Analysis of Alternatives

Core Facility Revitalization (CFR) Project
Brookhaven National Laboratory

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Analysis of Alternatives for the Core Facility Revitalization (CFR) Project

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1.0 INTRODUCTION

The Core Facility Revitalization (CFR) project has been requested by the U.S. Department of Energy (DOE) as a new start in the FY2017 federal budget within the Science Laboratories Infrastructure program. The CFR Mission Need was approved September 1, 2015. In accordance with DOE Order 413.3B, this Analysis of Alternatives and associated Life Cycle Cost Analysis (LCCA) sets forth the descriptions, costs, and benefits of the alternatives analyzed for this project. The Office of Management and Budget (OMB) Circular A-94 guidelines apply to any analysis used to support Government decisions to initiate projects which would result in a series of measurable benefits or costs extending for three or more years into the future. The analysis is consistent with the cost Effectiveness, Constant Dollar analysis requirements of OMB Circular A-94 and is intended to support DOE's request for funding of the CFR project.

HDR Architects have been retained for the purpose of preparing the Life Cycle Cost Analysis for the project alternatives with the assistance of select SME's at the Brookhaven National Laboratory Site.

2.0 EXECUTIVE SUMMARY

The existing RHIC/ATLAS Computing Facility (RACF) currently occupies over 16,000 square feet of space in three rooms within Building 515 that was originally constructed in the 1960s and most recently expanded in 2009. The existing RACF facilities and infrastructure have finite capacities in terms of processing (computer cores), storage (petabytes of data), server space (racks), and power (kilowatts of electricity). The existing facility also has significant deficiencies due to its age, limited amount of usable area for data center equipment, rigid building configuration and marginally adequate power distribution and cooling systems.

Although the RACF is adequate to meet current demands, the facility will be unable to meet future requirements in terms of capacity and reliability due to the evolution of technology and data center operating standards. The overall computing capacity of the RACF is expected to decrease over the next ten years, beginning in FY 2018 and significantly decreasing after FY 2020. This overall reduction will be caused primarily by the limitations of Building 515 in terms of space and utilities. As server and tape storage equipment is replaced at the end of their useful lives (approximately four years), the racks to accommodate new equipment will need to be deployed with increased distances between them and of lower density to enable the necessary cooling and to account for limitations of the existing floor structure.

The data volume generated by the RHIC experiments and ATLAS are expected to increase three to six times over the next ten years and will require proportional increases in computation and data storage capacities. These increases will drive increased requirements for space, power and cooling capabilities. The existing capacity limitations and facility deficiencies of the RACF will negatively impact the availability and reliability of computational support to NP and HEP funded research as well as other BNL programs. Failure to accommodate these projected increases will result in significant infrastructure capacity gaps, will significantly impede mission readiness of the RACF and will impose significant risks on research funded by NP and HEP, as well as other programs that may rely on BNL data storage and computational capabilities.

Due to the rapid evolution of computing technologies and the expected service life for the major mechanical and electrical components of a modern computing facility, a 25-year study was selected for this analysis. It is unreasonable to assume we can project the future of computing facilities 25-30 years from today. In contrast, a typical LCCA for a conventional office/laboratory structure would typically utilize a 50 year study period. A facility service life of 80 years is assumed in BNL's master site planning for all facilities.

This analysis compares the life cycle cost of remaining in B515, Alternative 1 – Maintain Status Quo or "Do Nothing", with the life cycle cost of renovating an existing BNL facility (Alternative 2) or constructing a new facility (Alternative 3). The categories of cash flow considered in the evaluation of the life cycle cost consisted of capital investment costs, energy costs, general maintenance and major equipment repair and replacement costs, deferred maintenance cost, and costs associated with opportunity loss and productivity gains. The critical deferred maintenance cost is the minimum initial repair costs required to bring the existing facility and existing mechanical systems up to acceptable standards and safe operating conditions.

The Life Cycle Cost analysis results for the three (3) cases analyzed are summarized as follows. The Building Life Cycle Cost program (BLCC 5.3-15) developed by NIST was used for this analysis.

	Alternative 1 Maintain Status Quo (Base Case)	Alternative 2 Renovate Existing Facility	Alternative 3 Construct New Facility
Total Life Cycle Cost	$109,328,869	$125,182,303	$148,144,853

Table 1 - Life Cycle Cost Analysis Present Value Results

The present value of costs, average annual cost, simple payback period and rate of return on investment are the recommended measures to be used to gauge the economic performance of the alternatives. Summarized as follows are the estimated capital investment, average annual operating cost savings, simple payback period and rate of return on investment for Alternatives 2 and 3 compared to the Base Case (Alternative 1).

	Alternative 2 Renovate Existing Facility	Alternative 3 Construct New Facility
Capital Investment	$67,922,000	$106,141,000
Net Cost Saving	-$15,853,434	-$38,815,984
Simple Payback	25 years	Outside the study (>25 years)
Adjusted Internal Rate of Return	0.75%	- 0.53%

Table 2 - Simple Payback and Return on Investment

Appendix C contains a complete comparative analysis of the two alternatives to the base case. The analysis indicated that Base Case (Alternative 1) yields economic benefits. The initial investment of $8,420,241 would result in cost savings of $15,853,434 over Alternative -2 (Renovate Existing Facility) and $38,815,984 over Alternative-3 (New Facility) over a 25-year period. It is important to note that the significant potential benefits gained by other DOE programs at the BNL site are not addressed or quantified in this study.

A sensitivity study was also performed to determine the uncertainty of this outcome. The objectives of the sensitivity analyses were to: (a) account for uncertainty in certain key parameters, and (b) determine which alternative was more cost-effective under different assumptions. The sensitivity analysis consists of six scenario-based analyses. The results of the Sensitivity Study, shown in Table 3 below, indicate that in all scenarios, the Maintain Status Quo (Base Case) has the lowest LCC when compared to the other Alternative Cases (Alternative 2 and 3).

Analysis Scenario	Parameter Changed from Base Case Scenario	Lowest LCC Alternative	Maintain Status Quo	Renovation			New Facility		
			NPV [$M]	NPV [$M]	Payback Period [years]	Discounted Payback Period [years]	NPV [$M}	Payback Period [years]	Discounted Payback Period [years]
Base Case	None	Maintain Status Quo	$109.3	$125.2	25 years	None	$148.1	None	None
A	Decreased Discount Rate to 1.5%	Maintain Status Quo	$116.1	$128.9	25 years	None	$149.9	None	None
B	Increased Discount Rate to 2.9%	Maintain Status Quo	$94.6	$116.9	25 years	None	$143.9	None	None
C	Decreased Capital Costs by 20%	Maintain Status Quo	$107.6	$112.2	22 years	None	$131.0	25 years	None
D	Increased Capital Costs by 20%	Maintain Status Quo	$111.1	$138.2	None	None	$165.3	None	None
E	Decreased O&M & Repair Costs by 20%	Maintain Status Quo	$105.7	$119.9	25 years	None	$142.4	None	None
F	Decreased Productivity Loss	Maintain Status Quo	$109.3	$131.5	None	None	$154.4	None	None

Table 3 - Summary of Sensitivity Study Results

3.0 LIFE CYCLE COST ANALYSIS

3.1 Summary of Approach

When the purpose of a life cycle cost analysis is to evaluate cost-effectiveness, lease purchase, internal government investment, and asset sales rather than to primarily assess energy-related savings, the analysis is subject to Office of Management and Budget (OMB) Circular A-94. The Building Life-Cycle Cost (BLCC5 5.3-15) software, developed by the National Institute of Standards and Technology (NIST) contains modules designed to perform life-cycle-cost analyses subject to OMB Circular A-94 and was used to perform this analysis.

LCC estimates in present dollars; that is all future costs are discounted to a present value as of the base date and summed.

Section 3.2 Alternatives Description, summarizes the multiple strategies considered for addressing the capability gap and supporting the mission need. Two alternatives were identified for final/detailed evaluation. Alternative 2 – Renovate B725 and Alternative 3 – Construct a new facility. The purpose of this analysis was to perform life cycle cost analyses comparing these two alternatives with the base case of operating the existing B515 RACF (Alternative 1 – Maintain Status Quo or “base case”) for the next 25 year time period. Alternative 1 includes the minimum initial repair costs (critical deferred maintenance and compliance modifications) required to maintain the computational facilities in building 515 in a minimally functional state but does not address the capability gap detailed in the sections above.

3.2 Alternatives Description

Beginning prior to the spring of 2014, preliminary planning efforts were initiated by BNL to address the growing capability gap at the B515 RHIC/ATLAS Computing Facility. Lists of potential alternatives were identified as well as potential locations. The alternatives considered can generally be organized into five (5) categories. A summary of each is presented below.

Category 1 – Maintain Status Quo (do nothing): Under this option, the use of the existing RACF at B515 would be continued to the greatest extent possible. The required deferred maintenance and compliance upgrades would be performed. Substantial productivity loss and programmatic opportunity loss would be realized. This category of alternatives does not address the capability gap or contribute to the support of the HEP/NP mission need.

Category 2 – Renovate Existing Facilities at BNL: This category of alternatives involves the renovation and/or expansion of existing available facilities on the BNL site.

Expand and Renovate B515 (The Existing RACF):
Similar to category 1, B515 would require the immediate execution of significant compliance upgrades and infrastructure replacement. B515, originally constructed in 1966, has significant limitations due to inadequate power/cooling infrastructure and physical configuration. Adequate

space does not exist to construct a new modern data center addition with required office space that would need significant mechanical and programmatic space nor accommodate future growth needs. It is highly unlikely the existing facility could be re-configured to meet current federal DCOI requirements. Siting of the required exterior infrastructure (Generators and electrical gear) would require the elimination of significant parking capabilities in what is already a problematic area of the site. As this is a fully operational critical facility, phased construction at this facility would add years to the project execution schedule and negatively impact research. This option was not considered for additional study.

Renovate B725:
B725, originally constructed in 1980 with multiple significant additions from 1985 through 1995, served as the former home of the NSLS-I program. A sound building containing approximately 155,000 GSF, the facility contains adequate space for all of the present and future computing and support space needs. The Building is ideally located with respect to available utility infrastructure and proximity to the users and researchers. The facility contains significant existing quality office space (approx. 38,000 GSF) and other space easily configured for use by other BNL research groups. Re-use and re-purpose of this facility supports federal “Freeze the Footprint” principles with respect to office space. Significant investment in hazardous material remediation and maintenance has been made over the past several years. Renovating this facility would avoid adding significant vacant space to the BNL inventory. The CFR Project would renovate approximately 50% of the first floor gross square footage of this facility to address the capability gaps noted above. This option will be considered for additional study.

Consider other BNL Facilities for Renovation:
Several other existing facilities/locations were considered. Both B462 and B477 were preliminarily analyzed but rejected as candidates for renovation based on their age (both constructed in 1945), poor proximity to BNL power and cooling infrastructure, inadequate size to meet the present and future program requirements, and logistical issues with building access and co-location with researchers/users. This option was not considered for additional study.

Category 3 – Construct New Building at BNL (Line Item Funding): This option involves the utilization of Line Item funding for the construction of a new building to house the computing facility scope plus future expansion capabilities on the BNL site. Included in the scope is approximately 20,000 SF required to house the required supporting technical and research staff.

Alternative strategies were considered with respect to satisfying the one-for-one demolition space offset requirement associated with the construction of new federal facilities. At present, BNL does not have adequate square footage available for immediate demolition without considering the demolition of the vacated B725 facility. A vacant B725 would also remain a significant liability on the BNL site with respect to carrying costs. There are also significant advantages to re-use of the B725 site with respect to site utility access (Power, Fiber, and Chilled Water). Therefore, it is determined that the option to construct a new facility at BNL will include the required demolition of the existing B725 facility. This option will be considered for additional study.

Category 4 – Construct New Building at BNL (Alternative Financing): This category of alternatives involves the construction of a new building to house the Computing Facility base scope on existing land contiguous to or in close proximity to the BNL site. Also included is the approximately 20,000 gsf required to house the required supporting technical and research staff. In both cases, fixed lease payments would be made to a 3rd party developer.

These options are problematic because of the following reasons -

a. Locating the facility and staff remote to the BNL site will result in a significant productivity loss.
b. Considering the Long Island real estate market, it is likely that a suitable developer does not exist with the capabilities and desire to operate and maintain a facility such as the RACF nor would they want to assume the risk associated with the facility reliability requirements. Therefore, the only potential path forward with respect to alternative financing would to be to identify a developer willing to construct a “white box”, leaving the cost of all “tenant improvements” including the sophisticated electrical and mechanical systems, their maintenance, and strict performance requirements the responsibility of BNL.
c. OMB approval of a long term “tenant/landlord” lease agreement of this nature is highly unlikely.

This category of options will not be considered for further evaluation.

Category 5– Establish Capability at Another Location: This category considered two options.

Option A – Establish the capability at another national laboratory computing facility. *Option B* – Establish the capability via private Cloud Computing.

Option A will not be considered for further evaluation as The RACF computing facility will require significant additional infrastructure, space, and hardware which is not available at this time at other institutions and would require significant investment at the respective sites. This is particularly relative to the significant day one data storage needs (80PB “+”) of the RHIC and ATLAS programs. Adequate capacity dos not exist at this time. In addition, the necessary expertise to support the mission need also resides at BNL. Significant cost and effort would be required to develop this expertise elsewhere and establish the efficient communication/data transfer protocols required. There is also high risk associated with outsourcing operational responsibilities away from the existing RACF team.

Option B establishes the computing capabilities via cloud computing services. While the first four alternatives lend themselves to an objective LCCA, private cloud computing options remain less defined, highly case sensitive, technically problematic, and subject to rapid change in the market due to economic pressures. Prior DOE studies have concluded that cloud computing is more expensive than DOE HPC facilities and demonstrated poor performance with communication and I/O intensive scientific applications. These findings are detailed in the Magellan Report on Cloud Computing for Science, Dec 2011.

Progress is evident over the last few years. Data storage cost has dropped to approximately $0.03 per gigabyte per month. Alternative “SPOT” service agreements for computing have significant cost savings over “reserved” computing service capabilities by a factor of approximately 3. This “bidding” option is viable if programs are willing and capable to run workloads that can tolerate unexpected terminations. These rates have been monitored by BSA and remain constant for over one year. However, the total costs for compute and storage capabilities deployed at the RHIC/ATLAS Computing Facility remain approximately one-half the cost of comparable cloud-based services and when calculated for the entire RACF computing capability, they represent a significant savings to the programs. These calculations as presented and researched by Dr. Michael Ernst, former Director of the RACF, are summarized below:

		FY15 Cost	**Total 3-Yr. Cost**	
Procure In-House Capabilities	HEP/NP 3-Yr. Cost for In-house Infrastructure (7 PB storage + 10-15% of total compute capability)	$1,238,000	$1,238,000	
Procure Cloud Based Capabilities	3-Yr. Cost of AWS Data Storage (7 PB @ $0.03/GB/Month)	$2,030,000		
	3-Yr. Cost of AWS SPOT Computing Services (10-15% of total compute capability)	$225,000		
			$2,255,000	
			$1,017,000	**Total 3-Yr. Savings In-house vs. Cloud services**

Note: Calculation based on approximately 10-15% of the total HEP/NP computing and data storage requirement. Total 3-Yr. savings for entire facility capability is approximately $10,170,000 - $8,644,500.

Table A - In-House Vs. Cloud Computing Capabilities

The expectation is that cloud computing and storage costs should continue to decrease. That has not been the case for the last 2 years. Predicting cloud costs for the next 25 years and making long term financial decisions based on little historic data extremely risky. There has not been adequate historic cost data to analyze nor documented success to validate the long term commitment of significant large scientific research program funding, such as that which is associated with the RHIC/ATLAS computing mission.

Commitment to cloud computing capabilities is somewhat problematic as it is essentially remains an all or nothing approach. DOE Program funding is generally based on short term commitments. These commitments are subject to continuous change brought on by economic factors. Once a program is committed, particularly with respect to data storage, it is costly to move to back to any form of institutionally based computing infrastructure. Cloud computing is a long term commitment with significant risk tied directly to the ability to maintain consistent, long term funding. It is subject to volatility in the private cloud services market and does not provide scientific programs the opportunity to economically manage infrastructure to meet changing needs.

This category of options will not be considered for further evaluation.

3.3 Analysis Input

Input data for the BLCC software is organized into several levels. Overall project level parameters and multiple input parameter levels for each alternative are considered.
Project level parameters apply to each alternative. The multiple input parameters are specific to individual alternatives. The overall parameters, specific alternative parameters, and the analysis results are discussed below.

3.4 Overall Project Parameters

The table below summarizes the overall project level parameters. The study period is the length of the time covered by the economic analysis. The base date is the beginning of the first year of the study period and service date is the point in time during the study period when the alternative is put into use. All costs, other than capital investment, which occur prior to the service date are considered to be mutually exclusive and are therefore not addressed.

Parameter	**Value**
Discounting convention	End-Of -Year
Analysis Type	Constant Dollar
Real Discount Rate	1.9% as per OMB Circular A-94
Base Date	October 1, 2016
Service Date	October 1, 2020
Study Period	25 Years
Electric Cost – BNL Site	$0.07 / KWh
Fuel Cost (Blended Rate)	$2.57 / SF
Water Cost (Usage + Disposal)	$.50 / 1,000 Gal.
Average Annual Salary (RACF) Total Annual Salaries	$254,540 $6,877,681
Energy Price Escalation Rates	BLCC5.3-15 software

Table 4 - Overall Project Parameters

Electricity, natural gas, and fuel oil are the major energy sources used at BNL. Current unit costs are presented above. Electrical costs and fuel cost is a blended rate. These per unit energy costs are escalated throughout the study period using the DOE recommended values, which are internal to the BLCC software. The energy price escalation rate is the projected rate of price increase above the projected general rate of inflation.

Average annual salary reflects the current (FY2016) RHIC/ATLAS Computing Facility staffing level of 27 individuals. The calculation is fully burdened.

3.5 Alternative-specific Parameters

The categories of cash flow data required for evaluation of the life cycle cost of each alternative consists of non-recurring capital investment costs such as construction or renovation; energy consumption costs; general maintenance and major equipment repair and replacement costs; productivity and opportunity losses; demolition costs to remove excess facilities (i.e. one-for-one replacement for new construction); and future demolition costs of the new asset. The initial costs of critical deferred maintenance and compliance modifications represent the work which must be completed by BNL within the next year or two to keep the facility operational and safe. They are applicable to the base case. The specific constant dollar value for these parameters used for each alternative, as applicable, is presented in the discussion of each alternative.

Cost figures are based on conceptual design estimates and new building construction costs at BNL, historical data for energy consumption at BNL, actual BNL employee salary information, and maintenance and repair costs as reported by The Whitestone Building Maintenance and Repair Cost Reference 2014-2015.

Energy and Water Costs - The actual electric and steam consumption was taken from metered data (three year average) for the existing facility. Alternative 2 and 3 energy consumption estimates are based on incorporating sustainable design requirements increase energy efficiency by 40% over the base case (Alternative 1). This is a conservative estimate as P.U.E. requirements for the new facility approach half of the current facilities actual P.U.E. factor. The DOE escalation factors in the BLCC-5.3-13 were used to determine the energy costs based on estimated usage.

Operations, Maintenance and Repair Costs - Maintenance and repair costs were estimated based the distribution of costs in the Whitestone Building Maintenance and Repair Cost Reference (2014-2015) for a “Data Center, Tier III”. Age-adjusted maintenance and repair costs were required and developed as the CFR LCCA is a 25 year study period. Whitestone data is presented as a 50 year cost summary. An analysis of the cost per GSF by system resulted in a lower total M&R cost as it will be assumed all major equipment components will be at the end of their useful life and will not be replaced. This is applied consistently to both the new building and renovation alternative. M& R costs were also adjusted utilizing the Whitestone Local Cost Index for our area.

Incremental activities that are not captured by the Whitestone cost profile and are in addition to the base maintenance and repair cost projections were also included for the alternatives where appropriate. These include upkeep of LEED Certification; exterior site maintenance and operations activities involving snow removal, landscaping, on-going site improvements such as new sidewalks and paving; waste removal; additional training of HVAC technicians required for new complex building equipment and systems; and additional administrative and operational costs involving management systems implementation and reporting (DCIM).

Custodial costs were estimated as two full time employees for all alternatives. The salary for one additional new building manager was included in Alternative 2 – the new building.

Productivity Gain - The productivity analysis was based on a scientific staff of 27 researchers assigned to the RACF. A $254,540 weighted average annual salary was calculated for the scientific staff including benefits, overhead, and burden based on interviews with the scientific departments. A conservative estimate of a 10% productivity gain over Alternative 1 for the renovation (Alternative 2) and new building (Alternative 3) was used as described below.

Higher utilization of space, equipment, and people. The project will either transform or create space that will become the most flexible and desirable computational spaces on the BNL site with the most reliable support systems. The result will be an increased utilization of space and equipment and therefore increased productivity. + 5%

Improved facility conditions, environment, and life safety. The work will provide facilities that are modern and reliable. The facility will have improved lighting systems, temperature and humidity control. The project shall provide for energy efficiency and efficient use of potable water. The life safety upgrades will provide for a safe work environment and promote health and well-being. All of which will result in minimizing equipment failure and down time. + 3%

- Improved employee morale and ability to attract and retain the most promising and productive researchers. The current occupants will experience an improved sense of confidence in their infrastructure and built environment. The current facility and working conditions reduce employee morale and motivation and negatively impact the ability to hire and retain the brightest and most productive researchers. The existing facilities are approximately 45 years old. Although well maintained, they convey the false message to employees, and visiting scientists, that research conducted in these facilities is not very important. This inferred lower expectation negatively impacts productive research output and leads to less valid data produced for a given investment. Corporate America has realized that modern research facilities empower employees and convey the message of expected results. +2%

Productivity Loss – Productivity loss was applied only to Alternative 1
Catastrophic failure does remain a significant risk with Alternative 1 due to the lack of adequate back-up capabilities/services. However, no catastrophic failures were calculated in this life

cycle cost analysis. The base case does include the initial cost of the critical deferred maintenance and upgrades immediately required to keep the existing RACF "functional".

A conservative 5% per year productivity loss was applied to the base case as calculated from the RACF weighted average annual salary and staffing numbers identified above. This is primarily due to the frequent interruptions attributed to the completion of the required deferred maintenance and the on-going inability to execute concurrent maintenance tasks. Other contributing factors include the inability to efficiently deploy equipment due to the existing B515 power and cooling infrastructure limitations and space constraints.

Opportunity Loss - An opportunity loss was calculated for the base case (Alternative 1) due to the difficulty of performing research in the current facility and inability to meet future computing requirements. Failure to address the existing deficiencies will impact BNL's ability to retain scientific programs and could be expected to result in a loss of a portion of the research over time. This is due to the increasing number of interruptions attributed to ageing infrastructure and inability to expand the RACF computing capabilities. The significant planned growth of the RACF's capabilities is detailed in the CFR Conceptual Design Report.

The annual dollar value of the research performed (The RACF annual budget) in the study area is approximately $15M. It is estimated based on future needs and decreasing capabilities that beginning in 2021, an opportunity loss of approximately 4% per year for data storage and 8% per year for computing capabilities and will be realized. This is consistent with the RACF projections for future computing and data storage requirements. A cumulative estimated opportunity loss of 12% per year of the RACF annual program budget, beginning at the study's service date, was applied to the analysis of Alternative 1.

Replacement Costs - Replacement costs were not considered for this analysis because of the 25-year study period. No new systems and components would be required for the new building or the renovation alternative based on an expected 25-30 year service life of the computing facility and a 25 year analysis.

Residual Value - The residual value of a component is its remaining value at the end of the study period. The new building (Alternate 3) residual value is estimated at approximately 1/3 of the original construction cost of the building which reflects the future value of the core and shell of the building. Other building systems and components such as HVAC systems, lighting and ceilings, electrical distribution, roofing, plumbing fixtures, conveying systems, and general finishes/furniture will be near the end of their service life.

Based on an estimated 80 year service life for the facility, the residual value of B725 will be relatively low. A value of 1/8 of the replacement value will be assigned for the purpose of this study.

Demolition Costs - Demolition Costs were included at the end of the 25 year study period for all alternatives.

4.0 SUMMARY OF SELECTED ALTERNATIVES AND INPUT DATA

A summary of the alternatives and input data for each of the alternatives follows.

Alternative 1 - Base Case – Maintain Status Quo (Do nothing): Under this option, the use of the existing RACF at B515 would be continued. The required critical deferred maintenance and compliance upgrades would be performed. The actual electric is taken from metered data (FY 2015) for the existing computing facility. Support space usage is based on historic square foot data for BNL office and support space. Maintenance costs were calculated for the base case using the average actual cost for the last 3 fiscal years. Custodial costs were estimated as 75% of one full time employee. An opportunity loss (See detailed discussion) of 12 % per year of the research performed in the study area was assumed. An annual productivity loss (See detailed discussion) calculated as 5% of the annual research staff labor cost was assumed.

1. Service date October 2020
2. Annual Electrical Consumption, Data Center – 24,714,041 kWh (FY15)
3. Annual Electric Consumption, Support Space – 495,040 kWh
4. Annual Fuel Consumption – 5,461 MBTU
5. Annual Fuel Cost – $43,690
6. Annual Water Usage – 680,000 Gal. (40 Gal/SF/Yr.)
7. Required Critical Deferred Maintenance - $8,420,241 (FY 15)
8. Annual Maintenance - $882,393 (Avg. last 3 FY)
9. Annual Custodial - $106,798 (Actual)
10. RHIC/ATLAS Annual Research Opportunity Loss - $1,800,000 (12% / Yr.)
11. Annual Research Productivity Loss – $343,269 / Yr. (-5%)
12. Demolition of the Existing 515 computing facility, mechanical space, and associated support space at end of 25-year study period – $2,961,950

Alternative 2 – Renovate Existing Facilities at BNL: This alternative involves the renovation of existing available facilities at B725. Based on conceptual design efforts during FY 2016, approximately 54,998 SF of the buildings first floor would be renovated including approximately 20,800 SF of dedicated computing space. Approximately 20,000 SF of existing second floor office area required to house supporting technical and research staff will be occupied. The data center electric and fuel consumption will be modeled based on a preliminary program and new DOE energy efficiency/PUE requirements. Support space usage is based on an anticipated 30% improvement on square foot historic data. Annual maintenance costs are estimated using

Whitestone Research Data (See detailed discussion). Custodial costs are estimated as one full time employee. A conservative 10% annual productivity gain was assumed (See detailed discussion). The future demolition cost was also estimated at $50/gsf and escalated to the base date.

1. Service date October 2020
2. Annual Electrical Consumption, New Data Center – 24,125,040 kWh
3. Annual Electric Consumption, Support Space – 495,000 kWh
4. Annual Fuel Consumption –24,094 MBTU
5. Annual Fuel Cost – $192,750
6. Annual Water Usage – 560,000 Gal. (30% improvement over Base Case of 40 Gal/SF/Yr.)
7. Renovation Cost – $67,922,000
8. Annual Maintenance - $1,300,853
9. Annual Custodial - $142,397 (1 FTE)
10. Annual Research Productivity Gain – $687,258 / Yr. (10%)
11. Residual Value (12.5% of Construction cost) = $5,236,786
12. Pro-rated share of the future demolition of the 725 facility at end of study period – $3,720,000 (48% of 155,000 GSF @ $50/GSF)

Alternative 3 – Construct New Building at BNL (Line Item Funding): This alternative involves the construction of a new 71,488 gsf building to house the approximate 20,800 SF computing facilities base scope plus additional expansion capability on the BNL site. Also included is the approximately 20,000 SF required to house the required supporting technical and research staff. The total project cost of the new building is estimated and includes project management, engineering, escalation to midpoint of construction, etc. A residual value of approximately 1/3 of the original construction cost of the building which reflects the future value of the core and shell of the building. Other building systems and components such as HVAC systems, lighting and ceilings, electrical distribution, roofing, plumbing fixtures, conveying systems, and general finishes/furniture will be near the end of their service life. Annual maintenance costs were estimated using Whitestone Research Data. The data center electric and fuel consumption will be modeled based on a preliminary program and new DOE energy efficiency requirements. Support space usage is based on an anticipated 30% improvement on square foot historic data Custodial services were estimated at two full time employees. A conservative 10% productivity gain was used as described previously. The cost of the required one-for-one demolition to offset the new building is included at $50/gsf, escalated to the base date. The future demolition cost was also estimated at $50/gsf and escalated to the base date.

1. Service date October 2020
2. Annual Electrical Consumption, New Data Center – 24,125,000 kWh
3. Annual Electrical Consumption, support space - 495,600 kWh
4. Annual Fuel Consumption, New Building –24,094 MBTU
5. Annual Fuel Cost, New Building – $192,750
6. Annual Water Usage, New Building – 560,000 Gal.
7. Total Project Cost – $106,141,000 (Incl. one-to-one demolition)
8. Demolition of New Asset @ end of life - $3,574,000
9. Annual Maintenance, - $1,300,853
10. Annual BNL Site Support Costs - $125,000
11. Annual Custodial - $142,397 (1 FTE)
12. Annual Research Productivity Gain - $687,258 / Yr. (10%)
13. Residual Value (33.33% of the total project cost) = $35,376,795

5.0 SUMMARY OF RESULTS

The present value of costs, average annual cost, simple payback period and rate of return on investment are the recommended measures to be used to gauge the economic performance of the alternatives. Summarized as follows are the estimated capital investment, average annual operating cost savings, simple payback period and rate of return on investment for Alternatives 2 and 3 compared to the Alternative 1 (Base Case).

	Alternative 1 Maintain Status Quo (Base Case)	Alternative 2 Renovate Existing Facility	Alternative 3 Construct New Facility
Total Life Cycle Cost	$109,328,869	$125,182,303	$148,144,853

Table 5 - Life Cycle Cost Analysis Present Value Results

	Alternative 2 Renovate Existing Facilities	Alternative 3 Construct New Facility (Line Item)
Capital Investment	$67,922,000	$106,141,000
Net Cost Saving	-$15,853,434	-$38,815,984
Simple Payback	25 years	Outside the study (>25 years)
Adjusted Internal Rate of Return	0.75%	- 0.53%

Table 6 - Simple Payback and Return on Investment

The analysis indicated that Base Case (Alternative 1) yields economic benefits. The initial investment of $8,420,241 would result in cost savings of $15,853,434 over Alternative -2 (Renovate Existing Facility) and $38,815,984 over Alternative-3 (New Facility) over a 25-year period. Appendix C contains a complete comparative analysis of the two alternatives to the base case.

6.0 SENSITIVITY STUDY

Estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. The effects of this uncertainty were analyzed.

Major assumptions were varied and the outcomes were recomputed to determine how sensitive the outcomes are to changes in the assumptions. The objectives of the sensitivity analyses were to: (a) account for uncertainty in certain key parameters, and (b) determine which alternative was more cost-effective under different assumptions. The sensitivity analyses consist of six scenario-based analyses. In each of the six scenarios, only the value of the key parameter of interest is changed, and the values of all other parameters assumed in the Base Case were held constant. Quantitative results are shown in Table 7

A. Lower Discount Rate

The purpose of this scenario is to test sensitivity of the Base Case results to uncertainty associated with general inflation and the time value of money. The 30 year nominal discount rate is used to adjust each annual cash flow throughout the period of analysis to reflect the time-value of money. This scenario decreases the assumed annual discount rate from 1.9% to 1.5%.

B. Higher Discount Rate

The purpose of this scenario is to test sensitivity of the Base Case results to uncertainty associated with general inflation and the time value of money. The 30 year nominal discount rate is used to adjust each annual cash flow throughout the period of analysis to reflect the time-value of money. This scenario increases the assumed annual discount rate from 1.9% to 2.9%.

C. Reduced Capital Costs

The purpose of this scenario is to test the sensitivity of the Base Case results to the assumed costs to construct/renovate the facilities. This scenario reduces estimated construction/renovation costs by 20% to determine the outcome if an over estimate of construction/renovation costs was assumed in the Base Case.

D. Increased Capital Costs

The purpose of this scenario is to test the sensitivity of the Base Case results to the assumed costs to construct/renovate the facilities. This scenario increases estimated construction/renovation costs by 20% to determine the outcome if an under estimate of construction/renovation costs was assumed in the Base Case.

E. Decreased O&M and Repair Costs

The purpose of this scenario is to test the sensitivity of the Base Case results to the assumed costs for annually recurring maintenance and repair. This scenario decreases estimated O&M and repair costs by 20% to determine the outcome if an over estimate of O&M and repair costs was estimated in the Base Case.

F. Decreased Productivity Loss

The purpose of this scenario is to test the sensitivity of the Base Case results to projected increases in productivity associated with updated work areas and collocation and consolidation of technical functions. This scenario decreases the estimated cost of productivity gain by 50% (or 5% productivity gain) for alternative 2 and 3 to determine the outcome if an over-estimate of productivity loss was assumed for Alternative 1 in the Base Case.

Analysis Scenario	Parameter Changed from Base Case Scenario	Lowest LCC Alternative	Maintain Status Quo	Renovation			New Facility		
			NPV [$M]	NPV [$M]	Payback Period [years]	Discounted Payback Period [years]	NPV [$M}	Payback Period [years]	Discounted Payback Period [years]
Base Case	None	Maintain Status Quo	$109.3	$125.2	25 years	None	$148.1	None	None
A	Decreased Discount Rate to 1.5%	Maintain Status Quo	$116.1	$128.9	25 years	None	$149.9	None	None
B	Increased Discount Rate to 2.9%	Maintain Status Quo	$94.6	$116.9	25 years	None	$143.9	None	None
C	Decreased Capital Costs by 20%	Maintain Status Quo	$107.6	$112.2	22 years	None	$131.0	25 years	None
D	Increased Capital Costs by 20%	Maintain Status Quo	$111.1	$138.2	None	None	$165.3	None	None
E	Decreased O&M & Repair Costs by 20%	Maintain Status Quo	$105.7	$119.9	25 years	None	$142.4	None	None
F	Decreased Productivity Loss	Maintain Status Quo	$109.3	$131.5	None	None	$154.4	None	None

Table 7 - Summary of Sensitivity Study Results

The results of the Sensitivity Study show that in all scenarios, the Maintain Status Quo (Alternative 1) has the lowest LCC when compared to the Renovation (Alternative 2) and new facility (Alternative 3) options.

APPENDIX A
Lowest Life Cycle Cost Analysis Report

NIST BLCC 5.3-15: LOWEST LCC

Consistent with Federal Life Cycle Cost Methodology in OMB Circular A-94

General Information

File Name:	C:\Users\nkhanna\BLCC 5\projects\Projects\BNL Study.xml
Date of Study:	Tue Jul 26 11:56:23 MDT 2016
Analysis Type:	OMB Analysis, Non-Energy Project
Analysis Purpose:	Cost Effectiveness, Lease Purchase, Government Investment or Asset Sale Analysis
Project Name:	BNL Study
Project Location:	New York
Analyst:	Nidhi Khanna
Base Date:	October 1, 2016
Service Date:	October 1, 2020
Study Period:	29 years 0 months (October 1, 2016 through September 30, 2045)
Discount Rate:	1.9%
Discounting Convention:	End-of-Year

Lowest LCC

Comparative Present-Value Costs of Alternatives

(Shown in Ascending Order of Initial Cost, * = Lowest LCC)

Alternative	Initial Cost (PV)	Life Cycle Cost (PV)	
Alternative 1 - Base Case	$8,420,241	$109,328,869	*
Alternative 2 - Renovate	$67,922,000	$125,182,303	
Alternative 3 - New Building	$106,141,000	$148,144,853	

APPENDIX B
Life Cycle Cost Analysis Summary Report

NIST BLCC 5.3-15: SUMMARY LCC

Consistent with Federal Life Cycle Cost Methodology in OMB Circular A-94

General Information

File Name:	C:\Users\nkhanna\BLCC 5\projects\Projects\BNL Study 060716.xml
Date of Study:	Tue Jul 26 12:36:17 MDT 2016
Analysis Type:	OMB Analysis, Non-Energy Project
Analysis Purpose:	Cost Effectiveness, Lease Purchase, Government Investment or Asset Sale Analysis
Project Name:	BNL Study
Project Location:	New York
Analyst:	Nidhi Khanna
Base Date:	October 1, 2016
Service Date:	October 1, 2020
Study Period:	29 years 0 months (October 1, 2016 through September 30, 2045)
Discount Rate:	1.9%
Discounting Convention:	End-of-Year

Discount and Escalation Rates are REAL (exclusive of general inflation)

ALTERNATIVE 1: BASE CASE

LCC Summary

	Present Value	Annual Value
Initial Cost Paid By Agency	$8,420,241	$380,370
Energy Consumption Costs	$41,786,760	$1,887,644
Energy Demand Costs	$0	$0
Energy Utility Rebates	$0	$0
Water Usage Costs	$6,230	$281
Water Disposal Costs	$0	$0
Annually Recurring OM&R Costs	$57,396,925	$2,592,806
Non-Annually Recurring OM&R Costs	$1,718,713	$77,640
Replacement Costs	$0	$0
Less Remaining Value	$0	$0
	------------	------------
Total Life-Cycle Cost	$109,328,869	$4,938,741

ALTERNATIVE 2: RENOVATE

LCC Summary

	Present Value	Annual Value
Initial Cost Paid By Agency	$67,922,000	$3,068,258
Energy Consumption Costs	$44,278,522	$2,000,205
Energy Demand Costs	$0	$0
Energy Utility Rebates	$0	$0
Water Usage Costs	$5,131	$232
Water Disposal Costs	$0	$0
Annually Recurring OM&R Costs	$13,852,249	$625,751
Non-Annually Recurring OM&R Costs	$2,158,582	$97,510
Replacement Costs	$0	$0
Less Remaining Value	-$3,034,181	-$137,064
	------------	------------
Total Life-Cycle Cost	$125,182,303	$5,654,892

ALTERNATIVE 3: NEW BUILDING

LCC Summary

	Present Value	Annual Value
Initial Cost Paid By Agency	$106,141,000	$4,794,735
Energy Consumption Costs	$44,279,428	$2,000,246
Energy Demand Costs	$0	$0
Energy Utility Rebates	$0	$0
Water Usage Costs	$5,131	$232
Water Disposal Costs	$0	$0
Annually Recurring OM&R Costs	$16,142,658	$729,216
Non-Annually Recurring OM&R Costs	$2,073,864	$93,683
Replacement Costs	$0	$0
Less Remaining Value	-$20,497,228	-$925,927
	------------	------------
Total Life-Cycle Cost	$148,144,853	$6,692,186

APPENDIX C
Comparative Analysis Report

NIST BLCC 5.3-15: COMPARATIVE ANALYSIS

Consistent with Federal Life Cycle Cost Methodology in OMB Circular A-94

Base Case: Alternative 1 - Base Case

Alternative: Alternative 2 - Renovate

General Information

File Name:	C:\Users\nkhanna\BLCC 5\projects\Projects\BNL Study 060716.xml
Date of Study:	Tue Jul 26 13:37:10 MDT 2016
Project Name:	BNL Study
Project Location:	New York
Analysis Type:	OMB Analysis, Non-Energy Project
Analysis Purpose:	Cost Effectiveness, Lease Purchase, Government Investment or Asset Sale Analysis
Analyst:	Nidhi Khanna
Base Date:	October 1, 2016
Service Date:	October 1, 2020
Study Period:	29 years 0 months(October 1, 2016 through September 30, 2045)
Discount Rate:	1.9%
Discounting Convention:	End-of-Year

COMPARISON OF PRESENT-VALUE COSTS

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$8,420,241	$67,922,000	-$59,501,759
Future Costs:			
Energy Consumption Costs	$41,786,760	$44,278,522	-$2,491,763
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$6,230	$5,131	$1,099
Recurring and Non-Recurring OM&R Costs	$59,115,638	$16,010,831	$43,104,807
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	-$3,034,181	$3,034,181
	------------	------------	------------
Subtotal (for Future Cost Items)	$100,908,628	$57,260,303	$43,648,325
	------------	------------	------------
Total PV Life-Cycle Cost	$109,328,869	$125,182,303	-$15,853,434

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$40,614,144
- Increased Total Investment	$56,467,578

Net Savings	-$15,853,434

Savings-to-Investment Ratio (SIR)

SIR = 0.72

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = 0.75%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Service Period)

Discounted Payback never reached during study period.

Simple Payback occurs in year 25

ENERGY SAVINGS SUMMARY

Energy Savings Summary (in stated units)

Units for every energy type not the same, can't report energy savings

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	91,477.9 MBtu	108,101.0 MBtu	-16,623.1 MBtu	-415,520.8 MBtu

EMISSIONS REDUCTION SUMMARY

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO_2	10,822,381.21 kg	12,788,993.43 kg	-1,966,612.22 kg	-49,158,575.04 kg
SO_2	31,854.10 kg	37,642.53 kg	-5,788.44 kg	-144,691.08 kg
NOx	11,486.78 kg	13,574.13 kg	-2,087.34 kg	-52,176.48 kg
Total:				
CO_2	10,822,381.21 kg	12,788,993.43 kg	-1,966,612.22 kg	-49,158,575.04 kg
SO_2	31,854.10 kg	37,642.53 kg	-5,788.44 kg	-144,691.08 kg
NOx	11,486.78 kg	13,574.13 kg	-2,087.34 kg	-52,176.48 kg

NIST BLCC 5.3-15: COMPARATIVE ANALYSIS

Consistent with Federal Life Cycle Cost Methodology in OMB Circular A-94

Base Case: Alternative 1- Base Case

Alternative: Alternative 2 - New Building

General Information

File Name:	C:\Users\nkhanna\BLCC 5\projects\Projects\BNL Study 060716.xml
Date of Study:	Tue Jul 26 13:38:38 MDT 2016
Project Name:	BNL Study
Project Location:	New York
Analysis Type:	OMB Analysis, Non-Energy Project
Analysis Purpose:	Cost Effectiveness, Lease Purchase, Government Investment or Asset Sale Analysis
Analyst:	Nidhi Khanna
Base Date:	October 1, 2016
Service Date:	October 1, 2020
Study Period:	29 years 0 months(October 1, 2016 through September 30, 2045)
Discount Rate:	1.9%
Discounting Convention:	End-of-Year

COMPARISON OF PRESENT-VALUE COSTS

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$8,420,241	$106,141,000	-$97,720,759
Future Costs:			
Energy Consumption Costs	$41,786,760	$44,279,428	-$2,492,669
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$6,230	$5,131	$1,099
Recurring and Non-Recurring OM&R Costs	$59,115,638	$18,216,522	$40,899,116
Capital Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	-$20,497,228	$20,497,228
	------------	------------	------------
Subtotal (for Future Cost Items)	$100,908,628	$42,003,853	$58,904,775
	------------	------------	------------
Total PV Life-Cycle Cost	$109,328,869	$148,144,853	-$38,815,984

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$38,407,547
- Increased Total Investment	$77,223,531

Net Savings	-$38,815,984

Savings-to-Investment Ratio (SIR)

SIR = 0.50

SIR is lower than 1.0; project alternative is not cost effective.

Adjusted Internal Rate of Return

AIRR = -0.53%

AIRR is lower than your discount rate; project alternative is not cost effective.

Payback Period

Estimated Years to Payback (from beginning of Service Period)

Simple Payback never reached during study period.

Discounted Payback never reached during study period.

ENERGY SAVINGS SUMMARY

Energy Savings Summary (in stated units)

Units for every energy type not the same, can't report energy savings

Energy Savings Summary (in MBtu)

Energy	-----Average	Annual	Consumption-----	Life-Cycle
Type	Base Case	Alternative	Savings	Savings
Electricity	91,477.9 MBtu	108,103.0 MBtu	-16,625.0 MBtu	-415,568.6 MBtu

EMISSIONS REDUCTION SUMMARY

Energy	-----Average	Annual	Emissions-----	Life-Cycle
Type	Base Case	Alternative	Reduction	Reduction
Electricity				
CO_2	10,822,381.21 kg	12,789,219.49 kg	-1,966,838.28 kg	-49,164,225.74 kg
SO_2	31,854.10 kg	37,643.20 kg	-5,789.10 kg	-144,707.71 kg
NOx	11,486.78 kg	13,574.37 kg	-2,087.58 kg	-52,182.48 kg
Total:				
CO_2	10,822,381.21 kg	12,789,219.49 kg	-1,966,838.28 kg	-49,164,225.74 kg
SO_2	31,854.10 kg	37,643.20 kg	-5,789.10 kg	-144,707.71 kg
NOx	11,486.78 kg	13,574.37 kg	-2,087.58 kg	-52,182.48 kg