DOC # UI-RPT-026-R0

# Los Alamos National Laboratory TA-3 Steam Plant Replacement Analysis of Alternatives

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# Abbreviations & Acronyms

| | |
|---|---|
| *CDA* | *Critical Design Analysis* |
| *CGTG* | *Combustion Gas Turbine Generator* |
| *CHP* | *Combined Heating and Power* |
| *DOE* | *U.S. Department of Energy* |
| *ESH* | *Environment, Safety, and Health* |
| *ESPC* | *Energy Savings Performance Contract* |
| *HRSG* | *Heat Recovery Steam Generator* |
| *LANL* | *Los Alamos National Laboratory* |
| *SMSI* | *Strategic Management Solutions LLC* |
| *UI* | *Utilities & Institutional Facilities Division* |

# Section 1 Executive Summary

*This document presents an analysis of alternatives for replacement of LANL's obsolete TA-3 Steam Plant and Distribution System. This system faces major challenges related to condition, maintainability, safety, and function that must be addressed.*

### *System Description and Functions*

The Steam Plant and Distribution System consists of the following elements:

- Building heating for TA-3:
  - 3 boilers, originally installed in 1949, which burn natural gas, with fuel oil backup, to produce steam
  - Steam distribution system, providing heat to TA-3 buildings, with return condensate piping
- Backup electrical generation for the LANL campus:
  - Superheaters
  - Electrical generators driven by boiler steam
  - Combustion Gas Turbine Generator (CGTG), a large single-cycle turbofan jet engine fueled by natural gas driving an electrical generator

The analysis was conducted in response to a Department of Energy (DOE) request to perform an analysis similar to one performed by Sandia National Laboratory in 2004 as part of the critical decision process for replacement of its central heating plant. (See Appendix A. Email, A. Erickson to I. Valdez, Subject: LANL ESPC, May 23, 2014.) The analysis compares alternatives on the basis of life cycle costs, risks, and how well they meet requirements.

### *System Requirements*

The selected alternative must meet the following requirements:

- Building thermal energy demands
- Reliability
- Safety
- Maintainability and operability
- Environmental standards and goals
- Efficiency – e.g., DOE sustainability goals
- Site electrical supply needs

***Alternatives Examined***

The following alternatives were selected for analysis:

- Alternative 1. Do Nothing but Make Necessary Repairs
- Alternative 2. Local Boilers Only
- Alternative 3. Combined Heat and Power (CHP), New Hot Water Distribution System and Some Local Boilers
- Alternative 4. CHP and Refurbished Steam Distribution System

**Aerial view of TA-3 (Steam Plant at far left) c. 1951**

***Selected Alternative***

The analysis has determined that Alternative 4, CHP and Refurbished Steam Distribution System, will best satisfy requirements, presents the least risk, has the most promising financing opportunities, and has the most favorable life cycle benefit/cost ratio.

# Section 2 Functional Requirements

*A fundamental requirement is that the Power Plant must provide sufficient capacity to serve the TA-3 buildings' thermal energy requirements, including space heating, domestic water heating, humidification and process loads, with sufficient capacity to support future TA-3 campus growth. Other requirements include the following:*

***Reliability***

No single-contingency failure may interrupt service for an extended period (> 24 hours), except for:

- Single contingency failures outside the control of LANL, such as loss of utility supply, e.g., loss of site-wide natural gas supply.
- Equipment without moving parts, such as pipe and heat exchangers.

***Safety***

Systems must be safe to own and operate. Existing retained systems, upgraded systems, and new systems must all comply with applicable codes, industry standards, and the LANL Engineering Standards Manual.

***Maintainability and Operability***

New systems must reduce deferred maintenance and be readily maintainable, including commonality of systems and equipment, proper access to components requiring service, and availability of spare parts. Skill levels needed for maintenance must be consistent with the skill levels of the existing personnel.

***Environment***

Systems must comply with applicable environmental regulations, may not exceed existing adverse environmental impacts, preferably must significantly reduce adverse environmental impacts, and must minimize environmental risks.

***Meet DOE Sustainability Goals***

Systems must enhance energy efficiency to meet the energy intensity and carbon emissions reduction goals set by Executive Order and DOE.

***Address Site Electrical Supply Needs***

Systems must, where possible, enhance the ability to successfully navigate the future needs in accessing energy and avoiding transmission bottlenecks.

# Section 3 Alternative Descriptions

*LANL's 65-year-old Cogeneration Plant (CoGen Plant) is designed to generate 20 MW of electricity and provide heating steam for 3.2 million square feet of computing facilities, scientific laboratories, and administrative facilities in the central TA-3 campus. Heating steam is distributed through a network of underground steam pipes. Condensate is returned back to the boilers in a separate piping system.*

### Challenges

The condensate system returns, on average, 50–60% of the expected flow. LANL currently spends approximately $1M per year repairing it. Lost condensate is released to the environment. Replenishing boiler feed water adds further water and water treatment expense.

Due to its age, extensive reinvestment in the facility will be required to maintain reliable service. Annual maintenance expenses will continue to rise. The plant's steam turbine-generators account for a significant portion of this expense. They have not run as base load generators since the mid-1980s. Recent inspections indicate extensive corrosion pitting in the superheating tubes in all three boilers. DOE FIMS captured more than $15 million in deferred plant maintenance. PCB holdup in the turbine generator cooling system preclude their operation except under emergency conditions.

LANL is forecast to use 515 GW-hours of electrical power in FY 2015 with a peak hourly demand of 78 MW. With projected mission growth, this demand is expected to grow to 100 MW by FY 2019, which means that LANL will need approximately 22 MW of additional energy supplies to meet forecast mission growth. Peak heating demand for steam for 3.2 million square feet of facilities is approximately 100,000 pounds steam per hour.

### Previous Analyses

Earlier this fiscal year, the LANL Utilities & Institutional Facilities (UI) Division employed the engineering firm Strategic Management Solutions Inc. (SMSI) to examine the economics of steam plant replacement alternatives, including Alternatives 1, 3 and 4, described below. (See Appendix B. SMSI Steam Plant Replacement Feasibility Analysis Summary.)

SMSI was not asked to analyze the economics of Alternative 2, using local boilers only to serve the entire heating load, because it was previously examined in 2007 by energy saving performance contractor NORESCO. (See Appendix C, NORESCO, Energy Savings Performance Contract – Initial Proposal Submission to DOE/LANL, September 25, 2007, pp. 1–23.)

### Assumptions

To provide a fair comparison between the alternatives, SMSI assumed that the CGTG would operate as a base load generation source in Alternative 1 and that it would also operate as a base load source in combination with a Heat Recovery Steam Generator (HRSG) in Alternatives 3 and 4.

The NORESCO analysis did not address how the CGTG would be operated in Alternative 2, Local Boilers, but to make the comparison fair it was assumed the CGTG would operate as a base load source.

In determining life cycle costs, assumptions had to be made about the means of funding the alternatives. For Alternative 1, operation and maintenance funding is projected to continue at its current level, but within five years General Plant Project funding would be secured to replace the existing boilers and decommission the steam turbines. The three other alternatives are assumed to be funded through energy-saving performance contracts (ESPCs)

***Alternative 1 Do Nothing but Make Necessary Repairs***

In this alternative, the Steam Plant would continue to function as a heating plant but would no longer serve as a component of the Lab's emergency electrical power supply. This would address the fact that the superheating sections of the existing boilers are failing. If the plant is to continue to function as part of the Lab's emergency power supply, they will have to be replaced at great expense. They would therefore be removed.

The steam distribution system within the buildings and between them would remain in place at its current level of maintenance.

The 65 year-old boilers would be replaced, in the fifth year, by modular steam boilers through a $5 million GPP project.

**Life Cycle Cost – 30 Year Timeframe**
Present Value Revenue, 30 years: $456,000,000
Present Value Expense, 30 years: $375,000,000
Benefit/Cost Ratio: 1.22

This is the least expensive alternative, but it would leave a large amount of deferred maintenance unaddressed, would not reduce operating risks, and does not address DOE sustainability goals.

***Alternative 2 Local Boilers Only***

In this alternative, all buildings now served by the existing steam system would be served by new local steam or heating hot water boilers. As conceived by NORESCO in the 2007 proposal, some boilers would serve a single building and some would serve a cluster of buildings. The boilers would be located on rooftops, in mechanical rooms in place of abandoned equipment, or if necessary in new mechanical buildings.

**Life Cycle Cost – 30 Year Timeframe**
Present Value Revenue, 30 years: $456,000,000
Present Value Expense, 30 years: $410,000,000
Benefit/Cost Ratio: 1.11

Projected costs were $59 million in 2007 dollars ($66.4 million in current dollars). Projected reductions in annual energy consumption were from 494 billion to 304 billion BTU/year, or 38%, and annual O&M costs of $4 million/year.

NORESCO's claims in their initial proposal should be used cautiously; their numbers were based on preliminary assessments. The projection of $4 million in annual O&M savings is suspect, since the entire current O&M budget for the TA-3 plant and distribution system is $4.9 million. The number used in the above life cycle cost projects more reasonable O&M savings of $3.4 million.

The energy savings projections are reasonably conservative, falling within the range of the estimates presented by Sandia in their earlier analyses. Sandia ultimately saved more in the first years of operation than it first predicted, but it is reasonable to expect

that performance will deteriorate as the equipment ages and that over time it will approach the engineering estimates.

NORESCO's capital cost estimate for local boilers was $52.6 million, but this relied on a number of key assumptions that raise questions about whether this is sufficient. In describing the scope of work, the initial proposal excluded the costs of modifications to the LANL gas distribution system, assumed that local boilers would be easily accommodated within existing buildings, and assumed that asbestos abatement expenses could be excluded. To cover these scope exclusions, NORESCO's base estimate has been increased to $59 million.

To bring the base estimate forward to 2013, the year used by SMSI for its projections, a 2% annual inflation factor has been applied, resulting in a base estimate of $66.4 million. Finally, the NORESCO analysis assumes a site cost factor for the LANL environment of 1.3. While this may be reasonable for green-field construction, it is not realistic for work performed in occupied LANL buildings. A realistic site factor is 2.2, yielding a base estimate of $112.4 million.

It may be asked whether these results would change greatly if assumptions more favorable to the local boiler alternative were made. For instance, if the energy savings were equivalent to the best year at Sandia, would the result improve significantly? The answer is no: if, for instance, local boilers saved 70% of current steam plant gas consumption, the benefit/cost ratio would move only from 1.11 to 1.16.

What effect would be seen if the LANL site cost factor for work in occupied buildings were decreased by half the amount shown above, to 1.75 instead of the 2.2? In this case, the benefit/cost ratio would move from 1.11 to 1.19. In both cases, more favorable assumptions fail to make the local boiler option more attractive than the other options.

### *Alternative 3*
### *Combined Heat and Power (CHP)*
### *New Hot Water Distribution System*
### *Some Local Boilers*

In this alternative, the CGTG would be retrofitted with an HRSG, with the two systems functioning as generators to provide base-load electricity. On-site power generation with natural gas would offset import of power generated from coal. New modular boilers would meet heating loads when the CGTG/HRSG is off line. The HRSG and boilers would be housed in a new building.

The system would use pumped hot water instead of steam to heat the TA-3 campus, serving approximately two-thirds of the buildings now served by the steam system. New, local boilers would serve the rest.

Modifications to equipment and controls would be made to facilitate summer shutdown of the distribution system.

**Life Cycle Cost – 30 Year Timeframe**

Present Value Revenue, 30 years: $849,000,000

Present Value Expense, 30 years: $680,000,000

Benefit/Cost Ratio: 1.25

### *Alternative 4 CHP and Refurbished Steam Distribution System*

In this alternative, the CGTG would be retrofitted with an HRSG, with the two systems In this alternative, the TA-3 campus would continue to be heated with steam. Condensate pipe, insulation, traps, and valves, along with other steam distribution components, would be repaired or replaced within buildings and the steam distribution system. Local boilers would not be added.

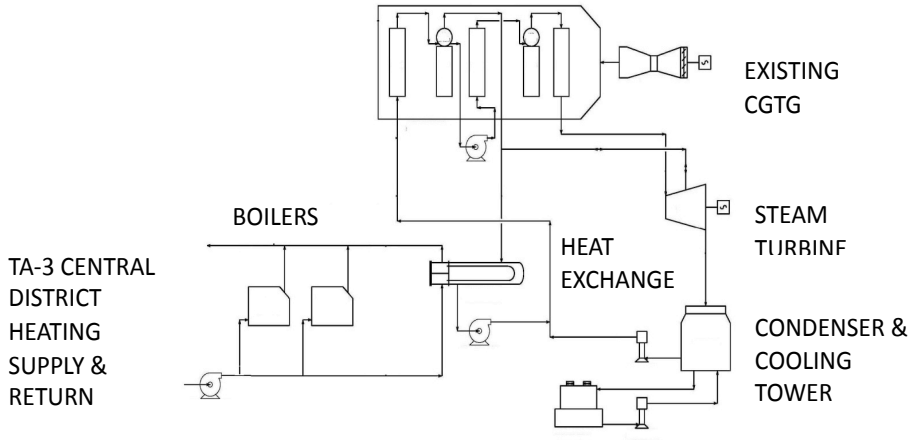
In other respects, this alternative would be the same as Alternative 3: the CGTG would be retrofitted with an HRSG, with the two systems functioning as generators to provide base-load electricity; on-site power generation with natural gas would offset import of power generated from coal; new modular steam boilers would meet heating loads when the CGTG/HRSG is off line; the HRSG and boilers would be housed in a new building; TA-3 buildings would be modified to permit summer shutdown of the heating system.

**Life Cycle Cost – 30 Year Timeframe**

Present Value Revenue, 30 years: $866,000,000

Present Value Expense, 30 years: $687,000,000

Benefit/Cost Ratio: 1.26




**HRSG System Schematic**

# Section 4
# Risk Analysis

*This section presents a summary followed by a discussion of the risks associated with each of the four alternatives.*

### *Risk Analysis Summary*

| | Alternative | | | |
|---|---|---|---|---|
| **Risk** | **1. Do Nothing** | **2. Local Boilers Only** | **3. New Hot Water Distribution System and Some Local Boilers** | **4. CHP & Steam System** |
| **Technical** | Low | Medium | Low | Low |
| **Cost** | High | Low | Medium | Low |
| **Schedule** | Low | Medium - | Medium | Low |
| **ES&H** | Medium+ | Low | Low | Low |
| **Funding** | High | Low | Low | Low |
| **Other** | High | High | Medium+ | Low |
| **Total*** | 13.5 | 9.5 | 9.5 | 6 |
| **Average** | 2.25 | 1.58 | 1.58 | 1.00 |
| **Overall** | Medium+ | Medium- | Medium- | Low |
| * Low = 1, Medium = 2, High = 3 | | | | |

## *Risk Analysis Discussion*

### *Alternative 1* *Do Nothing but Make Necessary Repairs*

***Technical risks*** There are no technical risks in doing nothing.

Probability: Low

Impact: Low

***Cost risks*** Steam system failures may cause interruption of service, emergency repairs, construction projects, maintenance costs, costs to mission, and escalating maintenance costs.

Probability: High

Impact: High

***Schedule risks*** No schedule is required for this alternative.

Probability: Low

Impact: Low

***ESH risks*** There are significant worker safety concerns connected with operation of this system, as well as contamination issues from leaking condensate lines.

Probability: High

Impact: Medium

***Funding risks*** In recent years, UI has presented conventional funding proposals for large projects at the Steam Plant and they have consistently been rejected in favor of other priorities.

Probability: High

Impact: High

***Other risks*** Continuing on the current path provides no hedge against future carbon costs, future energy cost escalation, and the need for future transmission line upgrades.

Probability: High

Impact: High

### *Alternative 2 Local Boilers Only*

***Technical risks*** Technical Risks: Time restrictions associated with scheduling sequence of construction. Incorporation of current code requirements into existing buildings presents a risk of additional renovation not currently in the scope.

Probability: High

Impact: Low

***Cost risks*** The construction risks are not unusual; field verification of as-built documents is expected to minimize cost risk.

Probability: Low

Impact: Low

***Schedule risks*** Schedule coordination between demolition and start-up of new systems.

Probability: Medium

Impact: Low

***ESH risks*** None identified.

Probability: Low

Impact: Low

***Funding risks*** Funding via an ESPC is seen as very feasible.

Probability: Low

Impact: Low

***Other risks*** Continuing on the current path provides no hedge against future carbon costs, future energy cost escalation, and the need for future transmission line upgrades.

Probability: High

Impact: High

***Alternative 3*** ***Combined Heat and Power (CHP)***
***New Hot Water Distribution System***
***Some Local Boilers***

***Technical risks*** Design and construction of Steam Plants and hot water distribution systems have become an area of specialization for contractors.

Probability: Low

Impact: Low

***Cost risks*** Cost risks are low due to experience of contractors providing Steam Plants and heating water distribution systems, however there is a challenge with excavating in potentially contaminated soils.

Probability: Medium

Impact: Medium

***Schedule risks*** Schedule risks are low due to experience of contractors providing Steam Plants and heating water distribution systems, however there is a challenge with excavating in potentially contaminated soils.

Probability: Medium

Impact: Medium

***ESH risks*** Identical to Alternative 2.

Probability: Low

Impact: Low

***Funding risks*** Identical to Alternative 2.

Probability: Low

Impact: Low

***Other risks*** Extensive construction work throughout TA-3 disrupts mission.

Probability: High

Impact: Medium

### *Alternative 4* *CHP and Refurbished Steam Distribution System*

***Technical risks*** Design and construction of Steam Plants has become an area of specialization for contractors.

Probability: Low

Impact: Low

***Cost risks*** Cost risks are low due to experience of contractors providing Steam Plants.

Probability: Low

Impact: Low

***Schedule risks*** Schedule risks are low due to experience of contractors providing Steam Plants.

Probability: Low

Impact: Low

***ESH risks*** The emissions permitted for the existing Steam Plant will cover the proposed CHP. Water consumption increases, however it remains within the limits described in the existing Environmental Impact Statement.

Probability: Low

Impact: Low

***Funding risks*** Identical to Alternative 2.

Probability: Low

Impact: Low

***Other risks*** None identified.

Probability: Low

Impact: Low

# Section 5 Alternative Selection

*An analysis was performed comparing the four alternatives versus functional requirements. Rankings, using a scale of 1–5, were determined by the LANL Utilities and Infrastructure staff, based on extensive analyses performed by Black and Veatch in the 1990s, Bechtel in 2009, and SMSI in recent years.*

Alternative 4, CHP and Refurbished Steam Distribution System, ranked highest.

***Analysis Matrix***

| Criterion | Meet Thermal Demand | Reliability | Safety | Risk | Maintain-ability & Oper-ability | Environ-mental | Sustain-ability | Address Electrical Supply Challenges | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Alternative** | **Score** | | | | | | | | |
| **1. Do Nothing** | 3 | 2 | 2 | 1.3 | 1 | 4 | 1 | 1 | **15.3** |
| **2. Local Boilers Only** | 3 | 4 | 3 | 2.4 | 5 | 5 | 2 | 1 | **25.4** |
| **3. New Hot Water Distribution System and Some Local Boilers** | 3 | 4 | 3 | 2.4 | 3 | 5 | 5 | 5 | **30.4** |
| **4. CHP & Steam System** | 3 | 4 | 3 | 3.3 | 3 | 5 | 5 | 5 | **31.3** |

# References

Black and Veatch, Los Alamos National Laboratory, TA-3 Power Plant Evaluation, August 27, 1999

NORESCO, Energy Savings Performance Contract – Initial Proposal Submission to DOE/LANL, September 25, 2007

SMSI Steam Plant Replacement Feasibility Analysis Summary

# Appendices

Appendix A. Email, A. Erickson to I. Valdez, Subject: LANL ESPC, May 23, 2014

Appendix B. SMSI Steam Plant Replacement Feasibility Analysis Summary

Appendix C, NORESCO, Energy Savings Performance Contract – Initial Proposal Submission to DOE/LANL, September 25, 2007 (pp. 1–23)