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The Cost of Going Green: Alternative Energy–Saving Retrofits for a Life Sciences Laboratory

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Recent legislation and policy require substantial reduction in energy use by federal agencies

Energy Policy Act of 2005 : 20% reduction in energy consumption per SF from 2006 to 2015 using 2003 baseline

Executive Order 13423: Reduce energy intensity by 3% per year or 30% in total through end of FY 2015 from 2003 baseline

Energy Independence and Security Act of 2007: Increase energy reduction goals of EPACT2005 to 30%

The 2007 Act requires building component retrofits if justified by life cycle cost analysis for a 40-year investment period

Life cycle cost analysis

A mathematical comparison of the costs and benefits of alternative projects typically accounting for initial purchase or construction, operation & maintenance, and any salvage or endpoint value. Comparisons are usually made on the basis of discounted values over a selected investment period.

OMB Circular A-94 "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs"

Code of Federal Regulations 10CFR436.10-24 "Methods and Procedures for Life Cycle Cost Analyses"

DOE Guidance: "Methods and Procedures for Life Cycle Cost Analyses;" "Renewable Energy Requirement Guidance for EPACT 2005 and Executive Order 13423"

Case study

Evaluate the life cycle cost effectiveness of alternative combinations of energy-saving components for a large laboratory at Pacific Northwest National Laboratory

DOE Life Sciences Research Laboratory, Building 331

- Built in 1970
- 115,000 GSFT
- Three floors of biological research and administrative space

Task plan

1. Define the current building component inventory
2. Develop two alternative inventories to reduce energy consumption, focusing on architectural, mechanical, and electrical building systems
   - Alternative 1: Low initial cost, low energy reduction
   - Alternative 2: Higher cost, higher energy reduction
3. Estimate M&R and energy costs of original inventory and two alternatives
4. Prepare a life cycle cost analysis
5. Review key assumptions and draft findings
6. Revise estimates and prepare final report

Develop alternatives

- Alternative components were specified by Jacobs Engineering and reviewed by PNNL staff
- Aged existing components (with high M&R requirements) replaced, more efficient components identified through extensive market search

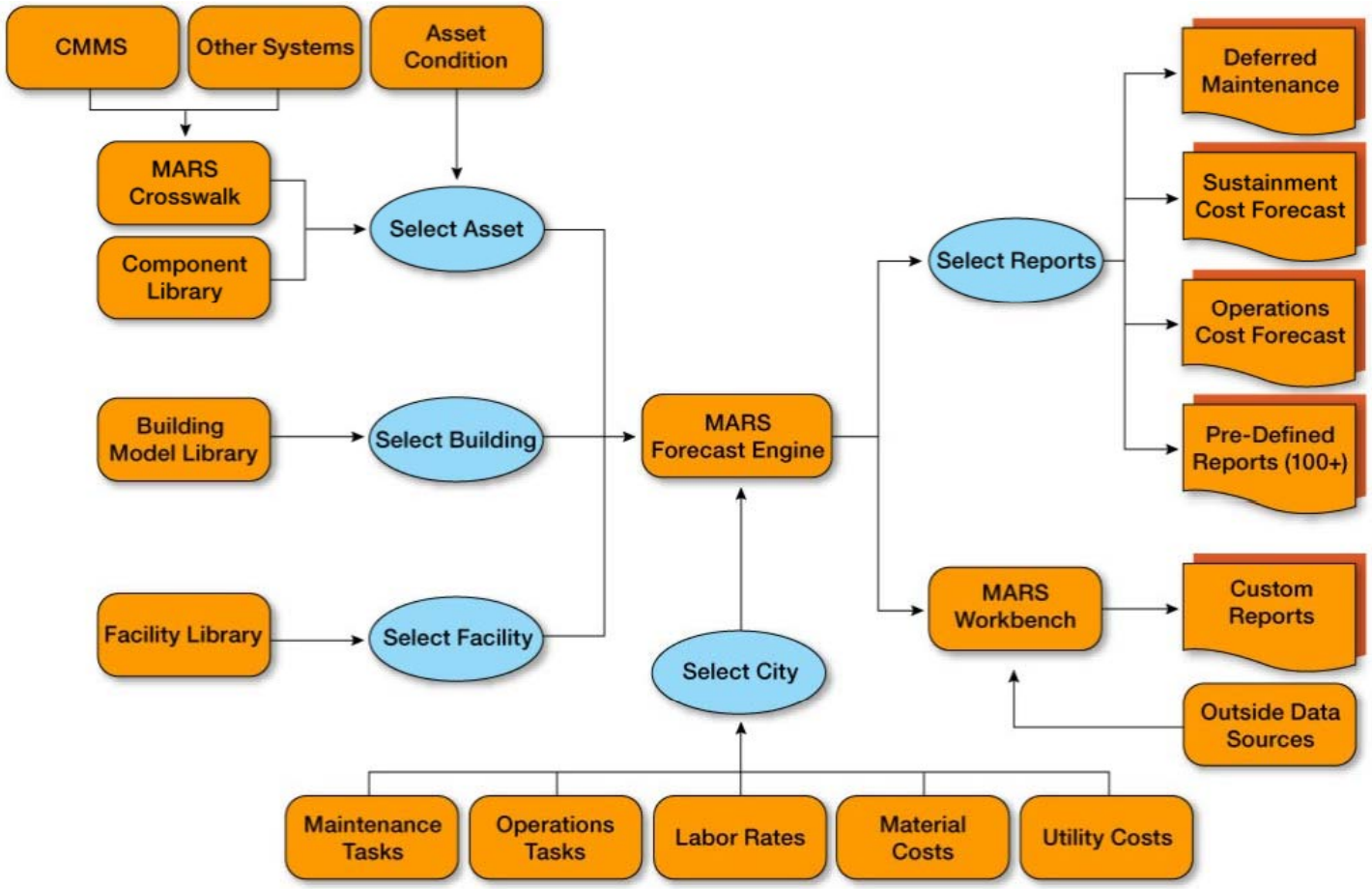
	Initial Cost	Component Change*	Energy reduction from FY03
Alternative 1	$2.3 mil	Reflective coating to built up roof, Double glazed windows, Water heater turbocharger, VAV air handlers, Powersmith transformers, Variable volume exhaust hoods	16%
Alternative 2	3.4 mil	Green roof w/ growing medium, Triple glazed windows, Water heater turbocharger, Heat recovery chiller, variable volume fancoil system, Powersmith transformers, Variable volume exhaust hoods w/ occupancy control	35%

*Some component changes not listed

Estimate M&R and energy costs

- M&R was estimated for preventative maintenance, unscheduled maintenance, and major repair & replacement using the MARS Facility Cost Forecast System
- Energy costs were calculated using equipment specifications, building requirements, and climatic variables. Included direct energy savings (from energy consuming equipment) and indirect savings (from reduced heat/cool loss; e.g. triple glazed windows).

MARS life cycle cost model



Life cycle cost comparison

- Alternative 2 had the lowest cost (12% less than the current building) despite the highest initial investment.
- Ranking is robust; shorter investment period (25 years) and lower discount rate (2.6%) still favors alternative 2 by 8%.

Table 2. Total Cost Comparison of Alternatives

	Total Cost[A]	Change in Energy Consumption (kBTU)[B]	Percent FY03 Baseline[C]
Baseline	$14,747,712	0	0%
Alternative 1	$14,914,084	-6,596,036	16%
Alternative 2	$12,801,852	-14,486,167	35%

[A] Total Cost is the 40 year sum of sustainment and energy costs. All costs are expressed in $2008 and discounted at 2.8% annually per OMB Circular No. A-94.

[B] Change in Energy Consumption is the annual change in energy requirements between the alternative building inventory and the baseline.

[C] Percent FY03 Baseline is the annual reduction in energy demand over the total energy demand for the Fiscal Year 2003 baseline (41.2 million kBTU).

Life cycle cost comparison

Most energy savings came from HVAC retrofit

Table 3. Annual Energy Savings by Building System

UniFormat	Title	Alternative 1 Change in Energy Consumption (kBTU)[a]	Alternative 1 Energy Savings[b]	Alternative 2 Change in Energy Consumption (kBTU)	Alternative 2 Energy Savings
B2020	Exterior Windows	-1,255,298	$18,783	-1,288,485	$19,250
B2030	Exterior Doors	0	$0	-133,833	$2,000
B3010	Roof Coverings	-37,158	$554	-118,089	$1,767
D2020	Domestic Water Distribution	-19,548	$1,038	-127,047	$2,292
D3030	Cooling Generating Systems	-91,700	$1,374	-2,670,807	$40,009
D3040	Distribution Systems	-4,828,008	$72,241	-13,333,982	$199,516
D3050	Terminal & Package Units	-240,211	$3,594	-3,303,749	-$52,424
D5010	Electrical Service & Distribution	-6,582	$117	-16,334	$336
D5020	Lighting & Branch Wiring	-85,802	$1,528	-199,803	$3,962
E1010	Commercial Equipment	-31,935	$570	-31,935	$570
E1020	Institutional Equipment	0	$0	0	$0
Total[c]		-6,536,938	$99,797	-14,466,167	$217,968

[a] Change in Energy Consumption is the total annual change in energy requirements between the alternative building inventory and the baseline.
[b] Energy Savings is the total annual savings in energy costs from a decrease in kBTU consumption.
[c] All costs expressed in $2008.

Life cycle cost comparison

The cost advantage of Alternative 2 is driven largely by changes in mechanical equipment, and much of the savings comes from reducing the load on other systems:

- Scroll Water-Cooled Chiller – Heat recovery system decreases the load on water heaters
- Variable Speed Chilled Water Primary Pump – improved circulation eliminates secondary pump.
- Motorized Dampers – Decreases operating hours of HVAC equipment
- Air Conditioner, Variable Refrigerant Volume – AC Package unit eliminates separate air handling equipment.
- Walk-in Freezer/Cooler – Heat recovery system decreases load on water heaters.
- Laboratory Exhaust Hoods, Variable Volume – Decreases load on Package Units

Life cycle cost comparison

Retrofits to roof coverings, water heaters, transformers, and commercial equipment were not cost effective (higher LCC costs than existing systems)

Table 4. Cost Comparison by Building System

Uniformat	Title	Baseline Cost[a]	Alternative 1 Cost	Alternative 2 Cost
B2020	Exterior Windows	$881,288	$800,288	$801,085
B2030	Exterior Doors	$165,047	$165,047	$167,288
B3010	Roof Coverings	$478,508	$888,881	$878,280
D2020	Domestic Water Distribution	$182,854	$803,012	$373,008
D3030	Cooling Generating Systems	$5,101,814	$5,881,722	$4 838,080
D3040	Distribution Systems	$5,488,881	$4,278,733	$110,878
D3060	Terminal & Package Units	$810,041	$848,133	$3 387,885
D5010	Electrical Service & Distribution	$87,230	$102,882	$103,884
D5020	Lighting & Branch Wiring	$888,878	$830,807	$810,884
E1010	Commercial Equipment	$884,882	$782,818	$1 087,418
E1020	Institutional Equipment	$810,082	$1,013,182	$1 038,813
Total[b]		$14,144,712	$14,814,884	$13,881,858

[a] Cost is the discounted sum of component sustainment requirements and energy consumption over 40 years.

[b] All costs are expressed in $2008 and are a 40 year total discounted at 2.8% annually per OMB Circular No. A-94.

Summary

- Alternative 2 reduced estimated energy consumption by 35% and reduced (discounted) cost by 12% over 40 years.
- Most of the savings came from HVAC changes; some retrofits—e.g. green roof and water heaters—were not cost effective.
- Safe to conclude that some conservation projects are cost effective, but depend on the individual components affected.

Limited life cycle cost data exists (in easily accessible format) on energy saving components—almost 100 interviews and secondary sources and a variety of models were required to estimate M&R and energy demand.

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