Energy Upgrades in Historic Buildings - Case Study:

The Metropolitan Museum of Art
1000 Fifth Avenue
New York, NY

February 2, 2022
PANELISTS

Brett Gaillard, Head of Capital and Infrastructure Planning
The Metropolitan Museum of Art

Jasmin Rivera, Director
Accelerated Conservation and Efficiency Program
NYC Department of Citywide Administrative Services

Michael Wetstone, Principal
Beyer Blinder Belle Architects & Planners LLP

Henry Miller, Senior Associate
Beyer Blinder Belle Architects & Planners LLP

Erik Bodelsen, Partner
Kohler Ronan Consulting Engineers

David Mackay, Principal
Kohler Ronan Consulting Engineers

Moderator: Madhav Munshi, Associate
Kohler Ronan Consulting Engineers
Overview of the Met
• The Met Fifth is comprised of 21 wings, the first built in 1880 and the last completed in 1991
• The building encloses 2.1 million square feet of floor area
• The building footprint is 1,000 feet long and 600 feet deep
• In 2019 the Met welcomed 7 million museum visitors
Curating & Caring for our Collection of Buildings: Met Fifth
Curating & Caring for our Collection of Buildings: Cloisters
Managing Change
Our Buildings Support our Mission
Mission Driven Planning

Key considerations for planning and prioritization:

✔ Programmatic priorities and contribution to mission
✔ Urgency for safety of people and/or care of the art
✔ Impact on visitor and/or staff experience
✔ Improvement to resiliency and sustainability
• The roof of the building is 500,000 SF in area, almost 12 acres.
• Skylights comprise 35% of the roof area, totalling 175,000 SF.
• Many of the skylights are outdated and in need of replacement, and are a major source of heat loss.
Energy Conservation Initiatives

• In 2019, the Met’s energy costs were $11.4 million.

• The Met is striving to reduce emissions in accordance with PlaNYC.

• As of 2020, the Met has reduced greenhouse gas emissions by approximately 33% and cumulatively saved over $15 million in energy costs (based on a benchmark established between 2006 and 2011).
The Department of Citywide Administrative Services (DCAS) Division of Energy Management (DEM) is the hub for energy management in City buildings.

DCAS DEM partnered with the Met by providing over $60 million in funding to support projects that will reduce emissions by over 7,000 metric tons of carbon dioxide equivalent (MTCO2e). This work includes lighting, HVAC, control systems, and envelope upgrades.

The Met upgrades supported by DCAS highlight the ability to improve energy and emissions performance during gallery renovations. This partnership benefits not only the art community, but the City of New York as well.

Contact:

Jasmin Rivera
Director of Accelerated Conservation & Efficiency Program NYC
JaRivera@dcas.nyc.gov
Met Engineering and Energy Overview
LTFS Equipment Service Life Analysis

Analysis of building systems and expected remaining service life
Equipment categorized by condition and transformational project association
Metropolitan Museum of Art LTFS Project Priorities

Creation of prioritized project groups
Metropolitan Museum of Art LTFS Cost Model

Budgeting and planning for project groups
Calibrated Energy Model

- **Total Actual vs. Simulation Energy Usage**
- **Actual vs. Simulation Steam Usage**
- **Actual vs. Simulation Electricity Usage**

Pie chart showing energy categories:
- Process
- Lighting
- Distribution
- Cooling
- Heating & Humidity Control

Bar charts showing actual vs. simulated usage for different months.
Calibrated Energy Model

Energy Model:
Energy Usage by Program Type
Calibrated Energy Model

Energy Model:
Energy Usage by Wing
### Energy Reduction Initiatives

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Project / Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY13</td>
<td>VFD's, Motors &amp; Controls Upgrades on Domestic Hot Water Booster Pumps</td>
</tr>
<tr>
<td>FY13</td>
<td>VFD's, Motors &amp; Controls Upgrades on Nine Air Handling Units</td>
</tr>
<tr>
<td>FY14</td>
<td>Sackler Wing HVAC Equipment &amp; Controls Replacement</td>
</tr>
<tr>
<td>FY15</td>
<td>W Plant Cooling Tower Upgrades</td>
</tr>
<tr>
<td>FY15</td>
<td>Great Hall Domes Laylights &amp; Lighting Improvements</td>
</tr>
<tr>
<td>FY16</td>
<td>VAV Conversion for Seven Air Handling Units</td>
</tr>
<tr>
<td>FY16</td>
<td>BMS DDC Controls Upgrades &amp; Training</td>
</tr>
<tr>
<td>FY16</td>
<td>Lighting Control Integration</td>
</tr>
<tr>
<td>FY16</td>
<td>Steam Trap Replacements</td>
</tr>
<tr>
<td>FY17</td>
<td>Luce Center Halogen Replacement</td>
</tr>
<tr>
<td>FY17</td>
<td>Outdoor Air Damper Investigation</td>
</tr>
<tr>
<td>FY18</td>
<td>VAV Conversion for Seven Air Handling Units</td>
</tr>
<tr>
<td>FY18</td>
<td>Elevator Upgrades</td>
</tr>
<tr>
<td>FY19</td>
<td>Outdoor Air Damper Replacement on Fourteen Air Handling Units</td>
</tr>
<tr>
<td>FY19</td>
<td>Morgan Wing HVAC Replacement</td>
</tr>
<tr>
<td>FY19</td>
<td>Back of House AHU Setbacks</td>
</tr>
<tr>
<td>FY20</td>
<td>ESDA Plant Controls &amp; Optimization</td>
</tr>
<tr>
<td>FY20</td>
<td>Electrocell for American Wing Condenser Water</td>
</tr>
<tr>
<td>FY20</td>
<td>VFD Upgrades for Seven Air Handling Units</td>
</tr>
<tr>
<td>FY20</td>
<td>Steam System Training</td>
</tr>
<tr>
<td>FY20</td>
<td>RCH-1 VFD Retrofit</td>
</tr>
<tr>
<td>FY20</td>
<td>North Garage Exhaust System</td>
</tr>
<tr>
<td>FY20</td>
<td>Special Exhibition LED Lighting Conversion</td>
</tr>
<tr>
<td>FY20</td>
<td>Wings ABC Skylight Replacement &amp; Infrastructure Project</td>
</tr>
<tr>
<td>FY21</td>
<td>European Paintings Galleries ABC Skylights</td>
</tr>
<tr>
<td>FY22</td>
<td>Convert Seven Fans to Variable Speed</td>
</tr>
<tr>
<td>FY22</td>
<td>Electrocell for R&amp;K Condenser Water Treatment</td>
</tr>
<tr>
<td>FY22</td>
<td>Refurbish Heat Exchanger for AM Waterside Economizing</td>
</tr>
<tr>
<td>FY22</td>
<td>HVAC &amp; Envelope Improvements Supporting Rockefeller Renovation</td>
</tr>
</tbody>
</table>
Energy Performance Trends

### Historic Energy Consumption [kBTU/ft²/yr.]

<table>
<thead>
<tr>
<th>Year</th>
<th>kBTU/ft²/yr</th>
<th>$/ft²/yr</th>
<th>kgCO₂e/ft²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>250</td>
<td>$6.87</td>
<td>12.87</td>
</tr>
<tr>
<td>2014</td>
<td>248</td>
<td>$6.88</td>
<td>12.86</td>
</tr>
<tr>
<td>2015</td>
<td>249</td>
<td>$6.57</td>
<td>12.88</td>
</tr>
<tr>
<td>2016</td>
<td>232</td>
<td>$5.57</td>
<td>12.10</td>
</tr>
<tr>
<td>2017</td>
<td>226</td>
<td>$6.00</td>
<td>11.75</td>
</tr>
<tr>
<td>2018</td>
<td>231</td>
<td>$6.42</td>
<td>11.97</td>
</tr>
<tr>
<td>2019</td>
<td>196</td>
<td>$5.28</td>
<td>10.37</td>
</tr>
<tr>
<td>2020</td>
<td>165</td>
<td>$4.33</td>
<td>8.60</td>
</tr>
</tbody>
</table>

#### Other Data Points:

- 5-Yr. Ave. [Pre Implementation Start]:
  - 250 kBTU/ft²/yr
  - $6.87/ft²/yr
  - 12.87 kgCO₂e/ft²/yr

- 5-Yr. Ave. [Post Implementation Start]:
  - 210 kBTU/ft²/yr
  - $5.52/ft²/yr
  - 10.96 kgCO₂e/ft²/yr

- LTFS Implementation Target:
  - 186 kBTU/ft²/yr
  - $4.89/ft²/yr
  - 9.70 kgCO₂e/ft²/yr

- Revised 2025 Target [PlaNYC]:
  - 149 kBTU/ft²/yr
  - $4.13/ft²/yr
  - 7.71 kgCO₂e/ft²/yr

- Cumulative Savings vs. Benchmark:
  - MMBTU: 409,437
  - $: $15,319,291
  - MTCO₂e: 20,400

- 5-Yr. Ave. Savings vs. Benchmark:
  - Energy: 40 kBTU/ft²/yr
  - Cost: $1.35/ft²/yr
  - Emissions: 1.19 kgCO₂e/ft²/yr

- Annual Savings Variation vs. Benchmark:
  - Energy: 210 kBTU/ft²/yr
  - Cost: $5.52/ft²/yr
  - Emissions: 10.96 kgCO₂e/ft²/yr
Wings A, B and C European Paintings Galleries: Skylight and Infrastructure Replacement Project
(Construction 2018-2022)
Wings A, B and C are the oldest part of the museum, built in 1880-1894.
Second floor plan showing location of European Paintings Galleries in Wings A, B and C
Cutaway view showing European paintings galleries on second floor:
Forty-four skylit galleries totalling 50,000 SF

Aerial view showing skylights and mechanical enclosures.
Area of skylight replacement: 30,000 SF
Section showing typical arrangement of paintings galleries, glass laylight ceilings, attics, and skylights

The project replaces the skylights, the glass daylight ceiling, the HVAC system serving the galleries and attics, and the sun control louver system.
EXISTING SINGLE GLAZED CORRUGATED WIRE GLASS SKYLIGHTS INSTALLED AT WINGS A, B, AND C IN 1939-41
High performance system of insulated laminated translucent glass, structural silicone glazing with cassette subframes, aluminum framing system with thermal breaks and a pressure-equalized secondary internal drainage system.

Proposed Skylight System:
Adjustable sunscreen louver system at underside of skylights to control daylight levels in galleries
Reconfiguration of mechanical systems and distribution

- Removal of re-heat water piping over galleries, only air ducts in attic
- Equipment consolidation to waterproofed central mechanical spaces
- Detection & protection if systems fail
- Ductwork configured to allow for improved daylighting
Attic condensation prevention

- Active moisture monitoring dew point with corresponding supply air T°
- Air pressurization control between attic and gallery conditions
- Substantial energy improvement from previous approach
Attic condensation prevention
- Desiccant dehumidification
- Air movement at all glazed units
Wings ABC Skylights Replacement & Infrastructure Project:

### Annual Expenditures

- **Total Energy Cost**: $1,206,175
- **Steam Cost**: $542,287
- **Electricity Cost**: $663,888
- **Steam Cost Savings**: $313,037
- **Electricity Cost Savings**: $84,874

### Annual Emissions

- **Baseline Emissions**: 2,410 MTCO₂e
- **Proposed Emissions**: 1,520 MTCO₂e
- **Proposed Case Steam Emissions**: 794
- **Proposed Case Electricity Emissions**: 1,026

### Deep Energy Conservation Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Annual Energy Cost Savings</th>
<th>MTCO₂e/yr. Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECM-A-1 [ Skylights]</td>
<td>$298,686</td>
<td>442</td>
</tr>
<tr>
<td>DECM-A-2 [Insulation]</td>
<td>$1,494</td>
<td>2</td>
</tr>
<tr>
<td>DECM-B [HVAC Combined]</td>
<td>$147,564</td>
<td>219</td>
</tr>
<tr>
<td>DECM-B-3 [Attic Desiccant]</td>
<td>$104,094</td>
<td>153</td>
</tr>
<tr>
<td>DECM-B-4 [Gallery VVVT]</td>
<td>$27,765</td>
<td>43</td>
</tr>
<tr>
<td>Proposed Case</td>
<td>$397,911</td>
<td>590</td>
</tr>
</tbody>
</table>

**Proposed Case Energy Savings Summary [vs. Replacement in Kind]**
Michael C. Rockefeller Wing: Sloped Glazing Replacement, HVAC Upgrade and Galleries Renovation

Construction 2021-2023
The Rockefeller Wing was designed by Kevin Roche John Dinkeloo Associates to house the galleries for the arts of Africa, Oceania and the Americas. It opened in 1982.
Project Scope - Exploded Axonometric
Axonometric View:
Museum South Elevation

Existing Condition

Proposed Design
Proposed Glazing: Visual light transmittance

Limited Daylight Zone
- Translucent glass with lowest light transmission

Daylighting Zone
- Translucent glass with higher light transmission

View Zone
- 20% VLT

Rows 1-8
- Visual light transmittance gradient

Inner Laminated Lite
- Row 1: Vision glass with clear interlayer
- Rows 2-8: Glass with translucent interlayer

Low-E Coating
- Thermal performance and light reduction

Gray Frit at Exterior
- For bird safety and light reduction with varying percentage coverage

Interior

Schematic Diagram of Frit Pattern Gradation - Meets NYC Bird Safety Requirements
First Floor Interior of AAOA Galleries
Existing Condition View

Photo: One Quarter Scale Daylighting
Mockup Showing Proposed Glazing
Comparative Glazing Details

Existing Details:
Conventional insulated glass units with pressure caps

Proposed details: Triple glazing, laminated glass, structural silicon glazing, pressure equalized framing system with secondary internal drainage system
Convection Loops: Vertical and sloped glass

Therm Model Analysis

Design Conditions:
- Exterior: 0 degrees Fahrenheit, 12 mph wind
- Interior: 72 degrees Fahrenheit, 55% relative humidity
dew point at interior surface: 56 degrees Fahrenheit
Michael C Rockefeller Wing: Sloped Glazing Replacement
HVAC Distribution & Condensation Prevention
MCR – Mechanical Improvements

- Phasing of replacement air handlers, a project challenge, utilize existing units to temporarily condition occupied spaces
- Replacement of 4 aging constant volume air handlers with new variable volume custom units including energy-efficient fan arrays, 300,000 CFM total
- Modern controls allowing for turndown, chilled water load matching, enhanced ventilation strategies, improved efficiency
- Steam convertor stations, piping distribution to new air handlers, preheat coils, variable speed pumps, replacement of aging traps
- Equipment serves 100,000 sq ft of galleries, art storage & offices

Mechanical Systems - Service Building B

SBB – located adjacent to MCR wing