup>2</sup>

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<sup>1</sup> Bonneville Power Administration, "Request for Offers, Contract 1772, Attachment 3". R010. No reference was provided in the Request for Offers (RFO) for this figure.

<sup>2</sup> The primary level of analysis is the state or city (e.g., Seattle) level; the state results can be summed to develop regional estimates, and scaled down to estimate rough impacts at the utility service territory level.

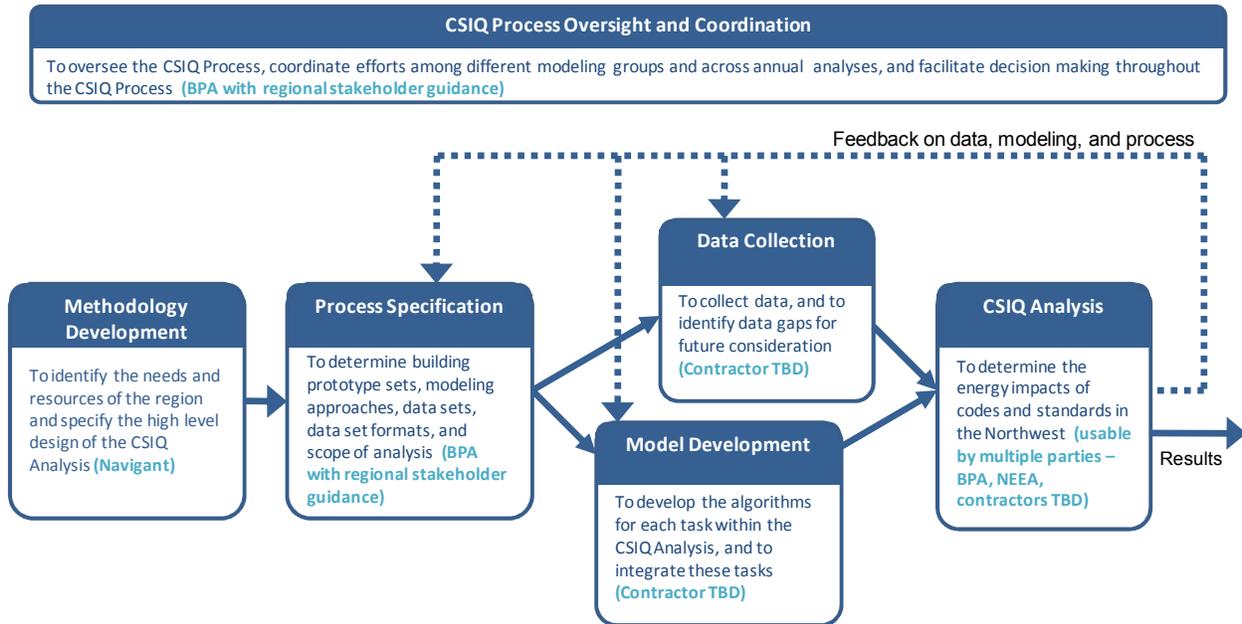
- **Transparency:** A major goal of the involved stakeholders is to develop a process that is transparent and credible. The CSIQ Analysis must have clear documentation of data inputs, assumptions, algorithms, and methods, including standardized data formats, and must also be implemented in a software platform that enables stakeholders to “look under the hood” and provide meaningful feedback to modelers. This transparency will ensure that the results of the CSIQ Analysis are considered credible by regional stakeholders and state commissions.
- **Integration with current regional efforts and existing data sources:** The CSIQ Analysis must build on current regional data collection and analysis efforts. The Council and NEEA have developed data sets and analytical processes that serve as a starting point for the process described in this document, and the past efforts and future cooperation of many regional stakeholders will be critical to the successful implementation of this process.
- **Collaboration:** The modeling work will likely be spread among many modelers from multiple organizations over a long period of time; thus, the CSIQ Analysis must be structured to facilitate easy collaboration between modelers.
- **Ongoing process maintenance/improvement:** The CSIQ Process is a significant undertaking involving multiple regional stakeholders that will likely require several years to fully implement. Thus, stakeholders desire a process that can be implemented modestly at the early stage using currently available data and then be improved gradually over time.

## 1.2 CSIQ Process

The CSIQ Process is a roadmap of the high-level tasks and coordination required to successfully develop, implement, and maintain the CSIQ Analysis. Navigant is responsible for the first task in the CSIQ Process, *Methodology Development*, in which a high-level methodology was developed to quantify codes and standards impacts; this report is the output of the *Methodology Development* task. The next step in the CSIQ Process is *Process Specification*, in which BPA will make a number of critical decisions on building prototypes, modeling approaches, data sets, data set formats, and scope of analysis (see Section 3). These decisions will need to be specified in sufficient detail to enable the completion of the *Model Development* and *Data Collection* tasks necessary to actually implement the *CSIQ Analysis*, which is where energy savings will be calculated. The CSIQ Process incorporates feedback loops to enable the CSIQ Analysis to be refined over time as new data become available and as modelers identify opportunities to improve the analytic approaches. 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 is used to inform future iterations of the CSIQ Analysis.

Figure 1 presents the structure of the CSIQ Process and identifies each task’s objective(s) and the party that is expected to be responsible for each task (in light blue text).

**Figure 1. CSIQ Process Diagram**



### 1.3 Methodology Development Goals and Objectives

This document by Navigant comprises the output of *Methodology Development* task in the CSIQ Process discussed in the previous section. The goals of the *Methodology Development* task were to:

- 1) Identify the various needs of multiple Northwest region stakeholders for quantifying the energy impacts of codes and standards (see Section 1.1). Identify and assess analytic efforts and data sources already in use in the Northwest as well as data and algorithmic gaps.
- 2) Describe—at a high level—the necessary steps in the CSIQ Analysis, the interactions and data flows between those steps, the critical decision points that were necessary to develop the high level methodology, and the key decisions that remain to be made during the *Process Specification* task.

This high level methodology presented in Section 2 is intended to provide enough description of the CSIQ Analysis to enable BPA (with regional stakeholder guidance) to develop process specifications and a scope of work for the next contracted tasks of this project, which will be to collect and assemble data and to build the necessary models. To develop the high level methodology, Navigant needed to make certain critical decisions regarding the structure of the CSIQ Analysis; these decision points, along with the rationale for the selected option, are described in Section 2.1. Section 3 identifies key decisions that remain to be made in the *Process Specification* task.

## 2 Methodology

This section describes, at a high level, a methodology for determining the Northwest energy impacts of changes to building codes and appliance/equipment standards. Section 2.1 describes several fundamental decisions about the approach to analyzing buildings and the appliances and equipment within them that were necessary to proceed with developing the methodology. Subsequent sections describe the four stages of the analysis, beginning with data collection (Section 2.2). Section 2.3 describes how these data will be used to develop inputs to models of buildings and appliances that describe both the baseline prior to codes/standards changes (the "pre" case) and the expected conditions after the introduction of the code/standard changes (the "post" case). Section 2.4 describes the technical analyses that will be conducted to determine differences in energy consumption between the pre and post cases on a per-building (or per-appliance) basis. These impacts will be scaled by the estimated quantity of building area (or appliances). Finally, Section 2.5 describes the adjustments that will be made to results to account for the interactive effects of changes to appliance/equipment energy consumption on building heating, ventilation, and air-conditioning (HVAC) loads. Section 2.6 summarizes the methodology and the relationships between the different analytic tasks.

### *2.1 Approach to Building and Appliance Analyses*

This section presents several key structural decisions that were necessary to make before developing the methodology.

#### **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. Navigant chose to keep the building and appliance analyses separate because of the significant data collection requirements that would be needed to thoroughly inventory and track appliances in buildings. The exception to this is lighting and HVAC, which are discussed in greater detail in the following section.

Building energy simulation software is commonly used for building energy analysis to determine the effects of the building shell, lighting, and heat gains from appliances/equipment (and from occupants) on the HVAC system. Typically, internal heat gains are represented by a single schedule of loads, rather than separate schedules for each appliance/equipment. The data collection requirements to accurately model individual appliance/equipment loads within buildings are simply too great, and would only improve the estimate of HVAC interactive effects, a second order impact. The difference in results between the two approaches is not likely to be more than a few percent of the total estimated energy consumption, provided that the individual appliance/equipment loads add up to the aggregated internal heat gain value.

Navigant recommends conducting a separate analysis of appliance and equipment impacts rather than including them in the building analysis for several 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. It

would also require multiple analyses of each building type to track different lifetimes of equipment in the population and the continual evolution of the appliance population in any given building. This would also require tracking the population of *all* appliances in buildings, not just those affected by the standards. Because of the large number of assumptions that such an analysis would be based on, the proposed alternative of using rich national level datasets would give more robust estimates.

- » 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.

The recommended approach creates two tracks: a building track and an appliance track. This allows for a bottom-up approach to building analysis and a top-down approach to appliance analysis, 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 building impacts in two ways. The first is that details from appliance saturation research and engineering analyses can inform the representation of internal heat gains in the building simulation. The second is that changes to the internal heat gains in buildings (as a result of changes to appliance/equipment efficiency) will affect HVAC loads. This interactive effect is addressed by determining sensitivities to internal gains (e.g.,  $\Delta\text{kWh}$  of cooling /  $\Delta\text{kWh}$  in appliance loads in conditioned spaces) as part of the building analysis, and scaling appliance/equipment end-use impacts by these interactive effects 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. Several examples illustrate this:

- » 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.
- » Some code provisions address equipment that is not typically modeled directly through building simulation – for example, water heater or compressor provisions.

#### **Lighting and HVAC Equipment Affected by Both Codes and Standards Analyzed in Building Path**

While the CSIQ Analysis treats appliances and buildings distinctly, some systems (lighting and HVAC) are best analyzed through consideration of the building as a single, complex system, rather than separated and treated as an individual appliance in the analysis. This is due to the interactions between building parameters (e.g., insulation and glazing) and energy consumption (HVAC, lighting), which are best analyzed using a bottom-up approach. Building energy simulation software (e.g., DOE 2, EnergyPlus, SEEM) is typically used to analyze these systems. For this reason, although lighting and HVAC are affected by *both* codes and standards, they are analyzed in the building path.

#### **Other Equipment Affected by Both Codes and Standards May Be Analyzed in Appliance Path**

Other appliances/equipment that may be affected by codes would be assessed through the appliance path if the expected lifetimes of the appliances/equipment are shorter than the expected building lifetime (e.g.,

water heater, compressor) and replacement of these products would not be considered a building retrofit/alteration.<sup>3</sup>

## 2.2 Data Collection

Successfully developing robust estimates of the impacts of codes and standards requires a diverse set of data collection activities. On-site audits can inform the models that estimate building and appliance impacts. To accurately characterize the building population, building characteristics for each building type, of each vintage, in each analysis period<sup>4</sup> will be necessary.<sup>5</sup> State-specific building characteristics may also need to be modeled where there are significant differences among the states; for example, aggressive building codes or energy efficiency program activity in one state in previous years may lead to significantly different existing building and/or new construction baseline characteristics from state to state. The characteristics of buildings will vary by analysis period as buildings evolve over time, due to retrofits and usage changes.

Appliance populations by efficiency level and age will be necessary to develop appliance stock turnover models. For example, the population of clothes washers in the region, disaggregated by vintage and efficiency factor, is needed—along with estimated lifetimes—to develop a model capable of forecasting stock turnover and increase going forward; the impact of appliance standards is a result of the difference in efficiency of replaced and increased quantities of appliances relative to current purchasing trends going forward in time from the introduction of the standard.

### Data Granularity

One important consideration is the level of granularity (in terms of distinctions between building types, building components, and appliances/equipment) in the building stock and appliance stock data. The granularity in the collected data should match the level of detail specified in the relevant codes and standards. For example, if code provisions are specific to HVAC types, then building characteristics data should be granular enough to map observed building HVAC types to those categories specified in the code. Likewise, standards vary by refrigerator configurations (e.g., side-by-side, freezer on top); therefore, refrigerator saturation data must be disaggregated by refrigerator configurations and provide estimates of trends in saturation by configuration. However, there are often competing needs and changes in code and standards specifications that may make it difficult to collect or find data that are available at the same granularity. In that case, the modeler will need to utilize mappings from observed categories to code/standard specified categories. These mappings should be clearly documented by the CSIQ modelers.<sup>6</sup>

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<sup>3</sup> Data on building alteration/retrofits can be used to inform the analysis of existing buildings in the building path. However, for characteristics not tracked through alteration/retrofit (e.g., appliance replacement), regional stock models informed by regional sales/shipments provide the quantity information needed to estimate regional impacts.

<sup>4</sup> An “analysis period” is the time range of codes and standards changes being evaluated. For example, NEEA has published analyses of codes introduced from 1996 to 2004, and from 2005 to 2008. Both of these are analysis periods.

<sup>5</sup> For example, the building characteristics of large office buildings built between 1980 and 1985, evaluated from 1995 to 2000. Unless otherwise noted, time periods used in this document are for illustrative purposes only. Actual time periods will be determined during the specification process and will depend on years of significant code/standard changes and data availability.

<sup>6</sup> Another important mapping is that from RTF climate zones (which regional building survey data conforms to) to the climate zones specified in building codes.

The importance of matching granularity indicates the need for the coordination of regional data collection efforts with the CSIQ Process development and implementation. Coordination between these two efforts is also necessary to ensure that data field definitions are unambiguous and are developed to ensure usefulness within the CSIQ Process. For example, NEEA building survey definitions, guides, and data collection methods could be aligned with CSIQ modeling approaches (and vice-versa) and building type and vintage definitions. Also, building stock forecasts developed by the Council can be used by the CSIQ Process, provided that the categorization and data formats are compatible.

### **Current and Historical Data**

To fully estimate impacts from both current and historical codes and appliance standards, as well as for retrofits and new construction, the CSIQ Process will require both current and historical data. Current data includes current datasets of characteristics for new and existing buildings and the current population of appliances (by efficiency level). Historical data is this same information at previous periods of time. Note that existing buildings of the same vintage may have different characteristics at different periods of time. For example, hospitals constructed from 1980 to 1985 might have one set of baseline characteristics in an evaluation of codes and standards introduced between 1995 and 2000, and might have a different set of baseline characteristics in an evaluation of codes and standards introduced between 2005 and 2010 because of alterations or changes in usage.

Sample size and stratification for regional data collection will determine the statistical significance of results at the regional level, and at smaller levels such as by state or building type. At the current levels of data collection, statistical significance at the building type level or at the service territory level is unlikely. Previous new construction code impact estimates conducted by NEEA offer a data set from which to examine distributions of results and estimated sample sizes required for desired levels of confidence and precision.<sup>7</sup>

### **Data Sources**

Data sources currently available for use by the Northwest include:

- » **Building characteristics** will come primarily from regional building surveys (i.e., NEEA's Baseline Characteristics studies: Commercial Building Stock Assessment (CBSA), and Residential Building Stock Assessment (RBSA), and the Pacific Northwest Residential Energy Survey (PNRES)) and national data sources (i.e., U.S. Energy Information Administration's (EIA's) Commercial Building Energy Consumption Survey (CBECS)<sup>8</sup>).
- » **Building stock** information has traditionally been developed by the Northwest Power and Conservation Council (NWPCC) through the use of FW Dodge (commercial) and Global Insights

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<sup>7</sup> This would assess sampling error only, not uncertainty in the building and/or appliance modeling. Sampling error is error caused by observing a sample of the population (of buildings), rather than the entire population.

<sup>8</sup> CBECS will likely not be a useful resource for tracking commercial building characteristics beyond 2003. The EIA has decided not to release results from the 2007 CBECS because it did not yield valid statistical estimates (U.S. EIA, "Commercial Building Energy Consumption Survey", <http://www.eia.gov/emeu/cbecs/contents.html>, last accessed 10 May 2011). The EIA has also suspended work on the 2011 CBECS because of FY 2011 funding cuts (U.S. EIA, "Press Release - Immediate Reductions in the EIA Energy Data and Analysis Programs Necessitated by FY 2011 Funding Cut", <http://www.eia.gov/pressroom/releases/press362.cfm>, last accessed 10 May 2011).

(residential) construction data for historical representation and regional economic and employment forecasts by sector for future representation.

- » **Appliance stock** data sources will vary by appliance. Typical sources include DOE appliance/equipment standards analysis supporting data, sales and shipment data from trade organizations such as the Association of Home Appliance Manufacturers (AHAM), and baseline and appliance/equipment saturation studies. Regional building surveys (CBSA, RBSA) may inform the distribution of appliance stock among buildings by type and vintage.
- » **Appliance efficiency impacts** may come from existing engineering analyses, metered studies, and program impact evaluations. Where secondary data from other regions or times is used, CSIQ Analysis developers may need to adjust results to reflect regional differences in climate and usage or trends in efficiency levels over time. Where secondary sources are not available, original engineering analyses will be needed.
- » **Codes and standards specifications** must be collected to determine the adjustments to baseline characteristics. The codes and standards being considered are state building codes, Seattle building codes, Federal appliance/equipment standards, Oregon's state appliance/equipment standards, and Washington's state appliance/equipment standards. Sources that summarize codes and standards are helpful, and include summaries of codes from NEEA, summaries of standards from the Appliance Standards Awareness Project (ASAP), supporting documentation of federal appliance/equipment standards from the U.S. Department of Energy (DOE), and appliance and commercial equipment standards website. See Appendices B and C for partial listings of sources for codes and standards active in the Northwest region.

Data sources need to be developed in tandem with CSIQ models: as data become more available and more granular, more detailed models become possible. A review of the strengths and weaknesses of CSIQ models can help to identify, target, and prioritize data needs.

## 2.3 *Input Development*

After collecting building and appliance data, this data must be assembled into two analysis cases: a base (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, data from building surveys is used to develop building simulation models, and data from appliance saturation and shipment research is used to develop an appliance stock model.

### Pre and Post Case Definition

There are multiple pre and post case definitions, which vary by baseline definition and predicted outcomes of the change in codes/standards. The pre case (or baseline) may be defined as existing code/standard, Power Plan defined baseline, observed current practice, or an estimate of current practice.<sup>9</sup> Data requirements and the input development process will vary with pre case selection. The primary data requirements for pre cases other than observed current practice are minimal; only the parameters that define the case are needed (e.g., the code provisions, the power plan baseline description). The data requirements for the observed current practice are the most significant; this requires surveys of current building and appliance stock. The pre case for a given vintage cohort of buildings may change over time.

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<sup>9</sup> For example, estimating lighting power densities to be 10% greater than current code provisions.

Commercial building examples include increased hours of operation in grocery stores between the 1970's and 1990's and the introduction of grocery end-uses to big box retail buildings in the 1990's. A residential example is the increase in plug loads over the past several decades. Within all buildings, subsystems such as lighting and HVAC will turn over many times over the life of the building.<sup>10</sup>

The post case may be defined as the new code/standard or an estimate of what the practice will become as a result of the changes to codes/standards. The post case does not necessarily need to be more stringent. For a post case defined as the new code/standard, building and appliance models are simply brought up to code to establish the post case inputs; if the pre case is observed current practice, and it turns out that current practice already exceeds the stringency of the new code, the result would be zero impact. The post case defined as the estimate of what practice becomes is more complicated to determine, as future practice may exceed the code/standard's stringency or compliance may be lower than expected. Here the CSIQ input developer must estimate the future effects of introduced codes and standards changes on baseline characteristics/current practices. As the effects of new codes/standards changes are not known at the time of the analysis, the analyst must use their professional judgment on a provision-by-provision/standard-by-standard basis to make reasonable estimates. For example, the effect of the introduction of more stringent lighting power density (LPD) provisions in buildings might be that LPDs in all buildings shifts from slightly above the old provision to slightly above the new provision. This estimate is based on observation of new construction lighting characteristics. CSIQ analysts should clearly document these estimates and their rationale.

For changes to codes/standards that are *increases* in stringency, there are two classes of responses to codes/standards changes for the analyst to consider. The first response is that only those sites (or appliances) not meeting the new code/standard are affected by the new codes/standards, and that the response is to bring non-compliant characteristics 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, or it may also influence the customers who would have previously opted for a more efficient model to purchase an even higher efficiency model due to shifts in the marketplace. Which response class an analyst selects for a particular code/standard will depend on such factors as the distribution of characteristics observed in the current practice and the cost and availability of products and procedures that meet and exceed the code/standard.

Changes in building/appliance characteristics that result from *decreases* to code/standard stringency may be more complicated to predict. However the same considerations must be taken: estimating how close to current code the current practice is and understanding cost trade-offs in moving to less efficient equipment and techniques.

### **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

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<sup>10</sup> Much of this change may be captured by performance parameters such as lighting power density (LPD) and heating and cooling efficiencies, rather than by modeling these systems directly.

buildings to capture the diversity of building stock in the region.<sup>11</sup> Using prototype models has the advantage of requiring fewer building models—typically 10 to 20—analyzed repeatedly for each climate zone. For assessments of impacts where the pre case is defined as existing codes/standards and the post case is defined as the updated codes/standards (i.e., “code to code”), building prototypes offer a simple (i.e., minimal number of models to assess) approach. Examples of commercial building prototypes that have already been developed include buildings modeled in DOE2<sup>12</sup> for California and buildings modeled in EnergyPlus for analysis of all US regions (developed by the Pacific Northwest National Laboratory).

Navigant does not recommend the use of building prototypes when the pre case is defined as standard practice, rather than existing codes/standards. A sampling approach is preferred in this situation because, in the prototype approach, the same 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, surveyed buildings 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 and alterations estimated through a building stock model.

### **Building Simulation Software and Input Templates**

The building simulation software to be used may be specified prior to further development of the CSIQ Analysis, or may be left to the discretion of the building analysts developing the building path of the CSIQ Analysis. Different software are available for residential and nonresidential building analyses. Criteria for selecting simulation software should be developed during the process specification phase and may include considerations such as: confidence of stakeholders in accuracy of results; ease of use in developing and executing models and in harvesting results; familiarity of users and stakeholders with the software; consistency with other regional efforts; and the ability to leverage existing modeling and analysis automation efforts. This may result in a list of recommended software.

Input templates will need to be developed to standardize the inputs and facilitate the sharing of data between different modelers, particularly between the appliances and the buildings modelers (which will,

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<sup>11</sup> Individual analyses can be fairly simplistic: the key building shell, lighting, and HVAC characteristics, along with usage characteristics, inform a larger template model of each building type. These analyses could be automated after the building and usage characteristics are developed.

<sup>12</sup> These prototypes have been developed as part of the Database for Energy Efficiency Resources efforts commissioned by the California Public Utilities Commission and the California Energy Commission.

in general, be different people). The development and use of a template will greatly increase transparency and the ability to integrate the process. These templates would be developed before model development can start. Building templates might look like input files to the building simulation software being used (e.g., DOE 2, EnergyPlus, SEEM). Appliance templates might look like the DOE National Impact Analysis (NIA) spreadsheets, which have separate sheets for sales/shipment data, appliance population by year and efficiency level, and population decay and turnover model parameters. Data for the pre and post cases should be in the same file for ease of comparison.

### **Data Gaps**

Despite efforts to collect meaningful and extensive data, it is inevitable that analysts will encounter data gaps, both of scope and of quantity. When developing assumptions to overcome these gaps, analysts should document any assumptions made and include justification for these assumptions. Careful documentation of the assumptions is critical for maintaining transparency in savings estimated and can be used at the regional level to prioritize future improvements in the CSIQ Analysis and supporting data collection efforts. This list can be reviewed at a regional level to help direct future data collection efforts.

## ***2.4 Impact and Turnover Analysis***

After the input data for the analysis has been assembled, separate impact analyses are conducted for the building and appliance paths. Additional building stock analysis is required to estimate the quantity of units (i.e., square feet of buildings, number of appliances) over time. The following subsections discuss these three analyses: building impact analysis, building stock model, and appliance impact analysis.

### **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. Examples of when engineering analysis would be used include the evaluation of performance-based paths to code compliance; code provisions that apply to a very small set of buildings that is not well represented by the building models; equipment provisions that do not strongly influence the HVAC system; where representation in the models would be too crude (e.g., controls such as occupancy sensors); or where available data on building characteristics is not detailed enough to justify a building energy simulation approach.

The building analysis must also determine the HVAC interaction factors<sup>13</sup> of each building type/vintage, so that they can be applied to the appliance/equipment end-use impacts. This is done by running the building simulation several times with varying internal heat gains and observing the effects on the HVAC system. Separate HVAC interaction factors may be determined for different load schedules (for example, based loads, daytime loads, night time loads). Interaction factors are expressed as the change in HVAC energy consumption (kWh or therms) per change in internal heat gains (kWh).

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<sup>13</sup> HVAC interaction factors are the sensitivity of HVAC loads to changes in internal heat gains.

## **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 must be disaggregated by building type, location<sup>14</sup>, and the building vintage (for alterations). For CSIQ analyses that forecast impacts into the future, future building stock must be estimated; the Council currently conducts this type of analysis for residential and non-residential new construction. For past and current building stock, proprietary data sources such as FW Dodge and Global Insights are typically used to determine the quantities of new construction, alterations, and demolitions during each time.

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 still affected by codes/standards. Furthermore, a given retrofit may be affected by some, but not all codes/standards. For example, a lighting retrofit would not require building shell improvements but an addition would be affected by both the lighting and the building shell provisions. 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 used in later steps (during *Results Integration*) scaled to the population of buildings in the Northwest, as determined by the building stock model.

## **Appliance Impact Analysis**

Appliance impact analysis determines the energy impact of code/standards changes per appliance. Appliance impacts may be obtained from secondary sources such as engineering analyses, metering studies, or impact evaluations. Where these studies are from other regions (e.g., Department of Energy analyses in support of federal standards rulemakings, impact evaluations in other regions), findings may need to be adjusted to reflect differences in time or location. 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.

Unlike the building impact analysis (which determines per-building or per-square foot impacts), for which there is a separate building stock analysis, the appliance impact analysis includes *both* the per-appliance savings estimates as well as the appliance stock estimates. These analyses are combined to determine the regional appliance end-use impact. The appliance stock and distribution across building types is necessary to provide input to the building input development task, and therefore cannot be put off until the final integration of building and appliance results, as is the case with the building impact analysis results. Another reason for including the appliance stock models within the appliance impact

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<sup>14</sup> Depending on the level of granularity of the analysis, location may need to be specified at the state, county, major metropolitan area, or zip code level. It must be granular enough to capture differences in climate zone, jurisdiction (state/Seattle), and perhaps utility service territory.

analysis is that each appliance will require a unique stock model, which may be derived from different data sources or used different analysis approaches. In other words, appliance stock and stock turnover is integral to the appliance analysis, whereas building stock and building stock turnover are not needed for the building impact analysis until the total impacts are estimated in the final step of the analysis.

The DOE NIAs provide a thorough template for conducting the appliance standards analyses, using shipment/sales data, a stock turnover model, and usage assumptions.<sup>15</sup> 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. Product costs by efficiency level are estimated to inform estimates of consumer decisions between more and less efficient products in the future. A base case and an efficient case are considered; the base case assumes no change in the current standard and the efficient case assumes an increase in the standard. The impact is then the per appliance impact multiplied by the difference in populations (by efficiency level) in the two cases.

The DOE NIAs typically do not consider HVAC interaction factors because of the variation in HVAC sensitivity by building type and climate zone across the U.S. To capture the HVAC interactions for the Northwest, two additional steps are required. The first is to estimate the distribution of appliance stock (which is in the NIAs) across building types and vintages. Building surveys can inform the development of these distributions, as can appliance/equipment specific studies and appliance saturation studies. The second is to apply the HVAC interaction factors determined in the building analysis to the impacts distributed to each building type/vintage. Where data do not exist to determine the distribution of appliances across building types, several approaches are possible: 1) assess only the end-use impacts, which does not require distributing appliances across buildings; 2) assess the end-use impacts and apply generic HVAC interaction factors developed by the Regional Technical Forum for other analyses; or 3) assume a flat distribution of appliances across all likely building types. The process specifications should address the heuristics for determining which of these three approaches to take for a given appliance.

## **2.5 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<sup>16</sup>), 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).

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<sup>15</sup> For example, the NIAs for refrigerators and freezers, available at [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/refrig\\_freezers\\_nopr\\_analytical\\_tools.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/refrig_freezers_nopr_analytical_tools.html)

<sup>16</sup> Appliance impacts are the product of the per-appliance energy impact and the total number of affected appliances; this calculation occurs in the Appliance Impact Analysis, so the Integration Model simply takes into account the HVAC interaction factor to estimate the whole-building impacts of the codes and standards in total.

- 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 (such as CBSA 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 results can be reliably reported. 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.

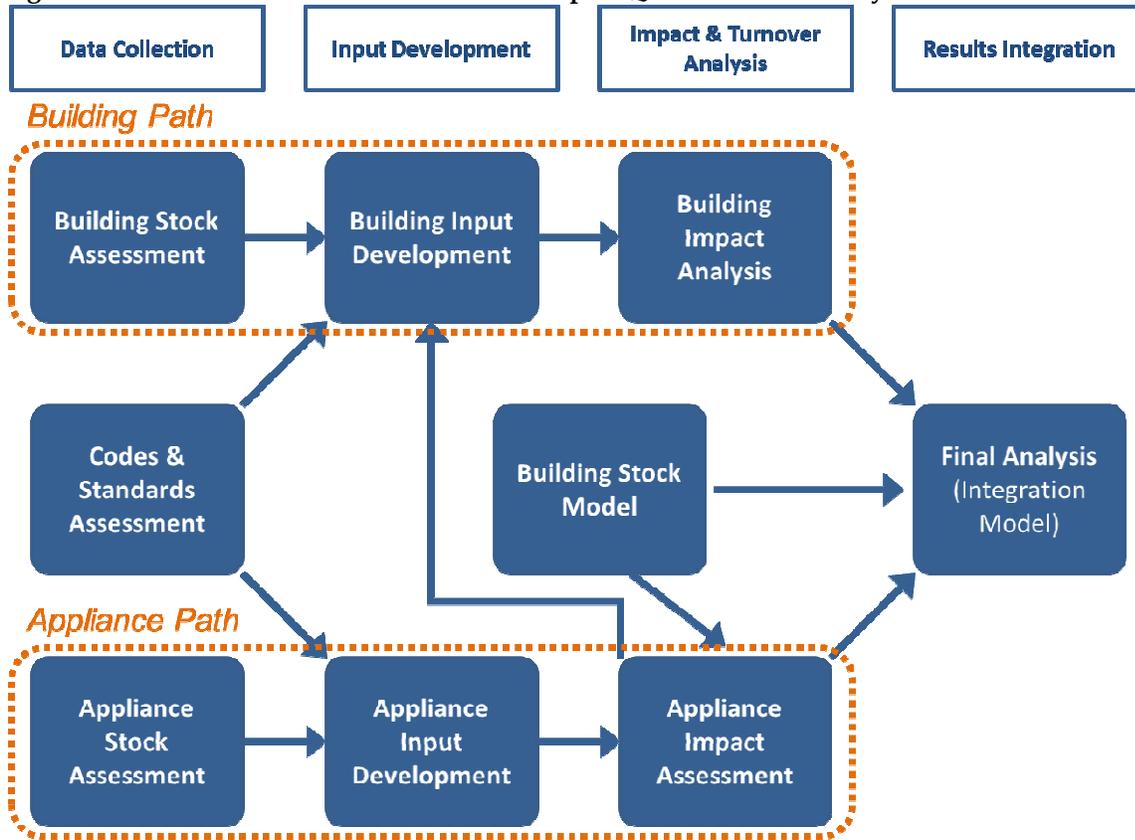
At geographic levels of granularity below the state level, an additional source of uncertainty is building stock forecasts. While these forecasts may be accurate at the state level, they may not be proportionally distributed across utility service territories, and in a small service territory, actual 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. However, retrospective analyses may be justified where local building census or permitting data is available.

## ***2.6 The Codes and Standards Impact Quantification (CSIQ) Analysis***

The previous subsections of Section 2 describe the activities necessary to estimate the energy impacts of changes to codes and standards. This subsection presents the Codes and Standards Impact Quantification (CSIQ) Analysis divided 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. 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. Detailed descriptions of the tasks and data inputs and flows are provided in Appendix A. The tasks required for the building analysis are indicated by the orange dashed box (labeled “Building Path”). These tasks are currently done by NEEA. The Council provides the building stock estimates to which these per-building impacts are applied. The NEEA analysis addresses nonresidential new construction. It does not address residential buildings, or existing buildings. The tasks required for the appliance analysis are indicated by the orange dashed box (labeled “Appliance Path”). The DOE NIAs address these tasks. For appliances for which NIAs exist, these analyses can be used (perhaps with modifications to reflect Northwest regional characteristics). 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. Overview of Codes and Standards Impact Quantification Analysis



## 3 Next Steps: Process Specifications

This document provides a high-level methodology for estimating the energy impacts of changes to building codes and appliance/equipment standards. As indicated in Section 1.3 (Figure 1), the next step in the CSIQ Process is for BPA (with guidance from regional stakeholders) to provide detailed specifications for the CSIQ Analysis. Process specifications include decisions on building modeling, modeling software and approaches, data sets, data set formats, and scope of analysis. These decisions will need to be specified in sufficient detail to enable contractors to build the necessary models, to coordinate between different models, and to collect data and populate datasets. This section identifies many of these specifications.

### 3.1 Analysis Scope

The scale of data collection and analysis efforts will depend on the scope of the CSIQ Analysis. From Navigant discussions with stakeholders, several limitations to the analysis have been identified:

- » **Disaggregation of codes and standards impacts:** In general, this method will not attribute the savings between codes and standards but rather will provide a single estimate of savings. This is because of the energy interactions between buildings, systems, and appliances (e.g., the HVAC interactive effects of appliance savings depends on the building shell characteristics). Also, some of the most significant energy consuming systems, such as lighting and HVAC, are affected by both codes and standards, resulting in some overlap of impacts from the two regulatory routes. However, the CSIQ Analysis can be set up to examine a single code or standard change, or any suite of changes; this property can be used to determine incremental effects of additional code/standard changes.
- » **Distributed generation:** Distributed generation will not be addressed, even though it may be included in building codes. Efforts external to this process would be necessary to determine the impacts of distributed generation and to adjust codes/standards impacts determined through the CSIQ Analysis.
- » **Program activities:** Program activity will not be considered by the CSIQ Analysis. Efforts external to this process would be necessary to determine the overlap of impacts between codes/standards changes and incentive program outcomes.
- » **Standards that do not affect building stock** – Standards or codes that affect equipment not in the building stock (for example, street lights and traffic lights) will not be addressed. Since the affected systems do not interact with buildings, a separate analysis could be added onto the CSIQ Analysis to address these systems. The extra-building codes/standards will become more significant over time.

An additional bound on the scope of the CSIQ Analysis will be the desired granularity of results. For example, results can be developed at the Northwest regional level, at the state/Seattle level, by building type at the regional level, by building type at the state level, or by utility service territory. The specified level of granularity will dictate the scale of data collection for the building analysis. At current levels of NEEA building surveying (100's of buildings), stakeholders suspect that results are statistically significant at the regional and state level, but not by building type.

### 3.2 *Process Oversight and Coordination*

As illustrated in Section 1.3 (Figure 1), oversight and coordination will be necessary to distribute and coordinate tasks amongst regional stakeholders (e.g., BPA, the Council, NEEA) and contractors. For example, building stock model development efforts by the Council should be coordinated with the development of CSIQ Analysis input requirements. Oversight will be required to ensure that regional needs are met and to prioritize the use of time and money towards incremental improvements in data collection and in modeling.

### 3.3 *Analysis Structure*

Several structural specifications are also necessary before data collection and input development efforts can be scoped:

- » **Baseline definition:** The pre case or baseline definition predicates the building characteristics data requirements. Examples of baseline options include existing codes/standards, practice, and Council power plan baseline. For example, building prototype models are available (e.g., PNNL EnergyPlus commercial prototypes) that reflect existing codes/standards, whereas extensive regional building surveying is required to model a baseline defined as current practice. Multiple baseline options could be specified depending on the needs of the region.
- » **Post case definitions:** The post case reflects how building and appliance populations change as a result of changes to codes/standards. Judgment is required to estimate the response of populations to each change of codes and standards, as discussed in Section 2.3. Heuristics for estimating how characteristics shift are necessary to standardize the treatment of this problem. These heuristics could be specified prior to development of the CSIQ Analysis, or could be included in the development of the CSIQ Analysis.
- » **Building versus appliance path:** Heuristics are also needed to determine whether specific elements are analyzed through the building or appliance path, as discussed in Section 2.1. Complicated situations arise when elements are addressed by both codes and standards (e.g., lighting, HVAC); when equipment in building codes requires a more detailed analysis than building simulation typically provides (e.g., commercial cooking equipment); when federal standards address buildings (e.g., manufactured housing); and when federal standards address widespread components already evaluated at the system level in the CSIQ Analysis (e.g., motor standards where motors are already included in HVAC system representation).
- » **Building models:** Building types and vintages groups will need to be defined prior to building data collection to determine data collection needs. Building types should be selected to minimize the number of building types while capturing significant differences in building construction and usage across building types. Examples of residential building types are single-family, multifamily, and manufactured homes. Typically, 3 to 5 residential building types are used. Examples of commercial building types are hospitals, grade schools, and small offices. Typically, 10 to 20 commercial building types are used. Existing buildings will also need to be grouped by vintage. For example, buildings constructed from 1981 to 1990, or from 1991 to 1995. Each vintage cohort of buildings is expected to evolve over time to reflect renovations and equipment replacements; buildings from the 1981 to 1985 cohort would have different baseline characteristics when they are evaluated in 1990 and in 2010. The agency or contractor selected to conduct the building analysis may have valuable insight into selecting building types and vintages to optimize the trade-off between accuracy of representation and scale of data collection requirements.

### 3.4 Technical Specifications

Several technical specifications related to modeling and data representation are also required:

- » **Building simulation platform:** Different simulation software are available for residential and nonresidential building analyses. Criteria for selecting simulation software include confidence of stakeholders in accuracy of results; ease of use in developing and executing models and in harvesting results; familiarity of users and stakeholders with the software; consistency with other regional efforts; and the ability to leverage existing modeling and analysis automation efforts. This topic is discussed in Section 2.3. The building simulation software to be used may be specified prior to developing the CSIQ Analysis, or may be left to the discretion of the building analysts developing the building path of the CSIQ Analysis.
- » **Fields/formats of data sets:** The CSIQ Analysis can be viewed as a set of discrete tasks. Outputs from each task become inputs to other tasks. Therefore, the fields and formats of data sets need to be specified during the initial stages of the CSIQ Analysis development. Using standardized data sets will provide transparency to the process by allowing stakeholders to review intermediate data sets as well as final process results.
- » **Software for data sets:** A platform will need to be specified for maintaining data sets. The most commonly used platform in the region is Microsoft Excel, which can be used for both storing and manipulating data. Other options for data representation include alternative modeling platforms and analytical tools such as Analytica, Stata,<sup>17</sup> and SAS and database platforms such as Microsoft Access. One advantage of using Microsoft's products is that the embedded programming language, Visual Basic for Applications (VBA), can be used to execute other programs such as building simulation software. Advantages of Analytica include built-in uncertainty analysis and dynamic set representation.<sup>18</sup>
- » **Software for automation of analysis:** As emphasized by describing this effort as a "process" rather than a "model", multiple analyses will be conducted using building simulation software, spreadsheet analysis, and possibly other modeling tools. The execution of these tools will need to be coordinated and automated, for example, the provision of input data to the building simulation and the collection of output data from the simulation. Each step of the process needs to be designed so that it can be controlled from a command line using defined inputs and producing defined outputs. Then, a master process needs to be developed based upon a scripting language to run all of the steps. Possible scripting languages include Visual Basic for Applications (VBA) within Microsoft Office documents, or languages that run at the operating system level, such as a Visual Basic Scripting (VBScript), Windows PowerShell, or Python.

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<sup>17</sup> Stata is the base format for all non-residential building characteristics data collected since 1990, and all input data for the current building codes impact estimation process is in Stata format.

<sup>18</sup> That is, when the size of an array or the organization of its fields is changed, the model automatically accommodates these changes.

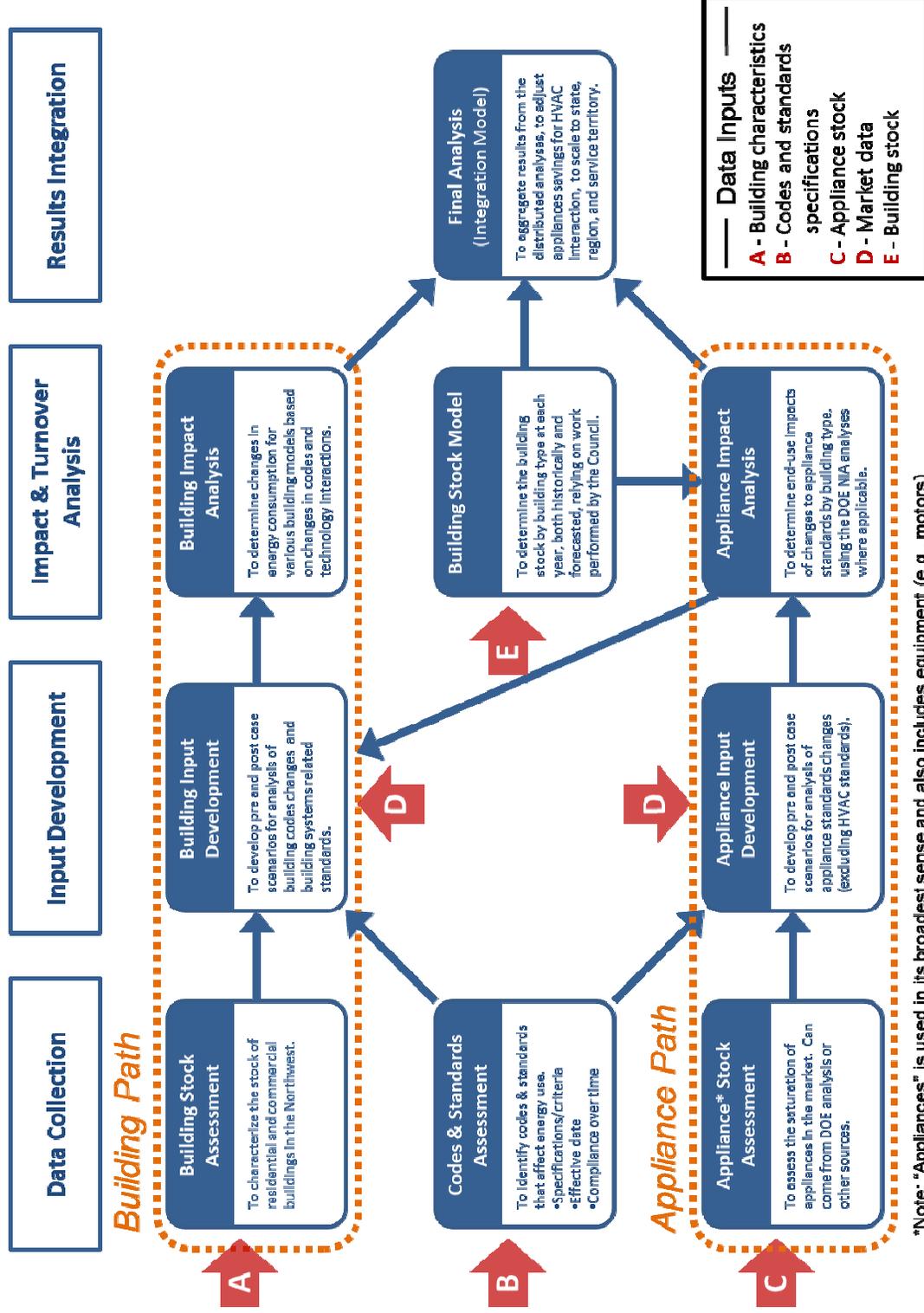
## Appendix A: CSIQ Analysis Tasks and Data Flow

As discussed in Section 2.6, the CSIQ Analysis comprises an interrelated set of data inputs, modular tasks, and data flows between the tasks. This modular approach facilitates division of labor between multiple modelers with a common framework for collaboration, enables existing efforts to be leveraged, identifies current data gaps, and enables ongoing process improvement over time by allowing stakeholders to prioritize specific tasks for further data collection or methodology refinements. This appendix reiterates much of the contents of Section 2 in a task by task format, including the data flows between the tasks. The tasks are organized into four groups:

- **Data Collection** tasks involve collecting and organizing a variety of data in useful data sets that will serve as the basis for modeling throughout the CSIQ Analysis. Tasks include:
  - **Building Stock Assessment**, which collects building stock data for the building scenarios.
  - **Codes and Standards Assessment**, which collects data on codes and standards' technical specifications.
  - **Appliance/Equipment Stock Assessment**, which collects appliance/equipment saturation data for use in the appliance standards scenarios.
- **Input Development** tasks involve development of the pre and post cases for each change in codes or standards. Each analysis using the CSIQ Analysis will involve the development of at least one pair of pre case inputs and post case inputs representing a change in a code or standard; the energy impact of the code/standard change is the difference in annual energy consumption between the pre case and the post case. Tasks include:
  - **Building Input Development**, which creates the representative building descriptions for the pre and post cases and feeds into the building and appliance analysis tasks.
  - **Appliance Input Development**, which creates the appliance/equipment saturations for the pre and post cases and also feeds into building and appliance analysis tasks. This includes modeling of appliance stock turnover and appliance distribution across building types.
- **Impact & Turnover Analysis** tasks involve a variety of engineering, forecasting, and simulation models that estimate the impacts of codes and standards changes. Tasks include:
  - **Building Simulation & Engineering Analysis**, which analyzes the difference in energy consumption between the pre and post cases.
  - **Building Stock Turnover Model**, which quantifies the building stock by building type for each year of the analysis, to scale results of the other analyses to the total population.
  - **Appliance Standards Impact Assessment**, which analyzes the difference in energy consumption between the pre and post cases.
- **Integration Model** involves the aggregation of results from impact and turnover modeling efforts, taking interactive effects between codes and standards into account, to develop estimates of the impacts from all codes and standards at the regional, state, or city level.

Figure 3 presents a diagram of the CSIQ Analysis. The red arrows refer to data sources required as inputs to the CSIQ Analysis, and blue arrows represent data flows between tasks. The building and appliance paths (as discussed in Section 2) are indicated by the dashed orange borders. Further descriptions of process inputs and data flows are provided following the figure.

Figure 3. CSIQ Analysis Diagram



## *Data Collection Tasks*

Data collection efforts translate raw data on the region's building stock, appliance stock, and active codes and standards into useful data sets for later phases of the CSIQ Analysis. Some of this data collection and processing is already going on in the region; CSIQ Analysis development efforts for these topics should focus on coordinating with current data collectors to capture relevant data in useful formats.<sup>19</sup> New efforts in the region will be required for other data collection. It will be particularly important to match the level of granularity (in terms of distinctions between building types, building components, and appliances/equipment) in the building stock and appliance stock data to the level of detail specified in the relevant codes and standards.

In some cases, the necessary data will not be available to achieve that level of granularity or the modeling will be prohibitively complex; the modelers should thoroughly document the simplifying assumptions used and note those as possible areas of future improvement to the CSIQ Analysis.

### *Data Inputs for Phase 1:*

- A. **Building characteristics** – Building surveys and Census data, e.g., the NEEA's Baseline Characteristics studies, Commercial Building Stock Assessment (CBSA), and Residential Building Stock Assessment (RBSA), U.S. Energy Information Administration's (EIA's) Commercial Building Energy Consumption Survey (CBECS)<sup>20</sup>, and the Pacific Northwest Residential Energy Survey (PNRES).
- B. **Codes and standards specifications** – State building codes, Seattle building codes, Federal appliance/equipment standards, Oregon's state appliance/equipment standards, and Washington state appliance/equipment standards. Summaries of codes from NEEA, summaries of standards from the Appliance Standards Awareness Project (ASAP), supporting documentation of federal appliance/equipment standards from the U.S. Department of Energy (DOE), and appliance and commercial equipment standards website. See Appendices A and B for partial listings of sources for codes and standards active in the Northwest region.
- C. **Appliance stock** – DOE appliance/equipment standards supporting analysis data, sales and shipment data from trade organizations such as the Association of Home Appliance Manufacturers (AHAM), and baseline and appliance/equipment saturation studies.

### **Building Stock Assessment**

The *Building Stock Assessment* task aggregates information related to building energy performance. It provides the snapshot of existing building stock details necessary to develop baseline models of building performance.

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<sup>19</sup> For example, developers of the CSIQ Analysis could provide suggestions to NEEA on Baseline Characteristics, CBSA, and RBSA survey topics.

<sup>20</sup> CBECS will likely not be a useful resource for tracking commercial building characteristics beyond 2003. The EIA has decided not to release results from the 2007 CBECS because it did not yield valid statistical estimates (U.S. EIA, "Commercial Building Energy Consumption Survey", <http://www.eia.gov/emeu/cbecs/contents.html>, last accessed 10 May 2011). The EIA has also suspended work on the 2011 CBECS because of FY 2011 funding cuts (U.S. EIA, "Press Release - Immediate Reductions in the EIA Energy Data and Analysis Programs Necessitated by FY 2011 Funding Cut", <http://www.eia.gov/pressroom/releases/press362.cfm>, last accessed 10 May 2011).

**Inputs:** This information primarily comes from regional (i.e., Baseline Characteristics, CBSA, RBSA, and PNRES) and national (i.e., CBECS) surveys. Additional information may come from other regional baseline studies and interviews with developers, regulators, and inspectors.

**Outputs:** The output from this task provides the building detail necessary to develop building models for the pre (baseline) case in the subsequent *Building Input Development* task. This baseline is also the starting point for developing the post (after codes/standards changes) case.

### **Codes and Standards Assessment**

**Function:** The *Codes and Standards Assessment* task aggregates current and historic codes, including their criteria, effective dates, and paths to compliance. For the retrospective capabilities of the CSIQ Analysis, the entire history of building codes for region of interest (e.g., the four Northwestern states, Seattle) will need to be collected.

**Inputs:** The primary inputs to this task are the documentation of codes and standards provided by the presiding jurisdictions.

**Outputs:** The product of this task is a concise and well-organized database of historic and current codes and standards at the level of detail necessary for later phases of the CSIQ Analysis. This database should also include estimates of the relative impacts of various measures, as a starting point for prioritizing which of the numerous codes to model for any impact effort. The outputs feed directly into the input development for both the building and appliance paths. This information is used by the scenario developers to examine correlations between code/standard changes and baseline changes and to inform changes to prototype building characteristics for the alternate scenarios.

### **Appliance/Equipment Stock Assessment**

**Function:** The *Appliance/Equipment Stock Assessment* task aggregates information on the saturation of appliances/equipment by type and efficiency level. For many federal standards, the associated National Impact Analyses (NIAs) provide this information, and efforts for this task should be focused on scaling this data to the Northwest population. For other standards, primary and/or secondary data collection efforts will be necessary. This task provides the snapshot of existing appliance/equipment stock to the level of detail necessary to develop baseline models of appliance/equipment presence and energy consumption.

**Inputs:** This information may come from numerous sources given the diversity of appliances/equipment and the absence of comprehensive appliance/equipment stock data.

**Outputs:** The output from this task provides the appliance/equipment stock detail necessary to develop appliance/equipment energy consumption for the pre (baseline) case in the *Appliance Input Development* task in Phase 2. This baseline is also the starting point for developing the post case.

### **Input Development Tasks**

The second phase of the CSIQ Analysis is to develop the two scenarios necessary for any execution of the CSIQ Analysis: the pre case and the post case. The pre case is a calibrated depiction of building and appliance/equipment presence and performance as it has historically been, as it currently is, and as it is forecasted to be under the current codes and standards and forecasts of relevant regional characteristics.

The post case is a depiction of the building/appliance/equipment presence and performance under a change to historic, current, or future codes/standards.

#### **Data Inputs:**

##### **D. Results of Data Collection tasks**

- E. Market data** – Data sources, research, and analysis that may be necessary to establish the likely distribution of building and appliance/equipment parameters in the population after a change to codes/standards. This includes material and appliance/equipment availability and life-cycle costs as well as regional energy costs (both historic and forecasted).

There are several baseline definitions that can be used, including code/standard, current practice, and Council power plan defined baselines. Likewise, the post case can be defined as the new codes/standards, or the expected practice in response to the new codes/standards. These options are discussed in Section 2.3.

Another key component of Phase 2 is calibration of the baseline parameters to actual regional sector-level energy consumption estimates. This also entails the impact analysis, which determines the energy consumption in the pre case. See Appendix E for more details on calibration.

Input development is divided into two tasks: *Building Scenario Development* and *Appliance/Equipment Scenario Development*. Both of these tasks involve development of pre case; in some executions of the CSIQ Analysis, modelers may only develop the post case for either a change in building codes or a change in appliance/equipment standards, not necessarily both. The following subsections provide more details on these two tasks.

#### **Building Input Development**

**Function:** The building input development task creates the representative building descriptions for the pre and post cases. The pre case results directly from the building stock assessment task. The post case requires interpretation of market data and the changes codes/standards changes in order to estimate the impact on building parameters. A key component of defining the pre and post cases is prioritizing which code changes will be examined, as codes can be numerous and complex; the highest priorities are the codes that are expected to have a relatively large impact and can be reliably modeled. See Appendix E for more discussion of how codes will be prioritized.

**Inputs:** The inputs to this task are the results of the *Building Stock Assessment* task and the *Codes and Standards Assessment* task, appliance presence and power draw information from the *Appliance Standards Impact Assessment* task, and market data such as building materials availability and costs.

**Outputs:** The outputs from this task are the pre and post case building descriptions necessary for the *Building Simulation and Engineering Analysis* task. See also Appendix E for more discussion of the set of building prototypes that will need to be defined and used consistently through the CSIQ Analysis.

#### **Appliance/Equipment Input Development**

**Function:** The appliance/equipment input development task creates the appliance/equipment saturation (by type and efficiency level) for the pre and post cases. The pre appliance/equipment case results directly from the appliance/equipment stock assessment task. The post appliance/equipment case requires interpretation of market data and the hypothetical standards changes in order to estimate the impact on

appliance/equipment saturation. For many federal appliance/equipment standards, the DOE's NIA workbooks provide the data and framework for developing both the baseline and alternate scenarios.

Presumably, many executions of the CSIQ Analysis will not include examination of appliance/equipment standards. In these cases, appliance/equipment scenario development is not necessary.

**Inputs:** The inputs to this task are the results of the *Appliance/Equipment Stock Assessment* task, the database of appliance/equipment standards compiled in the *Codes and Standards Assessment* task, and market data such as equipment availability and costs. Development of the baseline scenario will require market research, e.g., sales information from organizations such as AHAM and consumption data from regional surveys and energy efficiency program evaluations.

**Outputs:** The outputs from this task are the pre and post case appliance/equipment saturations necessary to determine the end-use impact of the change from pre to post case, as calculated in the *Appliance/Equipment Standards Impact Assessment* task.

### ***Impact and Turnover Analysis Tasks***

The third phase of the CSIQ Analysis is to evaluate the performance of the representative buildings and appliances/equipment for both the pre and post cases. Building performance is measured as whole-building and/or end-use energy consumption, as well as HVAC sensitivity to changes in internal gains (i.e., interaction factors). Appliance/equipment performance is measured as the sector- or region-wide energy consumption from the suite of appliances/equipment under consideration<sup>21</sup> and the distribution of this consumption across building types.

#### ***Data Inputs for Phase 3:***

- A. **Pre and post case inputs developed during the input development phase.**
- B. **Building stock data** – Historic and forecasted building stock, by building type. Council forecasting group estimates, FW Dodge, Global Insights, additional data sources needed to characterize code-touched retrofit prevalence.

### **Building Simulation and Engineering Analysis**

**Function:** The *Building Simulation and Engineering Analysis* task determines the difference in energy consumption between the two cases for each building type. The modeling approach to building codes (and standards concerning lighting, HVAC, and the building shell, as discussed in Section 2.1) is to develop prototype building models and then determine differences in energy consumption resulting from differences in the models that reflect pre and post cases. Building energy simulation will be the primary approach to determining this difference in energy consumption. Engineering analysis will supplement these results for impacts that cannot be represented well through building energy simulation.<sup>22</sup> Primary or secondary analysis could be used. The sensitivity of HVAC loads to changes in internal gains is determined as well, and is represented as an interaction factor. These interaction factors are used later, during results integration, to determine the whole-building impact of changes in appliance/equipment loads from the *Appliance/Equipment Standards Impact Assessment* task.

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<sup>21</sup> This would be any appliance for which the standards differ between the pre and post cases.

<sup>22</sup> Examples of changes that do not lend themselves well to analysis through building simulation are changes to codes that only influence a small set of buildings.

**Inputs:** The inputs to this task are the building descriptions developed in the *Building Input Development* task. For engineering analyses, additional inputs may be required (e.g., secondary studies on the observed impact of particular measures).

**Outputs:** The outputs of this task are 1) the difference in whole building and/or end-use energy consumption (both electric and gas) for each building type/vintage/HVAC type/state combination and 2) the HVAC interaction factors.

### **Appliance/Equipment Standards Impact Assessment**

**Function:** The *Appliance/Equipment Standards Impact Assessment* task determines the difference in end-use energy consumption between the two cases for each affected appliance/equipment. The distribution of appliances/equipment across building types is also required in order to assign proper HVAC interaction factors for the results integration phase. For many appliances/equipment regulated by federal standards, the NIA workbooks provide much of the information necessary to determine the impacts. For these appliances/equipment, the modeler's task will be to adjust NIA inputs and results to reflect the Northwest region and distribute them among building types.

**Inputs:** The inputs to this task are the appliance/equipment descriptions developed in the *Appliance/Equipment Scenario Development* task. Additional inputs (e.g., hours of use) may be required to conduct engineering analyses (or gather secondary data), which will be specific to each appliance/equipment.

**Outputs:** The outputs of this task are 1) information about appliance presence and power draw to inform the Building Input Development task and 2) the aggregate (i.e., for all appliances/equipment) end-use differences in energy consumption between the two cases, by building type/HVAC type/state/climate zone/vintage combination.

### **Building Turnover Model**

**Function:** This task determines the building stock at each year of the analysis. This is used to scale results from the building and appliance analyses to the estimated population and is also used to distribute appliances among building types as part of the appliance analysis. Each building type will have a different interaction factor and perhaps different usage patterns. To the extent that differences in codes/standards between the pre and post cases induce fuel choice/switching (between electricity and natural gas for heating and water heating), different building stocks must be considered for the two cases. This implies that the building stock turnover model must include methods for estimating the influence of codes/standards on fuel choice/switching, given the costs associated with fuel, equipment/materials, and maintenance.

Much of this work is currently being done by the Council for the pre case; however, retrofits have not been adequately addressed, nor have adjustments to building stock on account of codes/standards changes.

**Inputs:** Inputs to this task include new construction estimates from FW Dodge, Global Insights, and similar data sources, information from planning departments, regulators, and inspectors on retrofits prevalence and characteristics, and forecasts of regional growth.

**Outputs:** The output of this task is the complete estimated history and forecast of building stock (by building type/HVAC type/states/climate zone/vintage). If codes/standards influence fuel choice/switching in the post case, then two data sets are required—one for each case.

### ***Integration Model***

The final task of the CSIQ Analysis is to aggregate the building and appliance/equipment results to determine the total whole-building impact of a change in codes and/or standards from the baseline.

**Function:** The integration model will aggregate impact data from prior tasks and scale it appropriately to achieve results for the desired level of geography (region, state, city, or utility service territory). The integration model may also account for any interaction and overlap between codes and standards unaddressed within the distributed modeling tasks. The integration model will produce standard and custom outputs. The need for an integration model stems from the disaggregated impact modeling approach required to employ different methods, approaches, and simulation runs across the spectrum of codes, standards, and building/appliance/equipment characteristics.

**Inputs:** The inputs to this task are the per-building impacts and HVAC interaction factors from the *Building Simulation and Engineering Analysis* task; the building stock from the *Building Stock Model*; and the end-use appliance/equipment impact, by building type, from the *Appliance/Equipment Standard Impact Assessment* task.

**Output:** The output from this task is the final aggregate impact of the changes to codes/standards from the pre case to the post case. Results are reported at the specified level of geographic granularity (e.g. region, state, service territory).

## Appendix B: Building Codes – Background and Sources

### *Background*

Building codes specify building criteria to which both new buildings and certain retrofits and additions must adhere. Energy codes have been included in building codes in the Northwest for several decades, starting with residential energy codes in the 1970s and including commercial energy codes in the 1980s.<sup>23</sup> Specifications include building shell features such as insulation levels, window thermal and light properties, and maximum lighting power density. Specifications can vary by construction type, building type, and space type. Some codes allow for multiple paths to compliance; for example, a new building may meet code requirements through prescriptive criteria, or through a whole-building analytic approach.

The historic approach to Northwest regional impact estimates from code changes has been to focus on the approximately five to ten most significant building code changes that could be reliably modeled. Of course, this requires professional judgment upfront because it is the analysis itself that determines the significance of the code changes.

A recent trend in building codes has been to specify numerous codes that are each targeted to a relatively small population of buildings. Although the limited applicability of any one targeted code limits its individual impact, the large number of these targeted codes can add up to a significant impact. To date, however, the impact quantification efforts in the Northwest have not had the resources necessary to evaluate these many codes, and they have been largely neglected.

Building codes apply to both new construction and retrofits. To date, analysis efforts have focused on new construction. It is unknown how much of the retrofit market is affected by building codes. Given the large retrofit floor space each year relative to new construction, retrofits could represent a significant portion of energy impacts associated with building code changes. Even less is known about the attribution of impact to energy efficiency programs when code requirements are triggered. Attribution between codes and programs would be necessary to avoid double-counting savings from retrofits where incentive programs are involved.<sup>24</sup>

### *Sources*

Current building codes for the four Northwest states and Seattle can be found at the websites listed below. Additional research would be required to build a comprehensive record of historic codes in the region.

- **Oregon:** Residential and nonresidential codes:  
<http://www.cbs.state.or.us/external/bcd/programs/energy.html>

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<sup>23</sup> Optimal Energy, Inc., “Documentation of the Northwest Energy Efficiency Alliance Efforts to Support Energy Codes and Participate in the Federal Standard Setting Process,” April 2004.

<http://neea.org/research/documents/042104CodeDocumentationFinalReport.pdf>

<sup>24</sup> Programs most likely reduce the energy impacts of building codes determined through this methodology, because some retrofits would not have happened without the program influence.

- **Washington:** Residential and nonresidential codes:  
<http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx>
- **Idaho:** Residential and nonresidential codes used the 2009 International Energy Conservation Code (IECC), with the following amendments posted here:  
[http://www.idahoclrb.org/documents/Idaho\\_Amendments\\_to\\_the\\_international\\_building\\_and\\_energy\\_codes\\_2009.pdf](http://www.idahoclrb.org/documents/Idaho_Amendments_to_the_international_building_and_energy_codes_2009.pdf)
- **Montana – Residential Codes:**  
<http://deq.mt.gov/energy/conservation/homes/NewHomes/BuildingCodes.mcp>
- **Montana – Commercial Codes:** Commercial codes use the 2009 IECC, and the state defers to the International Code Council (ICC) website:  
<http://www.iccsafe.org/Pages/default.aspx>
- **Seattle:** Residential and nonresidential codes:  
[http://www.seattle.gov/DPD/Codes/Energy\\_Code/Overview/default.asp](http://www.seattle.gov/DPD/Codes/Energy_Code/Overview/default.asp)

### *Background*

Appliance/equipment energy standards specify minimum energy efficiency criteria for appliances/equipment, grouped by capacity, configuration, or other relevant features. Standards are typically federal mandates, although Oregon and Washington mandate additional appliance/equipment standards.<sup>25</sup> These standards influence whole-building energy consumption in several ways:

- **End-Use Load** – Standard-influenced appliances/equipment consume less energy per provision of utility than their previously allowed counterparts. This type of savings can be accounted for by observing baseline market conditions, conducting empirical or engineering analysis, and estimating the number of units affected and baseline market conditions.
- **HVAC Interaction** – Standard-influenced appliances in space-conditioned areas can influence building HVAC loads if the appliances/equipment emit more or less waste heat. HVAC interactions are typically captured by the use of an interaction factor (for example, the ratio of change in whole-building electricity consumption to change in end-use of electricity consumption), which approximates the year-round influence on both heating and cooling. There are separate interaction factors for electric and gas HVAC impacts, and separate interaction factors for buildings with different HVAC primary fuels.
- **Direct HVAC** – Standard-influenced HVAC equipment will consume less energy per provision of utility than the previously allowed counterparts. However, the amount of utility required (in this case, amount of heat rejection or addition) is dependent on building shell characteristics. These building shell characteristics in turn are influenced by building codes. For this reason, standards that relate to HVAC equipment should be considered together with building codes.

### *Sources*

**Federal Standards:** The U.S. Department of Energy’s Appliances and Commercial Equipment Standards website maintains a current list of appliances and commercial equipment subject to federal standards as well as links to associated documents. Associated documents include the rulemaking documents (including the standard specifications) and the technical and economic analyses done in support of the rulemaking. For standards initiated by Congress, rather than rulemaking, there are typically fewer supporting documents.

[http://www1.eere.energy.gov/buildings/appliance\\_standards/](http://www1.eere.energy.gov/buildings/appliance_standards/)

Most federal appliance standards have National Impact Analysis spreadsheets associated with these, which can also be found through the website. These analyses estimate historic shipments, useful stocks, and energy consumption over time, as well as forecasted values for both the baseline and efficient

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<sup>25</sup> State appliance standards address products not currently covered by federal standards. Although states may petition the DOE for a waiver to continue enforcing more stringent state standards on appliances and equipment covered by federal standards, no petitions have been filed. See the EIA’s State Appliance Standards webpage: [http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo\\_2009analysispapers/sas.html](http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2009analysispapers/sas.html).

(imposed federal standard) cases. These analyses are quite detailed, estimating stock over time by product class and efficiency level.<sup>26</sup>

[http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/heating\\_products\\_fr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_spreadsheets.html)

**Washington State Standards:** Washington State House Bill 1004 (2009) states the new standards implemented on July 26, 2009. This marked-up document shows the changes in Washington's appliance/equipment standards over time. Underlined text shows new standards implemented in 2009. Crossed-out text shows standards deleted from the 2005 state regulations.

<http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bills/Session%20Law%202009/1004-S.SL.pdf>

**Oregon State Standards:** State appliance standards and administrative rules to administer these standards can be found at:

<http://www.oregon.gov/ENERGY/CONS/StateRegulatedApplianceStandards.shtml>

In addition to the federal and state websites referenced above, ASAP<sup>27</sup> summarizes appliances and specifications covered by the federal and state standards in a user-friendly format.

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<sup>26</sup> For examples of these analyses, refer to the National Impacts Analyses for water heaters, direct heating equipment, and pool heaters:

[http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/heating\\_products\\_fr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_spreadsheets.html)

<sup>27</sup> Appliance Standards Awareness Project website, <http://www.standardsasap.org/index.htm>

## Appendix D: Current Regional Efforts

Current regional efforts to quantify the energy savings impacts of codes and standards changes are conducted by the Northwest Power and Conservation Council (the Council) and the Northwest Energy Efficiency Alliance (NEEA). These efforts are a significant starting point for the more comprehensive CSIQ Analysis. The primary architects and implementers of these efforts have greatly informed this methodology.

### *Regional Forecasting Efforts*

The Council's forecasting group currently develops regional forecasts of energy consumption for each Power Plan. These forecasts require building floor area growth by sector and building type, fuel price forecasts, and cost/efficiency functions by end use for determining end-use efficiency in light of fuel costs and standards. These forecasts are also used in the regional nonresidential building codes impact quantification efforts.

### *Regional Nonresidential Building Codes Efforts*

Regional estimates of impacts from changes to nonresidential building codes have been developed by NEEA and Mike Kennedy.<sup>28</sup> This process can be summarized as follows:

1. Collect building stock data from NEEA's Baseline Characteristics survey (2002-2004), building stock growth forecasts from the Council's forecasting group, and state- and Seattle-level building codes descriptions from the appropriate regulatory authorities.
2. Identify the building codes most likely to have large energy impacts that can be reliably assessed through building simulation or engineering calculations.
3. Apply "with new codes" and "without new codes" to the building sample. This is approximately 350 buildings. For each building and for each space type, the building descriptions for the buildings in the sample are brought up to code compliance for the two scenarios. Resulting performance metrics such as the change in whole-building UA<sup>29</sup> are determined.
4. Simulate prototype buildings to determine the energy sensitivities to changes in building performance metrics such as whole-building UA.
5. Apply building simulation results to the building sample to determine the energy implications of code changes for the building.
6. Scale results from the building sample to the population using the estimates of new construction square footage by building type provided by the Council.
7. Adjust results to account for building code changes modeled by engineering calculations rather than building simulation.

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<sup>28</sup> For example, Mike Kennedy, Inc., "Non-Residential Energy Savings from Northwest Energy Code Changes, 1996-2004, Final Report," March 2005.

<sup>29</sup> UA is the product of the building's U-factor and area. This product is the whole-building heat loss/gain rate.

This approach has the advantage over a simpler, straight prototype approach (in which the results of prototype simulation are directly scaled to the floor stock) in that it considers a larger sample of actual buildings that are individually brought up to code. This approach inherently addresses the distribution of building properties found in the population, some of which are already above proposed codes. This approach is consistent with the approach currently used by California investor-owned utilities and the 2013 Title 24 Codes and Standards Enhancement project.<sup>30</sup>

Conversely, the straight prototype approach cannot directly capture the distribution of building properties in the population, some of which would need to be brought up to code, and some of which would already exceed code.

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<sup>30</sup> This approach is described in: Heschong Mahone Group, "CA IOU Codes and Standards Earnings Claims Framework, Final Report" October, 2001. HMG Project #0006i2.

## Appendix E: Additional Modeling Considerations

### *Building Models*

The CSIQ Analysis requires a set of building models that represent the building stock of the region. Each model will be affected differently by code and standard changes. Models may be based on actual, individual, surveyed buildings (a sampling approach) or prototypical description (a prototype approach). Models are characterized by the following distinguishing characteristics:

- **Building/business type** – For the residential sector, this will typically be single-family, multi-family, and manufactured homes. For the commercial sector, typical prototypes include office, retail, schools, fast-food restaurants, sit-down restaurants, health care and assembly facilities, and lodging. The building/business type will influence building parameters such as hours of operation, construction materials, lighting, and loads affecting HVAC.
- **Building size** – For each building/business type, building size will influence HVAC and lighting loads as the ratio of perimeter and internal spaces varies. Operating hours may also be correlated to building size. For some building types, as many as three different building sizes might be reasonable.
- **Jurisdiction** – Codes and standards vary by the state (and Seattle).
- **HVAC type** – The type of HVAC system—both fuel source and delivery configuration—will influence energy usage.
- **Vintage** – Standard practice changes over time; building vintage cohorts will be required. Building codes impact existing building stock (of all vintages) because of code-triggering retrofit projects.
- **Climate zone** – Climate is an external factor affecting building HVAC loads. Weather from one or more cities can be applied to the building model in separate building simulation runs. A weighted average of results is then taken, in proportion to the building stock population in each of those cities.
- **Scenario** – Building characteristics will vary between the baseline and alternate scenarios.

The applicability and impact of codes and HVAC standards is highly dependent on these characteristics. However, the number of permutations of these parameters is infeasibly large to model each permutation separately. For illustration, if there were 20 building type/size combinations, five jurisdictions (four states and Seattle), three HVAC types, five vintage cohorts, three climate zones, and two scenarios, 4,500 separate models would need to be developed<sup>31</sup>. These requirements emphasize the need for a conscious effort both to minimize the number of models and simulation runs required and to automate the process of conducting simulations and synthesizing results.

*In developing the set of buildings to simulate throughout the CSIQ Analysis, it is important to limit representation to the level of detail for which significant data is available to support differences. Otherwise, results provide a false portrayal of precision.*

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<sup>31</sup> Where data is sparse, a single building may be used to model multiple categories. For example, a surveyed hospital may be assumed to be representative of multiple vintage cohorts.

## *Baseline Case Calibration*

The starting point for each analysis (i.e., each execution of the CSIQ Analysis) is the pre, or baseline, case, which is developed from data collected on what has actually happened historically and what is forecasted to happen. These baseline sector-level consumption estimates can be calibrated to actual sector-level consumption. The comparison point for each analysis is the post case. This is an incremental change in codes and/or standards from the historic and current levels.

- If the baseline sector-level consumption is relatively close to regional sector-level energy consumption estimates, then results from the CSIQ Analysis (for both the baseline and hypothetical cases) should simply be scaled by the ratio of regional estimates to CSIQ Analysis results in the pre case.
- If the baseline sector-level consumption differs significantly from regional sector-level energy consumption estimates, then additional analysis will be required by the modelers to understand where discrepancies are coming from and determine the most appropriate calibration approach. This may entail adjusting prototype building properties or adjusting floor stock and/or floor stock distribution estimates.

The calibration approach will be specified in greater detail during the CSIQ Analysis development.

## *Prioritization of Code Changes*

Code interpretation is a necessary part of the modeling efforts for the alternate case. Because building energy codes can be numerous and complex, the modeler must bound the problem within the realm of the budget and labor at hand. The first step in this process is to prioritize code changes in order of likely magnitude of impact and ability to reliably model a change. Reliability concerns arise when it is unclear how a code change will impact the building stock and/or it is unclear how an implemented code change affects energy consumption. There will be separate categorization efforts for the residential and nonresidential codes in each state and Seattle.

- **High-priority codes** are codes that are expected to have a relatively large impact and can be reliably modeled. All high-priority code changes will be modeled directly.
- **Medium-priority codes** are those expected to have relatively low to moderate impact on their own, yet may aggregate to significance impacts, and can be reliably modeled.

A sampling approach could be used to assess medium-priority code changes. This would likely require estimates of the affected floor space of all medium-priority code changes and a normalized average impact (energy/ft<sup>2</sup>) determined from analyses of a sample of medium-priority code changes.

- **Low-priority codes** are codes that are expected to have relatively minor impacts and/or cannot be reliably modeled.

Codes that are identified as having potentially large impacts yet not allowing for reliable modeling should be flagged for further research and addressed in the feedback loop of the CSIQ Process, as discussed in Section 1.2.

Each enumerated code should be labeled as high, medium, or low priority, along with a brief justification for this prioritization. This prioritization should be done by modelers that are familiar with the building stock and building codes of the region.

## Appendix F: Index of Modeling Topics

**Accounting for Numerous, Targeted Codes:** The building simulation approach used for the more comprehensive building codes and HVAC standards may not be appropriate for targeted building codes. For these cases, an engineering approach will be used. Where numerous targeted building codes are present, a sampling approach could be used to estimate the impact per square foot of affected building space. This will require a survey of all codes meeting this description, an estimate of the floor space affected, and a plan for sampling for the full set of targeted codes. See Appendix E.

**Accounting for Retrofits in Codes and HVAC Standards:** Retrofits are an unknown yet significant portion of building stock change from year to year. Section 2.4 discusses this important data gap.

**Building Types:** This methodology requires that a set of building types will need to be specified and used consistently throughout the CSIQ Analysis. See Section 2.2 and Appendix E.

**Code Compliance:** The potential implications of varying rates of code compliance are discussed in Section 2.2.

**Disaggregating Program Influence from Codes/Standards Impacts:** Energy efficiency programs may have enough impact to significantly affect standard practice in some cases. This disaggregation is beyond the proposed scope of the CSIQ Analysis (see Section 3.1).

**Fuel Choice/Switching:** For hypothetical scenarios, the building stock model may be adjusted to account for fuel choice/switching that is induced by changes to the cost/benefit situation brought about by changes to codes and standards. See Appendix A.

**HVAC Interaction Effects:** HVAC interaction effects are primarily addressed by using building simulation in the *Building Simulation and Engineering Analysis* task to estimate performance for the entire set of building parameters (e.g., shell, HVAC system, and windows). See Section 2.4.

**Modeling Building Changes over Time:** For each building type/vintage pair, a separate model may be used to describe the building at different times in the building's life. For the pre case, these characteristic shifts will be determined from the building stock assessments and additional, targeted research. The authors believe that there is currently not enough data on this building change to warrant the additional modeling process. However, this may be an area of refinement in the future.

**Scenario Definition:** Each execution of the CSIQ Analysis compares two scenarios: a pre case and post case. See Section 2 for more information.

**Tracking Appliances Through Buildings:** It will be computationally infeasible to track appliances/equipment through the building stock over the buildings lifetimes, given the number of buildings (by type, state, HVAC type, climate zone, and vintage) and the number of appliances/equipment. Instead, separate models of appliance/equipment stock in the region will be developed. Appliance/equipment stock will be distributed among building stock as part of the Appliance Impact Analysis (Section 2.4).