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Framework to Integrate Energy Efficiency and Occupant Health/Wellness

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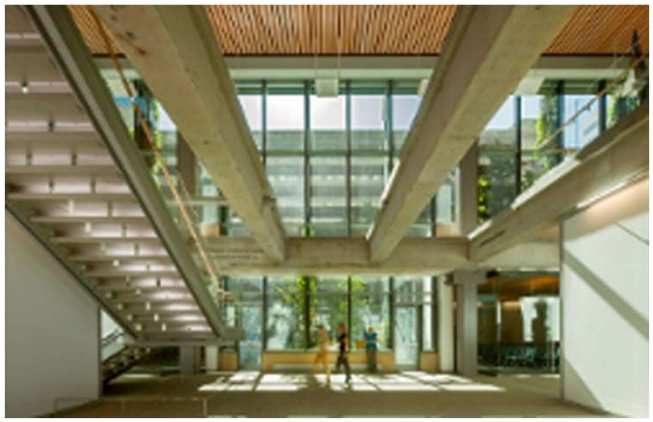
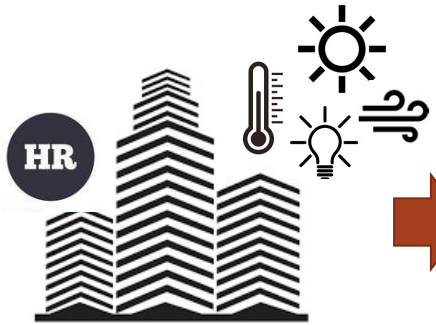
Objectives



Source: www.gsa.gov

- Quantify and customize the cost-benefit results in terms **of improved productivity**, **reduced absenteeism**, **and reduced employee turnover.**
- Integrate these interventions with building **energy efficiency** planning and investment, to provide a greater, more relevant context for decision makers.

Methodology



Baseline measurements (IAQ, thermal comfort, lighting, daylighting)

Potential improvement from baseline to targets

Literature

Correlation between building metrics and occupants (productivity, absenteeism, turnover)

Quantification of financial/personnel savings

Feedback loop to improve correlation

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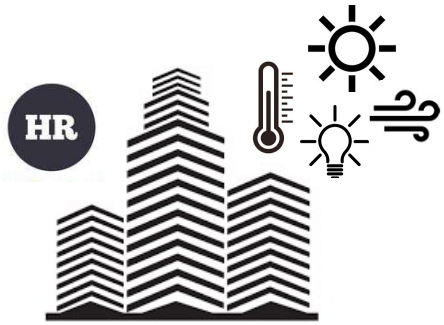


Baseline Measurements

- **Building Metrics**
  - Measured with an energy-style audit
  - Based off WELL, Fitwel, ASHRAE, IES
- **Occupant Metrics**
  - HR and manager info (default assumptions provided)
    - ✓ Absenteeism rate, turnover rate, and recruiting expense
  - Satisfaction survey (optional)
    - ✓ Supplementary to building metrics

Category	Building Metrics
Lighting Quality (visual comfort, circadian rhythms, customization)	Lighting Controls
	Light Zones
	Supplemental Lighting
	Equivalent Melanopic Lux
	Circadian Stimulus
	Illuminance
	Color Rendering Index
Daylight (access, quality)	Spatial Daylight Autonomy
	Window Proximity
	Visible Light Transmittance
	Light Shelves
	Control for Solar Glare
Indoor Air Quality (pollution, ventilation, control)	Ventilation Rate
	Individual Air Diffusers
	Demand Controlled Ventilation
	Variable Air Volume
	Air Quality Devices
	Air-side Economizers
	Particulate Matter – PM2.5, PM10
	Inorganic Gases – CO_2, CO, O_3
	Organic Gases – TVOC, Formaldehyde
Thermal Comfort (customization, comfort)	Thermal Zones
	Individual Thermal Control Devices
	Radiant Systems
	Dedicated Outdoor Air System
	Clothing Level
	Metabolic Level
	Temperature
	Humidity

Potential Building Improvement

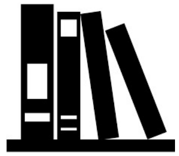
- The metrics have corresponding “target” values based on ASHRAE 189.1/55/62.1, IES Lighting Handbook, WELL v2 and Fitwel
- Metrics for each category (IAQ, lighting quality, daylight, thermal comfort) will be averaged into a single “potential improvement” value for each

Hypothetical Example:

Metric Category	Metric	Notes	Min	Baseline	Target	% Potential	Weight*
Lighting Quality	Illuminance (Horizontal Footcandles)	Average value by activity type, e.g. open office space	15	27	40	50%	1
	Circadian Stimulus (calculated)	Typical value between 9AM and 1PM	0.1	0.22	0.3	40%	3
	Supplemental Lighting (%)	Percent of office spaces that have task lighting available	0	20%	100%	80%	2

*Weights are being developed, these are samples values

- After data normalization and applying weights, the lighting quality for this example building has a potential improvement of 55% (see next slide for continuing analysis)



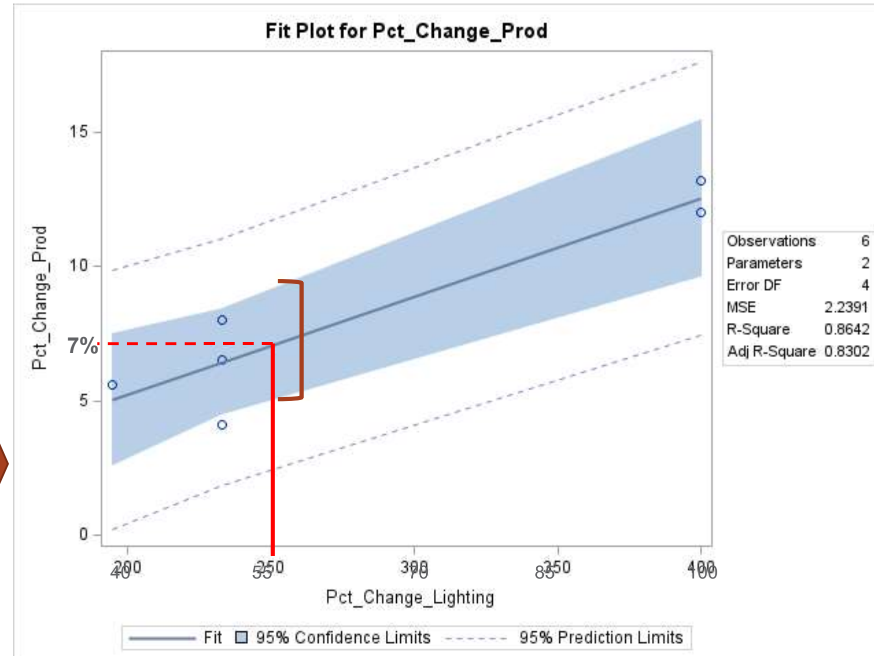
Literature Correlation From Building Systems to Occupant Health

Collection of publications relating lighting quality to productivity

Reference			Case Study Subject				Building Description			Impact Categories		Value							Notes			Source
Paper Title	Author	Pubication Year	Name	Countr	# of Participa	Study Duration	No. Buil	Use type	Total floor	Saving Catego	Design Element	Low Measu	High Measure	Unit	Measu Chan	Healt Impac	Value Typ					
Daylighting-Bias and Biophilia: Quantifying the Impacts of Daylighting on	Elzeyadi, I	2011	Oregon Hall, University of Oregon in Eugene	US	175			Office		Absenteeism	Lighting	Average Building	High Performance		400%	12.8%	Reduced Absenteeism		Scale of 1 to 7, where 7 is worst and 4.1 is average. 4.1 gives 63 hours and 7 (max) gives 70.8 hours	Regression: Sick Leave (hours) = 52.6 + 2.6 * (PLQ) where PLQ is poor lighting quality on a school of 1 to 7	Varied factors affecting daylighting availability, lighting quality, and view quality. Also contains data about view quality	https://www.usgbc.org/
Windows and offices: A Study of Office Worker Performance and the Indoor	Heschong-Mahone Group, California Energy	2003	SMUD Call Service Center	US	129		1	Call Center		Absenteeism	Daylight	Average Building	Better Performance		233%	6.50%	Reduced Absenteeism		Performance metrics: average talk time, average work time, average handling time, number of calls answered, etc.	Calculated productivity differences between cubicles with no views and cubicles with good views		https://www.energy.ca.g
Daylighting in schools: reanalysis report	Heschong-Mahone Group	2001	San Juan Capistrano, Seattle, and Fort Collins school	US	8008			School		Absenteeism	Daylight	Average Building	Better Performance		233%	25.0%	Reduced Tardiness		Found that improved daylighting had no significant effect on student absenteeism and a 5% reduction on tardiness for every level up in the code (0-5) meaning 25% maximum reduction			https://www.pge.com/in
Greening the Building and the Bottom Line	Romm, Joseph	1994	PA Lighting & Power					Office		Absenteeism	Lighting	Average Building	Better Performance		233%	25%	Reduced Absenteeism		PA Power and Light reduced sick leave by 25%	Improvements to glare, task lighting, and high-efficiency lamps		http://library.uniteddiver
The Impact of daytime light exposures on sleep and mood in office workers	Mariana Figuerio et al	2017	GSA	US	109	7 days x 2	5	Office		Cognitive	Daylight	0.115	0.35	Circadian Stimulus (CS)	204%	13.3%	Mood and Sleep Score		Objective measures of sleep (sleep onset latency, sleep time, wake time, and sleep efficiency) and subjective measures of mood and sleep (CES-D, PROMIS T-score, PANAS positive, PANAS negative, PSQI, and PSS-10	From low morning CS (avg 0.12) to high morning CS (avg 0.35), objective sleep improved 59.9%, 5.9%, 24.2%, and 3.8% (avg = 23.45%) and subjective sleep and mood improved 42%, 9.8%,	From low workday CS (avg 0.11) to high workday CS (avg 0.35), objective sleep improved 17.4%, 1.2%, 4.1%, and 1.5% (avg = 6.05%) and subjective sleep and mood	https://www.sciencedire
Windows and offices: A Study of Office Worker Performance and the Indoor Environment	Heschong-Mahone Group, California Energy Commission	2003	SMUD Desktop Study	US	201		3	Office		Cognitive	Views	Average Building	Better Performance		233%	5.83%	Cognitive Score		Used a variety of cognitive and memory tasks to measure performance	Changing primary or break view from worse view to best view had the following results: =16%, +8%, +10%, +16%, +8%, +9% which average to 5.83%		https://www.energy.ca.g
Windows and offices: A Study of Office Worker Performance and the Indoor Environment	Heschong-Mahone Group, California Energy Commission	2003	SMUD Desktop Study	US	201		3	Office		Cognitive	Daylight	1	40	footcandles	366%	15.79%	Cognitive Score		Used a variety of cognitive and memory tasks to measure performance	Improving lighting by 10% led to 0.45% improvement to Backwards Numbers (figure 53 for regression	Improved daylight also correlated with higher temperatures, which could negatively affect performance	https://www.energy.ca.g
Daylighting in	Heschong-		San Juan Capistrano, Seattle,									Average	Better						Used daylight code (0-5 scale) and found that the percent improvement to standardized test scores for reading	Those are the original resutls and then they did a reanalysis and		

- 80 publications in database – continuing to expand and quality check

Plot of studies with percent improvement to productivity vs percent improvement to lighting quality measure



- Percent Potential Improvement: **55%**
- Corresponding Productivity Improvement: **7%**
- Uncertainty: **+/- 3%**

→ Find improvements to absenteeism and turnover as well, and then repeat for daylight, thermal comfort, and IAQ

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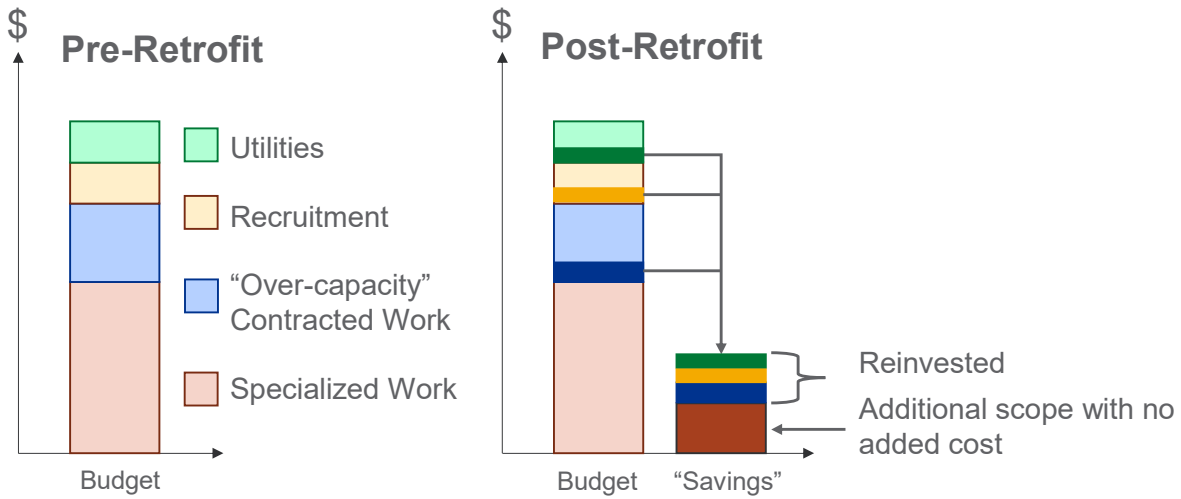
Quantification of Financial Savings



Savings Source	Savings Category	Explanation	Action
Utilities	**Energy**	Building retrofits will likely reduce energy consumption	Utilities savings can be reinvested in building retrofits or agency programs
Recruitment	**Turnover**	Reduced turnover saves overhead expenses on recruitment	Recruitment savings can be reinvested in agency programs
"Over-capacity" Contracted Work	**Productivity/ Absenteeism**	Federal employees and flexible contractors in building are more efficient and decrease need for contracted work	Contractor savings can be reinvested in agency programs
Specialized Work	**Productivity/ Absenteeism**	Federal employees and essential contractors are more efficient and complete specialized work sooner [and/or improved quality of service and mission achieved]	Programs can request additional scope with the same budget

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Decision Matrix, NPV, and Uncertainty

- Decision matrix can compare personnel savings to:
  - Energy savings/costs
  - Cost of construction
  - External/non-monetary benefits
    - Aesthetics, employee satisfaction, office culture, GHG emissions
- Uncertainty from the confidence intervals in literature data and number of metrics completed
- NPV to compare discounted benefits and payback period to upfront cost of improvements

Retrofit	Monetary					Non Monetary	
	NPV (personnel savings)	Uncertainty	NPV (energy savings)	Estimated Retrofit Cost	Benefit / Cost Ratio	Occupant Satisfaction	Office Culture
Option 1 Combined	$10,164K	+/- 15%	$1,994K	$2,010K	6.05 +/- 0.76	66%	High
Option 2 IAQ	$7,988K	+/- 10%	$798K	$1,546K	5.68 +/- 0.52	25%	Low
Option 3 Lighting	$6,196K	+/- 9%	$1,196K	$464K	15.9 +/- 1.23	35%	Medium