Maintenance and Operations of Building Systems

Edward von Bleichert, CEFP
Sustainability & Resiliency Program Manager
University of Colorado Boulder

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Course Description

Maintenance & Operations of Building Systems - APPAU201909B

This session will present an overview of the basic principles in maintaining and operating the various systems in higher education facilities.

The discussion will identify building systems and their components, operating characteristics, and general maintenance practices.

This course is intended to provide a basic overview as a foundation for **electives** that will address more detailed, technical information related to specific facility systems.

Deeper Dive

Current Institute Curriculum:

- O&M Management (Zumbrunn)
- Plant Renewal, DM & TCO (Thiemer)
- Reliability Centered Maintenance (Smeds) – *today*
- Maintaining Historic Properties (Stanis) *Elective*
- Retro Commissioning - an O&M Perspective (Boyette) *Elective*

Historic Offerings

- 525 – Mechanical Systems
- 532 – Preventive / Predictive Maintenance
- 545 – Designing for Maintainability
- 655 – O&M Staffing Levels
- Building Automation Systems

Learning Objectives

1. Learn to ensure effective implementation and control of operation activities
2. Learn to ensure efficient, safe, and reliable process operations
3. **Learn to be cognizant of status of all equipment**
4. Learn to ensure that operator knowledge and performance will support safe and reliable facilities operation

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Goal

To provide background on maintenance and operating issues of building systems so that facilities management personnel can understand the advantages and limitations of these systems and their operating practices.

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Course Outline

- Introduction
- Building System Identification
- Building System Requirements
- Major Building Systems
- Operation and Maintenance Issues

Personal Introduction

- Division of Infrastructure & Sustainability
- Sustainability Program Manager as of 1/1/17
- Formerly the Assistant Director for Environmental Operations
- Current Focus
  - High Performance Construction
  - Electrification
  - Reporting
  - Operational Support
- Former programs
  - In-house waste collection & processing
    - Recycling, composting, solid waste
    - On campus recycling facility
    - Service contracts
  - Integrated Pest Management (IPM)
  - Wildlife management

Intro Cont'd

- 19 yrs. of experience maintaining heavy fleet vehicles
- Management of on campus recycling facility
  - replaced in 2015
- Capital construction experience
  - Balance btwn. 1st cost, performance, maintainability
- Learned to make sustainability work from an O&M standpoint
  - Will revert to norm if not practical
- Integrated Pest Management
  - Manipulation of the environment

Temporary Facility

Forced to prioritize certain maintenance needs like heating & cooling

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The Building Blocks of Good Operations

Understand Needs → Understand System Characteristics → Operate System Appropriately

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Why are there systems in buildings?

- People
- Animals
- Research
- Equipment
- The building itself

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Building System List

- Architectural / Structural:_______________
- Mechanical:___________________________
- Electrical:_____________________________

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Mechanical System - Heating, Ventilation, Air Conditioning (HVAC)

Heating, ventilation, and air conditioning is the use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space.

Its goal is to provide:

- Human Thermal Comfort
- Acceptable Indoor Air Quality (IAQ).

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Six Variables of Human Thermal Comfort

1. Dry Bulb Temperature (°F)
2. Relative Humidity (%RH)
3. Air Velocity (fpm)
4. Mean Radiant Temperature (°F)
5. Activity Level (MET)
6. Clothing Level (Clo)
7. TIME

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Human Thermal Comfort Relationships

Variable	Range	Relationship
RH	30% to 60%	1 °F = -15% RH
Air Velocity	50 to 300 fpm	1 °F = 50 fpm
MRT	Room Temp.	1 °F = -0.7 °F
MET	1.0 to 3.0 MET	1 °F = -0.2 MET
Clo	0.5 to 3.0 Clo	1 °F = -0.06 Clo

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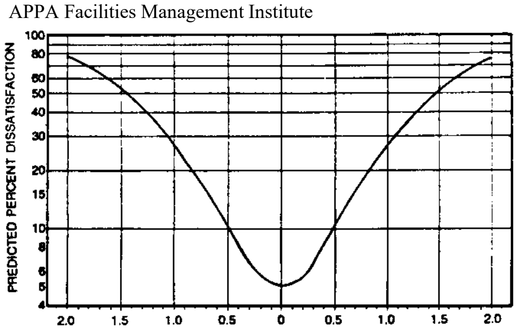

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Thermal Environmental Conditions for Human Occupancy

The American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc.

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Typical Relative Humidity Levels

• Museums	40% to 50%
• Libraries	40% to 50%
• High Tech	20% to 70%
• Laboratories	30% to 70%
• Office	30% to 40%

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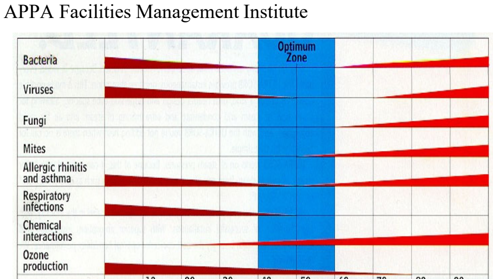

Criteria for Human Exposure to Humidity -1985 by Dr. Elia Sterling

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INDOOR AIR QUALITY

Sick Building Syndrome (SBS)
Building Related Illness (BRI)

Examples?

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Causes of SBS and BRI

- Toxic Gases
- Volatile Organic Compounds
- Biologicals
- Particulates
- Long-term Hazards
  - Asbestos
  - Radon

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Three Methods to Control Indoor Air Quality

1. Remove (contaminant)
2. Ventilate
3. Dilute

Impacts of COVID

- Increase in outdoor air (ventilation)
  - Requires additional heating or cooling
- MERV 13 filters
  - Motors using more amperage b/c of more restrictive filter
- Treating / scrubbing at the room level (rolling equipment)
  - More frequent filter changes

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Odor Threshold for Common Pollutants (mg/m^3)

- Hydrogen Sulfide - 0.007
- Ozone - 0.2
- Formaldehyde - 1.2
- Sulfur Dioxide - 1.2
- Ammonia - 33
- Propane - 1800
- Carbon Dioxide - Infinite
- Carbon Monoxide - Infinite

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Ventilation
for Acceptable
Indoor Air Quality

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Space Type	Ventilation Rate	
	CFM/SQFT	CFM/Per
• Offices	0.06	5
• Classrooms	0.06	7.5
• Conference	0.06	5
• Computer Lab	0.12	10
• Lobbies	0.06	7.5
• Bedroom	0.06	5
• Restaurant/Dining	0.18	7.5

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Heating, Cooling, Ventilating Design Issues

- Type of use – lab vs. classroom
- Occupancy - # of people
- Climate - HDD, CDD, humidity
- Orientation – solar exposure
- Footprint – size & shape, thermal bridging
- Building Envelope – window to wall (W:W) ratio, window quality, insulation, materials

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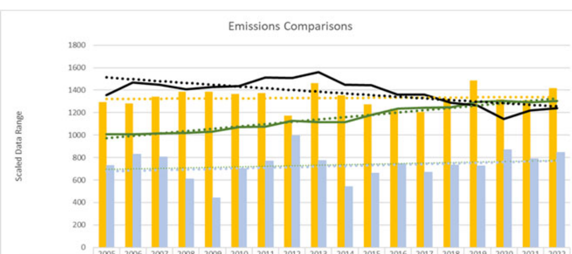

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HDD x 1.75	1293	1284	1342	1386	1384	1366	1375	1174	1464	1354	1274	1233	1207	1322	1487	1317	1311	1419
CDD	728	828	805	607	440	701	767	993	773	540	660	746	668	733	726	867	789	845
GSF x 10,000	1008	1006	1014	1021	1029	1072	1075	1128	1116	1117	1178	1236	1244	1249	1296	1303	1293	1304
MTCO2e x 100	1356	1469	1450	1409	1430	1435	1513	1508	1560	1448	1445	1361	1360	1288	1264	1145	1219	1240

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Three Fundamental Types of Systems

1. All Air Systems
2. All Water Systems
3. Air and Water Systems

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Types of Control

- Two Position
- Floating
- Proportional
- Integral
- Derivative

Analog: on/off, 1's & 0's
vs.
Digital: grading scale, range instead of open or closed

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Types of Control Power

- Electric
- Electronic
- Pneumatic
- Fluidic
- Hydraulic
- **Microprocessor**

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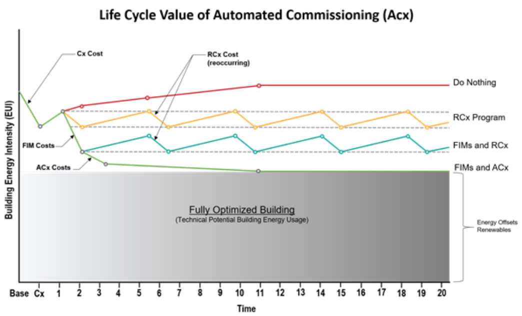
Energy Conservation Strategies

- Off-hour Setback
- Reset (Master/submaster)
  - Mixed Air Control
  - Drybulb Economizer
- True Economizer
- PID Control
- Adaptive Control

Energy Management Saw-tooth



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Fire Codes

- NFPA - National Fire Protection Association
- UFC - Uniform Fire Code
- BOCA - Basic Fire Prevention Code
- Southern Standard Fire Prevention Code
- Fire Prevention Code by AIA

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Fire protection based on:

1. Building Classification

- Non-combustible
- Combustible
- Building Elements
  - Exterior Wall
  - Primary Structural Frame
  - Floor Construction

  AND…

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2. Occupancy Classification (NFPA 101)

Example Criteria

- *Assembly* - automatic sprinkler system
- *Labs* (Research) - automatic extinguishing
- *Business* - no specific requirements
- *Residence Halls* - no specific requirements

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National Fire Protection Assoc. (NFPA) 101

- ✓ Classrooms under 50 people - Business
- ✓ Classrooms over 50 people - Assembly
- ✓ Labs, instructional - Business
- ✓ Labs, research - Industrial

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Fire Detection Methods

1. Heat Detection
2. Rate of Rise
3. Smoke Detection
4. Ionization Detection
5. Cross Zone Detection

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Fire Extinguishing Systems

Automatic Sprinklers
- Wet Pipe
- Dry Pipe
- Deluge
- Fire Cycle

Chemical Systems
- HALON (no longer used)
- CO_2

Standpipe Systems - Dry & Wet

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IES LIGHTING HANDBOOK

Application Volume

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA

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Space Type	Footcandles
Office Space	20 - 50
Classrooms	50 - 100
Conference Rooms	20 - 50
Laboratories	50 - 100
Libraries	20 - 50
Lobbies	10 - 20
Dining Rooms	5 - 10
Outdoors	1 - 3

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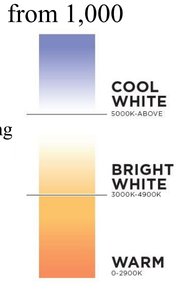
Lamp Coloring

Absolute color temperature is measured in degrees of Kelvin (K) on a scale from 1,000 to 10,000.

- Allows you to describe the quality of a light (warm vs. cool)
- In commercial and residential lighting Kelvin temperatures fall somewhere on a scale from $2000^{o}K$ to $6500^{o}K$.



Lamp Coloring

Color Rendering Index (CRI) is **a measurement of how natural colors render under an artificial white light source when compared with sunlight**.

- The index is measured from 0-100, with a perfect 100 indicating that colors of objects under the light source appear the same as they would under natural sunlight.
- It is arbitrarily based on an incandescent lamp having a CRI of 100.
- Typical office and classroom values are $3500^{o}K$ and a CRI of 70 to 75.

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LAMP	Lumens/Watt	CRI	Life (hrs)
Incandescent	17-22	100	800
Mercury Vapor	42-57	Blue/White	4,000
Fluorescent	65-80	70	6,000
Metal Halide	75-85	65	15,000
HPS	85-125	21	25,000
LPS	125-140	0	25,000
Induction	130-190	85	100,000
LED	60	Varies	100,000

Implications of Poor Maintenance

- Loss of efficiency / performance
- Code compliance
- Loss of research – ULT freezers
- Safety – fire, egress
- Health - IAQ / IEQ (SBS, BRI)
- Budget planning – unforeseen emergencies
- Loss of revenue – EV network, food service

Routine Maintenance

Operational funds provided to do daily tasks of service and maintenance

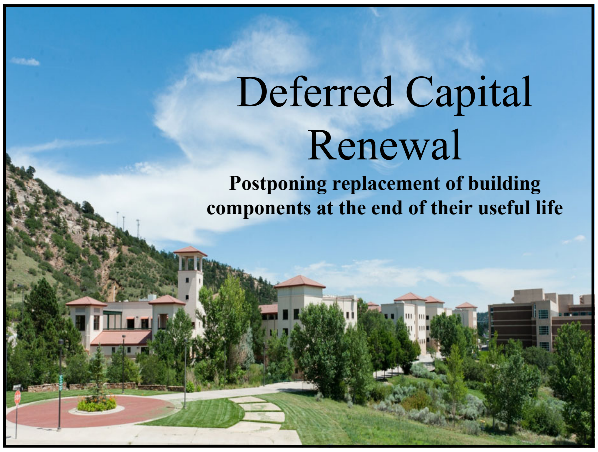

Major Repairs
Funds budgeted each year to make repairs that are outside routine maintenance funding


Deferred Maintenance
Routine maintenance and major repairs that are not done due to insufficient resources


Capital Renewal
Funds that are provided to replace building components at the end of their useful life

Deferred Capital Renewal

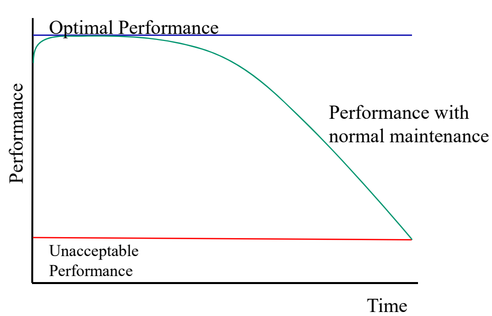
Postponing replacement of building components at the end of their useful life

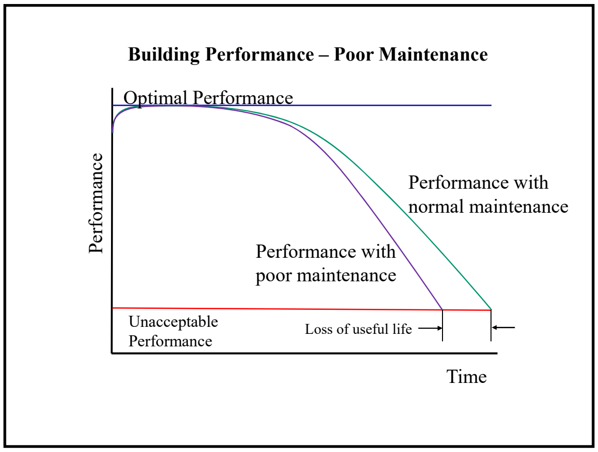


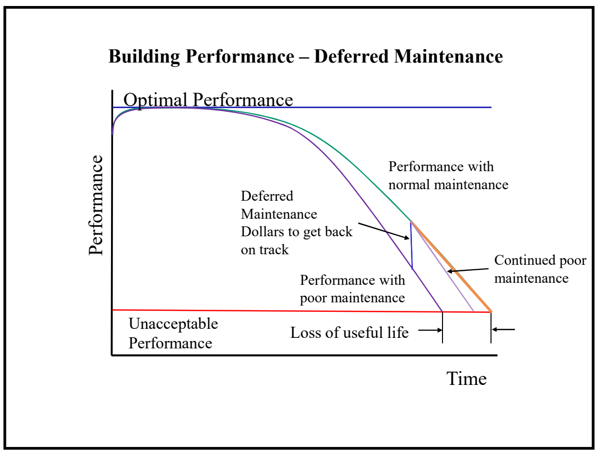
Capital Improvement

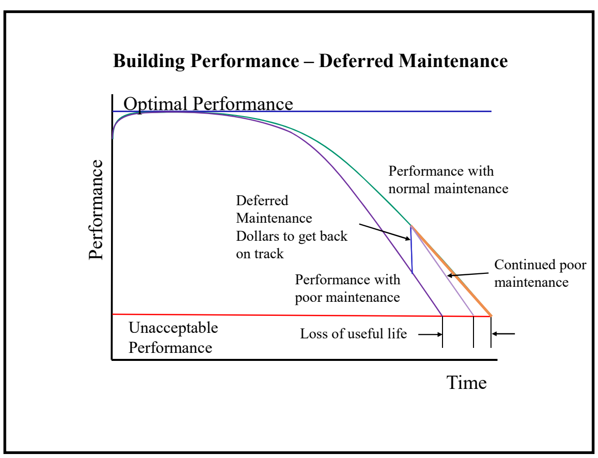
A change to a building component not driven by end of life or deferred maintenance

Building Performance - Normal




Building Performance – Poor Maintenance
Optimal Performance
Performance
Performance with
normal maintenance
Performance with
poor maintenance
Unacceptable
Performance
Loss of useful life
Time


Building Performance – Deferred Maintenance
Optimal Performance
Performance
Performance with
normal maintenance
Deferred
Maintenance
Dollars to get back
on track
Continued poor
maintenance
Performance with
poor maintenance
Unacceptable
Performance
Loss of useful life
Time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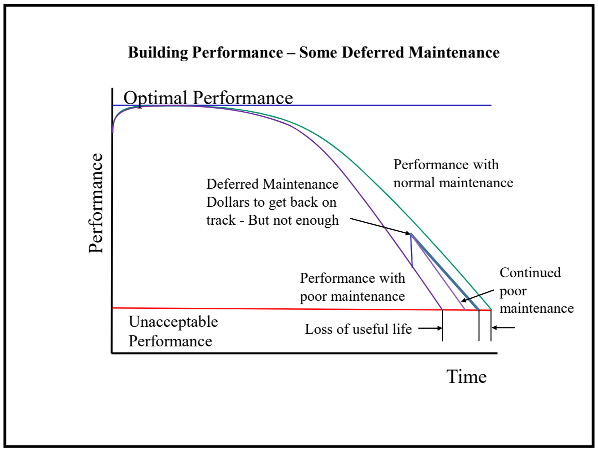
Building Performance – Some Deferred Maintenance
Optimal Performance
Performance
Deferred Maintenance
Dollars to get back on
track - But not enough
Performance with
normal maintenance
Performance with
poor maintenance
Continued
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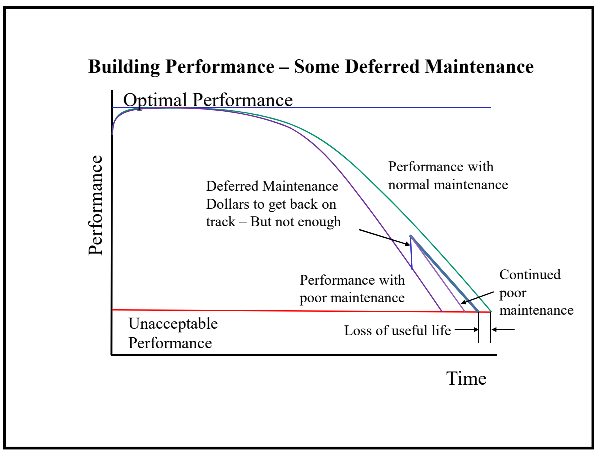
maintenance
Unacceptable
Performance
Loss of useful life
Time


Building Performance – Some Deferred Maintenance
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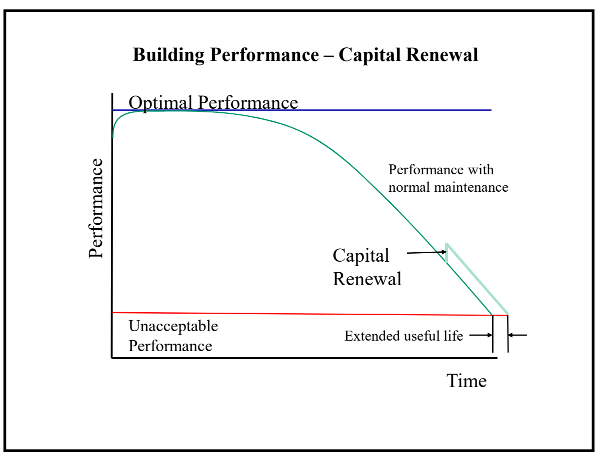
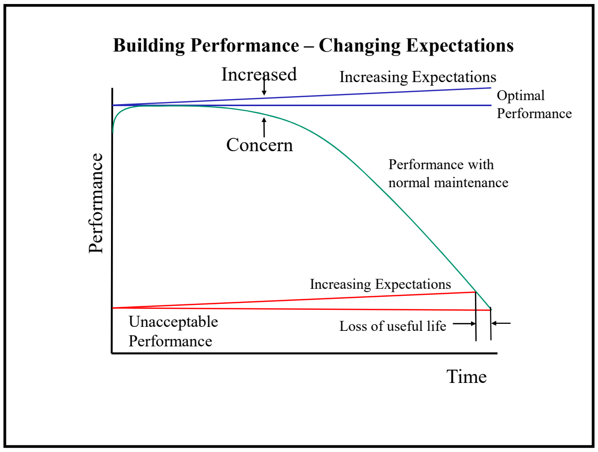
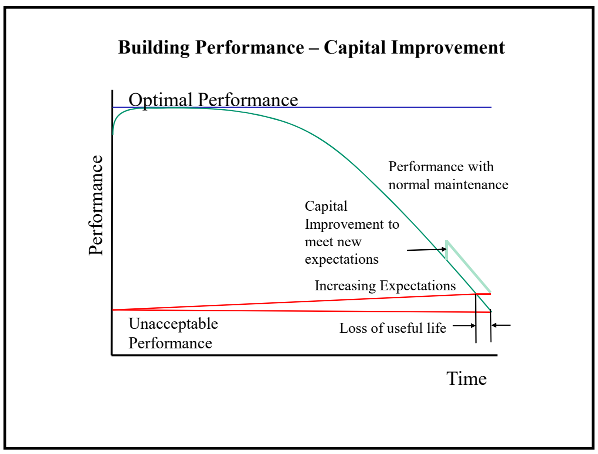
Unacceptable
Performance
Loss of useful life
Time

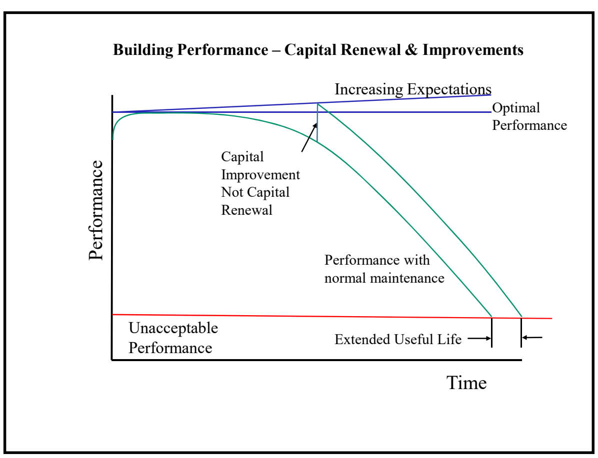

Building Performance – Capital Renewal
Optimal Performance
Performance
Performance with
normal maintenance
Capital
Renewal
Unacceptable
Performance
Extended useful life
Time



Building Performance – Changing Expectations
Increased
Concern
Increasing Expectations
Optimal
Performance
Performance with
normal maintenance
Performance
Increasing Expectations
Unacceptable
Performance
Loss of useful life
Time

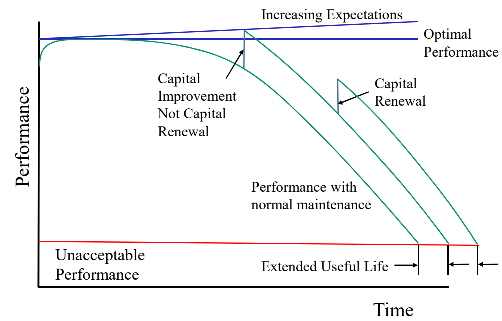


Building Performance – Capital Improvement
Optimal Performance
Performance with
normal maintenance
Performance
Capital
Improvement to
meet new
expectations
Increasing Expectations
Unacceptable
Performance
Loss of useful life
Time



Building Performance – Capital Renewal & Improvements
Increasing Expectations
Optimal
Performance
Capital
Improvement
Not Capital
Renewal
Performance
Performance with
normal maintenance
Unacceptable
Performance
Extended Useful Life
Time

Building Performance – Capital Improvement & Renewal



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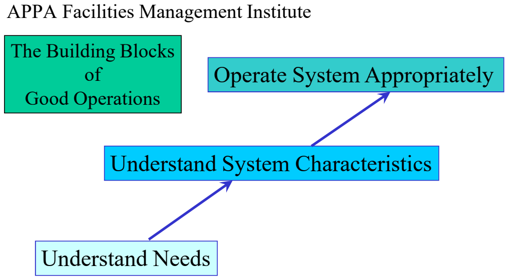

Takeaways

- Systems are increasingly complex
- Good maintenance has many benefits
  - Tends to be underfunded despite being best value
- Many implications to poorly maintained systems
- Useful life can be extended

Thank you!

Ed von Bleichert
Sustainability & Resiliency Program Manager
Division of Infrastructure & Sustainability
University of Colorado Boulder
vonb@Colorado.edu
www.Colorado.edu/fmgreen