Impacts of the Proposed Douglaston Tower on the Circadian Daylight Resource for Escala Condominium Residents

Prepared for the Escala Home Owners Association

Prepared by CIRCA DIES LLC

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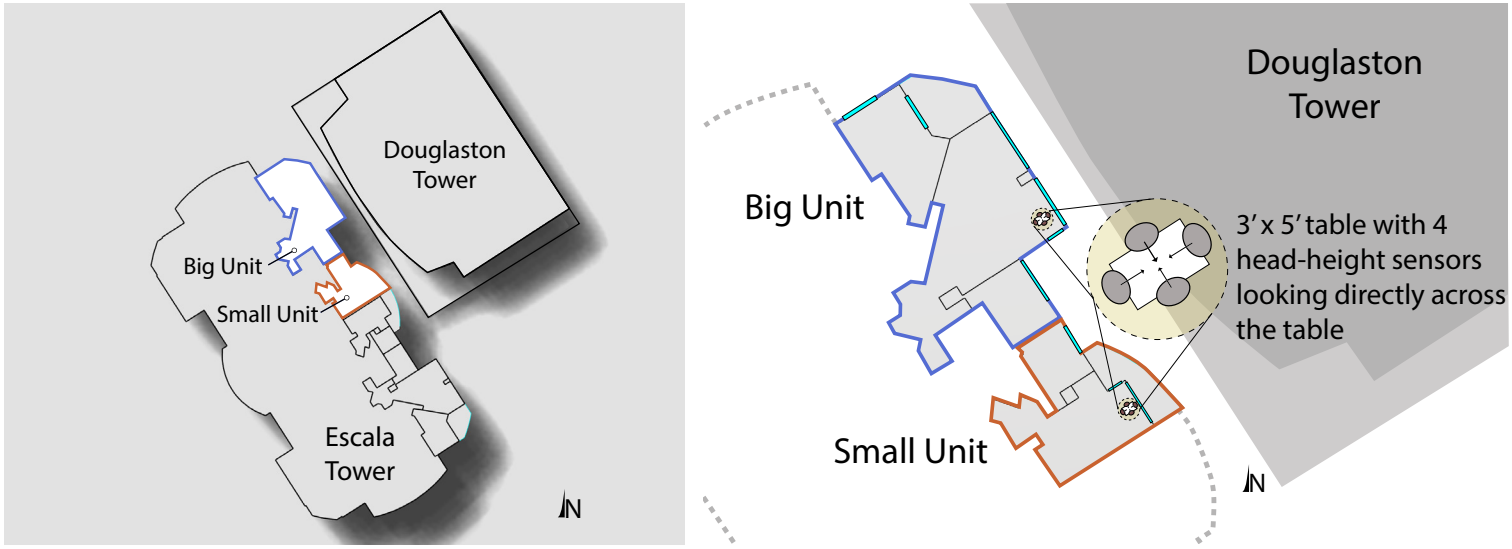
Introduction

The designers of the Escala Tower, recognized the universal human need to be connected to the natural world, and incorporated generous, nearly full-height windows that provide the light resource needed to maintain and support the occupant's connection to the sun and the sky, and the health supporting daylight resource.

The proposed Douglaston tower, in the adjacent lot will stand more than 100 feet taller than the Escala tower. The Douglaston tower dramatically reduces the daylight resource and connection to the sky and the daily journey of the sun for the east facing units in the Escala tower. Humans have an intrinsic need to be connected to natural systems, which is often accomplished with thoughtfully deployed glazing. The connection to natural systems and their daily rhythms not only provides psychological benefit, but also greatly impacts our physiology, as light is the primary environmental cue for the regulation of our circadian system. If we fail to receive the right light at the right time, our body clocks can diverge from local day-night cycles, resulting in a number of chronic health maladies. On the contrary, proper light exposure can improve mood, cognition, productivity and support overall wellness.

Because the intrinsic photo-receptive ganglion cells (IPRGCs), the receptors that receive circadian light are located in the retina, understanding point of view and the light resource within that view is critical to assessing the circadian light resource. To capture the circadian daylight resource, the simulation effort focused on four (4) view directions around a table, adjacent to the window in two units: the "Big Unit" on the 5th and 25th floors and the "Small Unit" on the 5th and 19th floors. The actual resource received will vary from the simulated views as people tend to vary their view frequently, with a combination of view exposures. For instance, one typically does not sit motionless staring in one direction for an hour at a time, but is in constant survey of their surroundings. Rather than create a series of averages or weightings to account for view variability, four (4) view directions, orthogonal to the window plane were used.

Time of exposure is critical, with hours before 1:00 pm being most beneficial to maintenance of the body clock and support of routine sleep and wake cycles for the typical 9-5 schedule. To quantify the impact of the Douglaston tower, the simulation focused on the daylight hours prior to 1:00 pm.

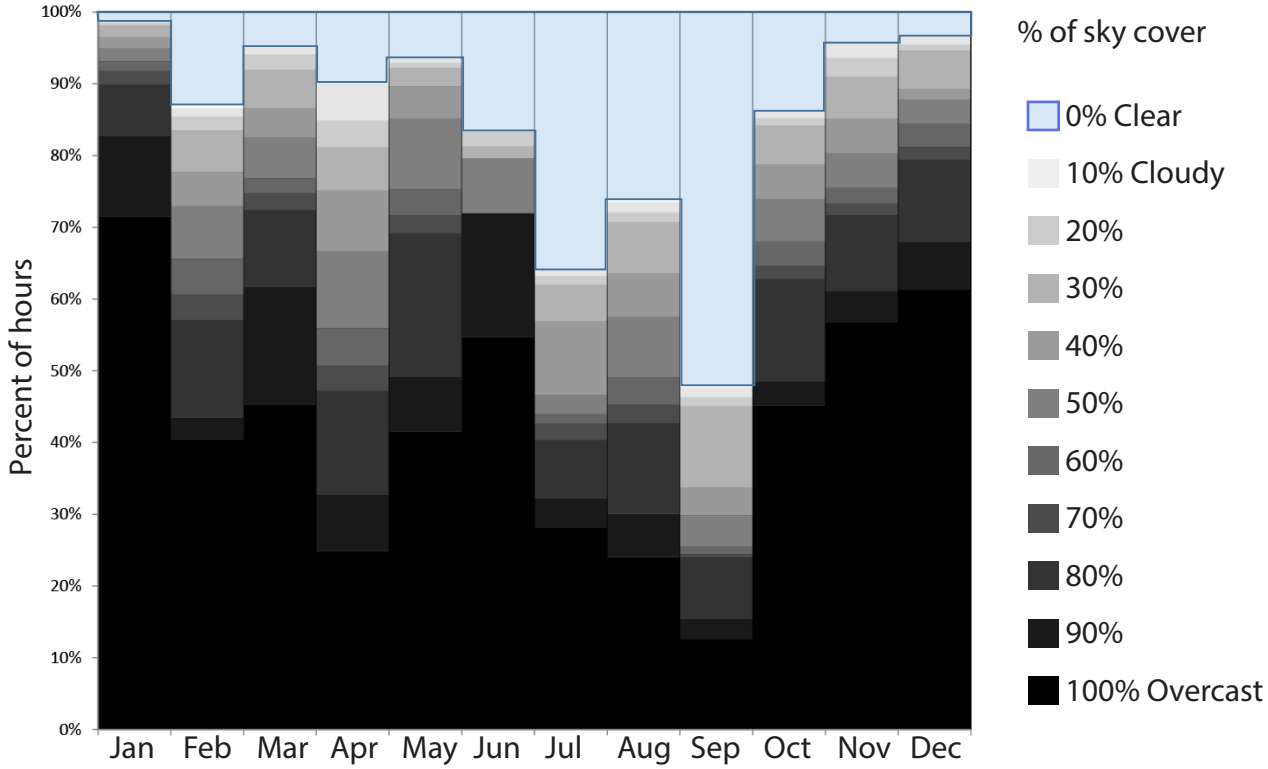


Escala Circadian Light Simulation Units and View Points

Simulation Results Summary

Climate Impacts

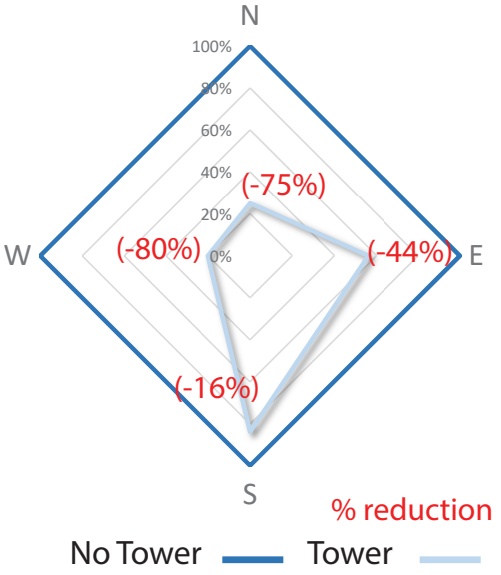
Climate of the Pacific Northwest plays a role in circadian regulation, with deeply overcast skies providing a diminished resource that requires generous views of the sky to satisfy circadian entrainment needs. Monthly opaque cloud cover, graphed below, illustrates the dominance of overcast skies.



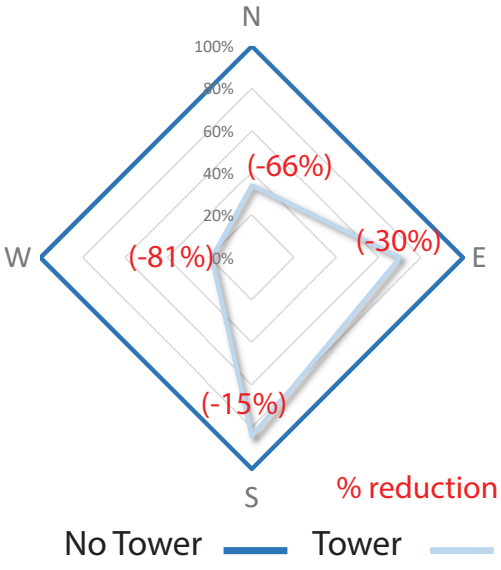
Monthly Opaque Cloud Cover , Seattle Boeing Field Climate File

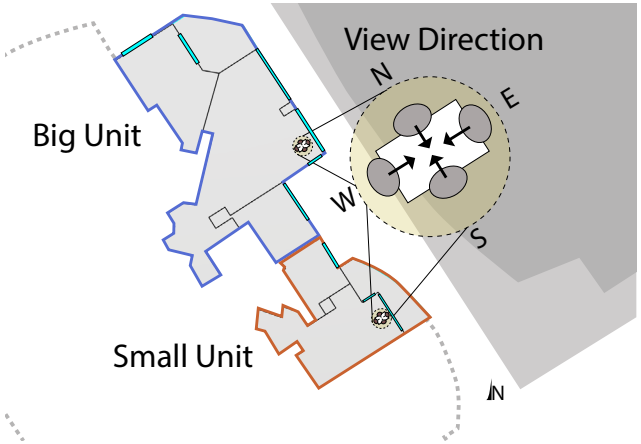
A combination of reduced lighting levels and warmer color temperature of overcast and intermediate skies of winter, late fall and early spring can be seen in the graph on the upper right, where the presence of the Douglaston tower amplifies the impact of seasonal variation and reduces circadian light levels in the Big Unit on the 5th floor as compared to the "No Tower" baseline by 75% looking north, 44% looking east, 16% looking south, and 80% looking west. As the weather changes in late spring, and bluer skies persist through summer and early fall, increases in illumination levels and higher concentration of blue rich light, provide modest improvements but still does not provide an adequate amount of daylight for routine circadian entrainment across all views. Even in April through September, the Douglaston tower reduces circadian light levels in the Big Unit on the 5th floor compared to the "No Tower" baseline by 66% looking north, 30% looking east, 15% looking south, and 81% looking west.

Circadian Daylight Hours Percentages
5th FL Big Unit | All Views | Oct - Mar



Circadian Daylight Hours Percentages
5th FL Big Unit | All Views | Apr - Sept





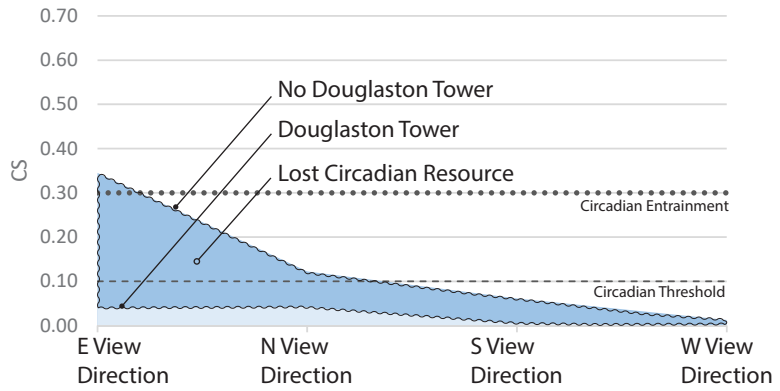
Circadian Stimulus by View Direction and Sky Color Temperature

The impact of sky conditions and associated sky color are illustrated to the right for the four (4) view directions for the 5th floor Small unit. The overcast sky provides a minimal resource without the Douglaston tower, and the addition of the Douglaston tower results in conditions that are essentially blind to the circadian system, failing to meet the threshold for the activation of the circadian system. The overcast sky is most common in winter months, and depending upon weather trends can persist beyond early spring, and into the summer. The intermediate, or partly cloudy sky, provides a slightly better resource than the completely overcast sky without the Douglaston tower. The addition of the Douglaston tower results in conditions that are too dim to provide circadian entrainment and only stimulate the circadian system in the northern view direction. The southern view is partially obscured by walls in the Small unit.

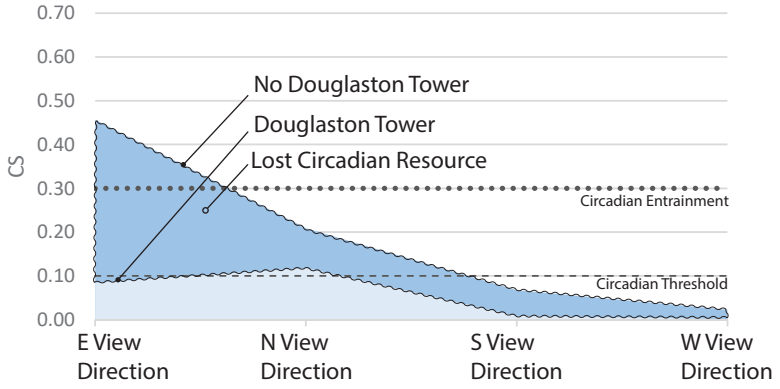
Decreasing cloud cover and increasing color temperature improve the circadian resource. When considering the presence of the Douglaston tower, light levels are high enough for circadian entrainment only when the sky is bright and clear, and for only the north and east view directions in the Small unit.

Lark Spectral Lighting and Radiance were used to perform the analysis at the right. (Inanici et al., 2015) The dates were chosen to correlate with the three sky conditions within the climate file during the spring equinox. The outputs are representative of conditions between the autumnal and spring equinoxes.

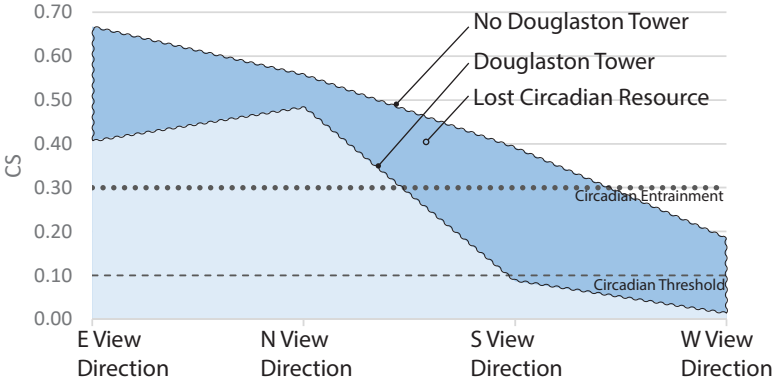
CS by View Direction | 5th FL Small Unit | Overcast Sky 5000K | Mar 17 10 am



CS by View Direction | 5th FL Small Unit | Intermediate Sky 7000k | Mar 10 10 am

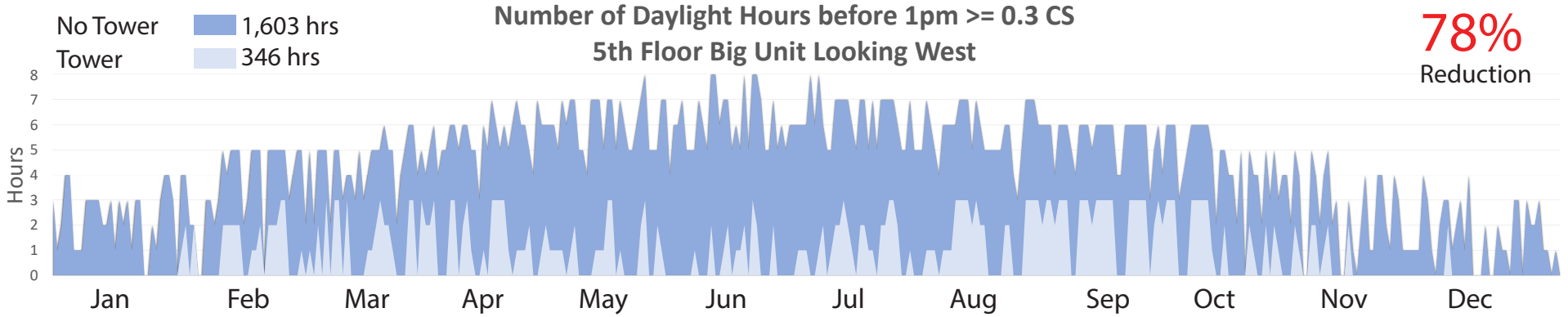


CS by View Direction | 5th FL Small Unit | Clear Sky 15000K | Mar 21 10 am



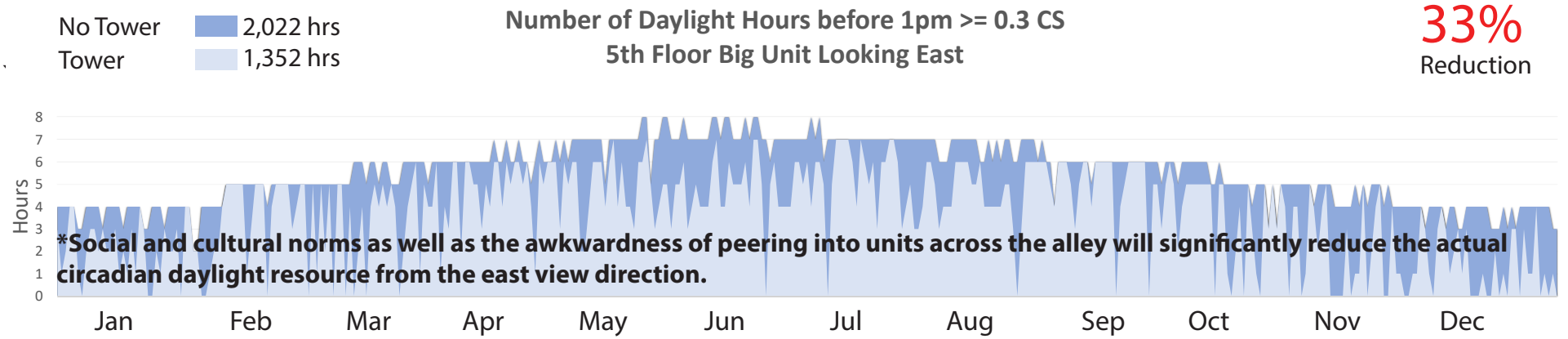
View Impacts on the Annual Circadian Daylight Resource

Simulation results indicate that the proposed Douglaston Tower will markedly reduce the healthful day light resource, and depending upon the occupant's view, can result in one spending a significant amount of time in biological darkness during the hours before 1:00 pm, the critical time frame for circadian clock entrainment. The worst case scenario is when occupants have their backs to the windows, looking west, receiving only 346 hours annually of adequate light for circadian entrainment compared to 1603 hours without the Douglaston Tower.



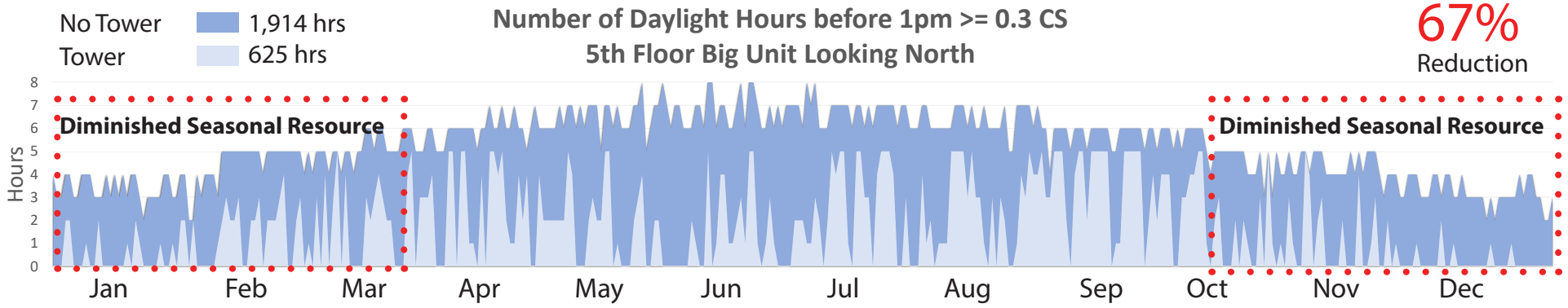
Annual Daylight Hours Before 1:00 pm with a CS of 0.3 and greater. Looking west, 5th floor, Big Unit. Occupants receive 1,603 hours of circadian active light without the Douglaston tower and 346 hours of circadian active light with the Douglaston tower.

Although looking east directly out the window provides a greater resource to the occupants, the Douglaston tower still provides a noteworthy reduction in annual circadian active daylight hours, receiving only 1,352 hours annually of adequate light for circadian entrainment compared to 2,022 hours without the Douglaston Tower. Although this view could potentially provide a routinely robust resource, due to social and cultural norms, it is unlikely that anybody will spend the morning hours looking directly across the alley, into another unit 22' feet away.

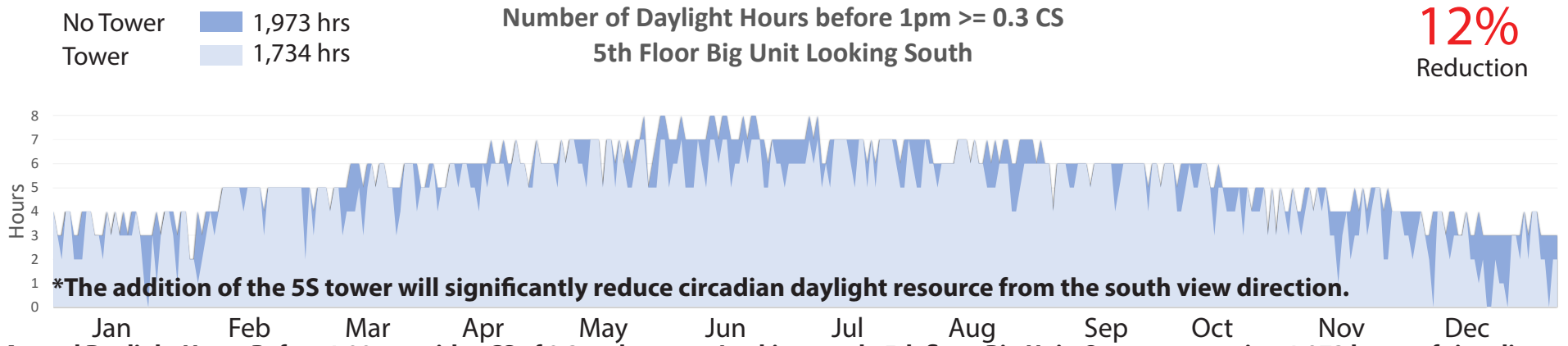


Annual Daylight Hours Before 1:00 pm with a CS of 0.3 and greater. Looking east, 5th floor, Big Unit. Occupants receive 2,022 hours of circadian active light without the Douglaston tower and 1,352 hours of circadian active light with the Douglaston tower.

View corridors through the alley, north and south vary in the Big and Small units due to glazing placement and the presence of columns and walls within the respective views. Although there are absolute differences in exposure between the units, the overall trends are the same. A diminished seasonal resource is well illustrated in the graph of the north looking view direction below, and can be attributed to an overall reduction of daylight illumination, less circadian active light in predominantly overcast skies and little or no visibility of the sun. During this time frame, the available circadian resource is dictated by the view to the sky dome, which is significantly obscured by the Douglaston tower, providing only slivers of views to the sky through the narrow alley corridor, amplifying the reduction of the seasonal resource. If unencumbered, the southern view can provide a brighter annual resource due to the presence of the sun, which has the greatest impact in the clear and intermediate, or partly cloudy, sky conditions of late spring through early fall. The proposed tower to the south of the Douglaston tower will substantially impact the southern exposure, resulting in a cumulative impact much greater than what is illustrated below.



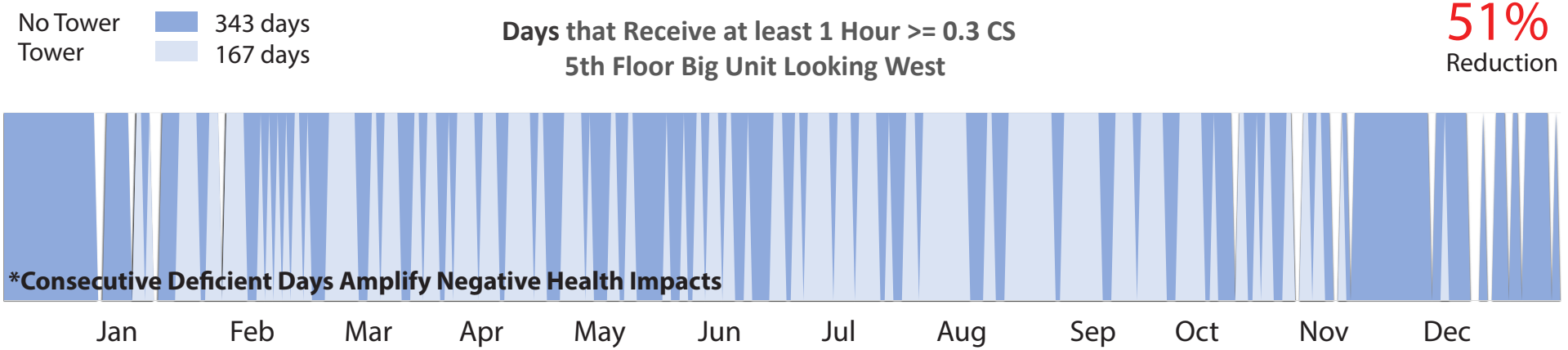
Annual Daylight Hours Before 1:00 pm with a CS of 0.3 and greater. Looking north, 5th floor, Big Unit. Occupants receive 1,914 hours of circadian active light without the Douglaston tower and 625 hours of circadian active light with the Douglaston tower.



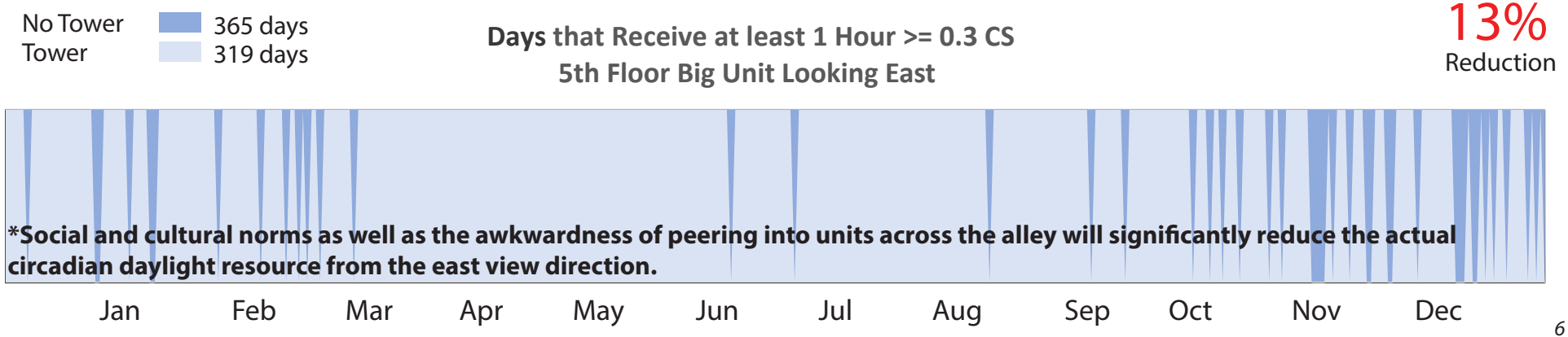
Annual Daylight Hours Before 1:00 pm with a CS of 0.3 and greater. Looking south, 5th floor, Big Unit. Occupants receive 1,973 hours of circadian active light without the Douglaston tower and 1,734 hours of circadian active light with the Douglaston tower.

The number of days that receive at least one (1) hour of adequate circadian light prior to 1:00 pm were also counted. This analysis indicates the available resource but does not guarantee that the timing of the resource will be aligned with the occupant's schedule and may over-predict the opportunities for entrainment, or body clock synchronization with local time. Access to multiple hours of the daily circadian resource will increase the likelihood that occupants will receive what they need to support and maintain their body clocks.

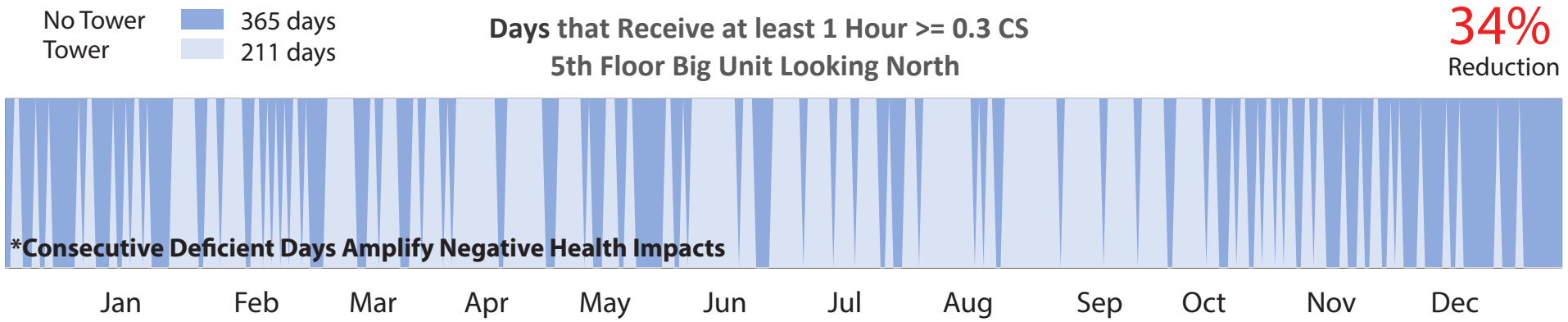
As with the hours counts, the west looking view is most impacted by the Douglaston tower, resulting in a greater than 50% reduction in the number of days that at least one (1) hour of circadian impactful light is available to occupants to only 167 days of the year. Because the body clock shifts daily, cumulative days without exposure amplify the impact of the Douglaston tower and create greater risk of negative wellness impacts.



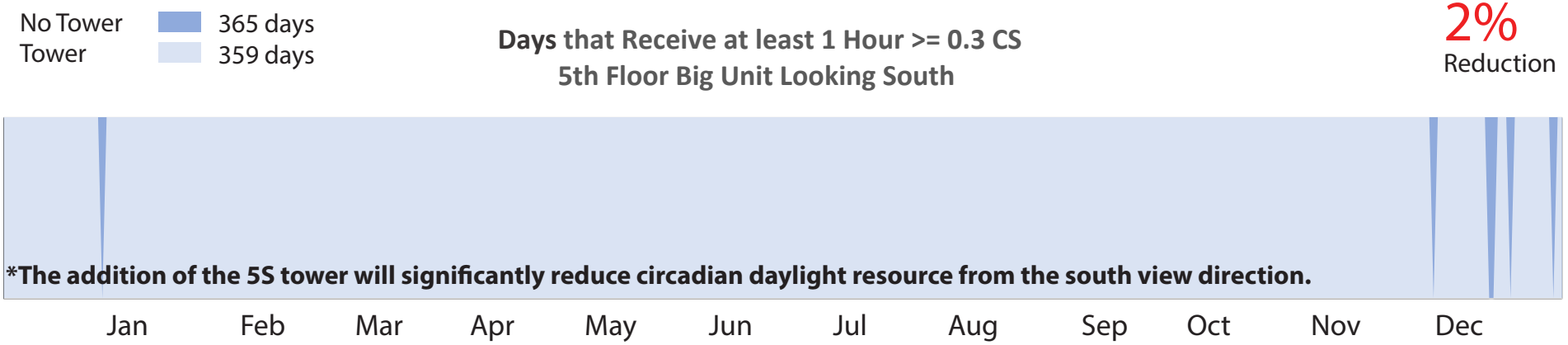
Although looking east, directly out the window, provides a greater resource to the occupants than the west view direction, the Douglaston tower still reduces the number of days that at least one (1) hour of circadian impactfiul light is available to occupants, and the cumulative days without exposure pose a health risk.



The days counts for the north and south view directions exhibit similar trends as the hours counts, illustrating the seasonal reduction, as well as cumulative resource deficient days. Although there are absolute differences in exposure between the Big and Small units, the overall trends are the same. A diminished seasonal resource is well illustrated in the graph of the north looking view which can be attributed to an overall reduction of daylight illumination, less circadian active light in predominantly overcast skies and little or no visibility of the sun. During this time frame, the available circadian resource is dictated by the view to the sky dome, which is significantly obscured by the Douglaston tower, providing only slivers of views to the sky through the narrow alley corridor.



As with the hours count, the resource provided in the southern view direction is through the alley corridor. If unencumbered, the southern view can provide a brighter annual resource due to the presence of the sun, which has the greatest impact in the clear and intermediate, or partly cloudy, sky conditions of late spring through early fall. The proposed tower to the south of the Douglaston tower will substantially impact the southern exposure, resulting in a cumulative impact much greater than what is illustrated below.



Light at Home Matters

Poor seasonal light exposure has been linked to Seasonal Affective Disorder (S.A.D.) and Winter Blues, with increased light exposure employed as a component of prescribed remedies. In occupational settings, Seasonal Affective Disorder is protected by the Americans with Disabilities Act and must be accommodated. The same protection does not yet exist for residences. Even if occupants adhere to traditional work life schedules, and work in well daylit buildings, they rarely receive enough light and many can live in biological darkness. (Figueiro 2016) Although not yet legally mandated, the protection of occupants is expanding well beyond occupational and public settings through a new focus by design communities, builders and regulators to provide environments that nurture occupants.

A survey sent to Escala residents was used to understand how much time is spent at home during hours prior to 1:00 pm, the optimal times for light exposure for circadian entrainment. The survey was sent to all 273 units, with a 126 responses. This is a 46% response rate resulting in a 6% margin of error at 95% confidence level. The survey ran for 1 week.

The residents of the Escala are a population that is divergent from the stereotypical work-life schedule. A recent Bureau of Labor Statistics press release states that greater than 80% of employed people spend 8 or more hours at work, away from home, not accounting for time spent commuting. (BLS 2018) On the contrary, a high proportion of Escala respondents, 67%, spend part of their morning hours prior to 1:00 pm, working in their residence, not including email and social media correspondence. Additionally, 67% and 60% of the residents in the Big and Small Units respectively, are at home during the weekday prior to 1:00 pm, and 77% and 69% are home on the weekends, October through March. The residents spend the same amount of time at home on the weekdays April through September, with slightly less time spent in their residences on the weekends. The Escala is where people spend a significant percentage of hours before 1:00 pm and is the best opportunity to receive the daylight they need to support their circadian system.

October to March	**Big Unit**	**Small Unit**
% of hours in unit before 1:00 pm (weekdays)	67%	60%
% of hours in unit before 1:00 pm (weekends)	77%	69%
April to October		
% of hours in unit before 1:00 pm (weekdays)	68%	61%
% of hours in unit before 1:00 pm (weekends)	71%	66%

Percentage of hours before 1:00 pm that Escala residents spend at home.

The Healthy Building Movement

As indicated by the increasingly applied WELL Building Standard, the construction community is in the midst of a healthy building revolution, shifting design paradigm towards the creation of healthier spaces with design strategies that include increased connection to nature and the inclusion of qualities of the natural environment, the use of healthier building and finish materials, as well as the application of circadian supportive design solutions.

Recommendations to Improve the Daylight Circadian Resource for residents in the north east (alley side) of the Escala tower.

In locations, like Seattle, with climates that have predominantly overcast skies, the view of the sky dome has the greatest impact on the light resource available to occupants. Therefore, increases in the access to the sky dome will directly improve the daylight circadian resource and conversely, obstructions within that view will directly reduce the daylight circadian light resource.

It is important to note that solutions that will positively impact the daylight circadian resource for the Escala residents will also positively benefit occupants directly across the alley in the Douglaston tower.

The following recommendations could improve the daylight resource for the simulated units within the Escala tower as well as those across the alley in the Douglaston tower.

1. Modify the design with a slimmer and taller tower to increase the view of the sky dome and access to sunlight for Escala tower occupants and take advantage of the tower separation provision for the DOC2 zone to counter reduction in floor area of a slimmer tower.
    a) Significantly taper the Douglaston tower in plan, with its narrowest point at the west alley.
    b) Taper or step the tower in section to increase distance from the Escala tower as the Douglaston tower ascends.
    c) Pull the west facade of the Douglaston tower further from the west alley and Escala tower.

2. In addition to recommendation 1, increase the diffuse reflectance of the Douglaston tower west facade. As light is absorbed with each reflection off of a surface, material changes alone will not resolve the circadian daylight deficiency but will be helpful in making the best use of the available light resource. Glare or overly bright reflections from the Douglaston tower, which can contribute to visual discomfort and overheating, should be considered with approach.

Light Supports Life - A Circadian Light Primer

Humans evolved in an environment dominated by the light of the sun and its daily light dark cycle. We awoke to the sun's light and activity ceased as the sun set. We harbor the genetics of our hunter-gatherer forefathers but live in strikingly different environments; environments that are ill-suited for optimal survival. Our bodies adapt to environmental change, but the rate we alter our environment has outpaced our physiology's ability to catch up. If we fail to receive enough light during the day and receive too much light at night to properly support our body clocks, we may well suffer from chronic health maladies.

We have two systems that respond to light, often referred to as the visual and non-visual systems. The visual systems consist of the rods and the cones and allow us to understand and navigate our world. The non-visual system, or circadian system, relies upon an alternate set of receptors called the intrinsic photoreceptive ganglion cells or the IPRGCs. These cells send information to a different area of the brain than the visual system and informs the regulation of our body clock. Light is the primary regulator of our body clock, with spectral content, timing of exposure, and duration of exposure all playing roles in body clock regulation.

The visual and non-visual system have different stimulus response curves, with the visual system being most sensitive to green light and the non-visual system being most sensitive to blue light. Understanding the spectral content of light and the different human spectral response curves, allows for the understanding of the impact of light on both the visual and non-visual systems and the simulation of the light resource.

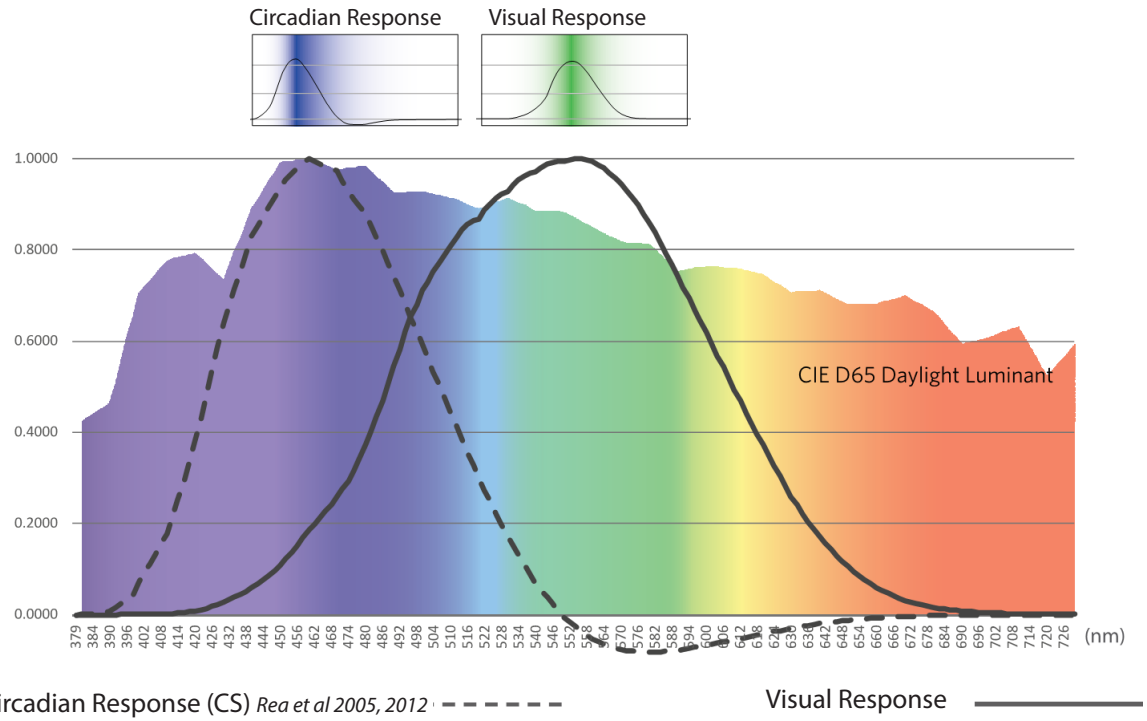
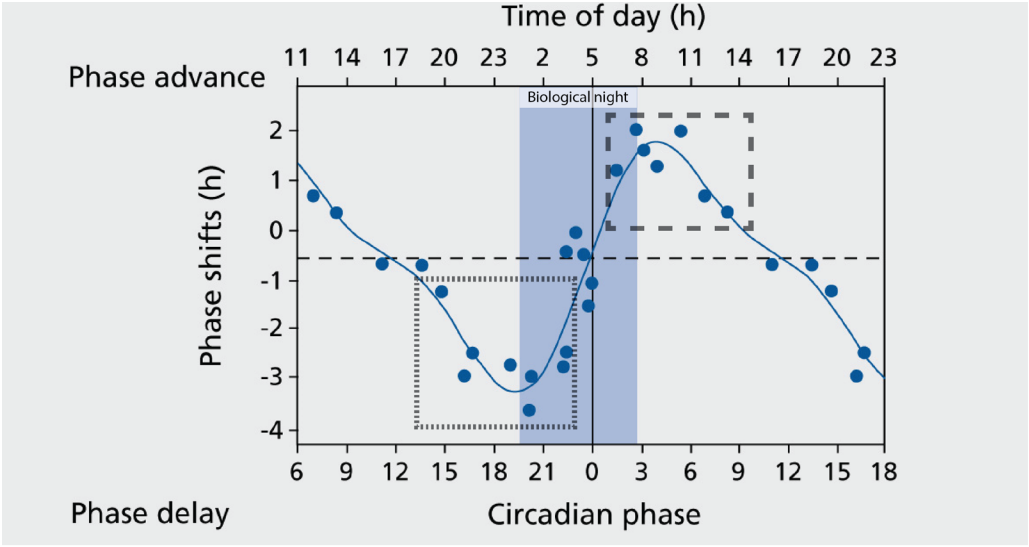


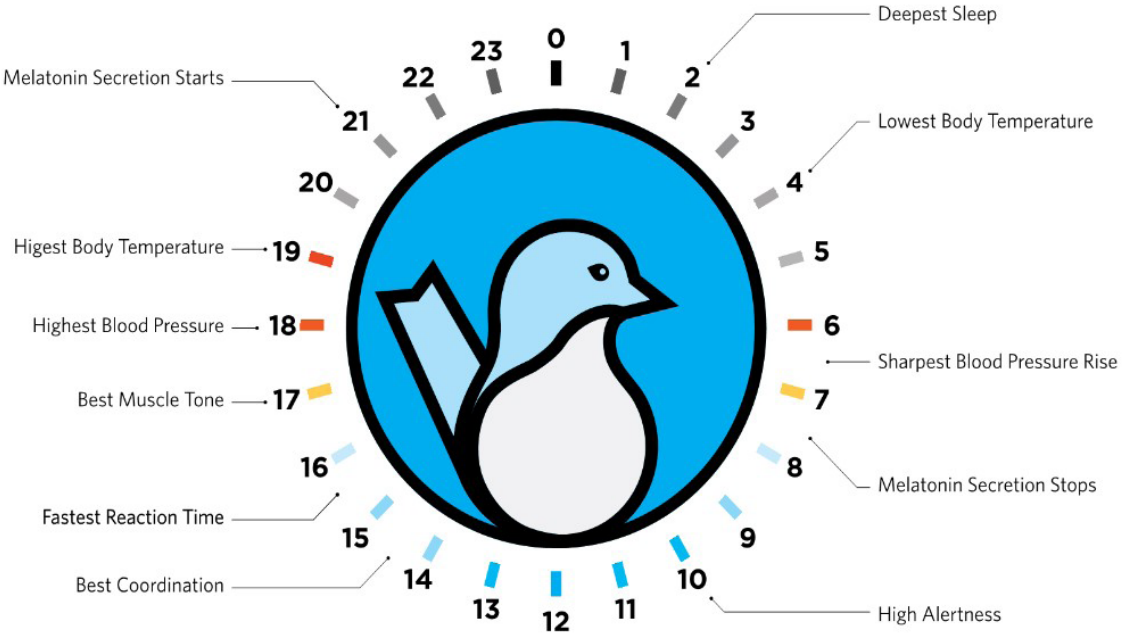
Fig Circadian and Visual Stimulus Response Curves

Timing and duration are important for body clock regulation and routine entrainment, or synchronization with the local solar cycle. Daily light exposure is necessary to reinforce the body clock and maintain a regular sleep wake cycle. Circadian "midnight" occurs at the minimum core body temperature, typically near 5:00 am for those with a 9-5 schedule and associated sleep wake cycles. Light received before or after circadian zero dictates whether the body clock advances or retards, allowing sleep to occur earlier or later in the evening, respectively. For instance, strong morning light advances the body clock, and will allow sleepiness to occur earlier in the evening.

When our body clock is routine, cyclical functions can be predicted and we can leverage our biology for maximum efficiency whether that be for task, wellness, or recovery from illness. For instance, highest alertness will occur at similar daily times as well as best coordination or best muscle tone. Even planning meals around the circadian cycle has proven health benefits. (Gill 2015). Pharmaceuticals are more effective during specific times of day with recommendations of treatment times based upon routine physiological cycles. (Baraldo, 2008).



Circadian Phase Shift by Time of Exposure (Munch 2012)



Circadian Rhythm and Physiological Function

Health and Wellness Impacts

Sleep is one of the most basic physical requirements for human functioning. Amount and quality of lighting invariably affect the degree and quality of sleep in humans and regulates our biological clocks. The combination of poor, irregular sleep and lack of circadian synchronization to local time has been shown to result in numerous health maladies.

As summarized in "Intersection between circadian rhythms and stress", Kock et al. 2017:

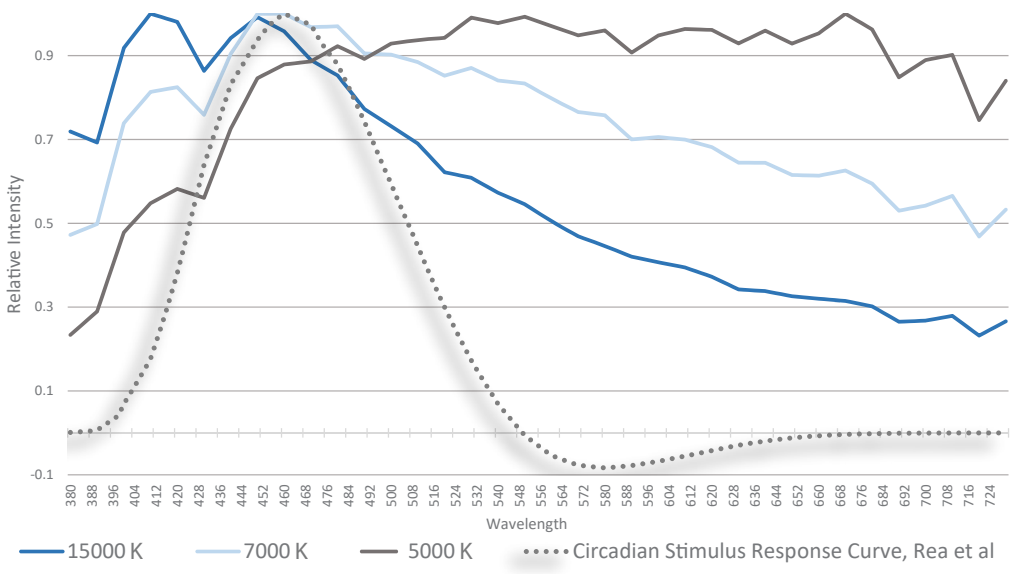
Rhythm disruptions bear wide-ranging consequences on human health (Jones and Benca, 2015, Li et al., 2011). Even after short-term circadian misalignment protocols (8 days), human subjects show higher blood glucose and insulin levels as well as elevated blood pressure, which are markers for metabolic and cardiovascular disease, respectively (Scheer et al., 2009). This translates into a higher incidence of obesity, diabetes type II and related metabolic disturbances (Karlsson et al., 2003, Pan et al., 2011, Proper et al., 2016), along with hypertension (Kubo et al., 2013), coronary heart disease (Vetter et al., 2016), and ischemic stroke (Vyas et al., 2012) in shift workers. Finally, modest, yet significant increases of risk can be observed for breast cancer in chronic shift workers and flight attendants (He et al., 2015). In consequence, the International Agency for Research on Cancer has classified shift work as a potential carcinogen (Straif et al., 2007).

Light exposure has shown positive benefits in those with dementia, resulting in improvements of sleep quality and duration, and reductions of depression and agitation. Figueiro et al (2014) concluded that "...increase(d) daytime circadian stimulation, can be used to increase sleep quality and improve behavior in patients with ADRD (Alzheimer's Disease and Related Dementia).

Acute impacts of light exposure has shown benefits to student cognitive performance and concentration as well as improvements in alertness, performance and sleep quality in the workplace. (Viola 2008, Barkman 2012, Sleegers 2012) A study published by Wright et al in 2006, indicated that cognitive performance (i.e., learning) was better in a synchronized group of people, whereas learning was impaired in a nonsynchronized group of people. This indicates that proper alignment between sleep–wakefulness and biological (internal circadian) time is crucial, not only for sleep quality but also for enhancement of cognitive performance.

Circadian Stimulus

Circadian Stimulus, or CS, is a metric developed by the Lighting Research Center at Rensselaer Polytechnic and describes a holistic physiological response to light exposure. CS is based upon the impact of one (1) hour light exposure on dim light melatonin onset. The threshold for response of the circadian system is 0.1 CS, and the saturation of the system occurs at 0.7 CS. The recommended value for entrainment of the circadian system is at least one (1) hour exposure to light with a CS value of 0.3. CS is determined by both the spectral content of the light source as well as intensity at the occupant eye. (Rea et al, 2005, 2012) The graph at the right illustrates the spectral distribution of the simulated skies overlaid by the Circadian stimulus response curve. The x-axis is wavelength (nm). The y-axis is relative intensity. `



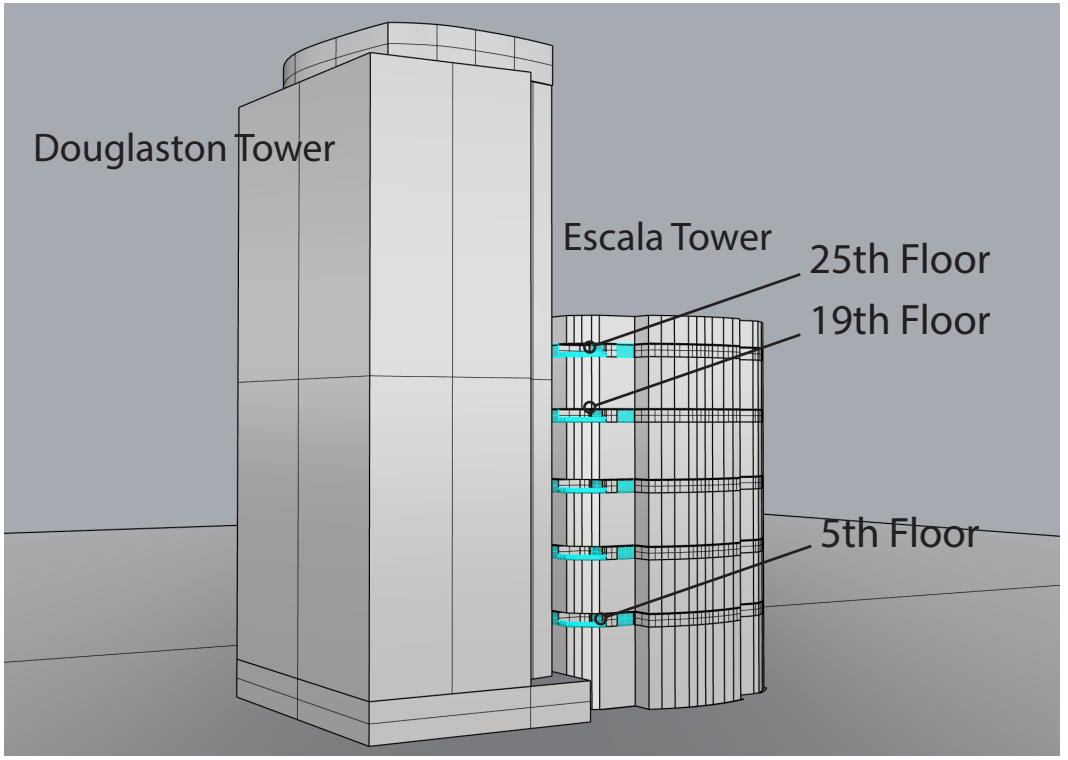
Spectral Power Distributions of Simulated Skies and the CS Response Curve

Simulation of Circadian Light

Daylight simulations are typically used to understand the impact of light, form and materiality upon our visual system. The analysis includes understanding brightness to facilitate a task, conditions for safe mobility, and improvements of visual comfort or remediation of glare.

Rather than focusing upon the visual system, the analysis described below is based upon the understanding of the non-visual or the circadian system.

This simulation quantifies the circadian daylight resource for the north eastern (alley side) on the 5th, 19th and 25th floor of the Escala tower, with and without the proposed Douglaston tower. This simulation is from the occupant's perspective. The annual light resource received by four sensors, imagined as a set of four (4) people sitting around a table is quantified by view direction and by floor.



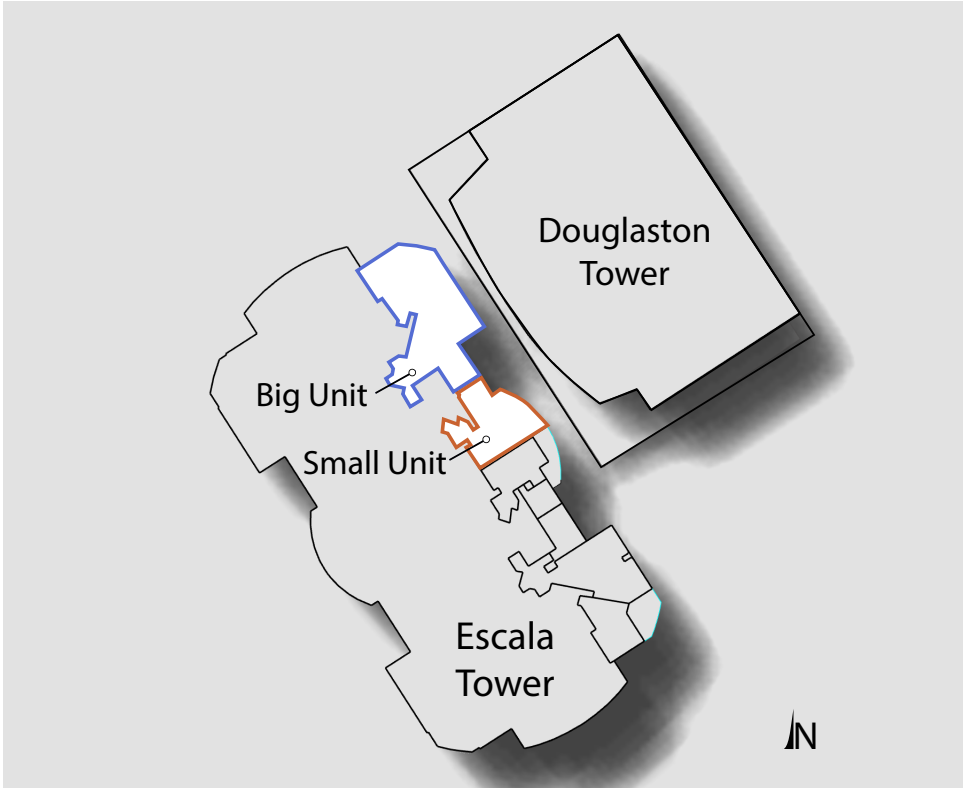
Douglaston and Escala towers with Simulated Floors Identified

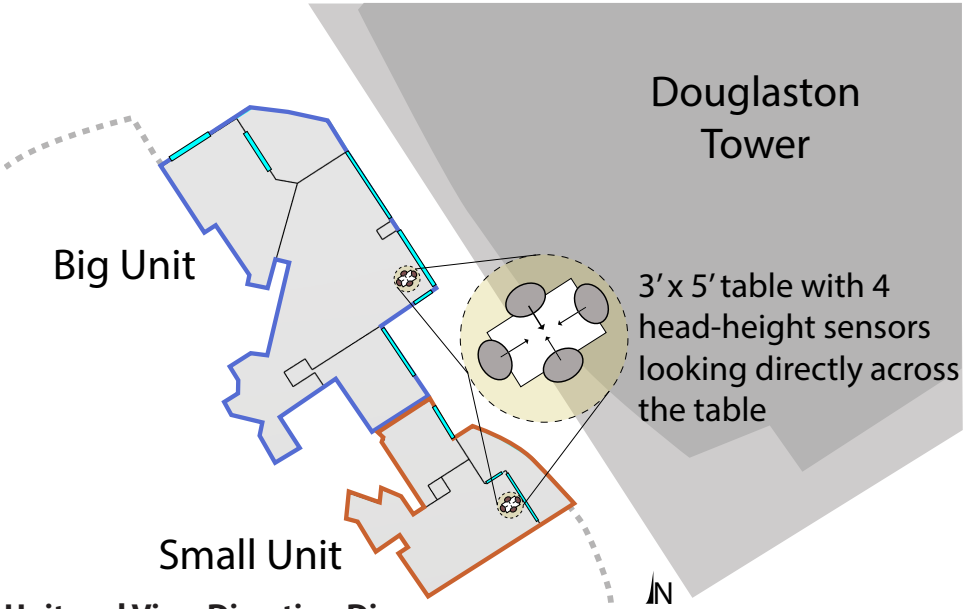
Annual Analysis:

DAYSIM was used to perform annual analysis of the circadian resource for floors 5 and 25, for the Big Unit and floors 5 and 19 for the Small Unit. Four (4) views around a rectangular table were analyzed for three (3) different sky conditions. The hourly sky conditions within the TMY 3 Boeing Airport Data set was correlated to sky color temperatures. To determine the needed illumination levels for circadian entrainment for each sky type, spectral definitions for the three (3) sky color temperatures were created and input into the circadian stimulus (CS) calculator created by the Lighting Research Center at Rensselaer Polytechnic (http://www.lrc.rpi.edu/resources/CSCalculator_2017_10_03_Mac.xlsm).

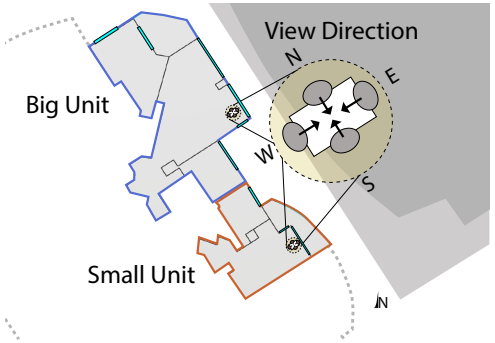
Hourly TMY Cloud Cover	Sky Condition	Sky Correlated Color Temperature (K)	Lux = 0.3 CS
>6	Overcast	5000	250
4-6	Intermediate w/ Sun	7000	168
0-3	Clear w/ Sun	15000	105

Climate file sky conditions were correlated with sky color/ spectral definitions to determine needed illumination levels to achieve a circadian stimulus (CS) of 0.3.





Unit and View Direction Diagrams



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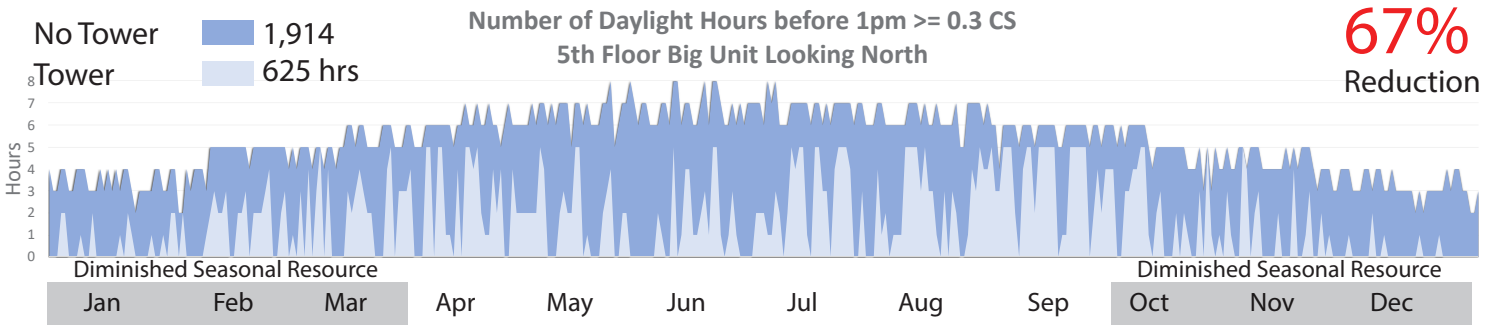

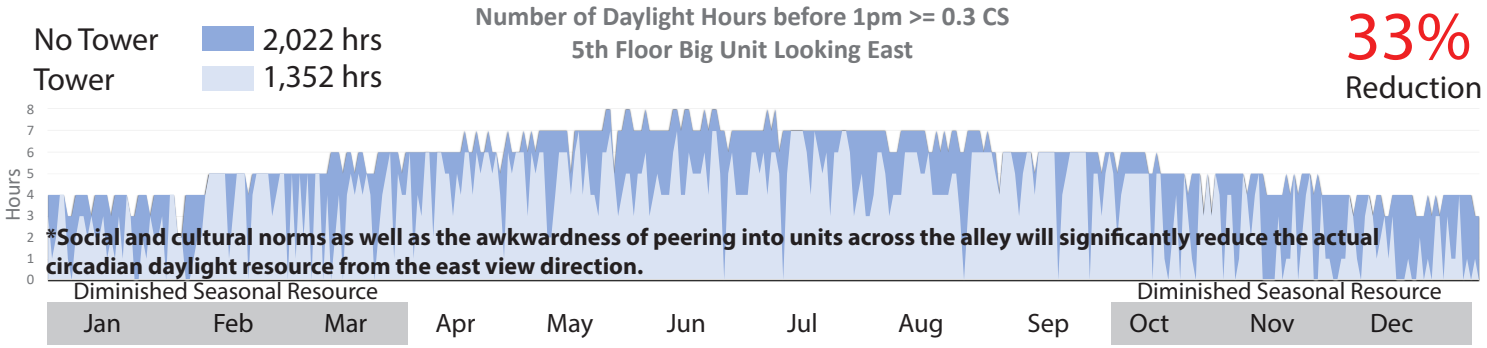

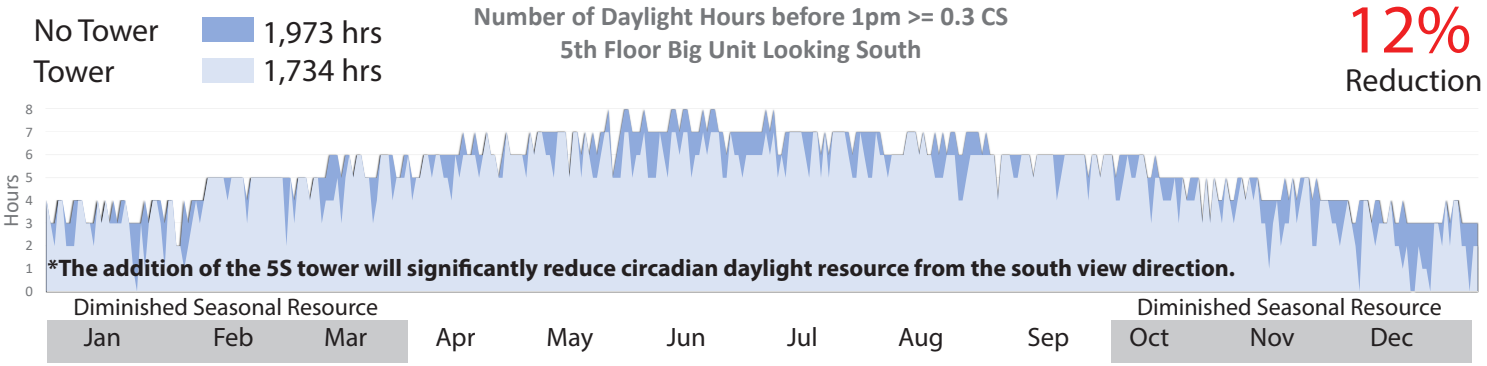

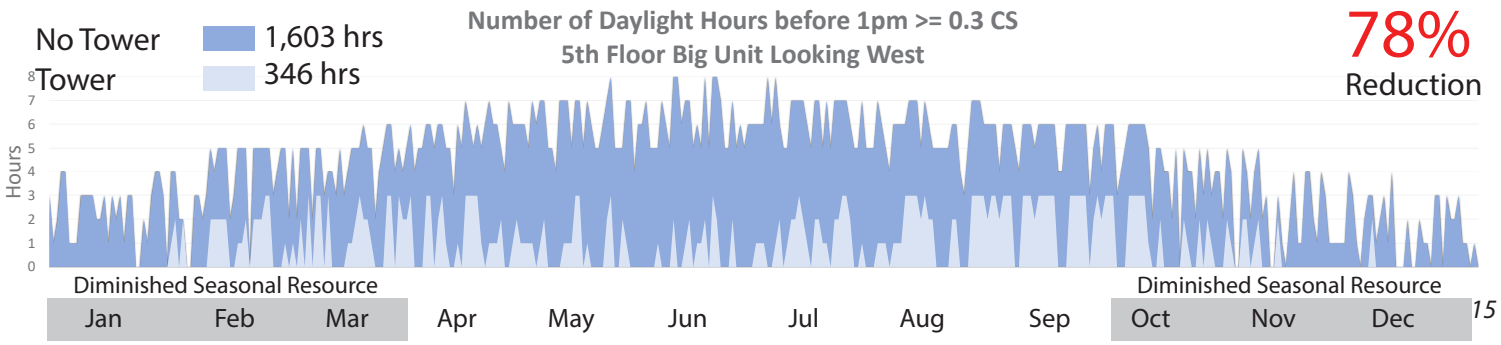

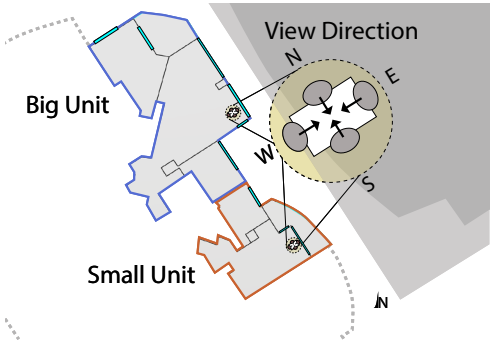

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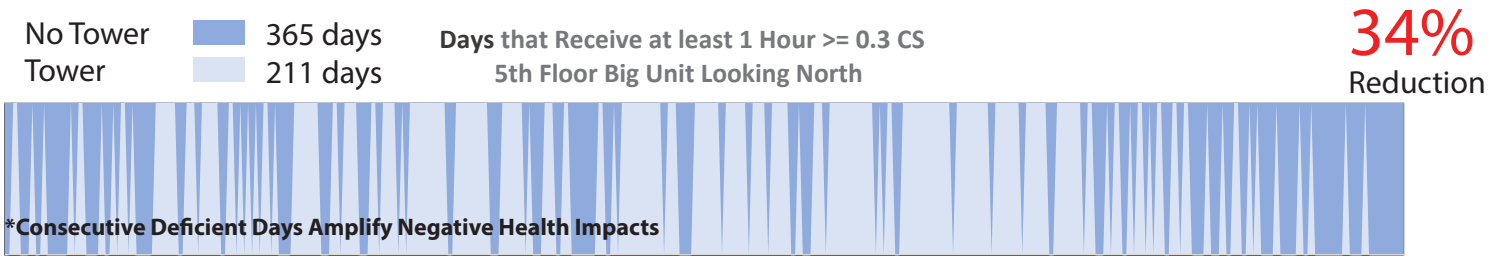

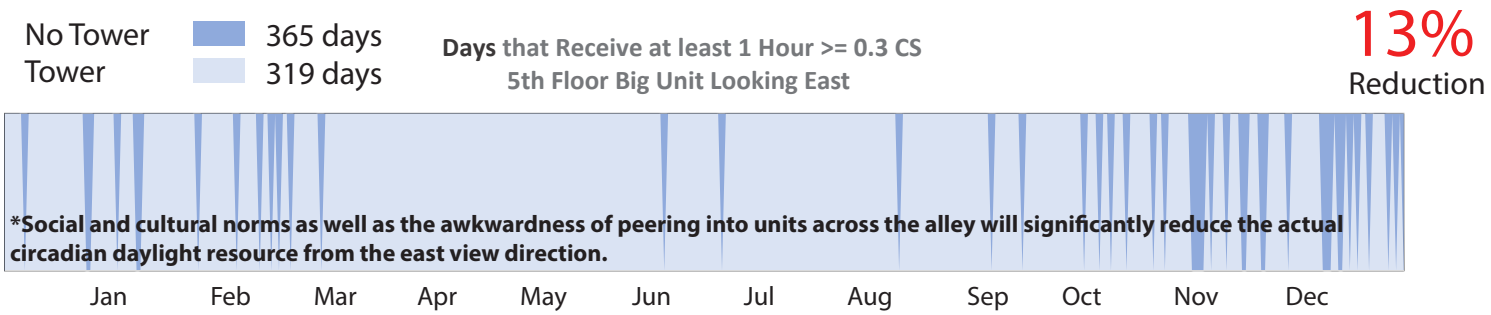

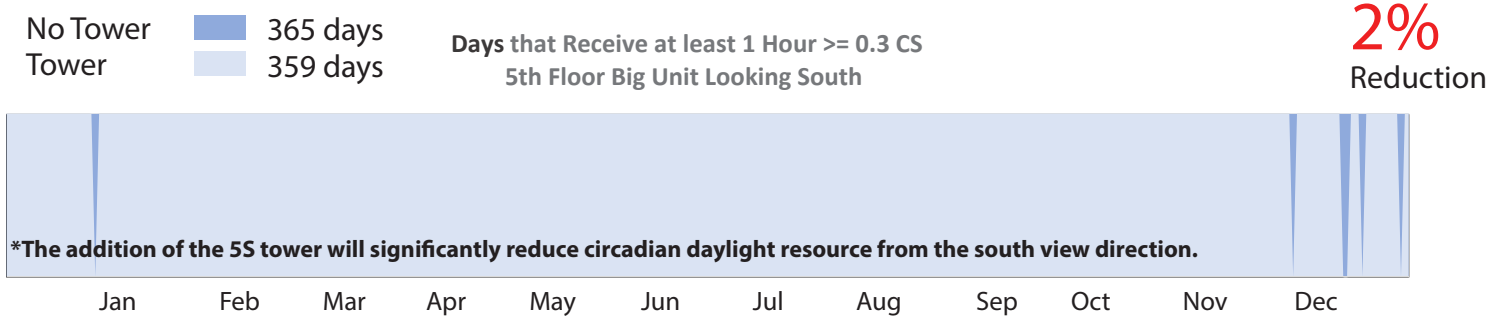

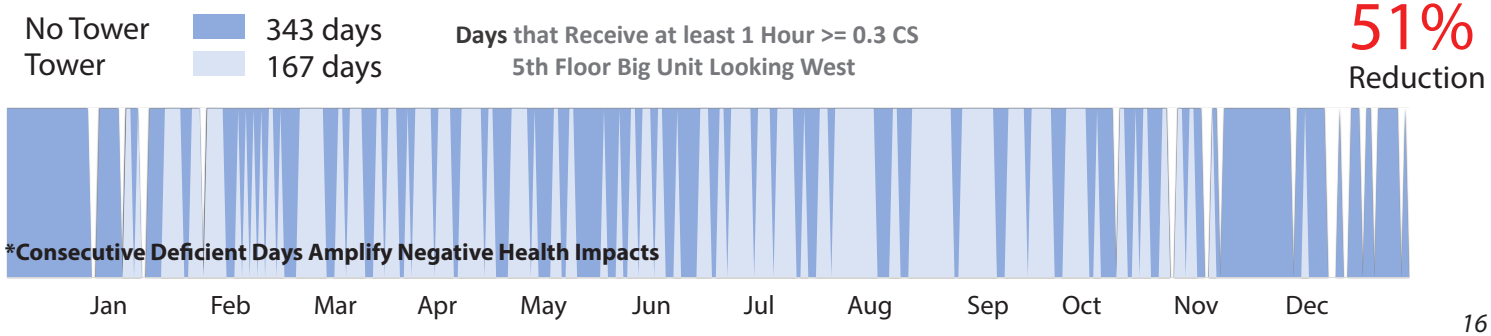

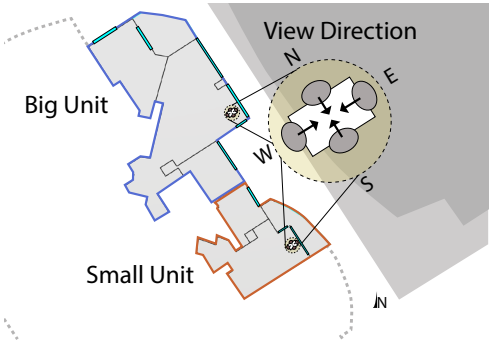

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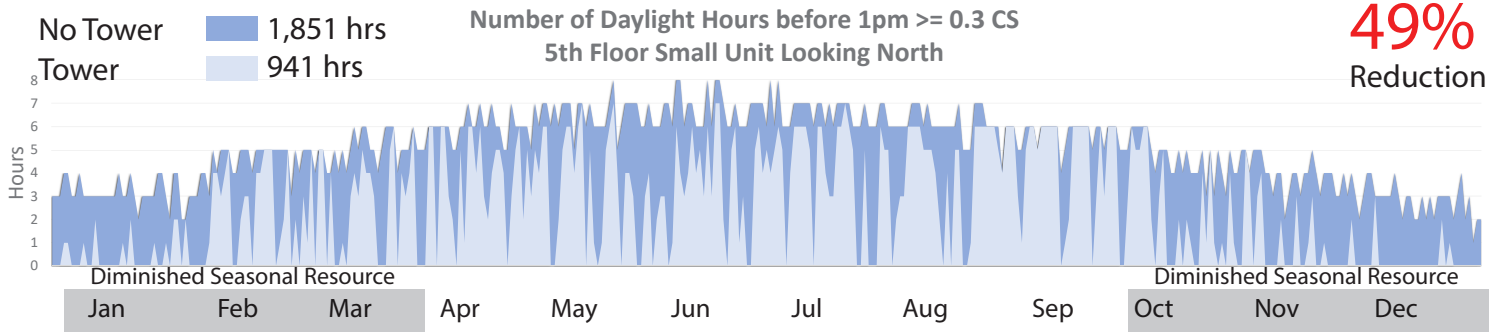

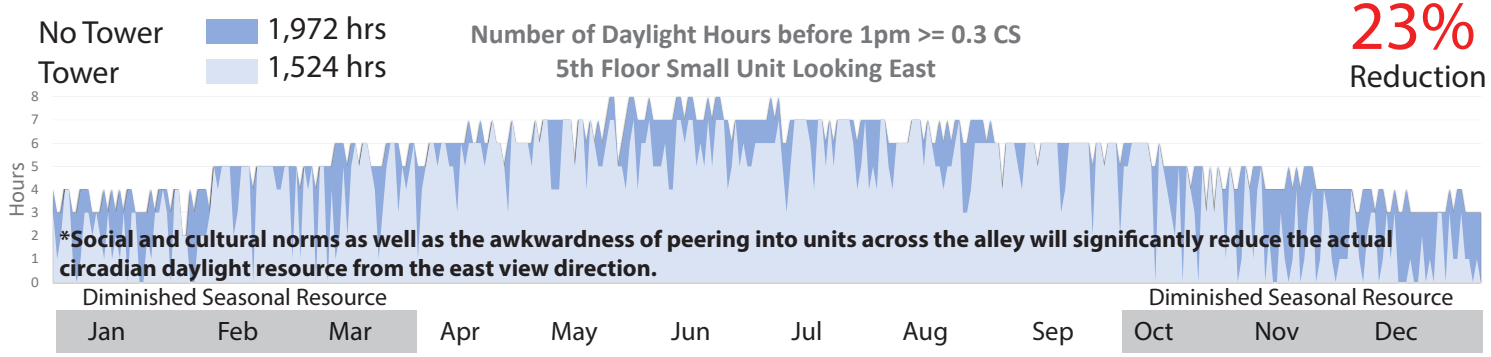

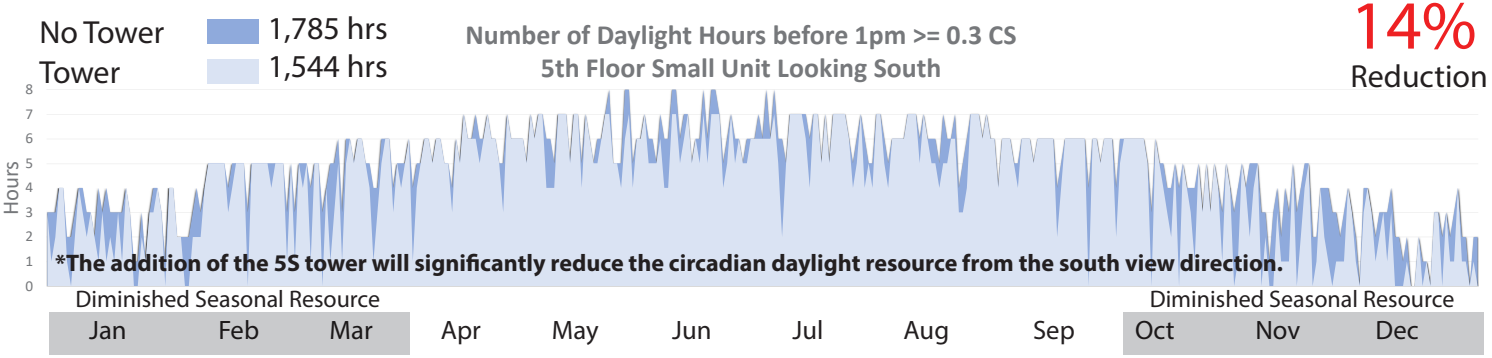

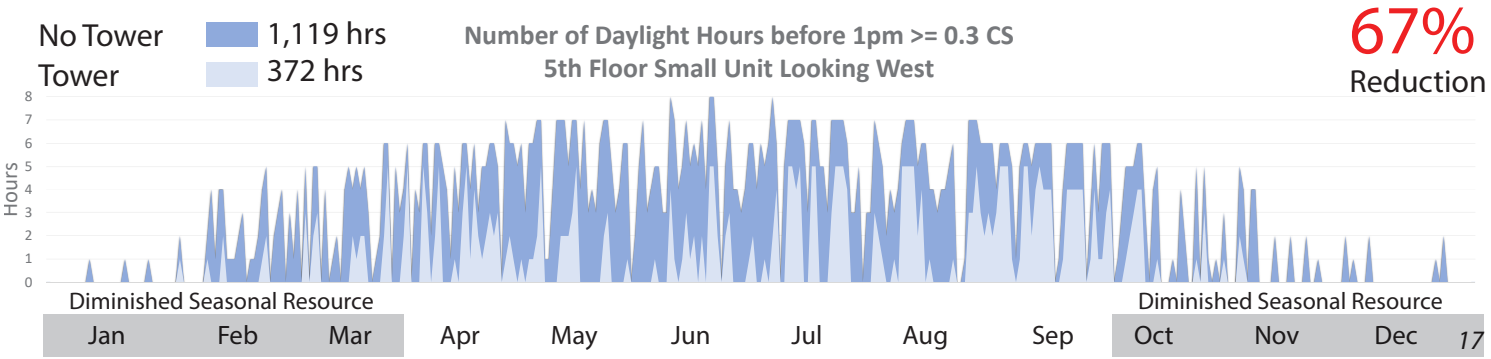

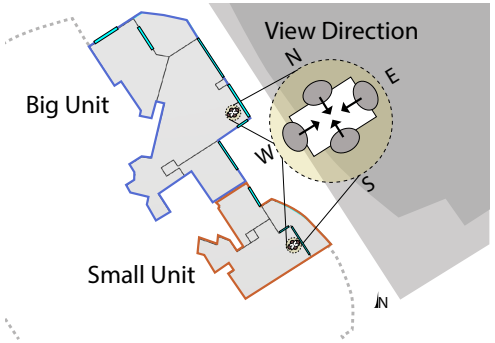

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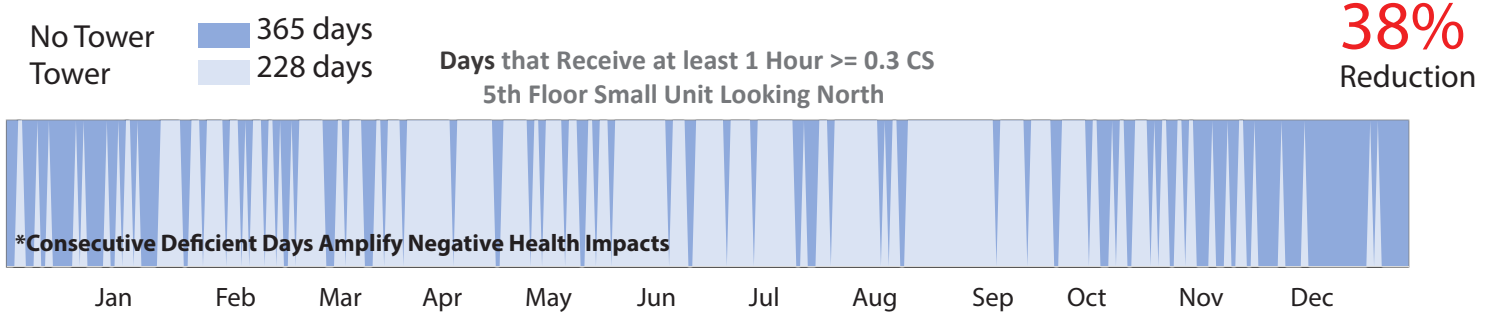

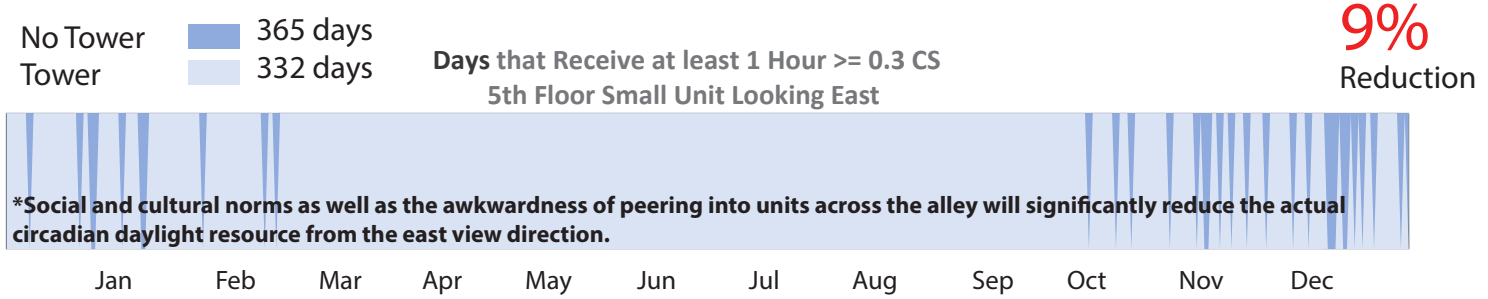

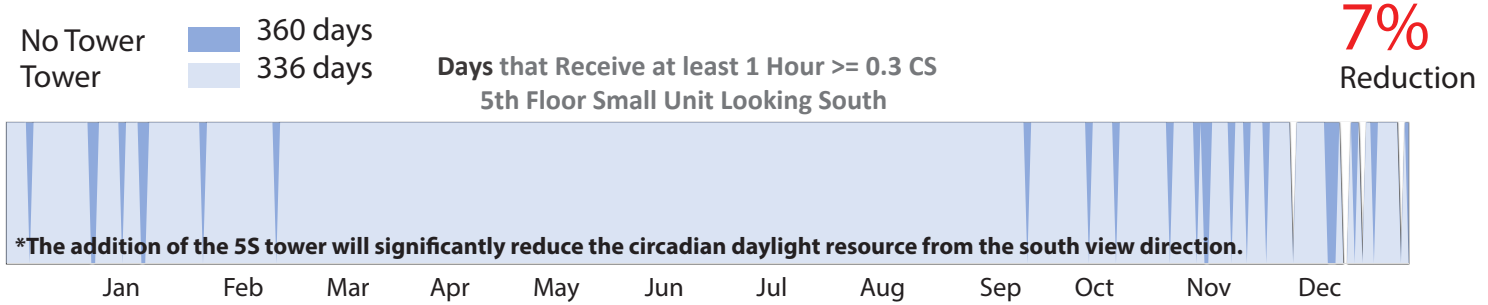

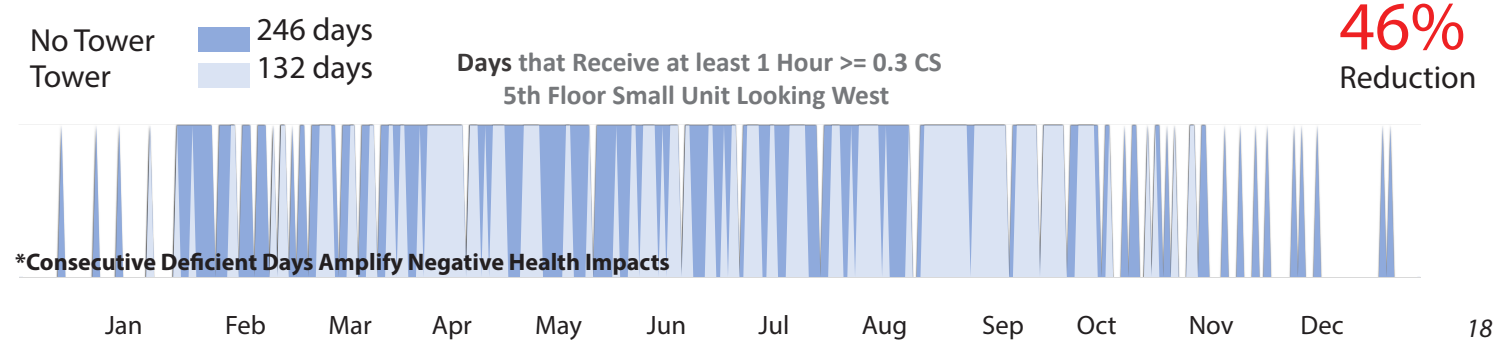

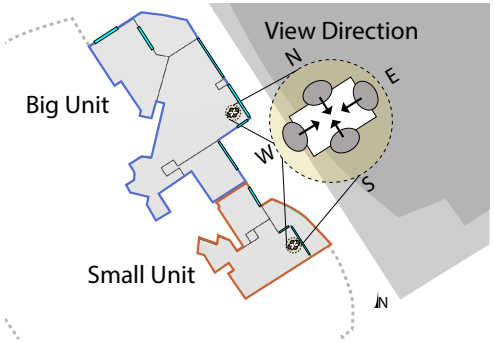

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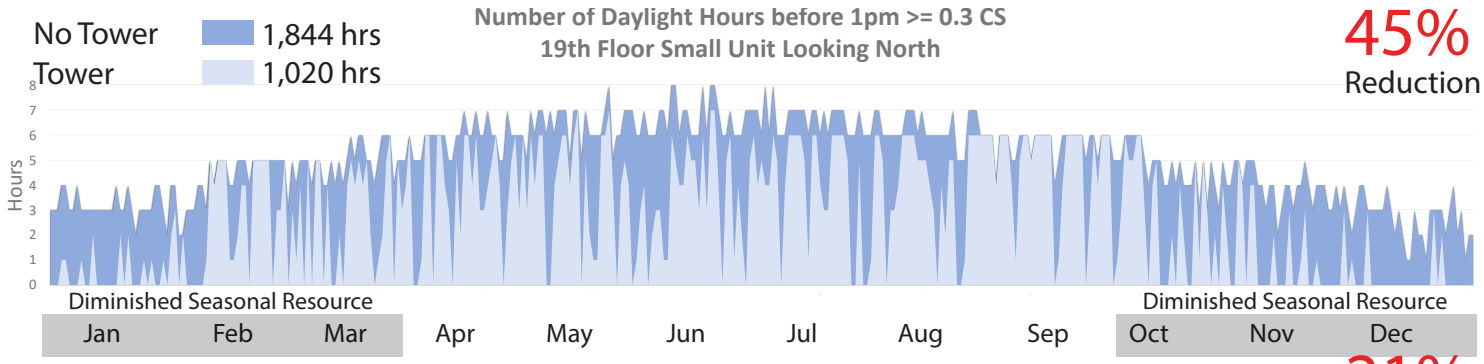

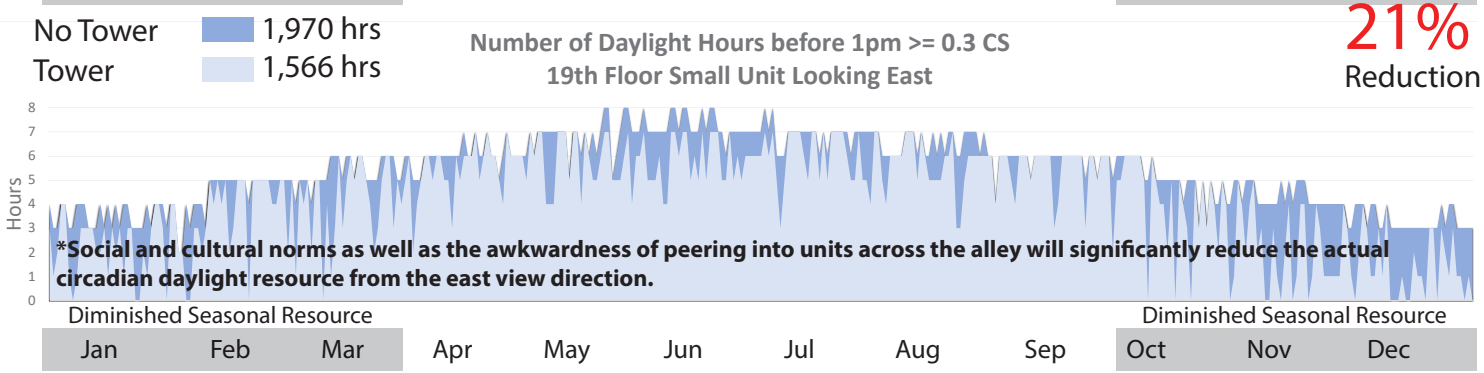

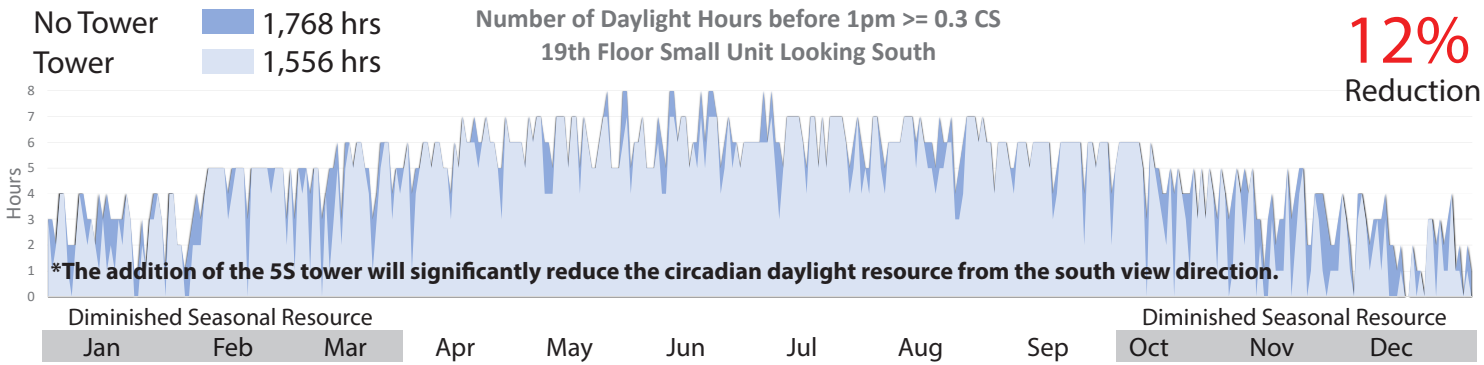

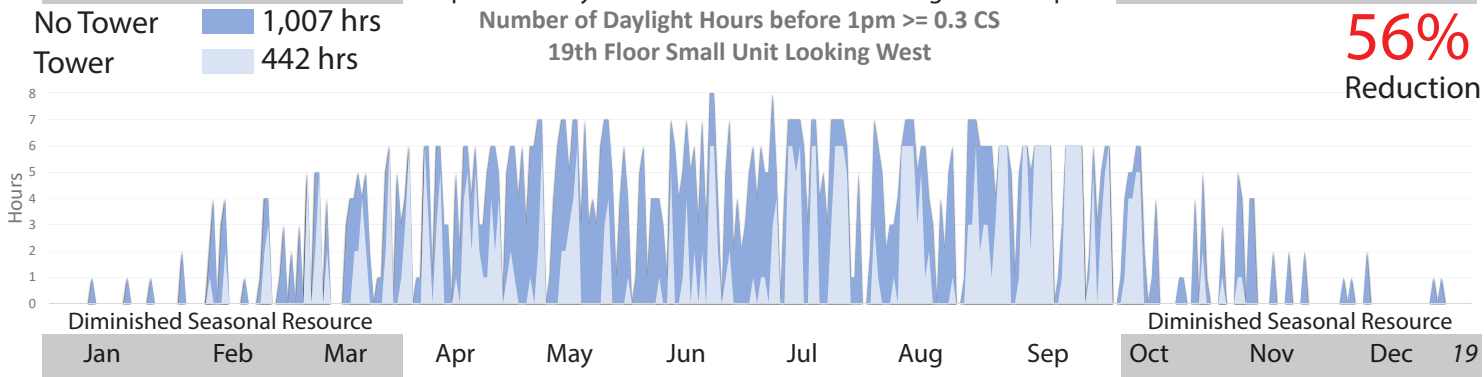

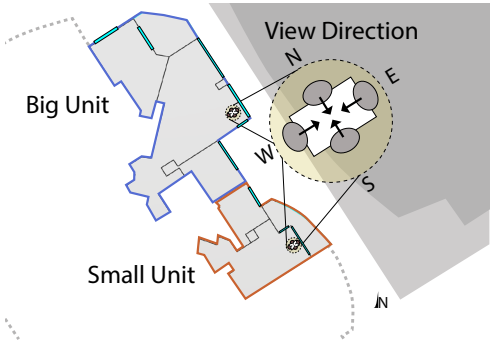

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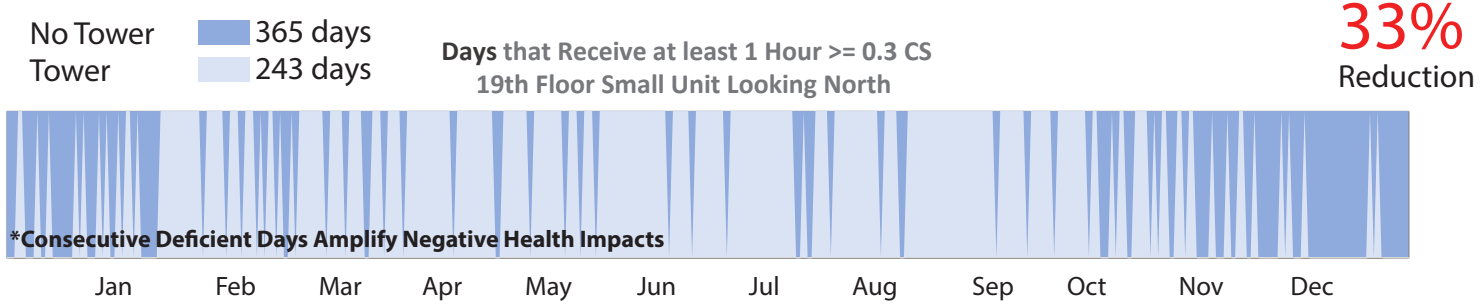

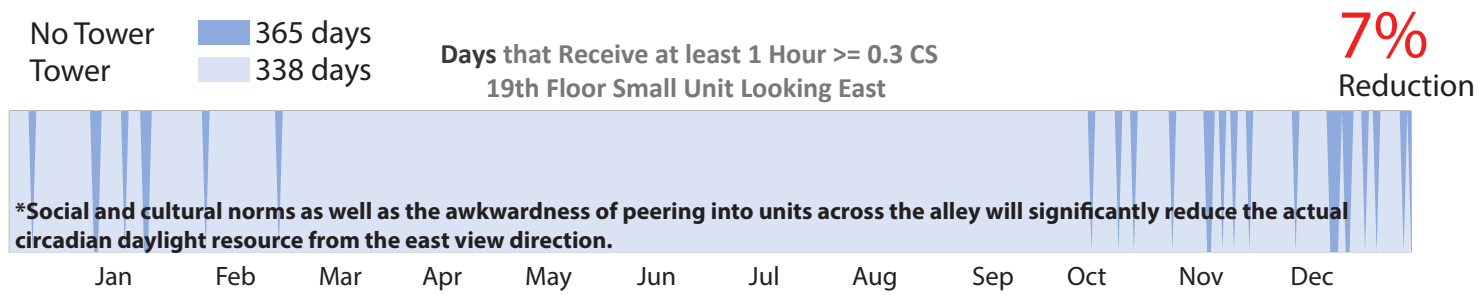

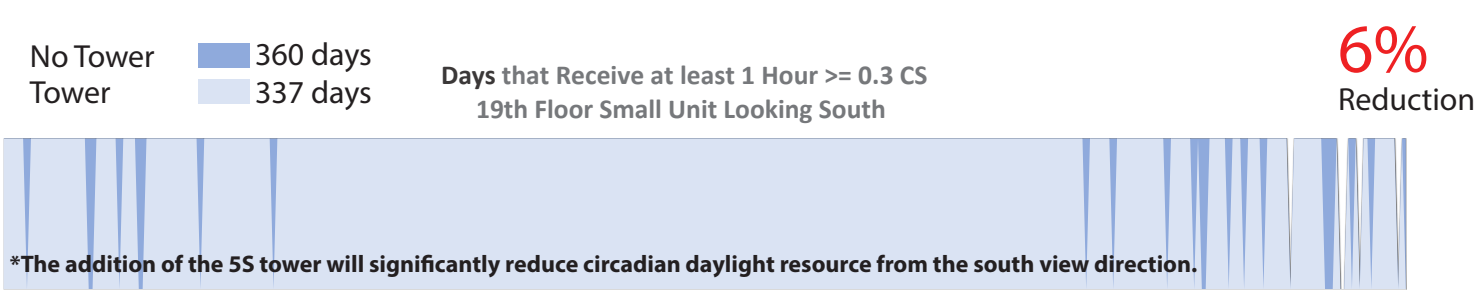

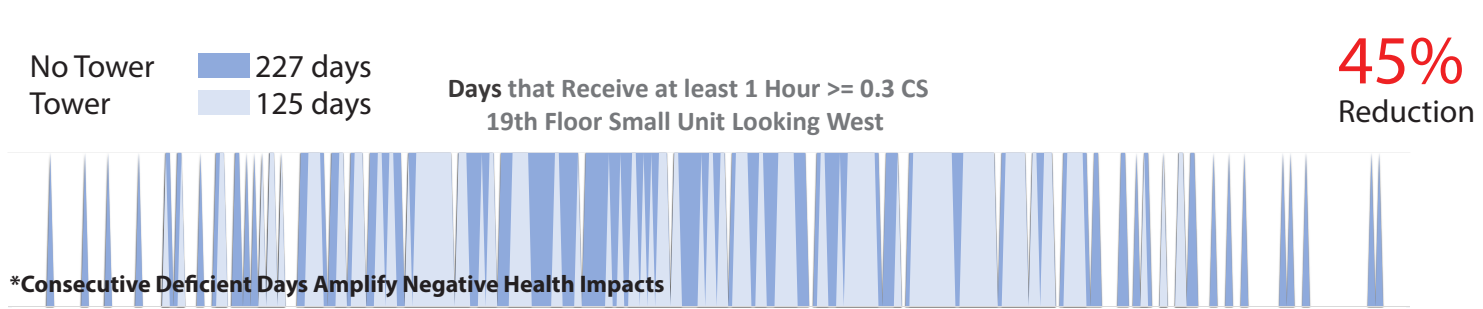

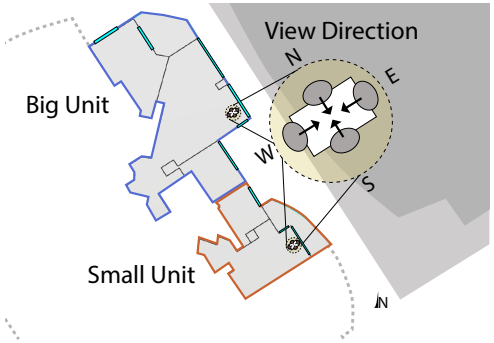

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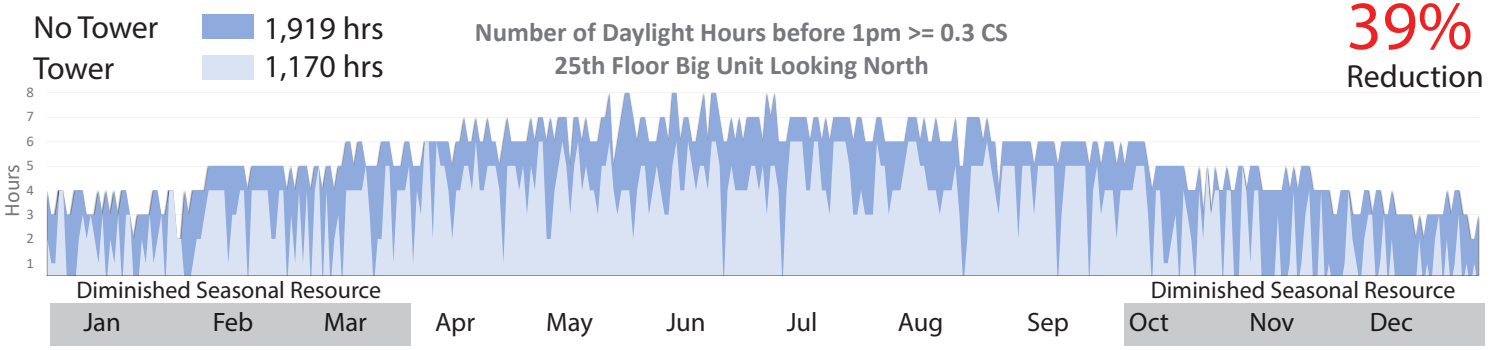

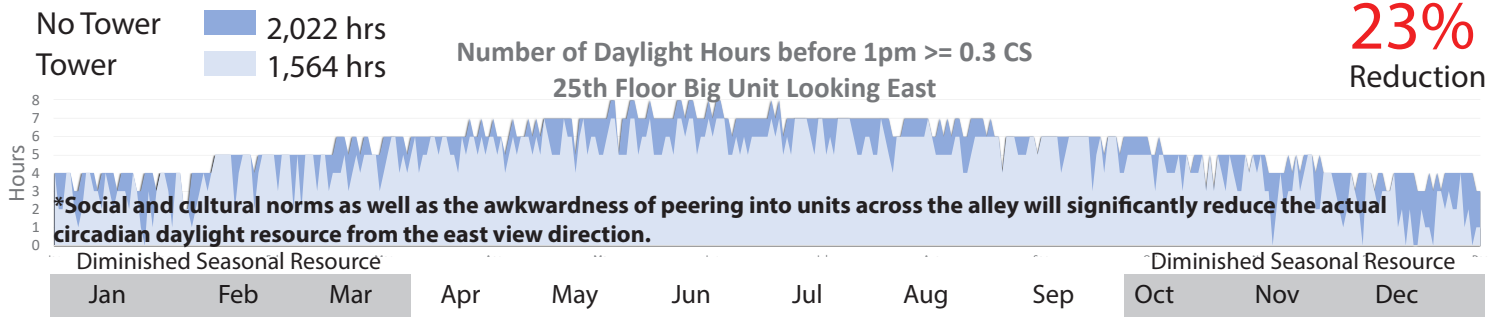

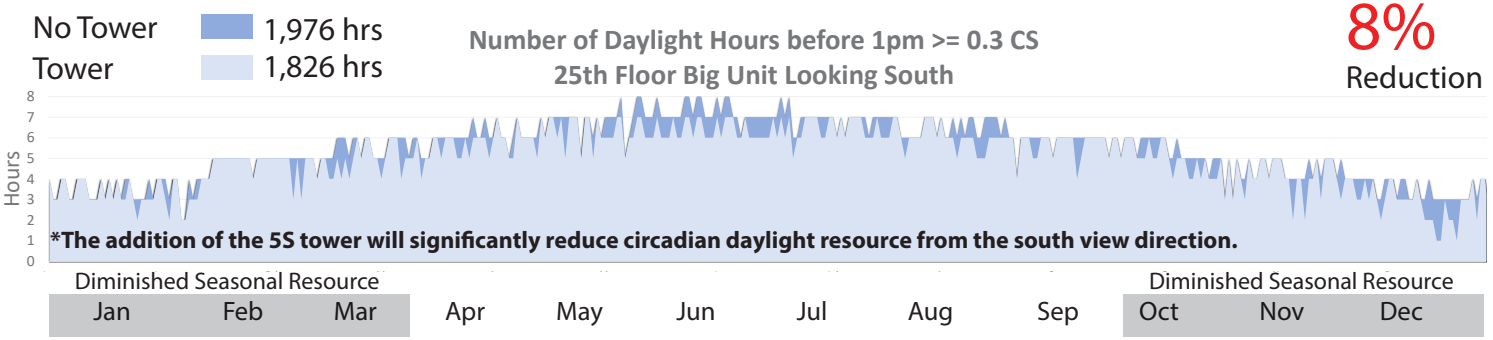

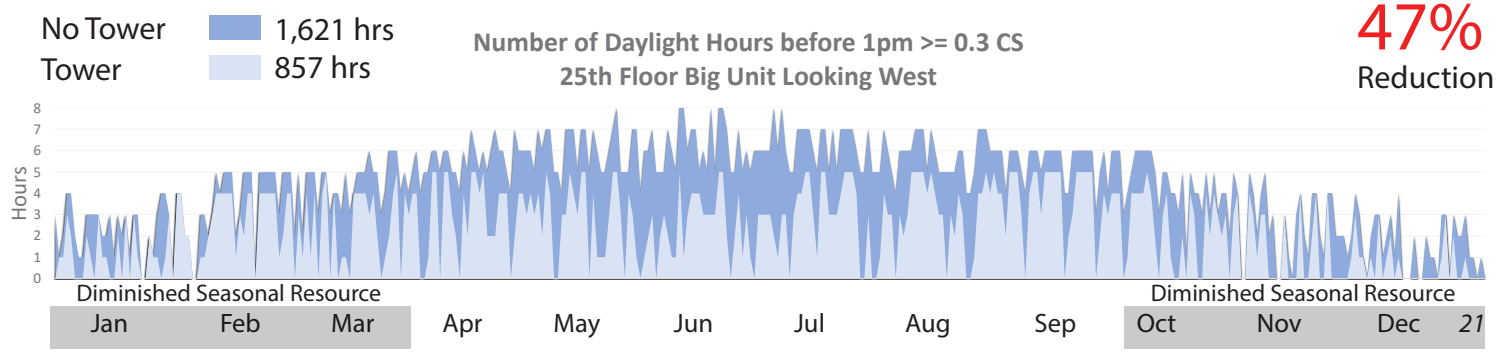

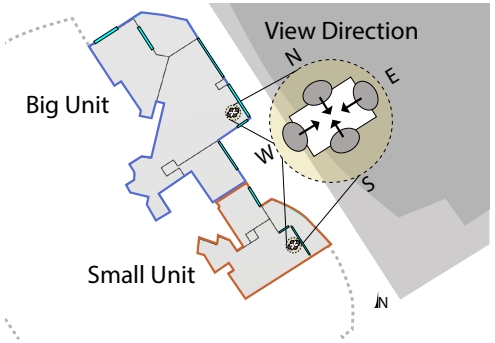

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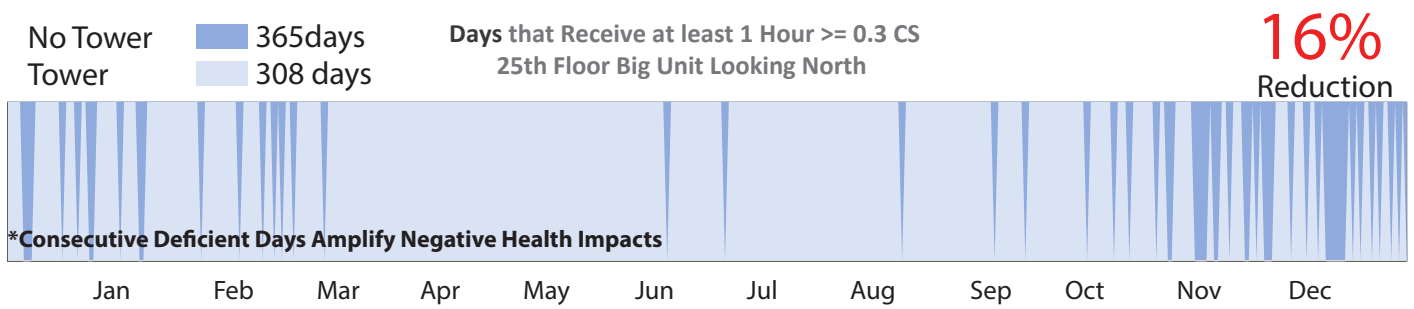

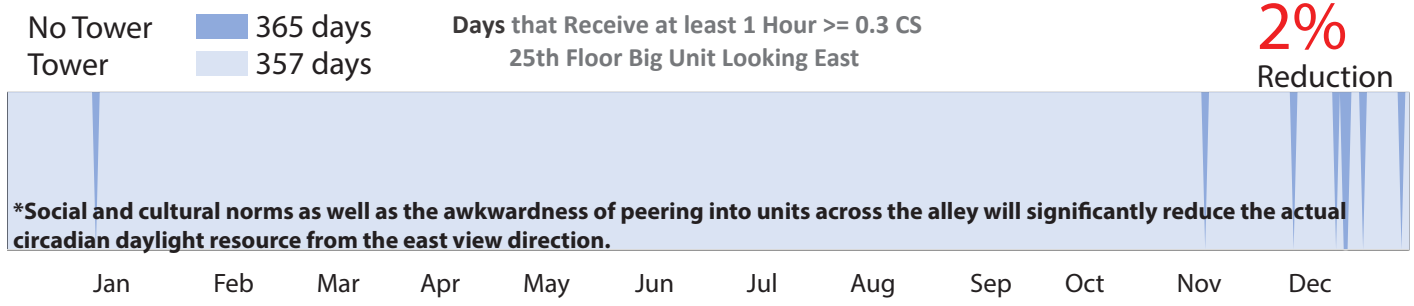

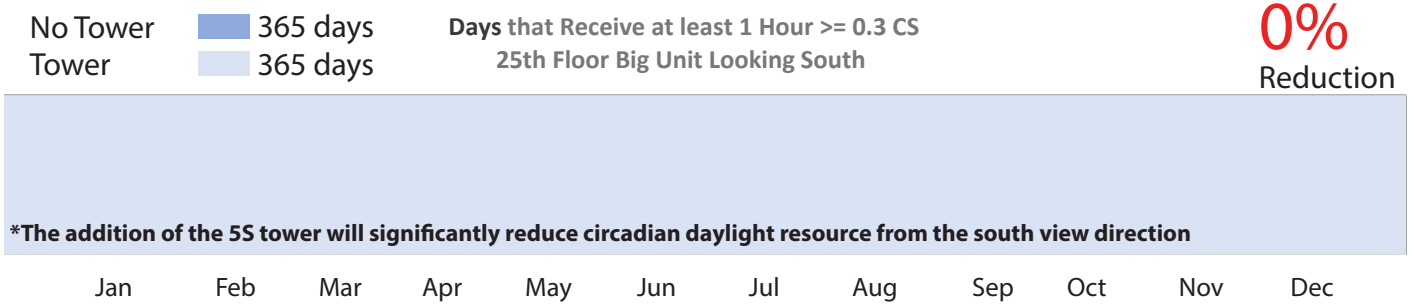

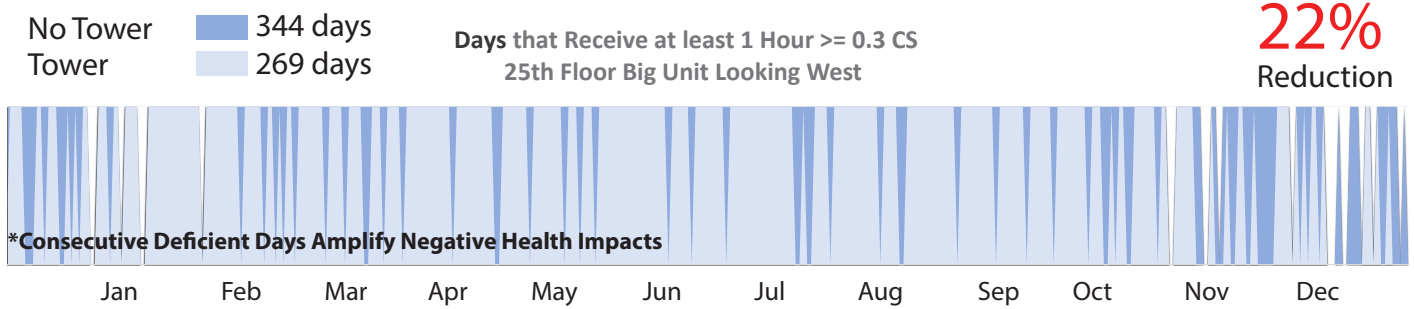

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Prepared by:

Edward Clark, director, CIRCA DIES LLC
eclark@circa-dies.com
www.circa-dies.com

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