

THE COST OF DECAY

How Building Degradation Amplifies the Value of Passive Building



AGENDA

1. Introduction
2. Commercial Building Valuation
3. Impact of Energy Cost and Degradation
4. Hillandale Energy Modeling
5. Hillandale Financial Modeling
6. Conclusion
7. Q/A



INTRODUCTION



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INSPIRATION

Simple Payback is Too Simple for the Task

PhiusCon 2025
October 8, 2025



PhiusCon 2025

PhiusCon 2025 took place in Milwaukee, Wisconsin.

<https://www.phius.org/sites/default/files/2025-10/Energy%20Efficiency%20Presentation%20v4-final.pdf>

THE PROBLEM

Traditional economic analysis recognizes initial energy savings, but often overlooks how performance degradation (combined with the rising cost of energy) can alter operating costs, income, and value over time.

High-performance buildings may be **systematically undervalued** because conventional valuation is not fully recognizing the long-term economic value of more *durable energy performance*.

Our hypothesis is that design decisions that reduce energy use and limit the absolute growth in energy consumption as buildings age create an **operating-cost advantage** that persists over time.

That advantage leads to higher relative Net Operating Income (NOI) over time which should result in **higher asset value**.

BUILDING VALUATION ANALYSIS

Residential Homes are typically valued using a traditional “Comparable Sales Analysis”

Comparable Sales

What are similar properties selling for?



Influences on Value

Size, location, age, school district, number of bedrooms, number of bathrooms, et...

BUILDING VALUATION ANALYSIS

While comparable sales remain relevant, commercial buildings are generally valued primarily based on the **income they produce**.



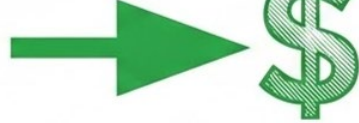
Comparable Sales
What are similar
properties selling for?



Income Approach
What income does this
property produce?

BUILDING VALUATION ANALYSIS

In an income-producing commercial building, an investor is essentially purchasing a “stream” of future income .



Net Operating Income (NOI)

What income does this property produce?

Gross
Operating Income



Operating Expenses



NET
Operating Income
(NOI)

BUILDING VALUATION ANALYSIS

Net Operating Income (NOI) is the income a property generates after paying the operating expenses required to run and maintain the building.

$$\begin{array}{ccc} \text{Gross} & & \text{NET} \\ \text{Operating Income} & \text{—} & \text{Operating Income} \\ & \text{Operating Expenses} & \text{(NOI)} \\ & \text{=} & \\ \text{Rent} & & \text{Income generated by} \\ & & \text{the property after} \\ & & \text{operating expenses} \\ & & \\ & \text{Utilities} & \\ & \text{Maintenance} & \\ & \text{Repairs} & \\ & \text{Staff} & \\ & \text{Taxes} & \\ & \text{Insurance} & \end{array}$$

BUILDING VALUATION ANALYSIS

The capitalization rate, or “cap rate,” is the market-derived rate used to convert a property's annual NOI into an indication of value. It reflects the market's assessment of the **risk and durability of that income** .

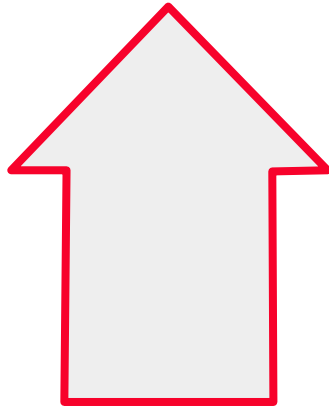
$$\frac{\text{ANNUAL NOI}}{\text{Capitalization Rate (Cap Rate)}} = \text{BUILDING VALUE}$$

WHAT IS CAP RATE?

The capitalization rate reflects how the market values a property's income based on the perceived **risk** and **durability of that income**.

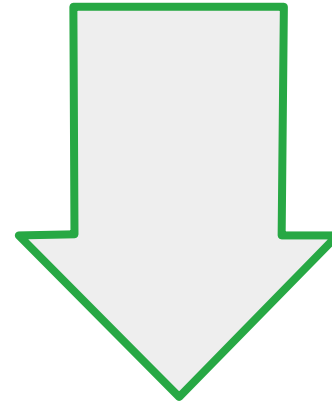
HIGHER CAP RATES

- Higher return relative to purchase price
- Higher perceived risk
- **Lower value**



LOWER CAP RATES

- Lower return relative to purchase price
- Lower perceived risk
- **Higher value**



WHERE DOES CAP RATE COME FROM

Cap rates reflect a combination of market, property, income, and investment risk factors.



BUILDING VALUATION EXAMPLE

$$\text{\textit{\$1,000,000}} \quad \text{—} \quad \text{\textit{\$400,000}} \quad \text{=} \quad \text{\textit{\$600,000}}$$

Gross
Operating Income

Operating Expenses

NET
Operating Income
(NOI)

$$\begin{array}{c} \text{NOI} \\ \text{\textit{\$600,000}} \\ \hline 6\% \\ \text{Market Derived Cap Rate} \end{array}$$

=

\\$10,000,000

Computed Building
Value

BUILDING VALUATION EXAMPLE

$$\text{\$1,000,000} - \text{\$400,000} = \text{\$600,000}$$

Gross
Operating Income

Operating Expenses

NET
Operating Income
(NOI)

$$\begin{array}{c} \text{NOI} \\ \text{\$600,000} \end{array}$$

5%

Market Derived Cap Rate

=

\\$12,000,000

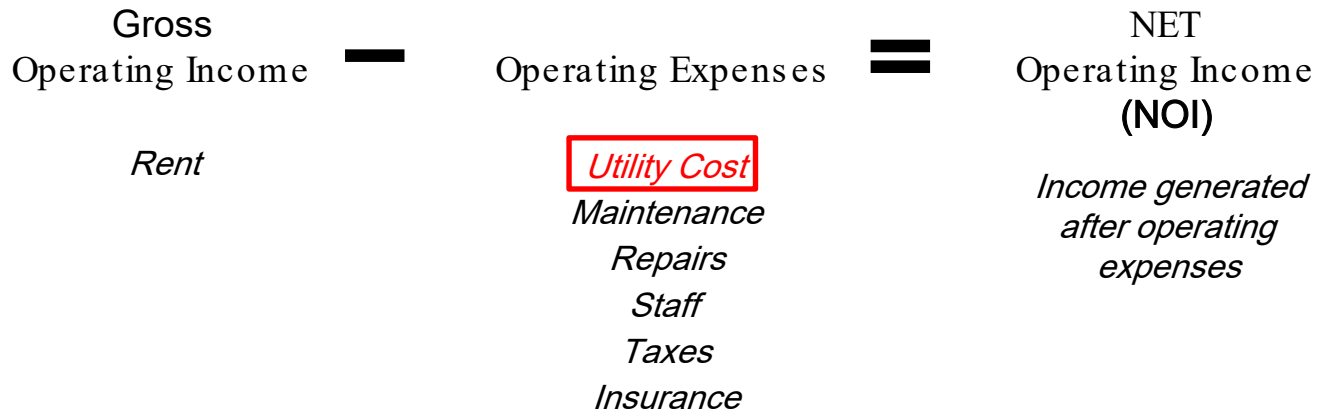
Computed Building
Value

THE IMPACT OF ENERGY COST & DEGRADATION

UTILITY COST IN OPEX

Energy consumption is integral to the analysis.

Building Valuation Methodology



WHAT IMPACTS UTILITY COST?

- **Utility Costs** are NOT constant and are a function of three main drivers:
 - Initially:
 - Energy Usage : Less used, less cost, i.e. passive building
 - Ongoing:
 - Energy Cost Inflation : Higher unit cost, Higher project cost
 - **Performance Degradation:** Building components and systems can lose performance over time, increasing energy use absent corrective maintenance or replacement.

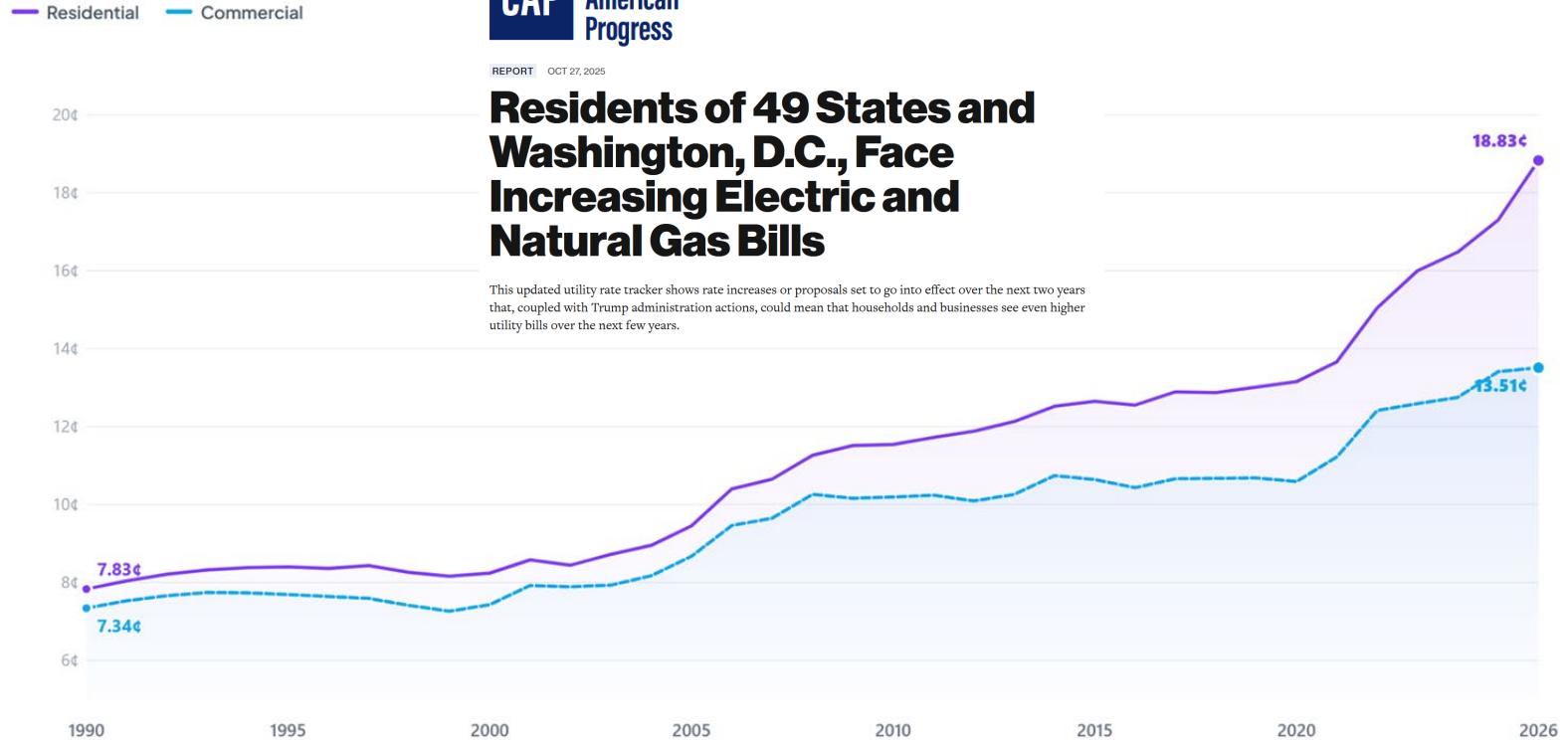
ENERGY COST INFLATION



REPORT OCT 27, 2025

Residents of 49 States and Washington, D.C., Face Increasing Electric and Natural Gas Bills

This updated utility rate tracker shows rate increases or proposals set to go into effect over the next two years that, coupled with Trump administration actions, could mean that households and businesses see even higher utility bills over the next few years.



National average electricity rates, 1990–2026. Source: [U.S. Energy Information Administration, Electric Power Monthly Table 5.3.](#)

ENERGY COST INFLATION

- Electricity is a volatile commodity.
- MARYLAND COMMERCIAL ELECTRICITY PRICES
 - RECENT HISTORICAL GROWTH: **8.7%**
 - 5-Year Compound Annual Growth Rate (CAGR), 2020–2025
 - HIGH ESCALATION SENSITIVITY: **10.0%**
 - Tests continued elevated electricity-cost growth; not a forecast



Source: U.S. Energy Information Administration (EIA), commercial average retail electricity prices.

PERFORMANCE DEGRADATION

Performance degradation is the increase in energy consumption over time as a building's envelope, systems, and components lose performance.

- **Air Leakage / Airtightness Loss** —deterioration of the continuous air barrier and increased infiltration.
- **Sealant & Gasket Deterioration** —particularly at windows, doors, façade joints, and penetrations.
- **Window & IGU Degradation**—gas loss, seal deterioration, glazing performance changes, and increased air leakage.
- **Insulation Degradation** —settling, compression, displacement, moisture, or physical damage reducing effective R-value.
- **Thermal Bridging** —new or worsened conductive paths resulting from deterioration, moisture, movement, or alterations.
- **Ventilation -System Degradation** —reduced ERV/HRV effectiveness, airflow imbalance, fouling, leakage, and control problems.
- **Maintenance & Alterations** —penetrations, repairs, replacements, renovations, and deferred maintenance that reduce original energy performance.
- **Controls & Sensor Drift** —thermostat, temperature, humidity, CO₂, occupancy, and building-control sensors moving out of calibration.
- **Duct & Distribution Leakage** —deterioration of duct seals, piping insulation, dampers, and distribution systems.
- **Heat-Exchanger Fouling** —accumulation of dirt and contaminants reducing heat-transfer efficiency.
- **Moisture Effects** —wet insulation and enclosure materials increasing thermal conductivity and HVAC loads.
- **Solar-Control Degradation** —deterioration or alteration of coatings, shading devices, glazing, and reflective surfaces.
- **Building Movement & Thermal Cycling** —movement that indirectly degrades airtightness, insulation continuity, glazing interfaces, and mechanical connections.
- **HVAC Efficiency Degradation** —declining heat-pump, chiller, boiler, fan, and pump efficiency.
- **Equipment & System Aging** —broader wear of motors, compressors, bearings, valves, dampers, refrigerant systems, and other energy-consuming components.

AIR LEAKAGE

Air Leakage / Airtightness Loss —deterioration of the continuous air barrier and increased infiltration.

Study	Sample	Interval	Result
Chan, Walker & Sherman 2015 (LBNL)	17 new homes, Atlanta	10 to 13 yr	+25% mean , increased in all but one
Chan, Walker & Sherman 2015	17 weatherized homes, Boise	5 to 7 yr	+12% mean . Retrofit-sealed joints held better than new construction
Moujalled et al. 2021 (Durabilit'air, FR)	30 dwellings, annual	3 yr	+18% , all in year 1, stable after
Moujalled et al. 2021	31 dwellings	3 to 10 yr	+20% , confirms front-loading
Erhorn-Kluttig 2009 (Fraunhofer IBP)	31 passive buildings	2 yr	+24% (0.37 to 0.46 ACH50) but 83% still met 0.6
Novák 2018 (CZ)	4 passive buildings	3 to 11 yr	House B: 0.50 to 0.65 in 3 yr, then only 0.65 to 0.70 over the next 7. Worst two (+137%, +103%) caused entirely by post-occupancy penetrations
Peper, Kah & Feist 2017 (PHI)	17 passive buildings, 8 locations, mixed construction	1.4 to 10.5 yr	Changes "almost always within measuring accuracy." The only study in TN71 showing no significant deterioration.

INSULATION DEGRADATION

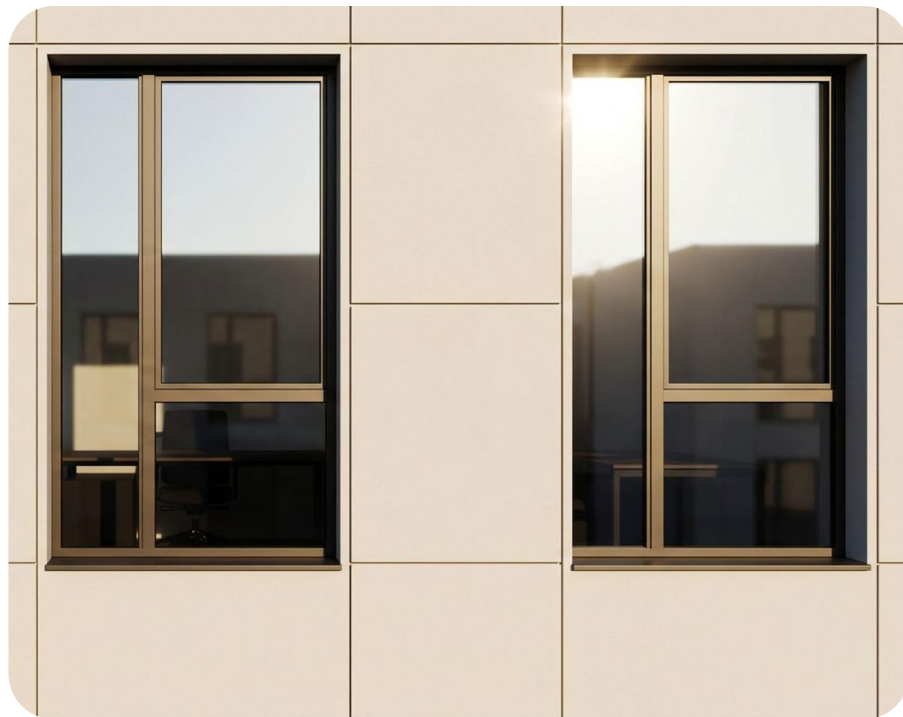
Insulation Degradation —settling, compression, displacement, moisture, or physical damage reducing effective R-value.

Material	Degradation	Source
EPS	No measurable change at 25 yr. No shrinkage, 1 unchanged, lab-verified at Univ. Innsbruck	Feist et al. 2016, Kranichstein
EPS	3% R-value loss over 20 yr	Industry field data
XPS	5% to 10% over 10 to 15 yr; 10% to 15% over 50 yr; 18.9% over 15 yr in one field-extracted study	Multiple
XPS (interior application, 7,200-day experiment)	Drives +23.2% to +36.2% heating energy over 15 yr in modelled multifamily	Choi 2018, then Park et al. 2025
Polyiso	Thermal drift plus cold-temperature R-value derating	Singh et al.
VIP	10% at 5 years	Molletti et al.
Glass wool (1980s cavity)	1 + 12% in service	Stazi et al.
Aerogel blanket	R -20% or worse at 20% moisture content or above	

WINDOWS

Window & IGU Degradation—gas loss, seal deterioration, glazing performance changes, and increased air leakage.

- Thermal cycling leads to multiple failure modes
 - Movement of spacer leads to loss of insulating gasses
- Argon loss can raise IGU's Uvalue by up to 32% (Asphaug et al.)
- Sealants are 6-8 times more permeable at 140°F than at 70°F



MECHANICAL SYSTEMS

A variety of factors influence the degradation of system performance.

- **Controls & Sensor Drift** —thermostat, temperature, humidity, CO₂, occupancy, and building -control sensors moving out of calibration.
- **HVAC Efficiency Degradation** —declining heat-pump, chiller, boiler, fan, and pump efficiency.
- **Duct & Distribution Leakage** —deterioration of duct seals, piping insulation, dampers, and distribution systems
- **Heat-Exchanger Fouling** —accumulation of dirt and contaminants reducing heat-transfer efficiency
- **Equipment & System Aging** —broader wear of motors, compressors, bearings, valves, dampers, refrigerant systems, and other energy-consuming components.



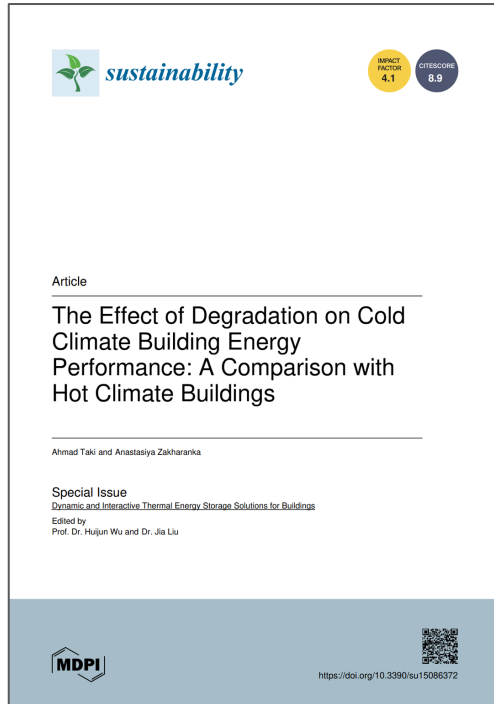
Given the impact of **Air Sealing**, **Insulation Choices**, and **System Detailing** on degradation, do we believe that passive buildings are likely to have the same level of degradation when compared to a Code Minimum Building?

DESIGN IMPACTS TO DEGRADATION

We hypothesize NO.

We hypothesize that passive buildings will experience less absolute energy-performance degradation over time because of their envelope, component selection, quality assurance, and system detailing.

BUILDING DEGRADATION



Under the study's worst-case degradation assumptions, the code-minimum building experiences nearly **TWICE** the absolute increase in heating energy use.

Cold-climate detached house, worst-case degradation over 25 yr

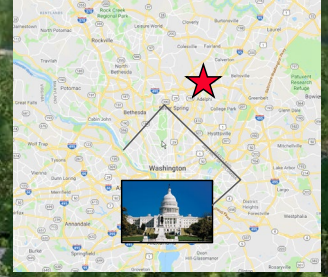
Annual Heating Energy (kWh/m ² -yr)			
	Year 0	Year 25	Change
High Performance	25.29	40.76	+15.5 (+61.2%)
Low Performance	59.55	89.18	+29.6 (+49.8%)

Note the rise is in absolute terms notwithstanding the higher percentage change in the high performance building which is the result of the materially lower starting point.

HILLANDALE GATEWAY

Energy + Financial Models

HILLANDALE GATEWAY





Site Program

- 463 total homes in two (2) residential buildings
- Three (3) free standing retail buildings.
- Mixed-use & mixed income
- Shared parking garage w/ 70 EV chargers
- Public site amenities & transit station



Hillandale Gateway Affordability (Sitewide)

30%	25	5.40%
40%	25	5.40%
50%	67	14.47%
60%	50	10.80%
70%	25	5.40%
80%	56	12.10%
Market	215	46.44%
TOTAL	463	100.0%

LUMINA AT HILLANDALE GATEWAY

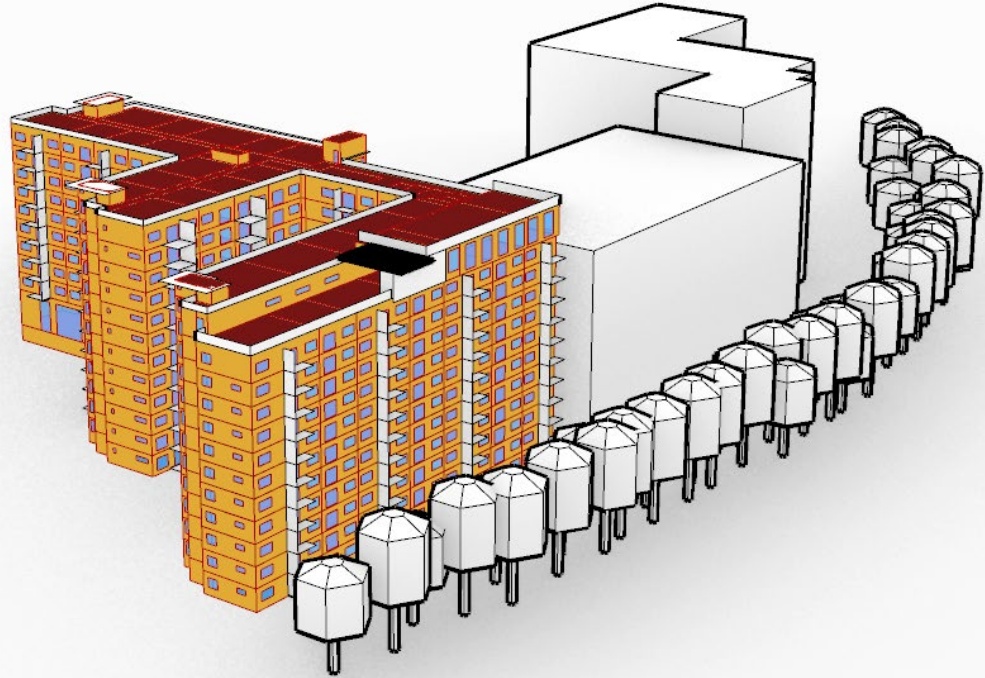
- 308 Homes
 - 30% Affordable
 - 1 Bed to 3 Bed Units
 - Phius CORE 2024 Design Certified Q1 2026
 - Completing Q2 2027
- Systems:
 - 1:1 Ducted Mini-Split
 - Heat Pump Water Heaters
 - EIFS Insulation
 - Neighborhood ERVs
 - All Electric Appliances



BASELINE COMPARISON

Study Methodology:

- Build a 'baseline' version of the building with code-min. values
- Change **envelope** to match ASHRAE 90.1 code-minimum
- Change **mechanical equip.** to match ASHRAE 90.1 code-minimum
- Change all **hot-water systems** to direct-electric
- Adjust all **lighting and appliance** values to code-minimum levels.
- All solar-PV excluded from both variants
- Rhino/Honeybee-PH to create variants, METr to calculate results



ENERGY MODEL ASSUMPTIONS

Category	Code minimum (ASHRAE 90.1 App. G)	Phius design	Notes
Roof	U-0.048 (R-21)	U-0.040 (R-25)	
Above-grade walls	U-0.064 (R-16)	U-0.039 (R-26)	Area-weighted, 6 wall types; range U0.038 to 0.054
Windows (residential)	U-0.40, SHGC 0.40	U-0.20, SHGC 0.38	Area-weighted whole-window U_w ; range U0.18 to 0.23
Curtain wall / storefront	U-0.50, SHGC 0.40	U-0.38, SHGC 0.34	Area-weighted; range U0.34 to 0.61
Opaque doors	U-0.70	U-0.19	
Thermal bridges	Not counted ($\psi = 0$)	Avg $\Psi = 0.066$ Btu/h-ft-F	21,600 ft total length; code U-factors are whole-assembly
Airtightness	3.0 ACH50 (0.6 cfm50/ft ²)	0.4 ACH50 (0.08 cfm50/ft ²)	
Ventilation heat recovery	None (0%)	ERV, 75% effective sensible recovery	Building-effective value from METr; units rated between 71 to 89%

ENERGY MODEL ASSUMPTIONS

Category	Code minimum (ASHRAE 90.1 App. G)	Phius design	Notes
Heating	PTHP, COP 3.34	Heat pump, COP 2.41 at 17F / 3.90 at 47F	
Cooling	PTHP, EER 9.5 (COP 2.78)	Heat pump, COP 6.54 (about 22 SEER)	METr seasonal cooling COP
Hot water	Electric resistance, EF 0.86	Heat pump water heater, COP 3.5	
Lighting power, dwelling units	0.90 W/ft2	0.46 W/ft2	
Lighting power, common areas	0.72 W/ft2	0.45 W/ft2	Area-weighted across space types
Refrigerator	529 kWh/unit-yr	553 kWh/unit-yr	
Dishwasher	206 kWh/unit-yr	240 kWh/unit-yr	
Clothes washer	81 kWh/unit-yr	106 kWh/unit-yr	
Clothes dryer	615 kWh/unit-yr	217 kWh/unit-yr	Heat-pump dryer in Phius case
Ventilation airflow, fan power, plug loads, cooking	Same as Phius	Same as code	Held constant
Solar PV	Excluded	Excluded	329,000 kWh/yr in the actual project, removed from both

ENERGY USAGE COMPARISON

Metric	Code minimum (ASHRAE 90.1 App. G)	Phius design	Change
Annual site energy	2,979,227 kWh/yr	1,887,138 kWh/yr	-1,092,089 kWh/yr (-37%)
Site EUI	26.03 kBtu/ft2 -yr	16.49 kBtu/ft2 -yr	-9.54 kBtu/ft2 -yr
Space heating energy	344,262 kWh/yr	45,023 kWh/yr	-87%
Space cooling energy	412,097 kWh/yr	208,161 kWh/yr	-49%
Hot water energy	389,919 kWh/yr	148,802 kWh/yr	-62%
Lighting energy	842,344 kWh/yr	487,747 kWh/yr	-42%
Heating demand	10.0 kBtu/ft2 -yr	1.4 kBtu/ft2 -yr	-86%
Cooling demand	7.2 kBtu/ft2 -yr	7.9 kBtu/ft2 -yr	+10%
Peak heating load	10.5 Btu/h-ft2	3.0 Btu/h-ft2	-72%
Peak cooling load	3.1 Btu/h-ft2	2.3 Btu/h-ft2	-27%
Source energy	8,009 kWh/person-yr	5,073 kWh/person-yr	-37%

FINANCIAL IMPACT OF DEGRADATION [IN A RISING ENERGY COST ENVIRONMENT]

FINANCIAL MODELING ASSUMPTIONS

In order to visualize the effect of rising utility costs we modeled **NOI over time** of **Hillandale Gateway** vs. a **Code Minimum building**.

Certain assumptions were made:

- Gross Operating Income: Increasing @ 5%/ year
- OPEX (not including utility): Increasing @ 5%/ year

$$\begin{array}{ccccc} \text{Gross} & & & & \text{NET} \\ \text{Operating Income} & \text{—} & \text{Operating Expenses} & \text{=} & \text{Operating Income} \\ & & & & \text{(NOI)} \\ & & & & \\ & & \text{Utility Cost} & & \\ & & \text{Maintenance} & & \\ & & \text{Repairs} & & \\ & & \text{Staff} & & \\ & & \text{Taxes} & & \\ & & \text{Insurance} & & \end{array}$$

Rent

FINANCIAL MODELING ASSUMPTIONS

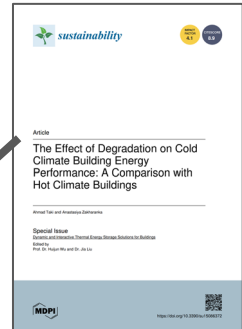
Utility Costs are NOT constant and are a function of three main drivers:

- Energy Usage : Starting with lower usage. [e.g. Hillandale at 37%]
- **Energy Cost Inflation** : Rising at various rates over time.
- **Performance Degradation** : Modeled at alternative annual degradation rates to test the financial sensitivity of differing long-term building performance.

- RECENT HISTORICAL GROWTH: **8.7%**
- HIGH ESCALATION SENSITIVITY: **10.0%**



Energy Costs (Annual Rate of Increase)	Code-Minimum Energy Degradation Rate (Annual Rate of Increase)		
	No	Low	High
8.7%	0.0%	2.0%	2.5%
10.0%	0.0%	2.0%	2.5%



Performance Degradation: Code-minimum energy consumption is modeled using the annual degradation assumptions shown above. **The resulting code-minimum increase above baseline is assumed to be approximately 1.9× the absolute energy increase of the high-performance building**, based on the relationship observed in the referenced study.

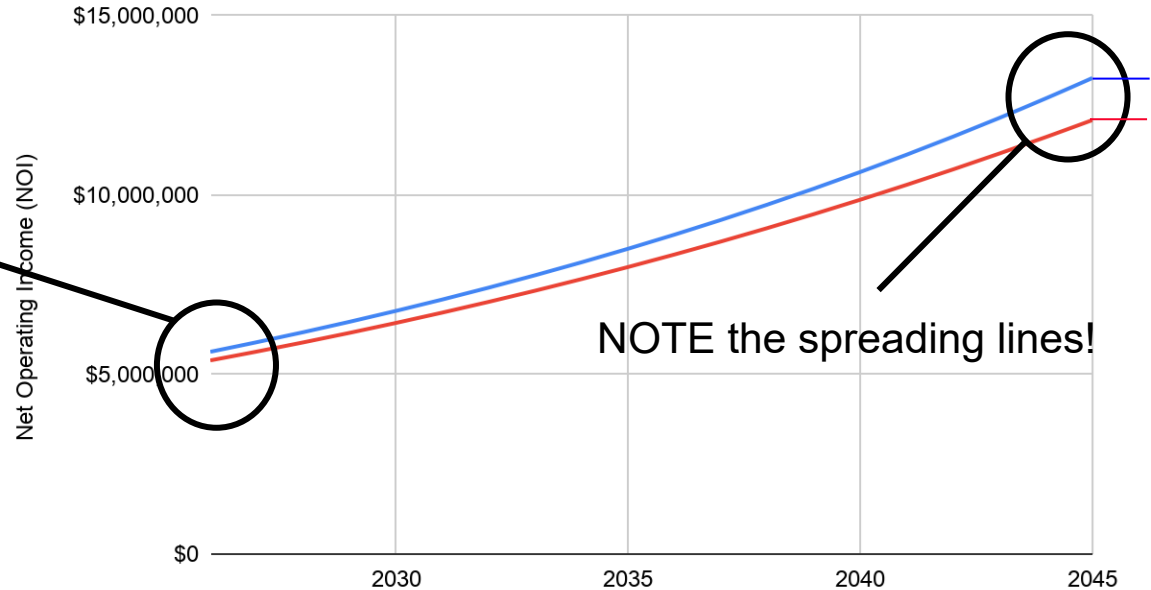
LOW ENERGY + NO DEGRADATION

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NOI OVER TIME

— Phius NOI — Code Min. NOI

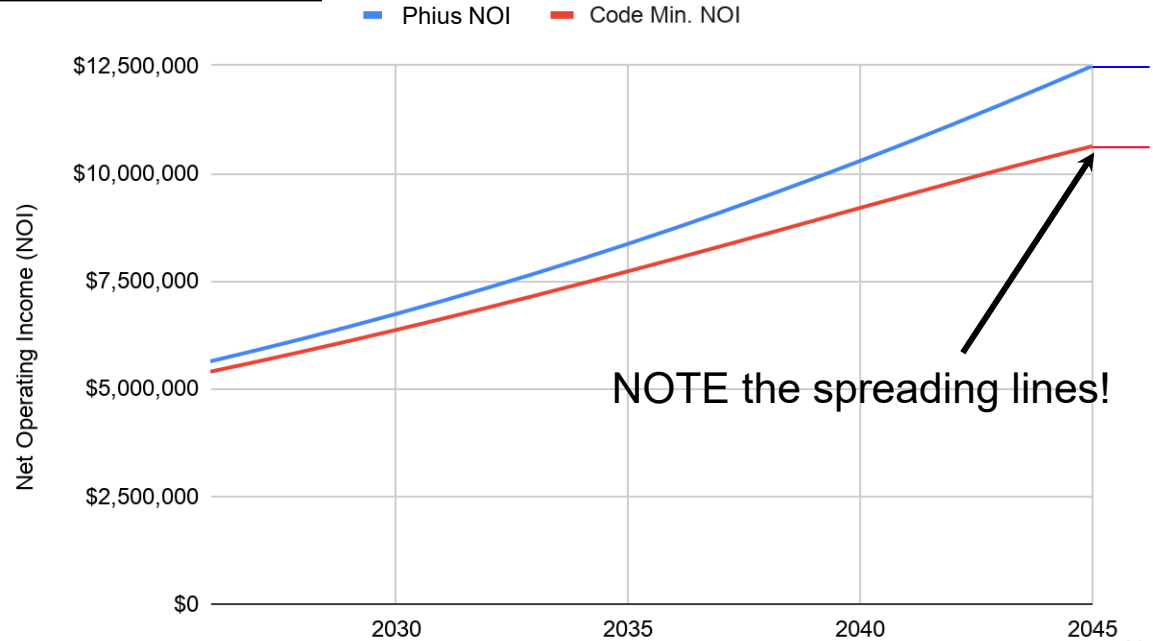
Impact to NOI of the initial
37% reduction in Energy Cost



LOW ENERGY + LOW DEGRADATION

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NOI OVER TIME

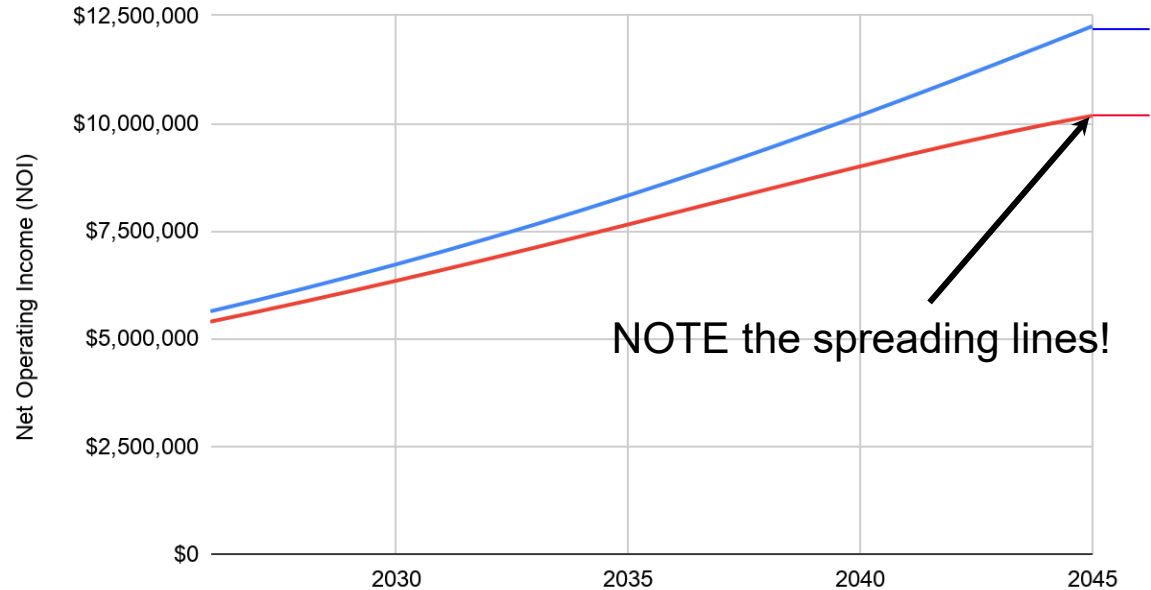


LOW ENERGY + HIGH DEGRADATION

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NOI OVER TIME

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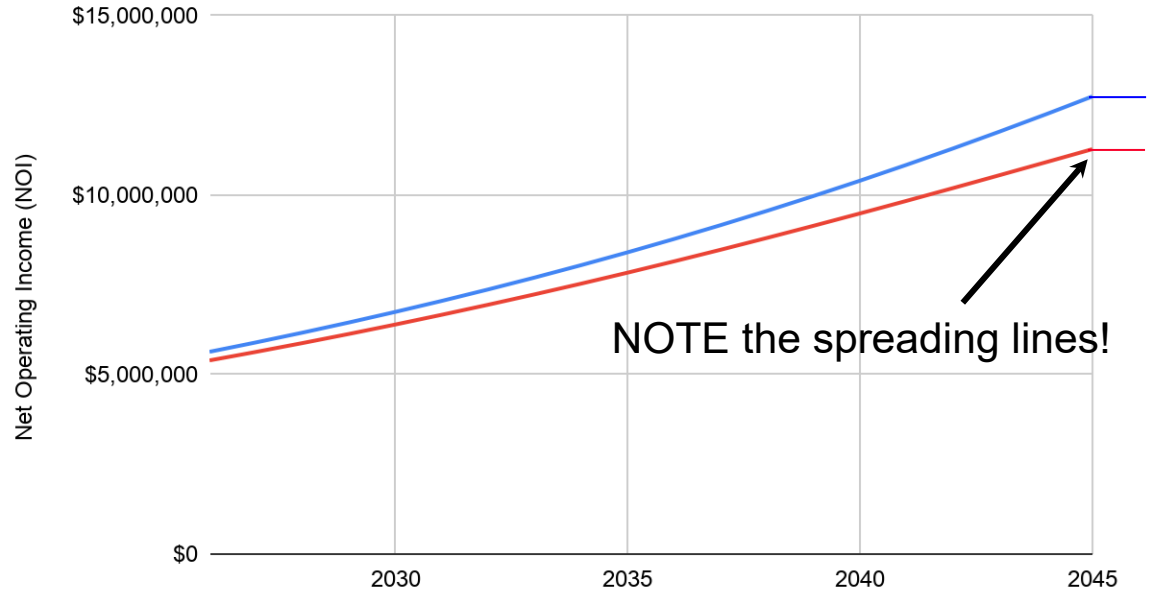


HIGH ENERGY + NO DEGRADATION

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NOI OVER TIME

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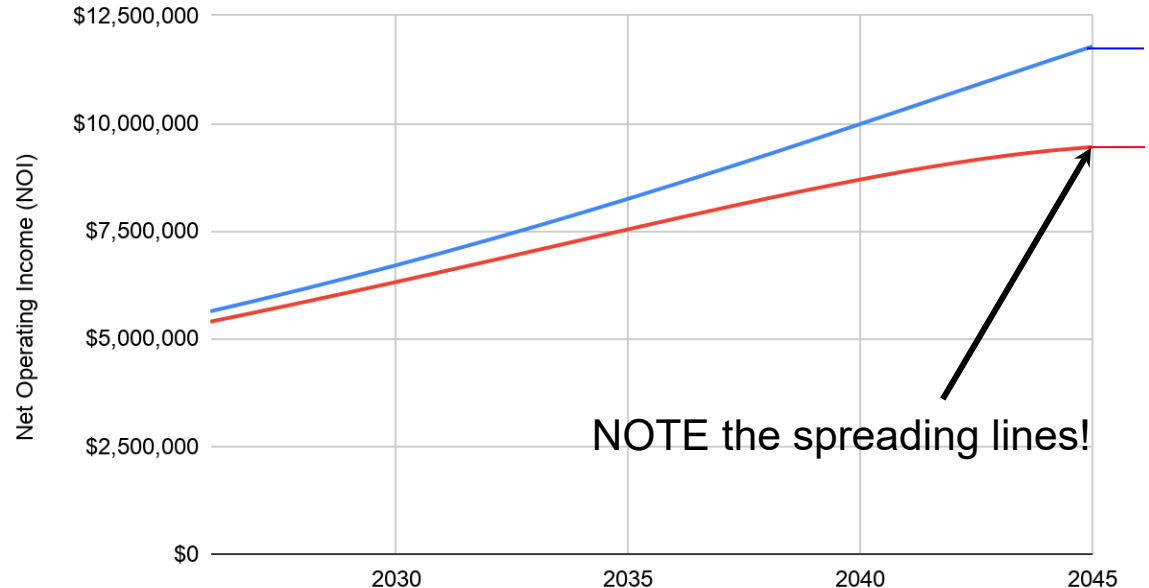


HIGH ENERGY + LOW DEGRADATION

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NOI OVER TIME

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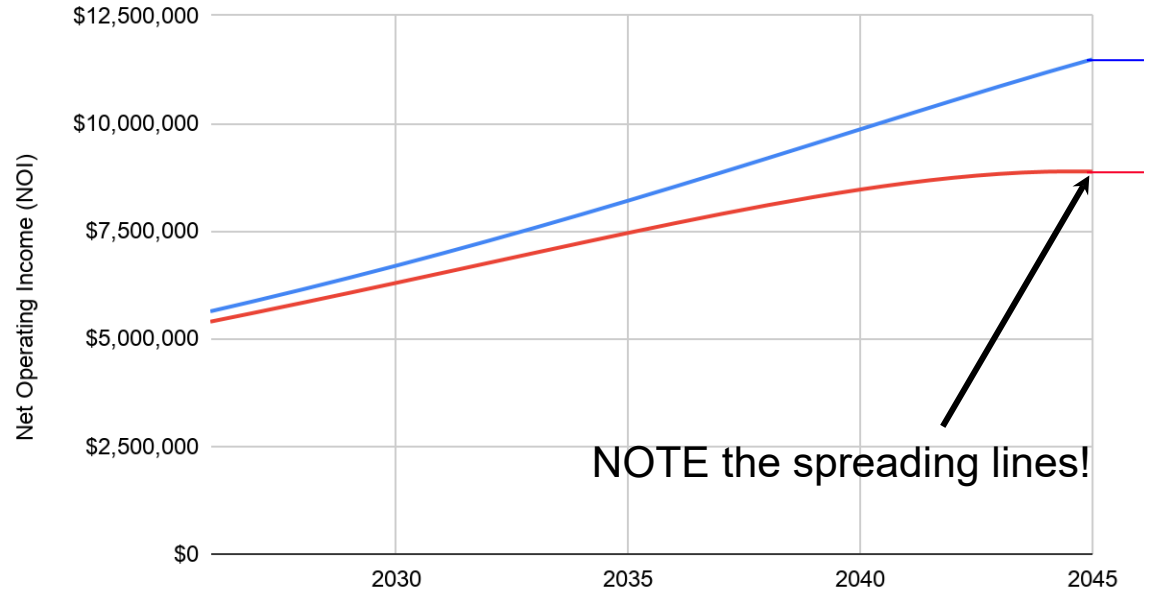


HIGH ENERGY + HIGH DEGRADATION

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NOI OVER TIME

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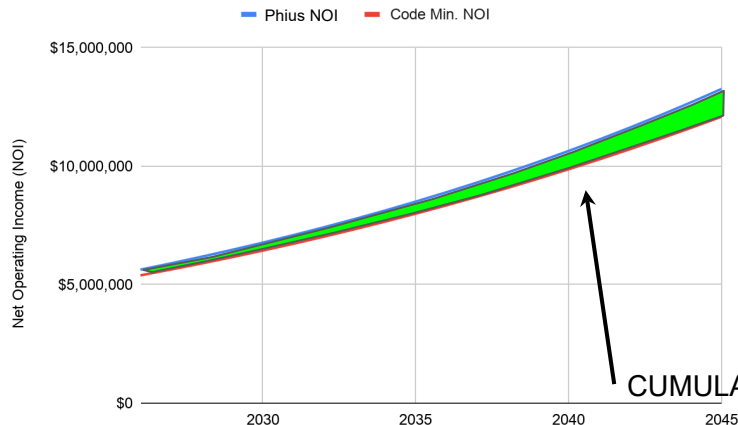


CONCLUSION

INCOME IMPLICATIONS

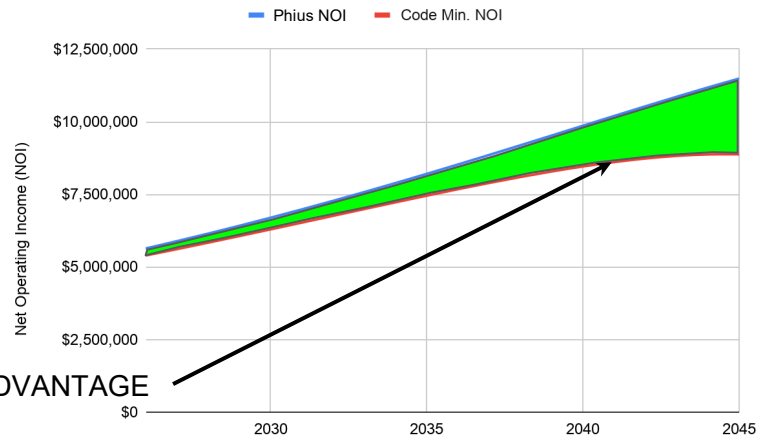
DIFFERENCES IN ENERGY PERFORMANCE DEGRADATION, COMBINED WITH RISING ENERGY COSTS, CAN RESULT IN MATERIALLY DIFFERENT LONG-TERM NOI.

NOI OVER TIME



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NOI OVER TIME



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Even without degradation, lower initial energy consumption creates an NOI advantage that grows as energy costs rise. When differential degradation is added to higher energy-cost inflation, the NOI trajectories diverge much more substantially

VALUE IMPLICATIONS

NOT ALL STREAMS OF INCOME ARE CREATED EQUAL!

NET Operating Income (NOI) = NET Operating Income (NOI)

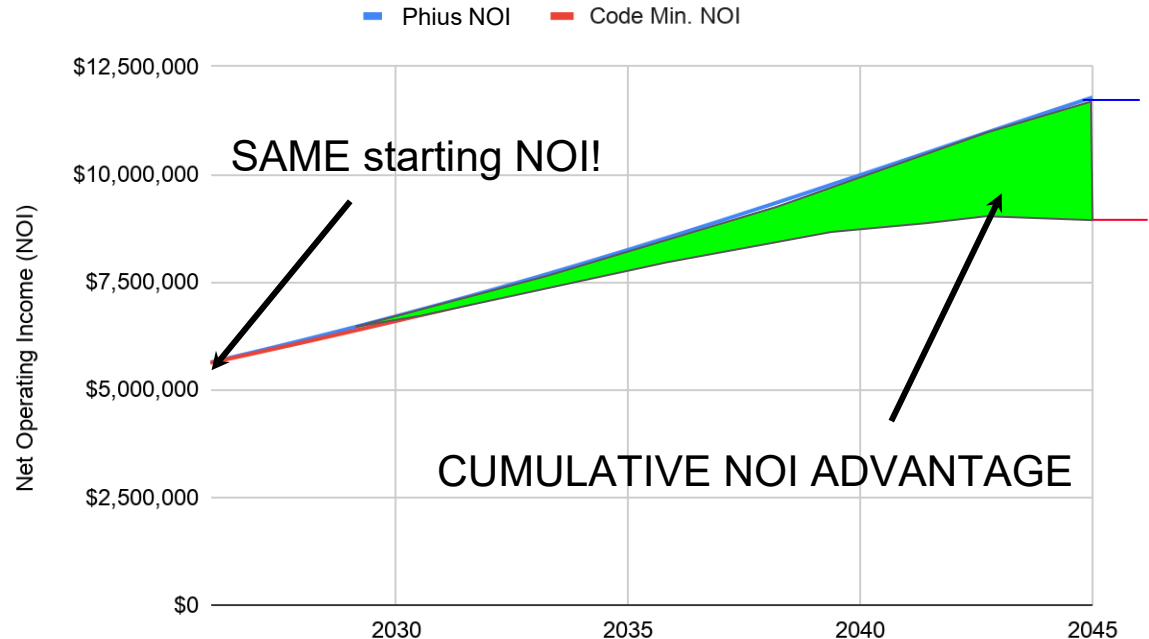
Market Conditions Location Interest Rates
Economic Growth Expected Growth Tenant Credit
Property Type Supply & Demand **Risk** Building Age
Income Stability Lease Terms Building Quality Operating Performance
Regulatory Risk Operating Expenses Insurance Costs
Capital Expenditures Obsolescence Risk Market Liquidity

CAP RATE



CAP RATE

NOI OVER TIME



ILLUSTRATIVE VALUATION

Passive building

- Net Operating Income: \$6,000,000
- CAP RATE: **5.75%**
- Building Value: **~\$104.35 million**

Code compliant building (typical)

- Net Operating Income: \$6,000,000
- CAP RATE: 6%
- Building Value: \$100,000,000

↖ A hypothetical **25-basis-point** cap-rate ↗
differential produces approximately
\$4.35 million of additional value.

NET
Operating
Income
(NOI) = NET
Operating
Income
(NOI)

Cap
Rate $\neq$ Cap
Rate

Building
Value $\neq$ Building
Value

DESIGN IMPLICATIONS

Designers have the ability to affect Degradation with informed design choices:

- **Air Seal** : A major driver of envelope related energy degradation; maintaining air-barrier continuity is critical to preserving energy performance over time.
- **Insulation** : Choose durable and long-lasting materials that have minimal thermal drift over time.
- **Windows** : Performance is tied to quality of seals, retainage of insulating gasses (if used), and protection from direct sunlight and overheating.
- **HVAC** : Favor durable, maintainable systems that minimize field-installed connections and other potential points of performance degradation.

THANK YOU

THE COST OF DECAY

How Building Degradation Amplifies the Value of Passive Building

