PURSUING HIGH-RISE MULTIFAMILY ENERGY EFFICIENCY IN SEATTLE

MAY 2019

RUSHING

WEBER THOMPSON

EXECUTIVE SUMMARY

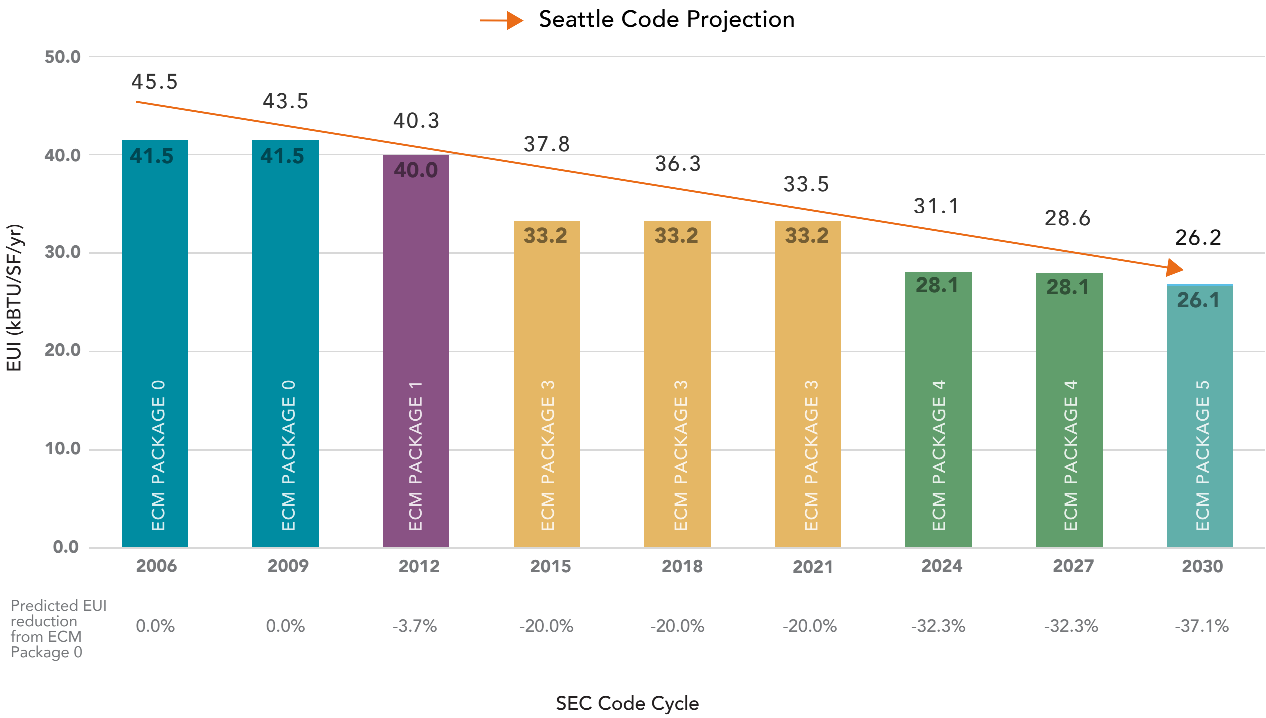
In 2018, over ten thousand residential units were built or approved to be built in high-rise buildings throughout Downtown Seattle, South Lake Union and First Hill.[1] There is no question that high-rise multifamily (HRMF) buildings account for a significant percentage of new dwelling units in Seattle. Of particular interest to developers, architects, engineers and city officials is how the continued evolution of the Seattle Energy Code (SEC), updated every three years, will impact the near future design and construction of this building type.

To map the progression of SEC compliance between now and the year 2030, this study was executed in two steps. First, we established a baseline and Energy Use Intensity (EUI) targets for future code cycles. Then, we identified and tested Energy Conservative Measure (ECM) packages to meet those targets.

Nexus, a single prototypical residential tower designed by Weber Thompson (MEP by Rushing) was chosen for this study in order to test the impacts of energy code and efficiency strategies. The energy model submitted for code compliance was re-purposed to test a number of scenarios employing a range of ECMs needed to design and construct a code-compliant building in each future code cycle.

Conclusion 1: The results for future code compliance are not as challenging as one might think. This study found that the following energy conservation measures (ECMs) resulted in anticipated code compliance for Nexus in the year 2030:

- Electric boilers
- Heat pumps for space heating
- Heat pump heating for Domestic Hot Water (DHW) (e.g. sewer thermal)
- Building envelope air tightness measures
- Lighting power density reduction
- Heat-pump clothes dryers
- Partial heat pump DHW plant
- Reduced unit ventilation
- Reduced corridor pressurization

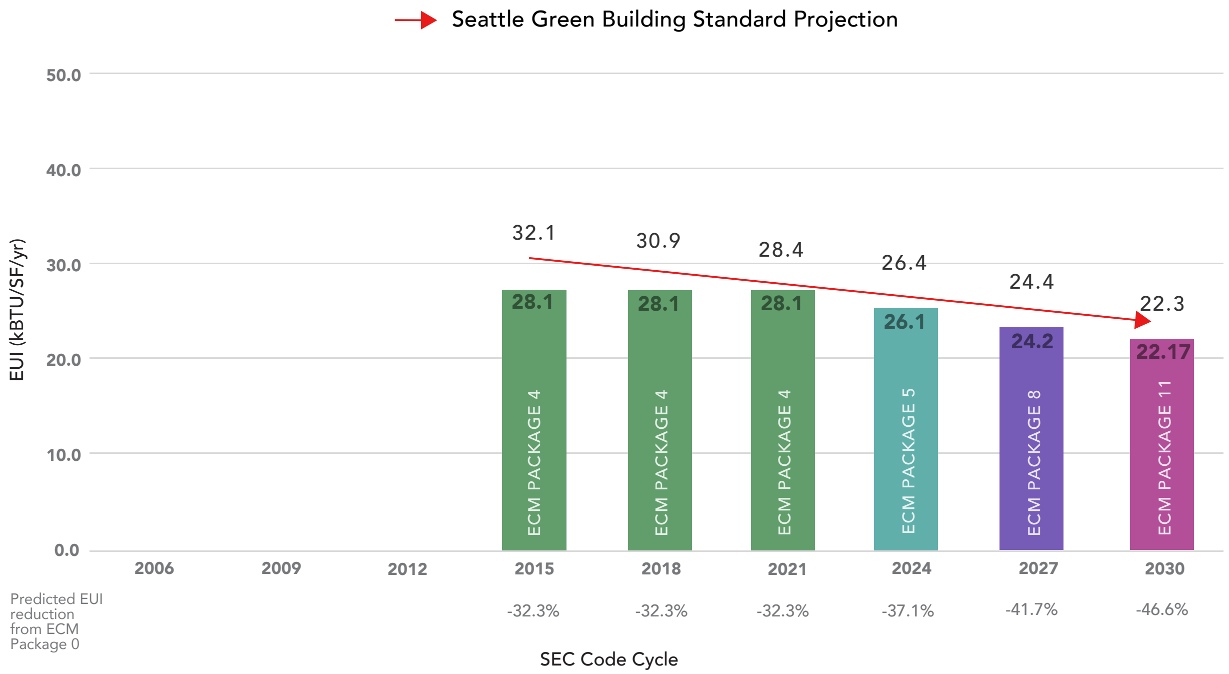


[1] This metric was gathered by Rushing via the Seattle In Progress website (https://www.seattleinprogress.com/), noting projects which have received permit or completed within the last year, and are above 20 stories.

The graph on page 2 illustrates how these strategies (described further on pages 16-17) are added on incrementally with each cycle of the SEC, culminating in the year 2030 with the full list above.

Conclusion 2: The story does not end there. In addition to basic energy code compliance, this study recognizes that Seattle adopted the Green Building Standard in 2016, which consolidated and updated several sections of the land use code. In several areas of the city[2], the incentive for additional allowable building height and development potential comes with an additional requirement to perform 15% better than the SEC. This study revisited the model and ECMs with the Green Building Standard in mind, and found that in order to meet this lower energy threshold, additional ECMs would be required in the 2027 and 2030 cycles. These additional measures are more challenging and more impactful to the building design. For Nexus, the additional ECMs shown to comply with the requirement to be 15% better than SEC would include the following:

- Energy recovery ventilation (ERV) for ~50% or more of outside air
- Triple pane glazing
- Reduced plug loads by 10% or more
- Rooftop photovoltaic panels of ~5,000sf or more
- Vertical wall photovoltaic panels of 8,000-10,000sf
- Reduced window-to-wall ratio (WWR) for building facades from 36.2% to 30% WWR or less



With these results, this study sheds light on the future of Seattle high-rise multifamily energy efficiency, and narrows and prioritizes the best practices and strategies to get "ahead of the curve" to achieve the next level of building performance.

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[2] See Appendix B

STUDY PARTNERS

RUSHING

Rushing is a multidisciplinary firm focused on mechanical, electrical and plumbing (MEP) engineering, energy analysis, sustainability consulting, commissioning, and lighting design services. Founded as a new model for consulting engineering, we come to work every day to generate holistic designs that support and enhance the visions of our clients. We view buildings and their systems interdependently – not as separate elements – and provide a full spectrum of integrated engineering and sustainability services to support and execute this approach.

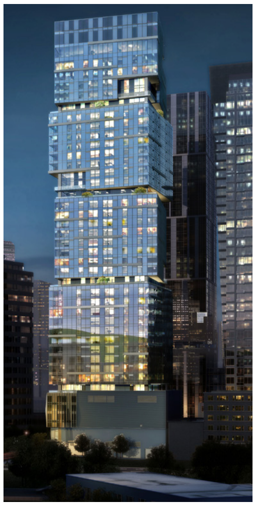
WEBER THOMPSON

Seattle-based Weber Thompson is a full service, West Coast design firm specializing in architecture, interior design and landscape architecture. This award winning design firm has a staff of 70 design and construction professionals, housed in the celebrated Terry Thomas, a LEED CS Gold certified office building in South Lake Union. Since 1988, Weber Thompson has developed a diverse practice with projects that include high-rises, high-density urban infill, residential, commercial office, hospitality, and affordable housing projects. Weber Thompson seeks effective results through a thoughtful and collaborative design process.

Rushing and Weber Thompson have worked together on over a dozen high-rise residential construction projects in Seattle since 2010, and value their combined expertise and integrative design process.

WEBER THOMPSON & RUSHING PROJECTS

- HELIOS (WTGBD PROJECT)
- CIRRUS
- STRATUS
- LUMA
- NEXUS
- ARRIVÉ
- ASCENT
- THE POST
- CERASA



Nexus

Cirrus

Stratus

Helios (WTGBD project)

Luma

AUTHORS

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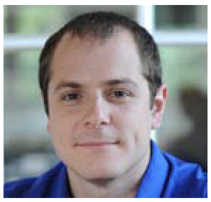
ALEXANDRA RAMSDEN LEED AP BD+C, BUILT GREEN VERIFIER, LEED FOR HOMES GREEN RATER, CSBA, WELL AP

PRINCIPAL, DIRECTOR OF SUSTAINABILITY

Alexandra leads Rushing's Sustainability and Commissioning Studios in providing commissioning services and consulting for sustainability strategy development, LEED and Built Green management, charrette facilitation, training, curriculum development, and cost-benefit analyses for strategy selection. Her expertise lies in guiding teams to identify cost-smart, project-appropriate sustainability solutions. Drawing from her multi-disciplinary background of both science and architecture, Alexandra approaches projects holistically and harnesses the expertise of all the team members at the table.



NATHAN MILLER P.E., LEED AP BD+C, CEM

MECHANICAL ENGINEER / SENIOR ENERGY ANALYST

Nathan is an experienced energy analyst who specializes in quantifying cost and energy saving strategies and establishing energy benchmarks to meet project sustainability goals. Nathan's expertise includes energy modeling, natural ventilation modeling, and systems analysis, all the LEED protocols, and the Living Building Challenge. He is one of only a few engineers in the country to have executed energy analysis and mechanical and plumbing system design for a Living Building Challenge Certified project, the Bertschi School Living Science Lab. With more than a decade in the design and construction industry, Nathan has instructed and lectured on energy efficiency, sustainable operations & maintenance, net-zero energy, LEED, Living Building Challenge, and other sustainability and engineering topics.

Weber Thompson

MYER HARRELL AIA, LEED AP BD+C, LEED FOR HOMES

PRINCIPAL, DIRECTOR OF SUSTAINABILITY

Myer believes in the power of design to promote a sustainable future and directs the WT Sustainabiliteam (WTST) to that end. Myer focuses on urban infill mid-rise, mixed use multifamily and boutique-scale commercial office construction, and has managed projects including DATA 1, certified LEED C&S Gold, the Watershed Office Building, targeting Living Building Petal certification and Living Stone, also pursuing Living Building Petal certification.

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Additional thanks go to Andrew Lee with the International Living Future Institute, for creating the map of the Seattle Green Building Standard zones for Appendix C.

The authors would like to recognize the work of those who have studied high-rise multifamily buildings and associated challenges regarding energy efficiency. For a small sample of prior studies for additional reading, see Appendix F.

Image credit: Weber Thompson

PURPOSE & GOALS

In May 2017, Seattle once again became the fastest growing big city in the country.[3]

In March 2017, census data indicated one thousand people were moving to Seattle every week.[4] This rate of growth has propelled the development of high-rise residential buildings like the city has never seen before.

Projections indicate this growth will continue, even if it slows slightly, and more residential space is needed to accommodate the expanding population. High-rise residential towers play a significant part in satisfying this need; future planning for how these projects will be built is critical.

While all variables in high-performance and sustainable buildings are important for human and environmental health, the most regulated, easily quantifiable, and best understood is energy consumption. This study is intentionally narrow in its focus on energy efficiency of high-rise multifamily (HRMF) buildings.

The evolution of the Seattle Energy Code has a significant impact on the ways high-rise residential buildings will be designed and constructed. Because of the evolution of the code language and uncertainty about future improvements, however, it can be difficult to understand where we've come from, where we are, and where we are headed in the progression of the code. This study outlines the ways in which this building type will need to change to accommodate the increased stringency of the Seattle Energy Code over time in new construction.

The purpose of this study is to address:

- **The Evolution of the Seattle Energy Code (SEC).** Identify a potential, predicted path for the rate of change of HRMF building compliance in the SEC through the year 2030.
- **Energy Strategies for Future Code Cycle Compliance.** Explore a sample high-rise residential building currently under construction, and a simulation of how it would need to be improved to align with predicted SEC compliance in code cycles between 2015 and 2030, assuming the current rate of change.
- **Energy Strategies for a Carbon Neutral Seattle.** Explore which strategies would need to be employed in HRMF buildings to meet year 2030 targets, if we consider the stated target of the City of Seattle (carbon neutral operations by the year 2050).
- **Energy Efficiency Beyond 2030.** Predict the strategies in HRMF buildings that will provide an impact beyond the year 2030.

The goals of this study are to:

- **Establish a Constant Metric.** Create an 'apples-to-apples' EUI equivalent of the recent past, current, and future energy code cycles for code compliance for HRMF buildings in Seattle.
- **Plan for the Future.** Provide guidance for future planning and integrated design of high-rise residential development.
- **Unveil the Real Building Impacts of Energy Measures.** Draw connections between code-required energy efficiency increases and real world high-rise multifamily design strategies, to illustrate how energy code improvements affect buildings in tangible ways.
- **Highlight the Tipping Point (for Less Typical Measures).** Identify the stage at which off-the-shelf technologies and strategies will not be enough, and less common strategies will need to be considered. These strategies include enhanced envelope design, window-to-wall ratio (WWR) reduction, and significant on-site renewable energy generation.

[3] Seattle previously had the greatest one-year population growth of the US 50 most populous cities in 2013. Seattle Times - https://www.seattletimes.com/seattle-news/data/seattle-once-again-nations-fastest-growing-big-city-population-exceeds-700000/ – May 25, 2017

[4] The Stranger - http://www.thestranger.com/slog/2017/03/27/25043201/more-than-1000-people-are-moving-to-seattle-every-week-census-report-shows

AUDIENCE

This is a simulation case study meant to challenge assumptions, provide informed observations, and set the stage for future investigations. It is not meant to promote a particular argument or policy recommendation.

The primary audience is new construction project teams, including design and engineering professionals and their clients. We intend for these parties to use this study to have informed discussions about the future of high-rise multifamily residential building energy performance in Seattle. This study could equip project teams to make educated decisions about energy conservation measures (ECMs) with the greatest relevance and potential for future projects. By investing in likely future ECMs now, project teams will help build market support of products and strategies detailed in this study. Knowledge is power in an evolving regulatory climate.

Another significant audience for this study is jurisdictional staff and policymakers. Initially, the City of Seattle and the State of Washington, who publicly announce targets and track them over time, will benefit from real data indicating actual building performance energy efficiency resulting from code advancements. The specific ECMs required in HRMF buildings in near future code cycles will provide crucial background information for the administrators of the code. Eventually, other jurisdictions who are developing their own energy codes and targets can use Seattle's example to check their assumptions about the effect that policies have on the HRMF building project type.

HYPOTHESIS

At the outset of the study, the authors predicted:

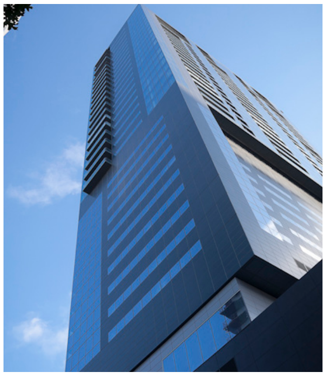
In order to meet state and city energy targets in near future code cycles, high-rise multifamily residential buildings will need to implement best practices in envelope improvements and heating and cooling systems, and incorporate the following:

(1) significant building envelope strategies like reduced window-to-wall ratio (WWR), closer to the prescriptive code 30% maximum

(2) extensive photovoltaics on roof and wall surfaces

(3) new or untested technology not currently available "off-the-shelf"

These additional measures would impact project construction costs in significant ways that are not currently understood.



Block 21 by Andersson Wise Architects, Austin, Texas. Image source: www.archdaily.com, Feb 24, 2014, copyright Andrew Pogue.

The House at Cornell Tech by Handel Architects, New York City, NY. Image source: www.handelarchitects.com

These buildings by others are examples of great design with increased solid walls in HRMF buildings, however many building developers are concerned about the impact of reduced glazing on views and natural light, i.e. the perceived luxury and market value of units.

ESTABLISHING THE ENERGY TARGET CONTEXT

The City of Seattle has established ambitious goals for improvements in energy efficiency for new buildings. However, the limited quantitative data and qualitative analysis of code revisions indicates that the necessary cycle-by-cycle code improvements are coming up short from these targets in high-rise multifamily housing energy efficiency. Rushing and Weber Thompson have analyzed the available data to benchmark both the "aspirational" targets and the more realistic "trending" targets for multifamily high-rise EUI. The City of Seattle's stated target is carbon neutral operations by the year 2050.[5] For additional context, the State of Washington has also set a target of 70% energy reduction for new buildings from the 2006 code by the year 2030.[6]

This study is focused on Seattle, located in the ASHRAE Climate Zone "4-Marine," one of the mildest climates in the continental United States. Our energy code-prescribed design temperatures (meaning the extreme conditions that should be used to size heating and cooling equipment) are 24° F in winter and 86° F in summer.[7]

Seattle is a "heating driven" climate, because much of our fall-spring season falls within the 35-45° F temperature range. Historical climatic data has shown that, throughout the year, average temperatures are creeping higher in recent decades, and the focus for reducing energy consumption largely remains on improving heating efficiency rather than cooling.

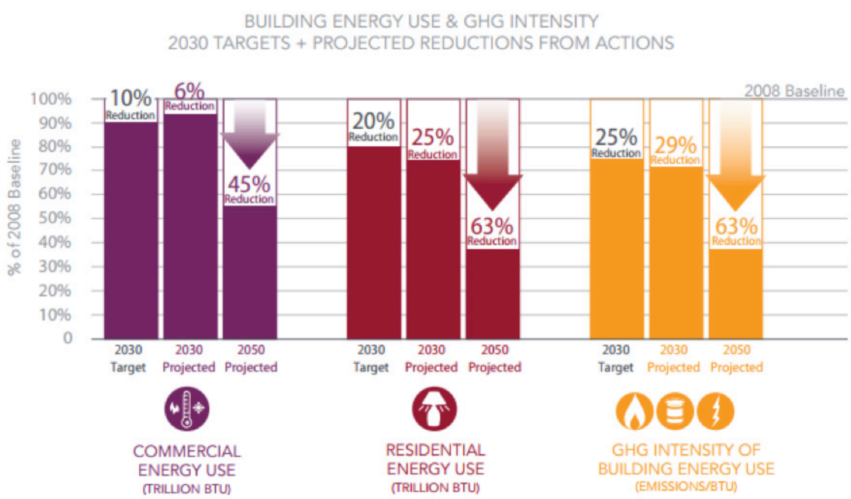


Chart from the Seattle Climate Action Plan (June 2013). Relative to 2008 baseline energy use, the city is targeting a 10% reduction in all commercial building energy use (new and existing, including HRMF buildings) by 2030 and a 45% reduction in energy use by 2050 for commercial buildings to hit the target of carbon neutral by 2050.[8] In order to meet these targets, fossil fuels are also being increasingly removed from energy sources across sectors.

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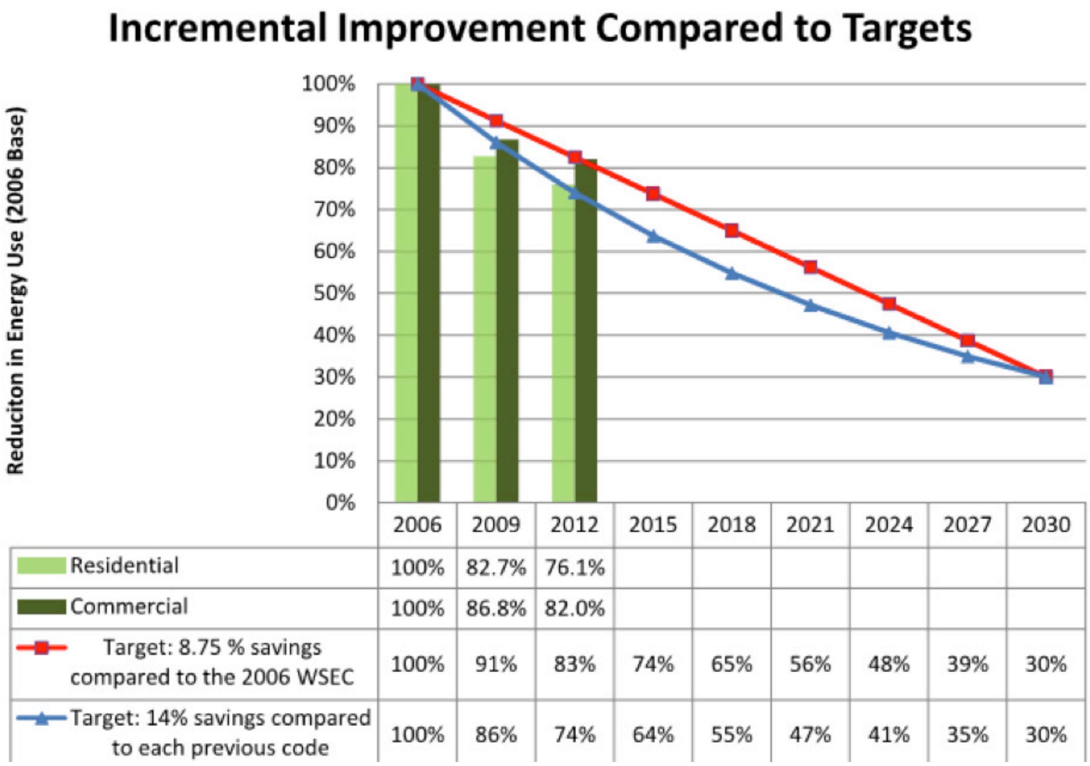
[5] Resolution 31447 – Seattle Climate Action Plan

[6] RCW 19.27A.160

[7] With a 67° F coincident wet-bulb, indicating our summer humidity is also relatively low.

[8] Further, the City of Seattle wants the commercial energy sector to reduce consumption by 10% by 2030, even though there is expected growth in the market. This means new buildings need to be significantly more efficient while improvements are made to existing stock so overall energy use decreases by 10%.



	2006	2009	2012	2015	2018	2021	2024	2027	2030
Residential	100%	82.7%	76.1%						
Commercial	100%	86.8%	82.0%						
Target: 8.75 % savings compared to the 2006 WSEC	100%	91%	83%	74%	65%	56%	48%	39%	30%
Target: 14% savings compared to each previous code	100%	86%	74%	64%	55%	47%	41%	35%	30%

Excerpt from 2012 Washington State Energy Code Legislative Report. Progress of WSEC relative to targets for 2006-2012 code cycle for all buildings governed under the residential and commercial energy codes. The graph illustrates the Washington State goal of a 70% reduction in building energy use between 2006 and 2030, which could follow either of two trajectories.

While, on the surface, the progress of the codes seems to be generally tracking with desired energy reductions, it is worth noting there are several complications in determining whether or not we are tracking with the stated above targets for HRMF projects.

First, HRMF buildings fall under the "commercial" code designation, which includes all other building types except residential projects larger than three stories, such as retail, office, education, etc. Therefore it is difficult to look at the overall commercial trends and say whether HRMF buildings are "meeting the projected target;" HRMF buildings would need to be somehow separated out from the average.

Second, there are multiple compliance paths within the energy codes. Though the intent is that they are equally stringent, in reality there can be significant variation in the energy consumption of similar code compliant buildings. Seattle has three compliance paths: prescriptive (including component trade-off), total building performance, and target performance pathway.

Unfortunately, 2006 HRMF-isolated EUI data is not available to use as a baseline for the Washington State 2030 70% reduction target, nor is there a 2008 EUI data point to create the Seattle 2050 "Carbon Neutral" baseline and quantitative reduction target (or the interim 2030 target for this study).[9]

This study helps define baseline energy performance for HRMF projects enabling an "apples to apples" comparison for energy reduction goals. After studying various options to accomplish this, it was concluded that the most defensible route was to focus on the Seattle Energy Code, which has "pegged" itself to be 20% better than ASHRAE 90.1 for each code cycle. Relatively good data is available on the modeled EUI progression of HRMF buildings for each recent 90.1 cycle. Therefore, we can establish a trend in HRMF energy efficiency improvements under that model code and project relevant EUI targets for future HRMF buildings under the SEC.[10]

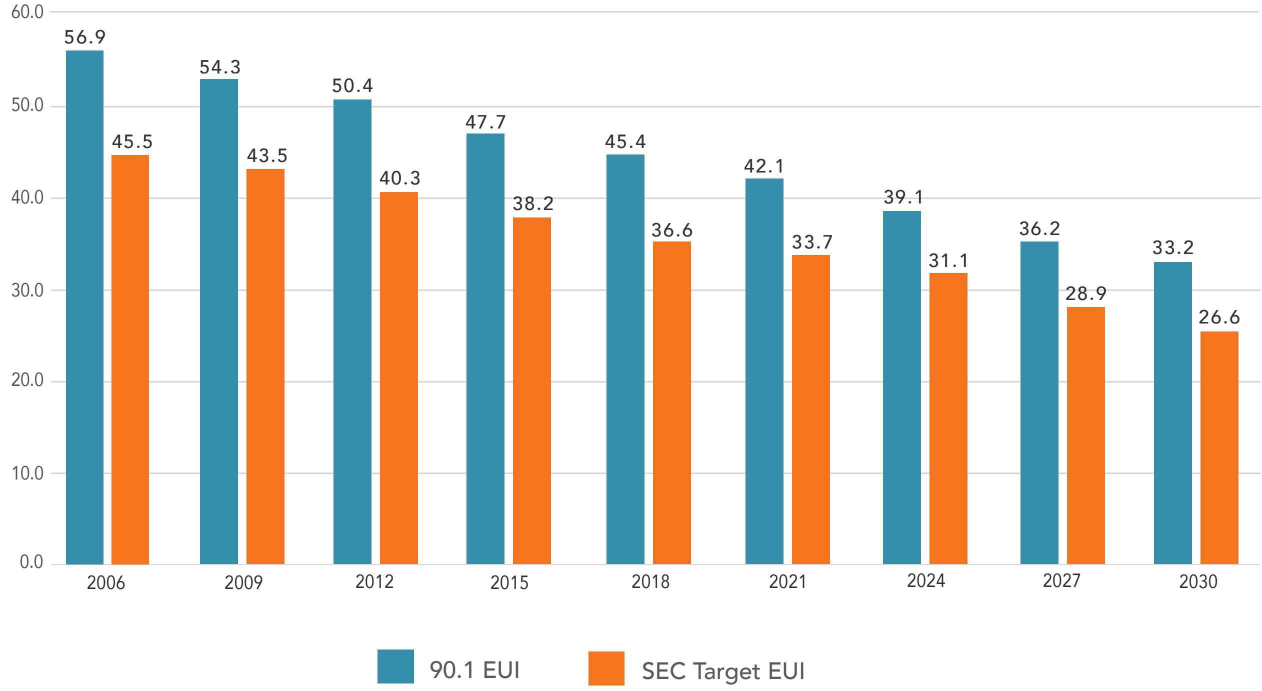
Once the EUI targets are established, the next task of the study was to check whether this curve was on track for HRMF buildings to meet the stated target of carbon neutral by 2050.

To form the basis for EUI trending:

- Seattle Resolution 30280 (Adopted Feb 2001) states that each version of the Seattle Energy Code should target 20% energy improvement over the current version of ASHRAE 90.1.
- The US Department of Energy has released official reports indexing the ASHRAE 90.1 energy performance of each iteration of the standard relative to the previous version (sometimes there are revisions to the model that cause the previous results to be revised).
- Recent DOE reports have specifically broken out the high-rise multifamily building type, so we have more specific trending on the direction of national codes for this building type (drawing a parallel between IECC and ASHRAE 90.1 development). We have comparative energy model results for high- rise MF for the 2007/2010/2013/2016 90.1 cycles, and comparative energy model results for mid-rise MF for the 2004/2007/2010/2013/2016 90.1 cycles.
- See Appendix A for full methodology on how we established the historic and future projected EUI targets for this report.

[9] Additionally, we do not yet have an update on the 2015 WSEC performance relative to the target reduction, but anecdotally we believe 2015 WSEC revisions were more impactful to non-residential buildings governed by the commercial code. Examples include: Direct Outside Air System requirements (not applicable to multi-family), lighting power density reductions (MF is largely exempt), and caps on ventilation rates (MF is exempt).

[10] It is worth noting that both the WSEC and SEC are modified versions of the International Energy Conservation Code, which is not identical to ASHRAE 90.1, but is similar enough that we are assuming similar progression of IECC cycle-to-cycle.



Progression of Seattle HRMF Energy Efficiency, 2006-2030.

This chart establishes the targets (in orange) for past, present, and future HRMF buildings that comply with the SEC. With these benchmarks, we can now proceed to evaluate ECMs in HRMF buildings that will help achieve these EUI targets in future cycles.

STUDY METHODOLOGY

Project Selection

In order to ground this study in a real world scenario, an in-progress high-rise multifamily project – Nexus, a 41-story tower in downtown Seattle – was studied. This building includes 382 for-sale condominium units and is located at the "nexus" of Minor Avenue and Howell Street, just west of Interstate Highway I-5.

This building was selected because:

- It is currently under construction and will be completed in mid-2019.
- It was designed under the 2012 Seattle Energy Code and Seattle Building Code.
- As a collaborative effort between WT (architectural design) and Rushing (energy analysis, mechanical and electrical engineering), we have good access to project data.
- The project is representative of a "typical" condominium and high-end apartment high-rise project.[11]

Image credit: Weber Thompson

Assumptions

For glazing, the starting point was the current standard practice for Seattle area window wall and curtain wall Insulated Glazing Units (IGUs): double-pane, single low-e coating, argon filled. While there can be further IGU thermal performance improvements made without introducing triple-pane glazing (such as adding an additional low-e coating to the interior surface of the glass), this has been ruled largely impractical thus far due to concerns about possible condensation.

For the purpose of this study, it is assumed that high-rise residential living trends will not differ between now and 2030. This includes average unit size and unit type, the patterns of plug loads based on devices, occupancy schedules, and vacancy.

It is also assumed that owner/developers of high-rise residential buildings have a strong desire and incentive to not reduce WWR beyond today's standard (approx. 44% glazing), predicted on the value brought by views and natural light.

As a result, the study treated reduction in WWR as a last

[11] Though, probably on the more challenging end for energy modeling due to building geometry.

resort in the ECM package prioritization. It was also assumed that any proposed technological improvements will be proven and market tested. In other words, no "futuristic" technology will be proposed to meet energy efficiency goals.

It is assumed that given their large share of total built area, HRMF buildings will need to continue to follow a general decreasing EUI target to meet the goals of the Seattle Climate Action Plan. In other words, the City will not be relying on other building types to over-perform in order to allow HRMF to continue at their current consumption levels.

It is assumed that the current pace and political drive will make code improvements stay the same through the next six code cycles, however, from cycle to cycle there will not be significantly disproportionate reductions in energy performance compared to previous cycles.

From code compliance model to predictive model

The actual energy model for 2012 SEC compliance was built following the Total Building Performance (TBP) protocol. For this, the SEC requires a comparative analysis between two models – the "proposed" building and a "standard reference" building, to demonstrate relative energy savings rather than predicting absolute energy use. This allows non-regulated energy consumption (including plug loads, elevators, etc.) to stay the same between the compared models and not have a significant impact on the results for code compliance.

In order to have a more predictive model than the TBP protocol, Rushing modified the original modeling file to account for several items left out of the TBP compliance documentation (i.e. no credit was allowed by the jurisdiction, even though these items have an impact on the model.) This includes low-flow plumbing fixtures, which effectively reduce the overall domestic hot water demand, and ENERGY STAR appliances (including washing machines, dish washers, and refrigerators), which effectively reduce both DHW demand and plug loads. As a result, the model is more predictive of anticipated energy use, though there are always assumptions and simplifications inherent in the energy modeling process that impact absolute accuracy.

Modeling process

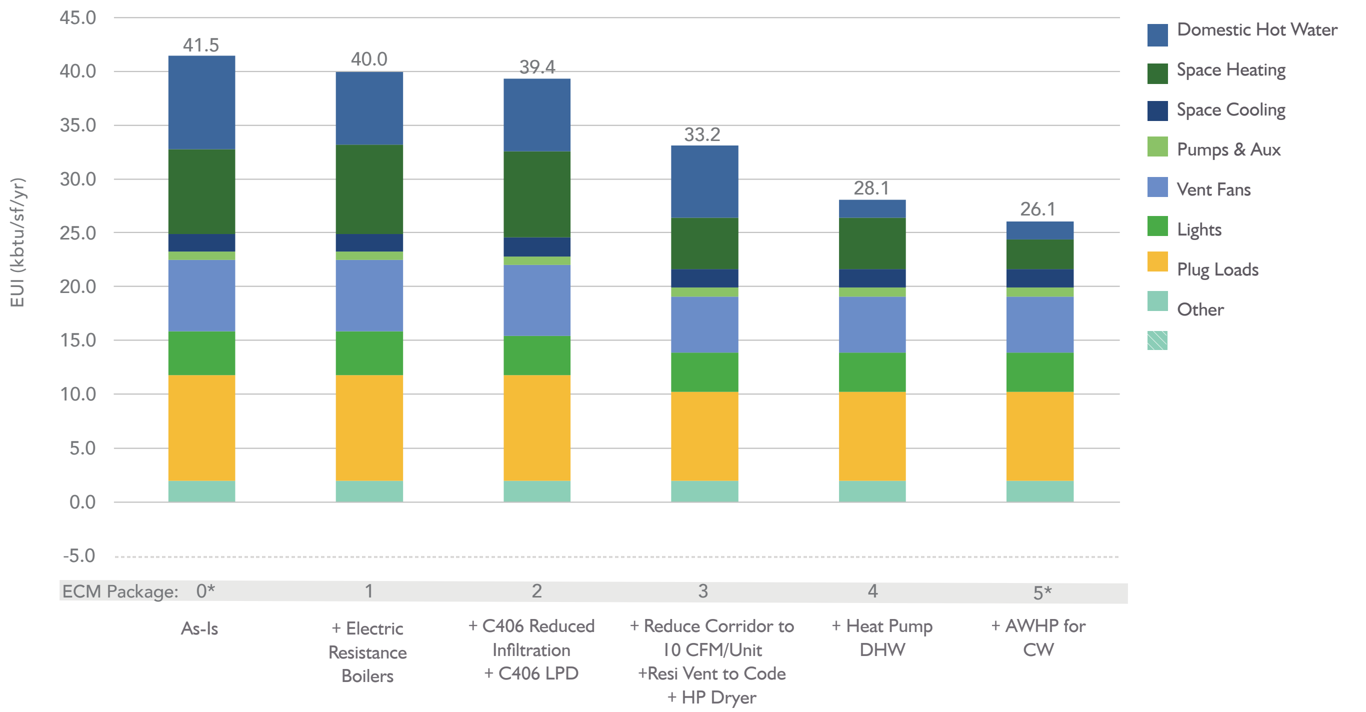
eQUEST v3.65 was used as the energy modeling program, supplemented with side calculations for items that could not be directly modeled.

Schedules, internal loads, and DHW demand follow the language of 2012 SEC Section C407 (Total Building Performance) or the ENERGY STAR Multifamily High-Rise Simulation Guidelines.

Energy Conservation Measures (ECMs)

The following ECMs were selected and prioritized based on cost, marketability, resident satisfaction, and ease of implementation to include in the project per current market conditions and the realities of typical HRMF construction. This is one approach, recognizing that there are many combinations and sequences of ECMs that can be explored. ECM "Packages" are presented with interactive effects as the result of multiple measures implemented together. Note that each ECM Package is cumulative; in other words, ECM Package 3 assumes the measures in ECM Package 1 and 2 have also been implemented.

Some of the explored ECMs stand alone and do not impact the other systems of the building. A rooftop photovoltaic system is an example. Other ECMs interact with each other, thus the total combined savings does not necessarily equal the sum of the individual ECM savings. For example, the measure to supplement the water source heat pump (WSHP) boilers with air-to-water-heat-pumps will see drastically different heating loads (and subsequent energy consumption) depending whether or not the air tightness measures have also been implemented.



*Energy Consumption by End Use Distribution pie charts on page 18

ECM Packages

Relative cost **Relative design, construction, or tenant impact**

ECM Package 0:
Nexus as designed & built for energy code compliance:

- 44% WWR on above-ground elevations.
- Glazing has a weighted U-Factor of 0.361 and an SHGC of 0.323.
- Apartments are conditioned by High Efficiency Water Source Heat Pumps (cycle per demand).
- Residential ventilation is provided by 100% outside air rooftop unit and ducted outside air.
- Corridor ventilation is provided by 100% outside air rooftop water source heat pumps w/ preheat coils.
- High Efficiency DHW Plant (96%)
- High Efficiency Condensing Hot Water Plant (92%)
- All spaces designed to designated Lighting Power Density allowances per SEC.

ECM Package 1:
Electric boilers in lieu of condensing natural gas boilers. This provides a site EUI advantage, and is a logical complement to heat pump water heating investigated in subsequent ECMs.[12]

ECM Package 2:
Improved envelope air tightness 25% and Lighting Power Density (LPD) reduction. Envelope air tightness measures to meet a reduced infiltration rate, as specified in 2015 SEC C406.9 (tests to air leakage maximum of 0.22 CFM/ft2 at 75 Pa). Additionally, an LPD reduction of approximately 25% across the board as specified in 2015 SEC C406.3.[13]

ECM Package 3:
Measures to reduce outdoor air flow + partial heat pump heating. This assumes heat-pump laundry dryers in lieu of conventional residential dryers.[14] As a result, reduced corridor pressurization air to 10 CFM per unit (down from about 30-35 CFM/unit), reduced dwelling unit ventilation to code minimum (from 50% excess), and reduced penetrations in the envelope (that would have been present with conventional dryers). To reduce DHW energy consumption, Heat pump is introduced to supplement the boiler plant.

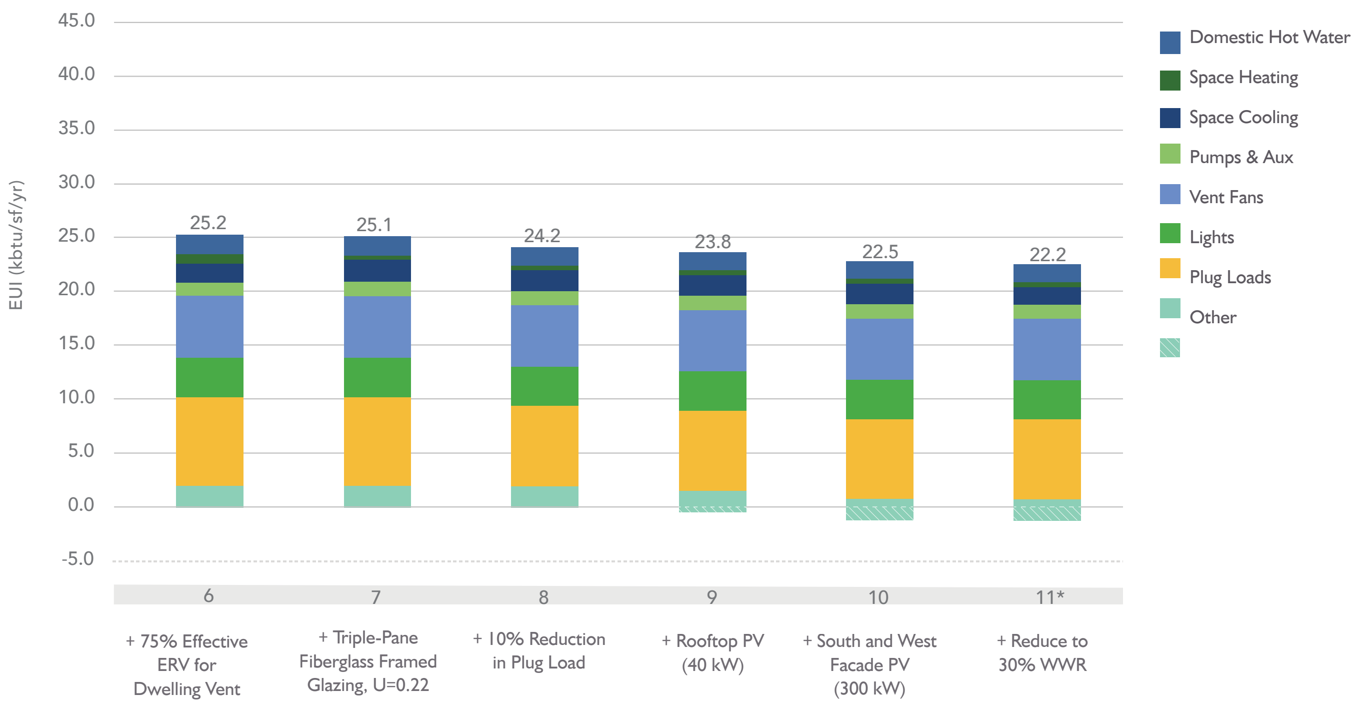
ECM Package 4:
Heat Pump heating for the DHW loop. Either an air-to-water-heat-pump or water-to-water-heat-pump (e.g. sewer thermal heat recovery). Assumes an average efficiency of COP = 4.

ECM Package 5:
Heat Pump for WSHP Condenser

[12] From a climate change perspective, it also has the benefit of reduced source carbon, as Seattle's electric power generation is much "cleaner" than natural gas.

[13] Note that we assumed this reduction could only be applied to a portion of the lights in the residences, as some fixtures will be occupant provided plug-in-lamps.

[14] Note that heat-pump dryers are more efficient and require no venting. However, they are slow to become standard in the US, as clothes take longer to dry compared to conventional dryers, therefore there is potential friction with expectations of residents, especially for condominiums.



*Energy Consumption by End Use Distribution pie charts on page 18

Water. Water-source heat pump loop translates to 2/3 of the WSHP boiler load provided by air-to-water-heat-pump (with the remainder met by the electric boiler). Assumes an average efficiency of COP = 3.

ECM Package 6:
Introduce 75% effective Energy Recovery Ventilation for residences. This would introduce some cost and space requirements, as it requires supply and exhaust ducting back to the central AHU.

ECM Package 7:
Replace conventional curtainwall with a triple-pane glazing in a fiberglass frame and keep the same WWR. The area-weighted U-factor is reduced from U = 0.395 to U = 0.22, and solar heat gain coefficient from SHGC = 0.336 to SHGC = 0.260.

ECM Package 8:
Reduce plug/miscellaneous loads in building by 10%. This assumes some combination of occupant- or load-sensing technologies and general improvement in plug equipment efficiency.[15]

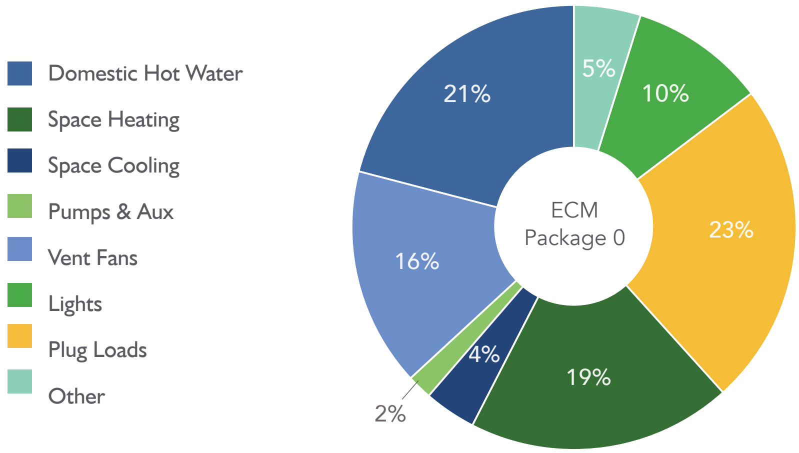
ECM Package 9:
Introduce a rooftop Photovoltaic (PV) system for onsite renewable energy. Assume 40.4 kW array (approximately 5,000 SF of roof area), with optimal angle and orientation.

ECM Package 10:
In addition to rooftop PV, introduce a façade (vertical) PV system on the west and south façades. Assumes one (1) 150 kW array per façade (300 kW total), mounted flush to each building face. This requires 8,000-10,000 SF/façade. This system has reduced efficiency compared to a rooftop array because of panel orientation, however it is an opportunity for additional on-site energy generation.

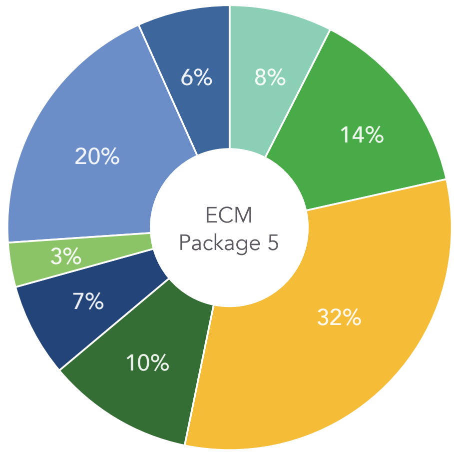
ECM Package 11:
Reduce the overall WWR from 36.2% to code-prescriptive 30%. This represents a change in the vision glazing portion of the façade from 76,100 SF to 63,100 SF.

[15] This is perhaps the most uncertain ECM value, since it is largely reliant on occupant choices. However, with improved building efficiency, plug loads are becoming such a large portion of the overall building energy consumption that they will likely be aggressively targeted.

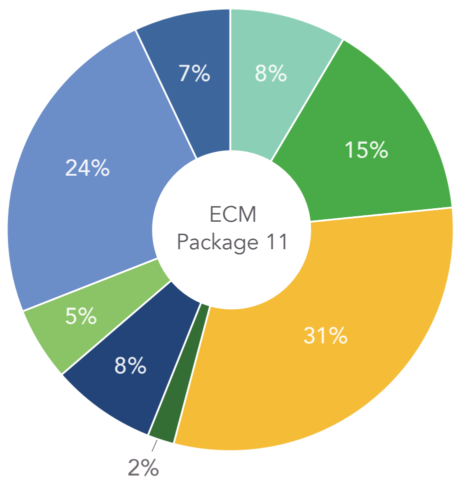
Energy Consumption by End Use Distribution



Pie chart illustrating energy demand breakdown in ECM Package 0, the Nexus project as designed and constructed.



Pie chart illustrating energy demand breakdown in ECM Package 5. Note that as domestic hot water, heating systems, and pumps become more efficient, lighting, plug loads, and ventilation take on a larger portion of the pie.

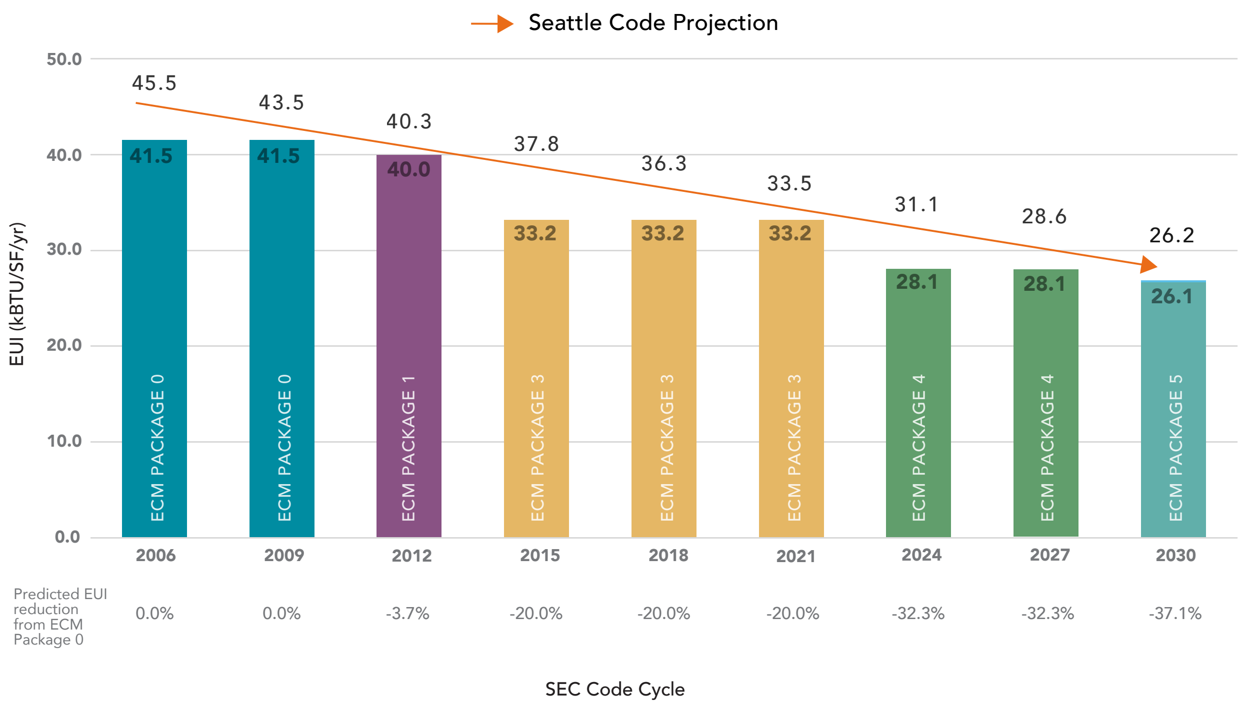


Pie chart illustrating energy demand breakdown in ECM Package 11. Note that as systems become more efficient, reliance on occupants to drive down energy use increases. Areas for future opportunity for new efficiencies include ventilation and occupant behavior.

RESULTS

Scenario 1: Seattle Energy Code compliance path

The first bar chart shows a progression of cumulative ECMs needed to meet the projected Seattle Energy Code targets for this building in each cycle from 2006 to 2030. Starting in the current cycle at the time of this study (2015), ECM Package 3 is needed to hit the target code-cycle EUI. The next additional ECM Package is required in 2024, when ECM Package 4 (Heat Pump for DHW loop) is introduced. In 2030, ECM Package 5 (Heat Pump for water-source heat pump loop) is introduced to reach the target (equivalent 26.1 EUI).



Progression of required ECM Packages for Nexus to meet code compliance in each SEC cycle from 2006 to 2030.

Scenario 1 Analysis

Following its current trajectory, Seattle Energy Code compliance can be achieved through the year 2030 for HRMF buildings primarily focused on mechanical system efficiencies, reduced lighting power density, a tight building envelope, and reduced corridor pressurization.

While it can benefit project performance, a WWR reduction (below the currently accepted industry norm of 44% glazing in elevation view) will not be a required strategy. On-site renewables and technologies that achieve plug load reductions are also encouraged, but not required.

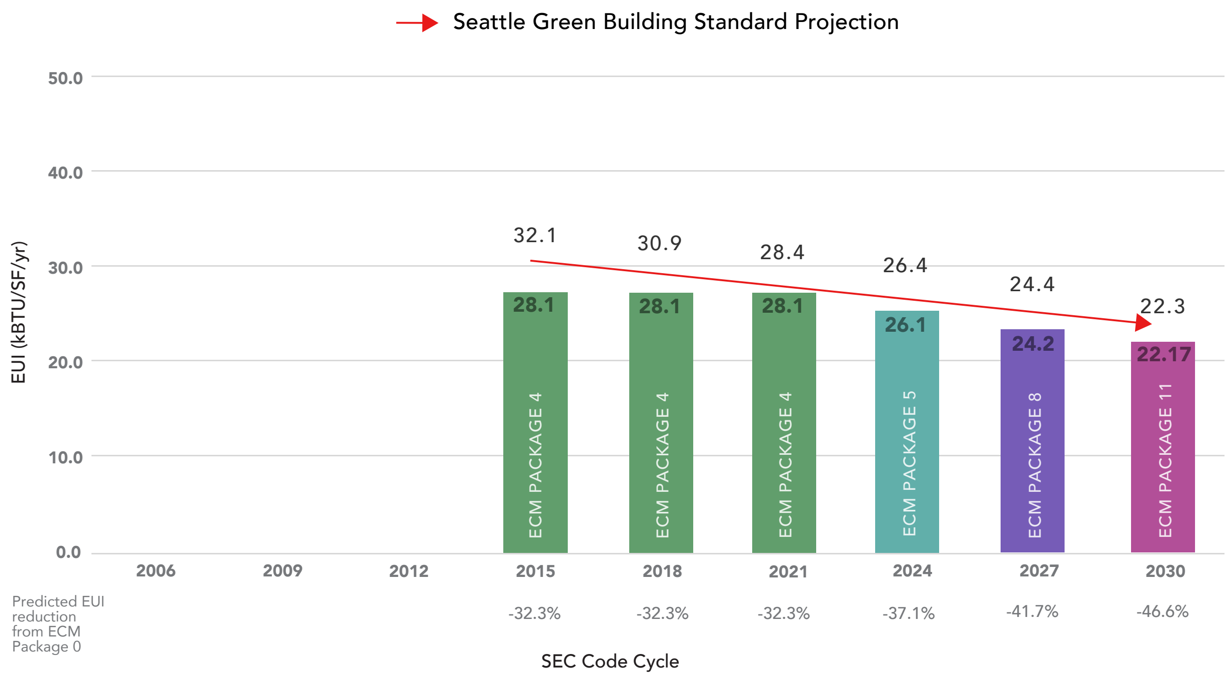
These findings are under the assumption that future codes would normalize the energy use metric to be EUI. As a result, measures which are not currently eligible for code compliance but result in true energy savings (i.e. reduced EUI) were included in this evaluation.

This bar chart shows that the authors' Hypothesis (p. 8) is disproven: significant building envelope strategies like reduced WWR, extensive photovoltaics, and new or untested technology **are not required to create code-compliant HRMF buildings through the 2030 SEC, based on our assumptions.**

Scenario 2: Green Building Standard compliance path

The second bar chart shows the introduction of the Green Building Standard, adopted in the Seattle Municipal Code 23.58D and 23.84A.014 "G" by Seattle Council Bill 118783 in October 2016, and further interpreted by Seattle Director's Rule 20-2017. This standard is required for project teams to take full advantage of incentive zoning for some sites in the urban center of Seattle (see the map in Appendix B), and therefore is relevant for a number of high-rise residential projects likely to be built in the near future. The Green Building Standard requires a 15% energy reduction in addition to SEC compliance.

As a result, ECM Package 4 is needed to meet the target EUI through the 2021 cycle. In 2024, ECM Package 5 is introduced. In 2027, ECM Package 8 (cumulatively ECM Packages 6-8, which include ERV unit ventilation, triple pane glazing with fiberglass frame, and plug load control) will be required. In 2030, ECM Package 11 (cumulatively ECM Packages 9-11, which include roof and façade-integrated PV and WWR reduction) will be required.



Progression of required ECM Packages for Nexus to meet the Seattle Green Building Standard (15% better than SEC) in each cycle from 2006 to 2030.

Scenario 2 Analysis

In order for projects to meet the newly adopted Green Building Standard in Seattle (Scenario 2), more difficulty is introduced as ECM Packages with a heavier "lift" need to be rapidly adopted. Unfortunately, the latter ECMs (especially #8 through #11) have diminishing results on the energy model for effort and cost expended.

This bar chart shows that the authors' Hypothesis (p. 8) is borne out in the context of projects that must comply with the Seattle Green Building Standard for incentive zoning, beginning with the 2027 SEC cycle.

This provides building owners and developers an opportunity to gain comfort with, and invest in, strategies that will provide the best value in future code cycles now, to reduce both construction and operating cost burdens later. Reduced WWR, on-site energy generation, and plug-load reduction are smart strategies for consideration to incorporate in projects now, not necessarily because they are inevitable requirements of code compliance, but because of likely alignment with other project goals. Integrated Design is a key method for project teams to identify the best suited strategies for compliance.

The jurisdiction should take note of these pathways, and check them against stated municipal goals. The City could consider partitioning out HRMFs from other residential building types in the code when establishing targets and tracking these projects over time. If summary data on average EUIs & GHG emissions by building type every year, the monitoring and recalibration of building codes could be done more consistently. The city should also continue to improve building energy disclosure resources (currently we are relying on 2016 data, the latest that is publicly available during much of 2018).


Image credit: Weber Thompson

NEXT STEPS FOR FUTURE STUDY

We consider this study the beginning of a conversation, and invite others to pick up these findings and run with them. What follows are considerations for research teams who wish to further understand the impact of future SEC code cycles on HRMF buildings:

Include more buildings for a larger data set. The limited data set of one project makes the results of the study less than conclusive. Future studies should include multiple projects built around the same time, under the same market conditions and code requirements, ideally both for-rent and for-sale units, with a range of unit sizes, amenities, and other design features. With the recent building boom of HRMF construction in Seattle, we will soon have the opportunity to capture data illustrating energy code compliance for several buildings designed under the same code cycle. This provides a more robust data set to test the preliminary conclusions from this study.

Evaluate on-site and off-site renewables in more detail. As photovoltaic (PV) arrays become more commonplace, building-integrated PV becomes more available, and the cost of installed PV systems is driven down, photovoltaics may move forward in the list of ECM Packages as a more palatable strategy for building developers.

Study the Impacts of a New Energy Code Modeling Protocol. As this report was completed, newer analyses on other high-rise multifamily projects indicated more aggressive approaches are needed to comply with the Green Building Standard requirement of 15% better than Seattle Energy Code (SEC). These studies revealed that Heat Pump for WSHP Condenser Water and ERV for corridors (i.e. ECM Package 5 and 6) are required in 2019, not in 2024 and 2027 as the Nexus analysis indicated. This is partially due to the new C407 modeling requirements implemented in the middle of the 2015 code cycle which greatly reduce the credit that could be claimed for dwelling unit fan energy savings. These new analyses also were not conducted in EUI, so they are not an exact parallel to this study. It would be beneficial to continue to evaluate the impacts to the progressing energy code on HRMF buildings given new legislations and energy code modeling impacts, as they evolve.

Track trends in electric vehicle (EV) charging

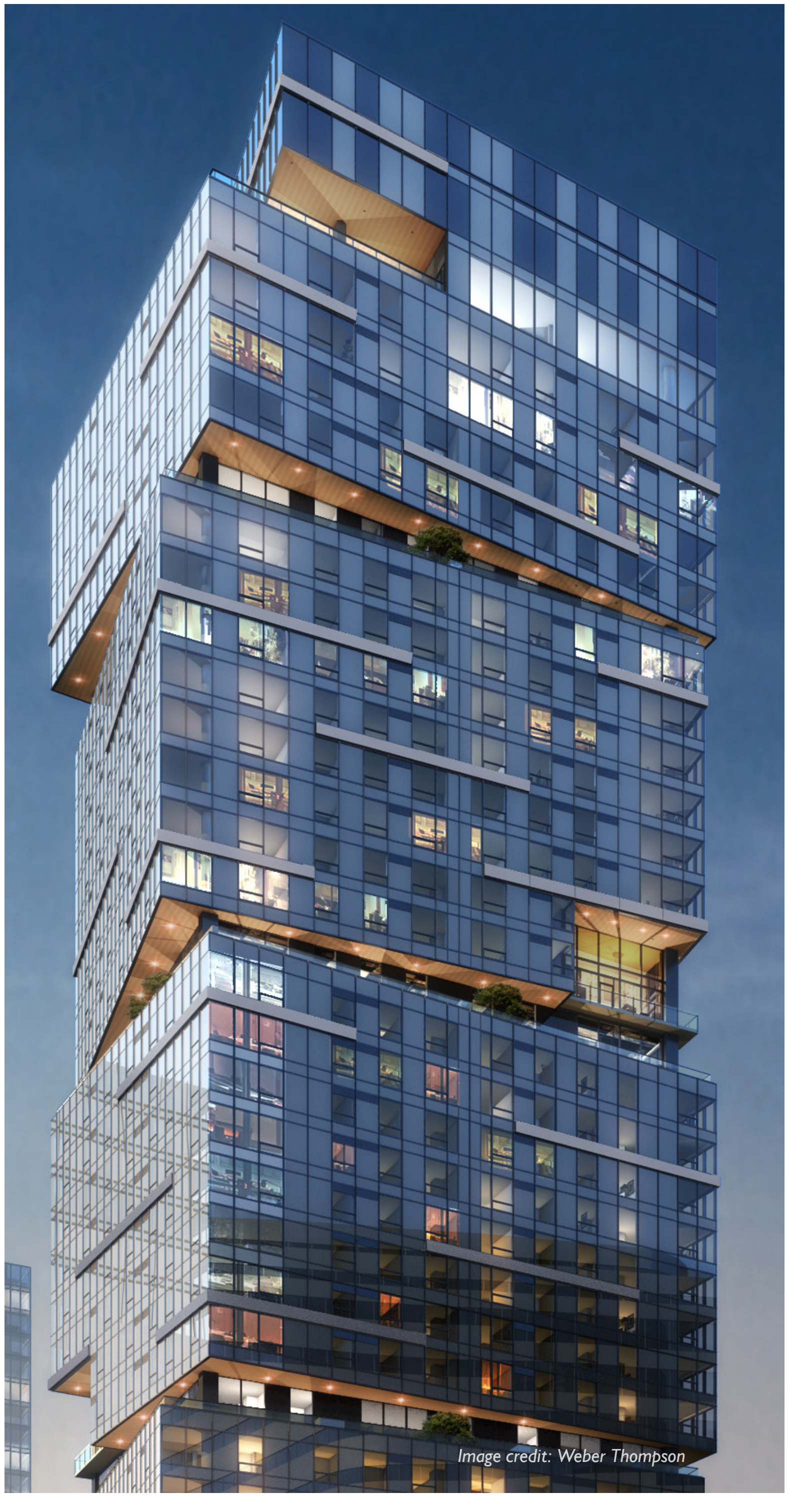


Image credit: Weber Thompson

stations. There are some multifamily housing trends that the study does not attempt to predict in future code cycles. In particular, the growth of EV charging stations may translate into a larger electricity demand for buildings. Perhaps coupled with future autonomous vehicles, EV charging stations could be in operation more hours of the day than currently observed, and more vehicles may be using the stations. Currently it is unknown what the overall impact EV charging stations will have on total building electricity use, and whether this will become a penalty for projects that would be effectively mingling transportation infrastructure with buildings.

Conduct a cost analysis. This study focuses on energy consumption reduction rather than energy cost reduction, as a good complement to the Seattle Energy Code. We assume decisions are made to serve energy reduction rather than energy cost reduction.[16] Without estimated costs to assign to each ECM, we do not have a complete picture of the level of effort to achieve code compliance in each predicted future cycle. This could be measured as cost in dollars per ECM Package, dollars per EUI reduction, and in both cases as a percentage of total construction cost. The limitations of cost analyses will be that they would not be comprehensive, would be valid for just a brief moment in time, and difficult to project into future scenarios.

Explore existing buildings' contribution to WA 2030 target. Evaluate any new existing building legislation proposal for how it contributes to the overall reduction of energy use. Study how this will impact new construction and the degree which new buildings must influence the WA State 2030 energy target. This may impact the degree to which new HRMF projects specifically must ratchet down energy use with each code cycle.

Explore non-ECM strategies to meet GHG reduction targets. Perform a study that further investigates GHG reduction through other systems and strategies, e.g. electricity storage and energy demand management, rather than focus only on direct building EUI reductions.

Address Climate Change. Conduct a sensitivity analysis on the assumptions in this study, based on the predicted changing climate of Seattle in future years.

[16] For example, if one were looking to improve Site EUI by a small amount, it might make sense to switch from natural-gas fired domestic hot water boilers to electric resistance boilers, because electric boilers operate at almost 100% efficiency (compared to 90-95% efficiency for the best natural gas boilers). This is a "win" from an energy perspective, but because of the relative cost difference between natural gas and electricity, for each unit of heat produced, electric boilers would cost more. Realistically, it would make more sense to skip the interim step of electric resistance boilers, and move straight to the higher efficiency heat-pump technology (which can beat natural gas boilers both in efficiency and cost of energy consumed). Indeed, we are starting to see multifamily projects utilize these systems.

APPENDIX

Appendix A: Establishing the Energy Target Context (expanded)

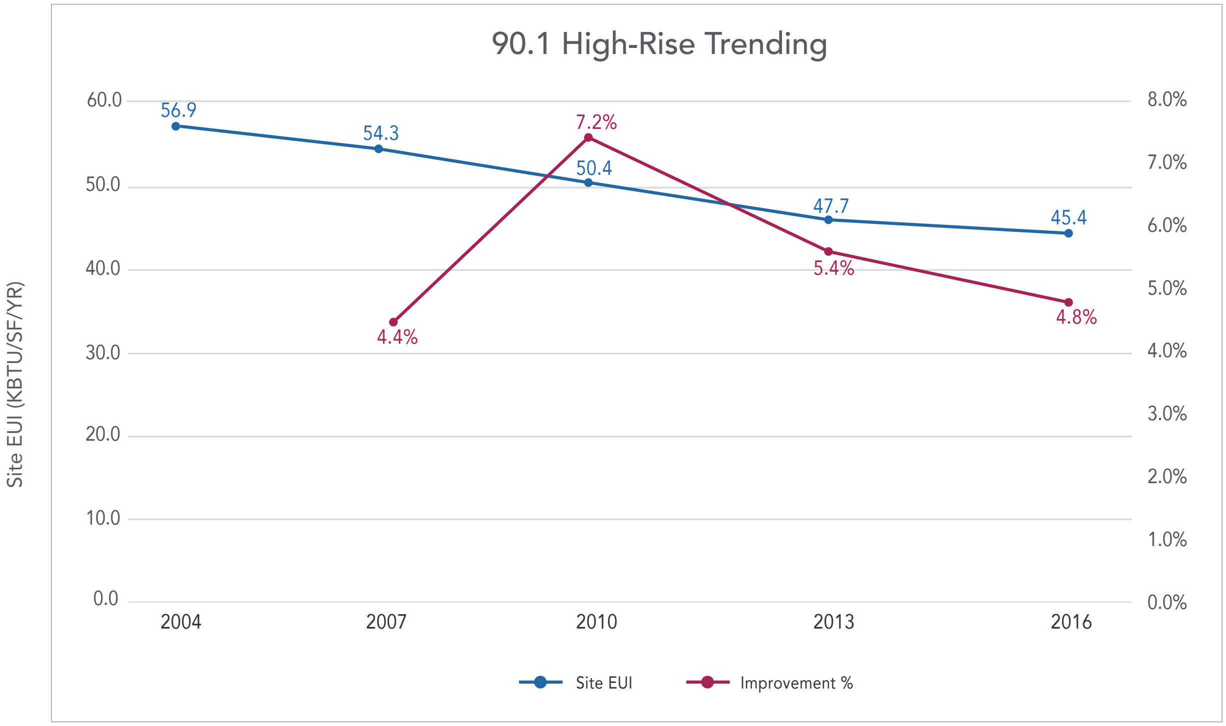
Rushing has "normalized" the HRMF EUI trending from the DOE 90.1 determinations by taking the most recent modeled EUIs (from the 2016 Quantitative Analysis, which indexed 90.1-2016 relative to 90.10-2013), and working backwards by removing the stated % improvement between each cycle from the respective Quantitative Analysis to back out the previous cycles EUI. This removes the impact of the revisions to the modeling procedure by indexing the EUIs to the most recent models. Thus we established an approximate history of HRMF EUIs for buildings that complied with 90.1 for the 2004-2016 Cycles.

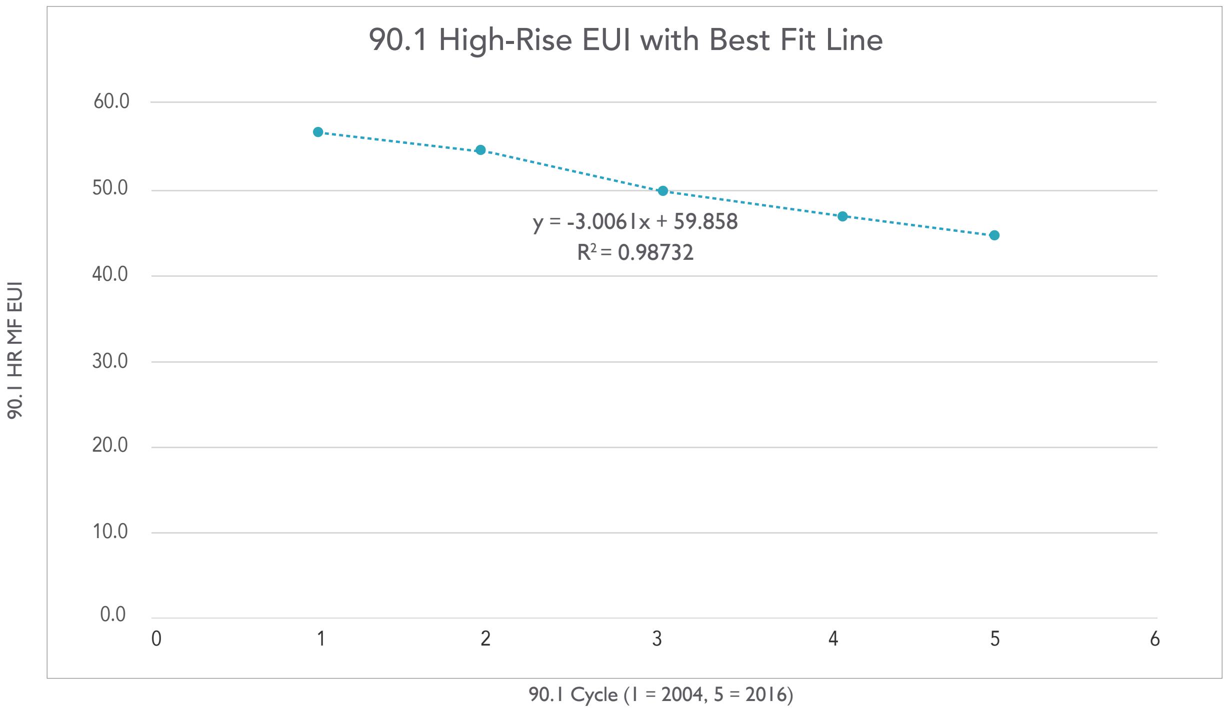
Determination Report	***Standard***	***Site EUI (kbtu/sf/yr)***	***% Improvement over Previous***	***Notes***
90.1-2007 DOE Quantitative Analysis	90.1-2004 MR	42.7	-	
	90.1-2007 MR	40.8	4.4%	
90.1-2010 DOE Quantitative Analysis	90.1-2007 MR	44.2	-3.5%	Revised 2007 Results
	90.1-2007 HR	44.2	-	Added HR Category
	90.1-2010 MR	41.2	6.8%	
	90.1-2010 HR	41	7.2%	
90.1-2013 DOE Quantitative Analysis	90.1-2010 MR	46.3	-4.8%	Revised 2010 Results
	90.10-2010 HR	50.4	-14.0%	Revised 2010 Results
	90.1-2013 MR	43.9	5.2%	
	90.1-2013 HR	46.9	6.9%	
90.1-2016 DOE *DRAFT* Quantitative Analysis	90.1-2013 MR	43.5	6.0%	Revised 2013 Results
	90.1-2013 HR	47.7	5.4%	Revised 2013 Results
	90.1-2016 MR	41.9	3.7%	
	90.1-2016 HR	45.4	4.8%	

Full Set of ASHRAE 90.1 Data (unfiltered). Note that the modeled HRMF EUI has bounced around a bit as there have been changes to the modeling procedures between cycles. For example the 2010 Quantitative analysis stated that 90.1-2010 HRMF EUI = 41 kbtu/sf/yr, whereas the revised methodology in the 2013 Quantitative Analysis pegged 90.1-2010 HRMF EUI at 50.4, indicating a substantial change to the modeling methodology.

Standard	***Site EUI (kbtu/sf/yr)***	***% Improvement over Previous***	***Notes***
90.1-2004 HR	56.9	NA	Extrapolated
90.1-2007 HR	54.3	4.4%	Extrapolated
90.1-2010 HR	50.4	7.2%	Extrapolated
90.1-2013 HR	47.7	5.4%	Modeled
90.1-2016 HR	45.4	4.8%	Modeled
Total Savings		**20.2%**	**2007-2016**

Next we looked to project out where HRMF EUIs will be headed as we move towards future cycles. Without knowing if 90.1, WSEC, or SEC will adopt significant changes that will alter the general progression path of energy reduction, we chose to extrapolate the 90.1 EUIs based on a best fit line for 2004-2016.





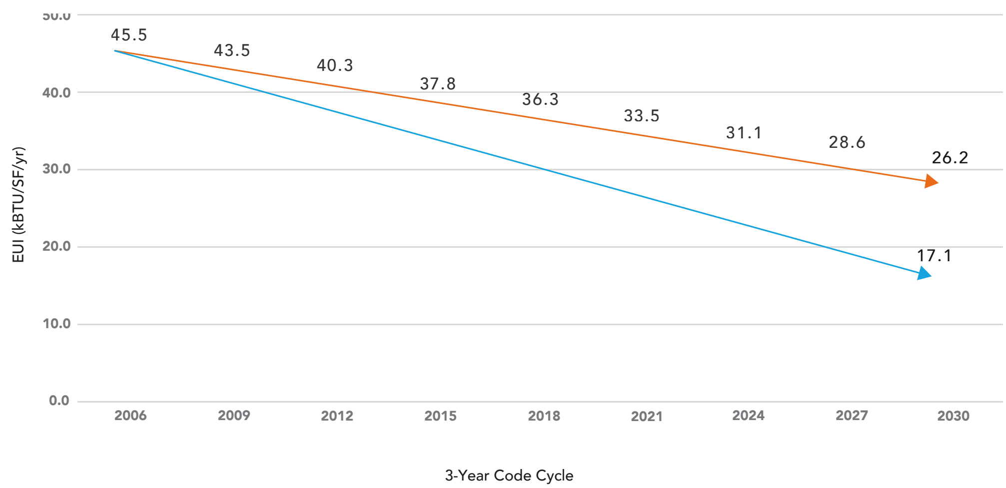
The table below summarizes the Projected Seattle HRMF Target EUIs based on indexing SEC performance to the 90.1 cycles above (assuming the stated target of 20% improvement over each 90.1 cycle). The yellow highlighted row indicates a base year of sample energy model for the subject building (Nexus).

A known source of error in our projection is that we are indexing the SEC performance to the 90.1 national average EUI for our building type, but we do not have access to the climate-zone specific historic 90.1 data.

We understand there are numerous simplifications made in our projection methodology, but we are most comfortable assuming similar HRMF progress in EUI reduction for the future based on historic progress rather than any more significant incremental step.

Cycle	90.1 Version	SEC Version	90.1 EUI	90.1 % Savings	Total Savings	Washington State Target	Seattle Target
1	2004	2006	56.9				45.5
2	2007	2009	54.3	4.4%	4.4%		43.5
3	2010	2012	50.4	7.2%	11.4%		40.3
4	2013	2015	47.7	5.4%	16.1%		38.2
5	2016	2018	45.4	4.8%	20.2%		36.3
6	2019	2021	42.1	7.3%	26.0%		33.7
7	2022	2024	39.1	7.0%	31.2%		31.3
8	2025	2027	36.2	7.6%	36.4%		28.9
9	2028	2030	33.2	8.2%	41.6%	17.06	26.6
Total				41.6%			

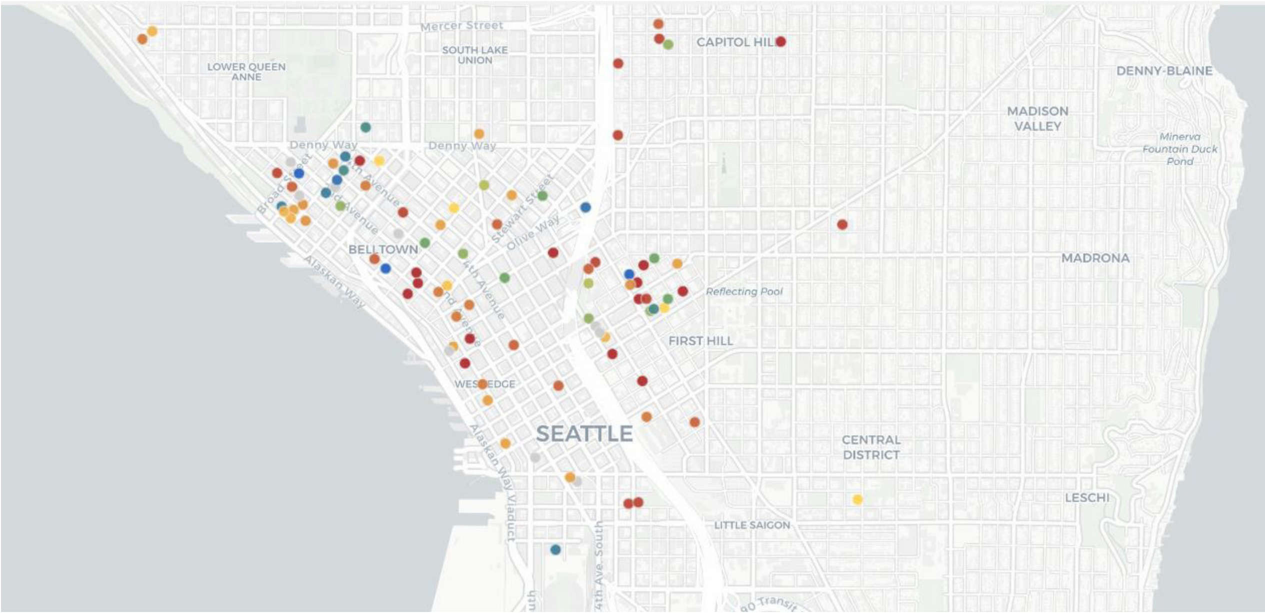
As shown in the graph below, our projection for a linear reduction in HRMF EUI is not as aggressive as the stated goal of reducing consumption by 70% from ASHRAE 90.1-2004 levels by 2030 across all building types. In our judgment there has not been the political will necessary to make the significant revisions to code necessary to drive HRMF down to the desired EUI target, hence our report uses the less stringent, but likely more realistic projection based on 90.1 progression. Our analysis does not account for thus far unknown future revisions to code that might significantly alter that trajectory.



Arrow 1: Proposed linear reduction in High-Rise Multifamily EUI in this study, based on ASHRAE 90.1 reduction to date for multifamily specifically. If code revisions shift to address multifamily buildings more aggressively, this reduction could be more dramatic.

Arrow 2: WA State goal of reducing consumption by 70% from ASHRAE 90.1-2004 levels by 2030 across all building types.

Appendix B: Seattle Disclosure Data for HRMF Buildings



Screen shot of Seattle Disclosure Map, showing HRMF buildings that provided data for the Seattle Disclosure Ordinance in 2015. Source: www.seattle.gov/energybenchmarkingmap (accessed 12/19/18)

Project Name	Address	Year Built	Property Size (ft²)	Site EUI (kBTU/ft²)	Floors	Units	Code Year Confirmed
Verve Apartments	2720 4TH AVE, 98121	2014	201,839	37.20	13	161	•
VIKTORIA APARTMENTS	1915 2ND AVE, 98101	2014	237,186	62.70	25	249	•
THE CENTURY	101 TAYLOR AVE N, 98109	2014	336,003	29.90	10	258	•
DIMENSION BY ALTA APTS	225 CEDAR ST, 98121	2014	269,065	37.80	26	298	•
STADIUM PLACE (THE WAVE & THE NOLO)	201 S KING ST, 98104	2014	619,416	47.80	26	333	
CIELO APTS	802 SENECA ST, 98101	2014	434,839	35.80	32	335	
JOSEPH ARNOLD LOFTS	62 CEDAR ST, 98121	2013	161,722	36.10	13	132	
THE MARTIN APARTMENTS	2105 5TH AVE, 98121	2013	295,754	41.70	24	188	
THE POST AT PIER 52 APTS	888 WESTERN AVE, 98104	2013	194,228	39.70	16	208	
COPPINS WELL	1200 MADISON ST, 98104	2012	236,148	46.90	17	236	
VIA 6 APARTMENTS	2121 6TH AVE, 98121	2012	602,398	34.20	24	654	
			2009 Section Average.	40.89 (37.8)*			
			Weighted Average (SF)	40.50			

2009-2011 ("2006 Seattle Energy Code")

Project Name	Address	Year Built	Property Size (ft²)	Site EUI (kBTU/ft²)	Floors	Units	Code Year Confirmed
ALTO APARTMENTS LLC - (2014)	311 CEDAR ST, 98121	2011	176,043	36.40	17	184	
ESCALA	1920 4TH AVE, 98101	2010	480,789	33.40	31	269	2012?
			2006 Section Average.	36.40 (34.9)*			
			Weighted Average (SF)	36.40			

2005-2008 ("2003 Seattle Energy Code")

Project Name	Address	Year Built	Property Size (ft²)	Site EUI (kBTU/ft²)	Floors	Units	Code Year Confirmed
FOUR SEASONS HOTEL & 99 UNION STREET PRIVATE RESIDENCES	99 UNION ST, 98101	2008	326,516	177.40	20	36	
FIFTEEN TWENTY-ONE SECOND AVENUE	1521 2ND AVE, 98101	2008	330,693	60.10	38	143	2012 ?
GALLERY BELLTOWN	2911 2ND AVE, 98121	2008	224,105	39.60	13	233	?
ASPIRA - APARTMENTS	1823 TERRY AVE, 98101	2008	517,164	29.20	37	326	2009?
SKYLINE FIRST HILL	725 9TH AVE, 98104	2008	629,615	43.30	26	402	2012?
5TH AND MADISON-Residential Portion	909 5TH AVE, 98104	2007	170,000	44.20	42	126	?
QUINTESSA APTS	201 YESLER WAY, 98104	2007	90,959	48.00	13	132	?
MOSLER LOFTS	2720 3RD AVE, 98121	2007	175,353	43.50	12	148	?
PARC-BELLTOWN	2700 WESTERN AVE, 98121	2007	187,139	35.90	13	186	
ROLLIN STREET	120 WESTLAKE AVE N, 98109	2007	399,935	48.00	11	209	
M STREET APTS, RETAIL, & OFFICE	910 8TH AVE, 98104	2006	332,781	64.70	17	220	
COSMOPOLITAN	819 VIRGINIA ST, 98101	2006	299,755	30.70	33	251	
			2003 Section Average.	44.29 (43.9)*			
			Weighted Average (SF)	43.86			

Compiled 2015 Seattle disclosure data for HRMF buildings, with weighted EUI averages, compiled by the authors. It was assumed that projects built in 2012-2014 were permitted under the 2009 SEC, however in fact some may have been permitted under the 2006 SEC. These data show that our projected EUIs in each code cycle are similar to the actual data collected through the Seattle Disclosure Ordinance. The authors did not expect perfect alignment, given the limited sample size.

Appendix C: Areas with Incentive Zoning requiring the Green Building Standard

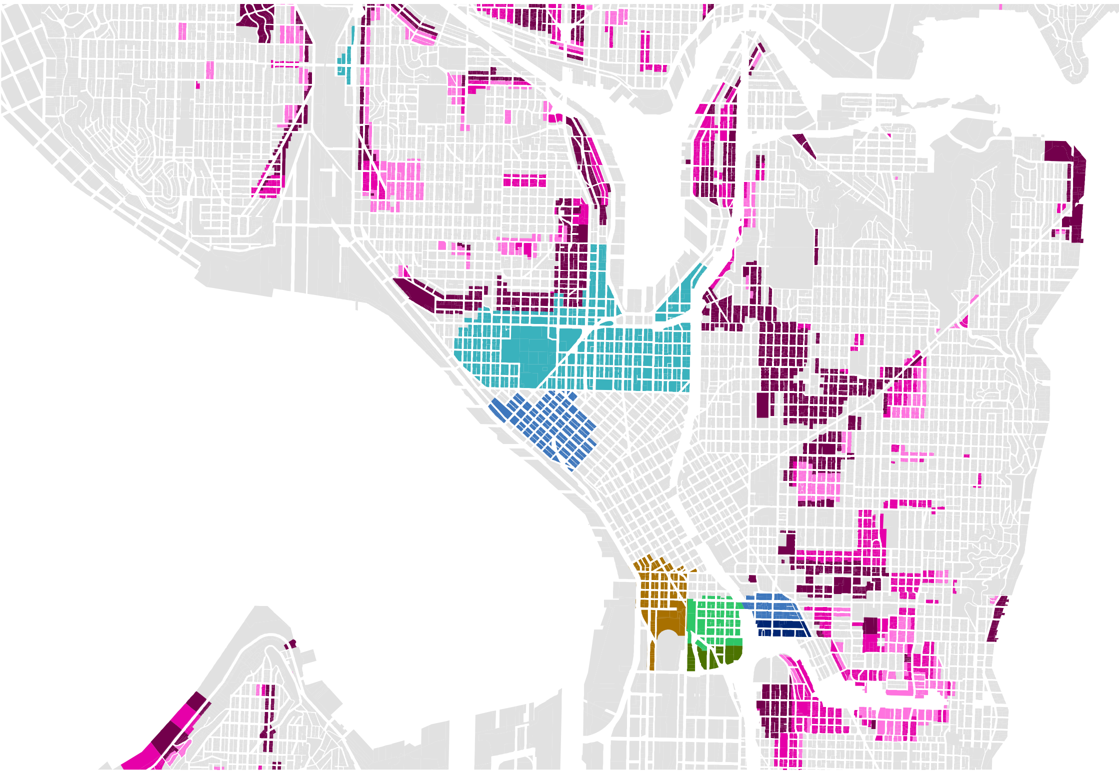


Image courtesy of Andrew Lee

Appendix D: Glossary for all acronyms

1. **AHU –** Air Handling Unit
2. **ASHRAE –** American Society of Heating, Refrigeration, and Air Conditioning Engineers
3. **AWHP** – Air to Water Heat Pump
4. **COP** – Coefficient of Performance
5. **DHW** – Domestic Hot Water
6. **ECM** – Energy Conservation Measures
7. **EUI** – Energy Use Intensity
8. **HRMF** – High-Rise Multifamily
9. **IGU –** Insulated Glazing Units
10. **LPD** – Lighting Power Density
11. **MEP** – Mechanical, Electrical, Plumbing
12. **MF** – Multifamily
13. **MURB** – Multi-Unit Residential Building
14. **PV** – Photovoltaic
15. **SEC** – Seattle Energy Code
16. **TBP** – Total Building Performance
17. **WSEC** – Washington State Energy Code
18. **WSHP** – Water Source Heat Pump
19. **WWR** – Window-to-Wall Ratio

Appendix E: Glossary

1. **Carbon-neutral** – Quality of only releasing as much carbon dioxide into the atmosphere as is absorbed.
2. **Charrette** – Session in which stakeholders of a project hold design, planning, and/or problem-solving activities.
3. **Climate-zones** – Areas with distinct temperature, humidity, and precipitation characteristics.
4. **Code cycle** – Round of updated regulations/standards.
5. **Commissioning** – Process in which the subsystems of a new building are verified for functionality and requirement compliance.
6. **Compliance path** – Approach to meeting code requirements.
7. **Corridor pressurization** – Force pushing air, through gaps in doors, into units.
8. **Dwelling unit** – Spaces in buildings used primarily for living and sleeping.
9. **Energy efficiency** – Reducing the ratio of energy put into a system to benefit as an output of the system.
10. **Energy recovery ventilation** – System which uses the existing heat energy in building air to heat incoming outdoor air, conserving energy.
11. **Heat pump loop** – Heat recovery system where existing heat in the chiller condenser water is transferred to areas it is needed rather than being rejected outside of the system.
12. **Integrated design** – An interdisciplinary approach to design, incorporating multiple fields of expertise.
13. **Internal load** – Result of external loads applied to a structure.
14. **Low-e coating** – Window coating which manipulates solar reflectance in order to optimize energy flow efficiency.
15. **Net-Zero Energy Building** – Building which only uses as much energy as renewable energy is produced.
16. **Photovoltaic system** – Energy system which uses photovoltaic cells to convert sunlight to usable electricity.
17. **Plug load** – Energy used by devices plugged into the building's electrical system, rather than energy used by major permanent installments.
18. **Renewable energy** – Energy from a source which is rapidly replenished, such as wind or sun energy.
19. **Urban infill** – New developments built within vacant areas of previously developed land.

Appendix F: Additional Reading

M Rosenburg, R Hart, J Zhang, R Athalye, "Roadmap for the Future of Commercial Energy Codes," Pacific Northwest National Laboratory, prepared for the US Department of Energy (PNNL 24009), January 2015.

This study analyzed several likely paths for the future of energy codes, and looked most favorably to "Differential Predictive Performance with a Stable and Independent Baseline." This path is reflected in the predicted targets for this study. Emphasis has been placed on establishing the correct baseline and targets in the first half of the study, while the second half addresses the ECMs needed to hit those targets.

Christian Cianfrone, Patrick Roppel, Dieter Hardock, "Holistic Approach to Achieving Low Energy High-Rise Residential Buildings," BEST4 Conference proceedings, 2015.

This paper emphasized that mechanical systems can and should be prioritized over envelope improvements with regard to future energy efficiency improvements, based on market conditions and complexities of this building type. This work also inspired the concept of "ECM packages" with bundles of interdependent measures employed throughout this study.

David Walsh, Allan Montpellier, Justin Stenkamp, Bret Lovely, "Seattle's 2015 Energy Code & Its Impacts on High-Rise Construction," March 2018.

This study investigated the effects of the then-new 2015 Seattle Energy Code, evaluating the performance goals and technical requirements in concert with the changing price points for mechanical systems, the inherent physical and zoning constraints of downtown sites, and the desire to maximize rentable area and glazing percentages to shape a project. The authors looked at both high-rise multifamily and office high-rise construction, and address both core & shell and tenant improvement mechanical costs. Similar to "Pursuing HRMF Energy Efficiency," they used a sample building as a case study to run multiple scenarios, and assumed that maintaining extensive glazing area was high priority for commercial developers and building owners in today's market.