Resilience as a Measure and its Impact on Energy Use Intensity and finance of Commercial Buildings

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Building as a Battery

Bodies at rest tend to stay at rest and bodies in motion tend to stay in motion unless acted upon by an external force. Getting a body at rest into motion comes at disproportionately intense energy expenditure and we tend to accept this expense of energy too rigidly and uniformly in our practice of Energy Management in buildings. Too often we are guided by the linear "0 to 60 mph" destination and overlook closer examination of the nonlinear journey between lower and upper limits and forfeit optimization. This is certainly not so in all areas relating to energy. Batteries for instance are engineered with an exact understanding of the non-linear relationship between remaining capacity and rate of discharge.

Understanding the energy gradient of a building's thermal capacitance is critical to developing efficiency in the use and application of energy. What insights might the analytics reveal using data that we derive from existing Building Automation System data in our "0 to 60 mph" analogy, if we segmented this transit into bins of 10 mph (0 – 9 mph, 10 – 19 mph, etc.)? Could those insights influence subsequent observations if we implement some adjustments? It is easy to imagine it would mirror what every track & field coach has observed in any footrace ever, no matter the distance: they are deeply interested in interval times because they understand performance varies over a continuum and they are vested in teasing out optimized performance whenever available.

We cannot manage what we do not measure. Conceiving Thermal Energy Storage as an asset worthy of the effort to develop it into a control input is vital to building a business case for optimization that extends well beyond Return on Investment. As an asset, Thermal Energy Storage holds extrinsic value - both operational and financial - that does not depreciate but requires the construction of a system to persistently reveal it. The effort to develop Thermal Energy Storage as a control input is justifiable.

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TES, the ghosted HVAC asset

Thermal Energy Storage (TES) is an insufficiently appreciated and misunderstood asset that is a critical element of Energy Management. TES is also a non-depreciating derivative asset that exists within the depreciating asset that is a building but to truly exploit its value, one must adapt from an implicitly clinical understanding of thermal capacitance across an enterprise to realize a suite of virtual building Thermal Energy Meters as distinct object instances with explicit States of Charge, Distances to Changes of State and Rates of Charge as attending objects with data streams. When TES can be used as a critical input in Energy Management it fulfills its value potential and plays a vital role in the development of Resilience as a Measure.

HVAC assets are too often looked upon as isolated data objects, or data objects that exist within a sequence of operation, but the operation of HVAC assets do not explicitly recognize the thermal characteristics of a building's structure and contents. Except in rare instances, data needed for TES are beyond the data stream of a building's HVAC assets and in this ghosted condition, TES is an unrecognized asset that consigns enthalpy to a continually unknown state of being that makes no measurable contribution to an enterprise's energy efficiency. Optimization changes that.

TES as a derived non-depreciating asset

Even as we understand that heat does not dissipate in synchrony with the use of the specific volume of electricity that supports mechanical cooling operations nor does heat dissipate at a constant rate over a 24 hour period, a concerted effort equal to the challenge of deriving TES measures in a virtual battery model has not been made. Possibly this is because making a business case for TES without supporting data makes the challenge insurmountable. However, if we position TES to make it integral to energy efficiency, then making the business case eases considerably.

Several studies have been conducted that statistically correlate energy efficiency and mortgage lending and default rates. Three studies of note are:

1. The Pricing Risk of Energy Use Intensity for Office and Multi-Family Mortgages by Paulo Issler, Paul Mathew & Nancy Wallace, May 2020

2. Should commercial mortgage lenders care about energy efficiency? Lessons from a Pilot Study by Paul Mathew, Paulo Issler & Nancy Wallace, 2021

3. Impact of Energy Factors on Default Risk in Commercial Mortgages by Nancy Wallace, Paulo Issler, Paul Mathew, and Kaiyu Sun, September 2017

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Unsurprisingly, EnergyStar is the standard bearer benchmarking vehicle cited by Issler, Mathew and Wallace in The Pricing Risk of Energy Use Intensity for Office and Multi-Family Mortgages. EnergyStar uses Source Energy Use Intensity (EUI) expressed in units of 1,000 BTUs (kBTU) per square foot, as the comparative metric. The authors scaled the EUI to the Net Operating Income (NOI) as indicated in the loan data they surveyed and then parsed their analysis into commercial buildings and multi-family buildings segments. This examination focuses only on the analysis relating to commercial buildings.

The Business Case for TES beyond ROI: Impact on Finance

The authors statistically established a positive relationship between commercial building Scaled EUI and the points applied to mortgages by plotting these two data on a graph and developed a strong correlation that renders the following slope intercept:

$$y = .0021x - 0.0261$$

We can apply the Slope Intercept to the study's EUI range in 5 kBTU increments (excluding outliers) to get a reasonable sense of scale of EUI's impact on a modest mortgage over the life of the note:

Slope Intercept:		y = 0.0021x - 0.0261	
Mortgage		$5,000,000	
Annualized Scaled Source EUI (kBTU/SF)	Annualized kWh EUI Equivalent	Points	Scaled Source EUI impact on Loan Note
0	0.00	-0.0261	-$130,500
5	1.47	-0.0156	-$78,000
10	2.93	-0.0051	-25,500
15	4.40	0.0054	$27,000
20	5.86	0.0159	$79,500
25	7.33	0.0264	$132,000
30	8.79	0.0369	$184,500
35	10.26	0.0474	$237,000
40	11.72	0.0579	$289,500

The business case for TES is that each kBTU per square foot increases the cost of a mortgage by 0.21% per square foot and that by decreasing the EUI, the borrowing power is improved with lending institutions along this same gradient.

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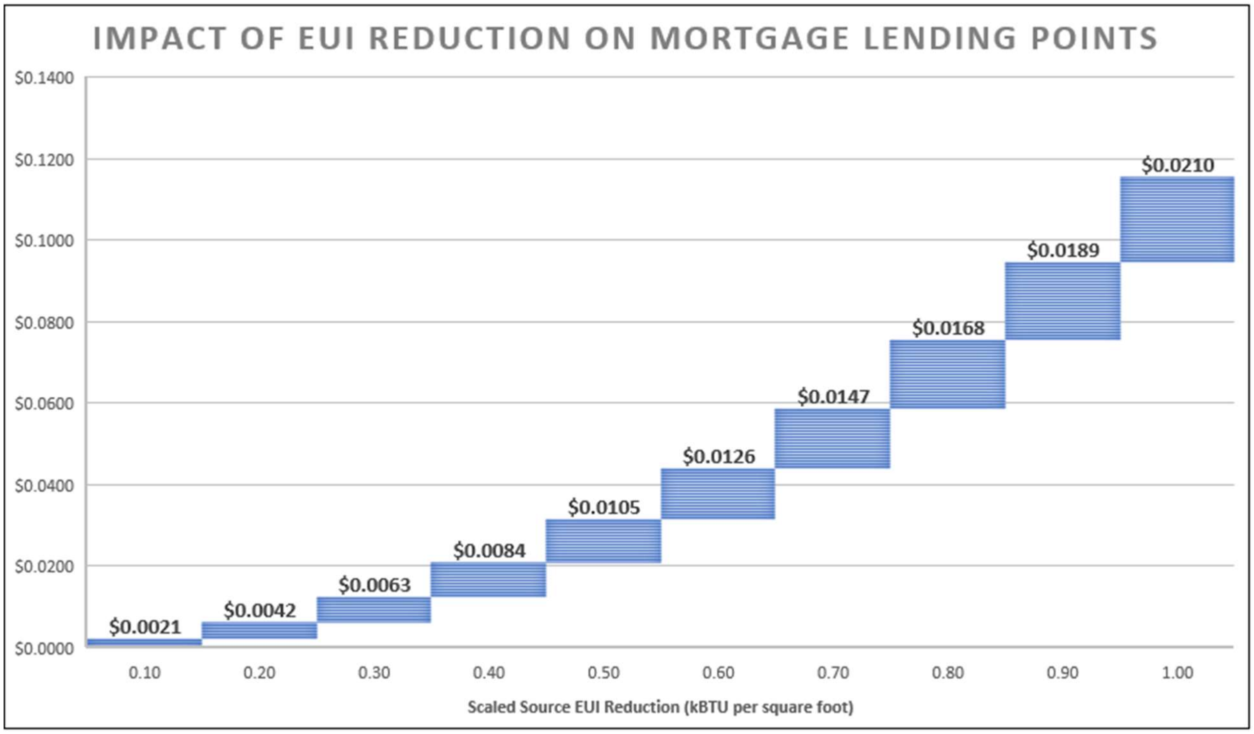

Bridging performance and benchmarking

EnergyStar scores are refreshed annually as new utility invoice data are collected and each building is assigned an annual percentile score relative to peer buildings that also subscribe to EnergyStar (US and Canadian authorities share the EnergyStar methodology but US and Canadian peer buildings are surveyed separately and kept distinct from one another). The survey methods over time are subject to revision, which the DEP indicates happens about every five years.

In the eyes of an Energy Manager, EnergyStar scores reflect a glacial timescale leaving them blind while awash in data acquired from their Building Automation System (BAS) suite as to how the enterprise's buildings are trending on the broad measure of EUI. If we go beyond the data the BAS provides and develop a functioning data model of a battery and use the resulting derived data as a control input, we can quantify and use TES to impact EUI.

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Battery Modeling: Peukert's Law

The engineering science behind battery operations is vast, but Peukert's Law which expresses the change in capacity of lead-acid batteries at different rates of discharge succinctly covers the elements we endeavor to understand in TES:

$$t = H(\frac{C}{IH})^k$$

H: rated discharge time (in hours)
C: rated capacity at that discharge rate (in ampere hours)
I: actual discharge current (in amperes)
k: Peukert constant (dimensionless, commonly between 1.1 and 1.3)
t: actual time to discharge the battery (in hours)

Puekert's Law serves as a template for how we may develop a model for TES due to the nonlinear relationship between a building's remaining thermal capacity and rate of discharge. By creating a TES model that accounts for nonlinear capacity we can trend remaining capacity in a burndown-like fashion. This higher level of abstraction means that we can capture TES algorithmically and utilize it as a control input, with the ultimate objective of reducing EUI and thereby improving financial position with lending institutions.

Resilience as a Measure

To distill the essence of TES to its operational least common denominator, the near term objective is to precisely predict when the crossover points between TES discharge and mechanical HVAC will occur (t in Peukert's Law) so that we can accurately and automatically align control parameters in timely fashion. Below is a loose representation of how TES and mechanical cooling might interact by degree of Outside Air Temperature. This graph conveys Resilience as a Measure expressed in terms of possible percentage reductions in mechanical cooling rates between passive unmeasured TES and active measured TES as a control input over a range of temperatures. The greater the area that active TES (crosshatched blue area) can displace mechanical cooling (red area), the greater the reduction in EUI and increased financial leverage.

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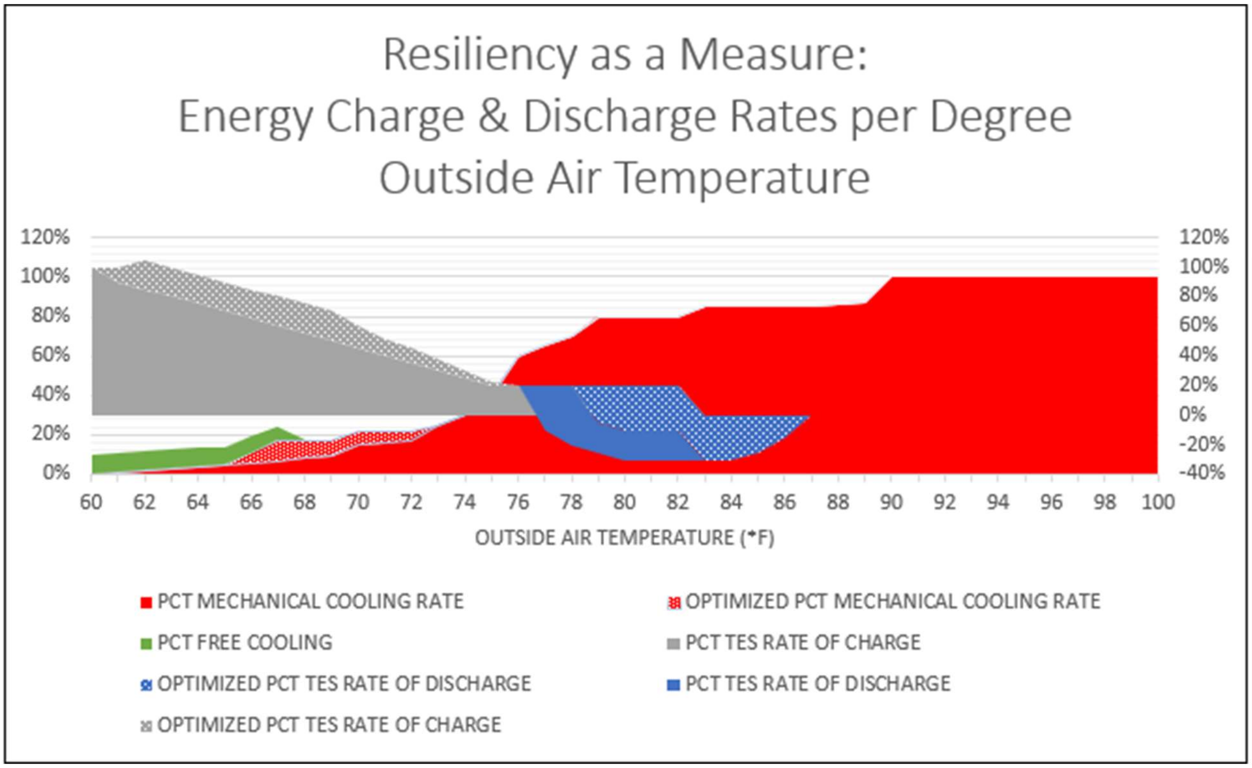

Conclusion: Near and Long Term

In the near term before active TES becomes more widely adopted, intentional and measured use of TES presents an opportunity using existing technology already in place to improve Energy Star scores relative to benchmarking peer groups by reducing EUI using derived data and measures, which would strengthen a building owner's position in the financial marketplace. In a manner of speaking the building owner would hold additional equity in the building not subject to taxation.

Once active TES becomes more widely adopted over the longer term and as the surveys behind the peer benchmarking groups are updated, at minimum active TES would maintain a building's relative Energy Star score. However, being slow to adopt active TES over time will become an error of omission and will negatively impact one's Energy Star score as peer buildings actively use TES and this would result in less attractive finance terms.