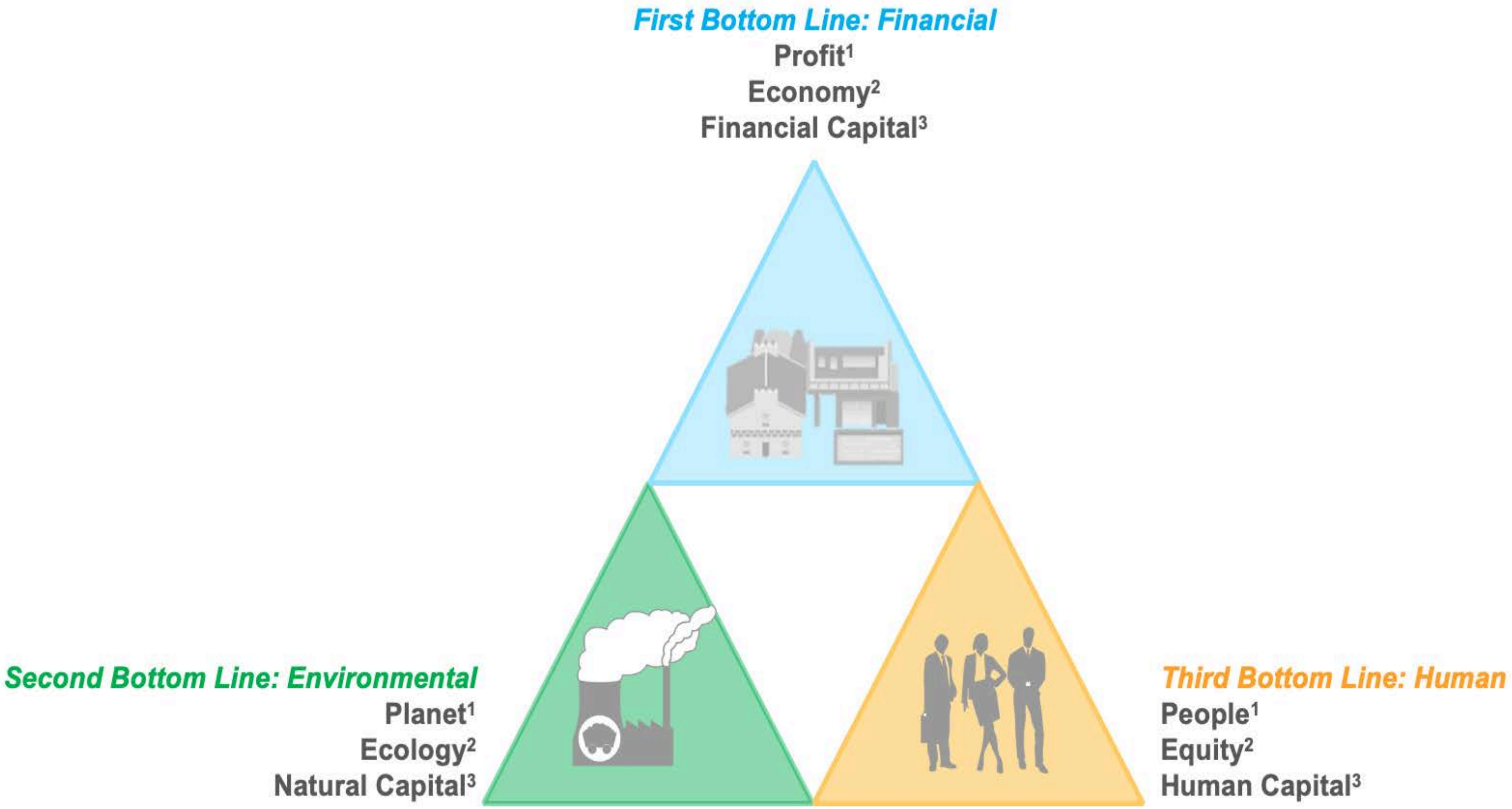
Life Cycle Triple Bottom Line Cost Analysis of High Performance Building Investments 2020 Case Studies

Construction Industry Institute®



1. Elkington, John. 1997. *Cannibals With Forks: Triple Bottom Line of 21st Century Business.*
2. McDonough, William, and Michael Braungart. 2002. "Design for the Triple Top Line: New Tools for Sustainable Commerce." *Corporate Environmental Strategy* 9 (3): 251–258.
3. Eccles, R. G., & Armbrester, K. (2011). Integrated Reporting in the Cloud. IESE Insight, (8.1), 13–20.

Life Cycle Costing (LCC) and Triple Bottom Line (TBL)

Incorporating Financial, Natural, and Human Capital in Facility Decision Making

- Method and approach
- Case studies
- Take-aways and report

Facility investment decisions are still grounded in a short term financial bottom line…

Financial Capital

Initial costs
Purchase, acquisition, construction costs

Finance Charges and taxes-
Loan Interest Payments

Operational Expenses
Energy, water and utilities

Operation, Maintenance and Repair Costs

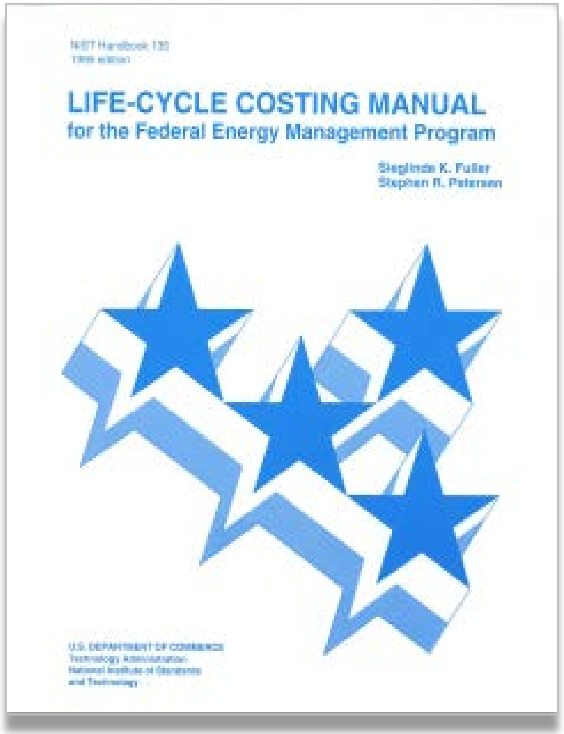
Replacement Costs

Other Costs – insurance, litigation, churn, security

Residual Values
Resale/salvage values or disposal

…so the federal government developed standards for calculating the long term financial bottom line

Life Cycle Costing (LCC)



(NIST, 1995, 2003, annual addenda)

LCC estimates the overall costs of project alternatives to select the design with the lowest overall ‘cost of ownership’ consistent with the facility quality and function. A long list of factors are to be considered, as available:

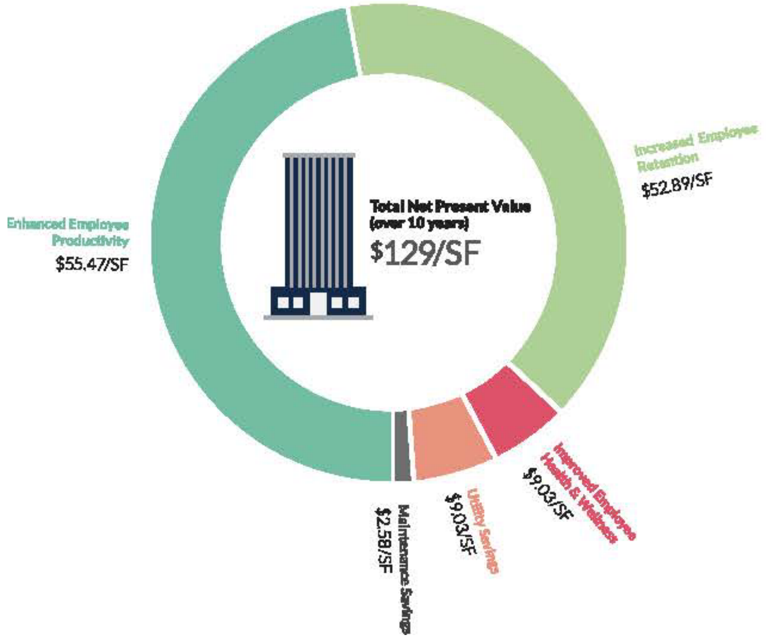
1. **Initial Costs**—Purchase, Acquisition, Construction Costs
2. **Fuel Costs**
3. **Operation, Maintenance, and Repair Costs**
4. **Replacement Costs**
5. **Residual Values**—Resale or Salvage Values or Disposal Costs
6. **Finance Charges**—Loan Interest Payments
7. **Non-Monetary Benefits or Costs**

LCC = investment cost + maintenance and repair + energy + water + replacement costs – salvage value

Future Values Discounted to Present Value

Other standard methods for calculating financial outcomes

Return on Investment (ROI), Payback, and Net Present Value (NPV)



ROI = Annual Benefits / First Costs

Payback = First Costs / Annual Benefits

NPV = Annual Benefits – Annual Costs

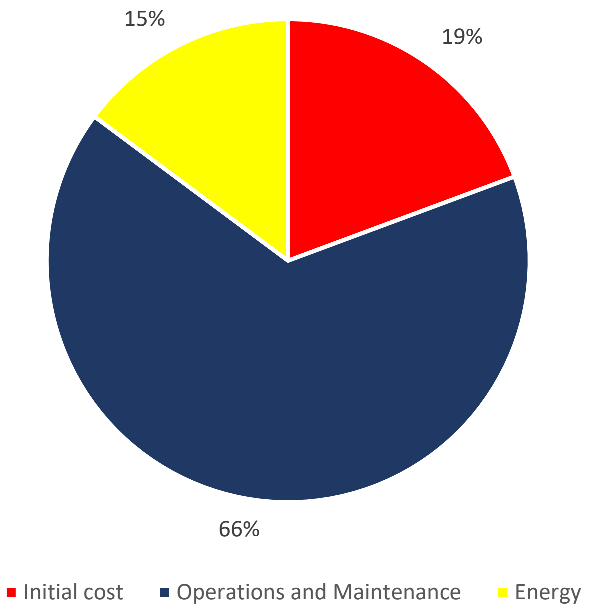
Future Values Discounted to Present Value

***Costs** can include investment, maintenance, and replacement costs*

***Benefits** can include income, energy related and other benefits*

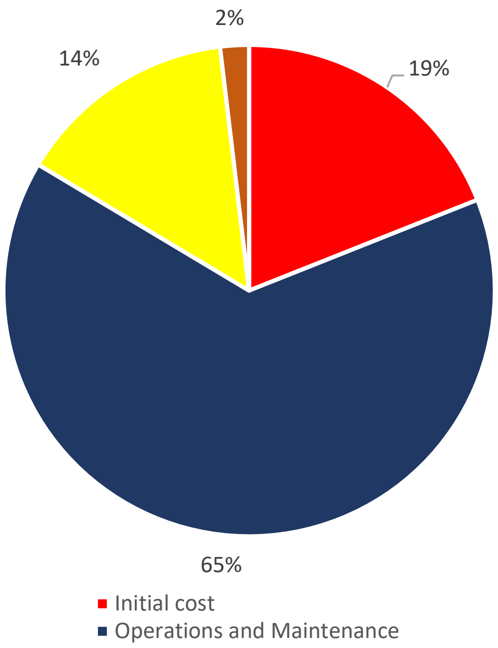
Financial Capital

Present Value Life Cycle Cost



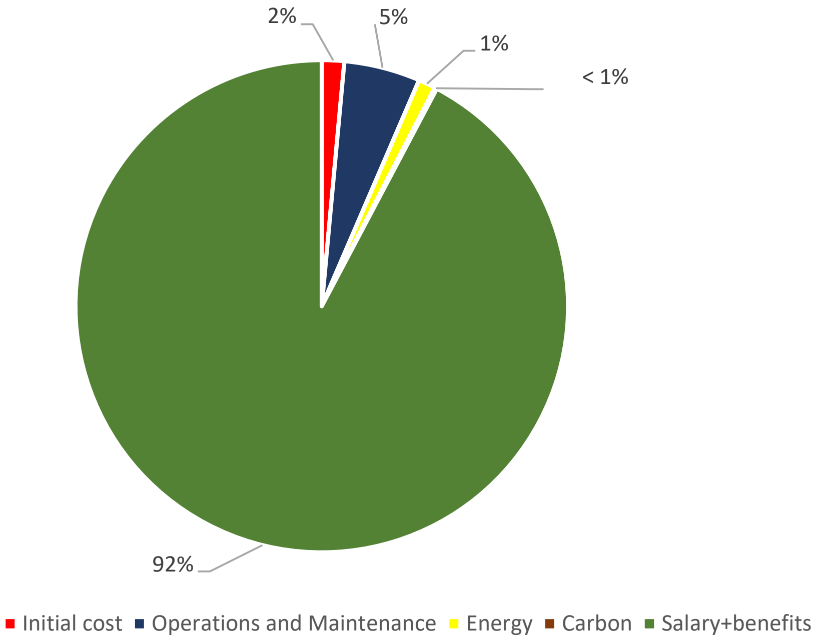
+ Natural Capital

Present Value Life Cycle Cost



+ Human Capital

Present Value Life Cycle Cost



NASA case study Hypothesis 2

Present Value Life Cycle Cost = 30 year study period, 2% discount rate

Ive (2006) Re-examining the costs and value ratios of owning and occupying buildings, Building Research and Information, 34:3, 230-245

Triple Bottom Line Life Cycle Cost elevates the total cost of ownership by deliberately calculating three bottom lines: Financial, Natural and Human Capital Cost and Benefits

The Triple Bottom Line (TBL)

Financial Capital

- **energy savings**
- **real estate space savings**
- **water savings**
- **stormwater fee savings**
- **flexible programming, event support with artifact security (museum specific)**
- **Marketing benefits**

- facility management savings
- avoided property damage
- peak power savings
- Real estate value/vacancy
- Tax code/insurance
- Salvage savings

Natural Capital

- **carbon savings** (of kWh savings)
- **air quality benefits** (of kWh) **(PM2.5, SOx, NOx, ozone..)**
- **water savings** (of kWh savings)
- **avoided regional flooding risk**

- artifact preservation (museum specific)
- reduced heat island
- reduced energy waste
- reduced material resource use

Human Capital

- **productivity**
- **visitor/customer numbers**
- **visitor length of stay, fatigue**
- **educational value**

- absenteeism
- presenteeism
- task/cognitive performance
- health: colds, flus, headaches, skin, eye, musculo-skeletal, stress, digestive, endocrine,
- occupant comfort and satisfaction
- customer satisfaction

TBL / LCC Methodology

Develop Hypotheses

- identify high performance components and / or systems

Establish Cost Differentials

- track cost differentials for high performance components and systems (paying for performance)

Identify Benefits

- identify possible benefits from those systems across financial, environmental and human outcomes

Assign Values through Expert Knowledge and Research

- quantify variables from project data or reputable sources, e.g., $50 mTCO2; Value of reduced headaches to employer relative to health care costs and productivity

Calculate Return-on-Investment

- using cost differentials and benefits, calculate annual ROI and payback period

Calculate Lifetime NPV and LCC

- for NPV and LCC calculation, set a timeline linked to the building life, investment life, or system life

Show all Assumptions

- keep all assumptions obvious (and cited) so they can be modified by the decisionmakers

Make the case!

CII TBL LCC Case studies 2020

UF Shands — Hypotheses Developed

Deloitte Edge — Hypotheses Developed

NMAAHC — Hypotheses Developed

NASA — Hypotheses Developed

Dept of State

Kaiser

Data Collected
LCCA and TBL Calculated
Case Studies Written

- Box-in-a-box
- High Performance Water System
- High Performance HVAC System

- Consolidation
- High performance building systems
- Photovoltaic Panels

The National Museum of African American History & Culture Case Study

Smithsonian Institution

The NMAAHC Case Study: 3 Hypotheses

BOX-IN-A-BOX-IN-A-BOX PLANNING

Each nested zone provides allows for diverse conditioning rules for daylight, temperature and humidity, as well as access.

WATER COLLECTION AND REUSE SYSTEM

Reusing water from rainwater, groundwater, and condensate, with 100,000 gallon holding tank, filtration, and a 15,000-gallon clean water storage tank.

DOAS, HEAT RECOVERY, AND CHILLED BEAM SYSTEM

Highly efficient central plan systems using fan walls, dedicated outside air, and enthalpy recovery as well as chilled beams in offices.

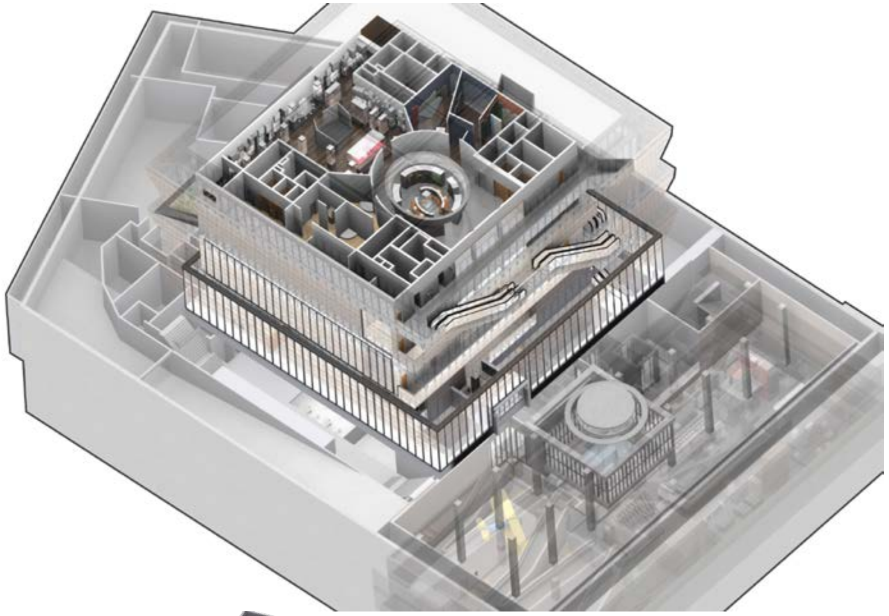
Box in a Box Hypothesis

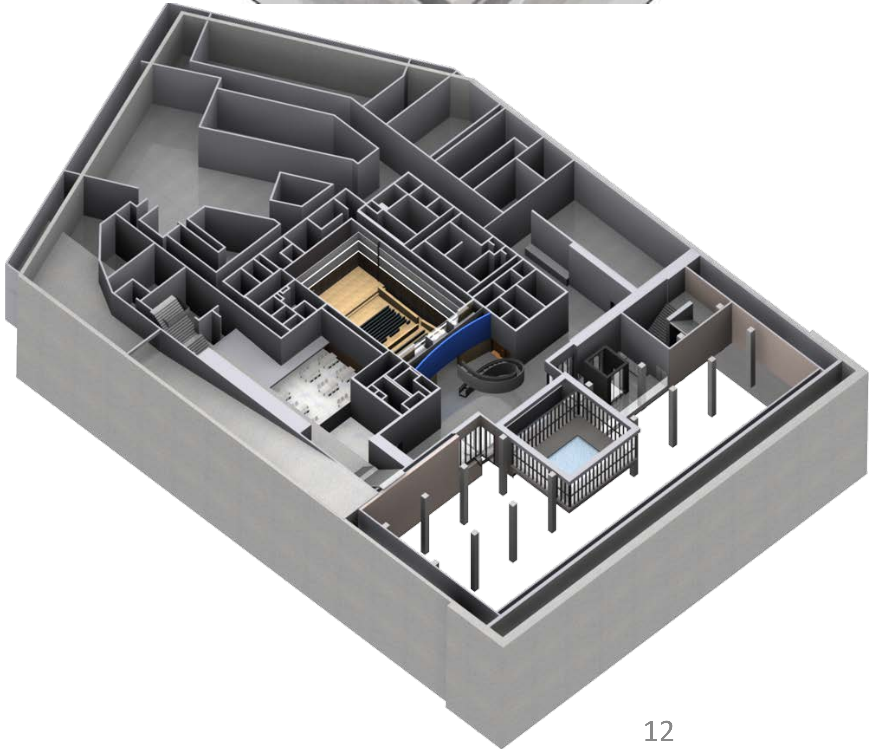
BOX-IN-A-BOX-IN-A-BOX PLANNING

The investments in the NMAAHC museum's four layered thermal conditioning zones – a box within a box within a box within a box -

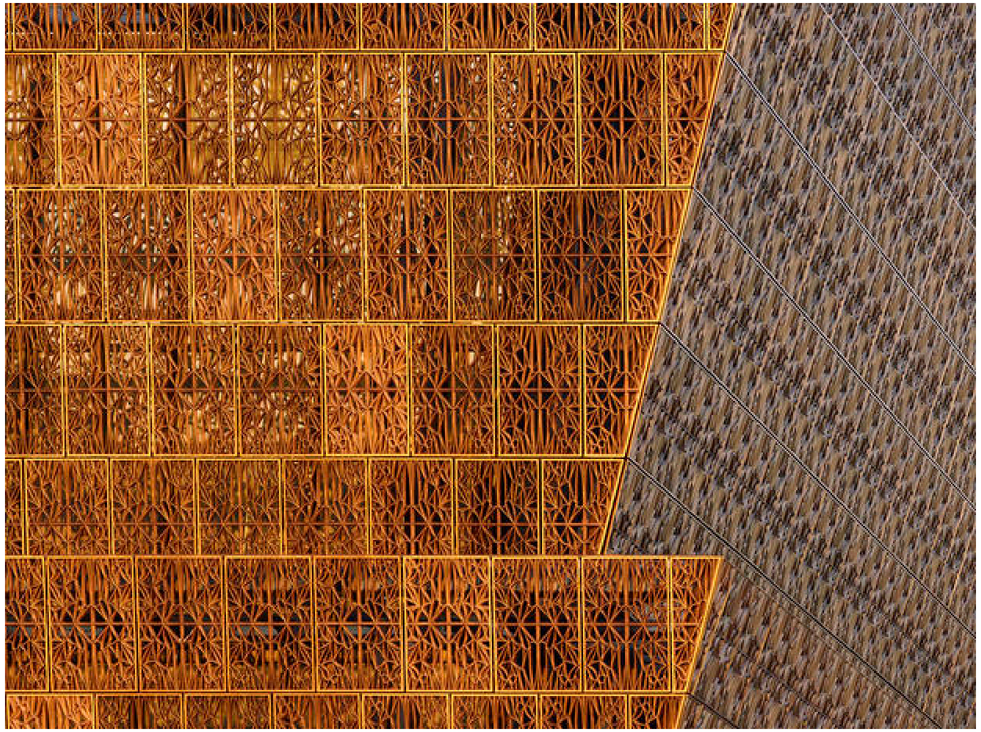
1. Airtight, dry exhibit cases (70F, 50% RH), inside
2. Exhibit visitor zone (70-74F, 50%+/- RH), inside
3. Generous, daylit circulation and congregation zone (68-78F, no RH control), inside
4. Shading zone (Corona)

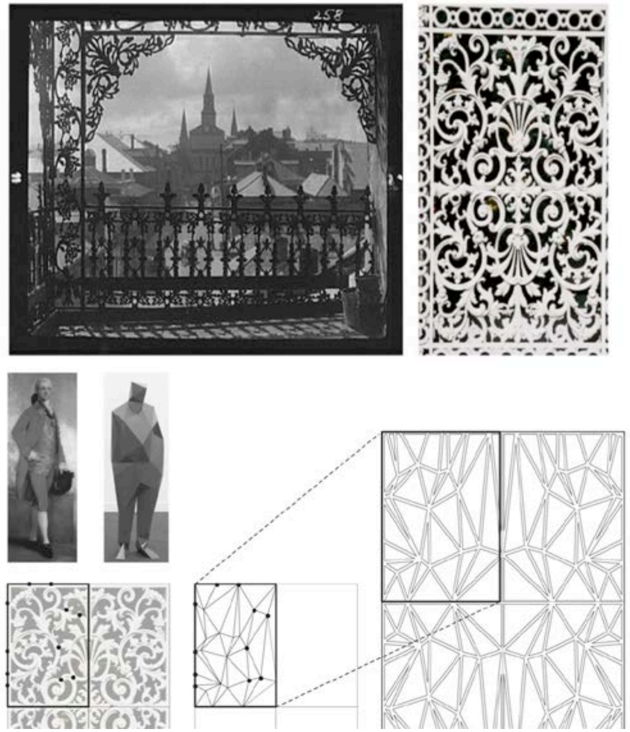
lead to significant triple bottom line benefits (profit, planet, people).



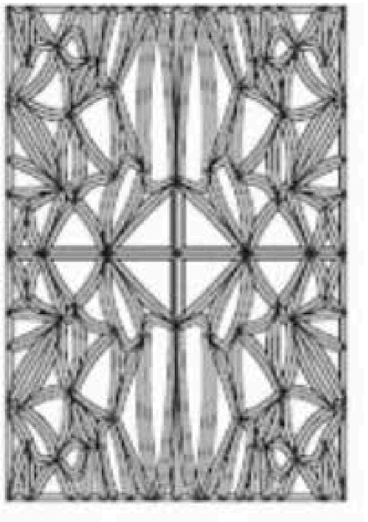


The Corona is an exhibit itself (with retail value), a cultural object, a minority industry, and an energy saver.

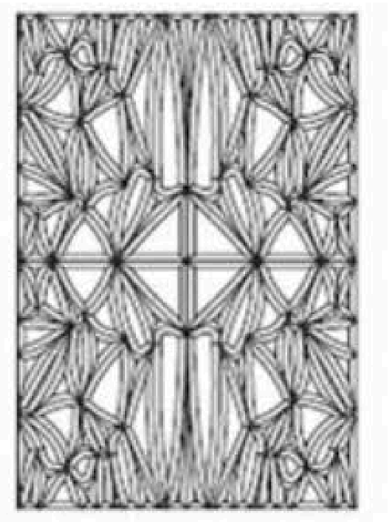




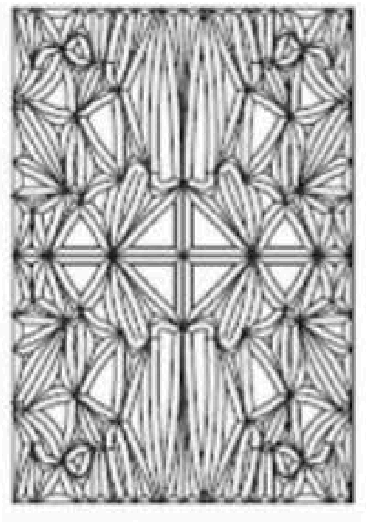
Variations in Corona densities manage heat gain and glare



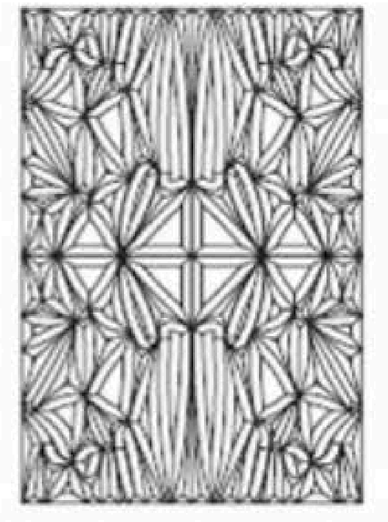
TYPE 1
65% Opacity



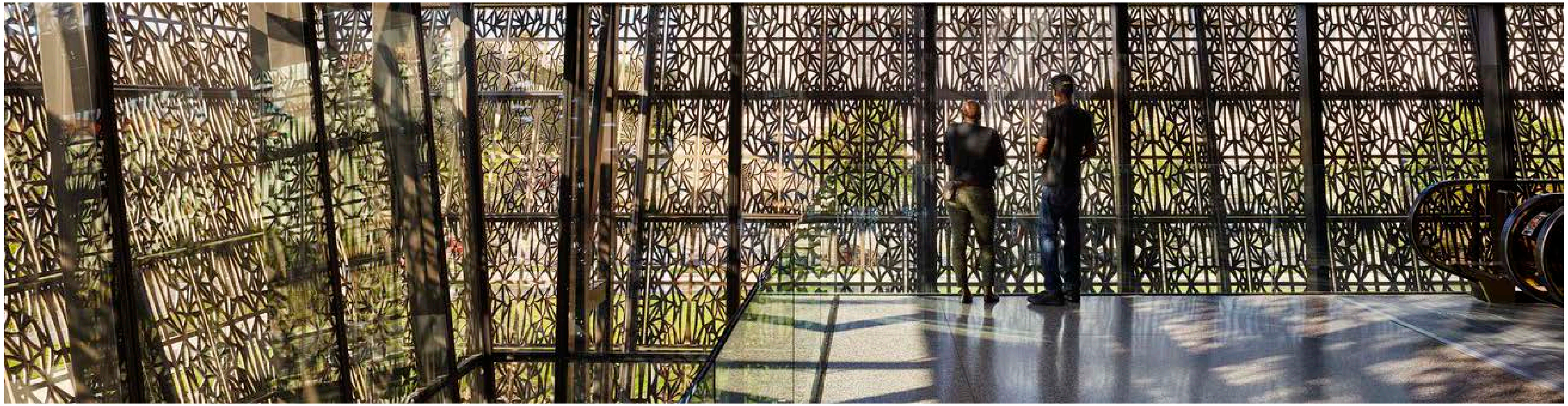
TYPE 3
75% Opacity



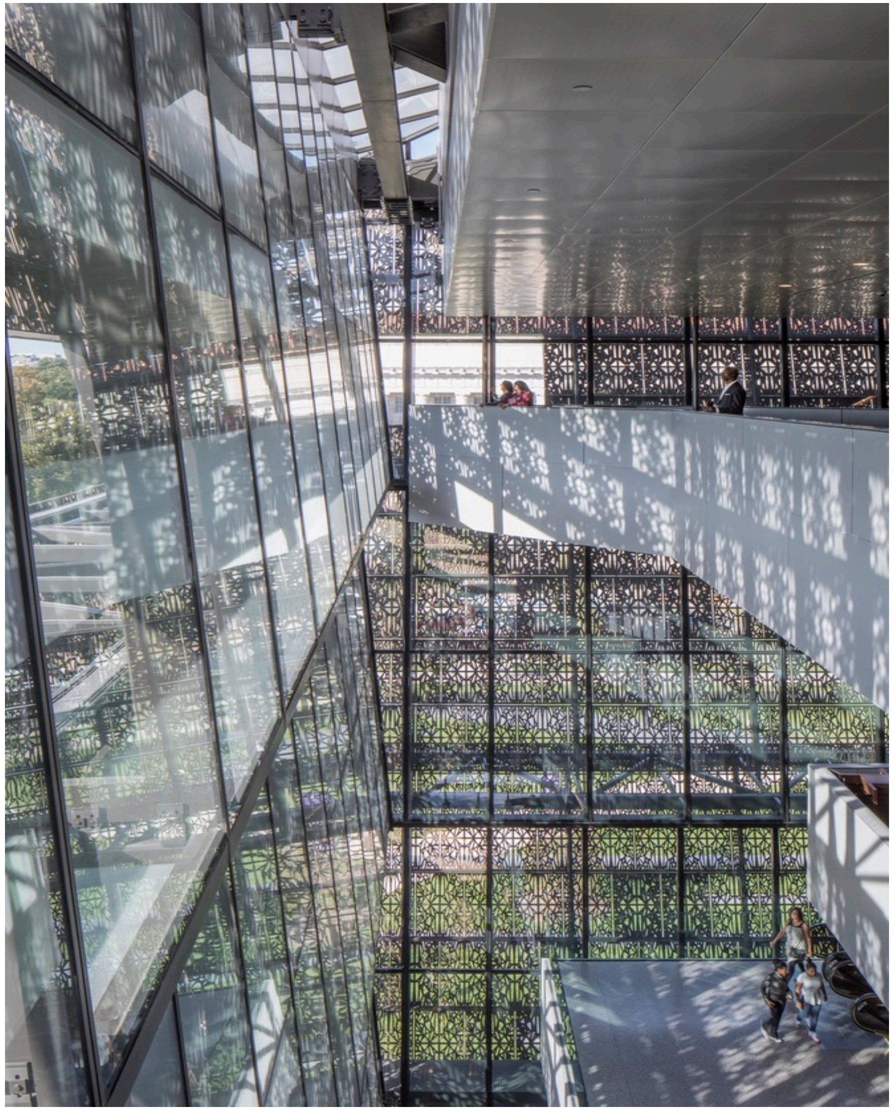
TYPE 5
85% Opacity

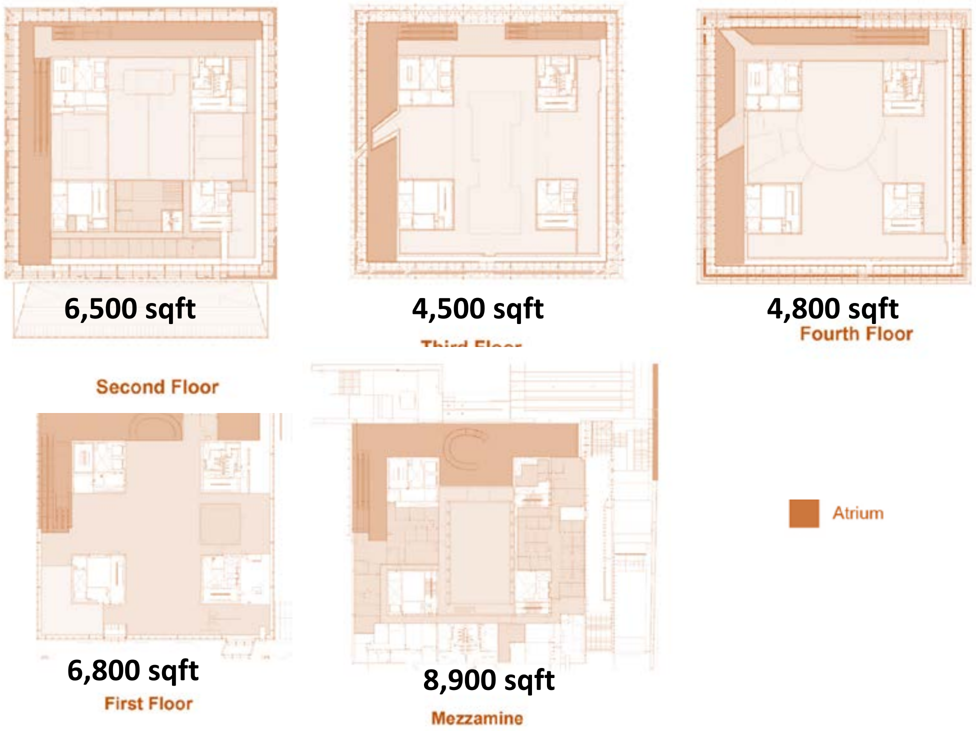


TYPE 6
90% Opacity



The vibrant atrium is a high function space, with dynamic environmental conditions separated from artifacts, with significant cost premiums…





3-D Atrium space cost premiums

31,000 sqft of space given up (7.72% of total area)
at $1000/ sqft = **$31 Million**

+ Corona first cost premiums

Corona and Glazing Increase = **$10 Million**

The exhibit space conditioning and quiet is ensured with automatic glass doors

and the artifacts are protected in airtight desiccant chambers

The first cost of the 'box in a box in a box' solution is substantial…

$

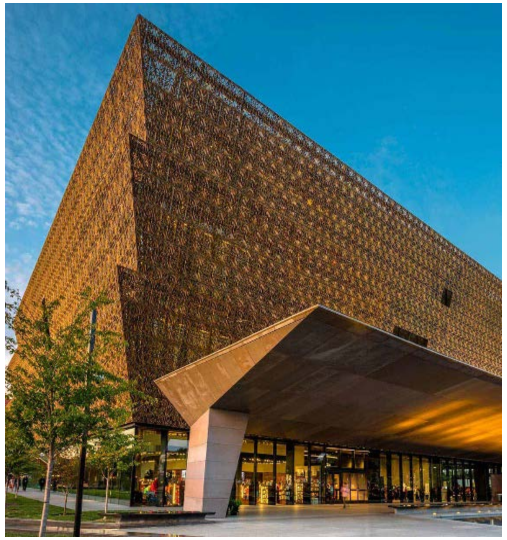
Triple Bottom Line calculation

Cost of layered thermal conditioning zones in NMAAHC

	Total Amount	Total Cost	$/ sq. ft.	$/ visitor
Airtight, dry exhibit cases upcharge (100 cases at $2,000 each)	100 cases	$200,000	$0.49	$0.1
Automatic doors for exhibit visitor zones (5 doors at $20,000 each)	5 doors	$100,000	$0.24	$0.05
Large circulation zones and atrium spaces (7.72% at $1,000/sqft))	31,000 sqft	$31,000,000	$75.61	$14.76
Cost of 77% glass vs 40% glass + Cost of Corona		$10,000,000	$24.39	$4.76
Increased Investment for NMAAHC		**$ 41,300,000**	**$100.7**	**$19.67**

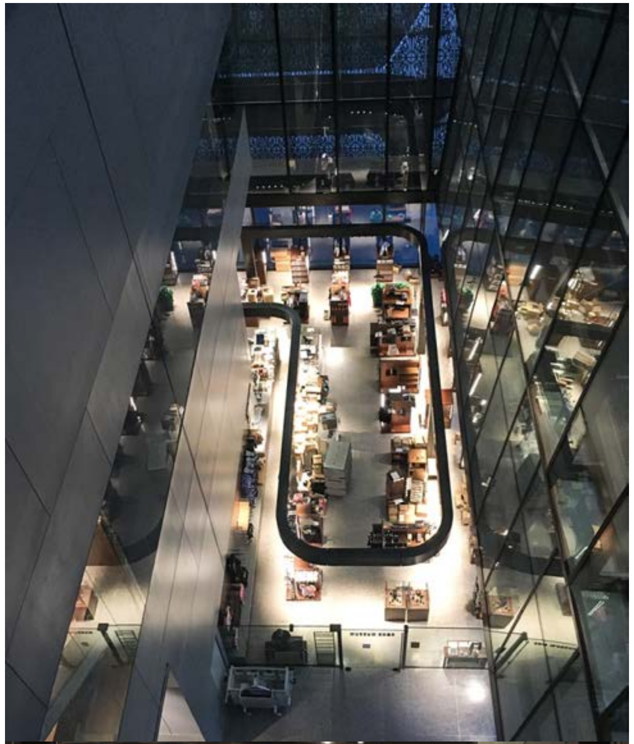
Increased first cost $41,300,000 or $100/sqft

Total Building Square Footage: 410,000
Averaged annual visitor number: 2,100,000



Yet the benefits of the nested zones are even more striking:

Visitor numbers
Visitor length of stay
Energy savings
Artifact preservation
Event destination
Retail sales



Triple Bottom Line

The investments in the NMAAHC museum's four layered thermal conditioning zones – a box within a box within a box within a box

BOX-IN-A-BOX-IN-A-BOX PLANNING

1. Airtight, dry exhibit cases (70F, 50% RH), inside
2. Exhibit visitor zone (70-74F, 50%), inside
3. Generous, daylit circulation and congregation zone (68-78F), inside
4. Shading zone (Corona)

led to the following triple bottom line benefits (profit, planet, people)

Increased Costs

- Airtight, dry exhibit cases vs alternative
- Exhibit visitor zone (70-74F) with automatic doors (vs open galleries)
- **Larger Circulation zone (68-78F)** with daylight, places to congregate (% area delta)
- **Shading zone (unconditioned)**; cost of 77% glass vs 40% and cost of Corona (with energy penalty?)

Financial capital benefits

- Conditioning energy savings
- Lighting energy savings
- Facility management savings (stringent conditions confined to smaller areas)
- Flexible programming, event support with artifact security

Natural capital benefits

- Carbon savings based on energy savings
- Artifact preservation and security

Human capital benefits

- Architecture as an exhibit and icon (see gift shop sales and branding)
- Visitor numbers
- Visitor satisfaction
- Visitor length of stay, reduced fatigue

$

1st Bottom Line for layered thermal conditioning zones
Financial Capital savings

	Total Savings Amount	Annual Financial Capital Benefit	$/ sq. ft.	$/ Visitor
9% less heating energy (20% of 47% total)	17,396 therms	$ 21,745	$0.05	$0.01
2% less electricity for cooling and ventilation energy	177,956 kWh	$ 23,134	$0.06	$0.01
4% less electricity for lighting energy	355,912 kWh	$ 46,269	$ 0.11	$ 0.02
Facility Management savings (fewer hot-cold-stuffy calls)	-	-	-	-
Event Venue with flexible programming (100 events at $20,000)	100 events	$ 2,000,000	$4.88	$0.95
Annual 1st bottom line savings		$2,091,147	+$5.10	+$1.00
ROI (Financial)		5.1%		
Simple Payback Period		19 years 8 months		
30-year NPV		$7,795,000		

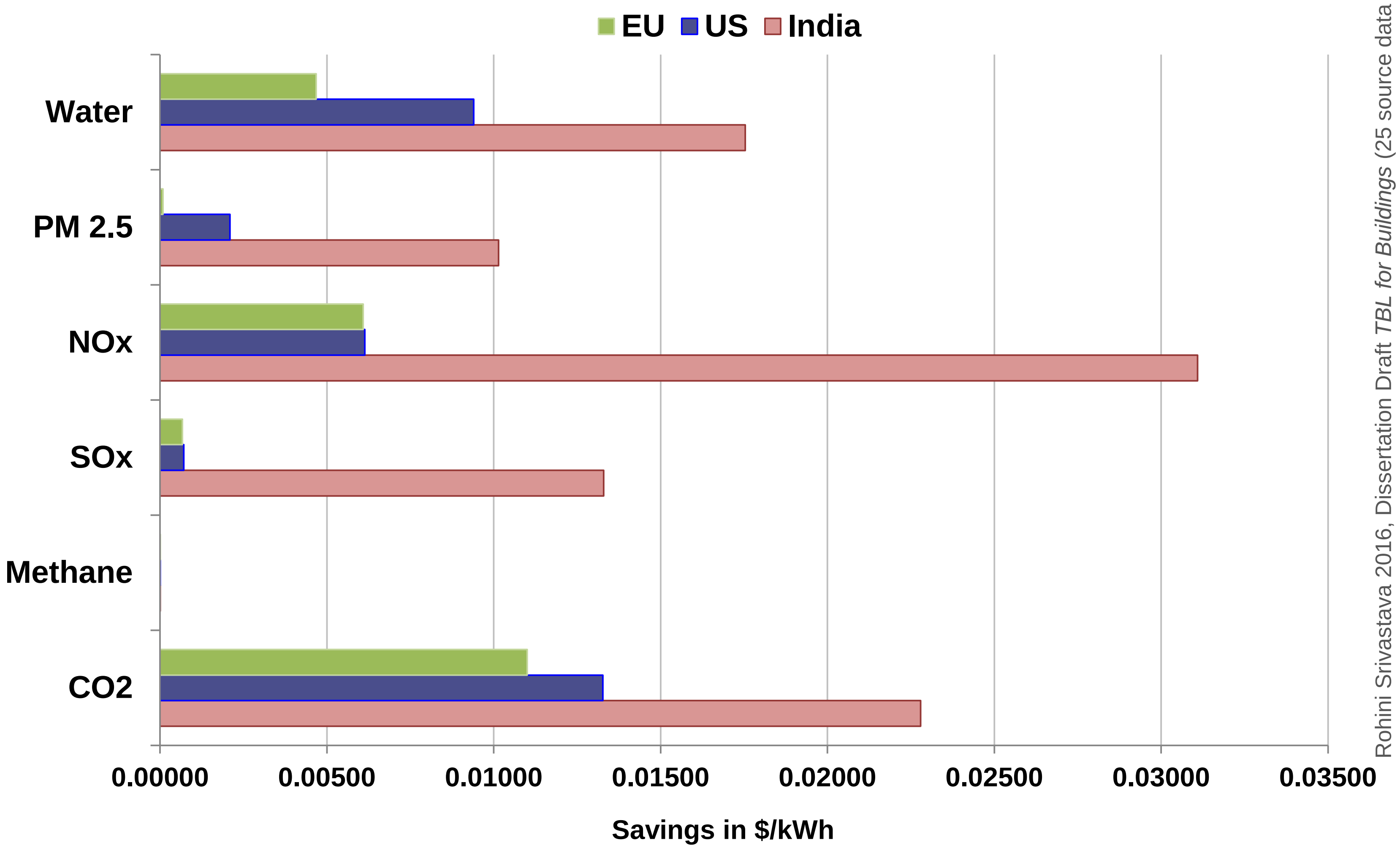
Increased first cost $41,300,000 or $100/sqft

1st BL $2.1 M with 19.7 years payback

Assumptions:

- NMAAHC heating energy savings are 47% of 109,000 therms of natural gas, of which including 90% for space heating, and 18% of the 7,960,000 kWh of electricity, of which including 50% for cooling and ventilation, 20% for lighting energy. **The layered thermal conditioning setting is contributing 20% of the heating, cooling and ventilation energy savings.**
- The gas price in DC area is around $1.25/therm, The electricity price has been set at $0.13/kwh (US Bureau of Labor Statistics, 2020).
- NMAAHC hosted 100 events in 2018, with an overall income of $2,000,000.

2nd Bottom Line: the carbon, SOx, NOx, particulate and water benefits of kWh savings



Rohini Srivastava 2016, Dissertation Draft *TBL for Buildings* (25 source data sets)

2nd Bottom Line for layered thermal conditioning zones
Natural Capital savings

	Total Amount savings	Annual Natural Capital Benefit	Per sq. ft.	Per visitor
NMAAHC energy savings	533,868 kWh	-	1.3 kWh	0.25 kWh
	17,396 therms	-	0.04 therms	0.01 therms
Carbon reduction	469 metric tons	$23,450	$0.06	$0.01
Air Quality benefits	-	$4,773	$0.01	$0.00
Artifact preservation and security	-	-	-	-
Annual 2nd bottom line savings	-	+$28,223	+$0.07	+$0.13
Cumulative ROI (Financial + Natural)			5.1%	
Simple Payback Period			19 years 6 months	
Cumulative 30-year NPV			$10,999,000	

Increased first cost $41,300,000 or $100/sqft

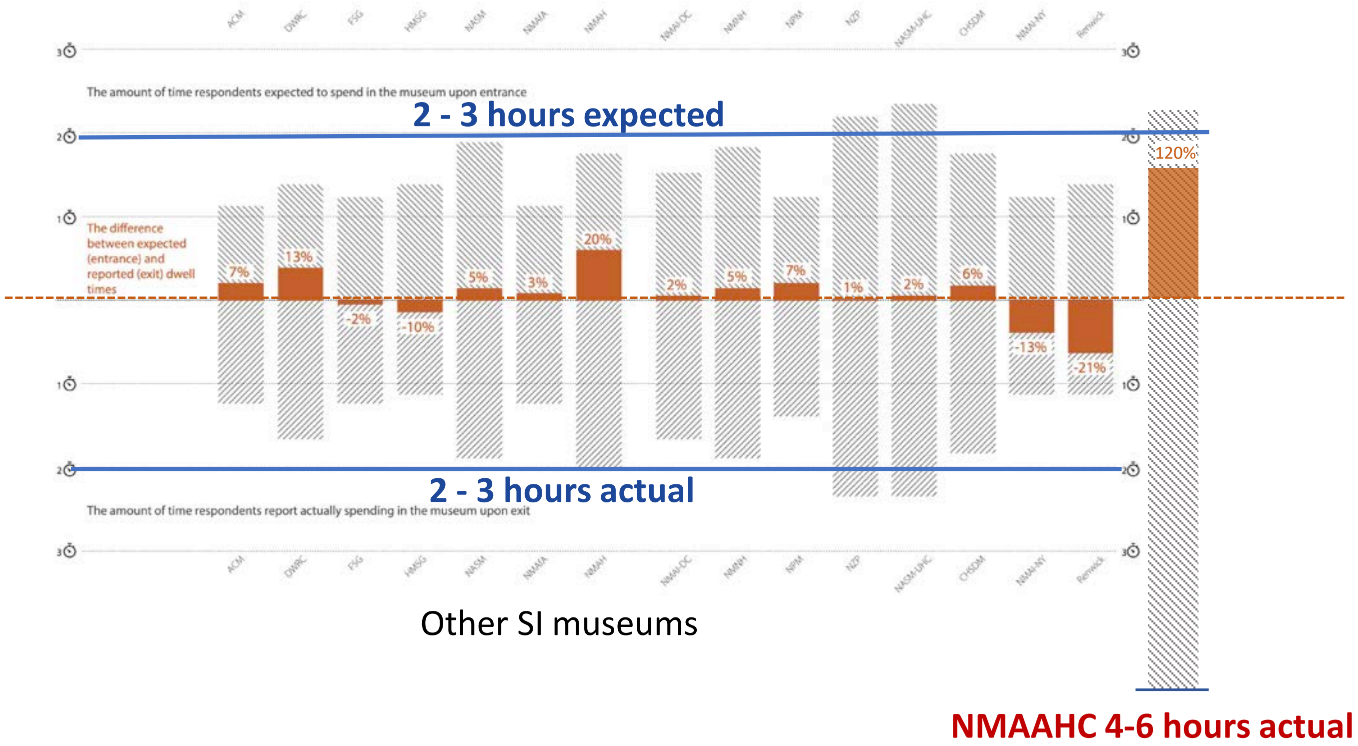
1st BL $2.1 M with 19.7 years payback

+ 2nd BL $28,300 with 19.5 years payback

Assumptions:

- Heating energy savings are 47% of 109,000 therms of natural gas, including 90% for space heating, and 18% of the 7,960,000 kWh of electricity, of which including 50% for cooling and ventilation, 20% for lighting energy. **The layered thermal conditioning setting is contributing 20% of the heating, cooling and ventilation energy savings.**
- Based on the EPA's greenhouse gas equivalencies calculator, these energy savings are equivalent to 469 metric tons of carbon reduction (EPA, 2018).
- $50/ metric ton of CO2 value; the economic value of the reductions in PM2.5, SOx and NOx, saving the region $0.00894/kWh, (Srivastava, 2017)

3rd Bottom Line: the doubling of Visitor Length of Stay



and increased visitor expenditures in gift shops and food service.

$7 /

National Average

$12 /

NMAAHC

3rd Bottom Line – Human Benefits

Possible explanations for the doubling of the visitor length of stay

The newest building, hard to get into, and a pilgrimage for many visitors (the newness should have faded by the 3rd year but did not) **(20%)**

The most powerful storyline, carrying you through history of great meaning and diversity, and 'you want to read to the end'. **(20%)**

The freshest air in a museum, that measurably reduces fatigue. **(15%)**

Thermally, visually, acoustically and spatially dynamic spaces between the hushed, cool galleries (**the box in a box calculation (20%)**), including an entry fountain and contemplation court to regenerate energies (the water calculation **(5%)**).

The best food on the Mall to regenerate energies **(20%)**

3rd Bottom Line for layered thermal conditioning zones
Human Capital savings

	Annual Human Capital Benefit	Per sq. ft.	Per visitor
Visitor numbers (10% avoided SI drop * $13 avg nat. entry*2.1 M visitors * 20% impact)	-	-	-
Visitor Satisfaction and Comfort	-	-	-
Visitor Length of Stay (20%) Reduced fatigue	$1,820,000	$4.44	$0.87
Architecture related retail sales Architecture as exhibit and icon	$1,396,500	$3.41	$0.67
Annual 3rd bottom line savings	**$3,216,500**	**+$7.85**	**+$1.54**
Cumulative ROI (Financial + Natural + Human)		**13%**	
Simple Payback Period		**7 years 8 months**	
Cumulative 30-year NPV		**$83,037,000**	

Assumptions:
- Average museum expenses per party per trip is $22 (Vander Steop, 2004)
- Assuming average expenses for NMAAHC is $35 per party per trip, and 3 people per party. Total visitor length of stay benefits is ($35- $22) /3 = $4.33.
- 20% of the benefits of visitor additional length of stay is contributed by the layered thermal conditioning settings.
- According to Tiffany Springgs, the district manager at Smithsonian Enterprise, the annual architecture related merchandise sales are captured at 19% of the total retail sales of $3.5 per visitor per year, resulting at $0.67 per visitor per year, translating into total benefits of $1,396,500 per year

First cost $41,300,000 or $100/sqft
1st BL $2.1 M with 19.7 years payback
+ 2nd BL $28,300 with 19.5 years payback
+ 3rd BL $3.2 M with 7.7 years payback

BOX-IN-A-BOX-IN-A-BOX PLANNING

NMAAHC Box in a Box Hypothesis

The investments in the NMAAHC museum's four nested thermal conditioning zones – a box within a box within a box within a box -

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2. Exhibit visitor zone (70-74F, 50%+/- RH), inside
3. Generous, daylit circulation and congregation zone (68-78F, no RH control), inside
4. Shading zone (Corona), outside

led to significant triple bottom line benefits (profit, planet, people).

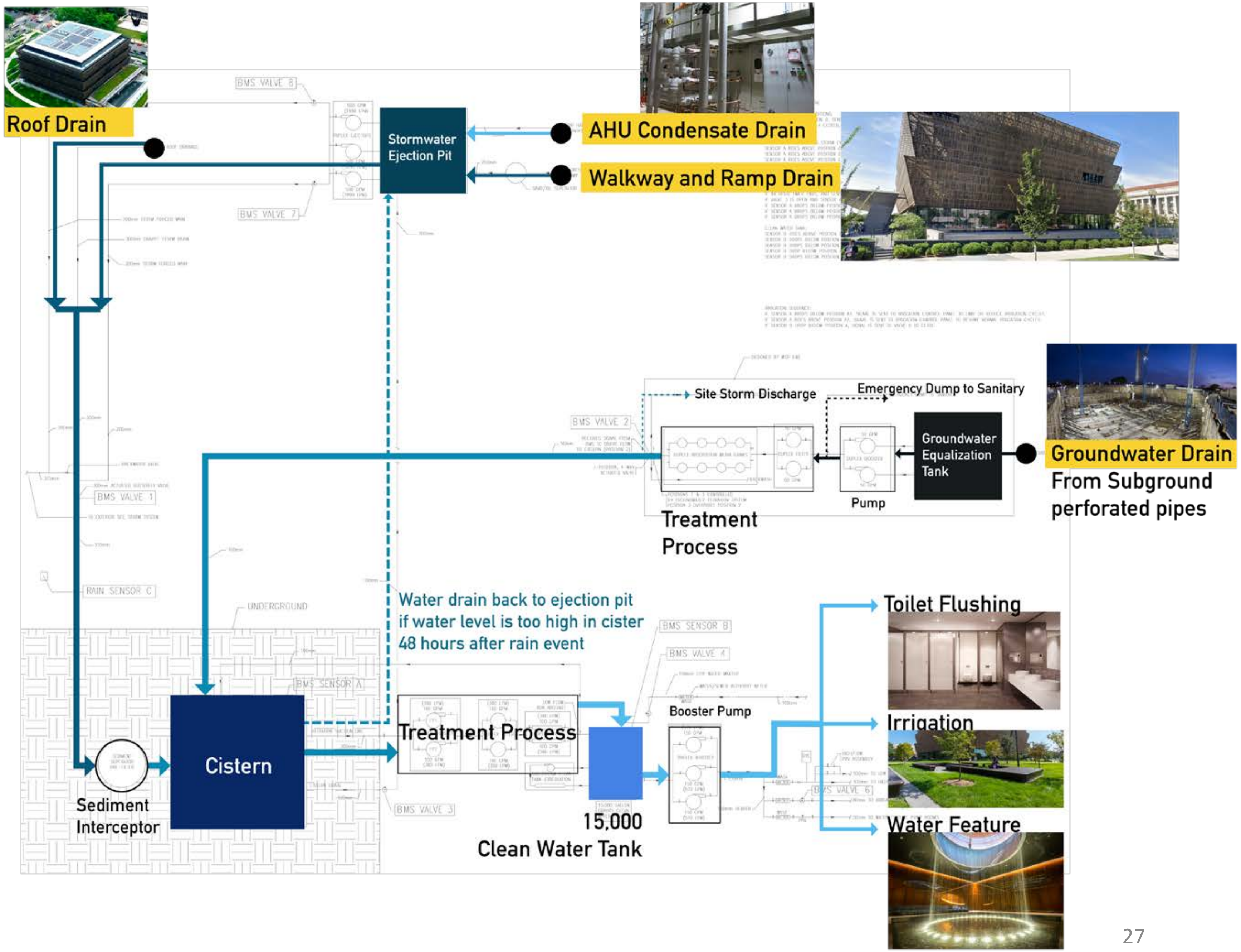
	Added Cost/ Benefit	Cumulative Payback	Cumulative ROI	30-year NPV
Increased cost of nested thermal zones	$41,300,000	-	-	-
Annual Financial Cost-Benefit	$2,100,000	19.7 yrs	5.1%	$7,795,000
Annual Financial + Environmental	$28,300	19.5 yrs	5.1%	$10,999,000
Annual Financial + Environmental + Human Cost-Benefit	$3,200,000	7.7 yrs	13%	$83,037,000

WATER COLLECTION AND
REUSE SYSTEM

The Advanced Water System Hypothesis

The investments in the NMAAHC rainwater system for capture and reuse led to triple bottom line benefits (profit, planet, people)

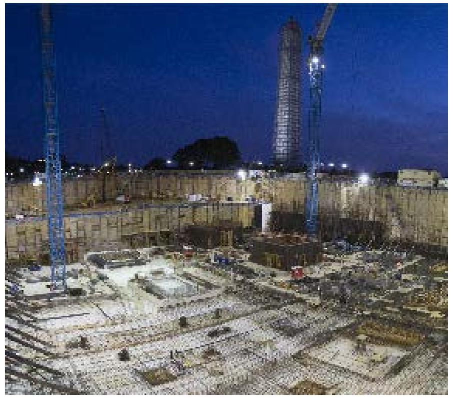
1. Green roofs
2. Rainwater capture
3. Condensate capture
4. Groundwater capture
5. Storage
6. Processing



The advanced water system costs were non-trivial at **$5,460,000 or $13/sqft.**

The first bottom line benefits were also non-trivial:

the water conservation and grey water sourcing system in NMAAHC eliminated 1,186,000 gallons of potable water demand each year, with additional avoided stormwater fees.



1st Bottom Line
Financial Capital savings

	Total Savings Amount	Annual Financial Capital Savings	$/ sq. ft.	$/ Visitor
Rainwater collection	11,000 gallons/mon	$ 2,442	$ 0.01	$0.00
Groundwater collection	1,000,000 gallons/mon	$ 222,000	$ 0.54	$0.11
Condensate water collection	175,000 gallons/mon	$38,850	$ 0.09	$0.02
Total Water use savings	**1,186,000 gallons/mon**	**$ 263,292**	**$ 0.64**	**$0.13**
Stormwater Fee Rebate	**20% off $25,128** (IAC)	**$5,026**	**$0.01**	**$0.00**
	55% off $3,204 (DOEE)	**$ 1,762**	**$0.00**	**$0.00**
Avoid Flooding damage to building	-	-	-	-
Annual cost for maintenance	-	-	-	-
Annual 1st bottom line savings		$270,079.8	$0.66	$0.13
ROI (Financial)		4.95%		
Simple Payback Period		20 years 3 months		
30-year NPV		$ (4,059,000)		

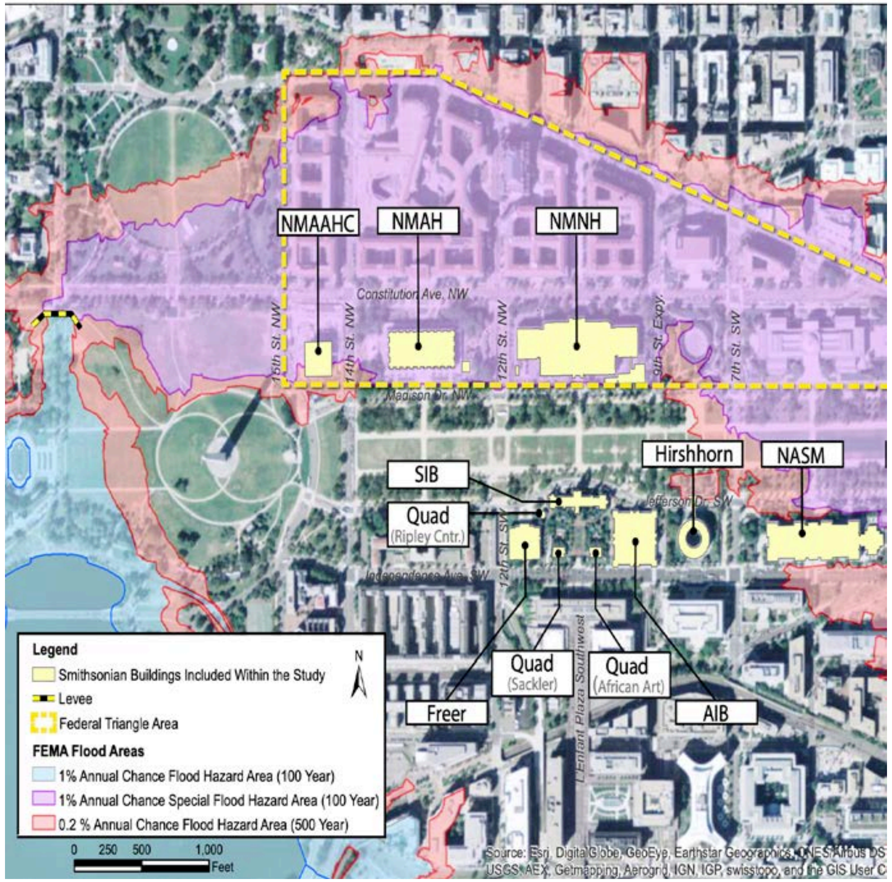
First cost $5,460,000 or $13/sqft

1st BL $270,000 with 20.2 years payback

Assumptions:
DC water River Smart rebates: RiverSmart Rewards: provides a discount of up to 55% off DOEE's Stormwater Fee and up to 20% off DC Water's Clean Rivers Impervious Area Charge.
D.C. Gov (2013). RiverSmart Rewards and Clean Rivers IAC Incentive Programs. Retrieved June 2020, from https://doee.dc.gov/riversmartrewards

The Natural Capital benefits of the NMAAHC's Advanced Water System include two factors:

the carbon benefits of reduced energy for water treatment and distribution



and the benefit of reducing flooding on the National Mall.

If every building that is added and renovated in this 'zone' had an advanced water system like NMAAHC, the proposed $360 million pumping station would not be needed.

2nd Bottom Line
Natural Capital savings

	Total Amount savings	Per sq. ft.	Per visitor
Environmental benefits from water energy savings	83,613 kWh	0.2 kWh	0.04 kWh
Carbon reduction (4.1 TCO2/million gallons)	$ 2,918	$0.01	$0.00
Natural benefits from reduced flooding risk			
Avoided damage to Capital Mall	$120,000	$0.29	$0.06
Artifact preservation	-	-	-
Additional benefits from green roofs			
Reduced heat island	-	-	-
Annual 2nd bottom line savings	$122,929	+$0.30	+$0.06
Cumulative ROI (Financial + Natural)		7%	
Simple Payback Period		13 year 11 month	
Cumulative 30-year NPV		$ (433,000)	

First cost $5,460,000 or $13/sqft
1st BL $270,000 with 20.2 years payback
+ 2nd BL $123,000 with 13.9 years payback

Assumptions:

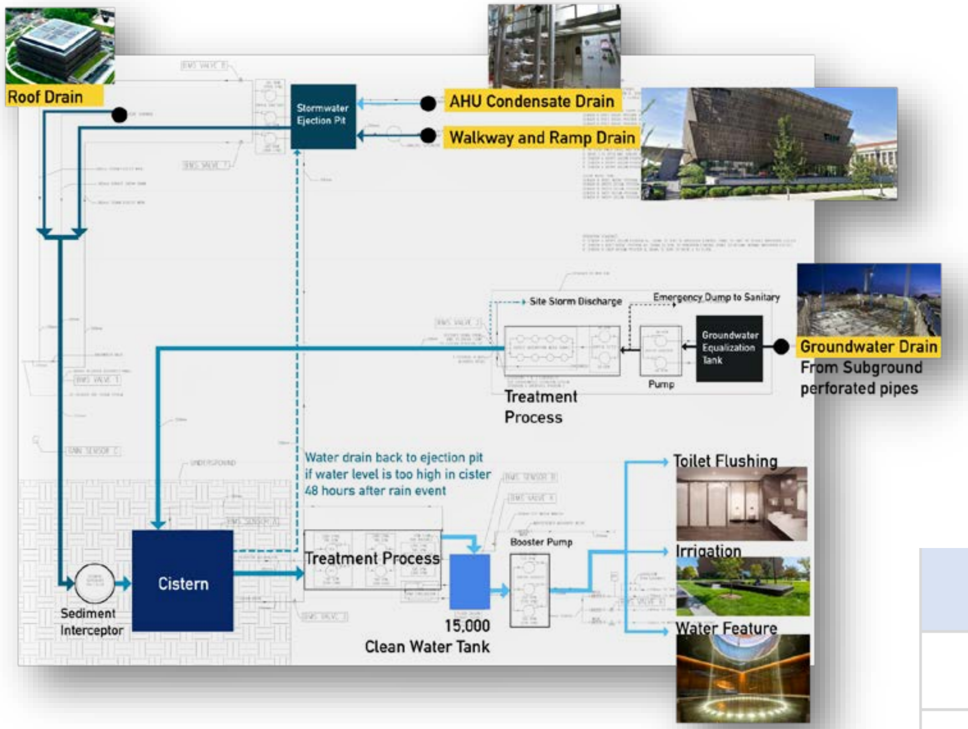
- 5875 kWh/million gallons energy are used for supplying and treating water. [1]
- 4.1 Metric ton carbon emission per million-gallon water used. [1] $50/ metric ton of CO2 value.
- Costs for alternative flooding control for national mall is $360 million. [2] Assuming lifetime of 100 years, shared by 30 buildings on the Mall and Federal Triangle.

1. *Griffiths-Sattenspiel, B., & Wilson, W. (2009). The Carbon Footprint of Water [PDF]. Portland: The River Network.*
2. *Greeley and Hansen LLC. (2011). Federal Triangle Stormwater Drainage Study (pp. 109-110, Rep.). Washington D.C.: DC Water. doi:https://www.ncpc.gov/docs/Federal_Triangle_Stormwater_Drainage_Study_Jul2011.pdf*

and in the 3rd Bottom Line is the 5% impact on visitor length of stay offered by the calming and rejuvenating effects of the water features at the entry queue and Contemplation Court.

Advanced Water Hypothesis

WATER COLLECTION AND REUSE SYSTEM

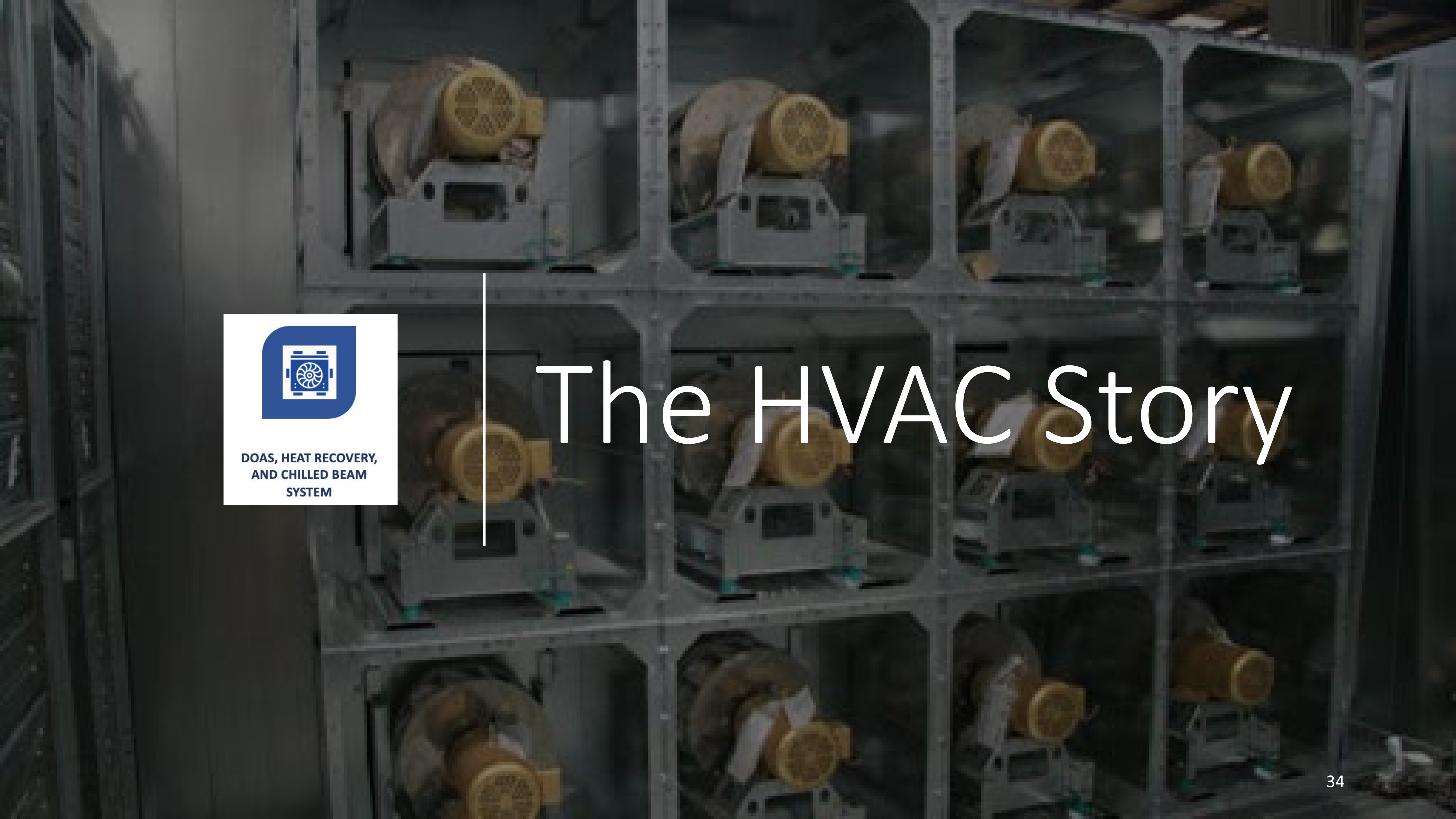


The investments in the NMAAHC rainwater system for capture and reuse for irrigation, toilet flushing and cooling towers:

1. Green roofs
2. Rainwater capture
3. Condensate capture
4. Groundwater capture
5. Water Storage
6. Water Processing

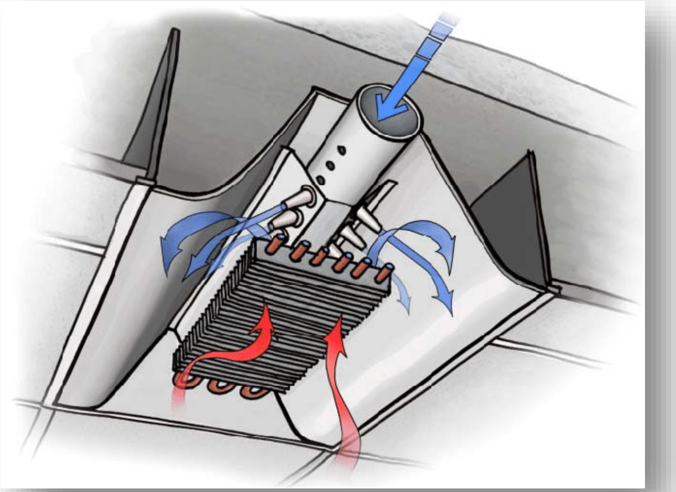
led to triple bottom line benefits (profit, planet, people)

	Added Cost/ Benefit	Cumulative Payback	Cumulative ROI	30-year NPV
Increased cost of Water System	**$5,460,000**	-	-	-
Annual Financial Cost-Benefit	$270,080	20.2 yrs	4.95%	$(4,059,000)
Annual Financial + Environmental	$122,918	13.9 yrs	7%	$(433,000)
Annual Financial + Environmental + Human Capital Benefit	$455,000	**6.4 yrs**	16%	**$9,758,000**

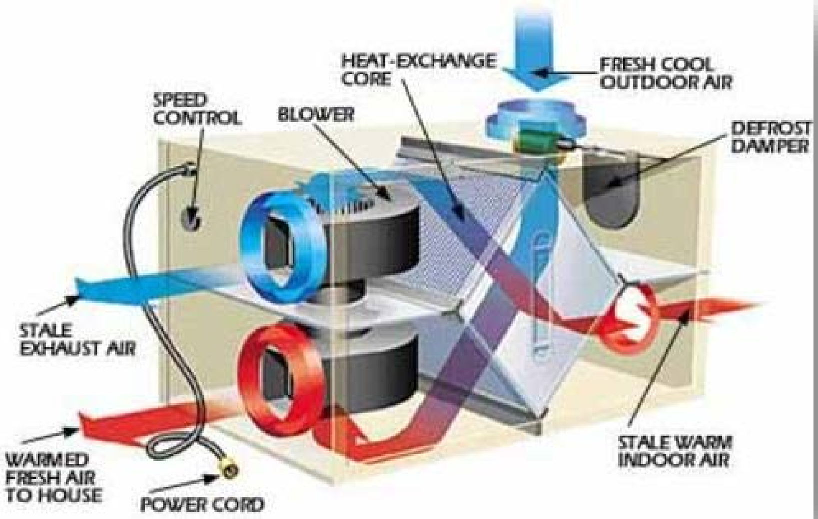


DOAS, HEAT RECOVERY, AND CHILLED BEAM SYSTEM

The HVAC Story



DOAS & Active Chilled beam



Airside Economizer

DOAS, HEAT RECOVERY, AND CHILLED BEAM SYSTEM

Advanced HVAC Hypothesis

The investments in the NMAAHC High Performance HVAC Systems

1. Fanwall Technology
2. Airside Economizer increasing Outside Air
3. Enthalpy Recovery
4. Electronic filtration
5. Waterside Economizer to turn off chillers.
6. Office DOAS (Dedicated Outside Air Delivery)
7. Office Chilled Beams

led to triple bottom line benefits (profit, planet, people)

	Added Cost/ Benefit	Cumulative Payback	Cumulative ROI	30-year NPV (NIST/LCC)
Increased cost of HVAC system	**$5,390,000**	-	-	-
One-time HVAC investment Space Cost saving	$2,158,000			
Annual Financial Cost-Benefit	$179,516	18 yrs	5.6%	$3,179,000
Annual Financial + Environmental	$49,914	14.1yrs	7.1%	$9,783,000
Annual Financial + Environmental + Human Capital Benefit	$1,364,000	2 yrs	49%	**$40,331,000**

NASA Central Campus Headquarters Building

Kennedy Space Center

Titusville, Florida

KSC Headquarters Case Study: 3 Hypotheses

CONSOLIDATING OLD FACILITIES

Consolidating aging, lower-performing facilities into a high-performance building

HIGH PERFORMANCE BUILDING COMPONENTS

High performance building strategies reduce facility LCC and carbon footprint.

PHOTOVOLTAIC PANELS

PV reduces facility LCC and carbon footprint.

KSC Headquarters Building

Concept

- Consolidate buildings from the 1960's
- Campus concept
- 5.5 acre site

KSC Headquarters

- Seven stories, 200,000 square feet
- 500 NASA civil service and contractor employees
- Shared services and shops

LCC analysis

- 30 year, 2% discount rate

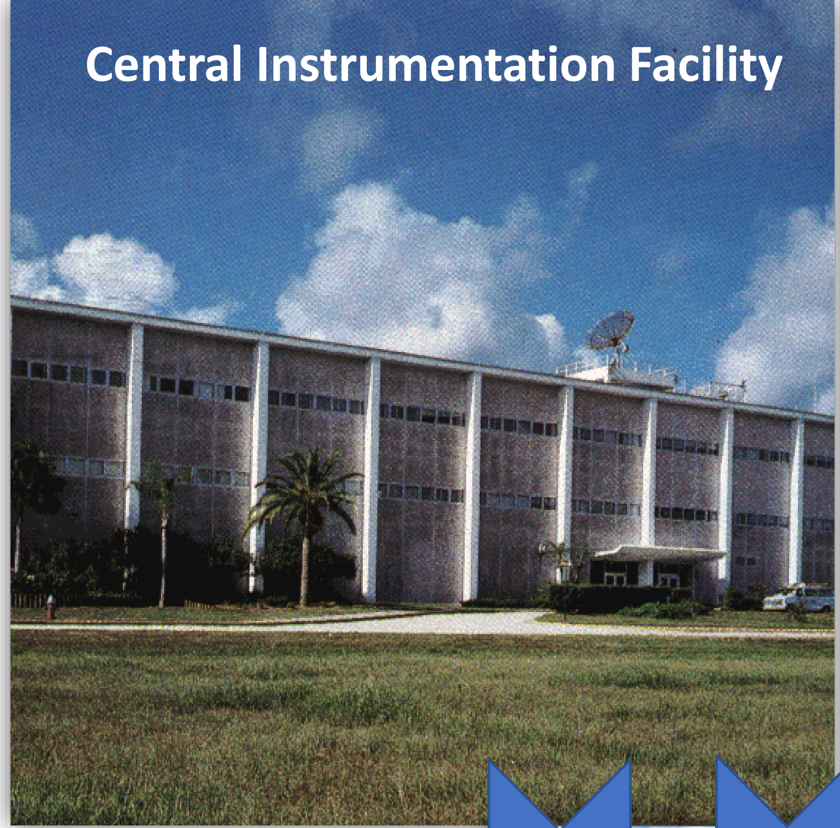
CONSOLIDATING EXISTING FACILITIES

The KDC Consolidation would address

- costly maintenance
- highly inefficient energy systems and buildings
- poor working environments
- inefficient workplace space utilization
- enhance the image of the Center
- reduce the NASA built footprint

The facilities were over 50 years old

or at the end of their life cycle in 2014


Central Instrumentation Facility


Old Headquarters Building


Operation & Support Building I


New Headquarters Building

CONSOLIDATING EXISTING FACILITIES

New Facility first costs

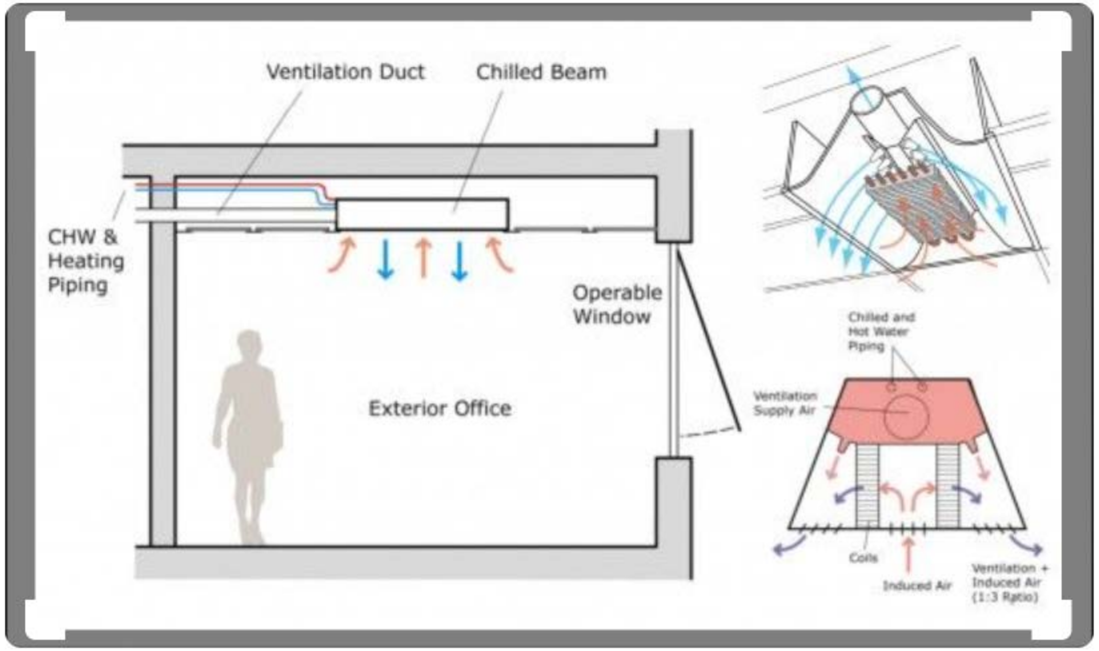
- Design
- Construction
- Demolition
- Activation and Move

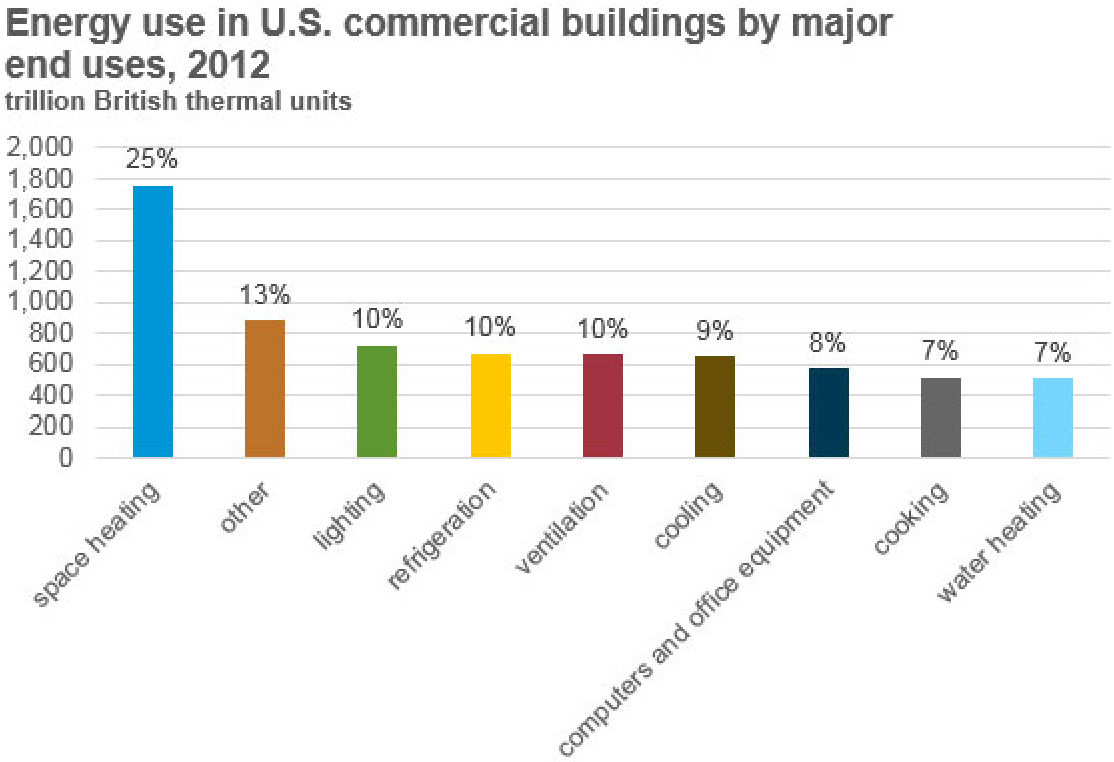
One-time transient start-up costs include

- LEED commissioning costs

Total	**$87,006,781**
Design	$2,804,281
Construction	$71,571,500
Demolition	$ 6,715,000
Activation & Move	$4,560,000
Transient Start-Up	$1,356,000

1st Bottom Line for High Performance Facilities
Financial Capital savings and LCC





Source: U.S. Energy Information Administration, *2012 Commercial Buildings Energy Consumption Survey: Energy Usage Summary*, Table 5 (March 2016)

Energy + Operation + Maintenance Savings of High Performance Facilities

Electricity, Natural Gas, and Operation and Maintenance Costs

	KSC HQ	Status Quo
Annual Electricity consumption	3,493,347 kWh	17,334,888 kWh
Cost of Annual Electricity consumption	$ 279,500	$ 1,386,791
Annual Natural Gas consumption	-	380,170 Therms
Cost of Natural Gas consumption	-	$ 416,149
Total Cost (Consumption + Operation + Maintenance)	$ 1,459,659	$ 5,272,998
Annual Consumption + Operation + Maintenance benefit	**$ 3,813,339**	
Present Value of Consumption + Operation + Maintenance	**$ 53,973,717**	**$ 204,488,426**

1st Bottom Line for High Performance Facilities
Financial Capital savings and economic measures

	Annual Savings	Annualized Financial Capital Benefit	$/sq. ft.
Financial Capital	13,841,540 kWh 380,170 Therms	$ 3,813,339	$ 19.50
Annualized 1st bottom line savings		$ 3,813,339	$ 19.50
ROI (Financial)	**4.4 %**		
Payback Period	**23 years**		
	KSC HQ	Status Quo	
30-Year LCC	**$ 140,980,498**	**$ 204,488,426**	
Reduction in 30-Year LCC	**$ 63,507,928**		

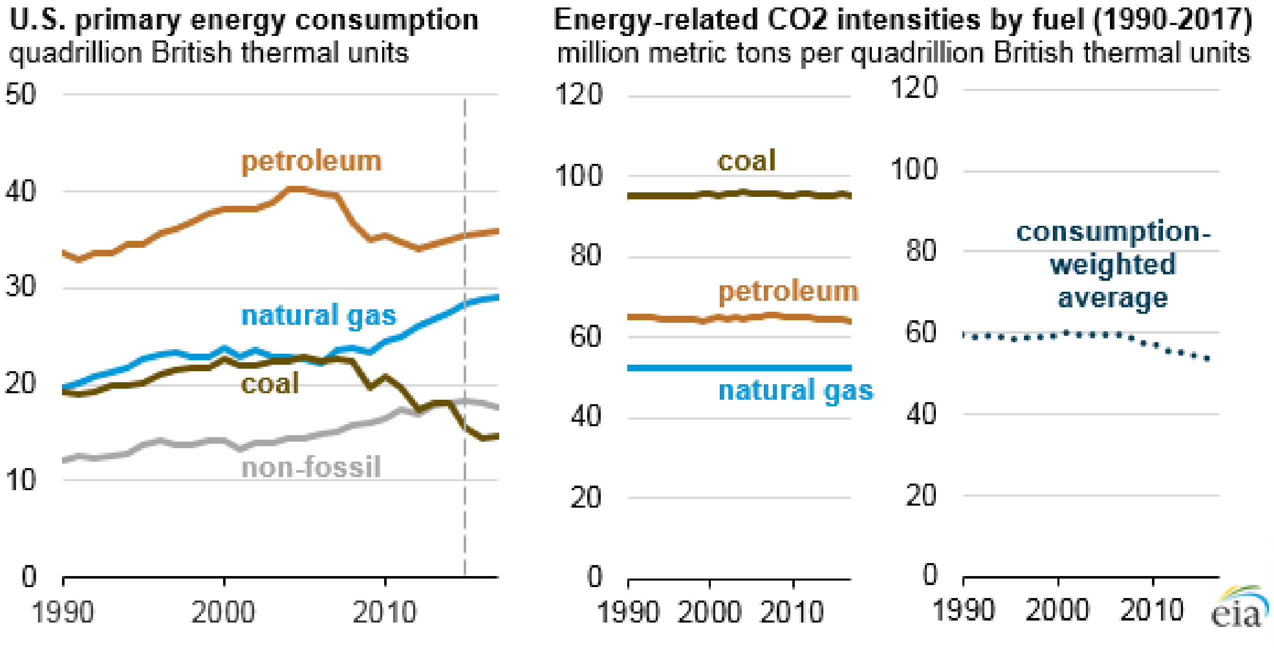
Increased first cost $87,006,781

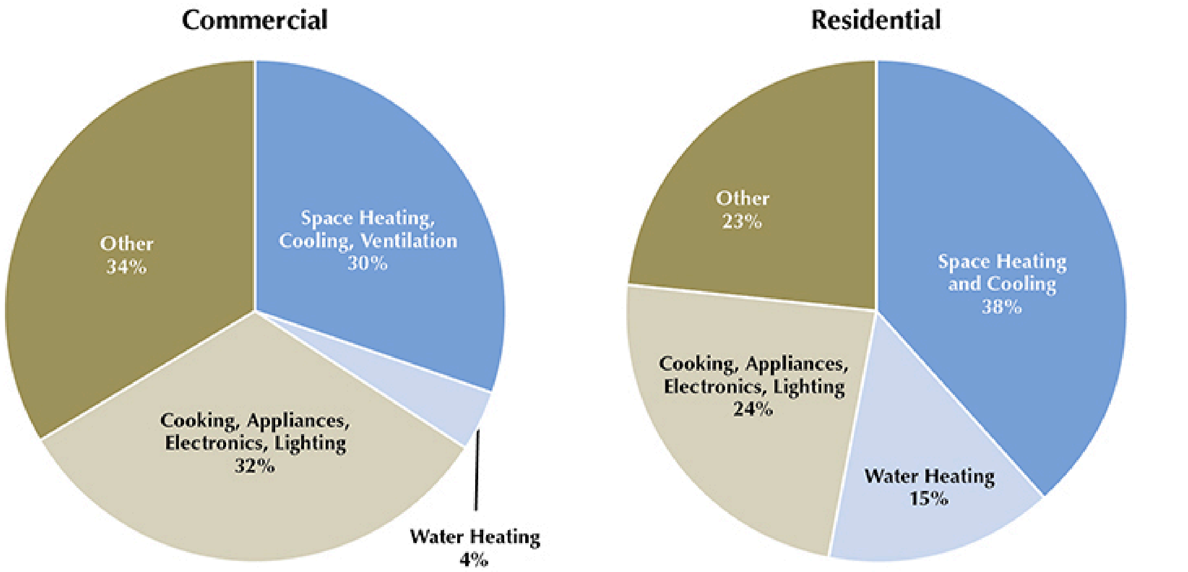
1st BL $2,835,624 with 23 year payback

Assumptions:

- *Electricity cost is calculated with US average which is $/kWh = $ 0.137 https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm*

2nd Bottom Line for High Performance Facilities
Natural Capital savings





"Other" in both the commercial and residential sector includes items such as data servers, medical imaging equipment, ceiling fans, and pool pumps which are categorized as "miscellaneous electric loads" by EIA.

Source: U.S. Energy Information Administration, Annual Energy Outlook 2018 (Washington, DC: U.S. Department of Energy, 2018), https://www.eia.gov/outlooks/aeo.

2nd Bottom Line
Environmental Savings of High Performance Facilities

Carbon Emission Costs and Benefits	KSC HQ	Status Quo
Annual Electricity consumption	3,493,347 kWh	17,334,888 kWh
Annual difference	**13,841,540 kWh**	
Annual Natural Gas consumption	-	380,168 Therms
Annual Carbon emissions	**1,696 Tons CO_2**	**10,640 Tons CO_2**
Cost of Annual Carbon emissions	$ 46,158	$ 300,215
Present Value of Carbon emissions	$ 2,905,379	$ 18,227,047
Annual Carbon Emissions reduction	**8,944 Tons CO_2 per year**	
Annual Carbon Emissions reduction benefit	$ 254,057	

2nd Bottom Line for High Performance Facilities
Natural Capital savings

	Savings	Annualized Natural Capital Benefit	$/sq.ft
Annual Carbon Emissions Related to Electricity and Natural Gas Consumption	8,944 Tons CO_2	$ 684,111	$3.50
Annualized 2nd bottom line savings		$ 684,111	$3.50
Cumulative (Financial + Natural) ROI	**4.7 %**		
Cumulative Payback Period	**21**		
	KSC HQ	Status Quo	
Cumulative 30-Year LCC	**$ 143,885,877**	**$ 222,715,473**	
Cumulative Reduction in 30-Year LCC	**$ 78,829,597**		

Increased first cost $87,006,781

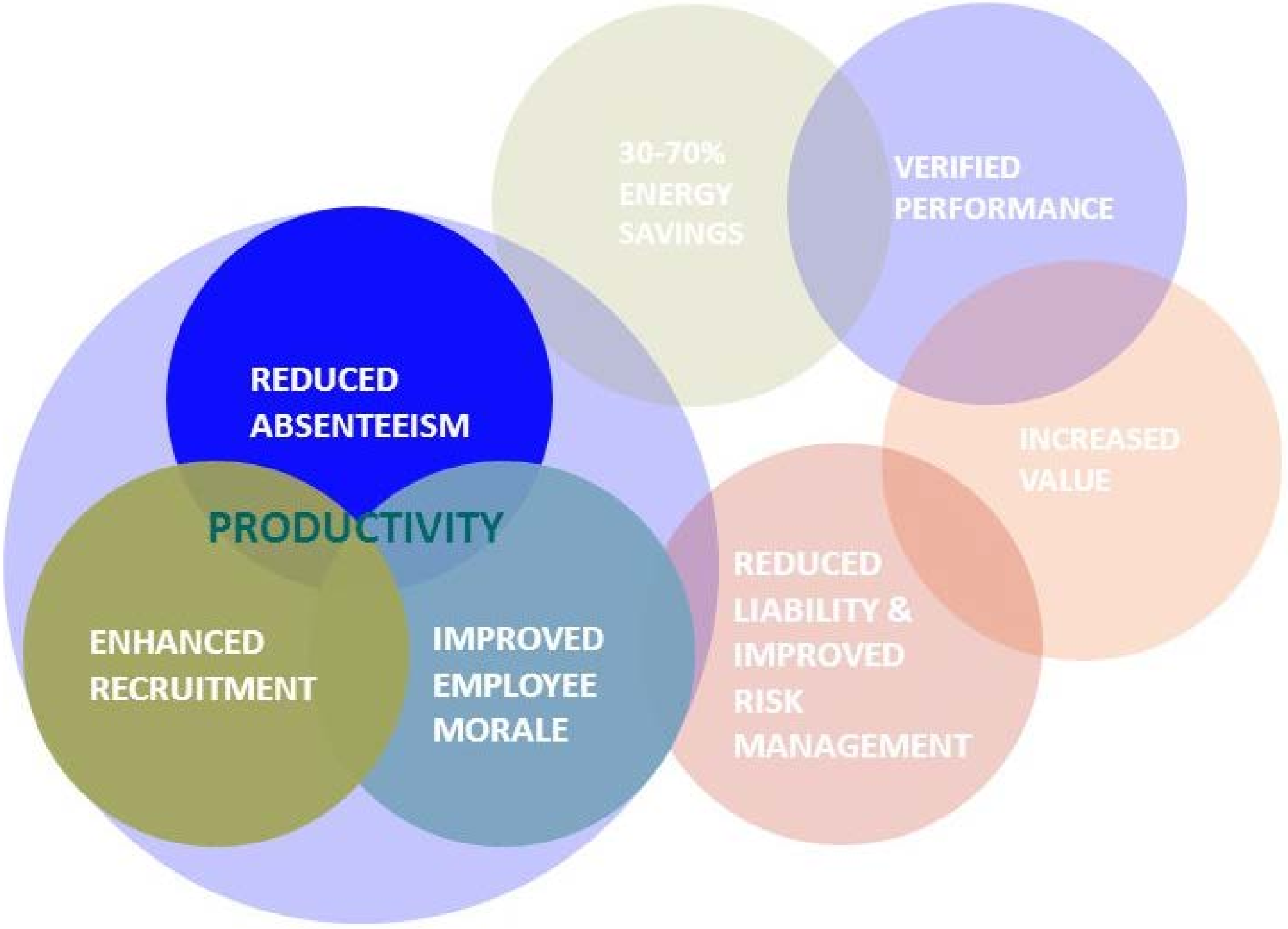
1st BL $2,835,624 with 23 year payback

+ 2nd BL $ 3,519,735 = cumulative 21 year payback

Assumptions:

- *CO2 emissions related to electricity consumption is 971 lbs per MWh https://www.eia.gov/electricity/state/florida/*
- *Annual value of CO2 offset from NISTIR 85-3273-35*

3rd Bottom Line for High Performance Facilities
Human Capital savings



3rd Bottom Line for High Performance Facilities
Human Capital savings

	Savings	Annualized Human Capital Benefit	$/sq.ft
Improved Productivity	3.5% productivity	$ 4,813,485	$ 51.70
Annualized 3rd bottom line savings		$ 4,813,485	$ 51.70
Cumulative ROI (Financial + Natural)	**6.1 %**		
Cumulative Payback Period	**16 years**		
	KSC HQ	Status Quo	
Cumulative 30-Year LCC	**$ 954,777,545**	**$ 1,062,582,556**	
Cumulative Reduction in 30-Year LCC	**$ 107,805,011**		

Increased first cost $ 87,006,781
1st BL $ 2,835,624 with 23 year payback
+ 2nd BL $ 3,519,735 = cumulative 21 year payback
+ 3rd BL $ 4,813,485 = cumulative 16 year payback

Assumptions:
20% to 50% reduction in sick building syndrome (SBS) symptoms is practical in office buildings.
SBS productivity impact is suggested 2%
Productivity gains due to improved IEQ is 0.5%-5%
Average salary per year of the HQ's employees is estimated $100,000

Number of employees are approximately 500.

HIGH PERFORMANCE BUILDING COMPONENTS

High performance building strategies reduce facility LCC and carbon footprint.

- Cost variables: envelope (glazing and shading), LED lighting, chilled beam, occupancy sensors, high SRI roof membrane, energy efficient elevator
- Financial benefit variables: reduced energy cost
- Environmental benefit variables: reduced carbon footprint of reduced energy use
- Human benefit variables: reduced absenteeism, improved occupant satisfaction and productivity

Operations Support Building (OSB II)

- Five-story
- 189,000-square-foot building
- consists of approximately 960 office spaces
- a 300-person mission conference center

Triple Bottom Line Life Cycle Cost

High Performance Building Components

The investments in the high-performance building strategies reduce facility LCC and carbon footprint

1. Enclosure (glazing and shading),
2. Lighting system
3. HVAC system

led to the following triple bottom line benefits

Financial capital benefits

- Conditioning energy savings
- Lighting energy savings

Natural capital benefits

- Lower carbon footprint
- Carbon savings based on energy savings

Human capital benefits

- Occupant satisfaction
- Improved productivity
- Lower absenteeism
- Improved thermal comfort

Increased Costs

- Glazing: insulated glass curtain wall systems (1-7 floor)
- LED lighting (37% additional cost for LED Light Fixtures in lieu of Fluorescent)
- Chilled beam (409 chilled beams, 2 chilled beam pumps, balance of system)

Triple Bottom Line Life Cycle Cost

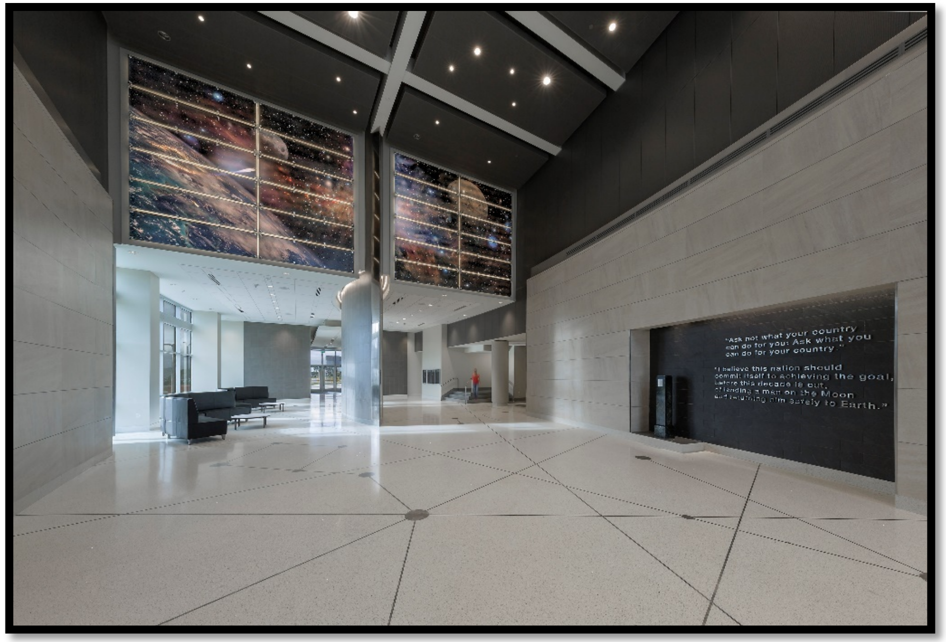
High Performance Building Components

The investments in the high-performance building strategies reduce facility LCC and carbon footprint

1. Enclosure (glazing and shading),
2. Lighting system
3. HVAC system
4. Energy efficient systems

led to the following triple bottom line benefits

	Added Cost/ Benefit	Cumulative Payback	Cumulative ROI	30-year NPV
Increased cost of high-performance building components	**$3,359,263**	-	-	-
Annual Financial Cost-Benefit	$46,500	68 yrs	1.5 %	$(3,129,119)
Annual Financial + Environmental	$33,000	62 yrs	1.6 %	$(1,796,976)
Annual Financial + Environmental + Human Cost-Benefit	$417,000	7 yrs	15%	**$8,281,429**



PHOTOVOLTAIC PANELS

PV reduces facility LCC and carbon footprint with benefits for air quality

PHOTOVOLTAIC PANELS

PHOTOVOLTAIC PANELS

The investments in PV reduces facility LCC and carbon footprint

1. Initial cost of PV system
2. Financial benefit variables: energy cost and savings
3. Environmental benefit variables: reduced carbon footprint

led to the following triple bottom line benefits

	Added Cost/ Benefit	Cumulative Payback	Cumulative ROI	30-year NPV
Increased cost of Photovoltaic System	**$5,867,330**	-	-	-
Annual Financial Cost-Benefit	$175,628	26 yrs	3.8%	$4,661,000
Annual Financial + Environmental	$227,281	23 yrs	4.3%	$5,818,000
Annual Financial + Environmental + Human Cost-Benefit	$227,281	23 yrs	4.3%	$5,818,000

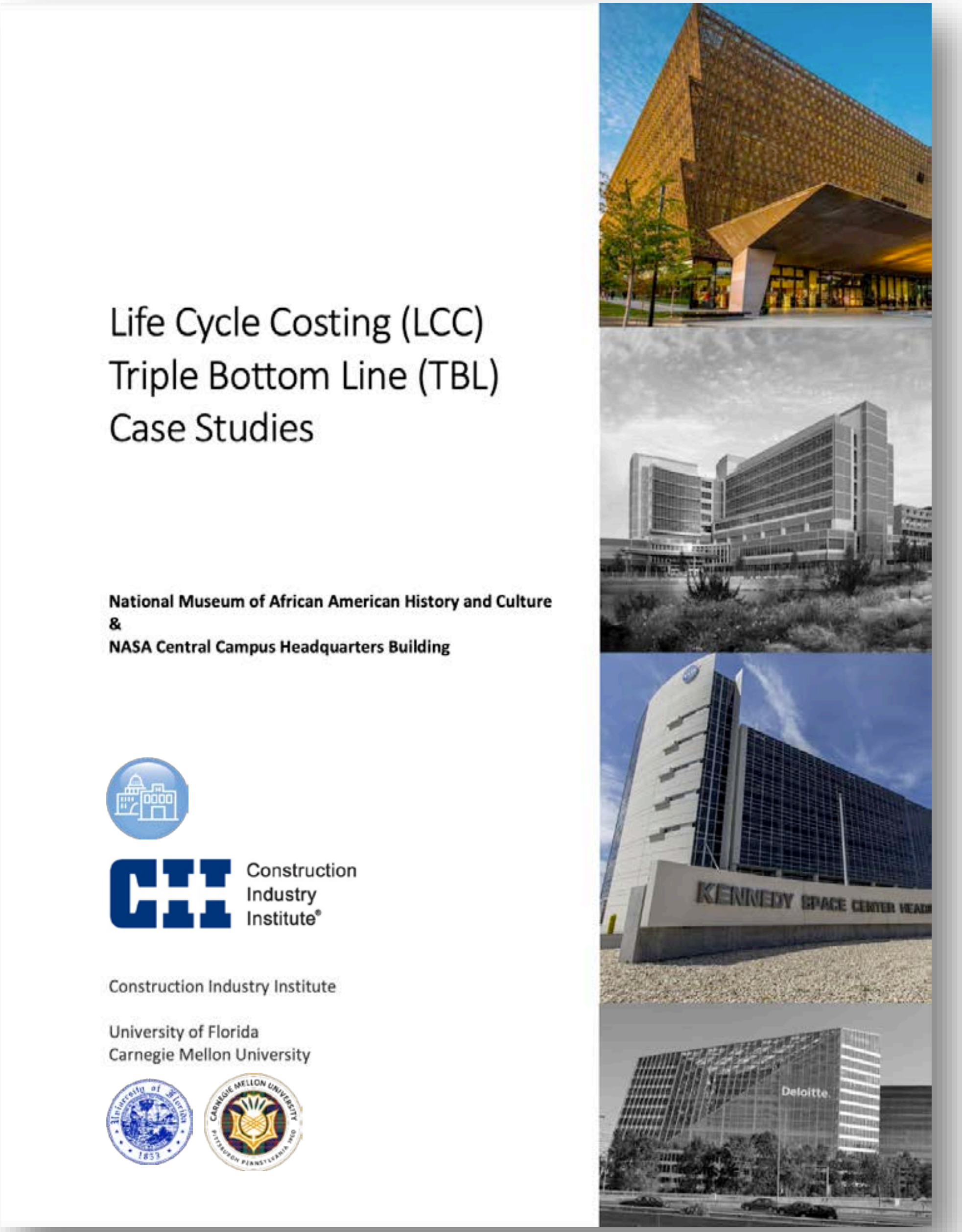
NASA Design and Management Team	
Specialty	***Name***
Primary Contact	Keith Britton, Senior Project Manager
	Nicholas Murdock
	Jennifer Hill
	Jonathan Haling
	Thomas Wilczek
Architect	HuntonBrady Architects
LEED Consultant	Exp U.S. Services, Inc

Life-Cycle Triple Bottom Line Analysis is only possible with the expertise and commitment of the project client, designers and managers.

Acknowledgement

We thank all the current or former employees listed here, who had worked on the NMAAHC project enthusiastically, and had provided us generous help and valuable information on the NMAAHC project.

Specialty	***Name***	***Title***
Primary Contact	Brenda Sanchez	Architect | Design Manager
	Larry Travis	Architect | predesign engineer
Facility Management	Thomas Reavey	Energy management group
	Paul Estrada	Facility manager
	Ryan Doyle	Zone manager
Engineer	David Venturoso	Senior Associate at WSP
	Paul Corrado	former Sr VP at WSP
	Jonathan Dickinson	former MEP at WSP
Exhibit & Design	Bryan Sieling	Assistant Director for Exhibition Design and Production
Architect | SmithGroup	Monteil Crawley	Associate |Architect at SmithGroup
Architect | Perkins&Will	Zena Howard	Principal
Customer Service	Sherri Wheeler	director of visitor services
Construction	Jared Oldroyd	vice president at Clark Construction
	Derek Ross	chief of Construction at Smithsonian
	Jessica Hibbert	senior project manager
Construction	Mac Naeemi	Project Executive |Clark/Smoot/Consigli
Engineer	Victor Olgyay	Principal for Buildings| Rocky Mountain Institute
	Elaine Adams	Sustainability Director
Building Energy & Engineering	David Epley	Associate Director for Data & Benchmarking Division
Smithsonian Enterprise	Deborah Palazzo	VP Museum relations and project management
	Jasmine Utsey	Business Liaison Program Specialist



Calculating the full cost of ownership using the breadth and longevity of LCC/TBL methods is key to investing in high performance facilities that deliver robust organizational value.

CII LCC Final Report

LCC/TBL Methodology

Smithsonian NMAAHC Case Study

- Nested Zoning
- Advanced HVAC System
- Advanced Water System

NASA HQ Case Study

- High Performance Building Systems
- Photovoltaic System
- Consolidating Facilities